PUNJAB COLLEGE
ENTRY TEST PROGRAMME

PHYSICS

For
MCAT,ECAT,NUST,AGHA KHAN,GIKI,NTS
UCP & All Universities Entry Tests

PUNJAB GROUP OF COLLEGES

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ENTRY TEST
PHYSICS PART-I

Chapter 1
MEASUREMENTS/PHYSICAL QUANTITIES AND UNITS
MCAT UNIT 1

KEY POINTS

Physics: The branch of science which deals with the properties of matter and energy along with mutual relationship. It is study of the natural phenomena and material objects in orderly manner. The study of nature is classified into two branches.

(i) Biological sciences which deals with living things such as botany, zoology etc.

(ii) Physical sciences which deals with non-living things such as chemistry, astronomy, geology etc.

Physics is an important and basic part of physical science besides its other disciplines such as chemistry, astronomy, geology etc.

Main Frontiers of Fundamental Science: At the present time there are three main frontiers of fundamental science. The world of the extremely large, the universe itself. The world of extremely small, that of the particles such as, electron, protons, neutrons, mesons and others. The world of complex matter, it is also the world of "middle sized" things, from molecules at one extreme to the earth at the other. It is the study of matter and energy and relationship between them. The study of physics involves investigating such things as:

- Laws of motion.
- The nature and types of forces that hold the materials together.
- The interaction between different particles.
- The interaction of electromagnetic radiation with matter and so on.

Branches of Physics:

- Mechanics
- Waves and oscillations
- Relativistic Mechanics
- Electromagnetism
- Biophysics
- Nuclear physics
- Theoretical physics
- High energy physics or Particle Physics
- Plasma physics
- Magnetism
- Quantum physics
- Atomic physics
- Health physics
- Electricity
- Solid State Physics
- Modern physics
- Astrophysics
- Solid state physics

Importance of Physics in Technology: Physics also plays an important role in development of technology and engineering. We are living in the age of information technology. The computer networks are products of chips developed from basic ideas of physics. The chips are made of silicon. Silicon can be obtained from sand.

Physical Quantities: All those quantities in terms of which laws of physics can be described are called physical quantities. The foundation of physics is based upon the physical quantities.

Types of Physical Quantities: Physical quantities are often divided into two categories.

- Base quantities / Fundamental quantities
- Derived quantities

Base Quantities / Fundamental Quantities: These are the minimum number of physical quantities in term of which other physical quantities can be defined. The typical examples of base quantities are length, mass, time, temperature, electric current, luminos intensity and amount of substance.

Derived Quantities: Those physical quantities whose definitions are based on the other physical quantities are called derived quantities. The examples of derived quantities are velocity, acceleration, force, momentum etc.

Measurement of Base Quantities: The measurement of base quantity involves two steps.

- The choice of standard.
- The establishment of a procedure for comparing the quantity to be measured with the standard so that number and a unit are determined as the measure of that quantity.

Ideal Standard: An ideal standard has two principle characteristics.

- It is accessible.
- It is invariable.

System of Units: Before the development of SI system, three systems of units were commonly used.

- C.G.S. system
- M.K.S. System
- British Engineering System (F.P.S. system)

C.G.S. System: In C.G.S. System the fundamental unit of length, mass and time are centimeter, gram and second respectively.

M.K.S. System: In M.K.S. system the fundamental unit of length, mass and time are meter, kilogram and second respectively.

British Engineering System: In British Engineering system, the unit of mass, length, and time are chosen as the fundamental units. In this system, the fundamental unit of mass, length and time are pound, foot and second respectively.

International System of Units: In 1960 an international committee agreed on a set of definitions and standard to describe the physical quantities. The system that was established is called the system international (SI). The international system of units (SI) is built up from three kinds of units:

- Base units / Fundamental units
- Supplementary units
- Derived units

Base Units: The units of length, mass, time, electric current, temperature, light intensity and amount of substance are the base units. In SI-system, the seven physical quantities are considered as base quantities and their units are called base units.

Physical Quantity	SI Unit	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Intensity of light	Candela	cd
Amount of substance	Mole	mol

Supplementary Units: The general conference on weights and measures has not yet classified certain units of the SI under either base units or derived units. These units are called supplementary units. There are two supplementary units: (i) Plane angle (Radian) (ii) Solid angle (Steradian)

Physical Quantity	SI-units	Symbol
Plane angle	Radian	rad
Solid angle	Steradian	st

Derived Units: The units which are derived from the base units are called derived units. Some of the derived units are given below:

SI Units of Some Derived Quantities

Physical Quantity	S.I Units	Physical Quantity	S.I Units
Force	Newton (N)	Surface tension (T)	N/m
Work	Joule (J)	Quantity of heat (Q)	joule
Power	Watt (W)	Molar heat capacity (C)	J/mol.k
Pressure	Pascal (Pa) or Nm^{-2}	Capacitance	Farad (F) or $A.S.V^{-1}$
Electric charge	Coulomb (C)	Energy of charged capacitor	Joule (J)
Momentum	kg. ms^{-1} or N-S	Magnetic flux (ϕ_m)	weber (Wb)
Frequency	hertz (Hz)	Power of lens (D)	diopter (D)
Coefficient of viscosity (η)	kg $m^{-1}s^{-1}$ (Pa.s)		

Scientific Notation: If the numbers are expressed in term of power of ten, then this form is called standard form or scientific notation.

Conventions for Indicating Units: Use of S.I units requires special care, more particularly in writing prefixes:

Following points should be kept in mind while using units:

(i) Full name of the unit does not begin with a capital letter even if named after a scientist e.g., newton.

(ii) The symbol of unit named after a scientist has initial capital letter such as N for newton.

(iii) The prefix should be written before the unit without any space, such as 1×10^{-3} m is written as 1 mm. Standard prefixes are given in table.

(iv) A combination of base units is written each with one space apart. For example, newton metre is written as Nm.

(v) Compound prefixes are not allowed. For example, 1 μμF may be written as 1 pF.

(vi) A number such as 5.0×10^4 cm may be expressed in scientific notation as 5.0×10^2 m.

(vii) When a multiple of a base unit is raised to a power, the power applies to the whole multiple and not the base unit alone. Thus, $1\ km^2 = 1\ (km)^2 = 1 \times 10^6\ m^2$.

Some Prefixes for Powers of Ten

Factor	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	mili	m
10^{-2}	centi	c
10^{-1}	deci	d
10^{1}	deca	da
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

Errors and Uncertainties: All physical measurements are uncertain or imprecise to some extent. It is very difficult to elementate all possible errors and uncertainty in a measurement.

Errors: The error in a measurement may occur due to

- Negligence or inexperience of a person.
- The faulty apparatus.
- Inappropriate method or technique.

Types of Errors: There are two types of errors:

- Random error
- Systematic error

Random Error: Random error is said to occur when repeated measurements of a quantity, give different values under the same conditions. It is due to some unknown causes. Repeating the measurements several times and taking an average can reduce the effect of random error.

Cause of Random Error: It is produced due to some unknown causes.

Remedy: The random error in the measurements can be considerably reduced by taking the average of all the measurements of the same quantity.

Systematic Error: Systematic error is said to occur, when all measurement of a particular quantity are affected equally. It produces a consistent difference in readings.

	Interval (s)
Age of the universe	5×10^{17}
Age of the Earth	1.4×10^{17}
One year	3.2×10^{7}
One day	8.6×10^{4}
Time between normal heartbeats	8×10^{-1}
Period of audible sound waves	1×10^{-3}
Period of typical radio waves	1×10^{-6}
Period of vibration of an atom in a solid	1×10^{-13}
Period of visible light waves	2×10^{-15}

Approximate Values of Some Time Intervals

Cause of Systematic Error: Systematic error is produced due to

- Zero error in measuring instrument
- Poor calibration of instruments
- Incorrect marking of instrument

Remedy: Systematic error can be reduced by comparing the instrument with another which is known to be more accurate. For systematic error, a correction factor can be applied.

Uncertainty: The uncertainty is also usually described as an error is a measurement. The uncertainty may occur due to

- In adequacy or limitation of an instrument
- Natural variation of the object being measured.
- Natural imperfection of persons senses.

Significant Figures: Whenever a physical quantity is measured, there is some uncertainty about its determined value. Every measuring instrument is calibrated to a certain smallest division and this fact put a limit to the degree of accuracy while measuring with it. In any measurement, the accurately known digits and the first doubtful digit are called significant figures. A significant figure is the one which is known to be reasonable reliable. The significant figures can be increased by improving the quality of measuring instrument and techniques;

Rules for Deciding the Significant Figures: All digits 1, 2, 3, 4, 5, 6, 7, 8, 9 are significant. The zeros may or may not be significant. In case of zeros, the following rules may be adopted.

- A zero between two significant figures is itself significant.
- Zeros to the left of significant figures are not significant. For example, none of the zero in 0.00467 or 02.59 is significant.
- Zeros to the right of significant figure may or may not be significant. Now we have two cases.
- In decimal fraction, zeros to the right of a significant figure are significant. For example, all the zeros in 3.570 or 7.4000 are significant.

In integers, number of significant zeros is determined by the accuracy of the measuring instrument. If the measuring scale has a least count of 1kg then there are four significant figures in 8000 kg written in scientific notation as 8.000×10^3 kg and if the least count of the scale in 10 kg, then the number of significant figures will be 3 written in scientific notation as 8.00×10^3 kg and so on.

When a measurement is recorded in scientific notation or standard form, the figures other than the powers of ten are significant figures. For example, a measurement recorded as 8.70×10^4 kg has three significant figures.

Multiplication and Division of Numbers: In multiplying or dividing numbers, the number of significant figures in the product or quotient is not more than that contained in the least accurate factor.

For example: $\frac{5.348\times10^{-2}\times3.64\times10^{4}}{1.336}=1.45768982\times10^{3}$

As the factor 3.64×10^4 has three significant figures, the answer should be written to three significant figures only. The other figures are insignificant and should be deleted.

Rules for Rounding Off Numbers: If the first digit dropped is less than 5, the last digit retained should remain unchanged. If the first digit dropped is more than 5, the digit to be retained is increased by one. If the digit to be dropped is 5, the previous digit which is to be retained is increased by one if it is odd and retained as such if it is even. For example, the following numbers are rounded off to three significant figures as follows. The digits are deleting one by one.

56.8546 is rounded off as 56.9

64.350 is rounded off as 64.4

Following this rule, the correct answer of the computation given above is 1.46×10^3.

Addition or Subtraction of Numbers: In adding or subtracting numbers, the number of decimal places retained in the answer should be equal to the smallest number of decimal places in any of the quantities being added or subtracted. In this case, the number of significant figures is not important. For example:

(i)	(ii)
72.1	2.7543
3.42	4.10
0.003	1.273
75.523	8.1273
75.5 m	8.13 m

Prcision and Accuracy:

Precision: A precise measurement is the one which has less absolute uncertainty. The precision of a measurement depends on the quality of the instrument being used.

Accuracy: An accurate measurement is the one which has less fractional or percentage uncertainty. The accuracy of a measurement depends on the fractional or percentage uncertainty.

Assessment of Total Uncertainty in the Final Result: The maximum possible uncertainty or error in the final result can be found as follows.

For addition and subtraction absolute uncertainties are added. For multiplication and division percentage uncertainties are added. For power factor, multiply the percentage uncertainty by that power. For uncertainty in the average value of many measurements:

- Find the average value of measured values.
- Find the deviation of each measured value from the average value.
- The mean deviation is the uncertainty in the average value.

For the uncertainty in the time period of a vibrating body is found by dividing the least count of timing device by the number of vibrations. It is advisable to count large number of swings to reduce timing uncertainty.

Dimensions of Physical Quantities: Each base quantity of SI-system is considered a dimension denoted by a specific symbol written within square brackets. It stands for the qualitative nature of the physical quantity. For example, different quantities such as length, breadth, diameter, light year which are measured in metre denote the same dimension and has the dimension of length [L]. Similarly the mass and time dimensions are denoted by [M] and [T], respectively. Other quantities that we measure have dimension which are combinations of these dimensions. For example:

$$\text{Dimensions of speed} = \frac{\text{Length}}{\text{Time}}$$

$$[v] = \frac{[L]}{[T]} = [L][T^{-1}] = [LT^{-1}]$$

For Example

	Quantity	Dimensions	Dimensional Formula
1.	Area (A)	length × length	L^2
2.	Volume (V)	area × length	L^3
3.	Density (ρ)	mass/volume	ML^{-3}
4.	Relative density or specific gravity	density/density (ratio)	$M^0L^0T^0$
5.	Velocity (v)	length/time	LT^{-1}
6.	Acceleration (a)	change in velocity/time	LT^{-2}
7.	Force (F)	mass × acceleration	MLT^{-2}
8.	Momentum (p)	mass × velocity	MLT^{-1}
9.	Work energy kinetic, potential or rotational etc. (W or E)	force × distance	ML^2T^{-2}
10.	Power (P)	work/time	ML^2T^{-3}
11.	Pressure (p or P)	force/area	$ML^{-1}T^{-2}$
12.	Torque or couple (τ)	force × distance	ML^2T^{-2}
13.	Impulse (J)	force × time	MLT^{-1}
14.	Angular velocity (w)	angle/time	T^{-1}
15.	Angular acceleration (α)	change in angular velocity/time	T^{-2}
16.	Moment of inertia (I)	mass × radius of gyration	ML^2

	Quantity	Dimensions	Dimensional Formula
17.	Radius gyration (R)	average distance	L
18.	Centrepetal acceleration (a_c)	v^2/R	LT^{-2}
19.	Angular momentum (L)	mvr	M^2T^{-1}
20.	Tangential acceleration (a_T)	(dv/dt)	LT^{-2}
21.	Gravitational constant (G)	$F \times R^2/M_1M_2$ (N-m^2/kg^2)	$M^{-1}L^3T^{-2}$
22.	Intensity of gravitation field (Eg)	$-GM/r^2$	LT^{-2}
23.	Surface tension (T or σ)	force/length	MT^{-2}
24.	Surface energy (E)	energy/area	MT^{-2}
25.	Stress (S)	force/area	$ML^{-1}T^{-2}$
26.	Strain (σ)	length/length	$M^0L^0T^0$
27.	Young modulus, Bulk modulus, modulus of rigidity, stress and pressure all have same dimension	force/area	$M^{-1}L^{-1}T^{-2}$
28.	Couple per unit twist (C)	torque/angle	ML^2T^{-2}
29.	Coefficient of viscosity (η)	F/A (dv/dr)	$ML^{-1}T^{-1}$
30.	Velocity gradient (v_g)	dv/dr	T^{-1}
31.	Poissons ratio (σ)	lateral strain/longitudinal strain	$M^0L^0T^0$
32.	Time period (T)	time for one cycle	M^0L^0T
33.	Frequency (f)	no/time (= 1/T)	$M^0L^0T^{-1}$
34.	Force constant (K)	force/displacement	ML^0T^{-2}
35.	Temperature (T)	fundamental unit	K
36.	Heat (Q or W)	energy = work	ML^2T^{-2}
37.	Specific heat (C)	heat/mass × Δt	$L^2T^{-2}K^{-1}$
38.	Specific latent heat (L)	energy/mass	L^2T^{-2}
39.	Thermal conductivity (K)	$K = (Qx/tA\Delta t)$	$ML^{-1}T^{-3}K^{-1}$
40.	Thermal resistance (R)	$\Delta T/(Q/t)$	$M^{-1}L^{-2}T^3K$
41.	Temperature coefficient of resistance (α)	$\Delta R/R\Delta T$	$M^0L^0T^0K^{-1}$
42.	Mechanical equivalent of heat (J)	W/H ratio	$M^0L^0T^0$
43.	Universal gas constant (R)	$\frac{PV \text{ (or mole gas)}}{\text{temperature}}$	$ML^2T^{-2}K^{-1}\,mol^{-1}$
44.	Stefans constant (σ)	(energy/area × time × T^4)	$ML^0T^{-3}K^{-4}$
45.	Boltzmans constant (k)	E = 1/2 kT (energy/temperature)	$ML^2T^{-2}K^{-1}$
46.	Planks constant (h)	E = hν (energy × time)	ML^2T^{-1}
47.	Weins constant (b)	$= \lambda_m T$	M^0LT^0K
48.	Solar constant (s)	$\frac{\text{energy}}{\text{area} \times \text{time}}$	$M^0L^0T^{-3}$
49.	Entropy (S)	heat/temperature (= Q/T)	$ML^2T^{-2}K^{-1}$
50.	Enthalphy (H)	heat	ML^2T^{-2}
51.	Current (I)	fundamental quantity	$M^0L^0T^0A$
52.	Charge (q)	current × time	M^0L^0TA

	Quantity	Dimensions	Dimensional Formula
53.	Surface charge density (σ)	charge/area	$M^0L^{-2}TA$
54.	Dipole moment (p)	charge × distance	M^0LTA
55.	Electric field strength (E)	force/charge	$MLT^{-3}A^{-1}$
56.	Electric potential (V)	work/charge	$ML^2T^{-3}A^{-1}$
57.	Electric flux (ϕ_E)	electric intensity × area = (E × dS)	$ML^3T^{-3}A^{-1}$
58.	Resistance (R)	potential/current	$ML^2T^{-3}A^{-2}$
59.	Specific resistance or resistivity (ρ)	RA/l	$ML^3T^{-3}A^{-2}$
60.	Conductance (G)	1/resistance	$M^{-1}L^{-2}T^3A^2$
61.	Electric conductivity (σ)	1/resistivity	$M^{-1}TL^{-3}T^3A^2$
62.	Current density (J)	current/area	$M^0L^{-2}A^2$
63.	Capacitance (C)	charge/potential	$M^{-1}L^{-2}T^4A$
64.	Inductance (self or mutual) (L or M)	e.m.f./(dI/dt)	$ML^2T^{-2}A^{-2}$
65.	Permittivity of free space ($\in_o$)	$q_1q_2/4\pi Fr^2$	$M^{-1}L^{-3}T^4A^2$
66.	Dielectric constant (k)	$k = \in_r = \in a/\in_o$	$M^0L^0T^0$
67.	Electric polarisation (P)	dipole moment/volume	$M^0L^{-2}TA$
68.	Electric displacement (D)	charge/surface area	$M^0L^{-2}TA$
69.	Electric susaptibility (χ)	(= D/E)	$M^0L^0T^0$
70.	Impedance (Z)	voltage/current	$ML^2T^{-3}A^{-2}$
71.	Magnetic pole strength (m)	$\frac{\text{magnetic moment}}{\text{magnetic length}}$	M^0LT^0A
72.	Magnetic dipole moment (M)	IA	M^0L^2A
73.	Magnetic induction (B)	force/current × length (B = F/IL)	$ML^0T^{-2}A^{-1}$
74.	Intensity of magnetisation (I)	magnetic moment/volume	$M^0L^{-1}T^0A$
75.	Magnetic flux (ϕ_m)	B × area	$ML^2T^{-2}A^{-1}$
76.	Permeability of free space (μ_o)	$= 4\pi^2 F/m_1m_2 (= 1/C^2\in_o)$	$MLT^{-2}A^{-2}$
77.	Refractive index (n)	C/C_m (= ratio)	$M^0L^0T^0$
78.	Luminus flux (ϕ_L)	energy/time	ML^2T^{-3}
79.	Luminuous intensity (I)	luminous flux/solid angle	ML^2T^{-3}
80.	Intensity of illumination (L)	luminuous intensity/area	MT^{-3}
81.	Bohrs magneton (μ_B)	$eh/4\pi m$	L^2A
82.	Radioactive decay constant (λ)	0.693/T	T^{-1}
83.	Wave number ($\bar{v}$)	1/λ	L^{-1}
84.	Radioactivity (A)	dN/dT	T^{-1}
85.	Work function (w_o)	energy = $h\nu_o$	ML^2T^{-2}

Checking the Homogeneity of Physical Equation: In order to check the correctness of an equation, we are to show that the dimensions of the quantities on both sides of the equation are the same, irrespective of the form of the formula. This is called the principle of homogeneity of dimensions.

Deriving a Possible Formula: Using the method of dimensions called the dimensional analysis:

- We can check the correctness of a given formula or an equation.
- We can derive a formula for a physical quantity.

ASSIGNMENT NO. 1

(1) **The branch of physics "wave mechanics" introduced by:**
(a) Einstien (b) Max Planck (c) De-broglie (d) Bohr

(2) **Physicists started believing that every thing about physics has been discovered by the end of:**
(a) 20^{th} Century (b) 19^{th} Century (c) 15^{th} Century (d) None of these

(3) **Pascal is famous for his work:**
(a) Hydrostatics (b) Hydrodynamics
(c) Laws of gases (d) Behaviour of elastic bodies

(4) **System international (SI) was established in:**
(a) 1960 (b) 1967 (c) 1971 (d) 1930

(5) **The basic quantity among the following is:**
(a) Torque (b) Force (c) Mass (d) Velocity

(6) **Which one of the scientist made some contribution to geometrical optics:**
(a) Archimedes (b) Pythagoras (c) Euclid (d) Plato

(7) **Which of the following is the derived quantity:**
(a) Time (b) Area (c) Length (d) Mass

(8) **Which of the following is a set of supplementary units:**
(a) Radian & kilogram (b) Steradian & time (c) Mole & radian (d) Radian & steradian

(9) **The SI unit for measuring plane angle is:**
(a) Radian (b) Steradian (c) Both (a) & (b) (d) None of these

(10) **The present standard metre is defined as:**
(a) The distance between two points on an alloy bar
(b) The length of mean solar day
(c) The length equal to 1650763.73 wavelength of krypton 86-atom
(d) The distance travel by the light in vacuum during a time of $\frac{1}{299792458}$ second

(11) **The system international (SI) built up from:**
(a) Derived units (b) Basic units (c) Supplementary units (d) All of these

(12) **One mile is equal to:**
(a) 1.625 km (b) 1.609 km (c) 1.325 km (d) 1.850 km

(13) **One inch is equal to:**
(a) 1.32 cm (b) 25.4 cm (c) 2.10 cm (d) 2.54 cm

(14) **One foot is equal to:**
(a) 31.90 cm (b) 30.84 cm (c) 30.48 cm (d) 84.30 cm

(15) **Number of nano second in a year is:**
(a) 3.1536×10^7 (b) 3.1536×10^9 (c) 3.1536×10^{16} (d) None of these

(16) **One year is equal to:**
(a) 3.2×10^7 sec (b) 2.25×10^7 sec (c) 3.35×10^7 sec (d) All of these

(17) **Light year is the unit of:**
(a) Light (b) Time (c) Velocity (d) Distance

(18) **The unit of thermodynamic temperature is:**
(a) K (b) C° (c) F° (d) None of these

(19) **One atto is:**
(a) 10^{-20} (b) 10^{-16} (c) 10^{-14} (d) 10^{-18}

(20) **One femto is:**
(a) 10^{-16} (b) 10^{-12} (c) 10^{-15} (d) 10^{-9}

(21) **The number of significant figure in 8.80×10^6 kg is:**
(a) 1 (b) 5 (c) 3 (d) 6

(22) **The number 64.350 is rounded off as:**
(a) 64.35 (b) 64.46 (c) 64.36 (d) 64.4

(23) **In scientific notation, the number 0.01 may be written as:**
(a) 10^{-2} (b) 10^{-4} (c) 10×10^{-4} (d) 1×10^{-4}

(24) **If length = 0.233 m and width = 0.178 m, the most accurate area expressed space of significant figures is:**
(a) $0.041\ m^2$ (b) $0.0415\ m^2$ (c) $0.041747\ m^2$ (d) None of these

(25) **The number 0.0001 in scientific notation is:**
(a) 1×10^4 (b) 10^{-3} (c) 10×10^4 (d) 10^{-4}

(26) **One mega is equal to:**
(a) 10^6 (b) 10^{-6} (c) 10^3 (d) 10^9

(27) **The error in a certain measurement occurs due to:**
(a) Negligence of a person (b) Inappropriate technique
(c) Faulty apparatus (d) All of the above

(28) **The uncertainty may occur due to:**
(a) Limitation of an instrument (b) Natural variance of the object
(c) Personal negligence (d) All of the above

(29) **The least count of a unit meter rod is:**
(a) 0.01 cm (b) 0.01 mm (c) Cannot be zero (d) Can be zero

(30) **The number of base units in SI are:**
(a) Four (b) Five (c) Six (d) Seven

(31) **Deca, deci and mega, respectively mean:**
(a) $10^1, 10^{-1}, 10^6$ (b) $10^6, 10^{-1}, 10^1$ (c) $10^6, 10^1, 10^{-1}$ (d) $10^1, 10^6, 10^{-1}$

(32) **134.7 should be written in scientific notation as:**
(a) 134.7 (b) 13.47×10^1 (c) 1.347×10^2 (d) 0.1347×10^3

(33) **Pico, kilo and tera mean:**
(a) $10^{-12}, 10^{-3}, 10^{-18}$ (b) $10^{18}, 10^3, 10^{-12}$ (c) $10^{-12}, 10^3, 10^{12}$ (d) $10^{18}, 10^{-12}, 10^3$

(34) **The average time the Earth takes to make exactly one rotation about its axis is defined as:**
(a) A solar hour (b) A solar day (c) A light year (d) A solar month

(35) **The distance x determined by the difference between two separate position measurements are $x_1 = 10.5 \pm 0.1$ cm and $x_2 = 26.8 \pm 0.1$ cm. Then x will be recorded as:**
(a) 16.3 cm (b) 16.3 ± 0.1 cm (c) 16.3 ± 0.2 cm (d) 16.3 ± 0.01 cm

(36) **The length of a line was measured with a metre scale of least count = 1 mm by four students. The correct reading will be:**
(a) 0.5426 m (b) 0.542 m (c) 0.54 m (d) 0.5 m

(37) **Name the scientist who was awarded the Nobel Prize in physics in 1936 for the discovery of the positron:**
(a) Chadwick (b) Femi (c) Anderson (d) Einstein

(38) **The density of mercury is 13600 kg m^{-3}. its value in CGS system will be:**
(a) 13.6 g cm^{-3} (b) 1360 g cm^{-3} (c) 136 g cm^{-3} (d) 1.36 g cm^{-3}

(39) **The unit of force and length are doubled, the unit of energy will be:**
(a) $\frac{1}{2}$ times (b) $\frac{1}{2}$ times (c) 2 times (d) 4 times

(40) **The dimensional formula $[ML^0T^{-3}]$ is more closely associated with:**
(a) Power (b) Energy (c) Intensity (d) Velocity gradient

(41) **Which dimensions will be the same as that of time?**
(a) LC (b) $\frac{R}{L}$ (c) $\frac{L}{R}$ (d) $\frac{C}{L}$

(42) **Angular momentum has the same dimensions as:**
(a) Planck's constant (b) Universal gravitational constant
(c) Rydberg constant (d) Boltzmann constant

(43) **Which of the two have same dimensions?**
(a) Force and strain (b) Force and stress
(c) Angular velocity and frequency (d) Energy and strain

(44) **A student measured the diameter of a wire using a screw gauge with least count 0.001 cm and listed the measurements. The correct measurement is:**
(a) 5.320 cm (b) 5.3 cm (c) 5.32 cm (d) 5.3200 cm

(45) **Zero error belongs to the category of:**
(a) Constant errors (b) Personal errors (c) Instrumental errors (d) Accidental errors

(46) **Which one is the least sub-multiple?**
(a) pico (b) femto (c) atto (d) nano

(47) **In which system, the unit of force is a base unit:**
(a) SI system (b) CGS system
(c) British engineering system (d) MKS system

(48) **Which of the following cannot be expressed as N-m^{-2}:**
(a) Pressure (b) Stress
(c) Surface tension (d) Bulk modulus of elasticity

(49) **Which of the following units is used to measure the radius of nucleus?**
(a) Micron (b) Nanometer (c) Angstrom (d) Femtometer

(50) **Which of the following is not equal to watt?**
(a) Joule/second (b) Ampere × Volt (c) $(\text{Ampere})^2 \times$ Ohm (d) Ampere/volt

(51) **Temperature can be expressed as a derived quantity in terms of any of the following:**
(a) Length and mass (b) Mass and time
(c) Length, mass and time (d) In terms of none of these

(52) **erg m^{-1} can be the unit of the measure of:**
(a) Force (b) Momentum (c) Power (d) Acceleration

(53) **If the radius of the earth shrinks by 1.5% (mass remaining same) then the value of acceleration due to gravity changes by:**
(a) 1% (b) 2% (c) 3% (d) 4%

(54) **Which of the following readings taken by microscope of least count.0.001 cm is correct?**
(a) 3.28 (b) 3.00 (c) 3.000 (d) 0.02345

(55) **Which of the following is not a base unit in SI system:**
(a) Temperature (b) Amount of substance (c) Light intensity (d) Area

(56) **The minimum number of physical quantities which define other physical quantities in SI system are:**
(a) Two (b) Three (c) Five (d) Seven

(57) **Which of the following in not a unit of time:**
(a) Leap year (b) Light year (c) Lunar month (d) Micro-second

(58) **Three dimensional angle subtended at the centre of the sphere by an area of its surface equal to the square of radius of the sphere is called:**
(a) Radian (b) Steradian (c) Degree (d) All of the above

(59) **The ratio of 1 nanometre to 1 attometre is equal to:**
(a) 1 peta (b) 1 tera (c) 1 giga (d) 1 mega

(60) **A precise measurement is the one which has:**
(a) Less absolute uncertainty (b) Less percentage uncertainty
(c) Large fractional uncertainty (d) Large absolute uncertainty

(61) **The accuracy of a measurement depends on:**
(a) Absolute uncertainty (b) Percentage uncertainty
(c) Quality of the instrument (d) Calibration of the scale

(62) **Number of significant figure with increasing degree of approximation:**
(a) Decreases (b) Increases (c) Remains unchanged (d) None of the above

(63) **Solid angle subtended at the center by a sphere is:**
(a) 2π (b) 4π (c) 6π (d) 8π

(64) **A second pendulum strikes in a day:**
(a) 3600 times (b) 86400 times (c) 43200 times (d) 0.003 sec

(65) **The density of wood is 0.5 gm cm^{-3} in CGS system of units. The corresponding value in SI units is:**
(a) 500 kg m^{-3} (b) 5 kg m^{-3} (c) 0.5 kg m^{-3} (d) 5000 kg m^{-3}

(66) **Physical quantity is/are:**
(a) Time (b) Density (c) Temperature (d) All

(67) **The error is constant for ———— error.**
(a) Random (b) Systematic (c) Both (a), (b) (d) All

(68) **For 2.450 number of significant digits:**
(a) 4 (b) 3 (c) 2 (d) 1

(69) **Which of the following could be measured in the same units as force?**
(a) Energy/Distance (b) Energy × Distance
(c) Energy/Time (d) Momentum × Distance

(70) **What is the ratio $\frac{1\ \mu m}{1\ Gm}$?**
(a) 10^{-3} (b) 10^{-9} (c) 10^{-12} (d) 10^{-15}

ANSWERS

(1)	(c)	(2)	(b)	(3)	(b)	(4)	(a)	(5)	(c)
(6)	(a)	(7)	(b)	(8)	(d)	(9)	(a)	(10)	(c)
(11)	(d)	(12)	(b)	(13)	(d)	(14)	(c)	(15)	(c)
(16)	(a)	(17)	(d)	(18)	(a)	(19)	(d)	(20)	(c)
(21)	(c)	(22)	(d)	(23)	(a)	(24)	(a)	(25)	(d)
(26)	(a)	(27)	(d)	(28)	(d)	(29)	(c)	(30)	(d)
(31)	(a)	(32)	(c)	(33)	(c)	(34)	(b)	(35)	(c)
(36)	(b)	(37)	(c)	(38)	(a)	(39)	(d)	(40)	(c)
(41)	(c)	(42)	(a)	(43)	(d)	(44)	(a)	(45)	(c)
(46)	(c)	(47)	(c)	(48)	(c)	(49)	(d)	(50)	(d)
(51)	(d)	(52)	(a)	(53)	(c)	(54)	(c)	(55)	(d)
(56)	(d)	(57)	(b)	(58)	(b)	(59)	(c)	(60)	(a)
(61)	(b)	(62)	(a)	(63)	(b)	(64)	(c)	(65)	(a)
(66)	(d)	(67)	(b)	(68)	(a)	(69)	(a)	(70)	(d)

SOLUTION

(24)

$l = 0.233$ m

$w = 0.178$ m

$A = l \times w$

$A = (0.233)(0.178)$

$A = 0.041474$

But least no. of decimal is '3'

Therefore,

$A = 0.041$

(a) is correct

(35)

$x_1 = 10.5 \pm 0.1$ cm

$x_2 = 26.8 \pm 0.1$ cm

$x = x_2 - x_1$

$x = (26.8 - 10.5) \pm 0.2$

$x = 16.3 \pm 0.2$ cm

(c) is correct

(39) Energy $= F \times l$

Now if $F = 2F$, $l = 2l$

Energy $= (2F)(2l)$

$= 4Fl$

$= 4$ times

(d) is correct

(63) Solid angle $= \Omega = ?$

$\Omega = \frac{\text{Surface area}}{(\text{Radius})^2}$

$\Omega = \frac{4\pi r^2}{r^2}$

$\Omega = 4\pi$

(b) is correct

(65) 0.5 gm cm^{-3}

$\left(\frac{0.5}{1000} \times 100 \times 100 \times 100\right)$ kg m^{-3} $= 500$ kg m^{-3}

(a) is correct

Chapter 2

VECTORS AND EQUILIBRIUM

KEY POINTS

Physical Quantity: The property of matter which can be measured is called physical quantity. There are two types of physical quantities:

- Non-directional physical quantities or Scalars
- Directional physical quantities or Vectors

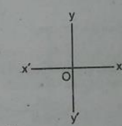
Scalars: Those physical quantities which can be specified completely by magnitude with proper units only are called scalars. Examples are Mass, Length, time, density, volume, pressure, temperature, speed, work, energy, power, etc. As scalars are numbers, so they are added, subtracted, multiplied and divided by ordinary arithmetic rules.

Vectors: Those physical quantities which can be specified completely by magnitude with proper units as well as direction are called vectors. Examples are Displacement, velocity, Acceleration, Force, weight, momentum, torque etc. Vectors are not added subtracted, divided and multiply ordinary arithmetic rules but it can be used as vector addition vector subtraction vector multiplication and vector division.

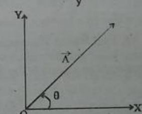
Representation of Vectors: Symbolically, a vector is usually represented by bold face letters such as **A**, **d**, **r** or as $\vec{A}, \vec{d}, \vec{r}$. Graphically, a vector is represented by a straight line with an arrow head at one end. The length of the line gives the magnitude of the vector according to a suitable scale while arrow head shows its direction. In order to draw a vector, we require two things:

- A Suitable Scale
- Direction Indicators

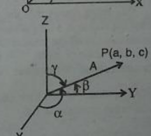
Rectangular Coordinate System: Two reference lines drawn at right-angle to each other are known as coordinate axes and their point of intersection is known as origin. This system of coordinate axes is called cartesian or rectangular coordinate system as shown.



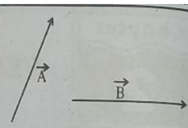
Two Dimensional Plane: The region bounded by two lines is called two dimensional planes such as x-y plane, y-z plane and x-z plane. A point in plane has two coordinates (a , b). The direction of a vector $\vec{A}$ in a plane is specified by angle 'θ' which the vector makes with positive side of x-axis in the anti-clock wise direction as shown in fig.



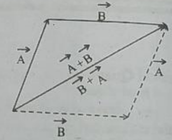
Three Dimensional Space: The region bounded by three mutually perpendicular lines is called three dimensional space. A point 'P' in space has three coordinates (a, b, c). The direction of a vector $\vec{A}$ in space is specified by three angles α, β and γ which the vector makes with positive sides of x, y and z-axis respectively as shown in figure.



Addition of Vectors:



Triangle Law: If we have to obtain the sum of two vectors **A** and **B** such as shown in figure showing two successive displacements of a point. Their vector sum **C** is obtained by representing graphically vector **A** and from the head of the vector **A** represent graphically vector **B**, then the line joining the head of **B** to the tail of **A** gives the vector sum of **A** and **B** represented by **C** and direction is from the tail of first vector to the head of last vector. This law of vector addition is called triangle law of vector addition.



Parallelogram Law: Now if we complete the parallelogram as shown in figure. Then the law of vector addition can be stated as:

If the two given vector **A** and **B** in direction as well as in magnitude, then the diagonal of the parallelogram will represent the vector sum **C** of the two given vectors **A** and **B**. This law is called the parallelogram law of vector addition.

If θ is the angle between **A** and **B** then the resultant **C** is given by:

$$C = \sqrt{A^2 + B^2 + 2\,AB\cos\theta}$$

and if resultant makes an angle α with A then:

$$\tan\alpha = \frac{B\sin\theta}{(A + B\cos\theta)}$$

When $\theta = 0°$ then:

$$C = \sqrt{A^2 + B^2 + 2AB\cos 0°} \Rightarrow C = A + B$$

When $\theta = 180°$ then:

$$C = \sqrt{A^2 + B^2 + 2AB\cos 180°} \Rightarrow C = A - B$$

When $\theta = 90°$ then:

$$C = \sqrt{A^2 + B^2}$$

If three coplanar vectors acting simultaneously on a particle be in equilibrium, then the ratio of magnitude of vector and the sine of the angle between the other two is constant i.e.

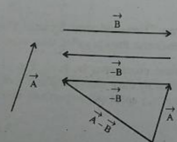
$$\frac{A}{\sin\alpha} = \frac{B}{\sin\beta} = \frac{C}{\sin\gamma}$$

where α is the angle between B and C, β is the angle between C and A and γ is angle between A and B.

Head to Tail Rule: The representative lines of all the vectors are drawn in such a way that the arrow head of first vector joins with the tail of second vector and the arrow head of second vector joins with the tail of third vector and so on as explain in the figure. It is clear from the figure.

$$\vec{A} + \vec{B} = \vec{B} + \vec{A}$$

This result shows that the addition of vectors is commutative. The resultant vector is a single vector which has the same effect as the combined effect of all the vectors to be added.



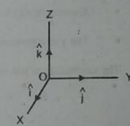
Subtraction of Vectors: In order to subtract vector $\vec{B}$ from vector $\vec{A}$ we find $-\vec{B}$ and then add $\vec{A}$ and $-\vec{B}$ by head to tail rule of vector addition as shown in fig.

Thus, $\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$

Multiplication of a Vector by a Scalar: When a vector $\vec{A}$ is multiplied with a scalar number n, the magnitude of resultant $\vec{A}$ becomes n-times the magnitude of $\vec{A}$. i.e., $|n\vec{A}| = n|A|$. The direction of resultant $\vec{A}$ will be same as that of $\vec{A}$ if $n > 0$. The direction of resultant $\vec{A}$ will be opposite to that of $\vec{A}$ if $n < 0$.

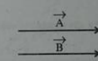
Unit Vector: A vector whose magnitude is one is called unit vector. It is used to represent the direction of a vector. It is represented by putting a cap (^) on the letter i.e., $\hat{A}, \hat{B}, \hat{i}, \hat{j}$. A unit vector in the direction of vector $\vec{A}$ is written as $\hat{A}$ and is given by:

$$\hat{A} = \frac{\vec{A}}{A} \Rightarrow \vec{A} = A\hat{A}$$

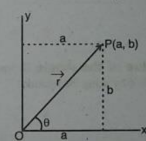


Orthogonal Unit Vector: The direction of x, y and z axes are generally represented by unit vectors $\hat{i}, \hat{j}$ and $\hat{k}$ respectively as shown in fig. These unit vectors are called orthogonal unit vectors.

Null Vector: A vector whose magnitude is zero is called null vector or zero vector. It is an imaginary vector so it has any arbitrary direction. e.g. $\vec{A} + (-\vec{A}) = \vec{0}$



Equal Vector: Two vectors $\vec{A}$ and $\vec{B}$ are said to be equal, if they have same magnitude and same direction regardless of the position of their initial points. Two parallel vectors having same magnitude are equal to each other.



Position Vector: Position vector describes the location of a particle with respect to the origin of the coordinate system. It is denoted by $\vec{r}$. The position vector is drawn in such a way that its tail coincides with the origin and head with the point. The position vector of a point P(a , b) in x-y plane is:

$$\vec{r} = \overrightarrow{OP} = a\hat{i} + b\hat{j}$$

The position vector of a point P(a,b,c) in space is:

$$\vec{r} = \overrightarrow{OP} = a\hat{i} + b\hat{j} + c\hat{k}$$

Resolution of Vectors: The process of splitting up of a vector into two or more vectors is called resolution of vector. It is the reverse process of addition of vectors. Usually a vector can be resolved into two parts called components of a vector.

Component of a Vector: A component of a vector is its effective part in a particular direction. A vector may be considered as the resultant of its components vectors.

Rectangular Components: Two components of a vector which are right angle to each other are called rectangular components of vector. One of them is along x-axis and is called x-component and the other component is along y-axis and is known as y-component.

The magnitude of x-component of $\vec{A}$ is given by $\boxed{A_x = A\cos\theta}$

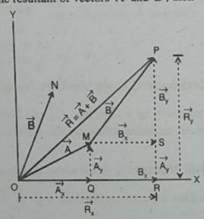
The magnitude of y-component of $\vec{A}$ is given by $\boxed{A_y = A\sin\theta}$

The magnitude of $\vec{A}$ is given by $A = \sqrt{A_x^2 + A_y^2}$

The direction of vector $\vec{A}$ is given by angle θ which can be determined as

$$\theta = \text{Tan}^{-1}\left(\frac{A_y}{A_x}\right)$$

Vector Addition by Rectangular Components: Let $\vec{R}$ is the resultant of vectors $\vec{A}$ and $\vec{B}$, then



- X-component of $\vec{R} = R_x = A_x + B_x$
- The y-component of $\vec{R} = R_y = A_y + B_y$

The magnitude of the resultant vector $\vec{R}$ is given as

$$R = \sqrt{(A_x + B_x)^2 + (A_y + B_y)^2}$$

The direction of the resultant vector $\vec{R}$ is given by the angle θ as:

$$\theta = \text{Tan}^{-1}\left(\frac{R_y}{R_x}\right)$$

For any number of coplanar vectors $\vec{A}$, $\vec{B}$, $\vec{C}$, ...,we can write

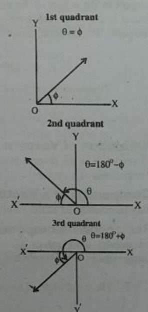
$$R = \sqrt{(A_x + B_x + C_x + ...)^2 + (A_y + B_y + C_y.....)^2}$$

$$\theta = \text{Tan}^{-1}\left(\frac{A_y + B_y + C_y + ...}{A_x + B_x + C_x + ...}\right)$$

Value of the Angle θ: Irrespective of the sign of R_x and R_y, find the value of angle ϕ by using the relation.

$$\phi = \text{Tan}^{-1}\left(\frac{R_y}{R_x}\right)$$

Knowing the value of ϕ, the angle θ can be determined as follows.



(i) If $R_x > 0$and $R_y > 0$, then the resultant vector $\vec{R}$ lies in the first quadrant and its direction is given $\theta = \phi$.

(ii) If $R_x < 0$ and $R_y > 0$, the resultant vector $\vec{R}$ lies in the second quadrant and its direction is given by:

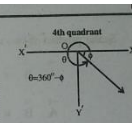
$$\theta = 180 - \phi$$

(iii) If $R_x < 0$ and $R_y < 0$, the resultant vector $\vec{R}$ lies in third quadrant and its direction is given by:

$$\theta = 180 + \phi$$

(iv) If $R_x > 0$ and $R_y < 0$, the resultant vector $\vec{R}$ lies in the fourth quadrant and its direction is given by:

$$\theta = 360° - \phi$$



Product of Two Vectors: There are two types of vector multiplications.

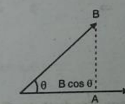
- Scalar Product
- Vector Product

Scalar Product or Dot Product: When the multiplication of two vectors results into a scalar quantity then the product is called scalar product. It is represented by putting a dot (•) between the vectors. The scalar product of two vectors $\vec{A}$ and $\vec{B}$ is written as $\vec{A} \cdot \vec{B}$ and is defined as:

$\vec{A} \cdot \vec{B}$ = Magnitude of $\vec{A}$ times the component of $\vec{B}$ along $\vec{A}$

$\vec{A} \cdot \vec{B} = A\,(B\cos\theta)$

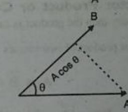
$\vec{A} \cdot \vec{B}$ = A (Projection of $\vec{B}$ on $\vec{A}$)



Similarly, $\vec{B} \cdot \vec{A}$ = Magnitude of $\vec{B}$ times the projection of $\vec{A}$ and $\vec{B}$

$= B\,(A\cos\theta)$

$\vec{B} \cdot \vec{A}$ = B (Projection of $\vec{A}$ on $\vec{B}$).



Examples of Scalar Product

- Work = $W = \vec{F} \cdot \vec{d} = Fd\cos\theta$
- Power = $P = \vec{F} \cdot \vec{v} = Fv\cos\theta$

Characteristics of Scalar Product:

(i) The scalar product of two vectors obey:

- Commutative law i.e., $\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$
- Associative law i.e., $m\vec{A} \cdot n\vec{B} = n\vec{A} \cdot m\vec{B} = mn\vec{A} \cdot \vec{B}$
- Distributive law over addition i.e., $\vec{A}\cdot(\vec{B}+\vec{C}) = \vec{A}\cdot\vec{B} + \vec{A}\cdot\vec{C}$

(ii) If $\vec{A} \perp \vec{B}$, $\theta = 90°$ $\therefore \vec{A} \cdot \vec{B} = AB\cos 90° = 0$

(iii) In case of unit vectors $\hat{i}$, $\hat{j}$ and $\hat{k}$ we have $\hat{i} \cdot \hat{j} = \hat{j} \cdot \hat{k} = \hat{k} \cdot \hat{i} = 0$

$\hat{i} \cdot \hat{i} = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k} = 1$

(iv) If $\vec{A} \parallel \vec{B}$, $\theta = 0°$ $\therefore \vec{A} \cdot \vec{B} = AB\cos 0° = AB$

For antiparallel vectors, $\theta = 180°$ $\therefore \vec{A} \cdot \vec{B} = AB\cos 180° = -AB$

(v) If $\vec{A} = \vec{B}$, $\theta = 0°$ $\therefore \vec{A} \cdot \vec{A} = A^2$

(vi) Scalar product of two vectors $\vec{A}$ and $\vec{B}$ in terms of their rectangular components is

$$\vec{A}\cdot\vec{B} = (A_x\hat{i}+A_y\hat{j}+A_z\hat{k}).(B_x\hat{i}+B_y\hat{j}+B_z\hat{k})$$

$$\vec{A}\cdot\vec{B} = A_xB_x+A_yB_y+A_zB_z$$

(vii) Angle between Vectors $\vec{A}$ and $\vec{B}$:

Since $\vec{A}\cdot\vec{B} = AB\cos\theta$

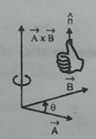
$$\Rightarrow \quad \theta = \cos^{-1}\left(\frac{\vec{A}\cdot\vec{B}}{AB}\right)$$

$$\theta = \cos^{-1}\left(\frac{A_xB_x+A_yB_y+A_zB_z}{AB}\right)$$

Vector Product or Cross Product: When the multiplication of two vectors results into a vector quantity then the product is called vector product. It is represented by putting a cross (×) between the vectors. The vector product of two vectors $\vec{A}$ and $\vec{B}$ is written as $\vec{A}\times\vec{B}$ and is defined as

$$\vec{A}\times\vec{B} = AB\sin\theta\,\hat{n}$$

Where $|\vec{A}\times\vec{B}| = AB\sin\theta$ and $\hat{n}$ is a unit vector perpendicular to the plane containing vector $\vec{A}$ and $\vec{B}$. The direction of $\vec{A}\times\vec{B}$ or $\hat{n}$ is determined by 'Right Hand Rule'. By applying right hand rule, the direction of $\vec{A}\times\vec{B}$ is opposite to that of $\vec{B}\times\vec{A}$.



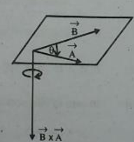
i.e., $\vec{A}\times\vec{B} = -\vec{B}\times\vec{A}$

Example of Vector Product:

(i) Torque $= \vec{\tau} = \vec{r}\times\vec{F}$

(ii) Angular momentum $= \vec{L} = \vec{r}\times\vec{P}$

(iii) Magnetic force $= \vec{F} = q(\vec{V}\times\vec{B})$



Characteristics of Cross Product:

(i) The cross product is not commutative.

i.e., $\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A}$

(ii) If $\vec{A}\perp\vec{B}$, $\theta = 90°$, then $\vec{A}\times\vec{B} = AB\sin 90\,\hat{n} = AB\,\hat{n}$

(iii) In case of unit vectors $\hat{i}$, $\hat{j}$ and $\hat{k}$, we have

$$\hat{i}\times\hat{j} = \hat{k},\quad \hat{j}\times\hat{k} = \hat{i},\quad \hat{k}\times\hat{i} = \hat{j}$$

$$\hat{j}\times\hat{i} = -\hat{k},\quad \hat{k}\times\hat{j} = -\hat{i},\quad \hat{i}\times\hat{k} = -\hat{j}$$

$$\hat{i}\times\hat{i} = \hat{j}\times\hat{j} = \hat{k}\times\hat{k} = 0$$

(iv) If $\vec{A}\parallel\vec{B}$, $\theta = 0°$, then $\vec{A}\times\vec{B} = AB\sin 0°\,\hat{n} = 0$

(v) For anti-parallel vectors $\theta = 180°$, then $\vec{A}\times\vec{B} = AB\sin 180°\,\hat{n} = 0$

(vi) If $\vec{A} = \vec{B}$, $\theta = 0$, then $\vec{A}\times\vec{A} = 0$

(viii) The cross product of two vectors $\vec{A}$ and $\vec{B}$ in terms of their rectangular components is:

$$\vec{A}\times\vec{B} = (A_x\hat{i}+A_y\hat{j}+A_z\hat{k})\times(B_x\hat{i}+B_y\hat{j}+B_z\hat{k})$$

$$\vec{A}\times\vec{B} = (A_yB_z-A_zB_y)\hat{i}+(A_zB_x-A_xB_z)\hat{j}+(A_xB_y-A_yB_x)\hat{k}$$

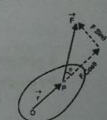
This result can be written in determinant form as:

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

(ix) $|\vec{A}\times\vec{B}|$ = area of the parallelogram formed with $\vec{A}$ and $\vec{B}$ as two adjacent sides.

Torque MCAT: The product of force ($\vec{F}$) and moment arm (ℓ).

i.e., $\tau = \ell F$

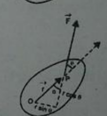


It is the vector product of position vector $\vec{r}$ and force $\vec{F}$.

i.e., $\vec{\tau} = \vec{r}\times\vec{F}$

The magnitude of the torque is given by:

$$\tau = rF\sin\theta$$



Torque depends on two factors.

- The magnitude of force $\vec{F}$
- The moment arm ℓ
- Value of θ

The SI-unit of torque is newton meter (Nm). The perpendicular distance between the line of action of force and the point of rotation is called moment arm. Torque produces turning effect, so it is the rotational analogue of force. When torque is applied on a rotating body, it produces the angular acceleration.

Special Cases: If $\vec{F}$ and $\vec{r}$ are in the same direction, then $\theta = 0°$.

$$\text{Torque} = \tau = rF\sin 0° = 0$$

If $\vec{F}$ and $\vec{r}$ are in the opposite direction, then $\theta = 180°$.

$$\text{Torque} = \tau = rF\sin 180° = 0$$

If $\vec{F}$ and $\vec{r}$ are perpendicular, then $\theta = 90°$.

$$\text{Torque} = \tau = rF\sin 90° = rF = \text{maximum value}$$

If force $\vec{F}$ is applied at the pivot then moment arm is zero, so torque will be zero.

i.e., $l = 0 \Rightarrow \text{Torque} = \tau = lF = 0$

Equilibrium: If a body is at rest or moving with a uniform velocity, then, it is said to be in equilibrium. If a body is at rest, it is said to be in **static equilibrium**. If a body is moving with uniform velocity, it is said to be in **dynamic equilibrium**.

Conditions of Equilibrium: There are two conditions of equilibrium.

First Condition of Equilibrium: If vector sum of all forces acting on a body is zero, the body is said to be in translational equilibrium.

i.e., $\sum \vec{F} = 0 \Rightarrow a = 0 \quad \because F = ma$

In case of rectangular components (coplanar forces), we can write

$$\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0$$

Second Condition of Equilibrium: If the vector sum of all torques acting on a body is zero, the body is said to be in rotational equilibrium.

i.e., $\sum \vec{\tau} = 0 \Rightarrow \alpha = 0 \quad \because \tau = I\alpha$

It is convention that the counter clockwise torque is taken as positive and clockwise torque as negative.

For complete equilibrium, we must have

$$\sum \vec{F} = 0 \quad \text{and} \quad \sum \vec{\tau} = 0$$

ASSIGNMENT NO. 2

(1) When a vector $\vec{A}$ is multiplied by a negative number then its direction:
(a) Remains same (b) Changed by 180° (c) Does not change (d) None of these

(2) What is the resultant of 3N and 4N forces acting at right angle to each other:
(a) 90 N (b) 5 N (c) 7 N (d) 1 N

(3) If a force of 10 N makes an angle of 30° with x-axis, its x-component is given by:
(a) 86.6 N (b) 0.866 N (c) 8.66 N (d) None of these

(4) Two forces act together on a body, the magnitude of their resultant is greatest when the angle between the forces is:
(a) 45° (b) 60° (c) 0° (d) 180°

(5) If a force of 50 N is acting along x-axis, then its component along y-axis will be:
(a) The same (b) Zero (c) Half magnitude (d) None of these

(6) A force of 10 N is acting along z-axis, its component along x-axis and y-axis is:
(a) 5 N, 8 N (b) 3 N, 4 N (c) 5 N each (d) Zero

(7) If a vector $\vec{A}$ makes an angle θ with x-axis, the magnitude of its x-component is:
(a) $A_y = A\sin\theta$ (b) $A_x = A\cos\theta$ (c) Both (a) and (b) (d) None of these

(8) The self scalar product of $\vec{A}$ is given by:
(a) $\sqrt{A}$ (b) A^3 (c) A^2 (d) A

(9) If $\vec{A} \times \vec{B}$ points along positive z-axis, then vector $\vec{A}$ and $\vec{B}$ will lie in:
(a) zx-plane (b) xy-plane (c) yz-plane (d) None of these

(10) If $\vec{A} = 2\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = -2\hat{i} + 2\hat{j} + \hat{k}$. What will be the value of $\vec{A} \cdot \vec{B}$:
(a) 9 (b) −9 (c) 5 (d) 10

(11) When line of action of applied force passes through the pivot point then torque will be:
(a) Maximum (b) Constant (c) Negative (d) Zero

(12) Parallel vectors of same magnitudes:
(a) Are equal (b) Are unequal
(c) When added, give the sum equal to zero (d) When multiplied, give the answer equal to zero

(13) Which one is correct?
(a) $\vec{A} = \vec{A}_x\hat{i} + \vec{A}_y\hat{j}$ (b) $\vec{A} = A_x\hat{i} + A_y\hat{k}$ (c) $\vec{A} = A_x\hat{j} + A_y\hat{i}$ (d) $\vec{A} = A_x\hat{i} + A_y\hat{j}$

(14) If both R_x and R_y components of a vector are negative, then the direction of the (resultant) vector will be determined by:
(a) $\theta = \phi$ (b) $\theta = 180 - \phi$ (c) $\theta = 180 + \phi$ (d) $\theta = 360 - \phi$

(15) When the magnitude of two component vectors are equal to that of their resultant, then the angle between the components is:
(a) 60° (b) 90° (c) 120° (d) 150°

(16) A vector of magnitude 5 N is added to a vector of magnitude 8 N while the orientations are change. Range of their possible sum will vary from:

(a) Zero to 3 N (b) 1 N to 13 N (c) 13 N to 3 N (d) None of these

(17) A vector of 10 N makes an angle of 45° with x-axis. Angle between its rectangular components with be:

(a) 45° (b) 90° (c) 135° (d) Zero

(18) Two forces each of 10 N magnitude act on a body. If the forces are inclined at 30° and 60°, respectively with x-axis, then x-component of their resultant is:

(a) 20 N (b) 13.66 N (c) 10 N (d) 8.66 N

(19) Two forces of 10 and 8 N are applied simultaneously to a body. The maximum value of their resultant is:

(a) 2 N (b) −2 N (c) 18 N (d) 36 N

(20) The magnitude of the resultant of two forces may be increased by:

(a) Increasing the angle between them (b) Decreasing the angle between them
(c) Drawing a triangle to represent them (d) None of these

(21) If two unit vectors are inclined at angle of 90°, the magnitude of their resultant will be:

(a) 2 (b) $\sqrt{2}$ (c) $\sqrt{3}$ (d) Zero

(22) Which of the following represents the magnitude of a position vector whose components are $\sqrt{2}\,\hat{i}, \sqrt{2}\,\hat{j}$ and $\sqrt{2}\,\hat{k}$:

(a) $3\sqrt{2}$ (b) $\frac{\sqrt{2}}{3}$ (c) $\sqrt{6}$ (d) $2\sqrt{2}$

(23) If the vectors $\vec{A}$ and $\vec{B}$ are such that $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$, then the angle between $\vec{A}$ and $\vec{B}$ will be:

(a) 0° (b) 60° (c) 90° (d) 180°

(24) If $\vec{A} = \hat{j} + \hat{k}$ and $\vec{B} = -\hat{j} - \hat{k}$, then angle between $\vec{A}$ and $\vec{B}$ will be nearly:

(a) 90° (b) 180° (c) 270° (d) 360°

(25) The magnitude of dot product and cross product of two vectors is 10 in each case. Find the angle between two vectors:

(a) 45° (b) 60° (c) 90° (d) 0°

(26) A vector $\vec{A}$ points vertically upwards and $\vec{B}$ points towards north. The vector product $\vec{A} \times \vec{B}$ is:

(a) Along west (b) Along east (c) Zero (d) Vertically downwards

(27) If $\vec{A} \times \vec{B} = \vec{B} \times \vec{A}$, then the angle between $\vec{A}$ and $\vec{B}$ is:

(a) π (b) $\frac{\pi}{3}$ (c) $\frac{\pi}{2}$ (d) $\frac{\pi}{4}$

(28) The two vectors have magnitudes 3 and 5. If angle between them is 60°, then the dot product of two vectors will be:

(a) 7.5 (b) 6.5 (c) 8.4 (d) 7.9

(29) The minimum number of vectors of equal magnitude required to produce a zero resultant is:

(a) 2 (b) 3 (c) 4 (d) more than 4

(30) The minimum number of vectors of unequal magnitude required to produce a zero resultant is:

(a) 2 (b) 3 (c) 4 (d) Infinite

(31) If $\vec{A} \cdot \vec{B} = |\vec{A} \times \vec{B}|$, then angle θ between vectors $\vec{A}$ and $\vec{B}$ is:

(a) 0 (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{2}$ (d) π

(32) If a unit vector is represented by $0.5\hat{i} + 0.8\hat{j} + c\hat{k}$, then the value of 'c' is:

(a) 1 (b) $\sqrt{0.11}$ (c) $\sqrt{0.01}$ (d) $\sqrt{0.39}$

(33) What is the angle between $\hat{i} + \hat{j} + \hat{k}$ and $\hat{i}$?

(a) $\frac{\pi}{6}$ (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{3}$ (d) None of these

(34) What can be the angle between $\vec{P} + \vec{Q}$ and $\vec{P} - \vec{Q}$?

(a) 0° only (b) 90° only (c) 180° (d) between 0° & 180°

(35) If $\vec{A} \times \vec{B} = \vec{0}$ and $\vec{B} \times \vec{C} = \vec{0}$, then the angle between $\vec{A}$ and $\vec{C}$ is:

(a) Zero (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{2}$ (d) None of these

(36) Given that both $\vec{A}$ and $\vec{B}$ are greater than 1. The magnitude of $\vec{A} \times \vec{B}$?

(a) equal to AB (b) less than AB (c) more than AB (d) equal to A/B

(37) The vector $\vec{P}$ makes 120° with the x-axis and the vector $\vec{Q}$ makes 30° with the y-axis. What is their resultant?

(a) P + Q (b) P − Q (c) $\sqrt{P^2 + Q^2}$ (d) $\sqrt{P^2 - Q^2}$

(38) The magnitude of the sum of the two vectors is equal to the difference of their magnitudes what is the angle between.

(a) 0° (b) 45° (c) 90° (d) 180°

(39) The magnitude of the resultant of $3\hat{i}$ and $4\hat{j}$ is:

(a) 1 (b) 5 (c) 7 (d) 25

(40) Two forces of 6 N and 8 N can produce a resultant of:

(a) 0 N (b) 1 N (c) 10 N (d) 18 N

(41) If the resultant of two forces each of magnitude F is also of magnitude F, then the angle between them is:

(a) 60° (b) 90° (c) 120° (d) 180°

(42) The minimum number of equal forces whose vector sum can be zero is:

(a) 1 (b) 2 (c) 3 (d) 4

(43) The forces of 10N and 8N are applied simultaneously to a body. The maximum value of their resultant is:

(a) 10 N (b) 15 N (c) 18 N (d) 15 N

(44) If vectors $\vec{A}$ and $\vec{B}$ are perpendicular, then magnitude of $\vec{A} \times \vec{B}$ is equal to:

(a) Zero (b) AB (c) AB $\hat{n}$ (d) AB sin θ

(45) If both rectangular components of a vector are equal and negative, the angle which the vector makes with +x-axis is:

(a) 45° (b) 135° (c) 225° (d) 315°

(46) A particle is rotating in a circle of radius r with constant speed v. The torque on the particle is:

(a) Constant (b) $vr \sin\theta$ (c) $fr \sin\theta$ (d) Zero

(47) The angle between two vectors $2\hat{i} - 3\hat{j} + \hat{k}$ and $3\hat{i} + 6\hat{k}$ is:

(a) 0° (b) 45° (c) 60° (d) 90°

(48) Given that $\vec{A} = \vec{B}$ what is the angle between $\vec{A} + \vec{B}$ and $\vec{A} - \vec{B}$?

(a) 30° (b) 60° (c) 90° (d) 180°

(49) The point of application of a force $5\hat{i} + 4\hat{j} + 10\hat{k}$ Newton is displaced from $2\hat{i} + 3\hat{j} + 4\hat{k}$ metre to $7\hat{i} + 7\hat{j} + 8\hat{k}$ metre. What is the kinetic energy gained by the system?

(a) 9 J (b) 11 J (c) 49 J (d) 81 J

(50) The flight of a bird can be an example of:

(a) Composition of vectors (b) Dot product of vectors
(c) Cross product of vector (d) Polygon law of vectors

(51) The maximum and minimum magnitudes of the resultant of vectors $\vec{A}$ and $\vec{B}$ are in the ratio of 3 : 1.

(a) $AB = 1$ (b) $A = B$ (c) $A = 2B$ (d) $A = 3B$

(52) If $\vec{A} \cdot \vec{B} = AB$ and $\vec{C} \times \vec{B} = 0$, then:

(a) $\vec{A}$ is a null vector (b) $\vec{B}$ is a null vector
(c) $\vec{A}$ and $\vec{C}$ are perpendicular to each other (d) $\vec{A}$ and $\vec{C}$ are parallel

(53) The scalar product of two vector is negative when:

(a) They are parallel vectors (b) They are perpendicular vectors
(c) They are anti-parallel vectors (d) None of these

(54) The projection of vector $\vec{A}$ on vector $\vec{B}$ is given by:

(a) $\frac{\vec{A} \cdot \vec{B}}{AB}$ (b) $\frac{\vec{A} \cdot \vec{B}}{A}$ (c) $\frac{\vec{A} \cdot \vec{B}}{B}$ (d) $\frac{\vec{A} \cdot \vec{B}}{(AB)^2}$

(55) The vector product does not obey:

(a) Commutative law (b) Distributive law (c) Associative law (d) None of above

(56) If $\vec{A} \cdot \vec{B} = 0$, then the magnitude of their cross product will be:

(a) $AB \sin\theta$ (b) $B \cos\theta$ (c) $B \sin 0$ (d) AB

(57) Two forces each of magnitude F act perpendicular to each other. The angle made by the resultant force with the X-axis will be:

(a) 30° (b) 45° (c) 60° (d) 90°

(58) The vector $\left[\frac{1}{\sqrt{2}}\hat{i} + \frac{1}{\sqrt{2}}\hat{j}\right]$ is a:

(a) Unit vector (b) Null vector
(c) Vector of magnitude $\sqrt{2}$ (d) Vector of magnitude $\frac{1}{\sqrt{2}}$

(59) Which of the following operations make no sense in case of scalars and vectors?

(a) Multiplying any vector by a scalar (b) Adding a component of vector to the same
(c) Multiplying any two scalars (d) Adding a scalar to a vector of the same dimensions

(60) If $\vec{A} \times \vec{B} = 0$ and $\vec{A} \cdot \vec{B} = -AB$, then angle between $\vec{A}$ and $\vec{B}$ is:

(a) Zero (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{2}$ (d) π

(61) Which of the following statements is false?

(a) Mass, speed and energy are scalar quantities
(b) Momentum, force and torque are vector quantities
(c) Distance is a scalar quantity but displacement is a vector quantity
(d) A vector has only magnitude, whereas a scalar has both magnitude and direction

(62) Two equal vectors have a resultant equal to either of them. The angle between them is:

(a) 60° (b) 90° (c) 100° (d) 120°

(63) If $\vec{A}$ and $\vec{B}$ are parallel, then:

(a) $\vec{A} \cdot \vec{B} = 0$ (b) $\vec{A} \cdot \vec{B} = AB$ (c) $\vec{A} \cdot \vec{B} = 1$ (d) $\vec{A} \times \vec{B} = AB$

(64) The component of $9\hat{i} + 17\hat{j}$ along z-axis is:

(a) Zero (b) 18 (c) 26 (d) 11

(65) The resultant of two vectors of magnitude 2 and 3 is 5. The angle between them is:

(a) 90° (b) 180° (c) 0° (d) None of these

(66) Current is a quantity:

(a) Scalar (b) Vector (c) Both (a), (b) (d) None of these

(67) Unit vector along z-axis is:

(a) $\hat{i}$ (b) $\hat{j}$ (c) Zero (d) $\hat{k}$

(68) If $\vec{P} = 3\hat{i} + 4\hat{j} - 2\hat{k}$, $\vec{Q} = 4\hat{i} - 3\hat{j} + 2\hat{k}$. Unit vector in the direction of $\vec{P} + \vec{Q}$ is:

(a) $7\hat{i} + \hat{j}$ (b) $\frac{7\hat{i} + \hat{j}}{\sqrt{50}}$ (c) $\frac{i}{29}(2\hat{i} - 14\hat{j} - 25\hat{k})$ (d) None of these

(69) If θ is angle between $\vec{A}$ and $\vec{B}$ then their resultant:

(a) $\sqrt{A^2 + B^2}$ (b) $\sqrt{A^2 + B^2 + AB\cos\theta}$
(c) $\sqrt{A^2 - B^2}$ (d) $\sqrt{A^2 + B^2 - AB\sin\theta}$

(70) Gives $\vec{A} = 3\hat{i} + 4\hat{j}$ and $\vec{B} = 6\hat{i} + 8\hat{j}$ which of the following statements is incorrect?

(a) $\vec{A} \times \vec{B} = 0$ (b) $\frac{|\vec{A}|}{|\vec{B}|} = \frac{1}{2}$ (c) $|\vec{A}| = 5$ (d) $\vec{A} \cdot \vec{B} = 48$

ANSWERS

(1)	(b)	(2)	(b)	(3)	(c)	(4)	(c)	(5)	(b)
(6)	(d)	(7)	(b)	(8)	(c)	(9)	(b)	(10)	(a)
(11)	(d)	(12)	(a)	(13)	(d)	(14)	(c)	(15)	(c)
(16)	(c)	(17)	(b)	(18)	(b)	(19)	(c)	(20)	(b)
(21)	(b)	(22)	(c)	(23)	(c)	(24)	(b)	(25)	(c)
(26)	(a)	(27)	(a)	(28)	(a)	(29)	(a)	(30)	(b)
(31)	(b)	(32)	(b)	(33)	(d)	(34)	(d)	(35)	(a)
(36)	(c)	(37)	(a)	(38)	(d)	(39)	(b)	(40)	(c)
(41)	(c)	(42)	(b)	(43)	(c)	(44)	(c)	(45)	(c)
(46)	(d)	(47)	(d)	(48)	(c)	(49)	(d)	(50)	(a)
(51)	(c)	(52)	(d)	(53)	(c)	(54)	(c)	(55)	(a)
(56)	(d)	(57)	(b)	(58)	(a)	(59)	(d)	(60)	(d)
(61)	(d)	(62)	(d)	(63)	(b)	(64)	(a)	(65)	(c)
(66)	(a)	(67)	(d)	(68)	(b)	(69)	(b)	(70)	(d)

SOLUTION

(18)

$$R_x = A_x + B_x$$
$$R_x = 10\cos 30^\circ + 10\cos 60^\circ$$
$$= 10(0.866) + 10\left(\frac{1}{2}\right)$$
$$= 8.66 + 5$$
$$= 13.66\ N$$

(b) is correct

(23)

$$|\vec{A} + \vec{B}| = |\vec{A} - \vec{B}|$$
$$(\vec{A} + \vec{B}).(\vec{A} + \vec{B}) = (\vec{A} - \vec{B}).(\vec{A} - \vec{B})$$
$$\vec{A}.\vec{A} + \vec{A}.\vec{B} + \vec{B}.\vec{A} + \vec{B}.\vec{B}$$
$$= \vec{A}.\vec{A} - \vec{A}.\vec{B} - \vec{B}.\vec{A} - \vec{B}.\vec{B}$$
$$A^2 + 2\vec{A}.\vec{B} + B^2 = A^2 - 2\vec{A}.\vec{B} + B^2$$
$$4\vec{A}.\vec{B} = 0$$
$$\Rightarrow \vec{A}.\vec{B} = 0$$
$$\vec{A} \perp \vec{B}$$

(c) is correct

(25)

$$\frac{|\vec{A} \times \vec{B}|}{|\vec{A}.\vec{B}|} = \frac{10}{10}$$
$$\frac{AB\sin\theta}{AB\cos\theta} = 1$$
$$\tan\theta = 1 \Rightarrow \theta = \tan^{-1}(1)$$
$$\theta = 45^\circ$$

(a) is correct

(51)

$$\frac{\text{Maximum value}}{\text{Minimum value}} : \frac{A+B}{A-B} = \frac{3}{1}$$
$$\therefore \frac{A}{B} = \frac{2}{1} \Rightarrow A = 2B$$

(c) is correct

Chapter 3

MOTION AND FORCE

MCAT UNIT 2

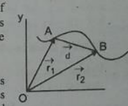
KEY POINTS

Motion: If a body changes its position with respect to its surroundings, the body is said to be in motion.

Rest: If a body does not change its position with respect to its surroundings, the body is said to be at rest. The state of rest or motion are the relative states but not absolute.

Distance: The actual length of path moved by a body is called its distance. It is a scalar quantity. Its unit is metre.

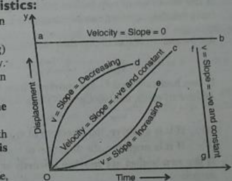
Displacement: The shortest distance between two points is called displacement. If a body is moving along a curve as shown in figure with A as its initial position and B as its final position. Then the displacement 'd' of the body is represented by AB. If r_1 is the position vector of A and r_2 that of point B then



$$d = r_2 - r_1$$

Thus the displacement is the change in the position of body from its initial to its final position when a body moves along the straight line, the displacement coincides with the path of the motion. The distance and displacement have the same unit (m) and same dimensions [L].

Displacement-time Graphs and their Characteristics:



(i) If the graph is a straight line parallel to time-axis, shown by line ab, it means that the body is **at rest, i.e., v = 0.**

(ii) A straight line inclined to x-axis (such as O and fg) shows that body is moving with a constant velocity. Remember that a straight line inclined to x-axis by an angle > 90° (line fg) represent **negative velocity.**

(iii) **It is worth nothing that no line can ever be ⊥ to the time axis** because it implies **infinite velocity**.

(iv) If the curve is of the type Od whose slope decreases with time, the velocity goes on decreasing, i.e., **motion is retarded.**

(v) If the curve is of the type O whose slope increases with time, the velocity goes on increasing, i.e., motion is **accelerated.**

Speed: The time rate of change of distance is called its speed. It is a scalar quantity and its SI-unit is m/s or ms^{-1}.

Velocity: The time rate of change of displacement is called velocity. It is a vector quantity and SI-unit of velocity is m/s or $m\,s^{-1}$. The speed and velocity have the same dimensions $[L\,T^{-1}]$.

Average Velocity: The total displacement divided by total time is called average velocity. Mathematically:

$$V_{ave} = \frac{d}{t}$$

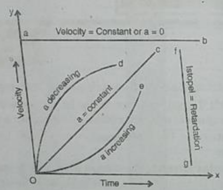
Instantaneous Velocity: It is the velocity of a body at any instant or at any point during motion. Mathematically:

$$V_{ins} = \underset{\Delta t \to 0}{\text{Limit}} \frac{\Delta d}{\Delta t}$$

Uniform Velocity: If the magnitude and direction of the velocity do not change with time, the body is said to be moving with uniform velocity. **If the instantaneous velocity does not change, the body is said to be moving with uniform velocity.**

Variable Velocity: If the magnitude or direction or both change with time, the body is said to be moving with variable velocity.

Velocity-time Graphs and their Characteristics:



(i) If the graph is a straight line parallel to time axis shown by line ab, it means that the body is moving with a constant velocity or **acceleration (a) is zero**.

(ii) If the graph is a straight line inclined to the x-axis with +ve slope (line Oc) it means that the **body is moving with constant acceleration**.

(iii) As $h = \frac{1}{2}g^2$, i.e., $h \propto r^2$, distance fallen in time t, 2t, 3t, ..., etc., will be in the ratio of $1^2, 2^2, 3^2$, ...

(iii) Distances travelled by the falling body in 1st, 2nd, 3rd second .:. are in the ratio of odd numbers, i.e., $h \propto (2n - 1)$, i.e., $h_1, : h_2 : h_3 : ...... = 1 : 2 : 5 : ....$

Distance fallen in nth sec $= h_{(n)} - h_{(n-1)} = \frac{1}{2}g(n)^2 - \frac{1}{2}g(2n-1)^2 = \frac{1}{2}g(2n-1)$

(iv) Velocities acquired by a freely falling body at the end of 1st, 2nd, 3rd second ...... are in the ratio of the integers (as $v \propto t$).

$$v_1 : v_2 : v_3 : ...... = 1 : 2 : 3 : ......$$

Relative Velocity:

(i) If the velocities of two bodies are known with respect to a common frame of reference, velocity of one body relative to other can be determined. Thus, if velocities of two bodies P and Q with respect to earth are $\vec{v}_P$ and $\vec{v}_Q$ respectively, then the velocity of Q relative to P is expressed as follows:

$$\vec{v}_{QP} = \vec{v}_Q - \vec{v}_P.$$

(ii) **If two bodies P and Q are moving along the same line in the same direction with velocities** v_P and v_Q relative to earth, the velocity of Q relative to P is:

$$v_{QP} = v_Q - v_P$$

(a) **If it is positive**, the direction of v_{QP} is same as that of Q, and

(b) **If it is negative**, the direction of v_{QP} is opposite to that of Q.

(iii) **If the two bodies are moving towards or away from each other**, velocity of Q relative to P will have magnitude

$$v_{QP} = v_Q - (-v_P) = v_Q + v_P$$

(as direction of v_P and v_Q are opposite) and directed towards P or away from P respectively.

(iv) It is worth nothing here that in dealing with the motion of two bodies relative to each other, $\vec{v}_{rel.}$ **is the difference of velocities of two bodies if they are moving in the same direction and is the sum of two velocities if they are moving in opposite directions.**

(v) **No velocity-time graph can ever be perpendicular to time-axis because it implies infinite acceleration.**

(vi) If the graph obtained is a curve like Od whose slope decreases with time, the acceleration goes on decreasing.

(vii) If the graph obtained is a curve like Oe whose slope increases with time, the acceleration goes on increasing.

(viii) **The area of velocity-time graph with time axis represents the displacement of that body.**

Acceleration: The time rate of change of velocity of a body is called acceleration. Mathematically:

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

It is a vector quantity and its direction is same as that of change in velocity. The acceleration may be produced due to change in magnitude, or direction or both. The SI unit and dimension of acceleration are m s^{-2} and $[LT^{-2}]$ respectively.

Average Acceleration: The total change in velocity divided by total time is called average acceleration.

$$a_{av} = \frac{v_2 - v_1}{\Delta t} = \frac{\Delta v}{\Delta t}$$

Instantaneous Acceleration: The acceleration of a body at any instant of time is called instantaneous acceleration.

$$a_{inst} = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

(i) If a body moves along a straight line with increasing velocity, then acceleration is directed in the direction of motion of the body and the **acceleration is positive**.

(ii) If the body moves along a straight line with decreasing velocity, then acceleration is directed opposite to the direction of motion of the body and the **acceleration is negative**.

(iii) When a body moves along a circular path with constant speed, its velocity continuously changes due to change in direction of velocity. This change in velocity per unit time is called **normal acceleration** which is always ⊥ to the velocity.

(iv) **A body can have zero velocity and still accelerating**, e.g., at the highest point of a body projected vertically upwards.

(v) **A body can have non-zero velocity and zero acceleration**. In this case velocity will be constant and motion will be uniform. However, **if acceleration is constant, acceleration is uniform but motion is non-uniform and if acceleration is not constant, both motion and acceleration are non-uniform.**

(vi) Slope of $\vec{v}$ versus time graph gives acceleration while slope of $\vec{a}$ versus time graph is a measure of rate of non-uniformity of acceleration.

(vii) **A body can have velocity varying in both magnitude and direction but still have constant acceleration**, e.g., in case of projectile motion, velocity is varying both in magnitude and direction but still have constant acceleration g.

(viii) **A body can have zero velocity and finite acceleration**, e.g., in extreme positions of an SHM.

(ix) In SHM and in circular motion, the body moves with **non-uniform acceleration**.

Time-acceleration Graphs and their Characteristics:

(i) When the graph is a straight line parallel to x-axis, then acceleration is constant.

(ii) When the graph is an oblique straight line having positive slope, then acceleration is uniformly increasing.

(iii) When the graph is an oblique straight line having negative slope, then acceleration is uniformly decreasing.

For a body starting from rest and moving with uniform acceleration:

(a) The ratio of distances covered in first one sec, two sec, three sec, ... is equal to $1^2 : 2^2 : 3^2 : ......$ i.e., 1 : 4 : 9 : ...... (or ratio of distances covered in 1st, 2nd, 3rd sec, ... is 1 : 3 : 5 : ......).

(b) The ratio of velocities after 1 sec, 2 sec, 3 sec, ... is 1 : 2 : 3 : ....

Acceleration Due to Gravity: When a body moves up or downward freely under the action of gravity, the acceleration produced in the motion of body is called acceleration due to gravity. Its value is positive, when body moves downward but it is negative when body moves upward. In SI-system, its value is 9.8 m s^{-2}. In CGS-system, its value is 980 cm s^{-2}. In British engineering -system, its value is 32 ft s^{-2}.

Equations of Motion:

- $v_f = v_i + at$
- $s = \frac{(v_f + v_i)}{2} \times t$
- $s = v_i t + \frac{1}{2} at^2$
- $2as = v_f^2 - v_i^2$

Newton's Laws of Motion: In 1687, Sir Isaac Newton proposed three laws of motion which established the relation among force, mass and motion of a body in a mathematical form.

Newton's First Law of Motion: A body will continue its state of rest or uniform motion along a straight line, unless it is acted upon by some unbalanced external force. This law is also called as law of inertia.

Inertia: The property of a body to maintain the state of rest or state of uniform motion is called its inertia. The mass is the quantitative measure of inertia of a body. Greater is the mass, greater will be the inertia and vice versa.

Inertial Frame of Reference: It is a frame of reference in which Newton's first law of motion hold. It is also known as non accelerated frame of reference because its acceleration is zero. A frame of reference fixed on the Earth is approximately an inertial frame of reference because the rotational acceleration of the Earth is very small.

Non-Inertial Frame of Reference: It is a frame of reference in which Newton's first law of motion is not valid. It is also known as accelerated frame of reference. A car moving with acceleration is an example of non-inertial frame of reference.

Force:

(i) A force is something which changes the state of rest or motion of a body. It causes a body to start moving if it is at rest or stop it, if it is in motion or to deflect it from its initial path of motion.

(ii) Force is also defined as an **interaction** between two bodies. Two bodies can also exert force on each other even without being in physical contact. This is called as **action at a distance**, e.g., electric force between two charges, gravitational force between any two bodies of the universe.

(iii) Force is a **vector** quantity having SI unit Newton (N) and dimensions $[MLT^{-2}]$.

(iv) **System of forces:**

(a) ***Concurrent forces:*** When many forces act at a point on a body, they are called concurrent forces. In the system of concurrent forces, the forces may be collinear, i.e., along the same straight line or coplanar, i.e., in the same plane.

(b) ***Coplanar forces:*** When many forces act at different points of a body but all lie in one plane, they are called coplanar forces.

(c) ***General system of forces:*** In some cases, the different forces acting on a body are not confined to a single plane. Such forces form a general system of forces.

(v) **Superposition of forces:** When many forces are acting on a single body, the resultant force is obtained by using the laws of vector addition.

Basic Forces in Nature:

(i) There are four types of basic forces that exist in nature:
(a) Gravitational force (b) Electromagnetic force (c) Nuclear force (d) Weak force

(ii) Many other well known forces like frictional force, elastic force, viscous force, spring force, etc.

Newton's Second Law of Motion: When a force acts on a body, it produces the acceleration in its own direction which is directly proportional to the force applied and inversely proportional to the mass of the body.

Mathematically: $a \propto F$ and $a \propto \frac{1}{m} \Rightarrow F = ma$

If mass m is constant, then $\frac{F_1}{F_2} = \frac{a_1}{a_2}$

If force F is constant, then $\frac{a_1}{a_2} = \frac{m_2}{m_1}$

Newton's Third Law of Motion: To every action, there is an equal and opposite reaction. If body A exerts a force $\vec{F}$ on body B, then B exerts equal and opposite force $-\vec{F'}$ on A.

Thus, $\vec{F} = -\vec{F'}$.

Action and reaction forces act on different bodies, so, they never cancel the effect of each other.

Momentum: The product of mass (m) and velocity ($\vec{v}$) of the body is called linear momentum.

i.e., $\vec{p} = m\vec{v}$

The momentum is a vector quantity and it has the same direction as that of velocity. The SI-unit of momentum kg ms^{-1} or Ns. The dimensions of momentum are $[MLT^{-1}]$. The time rate of change of linear momentum of a body is equal to the applied force.

i.e., $\vec{F} = \frac{\Delta\vec{P}}{t}$

Impulse: When a large force acts on the body for a very short interval of times the momentum changes then the product of force $\vec{F}$ and time 't' is called impulse of force or impulse.

i.e., Impulse $= \vec{I} = \vec{F} \times t$

Impulse is a vector quantity and its direction is same as that of force $\vec{F}$. In SI system, the unit of impulse is Newton second (Ns). The impulse and momentum has same dimension i.e. $[MLT^{-1}]$.

Law of Conservation of Momentum: This law state that total linear momentum of an isolated system remains constant. Total initial momentum of the system before collision is equal to the total final momentum of the system after collision.

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

Elastic Collision: A collision in which the K.E of the system is conserved is called elastic collision.

Inelastic Collision: A collision in which the K.E of the system is not conserved is called inelastic collision.

Elastic Collision in One Dimension: If the colliding bodies do not leave their line of motion before and after collision, the collision is called one dimensional collision. When two balls of masses m_1 and m_2 make one dimension elastic collision, then we observed that:

- Velocity of m_1 w.r.t. m_2 before collision = Velocity of m_1 w.r.t. m_2 after collision

$$v_1 - v_2 = -(v_1' - v_2')$$

i.e., Velocity of approach = –Velocity of separation
Speed of approach = Speed of separation

Velocities of the Balls after Collision: The velocities of balls of 6 masses m_1 and m_2 after collision are given by

$$v_1' = \frac{(m_1 - m_2)}{(m_1 + m_2)}v_1 + \frac{2m_2}{(m_1 + m_2)}v_2$$

$$v_2' = \frac{2m_1}{(m_1 + m_2)}v_1 + \frac{(m_2 - m_1)}{(m_1 + m_2)}v_2$$

Special Cases: When two identical balls collide elastically, then after the collision they interchange their velocities. i.e.,

When $m_1 = m_2$ then $v_1' = v_2$ and $v_2' = v_1$

If $m_1 = m_2$ and $v_2 = 0$ then $v_1' = 0$ and $v_2' = v_1$

When a light body collides with a massive body at rest then after collision the light body will bounce back with same velocity while heavy body will remain stationary. i.e.,

When $m_1 << m_2$ and $v_2 = 0$ then $v_1' = -v_1$ and $v_2' = 0$

When a massive body collides with a light stationary body, then the massive body after collision continues its motion with same velocity but the light body flies off in the forward direction with twice the velocity of the massive body. i.e.,

When $m_1 >> m_2$ and $v_2 = 0$ then $v_1' = v_1$ and $v_2' = 2v_1$

Force Due to Water Flow: When water from a horizontal pipe strikes a wall normally, a force is exerted on the wall. The force exerted by water on wall is given by

$$F = \frac{m}{t} \times v$$

Force = Mass per time × Change in velocity

Suppose the water flows out from a pipe at 3 kg/s and its velocity changes from 5 m/s to zero on striking the wall then:

$$F = \frac{m}{t} \times \Delta v$$
$$= 3 \times (5 - 0)$$
$$= 15\ kg/ms^2$$
$$F = 15\ N$$

Momentum and Explosive Forces: The explosive forces change the momentum within an isolated system but total momentum of the system remains constant.

- When a bomb explodes in mid-air, its fragments fly off in different directions. The total momentum of all its fragments equals to the initial momentum of the bomb.
- When a bullet is fired from rifle, then the momentum of the rifle is equal and opposite to that of bullet. Since, mass of rifle is much greater than the bullet, therefore the rifle moves back with very small velocity than that of the bullet.

i.e., $MV' = -mv$

$$\Rightarrow \quad V' = \frac{-mv}{M}$$

Rocket Propulsion: The rocket moves according to law of conservation of linear momentum. The rocket gains momentum equal to the momentum of the gas expelled from the engine but in opposite direction. A rocket carries its own fuel in the form of a liquid or solid and oxygen. A typical rocket consumes about 10,000 kg s^{-1} of fuel and ejects the burnet gases at speeds of over 4000 ms^{-1}. More than 80% of the launch mass of a rocket consists of fuel only. If m is the mass of the gases ejected per second with velocity v relative to the rocket, the force (up thrust) acting on the rocket is:

$$F = \frac{\Delta P}{t} \qquad (\therefore \Delta P = mv \text{ and } t = 1\text{ sec})$$
$$F = mv$$

The acceleration of the rocket is given by:

$$a = \frac{mv}{M}$$

When the fuel in the rocket is burned and ejected, the mass M of rocket decreases and hence the acceleration of the rocket increases.

Projectile: A body thrown in air by making a certain angle θ ($\theta \neq 90$) with horizontal and moves freely under the action of gravity is called projectile. The path of the trajectory of projectile in air is a parabola.

Ballistic Missiles: An un-powered and un-guided missile is called a ballistic missile. A flight in which a projectile is given an initial push and is then allowed to move freely due to inertia under the action of gravity is called ballistic flight. The path followed by the ballistic missile is called ballistic trajectory. The motion of ballistic missile is superposition of two independent motions.

- Inertial motion along a straight line in the direction of launch.
- Motion under the action of gravity.

For short ranges and flat earth approximation, the trajectory is parabolic but the drugless ballistic trajectory for spherical earth should actually be elliptical. At high speed and for long trajectories, the air friction is not negligible and some times the force of air friction is more than gravity.

Uses of Ballistic Missiles: The ballistic missiles are used only for short ranges. For long ranges and greater precision, powered and remote control guided missiles are used.

Some other Important Points Concerning Projectile Motion

(i) In case of projectile motion:

(a) **If g can be taken as constant in magnitude and direction**, i.e., if velocity of projection is small, the path is a **parabola**.

(b) **If g cannot be taken as constant in magnitude and direction**, i.e., if velocity of projection is large, the path is a **conic section**.

(c) **If $\theta = 90°$**, path is a **straight line.**

(d) **If $v = 7.8$ km/sec,** the path is a **circle**.

(e) **If v lies between 7.8 km/sec and 11.2 km/sec**, the path is an **ellipse**.

(ii) The velocity of projectile is minimum at the highest point of its path but it is not zero. Its value is $v_i \cos\theta$ and it remains same at all the instants during motion.

(iii) In case of projectile motion, quantities like acceleration, horizontal component of velocity and mechanical energy remain unchanged but speed, velocity, vertical component of velocity, momentum, KE and PE change.

(iv) **When the range of projectile is maximum** (for $\theta = 45°$) the height H attained by the projectile.

$$H = \frac{v^2 \sin^2 45°}{2g} = \frac{v^2}{4g} = \frac{R_{max}}{4}$$

(v) **When the height H attained by projectile is maximum** (for $\theta = 90°$), the range becomes zero.

(vi) If a man can throw a projectile to a maximum distance R_{max} ($= v^2/g$ for $\theta = 45°$), the maximum height to which he can throw the projectile is $= R_{max}/2$.

(vii) **In the presence of air resistance**, the range and the maximum height attained are reduced but the time of flight and the angle with which the projectile strikes the ground are increased.

(viii) If in case of a projectile motion, range R is n times the maximum height H, i.e., $R = nH$, then $\tan\theta = (4/n)$.

(a) If $R = H$, $n = 1$, $\theta = \tan^{-1}(4) = 76°$.

(b) If $R = 4H$, $n = 4$, $\theta = \tan^{-1}(1) = 45°$.

(ix) (a) If two bodies projected with angles θ_1 and θ_2 reach the same maximum height, then their velocities are in the ratio $(\sin\theta_2 / \sin\theta_1)$.

(b) If two bodies projected with angles θ_1 and θ_2 have the same range, then the initial velocities are in the ratio $\sqrt{(\sin 2\theta_2 / \sin 2\theta_1)}$.

(x) The angle between velocity and acceleration during ascent of a projectile is $180° < \theta < 90°$, but during descent it is $90° < \theta < 0°$.

Gravitation:

(i) Gravitation is the force of attraction between any two bodies in this universe. It is given by:

$$F = \frac{Gm_1m_2}{r^2}$$

where G is universal gravitational constant. The value of $G = 6.67 \times 10^{-11}$ N-m²/kg².

(ii) The value of G is independent of:
 (a) the nature and size of the bodies.
 (b) the nature of medium between the two bodies.

(iii) The gravitational force of attraction between two bodies is not affected by the presence of other nearby bodies.

(iv) Due to extremely small value of G, we do not experience gravitational force in our day-to-day life.

(v) Gravitational force between two charged particles is negligible as compared to the electric force.

(vi) Gravitational force is a **conservative force**.

(vii) Gravitational is the **central force**. It acts along the line joining the particles.

(viii) It is the weakest force in nature. It is 10^{38} times smaller than nuclear force and 10^{36} times smaller than electric force.

Gravity and Acceleration Due to Gravity:

(i) If one of the attracting bodies is **earth**, the force of attraction is called the **force of gravity** or simply **gravity**. If M is the mass of earth and R its radius then force of gravity on a body of mass m lying on or near the surface of earth is

$$F_g = \frac{GMm}{R^2}$$

(ii) Acceleration produced in a body due to force of gravity is called as acceleration due to gravity 'g'. It is given by:

$$g = \frac{GM}{R^2}$$

This equation provides the value of g on the surface of earth.

(iii) If ρ is the mean density of the material of earth, then

$$g = \frac{GM}{R^2} = \frac{G \cdot \frac{4}{3}\pi R^3 \rho}{R^2} = \frac{4}{3}\pi G R \rho$$

 (a) **g does not depend upon the mass, size and shape of the body when moving in vacuum.**
 (b) The value of g on the moon is about one-sixth of that on the earth and on the sun is about 27 times that on the earth.
 (c) **g is maximum on Jupiter and minimum on planet Mercury.**

Variation of 'g':

(i) **Due to altitude:** Acceleration due to gravity at a height h above the surface of earth is given by:

$$g_h = \frac{GM}{(R+h)^2} = g\left[1 - \frac{2h}{R}\right] \quad (\text{for } h << R)$$

(ii) **Due to depth:** Acceleration due to gravity at a depth h below the surface of earth is given by

$$g_h' = g\left[1 - \frac{h}{R}\right] \quad (\text{for } h << R)$$

At h = R (i.e., at the centre of earth): $g_h' = 0$.

(iii) For h << R, the rate of decrease of g with height is nearly two times of that with depth. g also represents gravitational intensity due to earth.

ASSIGNMENT NO. 3

(1) With the help of velocity-time graph, we can find:
(a) Distance (b) Time (c) Velocity (d) Momentum

(2) The area under the curve of velocity-time graph gives:
(a) Acceleration (b) Velocity (c) Distance (d) Direction

(3) If a body is moving with constant velocity of 20 m/s towards North then its acceleration is:
(a) 5 m/s² (b) 9 m/s² (c) 10 m/s² (d) Zero

(4) The laws of motion shows the relation between:
(a) Distance and velocity (b) Displacement and velocity
(c) Mass and velocity (d) Force and acceleration

(5) Inertia of a body is measured in terms of its:
(a) Weight (b) Force (c) Mass (d) Acceleration

(6) A force of 100 N acts on a body for 5 seconds, what will be the change in momentum:
(a) 20 N-s (b) 500 N-s (c) 100 N-s (d) 1000 N-s

(7) Velocity of the projectile at the maximum height attained when projected with velocity v_i is:
(a) $v_x = v_i \sin\theta$ (b) $v_H = v_i \cos\theta$ (c) Zero (d) v_i

(8) A body falling freely strikes the ground in 5 seconds, distance covered by it in 5 second is:
(a) 122.5 m (b) 25 m (c) 24.5 m (d) 34.5 m

(9) The total time for which the projectile remains in air is called:
(a) Time of projectile (b) Time period (c) Time of flight (d) Time constant

(10) The angle of projection to cover maximum horizontal range is:
(a) 90° (b) 120° (c) 18° (d) 45°

(11) The ballistic missiles are useful only for:
(a) Long range (b) Vertical range (c) Short range (d) Normal range

(12) When there is no loss of K.E and momentum then the collision is called:
(a) Elastic collision (b) In-elastic collision (c) Inertial collision (d) None of these

(13) The horizontal component of a projectile moving with initial velocity of 200 m/s at an angle of 60° to x-axis is:
(a) 100 m/s (b) 250 m/s (c) 50 m/s (d) 200 m/s

(14) A ball is dropped from a height of 4.2 metres. To what height will it rise if there is no loss of K.E. after rebounding?
(a) 4.2 m (b) 8.4 m (c) 12.6 m (d) None of these

(15) The dimension of linear inertia is:
(a) MLT^2 (b) ML^0T^{-2} (c) ML^0T^0 (d) MLT^{-1}

(16) A body of mass 5 kg is acted upon by a constant force of 20 N for 7 seconds. The total change in momentum will be:
(a) 10 NS (b) 100 NS (c) 140 NS (d) 200 NS

(17) **The magnitude of the force producing an acceleration of 10 m/sec^2 in a body of mass 0.5 kg is:**

(a) 3 N (b) 4 N (c) 5 N (d) 6 N

(18) **A certain force gives an acceleration of 4 m/sec^2 to a body of mass 10 kg. The same force would give a 20 kg object an acceleration of:**

(a) 0.5 m/sec^2 (b) 2.0 m/sec^2 (c) 1.5 m/sec^2 (d) 9.8 m/sec^2

(19) **One newton is a force that produces an acceleration of 5 m/sec^2 in a body of mass:**

(a) 0.2 kg (b) 3 kg (c) 4 kg (d) 8 kg

(20) **A body is thrown vertically upward with initial velocity of 19.6 m sec^{-1}. It will reach the height of:**

(a) 49.2 m (b) 29.4 m (c) 9.8 m (d) 4.9 m

(21) **If the acceleration of a body is negative, then slope of the velocity-time graph will be:**

(a) Zero (b) Positive (c) Negative (d) Infinity

(22) **Acceleration of 2.5 m sec^2 expressed in km hr^2 is:**

(a) 324 (b) 5.4 (c) 5400 (d) 32400

(23) **A body starting from rest covers a distance of 45 km and acquires a velocity of 100 km/hr. Its acceleration will be:**

(a) 0.092 m sec^{-2} (b) 0.8 m sec^{-2} (c) 7.71 m sec^{-2} (d) 0.15 m sec^{-2}

(24) **A force of 50 N acts on a body for 0.01 sec. and changes its velocity from 5 m sec^{-1} to 10 m sec^{-1}. The amount of impulse will be:**

(a) 100 N sec. (b) 250 N sec. (c) 10 N sec. (d) 5 N sec.

(25) **Two fast moving vehicles suffer head-on collision with a force of 1000 N for an interval of 10^{-3} seconds. The impulse is:**

(a) 10^{-5} NS (b) 1 NS (c) 10^{-3} NS (d) 10^5 NS

(26) **Range of the projectile is the same for the following pair of angles:**

(a) 0° and 45° (b) 35° and 55° (c) 15° and 60° (d) 30° and 75°

(27) **A body is moving with a velocity v in the east direction. If it travels with the same velocity in the north direction, then resultant velocity is:**

(a) v (b) 2v (c) $\frac{v}{\sqrt{2}}$ (d) $\sqrt{2v}$

(28) **If displacement of a particle is zero, the distance covered:**

(a) must be zero (b) may or may not be zero
(c) cannot be zero (d) depends upon the particle

(29) **A body moves 4 m towards east and then 3 m north. The displacement and distance covered by the body are:**

(a) 7 m, 6 m (b) 6 m, 5 m (c) 5 m, 7 m (d) 4 m, 3 m

(30) **A moving body is covering the distance directly proportional to the square of the time. The acceleration of the body is:**

(a) Increasing (b) Decreasing (c) Zero (d) Constant

(31) **A body covered a distance of 5 m along a semicircular path. The ratio of distance to displacement is:**

(a) 11 : 7 (b) 12 : 5 (c) 8 : 3 (d) 7 : 5

(32) **Which of the following changes when a particle is moving with uniform velocity?**

(a) Speed (b) Velocity (c) Acceleration (d) Position vector

(33) **If R is the maximum horizontal range of a particle, then the greatest height attained by it is:**

(a) R (b) 2R (c) $\frac{R}{2}$ (d) $\frac{R}{4}$

(34) **A stone is just released from the window of a train moving along a horizontal straight track. The stone will hit the ground following a:**

(a) Straight line path (b) Circular path (c) Parabolic path (d) Hyperbolic path

(35) **If the time of flight of a projectile is doubled, what happens to the maximum height attained?**

(a) Halved (b) Remains unchanged (c) Doubled (d) Becomes four times

(36) **A 10 N force is applied on a body which produces in it an acceleration of 1 m/s^2. The mass of the body is:**

(a) 10 kg (b) 5 kg (c) 15 kg (d) 20 kg

(37) **Which of the following changes when a particle is moving with uniform velocity:**

(a) Speed (b) Velocity (c) Acceleration (d) Position vector

(38) **The numerical ratio of velocity to speed is:**

(a) Less than 1 (b) Less than 0
(c) Greater than 1 (d) Either less than or equal to one

(39) **A moving particle finally comes to rest. What will be the angle between acceleration and displacement during motion?**

(a) $\frac{\pi}{2}$ (b) $\frac{\pi}{4}$ (c) π (d) 0

(40) **The gradient of the velocity time graph represents:**

(a) Speed (b) Acceleration (c) Distance (d) Velocity

(41) **A body of 2 kg moves with an acceleration of 20 ms^{-2}. Its rate of change of momentum is:**

(a) 10 kg ms^{-2} (b) 20 kg ms^{-2} (c) 40 kg ms^{-2} (d) 400 kg ms^{-2}

(42) **A bullet of mass 'm' is fired with a velocity V into a block mass M and sticks to it. The final velocity of the system is:**

(a) $\frac{m}{M}V$ (b) $\frac{m}{m+M}V$ (c) $\frac{M}{m}V$ (d) $\frac{m+M}{m}V$

(43) **A projectile is thrown at an angle 45^0 with horizontal. If K is the K.E with which the projectile was thrown, then the K.E at the top of the trajectory is:**

(a) 2K (b) 4K (c) $\frac{K}{2}$ (d) $\frac{K}{4}$

(44) **At the top of the trajectory of a projectile, the direction of its velocity and acceleration are:**

(a) Perpendicular to each other (b) Parallel to each other
(c) Inclined at an angle 45^0 of to the horizontal (d) None of the above is correct

(45) **A ball of weight 0.5 N is thrown vertically upward. The ball returns to the ground in 4 s, then the impulse of the ball is:**

(a) 1 Ns (b) 2 Ns (c) 4 Ns (d) 20 Ns

(46) If m is the mass of the gases ejected per second with velocity v relative to the rocket of mass M, then the up thrust acting on the rocket is:
(a) mv (b) mv/M (c) Mv/m (d) Mmv

(47) A projectile will cover same horizontal distance when the initial angles of projection are:
(a) 20°, 60° (b) 20°, 50° (c) 20°, 40° (d) 20°, 70°

(48) At what angle with the horizontal should a ball be thrown so that its range R is related to the time of flight as $R = 5T^2$ (Take $g = 10\ ms^{-2}$)
(a) 30° (b) 45° (c) 60° (d) 90°

(49) During projectile motion, the quantities that remain unchanged are:
(a) Force and vertical velocity (b) Acceleration and horizontal velocity
(c) Kinetic energy and acceleration (d) Acceleration and momentum

(50) A trolley runs down a slope from rest with constant acceleration. In the first second, it travels 1.6 m. its acceleration is:
(a) $0.8\ ms^{-2}$ (b) $1.6\ ms^{-2}$ (c) $3.2\ ms^{-2}$ (d) $6.4\ ms^{-2}$

(51) There are three Newton's laws of motion. We can derive:
(a) Second and third laws from first law (b) Third and first laws from second law
(c) First and second laws from third law (d) All the laws are independent of each other

(52) A shell in flight explodes into four unequal parts. Which of the following is conserved?
(a) Momentum and K.E (b) Momentum and total energy
(c) K.E (d) Neither momentum nor K.E

(53) The acceleration of a body sliding down a smooth inclined plane is given by:
(a) $g \sin\theta$ (b) $\mu \cos\theta$ (c) $g(\sin\theta + \mu\cos\theta)$ (d) $g(\sin\theta - \mu\cos\theta)$

(54) The string of a vibrating pendulum is cut when it is at extreme position. The bob will follow a:
(a) Vertical path (b) Horizontal path (c) Parabolic path (d) Circular path

(55) The numerical value of the ratio of displacement to distance is:
(a) Always less than one (b) Always equal to one
(c) Always more than one (d) Equal to or less than one

(56) Two bodies are projected at angle 'θ' and (90 – θ) to the horizontal with the same speed the ratio of their times of flight $\frac{T_1}{T_2}$ is:
(a) 1 : 1 (b) 1 : tan θ (c) tan θ : 1 (d) None of these

(57) The magnitude of average velocity is equal to the average speed when a particle moves:
(a) on a curved path (b) in the same direction
(c) with constant acceleration (d) with constant retardation

(58) A body is imparted motion from rest to move in a straight line. It is then obstructed by an opposite force; then:
(a) the body may necessarily change direction
(b) the body is sure to slow down
(c) the body will necessarily continue to move in the same direction at the same speed
(d) none of the above

(59) The distances travelled by a body falling freely from rest in the first, second and third seconds are in the ratio:
(a) 1 : 2 : 3 (b) 1 : 3 : 5 (c) 1 : 4 : 9 (d) None of these

(60) Which of the following four statements is false?
(a) A body can have zero velocity and still be accelerated
(b) A body can have a constant velocity and still have a varying speed
(c) A body can have a constant speed and still have a varying velocity
(d) The direction of the velocity of a body can change when its acceleration is constant

(61) If an iron ball and a wooden ball of the same radius are released from a height h in vacuum, then time taken by both of them to reach ground will be:
(a) Unequal (b) Exactly equal (c) Roughly equal (d) Zero

(62) The angle between instantaneous displacement and acceleration during the retarded motion is:
(a) 180° (b) 40° (c) 45° (d) 0°

(63) A fighter plane is chasing another plane, when it opens fire its speed.
(a) Increases (b) Decreases (c) Remains same (d) It stops

(64) During the projectile motion, the horizontal component of velocity.
(a) Changes with time (b) Becomes zero (c) Remains constant (d) Increases with time

(65) Newton's first law of motion gives definition of:
(a) Mass (b) Force (c) Acceleration (d) Speed

(66) The acceleration of projectile at the highest point is:
(a) Zero (b) Increases (c) Decreases (d) Constant

(67) Change of momentum is called:
(a) Force (b) Pressure (c) Impulse (d) Tension

(68) For a projectile, the ratio of maximum height reached to the square of flight time is:
(a) 5 : 4 (b) 5 : 2 (c) 5 : 1 (d) 10 : 1

(69) A body is dropped from a tower with zero velocity reaches ground in 4 seconds. The height of the tower is about:
(a) 80 m (b) 20 m (c) 160 m (d) 40 m

(70) A cricket ball is hit so that it travels straight up in air and it can acquires 3 seconds to reach the maximum height. Its initial velocity is:
(a) $10\ ms^{-1}$ (b) $15\ ms^{-1}$ (c) $29.4\ ms^{-1}$ (d) $12.2\ ms^{-1}$

ANSWERS

(1)	(a)	(2)	(c)	(3)	(d)	(4)	(d)	(5)	(c)
(6)	(b)	(7)	(b)	(8)	(a)	(9)	(c)	(10)	(d)
(11)	(c)	(12)	(a)	(13)	(a)	(14)	(a)	(15)	(c)
(16)	(c)	(17)	(c)	(18)	(b)	(19)	(a)	(20)	(c)
(21)	(c)	(22)	(d)	(23)	(b)	(24)	(b)	(25)	(b)
(26)	(b)	(27)	(d)	(28)	(b)	(29)	(c)	(30)	(d)
(31)	(a)	(32)	(d)	(33)	(d)	(34)	(c)	(35)	(d)
(36)	(a)	(37)	(d)	(38)	(d)	(39)	(c)	(40)	(b)
(41)	(c)	(42)	(b)	(43)	(c)	(44)	(a)	(45)	(b)
(46)	(b)	(47)	(d)	(48)	(b)	(49)	(b)	(50)	(c)
(51)	(b)	(52)	(b)	(53)	(a)	(54)	(a)	(55)	(d)
(56)	(c)	(57)	(b)	(58)	(b)	(59)	(b)	(60)	(b)
(61)	(b)	(62)	(a)	(63)	(b)	(64)	(c)	(65)	(b)
(66)	(d)	(67)	(c)	(68)	(a)	(69)	(a)	(70)	(c)

SOLUTION

(8) $S = v_i t + \frac{1}{2}gt^2$

As $v_i = 0$

$S = \frac{1}{2}gt^2$

$S = \frac{1}{2}(9.8)(5)^2 = 122.5\text{ m}$

(a) is correct

(16) $\Delta P = F \times \Delta t = 20(7) = 140\text{ Ns}$

(c) is correct

(19) $F = ma \Rightarrow m = \frac{F}{a}$

$m = \frac{1}{5} = 0.2\text{ kg}$

(a) is correct

(22) 2.5 ms^{-2}

$\frac{2.5 \times 3600 \times 3600}{1000} = 32400$

(d) is correct

(33) Max horizontal range at $\theta = 45°$.

$R_{max} = \frac{v_i^2}{g} \Rightarrow R = \frac{v_i^2}{g}$

$h = \frac{v_i^2 \sin^2\theta}{2g} \Rightarrow h = \frac{v_i^2}{2g}(\sin 45°)^2$

$h = \frac{v_i^2}{2g}\left(\frac{1}{\sqrt{2}}\right)^2$

$h = \frac{1}{4}\left(\frac{v_i^2}{g}\right)$

$h = \frac{R}{4}$

(d) is correct

(56) $\frac{T_1}{T_2} = \frac{\frac{2v_i \sin\theta}{g}}{\frac{2v_i \cos\theta}{g}} = \frac{\tan\theta}{1}$

(c) is correct

Chapter 4

WORK AND ENERGY

KEY POINTS

Work MCAT

(i) Work is said to be done by a force when the point of application of the force is displaced along same direction.

(ii) Work depends upon two factors:

(a) Force applied and (b) Distance travelled by the body in the direction of force.

(iii) The work done by the force is measured by the product of magnitude of force and the displacement of the point of application in the direction of force, i.e., $W = Fs$.

(iv) If the distance s moved by the body is not in the direction of force but makes an angle θ with it, then work done is given by: $W = F(s\cos\theta) = \vec{F} \cdot \vec{s}$.

(v) If the force and displacement are at right angles to each other, the work done is zero, i.e., $W = Fs\cos 90° = 0$.

(vi) If the angle between $\vec{F}$ and $\vec{s}$ is acute ($\theta < 90°$), then work done is positive. But, if the angle between $\vec{F}$ and $\vec{s}$ is obtuse ($\theta > 90°$), then the work done is negative. For example, when an object is pulled on a rough surface, the work done by the pulling force is positive. while work done by frictional force is negative.

(vii) The formula $W = Fs$ represents mechanical work. It is performed only when body is displaced. If there is no displacement no mechanical work is performed, e.g., if we push hard against a wall with our hands, no work is done from the point of view of physics, although our body uses chemical energy in its tissues and muscles to hold our hands against the wall. As the body uses this energy, it becomes tired but in terms of mechanical energy, no work is done.

(viii) **If the force and displacement both are variable quantities,** then the work done is represented by the area under force-displacement graph added with sign.

(ix) If the work done does not depend on path followed, then the force is called **conservative**. The gravitational and electrostatic forces are conservative forces.

(x) In a uniform circular motion of a body, the work done by centripetal force is zero. That is why the speed or KE remains constant.

(xi) The magnetic force $\vec{F} = q(\vec{v} \times \vec{B})$ on a moving charged particle is always perpendicular to $\vec{v}$ or $d\vec{r}$ therefore, work done by magnetic force on a moving charge is zero.

(xii) The SI unit of work is joule (J). Other units are erg, eV, MeV, kWh.

(a) $1\text{ joule} = 10^7\text{ erg}$ (b) $1\text{ erg} = 10^{-7}\text{ joule}$ (c) $1\text{ eV} = 1.6 \times 10^{-19}\text{ J}$

(d) $1\text{ joule} = 6.25 \times 10^{18}\text{ eV}$ (e) $1\text{ MeV} = 1.6 \times 10^{-13}\text{ J}$ (f) $1\text{ J} = 6.25 \times 10^{12}\text{ MeV}$

(g) $1\text{ kWh} = 3.6 \times 10^6\text{ J}$

Work Done by a Constant Force **MCAT**: Work is the scalar product of force $\vec{F}$ and the displacement $\vec{d}$.

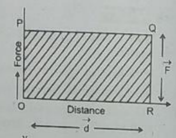
i.e., $W = \vec{F} \cdot \vec{d} = F d \cos\theta$

Where 'θ' is the angle between the force $\vec{F}$ and the displacement $\vec{d}$.
The SI-unit of work is N m whish is also known as joule.
i.e., 1 J = 1 Nm
The dimensions of work are $[ML^2T^{-2}]$.

Force Displacement Graph MCAT

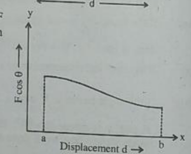
- A graph platted between force 'F' and displacement 'd' is called force displacement graph. The work done by force is equal to the area under the force displacement. The work done by a constant force is equal to area of rectangle as shown in figure.

  Work done $= F \times d =$ Area of rectangle



- The work done by a variable force is equal to the area under the F cos θ curve and d-axis between two points a and b as shown in figure.

$$W_{Total} = \lim_{\Delta d \to 0} \sum_{i=1}^{i=N} F_i \cos\theta_i \Delta d_i$$



Gravitational Field: It is the space around the Earth in which it exerts force on a body. In gravitational field, the force acting on the body is equal to weight of the body. In gravitational field,
- Work done is independent of the path followed.
- Work done in moving a body around a closed path is zero.

Conservative Field: A conservative field is that in which:
- Work done is independent of the path followed.
- Work done in moving a body around a closed path is zero.
- Examples are Gravitational Field, Electric Field and Magnetic Field.

Conservative Force: A conservative force is that force whose,
- Work done is independent of the path followed.
- Work done in moving a body around a closed path is zero.
- Examples are Gravitational Force, Electric Force and Magnetic Force.

Non-conservative Force: A non-conservative force is that force whose:
- Work done is dependent of the path followed.
- Work done in moving a body around a closed path is not zero.
- Examples are frictional force, air resistance, normal reaction of a surface, up thrust on a rocket, tension in a string etc.

Power: The rate of doing work is called power

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

In linear motion, the power is the scalar product of force and velocity,

i.e., $P = \vec{F} \cdot \vec{V}$

In angular motion, the power is the scalar product of torque and angular velocity.

$P = \vec{\tau} \cdot \vec{\omega}$

Average Power: The average power is defined as:

$$P_{av} = \frac{\text{total work done}}{\text{total time taken}}$$

Instantaneous Power: It is the power applied at any instant during the process of work done. Mathematically, it is defined as:

$$P = \lim_{\Delta t \to 0} \frac{\Delta w}{\Delta t}$$

Approximate Powers

Device	Power (W)
Jumbo Jet Aircraft	1.3×10^8
Car at 90 km h^{-1}	1.1×10^5
Electric heater	2×10^3
Colour TV	120
Flash light (two cells)	1.5
Pocket calculator	7.5×10^{-4}

Unit of Power: The S-I unit of power is a watt after James Watt. Where $1\ W = 1\ Js^{-1}$. In British Engineering System, the unit of power is horse power (h.p)

Where 1 h. p = 746 watts = 550 foot pound/sec.

Commercial Unit of Electrical Energy: Watt-second is the unit of work in term of power. The commercial unit of electrical energy is a kilowatt-hour. (KWh)

Where 1 KWh = 1000 watt × 1 hour $= 3.6 \times 10^6$ J = 3.6 MJ

Energy: The capacity of a body to do work is called its energy. Basic forms of energy are:
- Kinetic energy
- Potential energy

Kinetic Energy: It is the energy possessed by a body due to its motion and is given by the formula.

$$K.E = \frac{1}{2} m v^2$$

Approximate Energy Values

Source	Energy (J)
Burning 1 ton coal	30×10^9
Burning 1 litre petrol	5×10^7
K.E. of car at 90 km h^{-1}	1×10^6
Running person at 10 km h^{-1}	3×10^2
Fission of one atom of uranium	1.8×10^{-11}
K.E. of a molecule of air	6×10^{-21}

Potential Energy: It is the energy possessed by a body due to its position in a force field or due to its constrained state.

Examples:
- Gravitational potential energy
- Elastic potential energy.

Gravitational Potential Energy: It is the energy possessed by a body due to its position or height from the surface of the earth. It is given by the formula.

$$P.E. = mgh$$

Where 'h' is height of the body from the surface of Earth.

Elastic Potential Energy: It is the energy stored in a compressed or stretched spring.

Work-Energy Principle: Thus principle states that the work done on a body is equal to change in its kinetic energy. Mathematically:

Work done = Change in K.E.

Examples: Work done on a horizontally moving body is equal to its change in K.E.

$$\text{Work done} = (K.E)_f - (K.E)_i$$

- When a body is raised up from the Earth's surface, the work done is equal to the change in gravitational potential energy.
- When a spring is compressed, the work done on it equals the increase in its elastic potential energy.

Absolute Potential Energy: It is the work done by the gravitational force in displacing the object from Earth surface to infinity where the force of gravity becomes zero and is given by

$$U = \frac{-GMm}{R}$$

Here the negative sign shows that the Earth's gravitational field for the body is attractive and energy is required to take out the body from the Earth's gravitational field to point, where its potential energy with respect to Earth is zero.

Escape Velocity: It is the initial velocity given to an object with which it goes out of the Earth's gravitational fields. The escape velocity is given by the following relations

$$V_{esc} = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$$

The escape velocity does not depend upon the mass of body. It depends on the

- Mass of plant
- Radius of the plant

The value of escape velocity is:

$$V_{esc} = 11.2 \times 10^3\ ms^{-1} = 11.2\ km\ s^{-1}$$

Some Escape Speeds (kms^{-1})	
Heavenly body	**Escape speed**
Moon	2.4
Mercury	4.3
Mars	5.0
Venus	10.4
Earth	11.2
Uranus	22.4
Naptuna	25.4
Satum	37.0
Jupiter	61

Interconversion of Potential Energy and Kinetic Energy: If a body falls from height h_1 to height h_2, then we can write

Loss in P.E. = Gain in K.E

i.e., $mg(h_1 - h_2) = \frac{1}{2}m(v_2^2 - v_1^2)$

Where v_1 and v_2 are the velocities of the body at the heights h_1 and h_2 respectively. This result is true only when there is no friction or air resistance. When a fictional force 'f' is acting during the downward motion, then:

Loss in P.E = Gain in K.E + Work done against friction.

or $mgh = \frac{1}{2}mv^2 + fh$

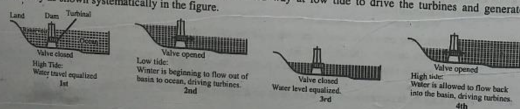
Law of Conservation of Energy: Energy can not be destroyed, it can be transformed from one kind into another, but the total amount of energy remains constant".

i.e., Energy = Constant

When an object falls, it P.E changes to K.E, but on striking the ground, the K.E changes into heat and sound. Ultimately all energy transfers result in heating of the environment and energy is wasted

Non-conventional Energy Sources: These are the energy sources not very common these days. Some of these are introduced briefly here.

Energy from Tides: If the water at the high tide is trapped in a basin by constructing a dam. The dam is filled at high tide and water is released in a controlled way at low tide to drive the turbines and generates electricity as shown systematically in the figure.



Energy from Waves: The tidal movement and the winds blowing across the surface of the ocean produce strong water waves. A method of harnessing wave energy is to use a device invented by Professor Salter is known Salter's duck. The wave energy makes duck float move relative to the balance float. The relative motion of the duck float is then used to run electricity generators.

Source of energy	Original source
Solar	Sun
Bio mass	Sun
Fossil fuels	Sun
Wind	Sun
Waves	Sun
Hydro electric	Sun
Tides	Moon
Geothermal	Earth

Solar Energy: Solar energy at normal incidence outside the Earth's atmosphere is about 1.4 kW m^{-2} which is referred as solar constant. This energy can be used directly to heat water using large solar reflectors and thermal absorbers or be converted to electricity. The sunlight can be converted into electricity through the use of semi conductor devices called solar cells also known as photo voltaic cells. Solar cells are thin wafers made from silicon. For cloudy days or nights, electric energy can be stored in Nickel cadmium batteries by connecting them to solar panels.

Energy from Biomass: Biomass is a potential source of renewable energy. The most common methods used for the conversion of biomass into fuels are:

- Direct combustion
- Fermentation

Direct combustion method is usually applied to get energy from waste products commonly known as solid waste. The waste material of the process is a good organic fertilizer.

Energy Source	
Renewable	**Nonrenewable**
Hydroelectric	Coal
Wind	Natural gas
Tides	Oil
Geothermal *	Uranium
Biomass	Oil shale
Sunlight	Tar sands
Ethanol/Methanol**	

* Individual fields may run off
** Renewable when made from bio mass

Energy from Waste Products: Waste products are burnt in a confined container. Heat produced in this way is directly utilized in the boiler to produce steam that can run turbine generator.

Geothermal Energy: This is the heat energy extracted from inside the Earth in the form of hot water or steam. Heat within the Earth is generated by the following processes.

- Radioactive Decay
- Residual Heat of the Earth
- Compression of Material

Geyser System: An interesting phenomenon of geothermal energy is a geyser. It is a hot spring that discharges steam and hot water, intermittently releasing an explosive column into the air. They usually occur in volcanic regions. Aquifer is a layer of rock holding water that allows water to percolate through it with pressure.

ASSIGNMENT NO. 4

(1) Work done will be maximum when angle between $\vec{F}$ and $\vec{d}$ is: **MCAT**
(a) 180° (b) 90° (c) 60° (d) 0°

(2) The work done will be negative when force and displacement are: **MCAT**
(a) In opposite direction (b) Same direction (c) Perpendicular (d) None of these

(3) The work done will be zero when angle between $\vec{F}$ and $\vec{d}$ is: **MCAT**
(a) 180° (b) 90° (c) 60° (d) 0°

(4) The area under force displacement curve gives: **MCAT**
(a) Energy (b) Work (c) Momentum (d) Torque

(5) The dimensions of work are: **MCAT**
(a) $[MLT^{-2}]$ (b) $[ML^2T]$ (c) $[ML^2T^{-2}]$ (d) $[MLT]$

(6) The unit of work is similar to that of: **MCAT**
(a) Energy (b) Power (c) Force (d) Weight

(7) Which of the following force can do no work on the body when it acts: **MCAT**
(a) Elastic force (b) Centripetal force (c) Frictional force (d) Gravitational force

(8) A force acting at right angle to the displacement perform: **MCAT**
(a) Negative work (b) No work (c) Positive work (d) Maximum work

(9) One horse power is equal to:
(a) 746 watt (b) 745 watt (c) 750 watt (d) 775 watt

(10) In British engineering system, the unit of power is:
(a) Joule (b) Watt (c) Horse power (d) Kilowatt horse

(11) 1 kwh is equal to:
(a) 3.6×10^5 J (b) 36×10^5 J (c) 36×10^6 J (d) 3.5×10^6 J

(12) The power needed to lift a mass of 5 kg to a height of 1 m in 2 sec is:
(a) 24.5 watt (b) 2.45 watt (c) 0.245 watt (d) 245 watt

(13) The power is one kilo-watt if work is done at the rate of:
(a) 500 J/s (b) 1000 J/s (c) 1000 J/min (d) 1500 J/s

(14) If an agent consumes a power of 1 kilo-watt in one hour, the work done is:
(a) One watt (b) One kilo-watt (c) One kilo-watt hour (d) None of these

(15) A body of mass 5 kg moving with a velocity of 2 m/s then its K.E is:
(a) 20 J (b) 5 J (c) 10 J (d) 15 J

(16) The velocity of a body with which it goes out of the earth's gravitational field is called:
(a) Average velocity (b) Escape velocity
(c) Instantaneous velocity (d) Maximum velocity

(17) The expression for escape velocity is:
(a) $\sqrt{gR}$ (b) $2g\sqrt{R}$ (c) $2\sqrt{gR}$ (d) $\sqrt{2gR}$

(18) The formula for escape velocity of a planet $v_{es} = \sqrt{2gR}$ gives only approximate value since:
(a) Value of g is not constant (b) Mass of planet may also affect the escape velocity
(c) Radius of the planet (d) All of these

(19) What is the work done in kilo joules in lifting a man of 10 kg through a vertical height of 10 m:
(a) 9.8 kJ (b) 980 kJ (c) 0.98 kJ (d) 98 kJ

(20) 25000 watts power is equal to:
(a) 2.6 kilowatt (b) 25 h-p (c) 50 h-p (d) 35.5 hp

(21) The power of a machine is one kilowatt when work is done by it at the rate:
(a) 1000 J/min (b) 500 J/s (c) 500 J/min (d) 1000 J/s

(22) If a body of mass 5 kg is raised vertically through a distance of 1 m then the work done is:
(a) 49.0 J (b) 4.9 J (c) 0.49 J (d) 490 J

(23) One dyne is equal to: **MCAT**
(a) 10^3 N (b) 10^5 N (c) 10^{-5} N (d) 10^{-3} N

(24) A body moves a distance of 10 m along a straight line under the action of a force of 5 N and work done is 25 J. The angle which the force makes with the direction of motion will be: **MCAT**
(a) 60° (b) 90° (c) 30° (d) 0°

(25) When a force of 0.5 N displaces a body through a distance of 2 m in the direction of force, the work done is: **MCAT**
(a) 0.5 J (b) 2 J (c) 0.25 J (d) 1 J

(26) The angle between centripetal force and displacement of the body moving in a circle is: **MCAT**
(a) 0° (b) 90° (c) 180° (d) None of these

(27) When a body moves against the force of friction on a horizontal plane, the work done by the body is: **MCAT**
(a) Positive (b) Negative (c) Zero (d) None of these

(28) A boy pulls a toy car through a distance of 5 m by applying a force of 0.5 N, which makes an angle of 60° with the horizontal. The work done by the boy is: **MCAT**
(a) 1.25 J (b) 12.5 J (c) 125 J (d) None of these

(29) Work-energy principle states that work done on the body by applied force is equal to change in:
(a) Potential energy (b) Kinetic energy (c) Linear momentum (d) None of these

(30) When two protons are brought closer potential energy of both of them:
(a) Increases (b) Decreases (c) Remains same (d) None of these

(31) Escape velocity from surface of Moon as compared to that from Earth surface is:
(a) Greater (b) Smaller (c) Equal (d) None of these

(32) A particle of mass m has momentum p. Its kinetic energy will be:
(a) $\frac{1}{2}mp$ (b) $\frac{1}{2}mp^2$ (c) $2\frac{p^2}{m}$ (d) $\frac{1}{2}\frac{p^2}{m}$

(33) A body moving with a velocity of 5 m/sec. possesses kinetic energy of 625 J while in motion. Mass of the body is:
(a) 50 grams (b) 500 grams (c) 5 kg (d) 50 kg

(34) If power of a machine is 10 watts, it means that work is being done at the rate of:
(a) 10 joules per minute (b) 60 joules per second
(c) 600 joules per minute (d) None of these

(35) If a power of 1 kilowatt is maintained for 1 minute, the work done is:
(a) 6.0×10^3 J (b) 6.0×10^4 J (c) 10^3 J (d) 3.6×10^4 J

(36) If work is done at the rate of 240 J per minute by a machine, then its power is:
(a) 240 watts (b) 4 watts (c) 0.4 watt (d) 0.04 watt

(37) The consumption of energy by a 60 W bulb in 2 minutes is:
(a) 2 watt-hour (b) 120 watt-hour (c) 30 watt-hour (d) None of these

(38) When the angle between force vector and displacement vector is obtuse, the work done is: MCAT
(a) 1 (b) Zero (c) +ve (d) −ve

(39) If a body is placed on another body and is moving with it, then work done by frictional force on the upper body relative to ground is: MCAT
(a) −ve (b) Zero (c) +ve (d) Unity

(40) When a body moves in a circular path, no work is done by the force since: MCAT
(a) there is no net force
(b) there is no displacement
(c) Force is always away from the centre
(d) Force and displacement are perpendicular to each other

(41) Two bodies of mass 1 kg and 2 kg have equal momentum. The ratio of their kinetic energies is:
(a) 1 : 1 (b) 2 : 1 (c) 1 : 3 (d) 3 : 1

(42) A body of mass 5 kg initially at rest is subjected to a force of 20 N. The kinetic energy acquired by the body at the end of 10 sec is:
(a) 4000 J (b) 400 J (c) 40 J (d) 4 J

(43) The momentum of body is P and its kinetic energy is E. Its momentum becomes 2P. Its kinetic energy will be:
(a) $\frac{E}{2}$ (b) 3 E (c) 2 E (d) 4 E

(44) A long spring is stretched by 2 cm; its potential energy is U. If the spring is stretched by 10cm, the potential energy stored in it will be:
(a) $\frac{U}{25}$ (b) $\frac{U}{5}$ (c) 5U (d) 25U

(45) The power of an engine which accelerates a car of mass 800 kg to a speed of 72 km/h from rest in 32 s is:
(a) 10 kW (b) 15 kW (c) 20 kW (d) 5 kW

(46) The momentum of a body is numerically equal to its kinetic energy. The velocity of the particle is:
(a) $1\ ms^{-1}$ (b) $4\ ms^{-1}$ (c) $8\ ms^{-1}$ (d) $2\ ms^{-1}$

(47) One man takes 1 minute of raise a box to a height of 1 metre and another man takes $\frac{1}{2}$ minute to do so. The energy of the two is:
(a) Different (b) Same
(c) Energy of the first is more (d) Energy of the second is more

(48) Two bodies with kinetic energies in the ratio of 4 : 1 are moving with equal linear momentum. The ratio of their masses is:
(a) 1 : 2 (b) 1 : 1 (c) 4 : 1 (d) 1 : 4

(49) A body of mass 2 Kg is being rotated in a circle by 0.5 m long string, the work done by centripetal force is:
(a) 1 J (b) 5 J (c) 10 J (d) Zero

(50) A stone is thrown up from the surface of the earth when it reaches its maximum height its KE is:
(a) Maximum (b) Zero (c) mgh (d) Constant

(51) The gravity does no work, when the body moves: MCAT
(a) Horizontally (b) Vertically up ward
(c) Vertically down ward (d) At an angle of 45° with horizontal

(52) On a microscopic scale, all forms of energy may be classified as:
(a) Kinetic energy (b) Potential energy (c) Kinetic or potential (d) Nuclear

(53) A force of 10 N acts on a body of mass 2 kg for a distance of 1 metre. The K.E acquired by the body is:
(a) 5 J (b) 10 J (c) 20 J (d) 4.9 J

(54) The escape velocity of the body depends upon:
(a) The mass of the body (b) The mass of the planet
(c) Density of the planet (d) Volume of the planet

(55) The ratio between orbital and escape velocities is:
(a) $1 : \sqrt{2}$ (b) $\sqrt{2} : 1$ (c) 2 : 1 (d) 1: 4

(56) The average power and instantaneous power become equal if work is done at:
(a) any rate (b) variable rate (c) uniform rate (d) high rate

(57) The important source of energy other than sun is:
(a) Tidal energy (b) Electric energy (c) Heat energy (d) Nuclear energy

(58) When a meteorite enters into earth's atmosphere, its energy converts into:
(a) Heat energy (b) Kinetic energy (c) Nuclear energy (d) Mechanic energy

(59) Solar energy at normal incidence outside the Earth's atmosphere is about:
(a) $1.4\ KW\ m^{-2}$ (b) $14\ KW\ m^{-2}$ (c) $0.1\ KW\ m^{-2}$ (d) $1.0\ KW\ m^{-2}$

(60) When the velocity of a body is doubled.
(a) its K.E is doubled (b) its P.E is doubled
(c) its momentum is doubled (d) its acceleration is doubled

(61) The time taken by an engine of power 10 kw to lift a mass of 200 kg to a height of 40 m is:
(a) 2 sec. (b) 4 sec. (c) 8 sec. (d) 16 sec.

(62) The decrease in the potential energy of a ball of mass 20 kg which falls from a height of 50 cm is:
(a) 968 J (b) 98 J (c) 1980 J (d) None

(63) The K.E of a body of mass 2 kg and momentum 2 Ns is:
(a) 1 J (b) 2 J (c) 3 J (d) 4 J

(64) The retarding force required to reduce velocity of a 3 kg body from $0.75\ ms^{-1}$ to $0.25\ ms^{-1}$ in 0.02 seconds will be:
(a) 100 N (b) 75 N (c) 50 N (d) 25 J

(65) One erg is equal to: MCAT
(a) 10^5 J (b) 10^7 J (c) 10^{-5} J (d) 10^{-7} J

(66) If moon's radius is 1600 km and 'g' on its surface is $1.6\ ms^{-2}$ then the escape velocity on the moon is:
(a) $1600\ ms^{-1}$ (b) $50.6\ ms^{-1}$ (c) $50.8\ ms^{-1}$ (d) $2263\ ms^{-1}$

(67) Two bodies of masses m_1 and m_2 have equal momentum their K.E E_1 and E_2 are in the ratio:
(a) $\sqrt{m_1} : \sqrt{m_2}$ (b) $m_1 : m_2$ (c) $m_2 : m_1$ (d) $m_1^2 : m_2^2$

(68) If a power of 1 kw is maintained for 1 second then work done is equal to:
(a) 10^3 J (b) 10^5 J (c) 3.6×10^6 J (d) 3.6×10^5 J

(69) Ratio of dimensions of power and K.E is:
(a) 1 : 1 (b) T : 1 (c) 1 : T (d) M : T

(70) How large a force is required to accelerate a body of weight 5 N with $4\ ms^{-2}$ is:
(a) 10 N (b) 5 N (c) 2 N (d) 1 N

ANSWERS

(1)	(d)	(2)	(a)	(3)	(b)	(4)	(b)	(5)	(c)
(6)	(a)	(7)	(b)	(8)	(b)	(9)	(a)	(10)	(c)
(11)	(a)	(12)	(a)	(13)	(b)	(14)	(c)	(15)	(c)
(16)	(b)	(17)	(d)	(18)	(d)	(19)	(c)	(20)	(d)
(21)	(d)	(22)	(a)	(23)	(c)	(24)	(a)	(25)	(d)
(26)	(b)	(27)	(b)	(28)	(a)	(29)	(b)	(30)	(a)
(31)	(b)	(32)	(d)	(33)	(d)	(34)	(c)	(35)	(b)
(36)	(b)	(37)	(a)	(38)	(d)	(39)	(c)	(40)	(d)
(41)	(b)	(42)	(a)	(43)	(d)	(44)	(d)	(45)	(d)
(46)	(d)	(47)	(b)	(48)	(d)	(49)	(d)	(50)	(b)
(51)	(a)	(52)	(c)	(53)	(b)	(54)	(b)	(55)	(a)
(56)	(c)	(57)	(d)	(58)	(a)	(59)	(a)	(60)	(c)
(61)	(c)	(62)	(b)	(63)	(a)	(64)	(b)	(65)	(d)
(66)	(d)	(67)	(c)	(68)	(a)	(69)	(c)	(70)	(c)

SOLUTION

(23)

$$1\,N = 1\,kg \times 1\,ms^{-2}$$
$$1\,N = 1000\,g \times 100\,cm\,s^{-2}$$
$$1\,N = (1 \times 10^3)(1 \times 10^2)\,g\,cm\,s^{-2}$$
$$1\,N = 1 \times 10^5\,dyne$$
$$1\,dyne = \frac{1}{1 \times 10^5}\,N$$
$$1\,dyne = 1 \times 10^{-5}\,N$$

(c) is correct

(41)

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{m^2v^2}{m}$$
$$E = \frac{\rho^2}{m} \qquad \because mv = \rho$$

For m_1

$$E_1 = \frac{\rho^2}{2m_1}$$

For m_2 $= \frac{\rho^2}{2m_2}$

$$\frac{E_1}{E_2} = \frac{\frac{\rho^2}{2m_1}}{\frac{\rho^2}{2m_2}}$$
$$\frac{E_1}{E_2} = \frac{\rho^2}{2m_1} \times \frac{2m_2}{\rho^2}$$
$$\frac{E_1}{E_2} = \frac{m_2}{m_1}$$
$$= \frac{2}{1} = 2:1$$

(b) is correct

(43) As

$$K.E = \frac{\rho^2}{2m}$$
$$E = \frac{\rho^2}{2m}$$

If momentum becomes double i.e., 2P.

$$E' = \frac{(2P)^2}{2m}$$
$$E' = \frac{4P^2}{2m}$$
$$E' = 4E$$

(d) is correct

(44) Elastic potential energy is given by

$$U = \frac{1}{2}Kx^2 \quad ; \quad U' = \frac{1}{2}Kx'^2$$
$$\frac{U'}{U} = \frac{\frac{1}{2}Kx'^2}{\frac{1}{2}Kx^2}$$
$$\frac{U'}{U} = \frac{x'^2}{x^2}$$
$$\frac{U'}{U} = \frac{(10)^2}{(2)^2}$$
$$U' = 25\,U$$

(d) is correct

(46) According to given condition:

$$\frac{1}{2}mv^2 = mv$$
$$v = 2\,m/s$$

(d) is correct

Chapter 5

CIRCULAR MOTION

KEY POINTS

Circular Motion: If a body moves in such a way that its distance from the fixed point remains constant is called circular motion. The fixed point is called its centre and the fixed distance is called its radius.

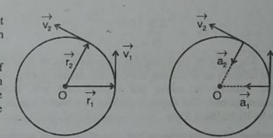
Examples:

(i) Motion of moon around the earth. (ii) Motion of electron around the nucleus.

Uniform Circular Motion:

(i) When a particle moves in a circle at a constant speed then the motion is said to be a uniform circular motion.

(ii) In uniform circular motion the position of particle goes on changing, i.e., the position vector keeps on changing. As a result the velocity of the particle goes on changing the direction i.e., the particle is accelerated.



(a) (b)

(iii) In a uniform circular motion:

(a) Speed of the particle remains constant.

(b) The position vector and velocity vector go on changing, though their magnitudes remain constant.

(c) The acceleration of the particle also goes on changing because of changing direction though magnitude again remains constant.

(iv) For a circular motion, the particle must have an acceleration which should be always directed towards the centre. Such an acceleration is called as **centripetal acceleration**.

(v) It follows from figure that in case of circular motion:

(a) Position vector is always perpendicular to the velocity vector, i.e., $\vec{r} \cdot \vec{v} = 0$.

(b) Velocity vector is always perpendicular to the acceleration vector, i.e., $\vec{v} \cdot \vec{a} = 0$.

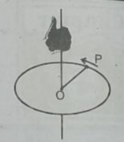
(c) The centripetal acceleration vector is directed opposite to the radius vector.

(d) The work done by centripetal force is zero because $\vec{F} = m\vec{a}$ is perpendicular to $\vec{v}$ or displacement vector $\Delta\vec{r}$.

(e) The kinetic energy of the particle remains constant or speed of the particle does not change although a force is acting on the particle, i.e., velocity but not the magnitude of velocity.

(vi) As the speed is constant and $v = r\omega$, so ω will be constant and motion will be **periodic** with time period $T = (2\pi/\omega) = 2\pi r/v$.

Angular Displacement: It is the angle traced by a rotating body at the centre of a circle in a certain time. The angular displacement is a vector quantity. Its direction is along the axis of rotation and is given by Right hand Rule. Grasp the axis of rotation in right hand with fingers curling in the direction of rotation, the thumb points in the direction of angular displacement. The SI-unit of angular displacement is radian. However, it can be expressed in degree and revolution. If Arc length = radius, then angular displacement = 1 radian. The angle θ in radian is defined as:



$$\theta = \frac{\text{Arc length}}{\text{Radius}} \text{ rad}$$

i.e., $\theta = \frac{S}{r} \Rightarrow S = r\theta$

1 revolution $= 360^\circ = 2\pi$ radian

1 radian $= 57.3^\circ$ and $1^\circ = 0.0174$ radian

Angular Velocity: The rate of change of angular displacement is called angular velocity.

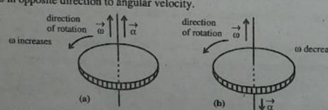
i.e., $\vec{\omega} = \frac{\Delta \vec{\theta}}{\Delta t}$

The ratio of total angular displacement to total time interval is called average angular velocity. The angular velocity of a rotating body at any instant during rotation is called instantaneous velocity. The SI-unit of angular velocity is radian per second (rad s^{-1}). However, it can be expressed in degree/second or revolution/second. The angular velocity is a vector quantity and its direction is along the axis of rotation and is given by Right Hand Rule.

Angular Acceleration: The rate of change of angular velocity is called angular acceleration.

i.e., $\vec{\alpha} = \frac{\Delta \vec{\omega}}{\Delta t}$

The ratio of total change in angular velocity to total time interval is called average angular acceleration. The angular acceleration of a rotating body at any instant during the rotation is called instantaneous angular acceleration. The SI-unit of angular acceleration is rad s^{-2}. The angular acceleration is a vector quantity and its direction is along the axis of rotation and is given by "Right Hand Rule". If the rotation of a body becomes faster and faster, then the angular acceleration of the body is said to be positive and is in the direction of angular velocity. If the rotation of the body becomes slower and slower, then the angular acceleration of the body is said to be negative and is in opposite direction to angular velocity.



The relations between linear and angular velocities in magnitude and vector form are given below

$v = r\omega$ and $\vec{v} = \vec{r} \times \vec{\omega}$

The relations between the linear and angular accelerations in magnitude and vector form are given below

$a = r\alpha$ and $\vec{a} = \vec{r} \times \vec{\alpha}$

Equations of Linear Motion and Angular Motion: The comparison of equations of linear motion and angular motion are given below.

Linear Motion	Angular Motion
• $v_f = v_i + at$	• $\omega_f = \omega_i + \alpha t$
• $2aS = v_f^2 - v_i^2$	• $2\alpha\theta = \omega_f^2 - \omega_i^2$
• $S = v_i t + \frac{1}{2}at^2$	• $\theta = \omega_i t + \frac{1}{2}\alpha t^2$
• $F = ma$	• $\tau = I\alpha$

The angular equations hold only in the case, when the axis of rotation is fixed. In this case, all the angular vectors (θ, ω, α) have the same direction, so they can be manipulated as scalars.

Centripetal Force and Centripetal Acceleration: The force needed to bend the normally straight path of the particle into a circular path is called centripetal force. The acceleration produced by centripetal force is called centripetal acceleration. Centripetal force and centripetal acceleration are directed towards the centre of the circle. The relation for centripetal acceleration and centripetal force are given by

$$a_c = \frac{v^2}{r} = m\omega^2 \quad \text{and} \quad F_c = \frac{mv^2}{r} = mr\omega^2$$

Moment of Inertia: The physical quantity which plays the same role in angular motion as played by mass in linear motion is called moment of inertia. The moment of inertia is the rotational analogue of mass in linear motion. The moment of inertia is represented by I and is given by.

$$I = mr^2$$

The SI-unit of moment of inertia is kg m^2. The dimensions of moment of inertia are $[ML^2]$.

The moment of inertia depends upon the mass of the body i.e. m. The distribution of mass from the axis of rotation i.e. r^2.

(i) The property of a body due to which it opposes any change in its state of rest or of uniform rotation about an axis is called as **moment of inertia or rotational inertia**.

(ii) Analytically, for a particle of mass m rotating in a circle of radius r, moment of inertia about the axis of rotation is given by:

$$I = mr^2$$

For a body made up of a number of particles (discrete distribution) of masses $m_1, m_2, \ldots$, etc. at positions $r_1, r_2, \ldots$, etc., respectively from the axis of rotation;

$$I = m_1r_1^2 + m_2r_2^2 + \ldots\ldots = \Sigma mr^2$$

(iii) **Just as mass is a measure of translational (linear) inertia, moment of inertia is a measure of rotational inertia.**

(iv) It has dimensions $[ML^2]$ and SI unit kg-m^2.

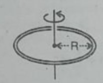
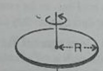
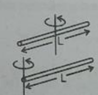
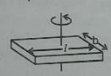
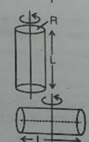
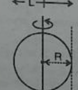
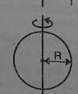
(v) It is not a vector as direction CW or ACW is not to be specified and also not a scalar as it has different values in different directions (i.e., about different axes). **It is actually a 'tensor'**.

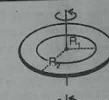
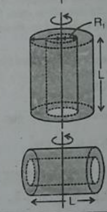
(vi) Moment of inertia for a given body depends on the axis of rotation. So if axis of rotation changes, usually moment of inertia will change.

(vii) Moment of inertia for a given axis depends on mass, shape and size of the body. If same mass is casted in different shapes with same axis, moment of inertia will be different.

(viii) For a given shape, size, mass and axis it depends on the distribution of mass within the body. This is why in case of a hollow and solid body of same mass, radius and shape for a given axis, moment of inertia of hollow body is greater than that for the solid body.

Moment of Inertia of Some Regular Bodies:

S. No.	Bodies	Axis	Figure	Moment of Inertia
1.	Ring	(i) passing through the centre and perpendicular to the plane		(i) MR^2
		(ii) any diameter		(ii) $\frac{1}{2}MR^2$
		(iii) any tangent		(iii) $\frac{3}{2}MR^2$
2.	Disc	(i) passing through its centre and perpendicular to the plane		(i) $\frac{1}{2}MR^2$
		(ii) any diameter		(ii) $\frac{1}{4}MR^2$
3.	Uniform rod of length L	(i) passing through the centre and perpendicular to the length		(i) $\frac{ML^3}{12}$
		(ii) perpendicular to the length and passing through one end		(i) $\frac{ML^3}{12}$
4.	Rectangular sheet of length l and breadth b	Perpendicular to the length and passing through the centre		(i) $\frac{M(l^2+b^2)}{12}$
5.	Solid cylinder of length L and radius R	(i) axis of the cylinder		(i) $\frac{MR^2}{2}$
		(ii) through the centre and perpendicular to the length		(ii) $M\left[\frac{L^2}{12}+\frac{R^2}{4}\right]$
6.	Solid sphere	(i) any diameter		(i) $\frac{2}{5}MR^2$
		(ii) any tangent		(ii) $\frac{7}{5}MR^2$
7.	Hollow sphere	(i) any diameter		(i) $\frac{2}{5}MR^2$
		(ii) any tangent		(ii) $\frac{7}{5}MR^2$

8.	Circular disc of inner radius R_1 and outer radius R_2	through centre and perpendicular to the plane		(i) $\frac{1}{2}M(R_1^2+R_2^2)$
9.	Hollow cylinder of inner radius R_1, outer radius R_2 and length L	(i) about axis of cylinder		(i) $\frac{1}{2}(MR_1^2+R_2^2)$
		(ii) through midpoint and perpendicular to axis		(ii) $M\left(\frac{R_1^2+R_2^2}{4}+\frac{L^2}{12}\right)$

Angular Momentum:

(i) The angular momentum of a moving particle about a point is defined as:

$$\vec{L} = \vec{r} \times \vec{p}$$

where $\vec{p}$ is the linear momentum and $\vec{r}$ its position vector from the point.

(ii) Mathematically, angular momentum is equal to moment of linear momentum, i.e.,

$$L = \text{Linear momentum} \times \text{Perpendicular distance}$$
$$= p(r \sin\theta)$$

(iii) Basically speaking, angular momentum is the ability of a body by virtue of which it imparts or tends to impart its rotatory motion to other objects.

(iv) In case of circular motion as the angle between linear momentum (along tangent) and radius vector is always 90° then

$$L = pr = mvr = mr^2\omega = I\omega$$

(v) It is an axial vector (i.e., always perpendicular to the plane to motion) having dimensions $[ML^2T^{-1}]$ and SI unit J-s (same as that of Planck's constant).

(vi) In Cartesian coordinates, angular momentum will be given by:

$$\vec{L} = \vec{r} \times \vec{p} = m(\vec{r} \times \vec{v}) = m\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ x & y & z \\ v_x & v_y & v_z \end{vmatrix}$$

$$= m[\hat{i}(yv_z - zv_y) + \hat{j}(zv_x - xv_z) + \hat{k}(xv_y - yv_x)]$$

(vii) As the magnitude of angular momentum is $L = mvr \sin\theta$, so

(a) **L will be minimum** (= 0), when $|\sin\theta|$ = min. = 0, i.e., θ = 0° or 180°, i.e., $\vec{r}$ and $\vec{v}$ are parallel or antiparallel, i.e., **if the point is on the line of motion, angular momentum is minimum or zero.**

(b) **L will be maximum** (= mvr), when $|\sin\theta|$ = max. = 1, i.e., θ = 90°, i.e., **angular momentum is maximum when $\vec{r}$ and $\vec{v}$ are orthogonal.**

Law of Conservation of Angular Momentum: In the absence of external torque, the total angular momentum of the rotating system remains constant.

$$I_1\omega_1 = I_2\omega_2 = \text{Constant}$$

The law has been verified from the cosmological to the submicroscopic level. The effect of the law is readily apparent, if a single isolated spinning body alters its moment of inertia. A diver changes his body position after diving in the pool. As a result he spins faster before going into the pool which enables the diver to take extra somersaults. The axis of rotation of an object will not change its orientation unless an external torque causes it to do so.

Rotational K.E: The energy possessed by a rotating body is called its rotational kinetic energy and is given by

$$K.E_{rot} = \frac{1}{2} I\omega^2$$

The rotational kinetic energy of disc is

$$K.E_{rot} = \frac{1}{4} mv^2$$

The rotational kinetic energy of hoop is

$$K.E_{rot} = \frac{1}{2} m v^2$$

When both disc and loop start moving down an inclined plane of height h, their velocities are

$$V_{disc} = \sqrt{\frac{4}{3}gh} \quad \text{and} \quad V_{hoop} = \sqrt{gh} \quad \Rightarrow \quad V_{dics} > V_{hoop}$$

Artificial Satellites: Satellites are put into orbit by rockets and are held in orbit by the gravitational pull of the Earth. The low flying Earth satellites have acceleration 9.8 ms^{-2} towards the centre of the Earth. If they do not, they would fly off in a straight line tangent to the Earth. The minimum velocity necessary to put a satellite into the orbit is called critical velocity and is given by

$$v = \sqrt{gR} = \sqrt{9.8 \times 6.4 \times 10^6} = 7.9 \text{ km s}^{-1}$$

The time taken by a satellite to complete one revolution around the Earth is called its period and is given by:

$$T = \frac{2\pi R}{V} = \frac{2 \times 3.14 \times 6.4 \times 10^6}{7.9 \times 10^3 \text{m}} = 5060 \text{ sec} = 84 \text{ min.}$$

The higher the satellite, slower will the required speed and longer it will take to complete one revolution around the Earth.

Global Positioning System: Close orbiting satellites orbit the Earth at a height of about 400 km. Twenty four such satellites form the "Global positioning system". An airline pilot, sailor or any other person can now use a pocket size instrument or mobile to find his position on the Earth's surface to within 10 m accuracy.

Real and Apparent Weight: The real weight of an object is the gravitational pull of the Earth on the object. It is measured by a spring balance. The reading of spring balance indicates the apparent of the object. The apparent weight of the object is not necessary equal to its real weight in an accelerating frame. It depends upon the acceleration of the frame. When the lift is at rest or moving with a uniform velocity, apparent weight is equal to its real weight. When the lift is moving up with acceleration 'a' then, the apparent weight of object increase by an amount 'ma'. When the lift moves down with acceleration 'a', the apparent weight of the object decreases by an amount 'ma'. When the lift is falling freely under the action of gravity, then apparent weight becomes zero. This state is called weightlessness in lift. When the lift moves down with acceleration greater than 'g' the apparent weight of object becomes negative.

Weightlessness in Satellite and Gravity Free System: When a satellite is falling freely in space, every thing within this appears to be weightless. During its motion, no force is acting from any side which prevents the free fall motion of the space ship and the objects within it. Such a system is called gravity free system.

Orbital Velocity: The velocity with which a planet or satellite revolves in circular orbit path is called orbital velocity and is given by

$$v = \sqrt{\frac{GM}{r}}$$

The orbital speed of the satellite does not depend upon the mass of the satellite but it depends upon the radius of the orbit. If the speed of satellite in less than as given by above equation, then satellite will tumbling back to the Earth.

Artificial Gravity MCAT: In order to overcome the state of weightlessness, an artificial gravity is provided in the spacecraft. This is done by rotating the spacecraft about its own axis with a certain frequency given by

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{R}}$$ where R is the radius of satellite.

When the spaceship rotates with this frequency, the artificial gravity equal to the gravity of the Earth is provided to the inhabitants of the spaceship.

Some Other Important Points Concerning Satellites MCAT:

(i) Escape velocity and orbital velocity of a satellite are related as: $v_{es} = \sqrt{2}v_0$, i.e., if the speed of the satellite is increased by 41.4% or its KE is increased by 100%, it will escape out to infinite distance from the centre of earth.

(ii) In an orbit, the magnitude of total energy of a body is equal to the magnitude of its KE.

(iii) As the radius of the orbit increases, i.e., the body moves away from the earth, its potential energy increases while KE decreases.

(iv) The total energy of a body in the orbit is always negative i.e., the body is bound to the earth.

(v) If we put a satellite in an orbit with a velocity v, then the velocity v_0 for which the satellite revolves around the earth in a circular orbit of radius r, is given by:

$$v_0 = \sqrt{(GM/r)}$$

- (a) **When $v < v_0$:** the satellite fails to revolve around the earth and spirals inwards with a decreasing radius till it falls on earth.
- (b) **When $v_{es} > v < v_0$:** the body revolves in **elliptical** orbit.
- (c) **When $v > v_{es}$:** the body escape following a **hyperbolic** path.

(vi) If a body is thrown with a velocity v, then the sum of KE and PE is:

- (a) **positive**, when $v > v_{es}$
- (b) **zero**, when $v = v_{es}$
- (c) **negative**, when $v < v_{es}$

(vii) If the gravitational attraction of the sun on the planet varies as $(1/r^n)$, then the

- (a) orbital velocity varies as $\frac{1}{\sqrt{r^{n-1}}}$;
- (b) time period varies as $r^{(n+1)/2}$;

where r is the distance of planet from the sun.

(viii) **Geostationary satellite:**

- (a) A satellite which appears to be stationary for a person on the surface of the earth is called geostationary satellite.
- (b) It revolves in the equatorial plane from west to east with a time period of 24 hours.
- (c) Its height from the surface of the earth is nearly 356000 km and radius of the circulatory orbit is nearly 42000 km.
- (d) The orbital velocity of this satellite is nearly 3.08 km/sec.
- (e) The relative velocity of geostationary satellite with respect to earth is zero.
- (f) The orbit of a geostationary satellite is called as **parking orbit**.

Ge tationary Satellite: A satellite whose orbital motion is synchronized with the rotation of the Earth is called Geo-stationary satellite or synchronous satellite. Geo-stationary satellite will always stay directly above a particular point on the surface of the Earth. i.e. they does not change its position w.r.t a particular point on the Earth. Such satellites are very useful for world-wide communication, weather observations, navigation and other military uses. Geostationary satellite completes one revolution around the Earth in one day. The orbital radius of a geostationary satellite measured from the centre of the Earth is given by

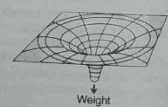
$$r = \left[\frac{GMt^2}{4\pi^2}\right]^{1/3} = 4.23 \times 10^4 \text{ km}$$

The height of geo-stationary satellite above the equator comes out to be 36000 km.

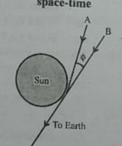
Communication Satellites: A geostationary satellites covers 120^0 of longitude, so that whole of the populated Earth's surface can be covered by there correctly positioned satellites. Micro waves are used as transmission carriers because they travel in a narrow beam, in a straight line and pass easily through the atmosphere of the earth. There are over 200 Earth stations which transmit signals to satellites and receive signals via satellites from other countries. The largest satellite system is managed by 126 countries, international telecommunication satellite organization (INTELSAT). An INTELSAT VI satellite operates at microwave frequency of 4, 6, 11 and 14 GHz and has capacity of 30,000 two way telephone circuits plus three T.V channels.

Communications satellite
INTELSAT VI

Newton's and Einstein's View of Gravitation: According to Einstein's theory, space time is curved, especially locally near massive bodies. In Einstein's theory, bodies and light rays move along geodesics in curved space time. Newton discovered the inverse square law of gravity but he could not explain why gravity should follow an inverse square law. According to Einstein's theory, gravity follow inverse square law (Expect in strong gravitational fields), but it tells us why this should be so. Einstein inferred that if gravitational acceleration and inertial acceleration are precisely equivalent, gravity must bend light by definite amount that could be calculated. Light from the star A is deflected as it passes close to the sun on its way to Earth. We see that star in the apparent direction B, shifted by the angle ϕ. Einstein predicted that ϕ = 1.745 seconds of angle which was found to be the same during the solar eclipse of 1919.



Rubber sheet analogy for curved space-time

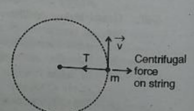


Bending of starlight by the sun

Centrifugal Force MCAT

(a) If an object is moving uniformly in a circle of radius r with speed v, then the tension in the string will be: $T = (mv^2/r)$ = centripetal force. According to Newton's 3rd law, to every action there is an equal and opposite reaction. This reaction force acting on the string is called **centrifugal force.**

(b) Centrifugal force makes the body to move along a straight line. It comes into play when the centripetal force ceases to exist.



(c) In an **inertial frame**, the centrifugal force does not act on the object on which centripetal force is acting.

ASSIGNMENT NO. 5

(1) The SI unit of angular displacement is:
(a) Metre (b) Kilometre (c) Radian (d) None of these

(2) One radian is equal to:
(a) 47.3° (b) 57.3° (c) 67.3° (d) 59.3°

(3) The direction of angular velocity of a body moving in a circle is:
(a) Towards the axis of rotation (b) Away from the axis of rotation
(c) Along the axis of rotation (d) None of these

(4) When an object moves in a circle, the angle between angular velocity ω and linear velocity v is:
(a) 90° (b) 0° (c) 45° (d) 60°

(5) If a particle moves in a circle of radius r with uniform angular velocity ω then the angle between radius r and linear velocity v is:
(a) 45° (b) 90° (c) 60° (d) 180°

(6) SI unit of angular acceleration is:
(a) rad/s^2 (b) rad/s (c) $rad.s^2$ (d) rad.s

(7) The dimensions of angular acceleration are:
(a) $[LT^{-2}]$ (b) $[T^{-2}]$ (c) $[LT^{-1}]$ (d) $[T^{-3}]$

(8) A body is moving in a circle of radius r with constant angular velocity ω, its centripetal acceleration is:
(a) $\frac{\omega}{r}$ (b) ωr (c) $\omega^2 r$ (d) ωr^2

(9) The angular momentum is defined as:
(a) $\vec{L} = m\vec{v}$ (b) $\vec{L} = \vec{r} \times \vec{F}$ (c) $\vec{L} = \vec{r} \times \vec{P}$ (d) $\vec{L} = \vec{P} \times \vec{r}$

(10) A body rotating in a circle of radius 1 m with an angular speed 10 rad/s has the tangential velocity:
(a) 2 m/s (b) 5 m/s (c) 10 m/s (d) 15 m/s

(11) Angular momentum of a rigid body is equal to:
(a) $I\omega$ (b) $I\alpha$ (c) $\frac{1}{2}I\omega$ (d) $\frac{1}{2}I^2\omega$

(12) Moment of inertia of a thin rod about mid length is:
(a) $I = \frac{1}{12}mL^2$ (b) $I = \frac{2}{5}mr^2$ (c) $I = \frac{1}{3}mr^2$ (d) $I = \frac{1}{2}mr^2$

(13) Moment of inertia of a hoop about its axis is:
(a) $I = \frac{1}{3}mr^2$ (b) $I = \frac{1}{2}mr^2$ (c) $I = \frac{2}{3}mr^2$ (d) $I = \frac{2}{5}mr^2$

(14) Moment of inertia of a solid disc about its axis is:
(a) $\frac{1}{2}mr^2$ (b) $\frac{2}{5}mr^3$ (c) $\frac{2}{3}mr^2$ (d) $\frac{1}{3}mr^2$

(15) Moment of inertia of a sphere is:
(a) $\frac{1}{2}mr^2$ (b) $\frac{2}{5}mr^3$ (c) $\frac{2}{5}mr^2$ (d) $\frac{1}{3}mr^2$

(16) **The dimensions of moment of inertia are:**
(a) $[ML^2]$ (b) $[ML^{-2}]$ (c) $[ML^{-1}]$ (d) $[M^2L]$

(17) **An elevator is accelerated upward with acceleration a, the apparent weight of a body of mass m in it will be:** MCAT
(a) m(a − g) (b) m(a + g) (c) m(g − a) (d) mg

(18) **If the rope of an elevator moving downward with acceleration a breaks, the apparent weight of a body of mass m in it will be:** MCAT
(a) m(a − g) (b) m(a + g) (c) m(g − a) (d) Zero

(19) **The K.E of a disc of mass m rolling down on an included plane is:**
(a) $\frac{1}{2}mv^2$ (b) $\frac{1}{4}mv^2$ (c) $\frac{3}{4}mv^2$ (d) None of these

(20) **The rotation K.E of any hoop of radius r is given by:**
(a) $\frac{1}{2}mr^2\omega^2$ (b) $\frac{1}{2}r\omega^2$ (c) $\frac{1}{2}r^2\omega^2$ (d) None of these

(21) **In a spaceship orbiting the earth, the apparent weight of the body in it is:**
(a) Less than its real weight (b) Greater than its real weight
(c) Weightlessness (d) None of these

(22) **Height of the closest orbit of the satellite above the earth is:**
(a) 300 km (b) 250 km (c) 500 km (d) 400 km

(23) **Radius of the geo-stationary orbit from the earths center is:**
(a) 4.24×10^4 km (b) 3.23×10^4 km (c) 4.23×10^3 km (d) None of these

(24) **Height of geo-stationary satellite above the equator is:**
(a) 40,000 km (b) 24,000 km (c) 30,000 km (d) 36,000 km

(25) **The geo-stationary satellite are used for:**
(a) World communications (b) Weather observations
(c) Navigation (d) All of above

(26) **1 rev/min is equal to:**
(a) $\frac{\pi}{6}$ rad/sec. (b) $\frac{\pi}{15}$ rad/sec. (c) $\frac{\pi}{20}$ rad/sec. (d) $\frac{\pi}{30}$ rad/sec.

(27) **Centripetal force performs:**
(a) Maximum work (b) No work (c) Positive work (d) None of these

(28) **An electric fan rotating at 3 rev/sec. is switched off and comes to rest in 6 seconds. Tick the correct answer:**
(a) $v_i = 0, v_f = 0, \alpha = -0.5$ m/sec^2 (b) $v_i \neq 0, v_f = 0, \alpha = -0.5$ m/sec^2
(c) $\omega_i = 0, \omega_f = 0, \alpha = -0.5$ rev/sec^2 (d) $\omega_i = 0, \omega_f = 0, \alpha = -0.5$ rad/sec^2

(29) **If a toy car moves with a uniform speed of 2 m/sec. in a circle of 0.4 m radius. His angular velocity in rev/sec. is:**
(a) 10π (b) 0.8 (c) 0.2π (d) None

(30) **A flywheel accelerates from rest to an angular velocity of 7 r...sec. in 7 seconds. Its average acceleration will be:**
(a) 49 rad/sec^2 (b) 1 rad/sec^2 (c) 0.16 rev/sec^2 (d) Both (b) and (c)

(31) **A body moving along the circumference of a circle of radius R completes one revolution. The radius of the covered path to the angle subtended at the centre is:**
(a) Radius of the circle (b) Twice the radius (c) Thrice the radius (d) None of these

(32) **A wheel, 2 m in diameter, makes 15 rev/min, the linear speed of point on its rim (in m/sec.) is:**
(a) 2π (b) π (c) $\frac{\pi}{2}$ (d) 10π

(33) **Angular speed for the daily rotation of Earth in radius per hour is:**
(a) π (b) 4π (c) $\frac{\pi}{12}$ (d) None of these

(34) **In racing car moving around a circular track, the centripetal force is provided by:**
(a) Banking of roads (b) Friction between wheels and road
(c) None of these (d) Both (a) and (b)

(35) **When a body is moving in a circle of radius r with constant angular speed ω, its centripetal force is:**
(a) $mr\omega^2$ (b) $mr^2\omega$ (c) $m^2r\omega$ (d) None of these

(36) **The outward force acting on a mass of 10 kg tied to one end of an inelastic string 10^3 cm long and rotated at a speed of 1 m sec^{-1} is:**
(a) 25 N (b) 2 N (c) 10 N (d) 1 N

(37) **J-second and kg-m^2 sec^{-1} refer to the following quantity/quantities:**
(a) Angular momentum, moment of inertia (b) Only angular momentum
(c) Angular momentum, power (d) Work, power

(38) **Earth moves around the Sun and travels a distance of 9.42×10^8 km in 3.16×10^7 seconds. Orbital speed of Earth comes out to be:**
(a) 3 m/sec. (b) 3×10^4 m/sec. (c) 3×10^6 m/sec. (d) None of these

(39) **Kinetic energy of rotation (E) of a spinning half is related to its angular momentum (L) as:**
(a) $E = 2L\omega$ (b) $E = \frac{L\omega}{2}$ (c) $E = \frac{L}{2\omega}$ (d) None of these

(40) **A body of mass 1 kg is suspended from the ceiling of an elevator moving up with an acceleration 'g'. Its apparent weight in the elevator will be:** MCAT
(a) 9.8 N (b) 19.6 N (c) 39.2 N (d) None of these

(41) **A spring balance attached to the ceiling of a moving elevator indicates the weight of a body as 1470 N whose real weight (on the ground) is 980 N. The direction and magnitude of acceleration of elevator is:** MCAT
(a) 4.9 m sec^{-2} downward (b) 9.8 m sec^{-2} upward
(c) Zero (d) 4.9 m sec^{-2} upward

(42) **A man of mass 100 kg on the ground is standing in an elevator. The force exerted by the man on the floor of the elevator when it moves down with an acceleration of 4 m sec^{-2} is given as:** MCAT
(a) 980 N (b) 580 N (c) 1380 N (d) Zero

3) **How many revolutions per second must a space station of diameter 19.6 m make in order to supply artificial (normal) gravity for the passengers:**

(a) 9.6 rev min^{-1} (b) 0.16 rev sec^{-1} (c) 12.56 rev sec^{-1} (d) None of these

4) **Moment of inertia plays the same role in rotator motion as in translator motion is played by:**

(a) Velocity (b) Acceleration (c) Mass (d) Force

5) **When a mass is rotating in a plane about a fixed axis, its angular momentum is directed along:**

(a) the radius (b) the tangent to the orbit
(c) the line at an angle of 5 to the plane of rotation (d) the axis of rotation

6) **When torque acting upon a system is zero. Which of the following will be constant?**

(a) Force (b) Linear momentum
(c) Angular momentum (d) Linear impulse

7) **The angular velocity of a car engine increases from 600 rev/min to 1500 rev/min in 6 sec, then the angular acceleration is:**

(a) 15.5 rad/sec^2 (b) 2.5 rad/sec^2 (c) 5 rad/sec^2 (d) None of these

8) **The angular speed of a flywheel making 120 revolutions per minute is: (in rad/sec)**

(a) π (b) 2π (c) 4π (d) $4\pi^2$

9) **When a sphere rolls without slipping, the ratio of its kinetic energy of translation to its total kinetic energy is:**

(a) 1 : 7 (b) 1 : 2 (c) 1 : 1 (d) 5 : 7

50) **If a particle moves in the x-y plane, the resultant angular momentum has:**

(a) Only x-component (b) Only y-component
(c) Both x and y components (d) Only z-component

51) **A uniform sphere of mass 200 gm rolls without slipping on a plane surface so that its centre moves at a speed of 2.00 cm/sec. Its K.E. is:**

(a) 5.6×10^{-5} J (b) 5.6×10^{-4} J (c) 5.6×10^{-3} J (d) 5.6×10^{-2} J

(52) **If there is a change of angular momentum from 1 J-s to 4 J-s in 4 sec, then the torque is:**

(a) $\frac{3}{4}$ J (b) 1 J (c) $\frac{5}{4}$ J (d) $\frac{4}{3}$ J

(53) **A solid sphere rolling on a surface has total kinetic energy given by:**

(a) $\frac{1}{2}mv^2$ (b) $\frac{7}{5}mv^2$ (c) $\frac{7}{10}mv^2$ (d) $\frac{3}{10}mv^2$

(54) **The gravitational force of earth on a ball of mass one kilogram is 9.8 N. The attraction of ball on the earth is:**

(a) 9.8 N (b) Negligible
(c) Slightly less than 9.8 N (d) More than 9.8 N

(55) **Which of the following cannot be used to measure time in a space ship orbiting around the earth?**

(a) Atomic watch (b) Pendulum clock
(c) A watch using elastic spring (d) A watch using electric oscillations

(56) **If the mass and radius of a planet are doubled, then acceleration due to gravity on its surface will become:**

(a) One fourth (b) One half (c) Double (d) Four times

(57) **The period of circular motion is given by:**

(a) $T = rv$ (b) $T = 2\pi/\omega$ (c) $T = v\omega$ (d) $T = 2\pi\omega$

(58) **If a rotating fan is switched off, then its angular acceleration and angular velocity are:**

(a) Parallel (b) Anti-parallel (c) Perpendicular (d) Constant

(59) **A body of mass 0.1 kg is rotated in a vertical circle of radius 1m with a constant speed of 10 ms^{-1}. The tension in the string when it is horizontal is:**

(a) 1 N (b) 5 N (c) 10 N (d) 100 N

(60) **A particle executing uniform circular motion in a circle of radius 0.1 m completes one revolution in 2 second. Its angular acceleration is:**

(a) π^2 rad s^{-2} (b) $\frac{\pi^2}{10}$ rad s^{-2} (c) Zero (d) $10\pi^2$ rad s^{-2}

MCAT

(61) **A 5 kg mass is falling freely, the force acting on its will be:**

(a) 5 N (b) 9.8 N (c) 19.6 N (d) Zero

(62) **The ratio of angular momentum and angular velocity is equal to:**

(a) Radius of circle (b) Moment of inertia (c) Angular acceleration (d) Torque

(63) **An astronaut of weight mg is moving up-ward in a rocket with acceleration 4 g. His apparent weight inside the rocket will be:** **MCAT**

(a) Zero (b) mg (c) 3 mg (d) 5 mg

(64) **Moment of inertia comes into play:**

(a) in translatory motion (b) in rotatory motion
(c) in vibratory motion (d) when the body is permanently at rest

(65) **The rotational analogue of mass in linear motion is:**

(a) Torque (b) Weight (c) Moment of inertia (d) Angular momentum

(66) **The rotational analogue of force in linear motion is:**

(a) Torque (b) Weight (c) Moment of inertia (d) Angular momentum

(67) **A particle is moving along a straight line parallel to x-axis with constant velocity. Its angular momentum about the origin:**

(a) Decreases with time (b) Increases with time (c) Remains constant (d) is zero

(68) **A circular disc is rolling on a horizontal plane. Its total kinetic energy is 150 J. What is its translational KE?**

(a) 200 J (b) 100 J (c) 125 J (d) None of these

(69) **A solid cylinder of mass M and radius R rolls down an inclined plane without slipping. The speed of its centre of mass when it reaches the bottom is: (h is the height of inclined plane)**

(a) $\sqrt{2gh}$ (b) $\sqrt{\frac{4}{3}gh}$ (c) $\sqrt{\frac{3}{4}gh}$ (d) $\sqrt{4g/h}$

(70) **When a body starts to roll on an inclined plane, its potential energy is converted into:**

(a) Translational KE only (b) Translational and rotational KE
(c) Rotational KE only (d) None of the above

ANSWERS

(1)	(c)	(2)	(b)	(3)	(a)	(4)	(a)	(5)	(b)
(6)	(a)	(7)	(b)	(8)	(c)	(9)	(c)	(10)	(c)
(11)	(a)	(12)	(a)	(13)	(b)	(14)	(a)	(15)	(b)
(16)	(a)	(17)	(b)	(18)	(d)	(19)	(b)	(20)	(a)
(21)	(c)	(22)	(d)	(23)	(a)	(24)	(d)	(25)	(d)
(26)	(d)	(27)	(b)	(28)	(c)	(29)	(a)	(30)	(d)
(31)	(a)	(32)	(c)	(33)	(c)	(34)	(d)	(35)	(a)
(36)	(d)	(37)	(b)	(38)	(b)	(39)	(b)	(40)	(b)
(41)	(d)	(42)	(b)	(43)	(b)	(44)	(c)	(45)	(d)
(46)	(c)	(47)	(b)	(48)	(c)	(49)	(d)	(50)	(d)
(51)	(a)	(52)	(a)	(53)	(c)	(54)	(a)	(55)	(b)
(56)	(b)	(57)	(b)	(58)	(b)	(59)	(c)	(60)	(b)
(61)	(d)	(62)	(b)	(63)	(d)	(64)	(b)	(65)	(c)
(66)	(a)	(67)	(c)	(68)	(b)	(69)	(b)	(70)	(b)

SOLUTION

(36) $F_c = \frac{mv^2}{r}$

As $r = 10^3$ cm

$r = \frac{10^3}{100}$

$r = 10$ m

$F_c = \frac{(10)(1)^2}{10}$

$F_c = 1$ N

(d) is correct

(52) $\tau = \frac{\Delta P}{\Delta t}$

$\tau = \frac{(4-1)}{4}$

$\tau = \frac{3}{4}$ Nm

(a) is correct

(56) As $g = \frac{GM}{R^2}$

$g' = \frac{G(2M)}{(2R)^2}$

$g' = \frac{2GM}{4R^2}$

$g' = \frac{1}{4}g$

(b) is correct

Chapter 6

FLUID DYNAMICS

MCAT UNIT 3

KEY POINTS

Fluid Dynamics: The branch of physics which deals with the fluid in motion is called the fluid dynamics.

Fluid Static: The branch of science which deals with the fluids at rest is called fluid static.

Fluid: The substance which can flow is called fluid. Liquids and gases are considered as fluid substances. The study of properties of flowing fluid is called fluid dynamics.

Viscosity and Newton's Law of Viscous Force:

(i) The property of a fluid due to which it opposes the relative motion between its different layers is called viscosity and the force between the layers opposing the relative motion viscous force. A briskly stirred fluid comes to rest after a short while because of viscosity.

(ii) Viscosity of layer depends only on the nature of fluid and is independent of area considered or velocity gradient.

(iii) Its dimensions are $[ML^{-1}T^{-1}]$ and SI units Poiseuille (Pl) while CGS units dynes-sec/cm^2 called Poise (P) with **1 Pl = 10 Poise.**

(iv) Viscosity of liquids is much greater (say about 100 times more) than that of gases, i.e., $n_L > n_G$.

(v) In case of liquids viscosity increases with density while for gases it decreases with increase in density.

(vi) **With rise in temperature** the viscosity of liquids decreases while that of gases increases.

(vii) **With increase in pressure**, the viscosity of liquids (except water) increases while that of gases is practically independent of pressure.

Stokes' Law and Terminal Velocity:

(i) When a body moves through a fluid, the fluid in contact with the body is dragged with it. This establishes relative motion in fluid layers near the body, due to which viscous force starts acting. The fluid exerts viscous force on the body to oppose its motion. The magnitude of the viscous force depends on the shape and size of the body, its speed and the viscosity of the fluid. Stokes established that if a sphere of radius r moves with velocity v through a fluid of viscosity η, the viscous force opposing the motion of the sphere is:

$$F = 6\pi\eta rv \quad \text{(Stoke's Law)}$$

(ii) The terminal velocity of a sphere of r falling in a fluid of density σ and coefficient of viscosity η is given by:

$$v_T = \frac{2\rho g r^2}{9\eta}$$

(a) $v_T \propto r^2$, i.e., terminal velocity depends on the radius of the sphere, so if radius is made n times, terminal velocity will become n^2 times.

(b) **V_T depends on the density of solid.** Greater the density of solid, greater will be the terminal velocity.

(c) **V_T depends on the nature of fluid**. Greater the density and viscosity of the fluid, lesser will be the terminal velocity.

(d) $V_T \propto g$, i.e., terminal velocity also depends on acceleration due to gravity 'g'. So, it will change with change of planet or in accelerated systems.

Viscosity: The frictional effect between the different layers of flowing fluid is described in terms of viscosity of the fluid. Viscosity of liquids with rise in temperature increases. Viscosity measures how much force required to slide one layer of a liquid over another.

Co-efficient of Viscosity: It is the tangential force per unit area required to maintain a unit velocity between its layers at unit distance apart.

$$\eta = \frac{F/A}{V/X}$$

The SI-unit of co-efficient of viscosity is $N\,m^{-2}\,s$ or $kg\,m^{-1}s^{-1}$. The dimensions of co-efficient of viscosity is $[ML^{-1}T^{-1}]$. Water and air have small co-efficient of viscosity than honey, thick tar.

Viscosities of Liquids and Gases at 30°C

Material	Viscosity 10^{-3} (Nsm^{-2})
Air	0.019
Acetone	0.295
Methanol	0.510
Benzene	0.564
Water	0.801
Ethanol	1.000
Plasma	1.6
Glycerin	6.29

Drag Force: An object moving through a fluid experiences a retarding force called a drag force or viscous drag. The drag force increases as the speed of the object increases. The drag force depends on the following factors:

- Speed of object
- Radius of object
- Nature of fluid
- Shape of object
- Orientation of object in fluid

Stoke's Law: The drag force on a spherical body of radius 'r' moving slowly with speed 'v' through a fluid of viscosity 'η' is given by $F = 6\pi\eta rv$. At high speeds the force is no longer simply proportional to the speed.

Terminal Velocity: The maximum constant velocity of a freely falling object, when the drag force on the object becomes equal to its weight, is called terminal velocity and is given by

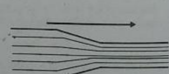
$$v_t = \frac{2\rho g r^2}{9\eta} \Rightarrow v_t \propto r^2 \text{ as } \frac{2\rho g}{9\eta} = \text{Constant}$$

Fluid Flow: The flow of the fluid may be of two types.

- Streamline flow
- Turbulent flow

The regular or steady flow of the fluid is called streamline flow or laminar flow. In streamline flow:

- The fluid particles move along a smooth path called streamlines.
- The different streamlines cannot cross each other.
- The velocity of the fluid remains constant.



(a) Streamlines (laminar flow)

The irregular or unsteady flow of the fluid is called turbulent flow. In turbulent flow:

- The exact path of the particles cannot be predicated.
- The velocity of the fluid changes abruptly.

(b) Turbulent flow

Ideal Fluid: A fluid is said to be an ideal fluid, if it satisfied the following three conditions.

- It is non-viscous. i.e., viscosity of the fluid zero
- It is incompressible. i.e., density remains constant
- Its flow is steady. i.e., fluid speed is steady

Flow Rate: The volume of fluid flowing per unit time is called flow rate.

$$\text{Flow rate} = \frac{\text{volume}}{\text{time}} = \frac{V}{t}$$

The S-I unit of flow rate is $m^3 s^{-1}$. However, it can be expressed in litre s^{-1}.

Equation of Continuity: For the steady flow of an ideal fluid, the mass of fluid passing through any cross-section of the pipe per unit time remains constant. i.e., $\frac{m}{t} = \rho_1 A_1 v_1 = \rho_2 A_2 v_2 = \text{Constant}$. Equation of continuity is based on the law of conservation of mass. For an ideal fluid, the equation of continuity becomes

$$A_1 v_1 = A_2 v_2 = \text{Flow rate} = \text{Constant} \Rightarrow A \propto \frac{1}{v}$$

Principle of Continuity:

(i) According to this principle, in case of steady flow of incompressible and non-viscous fluid through a tube of non-uniform cross-section, the product of the area of cross-section and the velocity of flow remains same at ever point in the tube, i.e.,

$$Av = \text{Constant}$$

(ii) Above equation is known as equation of continuity and represents the conservation of mass in case of moving fluids.

(iii) If the liquids are assumed non-viscous, the velocity of flow is independent of the nature of liquid.

(iv) The velocity of flow will increase if cross-section decreases and vice-versa. This is why

(a) deep water appears to be still, and; (b) falling stream of water becomes narrower.

Bernoulli's Theorem:

(i) According to this theorem, in case of steady flow of incompressible and non-viscous fluid through a tube of non-uniform cross-section, the sum of the pressure, the potential energy per unit volume and the kinetic energy per unit volume is same at every point in the tube, i.e., $P + \rho gh + (1/2)\rho v^2 = \text{constant}$.

(ii) Above equation is called Bernoulli's equation and represents conservation of mechanical energy in case of moving fluids.

(iii) **Drop of pressure when fluid moves from broader to narrower horizontal pipe:** According to continuity equation: $Av = \text{constant}$.

So, were the area is small, velocity will be large and vice-versa.

But by Bernoulli's equation for a horizontal pipe (i.e., $h = \text{constant}$)

$$P + (1/2)\rho v^2 = \text{Constant}$$

i.e., where the velocity is large, pressure will be small. Hence, when fluid flows from broader to narrower pipe, its velocity increases and so the pressure decreases.

(iv) **Blowing off of roots by wind storms:** During a tornado when a high speed wind blows over a roof of straw or tin, it creates a low pressure in accordance with Bernoulli's theorem. However, pressure below the roof is still atmospheric. So due to this difference of pressure, the roof is lifted up and is then blown off by the wind.

(v) **Attraction between two closely parallel moving boats or buses:** When two boats or buses move side by side in the same direction, the water (or air) in the region between them moves faster than that on the remote sides. Consequently in accordance with Bernoulli's principle, the pressure between them is reduced and hence due to pressure difference they are pulled towards each other creating the so called attraction.

(vi) **Magnus effect:** When a spinning ball is thrown, it deviates from its usual path in flight. This effect is called magnus effect. This effect also occurs in accordance with Bernoulli's theorem.

Applications of Bernoulli's Principle:

(i) **The action of aspirator, carburettor, paint-gun, scent spray or insect-sprayer is based on Bernoulli's principle.** In all these, by means of motion of a piston in a cylinder high speed air is passed over a tube dipped in liquid to be sprayed. High speed air creates low pressure over the tube due to which liquid rises in it and is then blown off in very small droplets with expelled air.

(ii) **Working of aeroplane is also based on Bernoulli's principle.**

(iii) **Velocity of efflux:**

If a liquid is filled in a vessel up to height H and a hole is made at a depth h below the free surface of the liquid, then velocity of liquid coming out from the hole is given by:

$$v = \sqrt{2gh}$$

which is the same speed that an object would

Bernoulli's Equation: For a steady flow of an ideal fluid, the sum of pressure, kinetic energy per unit volume and potential energy per unit of volume remains constant".

i.e., $$P + \frac{1}{2}\rho v^2 + \rho g h = \text{Constant}$$

Bernoulli's equation is based on the law of conservation of energy.

Applications of Bernoulli's Equation:

Torricelli's Theorem: The speed of efflux is equal to the velocity gained by the fluid in falling through a certain height under the action of gravity.

i.e., $$v = \sqrt{2gh}$$

When the top level of the tank is moved down a little, than P.E of the water is transferred into K.E of the efflux of the water through small orifice.

Venturi Effect: Where the speed is high, the pressure will be low and vice versa. The pressure in the narrow pipe is much smaller than in the wider pipe. Some others applications of Bernoulli's Equation are:

- Operation of paint sprayer or perfume sprayer.
- Operation of a chimney for smoke exhaust.
- Lift on an aeroplane.
- Swing of a cricket or tennis ball.
- Measurement of speed of liquid or gas in a pipe.
- Working of a carburetor of a car.
- Working of a filter pump.

Venturi Relation: The venture relation is given by

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

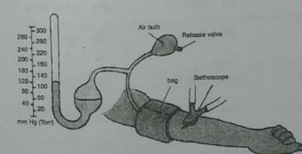
If v_1 is very small, then putting $v_1 = 0$ in the above equation

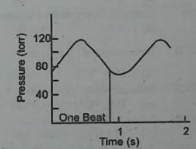
$$P_1 - P_2 = \frac{1}{2}\rho v_2^2$$

The venture relation is used in venture meter, a device used to measure speed of liquid flow.

Blood Flow: Blood is an incompressible fluid having a density nearly equal to that of water. A high concentration (~ 50%) of red blood cells increases its viscosity from three to fire times that of water. The pressure of blood inside the blood vessels is greater than the external atmospheric pressure. The pressure varies from a high systolic pressure of 120 torr to a low diastolic pressure of about 75 – 80 torr between beats in normal, healthy person. The blood pressure increases with age, corresponding to the decrease in the flexibility of the vessel walls. The unit torr or mm of Hg is used instead of SI-unit of pressure "Pascal" because of its extensive use in medical equipments. An instrument called "sphygmomanometer" measure blood pressure dynamically. When the external pressure applied becomes larger than the systolic pressure, the vessels collapse, cutting off the flow of the blood. When the external pressure becomes equal to the systolic pressure, the flow of blood is turbulent and the gurgle can be heard by stethoscope. When external pressure eventually equals the diastolic pressure, the flow switches from turbulent to laminar, and the gurgle in the stethoscope disappears. This is the signal to record diastolic pressure.

$$1 \text{ torr} = 133.3\ \text{Nm}^{-2}$$





ASSIGNMENT NO. 6

(1) **The frictional effect between different layers of a flowing fluid is called:**
(a) Viscosity of the fluid (b) Velocity of the fluid
(c) Displacement of the fluid (d) Acceleration of the fluid

(2) **The drag force F_d on a sphere of radius r moving slowly with speed v through the fluid of viscosity η is given by:**
(a) $4\pi\eta rv$ (b) $6\pi\eta rv$ (c) $2\pi\eta rv$ (d) $3\pi\eta rv$

(3) **The SI unit of coefficient of viscosity is:**
(a) $kg\,m^{-1}s^{-1}$ (b) Nm^2s^2 (c) $kg\,m^2s^{-2}$ (d) $kg\,ms^{-2}$

(4) **The terminal velocity of the spherical object is given by:**
(a) $v_t = \frac{2gr^2\rho}{9\eta}$ (b) $v_t = \frac{mg}{4\pi\eta r}$ (c) $v_t = \frac{mg}{5\pi\eta r}$ (d) None of these

(5) **The terminal velocity of water droplet of radius 1×10^{-4} m and density 1000 kg/m^3 falling through air of viscosity 19×10^{-6} kg/ms is:**
(a) 1.5 m/s (b) 2.3 m/s (c) 3.4 m/s (d) 1.1 m/s

(6) **The SI units of flow rate is:**
(a) m^2/s^2 (b) m^3/s (c) m^3/s^2 (d) m^2/s

(7) **Bernoullis equation is based upon law of conservation of:**
(a) Momentum (b) Energy (c) Mass (d) All of these

(8) **Blood is an incompressible fluid having a density nearly equal to that of:**
(a) Water (b) Oil (c) Milk (d) All of these

(9) **Human blood pressure is measured in:**
(a) N/m^2 (b) Torr (c) Pascal (d) cm

(10) **Dimensions of $\left[\frac{1}{2}\rho v^2\right]$ are:**
(a) $[ML^{-1}T^{-1}]$ (b) $[ML^3T^{-2}]$ (c) $[ML^{-1}T^{-2}]$ (d) $[ML^{-1}T^{-1}]$

(11) **Dimensions of [ρgh] are:**
(a) $[ML^{-1}T^{-2}]$ (b) $[ML^{-3}T^{-2}]$ (c) $[ML^{-1}T^{-1}]$ (d) $[ML^{-2}T^{-2}]$

(12) **1 torr in N/m^2 is:**
(a) 129 N/m^2 (b) 133.3 N/m^2 (c) 135.6 N/m^2 (d) 125 N/m^2

(13) **A liquid flows through a pipe of varying diameter. The velocity of the liquid is 2 m/s at a point where the diameter is 6 cm. The velocity of the liquid at a point where diameter is 3 cm will be:**
(a) 1 m/s (b) 4 m/s (c) 8 m/s (d) 16 m/s

(14) **Nsm^{-2} is unit of:**
(a) Drag force (b) Pressure (c) Surface tension (d) Coefficient of viscosity

(15) **Two copper balls of 1 cm and 2 cm in diameter are simultaneously dropped in the same viscous medium. The terminal velocity of bigger ball is:**
(a) Not affected due to its size (b) Twice that of small size ball
(c) Four times that of small size ball (d) 1/4th of that of small size ball

(16) **The dimensions of viscosity are:**
(a) $M^2L^{-1}T^{-2}$ (b) $M^{-1}L^{-1}T^{-1}$ (c) $M^{-1}L^{-1}T$ (d) $ML^{-1}T^{-1}$

(17) **A drop-like particle has a density of 10^3 kg/m^3. If falls through a fluid of $\eta = 10^{-3}$ (SI units) with a terminal velocity of 2.2×10^{-6} m/sec. The radius of the particle will be:**
(a) 10^{-3} m (b) 10^{-4} m (c) 10^{-5} m (d) 10^{-6} m

(18) **The drag force acting on a spherical droplet of radius 10^{-5} m moving with a velocity of 1 cm/sec. in a fluid of viscosity 5.31×10^{-7} (SI units) comes out to be:**
(a) 10^{-16} N (b) 10^{-14} N (c) 10^{-12} N (d) 10^{-10} N

(19) **Given that: ρ (for water) = 10^3 kg/m^3, η (for air) = 2×10^{-5} (SI units), Radius of droplet = 10^{-5} meters then terminal velocity of droplet comes out to be nearly:**
(a) 1 cm/sec. (b) 10 cm/sec. (c) 100 cm/sec. (d) None of these

(20) **If velocity of efflux is 100 m sec^{-1} and area of the hole is 0.06 cm^2, how much volume of water will flow out of the hole in one second?**
(a) 6×10^{-4} m^3 (b) 6.0 m^3 (c) 600 m^3 (d) 6.0 cm^3

(21) **Torricelli's theorem states that speed of efflux is ———— the velocity gained by the liquid in falling through the distance h under the action of ————.**
(a) Equal to, gravity (b) Equal to, surface tension
(c) Smaller than, gravity (d) Greater than, drag force

(22) **The unit of ρgh in Bernoulli's equation is:**
(a) Pressure (b) Volume (c) Work (d) Force

(23) **1000 kg/m^3 is equivalent to:**
(a) 1000 gms/cm^3 (b) 1 gm/cm^3 (c) 10 kg/cm^3 (d) None of these

(24) **Two stretched membranes of area 2 cm^2 and 3 cm^2 are placed in a liquid at the same depth. The ratio of pressures on them is:**
(a) 1 : 1 (b) 2 : 3 (c) 3 : 2 (d) $2^2 : 3^2$

(25) **As a bubble comes from the bottom of a lake to the top, its radius:**
(a) Increases (b) Decreases (c) Does not change (d) Becomes zero

(26) **When a body is wholly or partially immersed in a liquid it appears to lose weight. This loss of weight is equal to the weight of:**
(a) Water displaced by the body (b) Liquid displaced by the body
(c) Equal volume of water (d) Equal volume of liquid

(27) **Which of the following instruments is generally used to measure the specific gravity of milk?**
(a) Lactometer (b) Universal hydrometer
(c) Beaume hydrometer (d) Twaddle hydrometer

(28) **A body is floating in a liquid. The upthrust on the body is:**
(a) Equal to weight of liquid displaced (b) Zero
(c) Less than the weight of liquid displaced (d) Weight of body – Weight of liquid displaced

(29) **A liquid disturbed by stirring comes to rest after some time due to property of:**
(a) Surface tension (b) Viscosity
(c) Molecular attraction (d) Low compressibility

(30) **Viscosity of gases is:**
(a) about hundred times less than those of liquids
(b) about twenty times less than those of liquids
(c) about five hundred times less than those of liquids
(d) about ten hundred times less the those of liquids

(31) **The terminal velocity of a sphere moving through a viscous:**
(a) Directly proportional to the radius of the sphere
(b) Inversely proportional to the radius of the sphere
(c) Directly proportional to the square of the radius of sphere
(d) Inversely proportional to the square of the radius of sphere

(32) **With increase in temperature the viscosity of:**
(a) Both gases and liquids increases (b) Both gases and liquids decreases
(c) Gases increases and of liquids decreases (d) Gases decreases and of liquids increases

(33) **The viscous force on a small sphere of radius R moving in a fluid is:**
(a) αR^2 (b) αR (c) $\alpha\left(\frac{1}{R}\right)$ (d) $\alpha\left(\frac{1}{R}\right)^2$

(34) The rate of outflow of liquid through an orifice does not depend upon:
(a) Radius of the orifice (b) Height of liquid column
(c) Acceleration due to gravity (d) Density of the liquid

(35) A tank containing water has an orifice in one vertical side. If the centre of orifice is 4.9 m below the surface level in the tank, the velocity of discharge is:
(a) 4.9 metre/second (b) 9.8 metre/second (c) 2.45 metre/second (d) Zero

(36) The clouds float in the atmosphere because of:
(a) their low temperature (b) their low viscosity
(c) their low density (d) Creation of low pressure

(37) After attaining the terminal velocity, the acceleration of the body moving through viscous medium is:
(a) +ve (b) –ve
(c) Depends upon medium (d) Zero

(38) In a laminar flow the velocity of the liquid in contact with the walls of the tube is:
(a) Zero (b) Maximum
(c) in between zero and maximum (d) Equal to critical velocity

(39) When the drag force on a rain drop becomes equal to its weight, the net force on the drop:
(a) starts increasing (b) Starts decreasing (c) Remains constant (d) becomes zero

(40) The viscosity of a fluid with rise in temperature:
(a) Decreases (b) Increases (c) Does not change (d) None of these

(41) A sphere of mass 10 kg is falling with maximum velocity, then drag force on it is:
(a) 1 N (b) 98 N (c) 0 N (d) 4.9 N

(42) The terminal velocity of a body falling through a fluid:
(a) Increases with increasing mass (b) Decreases with increasing radius
(c) Decreases with increasing mass (d) Independent of mass

(43) A fog droplet falls vertically through air with an acceleration:
(a) Equal to g (b) Less than g (c) Greater than g (d) Equal to zero

(44) The terminal velocity of a sphere of radius r in a fluid of viscosity η is:
(a) $mg / 2\pi\eta r$ (b) $mg / 4\pi\eta r$ (c) $mg / 6\pi\eta r$ (d) $6\,mg\,\pi\eta r$

(45) In laminar flow, the velocity of the fluid:
(a) Remains constant (b) Changes abruptly (c) Changes slowly (d) Becomes zero

(46) The product of cross sectional area of the pipe and the fluid speed at any point along the pipe gives:
(a) Flow rate (b) Speed of influx (c) Speed of efflux (d) Viscosity

(47) The equation of continuity is based on the:
(a) Law of conservation of energy (b) Law of conservation of momentum
(c) Law of conservation of mass (d) Law of conservation of angular momentum

(48) Water is filled to a height h in a tank. If a small hole is made at the mid point of the tank, then its velocity of efflux is:
(a) $\sqrt{2gh}$ (b) $\sqrt{gh}$ (c) $2\sqrt{gh}$ (d) $\sqrt{\frac{1}{2}gh}$

(49) The equation that relates pressure to fluid speed and height is:
(a) Bernoulli's equation (b) Equation of continuity
(c) Venturi relation (d) Torricelli's theorem

(50) A flowing fluid possesses:
(a) K.E (b) P.E (c) Pressure energy (d) All of these

(51) If the cross-section area of a pipe increases, the pressure of the fluid:
(a) Increases (b) Decreases (c) Remains constant (d) None of these

(52) Where the stream lines are closer together, speed of flow is:
(a) Smaller (b) Greater (c) Remain same (d) Zero

(53) At high altitude, the blood flows out of nose and ear because:
(a) The blood pressure increases at high altitude (b) The atmospheric pressure decreases there
(c) The percentage of oxygen in the air decreases (d) The density of blood decreases at high altitude

(54) The venturi relation is given by:
(a) $P_1 + P_2 = \frac{1}{2}\rho v^2$ (b) $P_1 - P_2 = \frac{1}{2}\rho v^2$
(c) $P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$ (d) $P_1 - P_2 = \rho v^2$

(55) A stream of air passing over a tube dipped in a liquid will:
(a) Decrease the density of the liquid (b) Cause the liquid to rise in the tube
(c) Decrease the pressure in the tube (d) Decrease the viscosity of the liquid

(56) The working of atomizer depends upon:
(a) Bernoulli's equation (b) Boyle's law
(c) Newton's law of motion (d) Archimedes principle

(57) The terminal velocity of a spherical droplet is directly proportional to:
(a) The radius of the droplet (b) The square of the radius of the droplet
(c) The square root of the radius of the droplet (d) The cube of the radius of the droplet

(58) The blood pressure inside the blood vessels is:
(a) Smaller than the external atmospheric pressure
(b) Greater than the external atmospheric pressure
(c) Equal to the external atmospheric pressure
(d) Either smaller or equal to the external atmospheric pressure

(59) The velocity of efflux is measured by the relation:
(a) $\sqrt{2gh}$ (b) $2\sqrt{gh}$ (c) $\sqrt{gh}$ (d) $\frac{1}{2}\sqrt{gh}$

(60) High concentration of red blood cell increases the viscosity of blood from:
(a) 1 – 2 times that of water (b) 2 – 3 times that of water
(c) 3 – 4 times that of water (d) 3 – 5 times that of water

(61) Blood is flowing at the rate of $200\ cm^3 s^{-1}$ in a capillary of cross-sectional area $0.5\ m^2$. The velocity of flow in mms^{-1} is:
(a) 0.1 (b) 0.2 (c) 0.3 (d) 0.4

(62) At high speeds drag force:
(a) Proportional to speed (b) Not proportional to speed
(c) Inversely proportional to speed (d) All

(63) Terminal velocity is directly proportional to:
(a) Mass of object (b) Square of radius of object
(c) Both (a), (b) (d) None

(64) If volume of a sphere increases then terminal velocity:
(a) Remains same (b) Increases (c) Decreases (d) None

(65) If velocity of particle at different points does not change with time, flow is:
(a) Streamline (b) Laminar (c) Steady (d) All

(66) Equation of continuity is the basis of law of conservation of:
(a) Mass (b) Momentum (c) Energy (d) None

(67) Bernoulli's equation is the basis of law of conservation of:
(a) Energy (b) Mass (c) Charge (d) Momentum

(68) A device used to measure speed of liquid flow:
(a) Venturi-meter (b) Speed-meter (c) Sphyginomeno-meter (d) None

(69) Density of blood:
(a) Nearly equal to water (b) Less than water (c) Greater than water (d) None

ANSWERS

(1)	(a)	(2)	(b)	(3)	(a)	(4)	(a)	(5)	(d)
(6)	(b)	(7)	(b)	(8)	(a)	(9)	(b)	(10)	(c)
(11)	(a)	(12)	(b)	(13)	(c)	(14)	(d)	(15)	(c)
(16)	(d)	(17)	(d)	(18)	(c)	(19)	(a)	(20)	(a)
(21)	(a)	(22)	(a)	(23)	(b)	(24)	(a)	(25)	(a)
(26)	(b)	(27)	(a)	(28)	(a)	(29)	(b)	(30)	(a)
(31)	(c)	(32)	(c)	(33)	(b)	(34)	(d)	(35)	(b)
(36)	(c)	(37)	(d)	(38)	(a)	(39)	(d)	(40)	(a)
(41)	(b)	(42)	(a)	(43)	(b)	(44)	(c)	(45)	(a)
(46)	(a)	(47)	(c)	(48)	(b)	(49)	(a)	(50)	(d)
(51)	(a)	(52)	(b)	(53)	(b)	(54)	(b)	(55)	(b)
(56)	(a)	(57)	(b)	(58)	(b)	(59)	(a)	(60)	(d)
(61)	(d)	(62)	(b)	(63)	(c)	(64)	(b)	(65)	(d)
(66)	(a)	(67)	(a)	(68)	(a)	(69)	(a)		

SOLUTION

(15) As $V_t \propto r^2$

(c) is correct

(24) As $P = \frac{F}{A}$

(a) is correct

(61)

$$\frac{V}{t} = av$$

$$200 = 0.5 \times 10^4 \times V$$

$$\Rightarrow V = \frac{200}{0.5} \times 10^{-4}$$

$$V = 400 \times 10^{-4}$$

$$\Rightarrow V = 0.04\ cms^{-1}$$

$$V = \frac{0.04 \times 10^{-2}}{10^{-3}} \times 10^{-3}\ m/s$$

$$V = 0.04 \times 10\ m\ m/s$$

$$\Rightarrow V = 0.4\ m\ m/s$$

(d) is correct

Chapter 7

OSCILLATIONS

KEY POINTS

Vibratory Motion: To and fro motion of a body about its mean position is called vibratory motion.

Examples:

(i) Motion of a swing. (ii) Motion of a simple pendulum. (iii) Motion of a mass attached to a spring.

Periodic Motion:

(i) A motion is said to be periodic when it repeats itself again and again in a given fixed interval of time called **time period**.

(ii) A periodic motion can be either rectilinear or closed or open curvilinear.

(iii) A periodic motion can be synthesized from or analysed into a number of simple harmonic components.

(iv) In a periodic motion, force is always directed towards a fixed point which may or may not be on the path of motion.

Oscillatory Motion:

(i) A body is said to possess oscillatory or vibratory motion if it moves back and forth repeatedly about a mean position.

(ii) Oscillatory motion is basically a **constrained periodic motion** between two fixed limits.

(iii) Though every oscillatory motion is definitely periodic but every periodic motion is not always oscillatory.

Simple Harmonic Motion:

(i) SHM is the simplest kind of periodic motion. It may be defined as the periodic motion of a body such that:

(a) its acceleration at any instant is always directed towards a fixed point.

(b) the magnitude of its acceleration at that instant is directly proportional to its displacement from a fixed point in its path.

The fixed point is known as **mean position** and the force obeying above two conditions is called as **restoring force.**

(ii) **Requirements for motion to be SHM:**

(a) The motion is **periodic**.

(b) The motion is along a straight line about the mean or equilibrium position.

(c) The acceleration is proportional to displacement.

(d) Acceleration is directed towards mean or equilibrium position.

Important Terms Connected with SHM: The distance of a vibrating body from its mean position is called its displacement. The maximum displacement of the vibrating body from mean position is called amplitude of vibration. It is denoted by 'x_o'. A one complete round trip of a vibrating body about its mean position is called vibration. The time required to complete one vibration is called time period or period of vibration. It is denoted by 'T'. The number of vibrations completed by a vibrating body in one second is called frequency. It is denoted by 'f'. The SI-unit of frequency is Hertz (Hz). However it can be expressed in vibrations per second or cycles per second.

Frequency and the time period are related by the relation:

$$T = \frac{1}{f} \quad \text{or} \quad f = \frac{1}{T}$$

The angular frequency of a body executing SHM is defined as:

$$\omega = \frac{2\pi}{T} = 2\pi f$$

Angular frequency is expressed as radian per second or revolution per second.

SHM and Uniform Circular Motion: The expression for displacement of a body executing SHM is:

$$x = x_o \sin \omega t$$

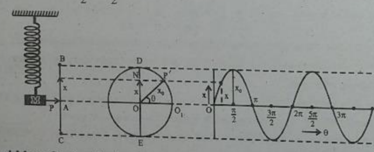
The displacement 'x' is zero when $\theta = 0^\circ$ or 180° (π radians) and it is maximum, when $\theta = 90^\circ$ $\left(\frac{\pi}{2} \text{radian}\right)$ or $\theta = 270^\circ \left(\frac{3\pi}{2} \text{radian}\right)$. The expression for velocity of a body executing SHM is

$$v = \omega\sqrt{x_0^2 - x^2}$$

At mean position, $x = 0$, so the velocity is maximum and at extreme position, where $x = x_o$ the velocity is zero. The expression for acceleration of a body executing SHM is

$$a = -\omega^2 x$$

The angle '$\theta = \omega t$' which specifies the displacement as well as the direction of motion of the point executing SHM is known as phase. At mean position, phase angle would be 0 or π radian and at the extreme positions, phase angle would be $\frac{\pi}{2}$ or $\frac{3\pi}{2}$ radian.



A Horizontal Mass Spring System

The restoring force acting on mass attached to a spring is:

$$F = -kx$$

The acceleration of a mass attached to a spring is given by:

$$a = -\frac{k}{m}x$$

The angular frequency of mass spring system is:

$$\omega = \sqrt{\frac{k}{m}}$$

The time period of the mass is given by:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

The instantaneous displacement of the mass is given by:

$$x = x_o \sin \sqrt{\frac{k}{m}}t$$

The instantaneous velocity of the mass is:

$$v = \sqrt{\frac{k}{m}}\sqrt{x_o^2 - x^2}$$

$$v = x_o\sqrt{\frac{k}{m}}\sqrt{1 - \frac{x_2}{x_o^2}}$$

The velocity of the mass is maximum at mean position, where x= o, and is given by:

$$\therefore \quad \text{Maximum velocity} = v_o = x_o\sqrt{\frac{k}{m}}$$

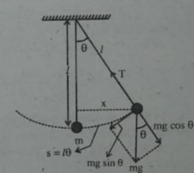
The relation between the instantaneous velocity and maximum velocity is:

$$v = v_o\sqrt{1 - \frac{x^2}{x_o^2}}$$

Simple Pendulum: A simple pendulum consists of a small heavy bob suspended by a light inextensible string whose other end is fixed to a rigid support as shown in. The component mg cosθ balances the tension of the string whereas the component mg sinθ provides the restoring force to bob.

$$\text{Restoring force} = F = -mg \sin \theta$$

The motion of simple pendulum is SHM, if θ is small (i.e., $\theta \angle 5^\circ$). The acceleration of the simple pendulum is given by:



$$a = \frac{-g}{l}x$$

The angular frequency of simple pendulum is given by:

$$\omega = \sqrt{\frac{g}{l}}$$

The time period of simple pendulum is:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

The time period of simple pendulum depends on the length of the pendulum and acceleration due to gravity but it is independent of mass of bob. A pendulum whose time period is 2 sec is called second pendulum. The frequency of second pendulum is 0.5 Hz.

Important Points:

(i) A simple pendulum consists of a heavy point mass suspended by a weightless, inextensible and perfectly flexible string from a rigid support. Such an ideal pendulum is not possible in practice but a heavy bob suspended by a light inextensible thread works as simple pendulum.

(ii) The motion of simple pendulum is angular SHM. Restoring torque acting on it is: $\tau = -mgL\theta$ and time period $T = 2\pi\sqrt{(L/g)}$.

(iii) When the time period of a simple pendulum is 2 second, it is called a **second pendulum.**

(iv) Time period of simple pendulum is independent of amplitude as long as θ is small.

(v) Time period of simple pendulum is independent of the mass of bob.

(vi) Time period of simple pendulum depends on L as $T \propto \sqrt{L}$; hence the graph between T and L will be a parabola while that between T^2 and L will be straight line.

(vii) As $T \propto \left(\sqrt{1/\sqrt{g}}\right)$, hence with increase in g, T will decrease.

Energy Conservation in SHM: In SHM, the total energy is conserved in the absence of frictional forces. The work done in displacing the mass m through displacement x appears as elastic potential energy of the spring and is given by

$$P.E = \frac{1}{2}kx^2$$

The P.E is maximum at the extreme Position where $x = x_0$ and is given by:

$$P.E_{max} = \frac{1}{2}kx_o^2$$

The kinetic energy of the mass is given by:

$$K.E = \frac{1}{2}kx_o^2\left(1-\frac{x^2}{x_o^2}\right)$$

The K.E of the mass is maximum at mean position, where $x = o$ and is given by:

$$K.E_{max} = \frac{1}{2}kx_o^2$$

At any displacement 'x', the total energy of the mass is equal to the sum of K.E and P.E.

i.e.,

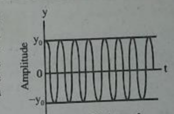
$$E_{Total} = \frac{1}{2}kx^2 + \frac{1}{2}kx_o^2\left(1-\frac{x^2}{x_o^2}\right) = \frac{1}{2}kx_o^2$$

In SHM, the energy oscillates from K.E and P.E and then K.E in such a way that the total energy is conserved. When the K.E of the mass is maximum, the P.E of the spring is zero and vice versa. If mass-spring system oscillates with frequency 'f', the its K.E. and P.E. oscillates between maximum and minimum values with frequency 2f.

Free and Forced Oscillations: If no external force acts on a vibrating system, then its oscillations are said to be free oscillations. If a system starts oscillating freely, then its frequency and period are called natural frequency and natural time period. If the oscillations of a vibrating system take place under the influence of an external force, then its oscillations are said to be forced oscillations. A physical system executing free vibrations is called simple Harmonic oscillator. A physical oscillating system under going forced vibrations is known as forced or driven harmonic oscillator.

Resonance: It is a specific response of a vibrating system to a periodic force acting on the system whose period is equal to the natural period of the vibrating system. At resonance the amplitude of vibration of the vibrating system becomes extra ordinary large under the action of periodic force. The energy of the oscillator comes from the deriving source. At resonance the transfer of energy is maximum. The resonance will also occur, if the period of the applied force is equal or integral multiple of the natural period of the vibrating body.

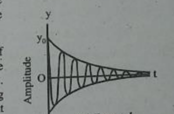
Example of Resonance: A swing is a good example of mechanical resonance. Tuning a radio is the best example of electric resonance. A single span bridge may break due to oscillations of dangerously large amplitude caused by rhythmic march of troops. Another good example of resonance is the heating and cooking of food very efficiently and evenly by microwave oven. The waves produced in the oven have a wavelength of 12 cm at a frequency of 2450 MHz.



(a) Undamped

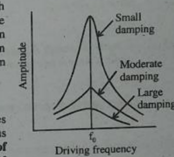
Uses of Resonance: It is used to fine the natural frequencies of the different bodies. It is used to determine the speed of sound with resonance apparatus.

Damped Oscillations: The oscillations in which the amplitude of vibration decreases gradually with time are called damped oscillation. The comparison of damped and un-damped harmonic wave is given in the figure. Damping is the process by which energy is dissipated from the oscillating system. The shock absorber of a car provides a damping force to prevent excessive oscillations.



(b) Damped

Sharpness of Resonance: The amplitude as well as its sharpness both depends upon the damping. Smaller the damping, greater will be the amplitude and more sharp will be the resonance. A heavily damped system has a fairly flat resonance curve as shown in an amplitude frequency graph in the figure. The sharpness of the resonance curve of a resonating system depends upon the frictional loss of energy.



Principle of Superposition:

(i) If two or more waves arrive simultaneously in a medium, the particles of the medium are subjected to two or more simultaneous displacements and a new wave is produced. **This phenomenon of intermixing of two or more waves to produce a new wave is called superposition of waves.**

(ii) In case of superposition of waves, the resultant wave function at any point is the algebraic sum of the wave-functions of individuals waves, i.e.,

$$y = y_1 + y_2 + y_3 + \ldots\ldots$$

This principle is called principle of superposition.

ASSIGNMENT NO. 7

(1) A force 20 N is applied on an elastic spring. If the extension produced in the spring is 10 cm, the spring constant k is:

(a) 20 N/m (b) 40 N/m (c) 10 N/m (d) 200 N/m

(2) The phase angle $\theta = \omega t$ of a body performing SHM indicates:

(a) Only the magnitude of displacement (b) Only the direction of the displacement
(c) Both magnitude and direction (d) None of these

(3) A body performing SHM has a displacement X given by the equation X = 30 sin 50 t, what is the frequency of oscillation:

(a) 0.020 Hz (b) 0.13 Hz (c) 8.0 Hz (d) 50 Hz

(4) If the position of oscillating object is given by the equation $X = \sqrt{2}\cos\left(\frac{\pi}{8}t\right)$ then its displacement after 2 second is:

(a) 3 m (b) 2 m (c) 1 m (d) 0 m

(5) A student made a simple pendulum of time period 1 sec. The string used is of length 1 m, in order to make a simple pendulum of time period 2 sec, he should use a string of length:

(a) 2 m (b) 3 m (c) 4 m (d) 5 m

(6) Time period of second pendulum at moon is:

(a) 1 sec. (b) 2 sec. (c) 3 sec. (d) 4 sec.

(7) A girl is swinging on a swing in the sitting position. How will the period of swing be affected if she stands up?

(a) The period will now be shorter
(b) The period will now be longer
(c) The period will remain unchanged
(d) The period may become longer or shorter depending upon the height of girl

(8) A simple harmonic oscillator has time period T. The time taken by it to travel from the extreme position to half the amplitude is:

(a) $\frac{T}{6}$ (b) $\frac{T}{4}$ (c) $\frac{T}{8}$ (d) $\frac{T}{2}$

(9) A particle executes S.H.M with frequency 'f', the frequency with which its K.E oscillates is:

(a) f (b) 2f (c) 3f (d) 4f

(10) A body executes S.H.M with an amplitude x_o. Its energy is half kinetic and half potential when displacement is:

(a) $\frac{x_o}{2}$ (b) $\frac{x_o}{3}$ (c) $\frac{x_o}{\sqrt{2}}$ (d) $\frac{x_o}{2\sqrt{2}}$

(11) Total energy of a particle executing S.H.M of amplitude A is proportional to:

(a) A^2 (b) A^{-2} (c) (d) A^{-1}

(12) The maximum velocity of 1 kg mass attached to a spring constant of 1 Nm^{-1} upto the displacement of 5 cm is:

(a) 1 ms^{-1} (b) 0.01 ms^{-1} (c) 5 ms^{-1} (d) 0.05 ms^{-1}

(13) A body of mass 5 kg in executing S.H.M with amplitude 10 cm. Its maximum velocity is 100 cms^{-1}. Its velocity will be 50 cms^{-1} at a displacement from the mean position equal to:

(a) 5 cm (b) $5\sqrt{3}$ cm (c) 10 cm (d) $10\sqrt{3}$ cm

(14) The equation of displacement of a body executing S.H.M is $x = x_o \cos \omega t$. What is initial phase?

(a) 0° (b) 90° (c) 180° (d) 270°

(15) Which of the following is an example of damped oscillations?

(a) Mass attached to a spring (b) Bob of pendulum
(c) Shock absorber of a car (d) All of them

(16) If a mass of 10 gm is suspended from a spring of k = 9.8 Nm^{-1}, then the extension will be:

(a) 1 cm (b) 1 m (c) 10 mm (d) None of these

(17) If a force of 0.05 N produces an elongation of 20 mm in a string, then its spring constant will be:

(a) 250 Nm^{-1} (b) 25 Nm^{-1} (c) 2.5 Nm^{-1} (d) None of these

(18) A spring of constant k = 0.4 Nm^{-1} is to be extended through 10 cm at a place where g = 10 cm sec^{-2}. The mass to be suspended should be:

(a) 4 gms (b) 0.4 gm (c) 40 gms (d) None of these

(19) If three identical springs each of constant k are hooked together, the spring constant of resultant spring will be:

(a) 3 k (b) 2 k (c) $\frac{k}{4}$ (d) $\frac{k}{3}$

(20) Distance covered during one vibration of an oscillating body in terms of amplitude A is:

(a) A (b) 2A (c) 3A (d) 4A

(21) If a body completes 20 vibrations in one minute, its time period will be:

(a) 0.05 sec. (b) 1.5 sec. (c) 3.0 sec. (d) 20 sec.

(22) A mass attached to a spring completes 60 vibrations in half minute. Its frequency is:

(a) 120 Hertz (b) 60 Hertz (c) 30 Hertz (d) 2 Hertz

(23) A body of mass 0.031 kg attached to one end of a spring of spring constant 0.3 N/m, then time period of spring mass system will be:

(a) 1.5 sec. (b) 2.0 sec. (c) 2.3 sec. (d) 2.5 sec.

(24) If ratio of time periods of two pendulum is 1 : 2, then the ratio of their lengths will be:

(a) 4 : 1 (b) 1 : 2 (c) 1 : 4 (d) None of these

(25) A simple pendulum of 3.4 m length vibrates with a time period of 3.7 seconds. The value of g at the place of experiment is nearly:

(a) 9.6 m sec^{-2} (b) 825 cm sec^{-2} (c) 10.2 m sec^{-2} (d) 9.8 m sec^{-2}

(26) Product of time period of a simple pendulum and its frequency is given by:

(a) π (b) One (c) $\sqrt{\pi}$ (d) 2π

(27) **Second's pendulum is the pendulum whose time period is:**

(a) 1 second (b) 2 seconds (c) 3 seconds (d) None of these

(28) **Length of a simple pendulum is 9.8 cm. Its frequency of oscillation at a place where $g = 9.8\ m/sec^2$ is given by:**

(a) $\frac{1}{2\pi}$ (b) $\frac{5}{\pi}$ (c) $\frac{\pi}{5}$ (d) $\frac{1}{\pi}$

(29) **The time period of a simple pendulum is 1 second. If $g = 9.8\ m/sec^2$, then length of the simple pendulum will be:**

(a) 380 m (b) 0.25 m (c) 2.5 m (d) None of these

(30) **A particle is fastened at the end of a string and whirled in a vertical circle with the other end of the string being fixed. The motion of the particle is:**

(a) Periodic (b) Oscillatory (c) Simple harmonic (d) Angular harmonic

(31) **A body executing SHM passes through equilibrium. At this instant it has:**

(a) max. P.E (b) max. K.E. (c) min. K.E. (d) max. acceleration

(32) **The K.E. and P.E. of a particle executing S.H.M. with amplitude A will be equal when its displacement is:**

(a) $A\sqrt{2}$ (b) $\frac{A}{2}$ (c) $\frac{A}{\sqrt{2}}$ (d) $A\sqrt{\frac{2}{3}}$

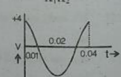
(33) **A simple pendulum suspended from the ceiling of a train has period T when the train is at rest. When the train is accelerating, the time period of the simple pendulum will:**

(a) Decrease (b) Increase (c) Remain unchanged (d) Become infinite

(34) **Two springs of spring constants K_1 and K_2 are joined in series the effective spring constant of combination is given by:**

(a) $\sqrt{K_1K_2}$ (b) $\frac{K_1+K_2}{2}$ (c) K_1+K_2 (d) $\frac{K_1+K_2}{K_1K_2}$

(35) **The velocity-time graph of a harmonic oscillator is shown in the following figure. The frequency of oscillation is:**



(a) 25 Hz (b) 50 Hz
(c) 12.25 Hz (d) 33.3 Hz

(36) **A girl is swinging in a swing in a sitting position. If she stands and swings, how will the period be affected?**

(a) the period will not change (b) the period will now be longer
(c) the period will now be shorter (d) the period will first increase and then decrease

(37) **For a simple harmonic oscillator, the potential energy will be equal to the kinetic energy:**

(a) Once during each cycle (b) Twice during each cycle
(c) Never (d) Always

(38) **To make the frequency double of an oscillator, we have to:**

(a) Double the mass (b) Half the mass
(c) Quadruple the mass (d) Reduce the mass to one-fourth

(39) **The total energy of simple harmonic motion is E. What will be the kinetic energy of the particle when displacement is half of the amplitude?**

(a) $\frac{3E}{4}$ (b) $\frac{E}{2}$ (c) $\frac{E}{4}$ (d) $\frac{E}{3}$

(40) **The total energy 'E' of a particle executing simple harmonic motion is:**

(a) $E \propto x$ (b) $E \propto x^2$ (c) Independent of x (d) $E \propto x^{1/2}$

(41) **In a simple pendulum the period of oscillation (T) is related to length of pendulum (L) as:**

(a) $\frac{L}{T}$ = Constant (b) $\frac{L^2}{T^2}$ = Constant (c) $\frac{L}{T^2}$ = Constant (d) $\frac{L^2}{T}$ = Constant

(42) **The bob of pendulum clock is made of iron. If a magnet is placed below the central position of bob, it will:**

(a) Start losing time (b) Start gaining time (c) Still gin correct time (d) Stop working

(43) **A particle is performing S.H.M. with amplitude A and angular velocity ω. The ratio of maximum velocity to maximum acceleration is:**

(a) ω (b) $\frac{1}{\omega}$ (c) ω^2 (d) $A\omega$

(44) **Which of the following characteristics does not change due to the damping of simple harmonic motion?**

(a) Angular frequency (b) Time period (c) Initial phase (d) Amplitude

(45) **The time period of a simple pendulum in a lift descending with constant acceleration g is:**

(a) Zero (b) $T = 2\pi\sqrt{\frac{l}{2g}}$ (c) $T = 2\pi\sqrt{\frac{l}{g}}$ (d) Infinite

(46) **The time-displacement graph of SHM is:**

(a) Pulse wave (b) Square wave (c) Sine wave (d) All of these

(47) **Frequency of the vibratory motion is:**

(a) Multiplication of time period (b) Reciprocal of time period
(c) Square of the time period (d) Square root of the time period

(48) **The SI unit of spring constant is identical with that of:**

(a) Force (b) Pressure (c) Surface Tension (d) Loudness

(49) **As the mass attached to a spring increases, then its angular frequency:**

(a) Remains constant (b) Decreases (c) Increases (d) Decreases slightly

(50) **In SHM, the velocity of a particle increases as the displacement:**

(a) Increases (b) Decreases
(c) Remain constant (d) First increases then decreases

(51) **In SHM, when acceleration is maximum, then velocity is:**

(a) Also maximum (b) Increases (c) Is constant (d) Zero

(52) **A simple pendulum is set up inside a lift. The period of oscillations is maximum when the lift is:**

(a) At rest (b) Moving downward with acceleration
(c) Moving upward with acceleration (d) Moving downward or upward with constant speed

(53) **The motion of projection of a particle describing uniform circular motion on the diameter is:**
(a) Periodic and simple harmonic (b) Periodic but not simple harmonic
(c) Simple harmonic but not periodic (d) Neither periodic nor simple harmonic

(54) **A body is suspended from a massless spring. What will be the effect on the period of oscillation, if mass is quadrupled:**
(a) It will be doubled (b) It will be halved
(c) It will be quadrupled (d) It will remain same

(55) **The length of second's pendulum is doubled. The new time period will be:**
(a) 2 s (b) $\frac{2}{\sqrt{2}}$ (c) $2\sqrt{2}$ (d) 4 s

(56) **A girl is swinging on a swing. If another girl sits along with her without disturbing her motion, then the period of swing will:**
(a) Increase (b) Decrease (c) Be doubled (d) Remain unchanged

(57) **A particle executing S.H.M. while passing through the mean position, has:**
(a) Maximum K.E and minimum P.E (b) Minimum K.E and maximum P.E
(c) Maximum K.E and maximum P.E (d) Zero K.E and maximum P.E

(58) **If a body starts its S.H.M from the extreme positions, its phase would be:**
(a) zero or π (b) zero or $\pi/2$ (c) π or $\frac{3\pi}{2}$ (d) $\frac{\pi}{2}$ or $\frac{3\pi}{2}$

(59) **At resonance, the transfer of energy is:**
(a) Zero (b) Maximum (c) Minimum (d) Very slow

(60) **Tuning a radio is the best example of:**
(a) Mechanical resonance (b) Elastic resonance
(c) Magnetic resonance (d) Electric resonance

(61) **The frequency of the mass spring system does not depend on:**
(a) Amplitude of oscillation (b) Period of oscillation
(c) Mass of the oscillator (d) Spring constant of spring

(62) **A body is executing S.H.M with amplitude x_o, the total displacement traveled by an object in a time equal to its period will be:**
(a) x_o (b) $2x_o$ (c) $4x_o$ (d) Zero

(63) **A microwave oven works according to the phenomenon of:**
(a) Interference (b) Reflection (c) Resonance (d) Refraction

(64) **The metal bob of a simple pendulum swings to and fro with S.H.M. Which quantity does not becomes zero at any time throughout the oscillation?**
(a) Weight (b) Acceleration (c) Speed (d) Momentum

(65) **If a spring of spring constant K is cut into three equal parts and these parts are joined parallel together, then the spring constant of their combination will be:**
(a) 3 K (b) 6 K (c) K/9 (d) 9 K

(66) **The equation of displacement of a body executing S.H.M is $x = x_o \cos \omega t$. What is initial phase?**
(a) 0° (b) 90° (c) 180° (d) 270°

(67) **The angular speed of the mass attached to a spring is:**
(a) $\omega = \frac{1}{2\pi\sqrt{m/k}}$ (b) $\omega = 2\pi\sqrt{m/k}$ (c) $\omega = \sqrt{k/m}$ (d) $\omega = 2\pi\sqrt{k/m}$

(68) **The maximum K.E. of the mass attached to an elastic spring is given by:**
(a) $(K.E.)_{max} = \frac{kx_o}{2}$ (b) $(K.E.)_{max} = \frac{kx_o^2}{2}$ (c) $(K.E.)_{max} = \frac{kx}{2}$ (d) $(K.E.)_{max} = \frac{kx^2}{2}$

(69) **If a body oscillates with the natural frequency without the interference of an external force, then it is said to be executing:**
(a) Forced vibration (b) Free vibrations (c) Mixed vibrations (d) None of the above

(70) **The frequency of waves produced in microwave oven is:**
(a) 1435 MHz (b) 2450 MHz (c) 1860 MHz (d) 2850 MHz

ANSWERS

(1)	(d)	(2)	(c)	(3)	(c)	(4)	(c)	(5)	(c)
(6)	(b)	(7)	(a)	(8)	(c)	(9)	(b)	(10)	(c)
(11)	(a)	(12)	(d)	(13)	(b)	(14)	(b)	(15)	(d)
(16)	(a)	(17)	(c)	(18)	(a)	(19)	(d)	(20)	(d)
(21)	(c)	(22)	(d)	(23)	(b)	(24)	(c)	(25)	(d)
(26)	(b)	(27)	(b)	(28)	(b)	(29)	(b)	(30)	(a)
(31)	(b)	(32)	(c)	(33)	(a)	(34)	(d)	(35)	(a)
(36)	(c)	(37)	(b)	(38)	(d)	(39)	(a)	(40)	(c)
(41)	(c)	(42)	(b)	(43)	(b)	(44)	(c)	(45)	(b)
(46)	(c)	(47)	(b)	(48)	(c)	(49)	(b)	(50)	(b)
(51)	(d)	(52)	(b)	(53)	(a)	(54)	(a)	(55)	(c)
(56)	(d)	(57)	(a)	(58)	(d)	(59)	(b)	(60)	(d)
(61)	(a)	(62)	(d)	(63)	(c)	(64)	(a)	(65)	(d)
(66)	(b)	(67)	(c)	(68)	(b)	(69)	(b)	(70)	(b)

SOLUTION

(5)

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$T^2 = 4\pi^2\frac{l}{g}$$

$$g = \frac{4\pi^2 l}{T^2}$$

$$g = \frac{4(3.14)^2(1)}{(1)^2}$$

$$g = 39.43$$

Now $T' = 2$ sec.

$$T' = 2\pi\sqrt{\frac{l'}{g}}$$

$$2 = 2\pi\sqrt{\frac{l'}{39.43}}$$

$$4 = 4\pi^2 \cdot \frac{l'}{39.43}$$

$$\frac{4(39.43)}{4\pi^2} = l'$$

$$\frac{39.43}{(3.14)^2} = l'$$

$$\frac{39.43}{9.859} = l'$$

$$3.99 = l'$$

$$l' = 4\text{ m}$$

(c) is correct

(10)

$$P.E = K.E = \frac{1}{2}m\omega^2x^2$$

$$T.E = \frac{1}{2}m\omega^2x_0^2$$

According to given condition:

$$P.E = \frac{1}{2}(\text{Total energy})$$

$$\frac{1}{2}m\omega^2x^2 = \frac{1}{2}\left[\frac{1}{2}m\omega^2x_0^2\right]$$

$$x^2 = \frac{x_0^2}{2}$$

$$x = \frac{x_0}{\sqrt{2}}$$

(c) is correct

(19)

$$\frac{1}{K_{eq}} = \frac{1}{K}+\frac{1}{K}+\frac{1}{K}$$

$$\frac{1}{K_{eq}} = \frac{1+1+1}{K}$$

$$\frac{1}{K_{eq}} = \frac{3}{K}$$

$$K_{eq} = \frac{K}{3}$$

(d) is correct

(22)

$$f = \frac{60}{30}$$

$$f = 2\text{ Hz}$$

(d) is correct

Chapter 8

WAVES

MCAT UNIT 5

KEY POINTS

Wave Motion:

(i) A wave motion is a kind of disturbance which is transferred from one part of the medium to the next due to the repeated periodic motion of medium particles about their mean position.

(ii) The disturbance travels through the medium with a certain definite velocity without any change in its form.

(iii) **Longitudinal waves:** A longitudinal wave is a wave in which the particles of the medium oscillate is simple harmonic fashion along the direction of propagation of the wave. The most common example of a longitudinal wave is a **sound wave**. Sound waves in gases and liquids are longitudinal waves. The propagation of compression and rarefaction in a long spring is also an example of a longitudinal wave.

(iv) **Transverse waves:** A transverse wave is a wave in which the particles of medium execute simple harmonic motion in a direction perpendicular to its direction of propagation. Waves of plucked strings, electromagnetic waves, light waves are the examples of transverse waves. **In solids, sound waves can be transverse or longitudinal. Transverse waves in a medium essentially require shear modulus.**

(v) **There are also some such waves in nature which are neither transverse nor longitudinal but a combination of both.** Such waves are known as ripples, for example, waves on the surface of a liquid.

(vi) **Only a transverse wave can be polarised but not a longitudinal one.** Hence, transverse or longitudinal nature of a wave can be decided on the basis of polarisation.

(vii) **Mechanical waves:**

(a) These waves require a material medium for their propagation.

(b) These waves transfer energy and momentum through the limited motion of the particles with the medium remaining at its own place.

(c) Force the propagation of mechanical waves it is essential that the medium must possess **elasticity, inertia and low resistance for motion.**

(d) Water waves, sound waves, waves in a spring or a stretched string are examples of mechanical waves.

(viii) **Non-mechanical waves:** These waves do not require any medium for their propagation. All electromagnetic waves such as light radiation, heat radiation, γ-rays, X-rays, microwaves and so on are non-mechanical.

(ix) **Mechanical waves can be either longitudinal or transverse.** Hence, if a wave is longitudinal, it is mechanical, but if a wave is mechanical it may or may not be longitudinal.

(x) **All non-mechanical waves are transverse in nature.** Hence, if a wave is non-mechanical, it is transverse, but if a wave is transverse, it may or may not be non-mechanical.

(xi) It is worth noting that **each kind of wave has two types of disturbances. Electromagnetic waves have electric and magnetic fields, sound waves have pressure variations and particle displacements, while stretched strings have particle displacements and variations of tension.**

Mechanical Waves in Different Media:

S. No.	Type of Media	Type of Mechanical Wave
1.	Strings	Mechanical waves are always transverse when the string is under a tension.
2.	Gases and liquids	Mechanical waves are always longitudinal as liquids and gases cannot sustain **shear**.
3.	Solids	Mechanical waves (may be sound waves) can be either transverse or longitudinal depending on the mode of excitation.
4.	Vibrating turning fork	Waves in the prongs are transverse while in the stem are longitudinal.
5.	Rocks during earthquake	S (shear) and P (pressure) waves are produced simultaneously which travel through the rock in the crust with different speeds [$v_s \simeq 5$ km/s while $v_p = 9$ km/s]. S-waves are transverse while P-waves are longitudinal.

Wave Characteristics:

(i) **Displacement and amplitude (A):**

(a) The instantaneous displacement of any particle of the medium, in which the wave is propagating, is the displacement of that particle from its equilibrium position.

(b) The amplitude of the waves is the maximum value of the displacement.

(c) Amplitude is a vector quantity.

(d) When two waves of different amplitudes A_1 and A_2 superimpose each other with a phase difference of ϕ, then the resultant amplitude $= \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos \phi}$.

(e) The maximum amplitude is $A_1 + A_2$, when $\phi = 0$ and minimum amplitude is $A_1 - A_2$, when $\phi = 180°$.

(ii) **Oscillation and time period (T):**

(a) Oscillation is defined as one complete to and fro motion of the vibrating particle.

(b) The time which a vibrating particle takes to complete its one oscillation is known as **time period** or the time after which a wave repeats itself is also called as **time period**.

(c) In case of a **transverse progressive wave**, the time taken by the **crest or trough** to change again into a crest or trough is known as time period.

(d) In case of a **longitudinal progressive wave**, the time taken by the **compression or rarefaction** to change again into compression or rarefaction is called as time period.

(iii) **Frequency (f):**

(a) It is defined as the number of oscillations made by a vibrating particle in one second.

(b) Frequency may also be defined as the number of waves crossing any point of the medium in one sec.

(c) The reciprocal of the time period is called as frequency.

(d) Frequency depends upon the source but not on the medium.

(e) Frequency does not change when a wave travels from one medium to other.

(iv) **Wavelength (λ):**

(a) The wavelength of a wave is the distance in the direction of propagation in which the wave repeats itself.

(b) It may also be defined as the distance travelled by a wave in the time the particle of the medium completes one oscillation.

(c) The distance between two consecutive points which are in the same state of vibration or phase (or differ in phase by 2π radian or T sec) is also defined as the wavelength.

(d) (I) **In case of transverse progressive waves:** λ = distance between two consecutive crests or troughs.

(II) **In case of longitudinal progressive waves:** λ = distance between two consecutive compression or rarefactions.

(e) Wavelength depends upon:

(I) **The nature of medium** (same source will produce waves of different wavelength in differ media).

(II) **The source producing the waves** (in a given medium sources of different frequencies will produce waves of different wavelengths).

Plane Progressive Wave and its Properties:

(i) A progressive wave is due to continuous periodic vibration of all the particles of the medium.

(ii) A progressive wave transfers energy from one part of space to the other.

(iii) In a progressive wave all the particles vibrate with the same amplitude and with same time period.

(iv) In a progressive wave every particle differs in phase from the neighbouring particle and the phase difference between two consecutive crests or troughs in the case of transverse waves is 2π rads or T.

(v) In a progressive wave all the particles pass through the equilibrium positions successively but with the same speed ($= A\omega$).

(vi) In a transverse progressive wave the distance between consecutive crests or troughs is equal to λ and in longitudinal progressive wave the distance between two consecutive compressions or rarefactions is equal to λ.

(vii) In a progressive wave, no particle is permanently at rest.

(viii) In a complete vibration at no instant all the particles will be in their mean position simultaneously in a progressive wave. At a particular instant, the particles of the medium fall on a sine curve.

(ix) In a progressive wave all the particles vibrate with same amplitude, same time period but every particle differs in phase from the neighbouring particle.

Audible, Infrasonic and Ultrasonic Waves:

(i) Mechanical waves can be transmitted in all the three states of matter, namely solids, liquids and gases.

(ii) **In liquids and gases**, these waves are always longitudinal waves.

(iii) **In solids**, these waves can be either transverse or longitudinal.

(iv) According to their frequencies, **longitudinal mechanical waves** are classified into three categories:

(a) **Audible or Sound Waves:**

(I) These are longitudinal mechanical waves.

(II) Their frequencies lie between 20 Hz and 20,000 Hz.

(III) These are generated by vibrating bodies such as vocal cords, stretched strings or membranes.

(IV) In air at NTP ($v = 330$ m/sec) their wavelength range is 16.5 m to 1.65 cm.

(b) **Infrasonic Waves:**

(I) These are also longitudinal mechanical waves.

(II) Their frequencies lie below 20 Hz.

(III) These waves are created by earthquakes (P-waves), volcanic eruption, ocean waves.

(c) **Ultrasonic Waves:**

(I) Longitudinal mechanical waves having frequency more than 20 kHz are known as ultrasonic waves.

(II) Human ear cannot detect these waves. Mosquitoes, fish, dogs and bats can detect these waves. Bats not only detect but also produce ultrasonics.

(III) These waves can be produced by the high frequency vibrations of a quartz crystal under an alternating electric field (Piezoelectric effect).

(IV) These waves can also be produced by the vibrations of a ferromagnetic rod under an alternating magnetic field (Magnetostriction effect).

(V) Ultrasonic waves are used for navigation under water (SONAR).

(VI) They are used in ultrasonography (in photographing or scanning soft tissues of body).

(VII) Ultrasonics are sued in bloodless surgery and wave therapy.

(VIII) These are also used to repel mosquitoes or attract fishes.

Periodic Waves: The waves which are produced due to continuous, regular and rhythmic disturbance of the source are called periodic waves.

Transverse Periodic Waves: In transverse waves, the particles of medium vibrate in a direction perpendicular to the direction of propagation of waves. e.g. water waves and waves in string or rope. The transverse wave consists of crests and troughs. The distance between any two consecutive crests or troughs is called wavelength.

Longitudinal Periodic Waves: In longitudinal waves, the particles of medium vibrate in the direction of propagation of waves. e.g. sound waves, waves in a spring. The longitudinal wave consists of compressions and rarefactions. The distance between any two consecutive compressions or rarefactions is called wavelength.

In Phase and Out of Phase Points: The points which have the same state of vibrations are called in phase point. The distance between any two consecutive in phase points is λ. The points which have exactly opposite state of vibrations are called out of phase points. The distance between any two consecutive out of phase points is $\lambda/2$.

Sound: The sensation of hearing produced by a vibrating body in the brain is called sound. Three factors are necessary for the production of sound waves.

- A vibrating body
- A material medium
- Receiver or ear

Speed of Sound in Air: The speed of sound in a medium depends upon the elasticity (E) of the medium and density (ρ) of the medium and is given by:

$$V = \sqrt{\frac{E}{\rho}}$$

Newton assumed that when sound waves travels through air, the temperature of the air remains constant. i.e., the sound travels through air under isothermal condition. Newton proves that for air $E_i = P$. Newton formula for the speed of sound in air is given by

$$V = \sqrt{P/\rho}$$

At S.T.P, the atmospheric pressure is $P = dgh$.

Where $h = 76$ cm of Hg

$g = 980\ cm/s^2$

$d = 13.6\ gm/cm^3$ = Density of mercury

Density of air $= \rho = 0.00129\ gm/cm^3$

Thus $V = \sqrt{P/\rho} = \sqrt{\frac{dgh}{\rho}} = 28100\ cm\ s^{-1}$ or $281\ m\ s^{-1}$

The experimental value of speed of sound in air at 0°C is $332\ ms^{-1}$. Thus, there is an error of 16% in Newton's value. Laplace corrected the newton formula. He suggested that the sound travels through air under adiabatic condition. According to Laplace, for air, $E_a = \gamma P$. Laplace formula for the speed of sound in air is given by:

$$V = \sqrt{\frac{\gamma P}{\rho}}$$

$$= \sqrt{\gamma} \times \sqrt{\frac{P}{\rho}}$$

Putting $\gamma = \frac{C_p}{C_v} = 1.41$ and $\sqrt{P/\rho} = 280$ m/s

$$V = \sqrt{1.41} \times 280$$

$$V = 333\ ms^{-1}$$

This value is very close to experimental value, so the Laplace correction is correct.

Velocity of Sound:

(i) Velocity of sound is the characteristic of the medium in which a wave propagates.

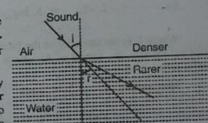
(ii) Velocity of sound in a medium is given by $v = \sqrt{(E/\rho)}$, where E is the modulus of elasticity and ρ is the density of the medium.

(iii) Velocity of sound is maximum in solids and minimum in gases since solids are most elastic and gases are least elastic.

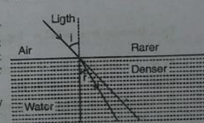
(iv) For examples, as $E_s > E_l > E_g$

So $v_{steel} > v_{water} > v_{air}$

(v) If we hear a distant momentary sound through a metallic pipe we will hear it twice, first in metal and then in air ($\because v_{steel} > v_{air}$) provided the time interval between two sounds is greater than (1/10) sec (persistence of ear).



(vi) (a) Velocity of sound in water (v_w) is more than the velocity of sound in air (v_a); thus **water is a rarer medium for sound waves**. When a beam of sound travels from air to water, it bends away from the normal since water is a rarer medium for sound waves.



(b) Velocity of light in water is less than the velocity of light in air; thus water is a **denser medium for light waves**. When a beam of light travels from air to water, it bends towards the normal since water is a denser medium for light.

(vii) In case of propagation of sound in solids (rods), elasticity involved is Young's modulus and velocity of sound is given by:

$$v_{solid} = \sqrt{\frac{Y}{\rho}}$$

Factors which Affect the Speed of Sound: The speed of sound is independent of pressure. At the same temperature and pressure, the velocity of sound is inversely proportional to the square root of density.

$$v \propto \frac{1}{\sqrt{\rho}}$$

The speed of sound in hydrogen is 4-times greater than the speed of sound in oxygen. The speed of sound is directly proportional to the square root of absolute temperature.

i.e., $v \ \alpha \ \sqrt{T}$

If v_0 and v_t are the speed of sound at absolute temperature T_o and T respectively, then

$$\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}}$$

If v_o is the speed of sound at 0°C, then speed of sound at temperature t°C is:

$$v_t = v_o + 0.61t$$

Intensity of Sound: Intensity of sound is the energy transmitted per second through a unit area placed perpendicular to the direction of sound waves.

i.e., $$\text{Intensity} = \frac{\text{Energy}}{\text{Time} \times \text{Area}}$$

The SI unit of intensity is $J\ s^{-1}\ m^{-2}$ or watt m^{-2}. (Because watt = $J\ s^{-1}$)

Loudness of Sound: Loudness of sound is the magnitude of auditory sensation produced by sound. Loudness depends upon the intensity of the sound as well as on the ear. Loudness of the sound is proportional to the logarithm of intensity (Weber-Fechner Law)

i.e., $$L \propto \log I \Rightarrow L = K \log I$$

Where K is constant of proportionality.

Intensity Level: It is the difference in the loudness of a sound (L) and the loudness of the faintest audible sound (L_o).

i.e., $$L - L_o = K \log_{10} \frac{I}{I_o}$$

Where I_o is the intensity of the faintest audible sound taken as $10^{-12}\ Wm^{-2}$. The unit of intensity level is called bel (b) after the named of Alexander Graham Bell. If the intensity of the sound is $10\ I_o$, then its intensity level is called 1 bel.

Now putting $L - L_o = 1$ bel and $I = 10\ I_o$, we have

$$1\ \text{bel} = K \log_{10} \frac{10I_o}{I_o} \Rightarrow K = 1\ \text{bel}$$

Thus, Intensity level in bel = $\log_{10} \frac{I}{I_o}$

As bel is a very large unit of intensity level, so a smaller unit called decibel (db) is used.

Where 1 bel = 10 db

The intensity level of the faintest audible sound is 1db and that for ordinary conversation is 60 db.

Unit of loudness is sone.

Where 1 sone = 40 db at 1000 Hz

The sone scale of loudness has been recognized internationally and being practiced.

Pitch: The pitch is the characteristic of a sound by which a shrill sound can be distinguished from a grave one. It is the sensation which depends on the frequency of the sound. The sounds of rats, cats and women are shrill and of higher pitch whereas the sounds of frogs, dogs and men are grave and of lower pitch.

Quality of Sound: It is a peculiar characteristic of the sound which enables us to recognize it and assign to its source. When a musical instrument is played, it produces not only the fundament tone but several overtones or harmonic are also produced. When two or more identical musical instruments are played simultaneously, they may have same fundamental but they differ in overtones. So their sounds can be recognized due to their quality.

Audible Frequency Range: An average human ear can hear a sound in the frequency range 20 Hz to 20,000 Hz. The sound waves with frequencies higher than 20,000 Hz are called ultrasonic and sound waves having frequencies lower than 20 Hz are called infrasonic. Both ultrasonics and infrasonics are not heard by human ears. The ear is most sensitive for the sound of frequency ranging between 2000 to 4000 Hz.

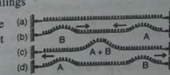
Acoustics: The application of the scientific study about the sound in designing a buildings, halls, concert rooms etc is called acoustics. If the buildings are not acoustically well-designed, one hear loud sound at some spots and very feeble at other spots. Such spots are respectively known as loud spots and dead spots. The factors which badly affect the acoustics of a big halls are:

- Resoundings or Echoes
- Reverberation of sound
- Focusing of sound

In a well-acoustically designed building, we should take the following steps:

- The distance between the walls should be less than 17 m to avoid echo.
- Cover walls and the ceilings with sound absorbing materials
- Avoid continuous flat and smooth walls
- Avoid in designing curved walls and spherical surface on the ceilings

Principle of Superposition: If n-waves passing through a medium give displacements $y_1, y_2, y_3, \ldots, y_n$ to a particle of the medium, then the net displacement 'y' of the particle is given by:



$$y = y_1 + y_2 + y_3 + \ldots\ldots + y_n$$

When two waves act upon a particle simultaneously, then three different phenomena are observed under different circumstances.

- Interference of waves
- Beats
- Stationary waves

Interference of Sound Waves: The increasing and canceling effect of two identical sound waves traveling through a medium is called interference. There are two types of interference.

- Constructive interference
- Destructive interference

Two identical sound waves reach at a point in phase, then they interfere constructively and loud sound is heard at that point. For constructive interference, the path difference between two waves should be integral multiple of λ.

i.e., $$\Delta S = n\lambda \quad \text{where} \quad n = 0, 1, 2, 3\ldots\ldots$$

When two identical sound waves reach at a point out of phase, they interfere destructively and no sound is heard at that point. For destructive interference, the path difference between two waves should be odd integral multiple of $\frac{\lambda}{2}$.

i.e., $$\Delta S = (2n+1)\frac{\lambda}{2} \quad \text{where} \quad n = 0, 1, 2, 3, \ldots\ldots$$

Beats: The periodic variation in the loudness of sound between maximum and minimum loudness are called beats. Beats are produced due to interference of two sound waves of slightly different frequencies. One rise and one fall in the loudness of sound makes one beat. If f_A and f_B are the frequencies of two tuning forks A and B, then the number of beats produced per second is given by $f_A - f_B = \pm n$. The number of beats produced per second is called beat frequency. It becomes difficult to recognize the beats, if difference between the frequencies of the two sounds is more then 10 Hz. Beats are used to:

- Find the unknown frequency of a body.
- To give variety in music.
- To tune a musical instrument at a particular frequency.

Some Important Points Concerning Beats:

(i) Phenomenon of beats is used by musicians in tuning their instruments. They sound their instruments along with a standard source and tune them till beats are no more heard. In this situation, frequency of the instrument becomes equal to that of standard source.

(ii) Phenomenon of beats can be used to determine the frequency of a tuning fork as follows:

(a) If a tuning fork of unknown (n_A) is sounded with a tuning fork of known frequency (n_B), then number of beats heard = $n_A \sim n_B$. If n is the beat frequency, then $n = n_A \sim n_B$ and frequency of the tuning fork $n_A = n_B \pm n$.

(b) Now the fork A is loaded with wax and sounded with the fork B; if the beat frequency decreases then $n_A > n_B$ otherwise $n_A < n_B$. If instead of loading the fork A with wax, fork A is filed and sounded with the fork B, then decrease in beat frequency implies $n_A < n_B$ and increase in beat frequency means $n_A > n_B$. Remember that loading a fork with wax decreases its frequency while filing a fork increases its frequency.

Reflection of Waves: When a wave moving in a medium strikes the boundary of another medium, a part of it reflected back in the same medium. The frequency and wavelength of reflected waves remain the same but the phase may change depending upon nature of boundary of medium. When a wave traveling through a rarer medium strikes the boundary of denser medium, it reflects back with a phase change of 180°. i.e., A crest on reflection becomes trough and vice versa. When a wave traveling through a denser medium strikes the boundary of rarer medium, it reflects back with no phase change. i.e., A crest after reflection remains crest and vice versa.

Stationary Waves: The stationary waves are formed, when two identical waves traveling in opposite direction in a medium meet each other. Stationary wave consists of nodes and antinodes. No energy is transferred from antinode to node in a stationary wave. At nodes, the strain is maximum and the amplitude is zero. But at antinodes, the strain is minimum and the amplitude is maximum. There is a node between two consecutive antinodes and an antinode between two consecutive nodes. Distance between two consecutive nodes or antinodes is $\frac{\lambda}{2}$. Distance between a node and the next antinode is $\frac{\lambda}{4}$. All particles except nodes perform SHM with the same time period.

Stationary Wave in a Stretched String: When a stretched string fixed at both ends is excited, and then the stationary waves of different modes are produced. If the string fixed at both ends vibrates into 'n' loops, then

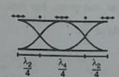
No. of nodes = N = n + 1

No. of antinodes = A = n

If the string fixed at one end only and the other end is free, then

No. of nodes = No. of antinodes

The fundament frequency is given by:

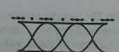


$$f_1 = \frac{v}{2l} = \frac{1}{2l}\sqrt{\frac{F}{m}}$$

Where l = Length of the string

F = Tension in the string

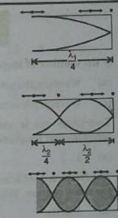
m = Mass per unit length of the string



The frequencies and wavelengths of other harmonics can be calculated by the following relations:

$$f_n = nf_1 \quad \text{and} \quad \lambda_n = \frac{2l}{n} \quad \text{where} \quad n = 1, 2, 3, \ldots$$

The stationary waves of discrete set of frequencies $f_1, f_2, f_3, \ldots, f_n$ can be set up in string. This fact is known as quantization of frequency.



Stationary Waves in Air Column: Stationary waves can be produced in air column such as in an organ pipe. The incident and reflected waves superpose to produce the stationary waves in the air column. If the pipe is open at both ends, then antinodes are formed at both ends. The frequency of any harmonic in an open pipe is given by

$$f_n = nf_1$$

Where $f_1 = \frac{v}{2l}$ = fundamental frequency and n = 1, 2, 3, ...

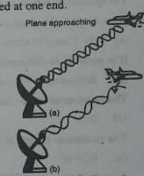
If pipe is closed at one end and open at the other end, then node is formed at closed end. The frequency of any harmonic in a closed pipe is:

$$f_n = nf_1$$

Where $f_1 = \frac{v}{4l}$ = Fundamental frequency

and n = 1, 3, 5, ... Odd No.

The pipe open at both ends is richer in harmonic than that of a pipe closed at one end.



Doppler Effect: If there is some relative motion between the source of sound and the observer, an apparent change in frequency (pitch) of waves is observed.

When an observer moves towards the stationary source with velocity u_o then the observed frequency of sound increases according to the relation.

$$f' = \frac{v+u_o}{v}f \text{ as } \frac{v+u_o}{v} > 1, \text{ so } f' > f$$

When an observer moves away from the stationary source with velocity u_o then the observed frequency of sound decreases according to the relation.

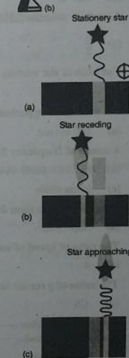
$$f' = \frac{v-u_o}{v}f \text{ as } \frac{v-u_o}{v} < 1, \text{ so } f' < f$$

If the source of sound moves towards the stationary observer with velocity u_s then the observed frequency of sound increases according to the relation.

$$f' = \frac{v}{v-u_s}f \text{ as } \frac{v}{v-u_s} > 1, \text{ so } f' > f$$

If the source of sound moves away from the stationary observer with velocity u_s then the observed frequency of sound decreases according to the relation

$$f' = \frac{v}{v+u_s}f \text{ as } \frac{v}{v+u_s} < 1, \text{ so } f' < f$$



Applications of Doppler Effect: Some most important applications of Doppler effect are:

- Radar.
- Echo-Ranging and Echo-Sounding system.
- Radar speed trap system.
- Determination the speed of satellites moving around the Earth.
- Determination the speeds of distant stars and galaxies in the space.
- Bats navigate and find food by echo location using the principle of Doppler Effect.

ASSIGNMENT NO. 8

(1) If the number of loops of a stationary waves are increasing then:
(a) Wavelengths gets higher (b) Wavelengths gets shorter
(c) Wavelength becomes constant (d) None of these

(2) Two pipes one is open and other is closed at one end are of same length then the ratio of their fundamental frequencies is:
(a) 1 : 2 (b) 2 : 1 (c) 1 : 1 (d) 1 : 4

(3) The frequency of a stretched wire 1000 mm long is 256 Hz. When the wire is shortened to 400 mm at the same tension. What is the fundamental frequency?
(a) 102 Hz (b) 640 Hz (c) 416 Hz (d) 162 Hz

(4) The quantities which together determine the speed of sound in a liquid are:
(a) the bulk Modulus and the density (b) the bulk Modulus and the pressure
(c) the Young Modulus and the volume (d) the Young Modulus and the density

(5) It is possible to distinguish between transverse and longitudinal waves from the property of:
(a) Refraction (b) Interference (c) Diffraction (d) Polarization

(6) The number of nodes between two consecutive antinodes is:
(a) Zero (b) 3 (c) 2 (d) 1

(7) The minimum length of a closed pipe which can resound with a note of wavelength 1 m is:
(a) 0.25 m (b) 0.5 m (c) 0.75 m (d) 1 m

(8) A particle executes S.H.M. with a period of 6 s and amplitude of 3 cm. Its maximum speed in cm/s is:
(a) $\frac{\pi}{2}$ (b) π (c) 2π (d) 3π

(9) The ratio of the velocity of sound in air at 4 atmosphere and that at 1 atmosphere pressure would be:
(a) 1 : 1 (b) 4 : 1 (c) 1 : 4 (d) 3 : 1

(10) If λ = 1 cm, time period = 0.02 seconds, then velocity of the wave will be:
(a) 100 cm sec^{-1} (b) 50 cm sec^{-1} (c) 0.6 m sec^{-1} (d) 20 cm sec^{-1}

(11) A sound of frequency 5 Hz:
(a) has very small wavelength (b) is very small
(c) is inaudible (d) is very loud

(12) Frequencies less than 20 hertz are called:
(a) Supersonics (b) Ultrasonics (c) Panasonics (d) Infrasonics

(13) The ratio of speed of sound in hydrogen to the speed of sound in oxygen is:
(a) 4 : 1 (b) 1 : 4 (c) 8 : 1 (d) 1 : 8

(14) The value of γ for air is:
(a) 1.6 (b) 2.6 (c) 1.4 (d) 2.4

(15) One degree Celsius ——— in temperature produces approximately 0.61 m/sec. ——— in the speed of sound.
(a) Fall, decrease (b) Rise, decrease (c) Fall, increase (d) None of them

(16) Two degree Celsius rise in temperature of the medium produces approximately increase in the speed of sound equal to:
(a) 0.61 cm/sec. (b) 0.61 m/sec. (c) 1.22 m/sec. (d) 0.61 mm/sec.

(17) Speed of sound in vacuum (in m/sec.) is:
(a) 330 (b) Zero (c) 156 (d) 1000

(18) Sound waves are:
(a) Stationary waves (b) Transverse waves (c) Longitudinal waves (d) None of these

(19) Speed of sound in air at room temperature (say 20°C) is nearly:
(a) 332 m sec^{-1} (b) 344 m sec^{-1} (c) 1087 m sec^{-1} (d) None of these

(20) It becomes difficult to recognise beats when the difference between the frequencies of two sounds is more than:
(a) 2 Hz (b) 5 Hz (c) 6 Hz (d) 10 Hz

(21) A tuning fork A of frequency 256 hertz produces 3 beats/sec. with another tuning fork B. The frequency of tuning fork B is:
(a) 256 (b) 253 (c) 256 ± 3 (d) 259

(22) In case of standing waves, as the string vibrates in more and more loops, its wavelength:
(a) Goes on increasing (b) Goes on decreasing (c) Remains constant (d) None of these

(23) In standing waves, if $\lambda = \frac{l}{2}$ in case of a string, then number of loops are:
(a) One (b) Two (c) Three (d) Four

(24) A 4 m long string fixed at its ends resonate in 4 segments. The wavelength of the wave is:
(a) 4 m (b) 2 m (c) 0.5 m (d) 0.25 m

(25) The wavelength of the fundamental mode of vibration of a closed end (one end closed) pipe is:
(a) $2l$ (b) l (c) $\frac{l}{2}$ (d) $4l$

(26) The ratio of the fundamental frequency of an open end and closed end organ pipes of the same length is:
(a) 2 : 1 (b) 1 : 2 (c) 1 : 1 (d) 4 : 1

(27) A train while whistling moves with a speed thrice the speed of sound away from a stationary listner. Then frequency of sound waves heard by the listner will become:
(a) 3 times (b) One-third (c) 4 times (d) One-fourth

(28) Two waves of the same frequency, travelling in the same medium but in opposite directions, if superposed give rise to:
(a) Resonance (b) Beats (c) Standing waves (d) Harmonics

(29) When two coherent waves interfere, there is:
(a) Loss in energy
(b) Gain in energy
(c) Redistribution of energy which changes with time
(d) Redistribution of energy which does not change with time

(30) **Energy is not carried by:**
(a) Transverse wave (b) Longitudinal wave (c) Stationary wave (d) Electromagnetic wave

(31) **In stationary waves:**
(a) Strain is maximum at antinodes (b) Strain is minimum at nodes
(c) Strain is maximum at node (d) Amplitude is same at all points

(32) **Two interfering waves have intensities in the ratio 9 : 1 then the ratio of maximum to minimum is:**
(a) 10 : 8 (b) 4 : 1 (c) 100 : 64 (d) 16 : 4

(33) **Phase difference between two particles of a medium lying between two consecutive nodes is:**
(a) Zero (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{2}$ (d) π

(34) **When stationary waves are produced in a medium, which physical characteristics change at antinodes?**
(a) Density only (b) Pressure only
(c) Density and pressure (d) Neither density nor pressure

(35) **Pitch is a sensation which depends upon:**
(a) Intensity (b) Amplitude (c) Velocity (d) Wavelength

(36) **If I be the intensity of sound, then loudness of sound wave is proportional to:**
(a) I (b) I^2 (c) $\sqrt{I}$ (d) log I

(37) **A set of tones whose frequencies are integral multiples of the fundamental frequency are called:**
(a) Overtones (b) Beat frequency
(c) Doppler frequencies (d) Harmonics

(38) **The law applicable for determining the apparent change in frequency when a source and an observer are in motion is:**
(a) Doppler's law (b) Huygens, law (c) Newton's law (d) Galileo's law

(39) **When the sound source is moving and the observer is stationary, then the cause of apparent change in frequency is:**
(a) Change in the velocity of sound wave relative to observer
(b) Change in the wavelength of the sound wave
(c) Change in the intensity of sound wave
(d) All of the above

(40) **A source is in motion towards a stationary observer. Frequency of sound heard by the observer will be: (Velocity of sound = v)**
(a) v (b) $\frac{v}{2}$ (c) 2v (d) $\frac{3v}{2}$

(41) **A couple of tuning forks produces two beats in the time internal of 0.4 second, so the beat frequency is:**
(a) 8 Hz (b) 5 Hz (c) 2 Hz (d) 6 Hz

(42) **A sound source is approaching a stationary observer with a constant velocity continuously emitting a note of frequency n. Then the apparent frequency of waves:**
(a) Increases (b) Decreases continuously
(c) Remains constant (d) Noting can be predicted

(43) **A whistle giving out 450 Hz approaches a stationary observer at a speed of 33 m/s. The frequency heard by the observer in Hz is:**
(a) 409 (b) 429 (c) 517 (d) 500

(44) **An air box attached to a musical instrument increases the:**
(a) Pitch of the sound (b) Intensity of the sound
(c) Quality of the sound (d) Shrillness of the sound

(45) **If a star is moving towards the earth, then the lines are shifted towards:**
(a) Red (b) Infrared (c) Blue (d) Green

(46) **Which of the following media can transmit both transverse and longitudinal waves:**
(a) Solid (b) Liquid (c) Gas (d) Plasma

(47) **Of the following properties of a wave, the one that is independent of the other is its:**
(a) Amplitude (b) Wavelength (c) Frequency (d) Time period

(48) **The linear distance between two nearest points of a medium vibrating in phase is:**
(a) $\frac{\lambda}{2}$ (b) $\frac{\lambda}{4}$ (c) λ (d) 2λ

(49) **Newton assumed that the passage of sound through air is a/an:**
(a) Iisobaric process (b) Isothermal process (c) Isochoric process (d) Adiabatic process

(50) **Which one of the following property of sound is affected by change in air temperature?**
(a) Frequency (b) Amplitude (c) Intensity (d) Wave-length

(51) **The speed of sound with the increase in pressure:**
(a) Increases
(b) Decreases
(c) Remains unchanged
(d) May increase or decrease depending upon the density of air

(52) **The velocity of sound is inversely proportional to the:**
(a) Temperature of air (b) Square root of density (c) Pressure of air (d) Reciprocal of density

(53) **Increase in velocity of sound in air for 1°C rise in temperature is:**
(a) $1.61\ ms^{-1}$ (b) $61.0\ ms^{-1}$ (c) $0.61\ ms^{-1}$ (d) $16\ ms^{-1}$

(54) **Two waves interfere constructively, if the path difference between them is:**
(a) $(2n + 1)\lambda$ (b) $\frac{n\lambda}{2}$ (c) $\frac{(2n+1)\lambda}{2}$ (d) $(2n)\frac{\lambda}{2}$

(55) **When a wave traveling through a rarer medium strikes the boundary of denser medium, it reflects back with:**
(a) No phase change (b) A phase change of 90°
(c) A phase change of 120° (d) A phase change of 180°

(56) **When the amplitude of a wave becomes double, its energy becomes:**
(a) Double (b) Four times (c) One half (d) Nine times

(57) **When the prongs of tuning fork is struck against some object, both prongs vibrate:**

(a) with a phase difference of π (b) with a phase difference of 2π
(c) with a phase difference of $\pi / 2$ (d) in the same phase

(58) **A pulse on the string is inverted when it is reflected from:**

(a) A free end (b) Fixed end (c) Either of the two (d) Rubber cord

(59) **If stretching force in the wire is increased by four times, then its frequency:**

(a) Decreases by two times (b) Increases by two times
(c) Remains the same (d) Increases by four times

(60) **At the closed end of an air column node occurs:**

(a) Never (b) Always (c) In certain cases (d) At higher temperature

(61) **The speed radar system is used to determine the:**

(a) Speed and elevation of aeroplane (b) Speeds of distant stars and galaxies
(c) The speed of moving object (d) All of the above

(62) **When the source of sound and the observer move with same speed in the same direction, then there is:**

(a) An apparent increase in frequency (b) An apparent decrease in frequency
(c) An apparent decrease in loudness (d) No apparent change in frequency

(63) **A closed pipe is excited to support the third overtone. It is found that air in the pipe has:**

(a) Three nodes and three antinodes (b) Three nodes and four antinodes
(c) Four nodes and three antinodes (d) Four nodes and four antinodes

(64) **Decibel is the unit of:**

(a) Absorbed dose (b) Absorption power (c) Intensity level (d) Intensity of light

(65) **If water is disturbed in a ripple tank periodically, waves one after the other passing through a point are known as:**

(a) Matter waves (b) Longitudinal waves
(c) Transverse period waves (d) Mechanical waves

(66) **When two identical travelling waves are superposed, the velocity of the resultant waves:**

(a) Decreases (b) Increases (c) Remains unchanged (d) Becomes zero

(67) **The velocity of sound in air would become double than its velocity at 20°C at:**

(a) 313 K (b) 586 K (c) 899 K (d) 1172 K

(68) **The unit of intensity level is:**

(a) Watt (b) Joule (c) Bel (d) Sabin

(69) **Silence Zone takes place due to:**

(a) Constructive interference (b) Destructive interference
(c) Beats (d) Resonance

(70) **Harmonics (or overtones) produced in an organ pipe closed at one end are given by:**

(a) $f_n = n(v/2l)$ (b) $f_n = n(v/4l)$ (c) $f_n = n(4l/v)$ (d) $f_n = n(2l/v)$

ANSWERS

(1)	(b)	(2)	(b)	(3)	(b)	(4)	(a)	(5)	(d)
(6)	(d)	(7)	(c)	(8)	(c)	(9)	(a)	(10)	(b)
(11)	(c)	(12)	(d)	(13)	(a)	(14)	(c)	(15)	(a)
(16)	(c)	(17)	(b)	(18)	(c)	(19)	(b)	(20)	(d)
(21)	(c)	(22)	(b)	(23)	(d)	(24)	(b)	(25)	(d)
(26)	(a)	(27)	(d)	(28)	(c)	(29)	(d)	(30)	(c)
(31)	(c)	(32)	(b)	(33)	(d)	(34)	(b)	(35)	(c)
(36)	(d)	(37)	(d)	(38)	(a)	(39)	(b)	(40)	(b)
(41)	(b)	(42)	(c)	(43)	(d)	(44)	(b)	(45)	(c)
(46)	(a)	(47)	(a)	(48)	(c)	(49)	(b)	(50)	(d)
(51)	(c)	(52)	(b)	(53)	(c)	(54)	(d)	(55)	(d)
(56)	(b)	(57)	(a)	(58)	(b)	(59)	(b)	(60)	(b)
(61)	(c)	(62)	(d)	(63)	(a)	(64)	(c)	(65)	(c)
(66)	(c)	(67)	(d)	(68)	(c)	(69)	(b)	(70)	(b)

SOLUTION

(4) As the formula for speed of sound is:

$$V = \sqrt{\frac{E}{\rho}}$$

Here for liquid E is bulk modulus ρ is density.

(a) is correct

(8)
$$V_0 = x_0\omega \qquad \omega = 2\pi f$$
$$V_0 = 3\left(\frac{2\pi}{6}\right) \qquad \omega = \frac{2\pi}{T}$$
$$V_0 = \pi$$

(b) is correct

(27)
$$U_s = 3V$$
$$f' = f\left(\frac{V}{V+U_s}\right)$$
$$f' = f\left(\frac{V}{V+3V}\right)$$
$$\Rightarrow f' = f\left(\frac{V}{4V}\right)$$
$$f' = \frac{1}{4}f$$

(d) is correct

(32) Amplitude ratio
$$= r = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{9}{1}} = 3$$
$$\frac{I_{max}}{I_{min}} = \left(\frac{3+1}{3-1}\right)^2 = 4$$

(b) is correct

(56) Because energy of wave is directly proportional to square of amplitude.

(b) is correct

(67)
$$\frac{V_T}{V_0} = \sqrt{\frac{T}{20+273}}$$
$$2 = \sqrt{\frac{T}{293}}$$
$$\Rightarrow T = 4 \times 293 \text{ K}$$
$$T = 1172 \text{ K}$$

(d) is correct

Chapter 9

PHYSICAL OPTICS/LIGHT

MCAT UNIT 4

KEY POINTS

Laws of Reflection:

(i) The angle of incidence ($\angle i$) is equal to the angle of reflection ($\angle r$), i.e., $\angle i = \angle r$.

(ii) The incident ray, the reflected ray and the normal all lie in the same plane.

Real and Virtual Images:

(i) A real image is one through which the rays of light actually pass and which can be formed on a screen.

(ii) The virtual image is one through which the rays do not actually pass, although they appear to come from it.

Newton's Corpuscular Theory of Light:

(i) A luminous source of light emits a stream of extremely small, very light weighed material particles in quick succession in all directions. These particles are called as **corpuscles**.

(ii) The corpuscles travel with velocity of light.

(iii) When these corpuscles fall on our retina, they produce sensation of vision.

(iv) Corpuscles of different colours possess different sizes.

(v) Corpuscular theory successfully explains the phenomena like reflection, refraction, rectilinear propagation of light, etc., but fails to explain the phenomena of interference, diffraction and polarisation of light.

(vi) This theory failed due to the following reasons:

(a) The corpuscular theory predict higher velocity of light in denser medium like water as compared to that in a rarer medium as vacuum.

(b) According to this theory, velocity of corpuscles and hence velocity of light increases with rise in temperature. But, in practice, velocity of light is independent of temperature.

(c) With the emission of corpuscles, the mass of the source of light should decrease but in practice no such change in mass is detected.

Wavefront:

(i) The locus of all particles vibrating in the same phase is called a **wavefront**.

(ii) For a point source of light, the wavefront is spherical in shape with source lying at its centre. When the source of light is linear, then the wavefront takes the cylindrical shape.

(iii) If a point or linear source is placed at infinity then the portion of spherical or cylindrical wavefront takes the cylindrical shape.

(iv) If a point or linear source is placed at infinity then the portion of spherical or cylindrical wavefront in limited or small region, is simply a plane and is called a plane wavefront.

Huygen's Wave Theory:

(i) Every point on the luminous source of light is a centre of disturbance and gives out waves in all directions. These waves set either particles into vibrations. The continuous locus of all either particles vibrating in the same phase is called a wavefront.

(ii) **Huygen's principle** provides a geometrical method of finding the successive positions of the wavefront as follows:

(a) Every point on the wavefront is a centre of new disturbance giving out secondary wavelets. These secondary wavelets travel out in all directions with the same speed as that of light.

(b) The envelope of these wavelets in the forward direction gives the position of the new wavefront at any subsequent time.

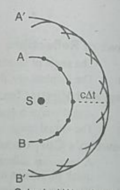
c) A ray of light is the direction along which light energy travels. It is impossible to separate a ray of light on account of diffraction of light. Though it is usual to represent a ray by a straight line but the ray has a finite width although a straight line has no width.

Physical Optics: The branch of physics which deals with the nature and properties of light is called physical optics. Light is form of energy which produces sensation of vision. There are five important theories about the nature of light.

- Newton's corpuscular theory of light.
- Huygen's wave theory of light.
- Maxwell's electromagnetic theory of light.
- Plank's quantum theory of light.
- Dual nature of light.

Huygen's Principle: This principle consists of two parts:

- Every point of a wave front may be considered as a source of secondary wave lets which spread out in forward direction with a speed equal to the speed of propagation of wave.
- The new position of the wave front after a certain interval of time can be found by constructing a surface that touches all the secondary wave lets.



Spherical Wavefront

Coherent Sources: The monochromatic sources of light which produce waves of same wavelength and same frequency that either have no phase difference or constant phase difference are known as coherent sources.

Conditions for Detectable Interference: In order to observe the interference of light.

- The light waves should be monochromatic (i.e., of single wave length)
- The light waves should be coherent

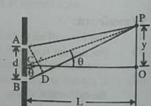
Interference of Light Waves: The increasing and canceling effect of light waves is called interference of light waves. When two light waves reach at a point in phase, they reinforce each other effects and a bright fringe is formed at this point. This type of interference is known as constructive interference. For constructive interference, the path difference between the two waves is an integral multiple of wavelength.

Path difference $= m\lambda$ Where $m = 0, 1, 2, 3, ...$

When two waves reach at a point out of phase, they cancel each other effect and a dark fringe is formed at this point. This type of interference is known destructive interference. For destructive interference, the path difference between the two waves is an odd multiple of $\frac{\lambda}{2}$.

Path difference $= (2m+1)\frac{\lambda}{2}$ Where $m = 0, 1, 2, 3, ...$

Young's Double Slits Experiment: In 1801, a British physicist Thomas young performed an experiment to study the interference of light. The experimental arrangement of Young's experiment is shown in figure. The path difference between the rays AP and BP reaching at P on the screen is



Path difference $= BP - AP = BD = d\sin\theta$

If a bright fringe is formed at point P then:

Path difference $= d\sin\theta = m\lambda$ Where $m = 0, 1, 2, 3, ...$

If a dark fringe is formed at point P, then:

Path difference $= d\sin\theta = (m+\frac{1}{2})\lambda$ Where $m = 0, 1, 2, 3, ...$

The position of m^{th} bright fringe from the center O is given by:

$$Y_m = m\frac{\lambda L}{d}$$

The position of m^{th} dark fringe from the center O is given by:

$$Y_m = (m+\frac{1}{2})\frac{\lambda L}{d}$$

The distance between two consecutive bright fringes or dark fringes is called fringe spacing. The width of bright and dark fringes are equal and is given by:

$$\text{Fringe spacing} = \Delta Y = \frac{\lambda L}{d}$$

θ°	sin θ	tan θ
2	0.035	0.035
4	0.070	0.070
6	0.104	0.105
8	0.139	0.140
10	0.174	0.176

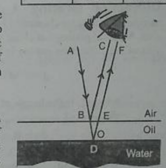
Interference in Thin Films: A thin film is a layer of transparent medium whose thickness is comparable with the wavelength of light. e.g.,

A thin layer of oil film on the surface of water.

- Surface of soap bubble
- Cracks on the glass

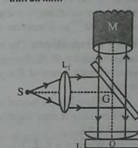
When light is incident on a thin film, it is partly reflected from the upper surface of the film and partly from its bottom surface. These two superpose each other and produces the interference. In case of monochromatic light, the interference pattern consists of bright and dark fringes. In case of white light, the interference pattern consists of colour fringes. The path difference depends upon two factors

- Thickness & nature of the film
- Angle of the incidence

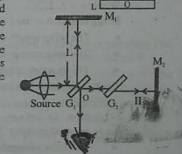


Geometrical construction of interference of light due to a thin oil film.

Newton's Ring: If a plano convex lens of long focal length is placed on a glass plate, a thin circular air film is produced between them. The thickness of the air film is almost zero at the point of contact and gradually increases as we move towards the periphery of the lens. When this circular thin film is illuminated by a monochromatic light falling normally on the plane surface of the lens, circular dark and bright fringes formed due to interference of light. At the point of contact, the thickness of the air film is zero but due to reflection at the lower surface of air film from denser medium, an additional path difference of $\frac{\lambda}{2}$ is produced. So as a result of destructive interference, the centre of the rings appears dark. In case of transmitted light, the central spot appears bright because of zero path difference.



Michelson Interferometer: It is an optical instrument which is used to study the interference of light". Albert A. Michelson devised this instrument in 1881using the idea of interference of light rays. A beam of light from the monochromatic source of light S is incident on the half silvered glass plate G_1. This plate G_1 partially reflects it towards the mirror M_1 and partially transmitted it towards mirror M_2. Another glass plate G_2 called compensator, cut from the piece of same of glass as G_1 is placed parallel to the plate G_1 to equalize the path length of two beams I and II. When the beams I and II arrive at the observer's eye, they interfere and produce the parallel interference fringes which can be seen by a telescope. If m are number of fringes shifted when the mirror M_1 is moved a distance L. Then we can write:



$$L = \frac{m\lambda}{2}$$

Uses:

- It can be used to measure the wavelength of light.
- It can be used to measure distance with extremly high precision.
- It is used to study the interference of light.

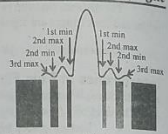
Importance: Michelson measured the length of standard meter in terms of the wavelength of red cadmium light and showed that the standard meter was equivalent to 1,553,163.5 wavelength of this light.

Diffraction of Light: The property of bending of light around the obstacles and spreading of the light waves into geometrical shadow of an obstacle is called diffraction of light. The diffraction is found to be prominent when wavelength of light is large as compared to the size of the obstacles or the aperture of the slit. Diffraction of light occurs due to interference of the rays coming from the different parts of the same wavefront.

Di... action Due to Narrow Slit: A narrow slit produces a series of bright and dark regions with the first bright region at the centre of the pattren. The condition for different orders of maxima and minima an either side of centre are given by

$$d \sin\theta = m\lambda \qquad \text{Where } m = 1, 2, 3, \ldots$$

The region between any two consective minima will be bright and vice versa.



Diffraction Grating: A diffraction grating is a glass plate having a large number of close parallel equidistance slits mechanically ruled on it. The transparent spacing between the scratches on the glass plate act as slits. Atypical grating has about 400 to5000 lines per centimeter. The distance between the centers of two adjacent slits of the diffraction grating is known as its grating element. It is given by

$$d = \frac{L}{N}$$

Where L is the length of grating on which N lines are ruled.

The grating equation in general can be written as:

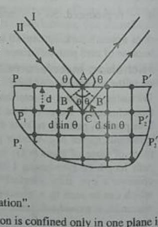
$$d \sin\theta = n\lambda$$

Where $n = 0, 1, 2, 3, \ldots$ etc., is the order of diffraction.

If white light is used, the diffraction grating produces different colour lines on both sides of the central maxima.

Diffraction of X-rays by Crystal: In order to observe the effects of the diffraction, the grating spacing must be of the order of wave length of light used. Ordinary grating can not be used to diffract the X-rays. The regular array of atoms in a crystal forms a natural diffraction grating with spacing of the order of wavelength of X-rays i.e. 10^{-10} m. Therefore the crystal can be used to diffract the X-rays.

Bragg's Equation: The study of the crystal structure by X-rays diffraction was initiated by W.H. Bragg and W. L. Bragg in 1914. They found that the monochromatic beam of X-rays was reflected from a crystal planes as if it acted like mirror.



When X-rays beams are diffracted from the crystal, the detector detects the beams only if they interfere constructively. The Bragg equation is given by $2d \sin\theta = n\lambda$.

Where $n = 1, 2, 3, \ldots$ and is called order of reflection.

Bragg equation is used to find out:

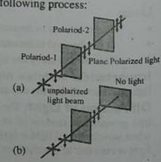
- The wave length of X-rays.
- The inter atomic spacing of the crystal.
- The structure of hemoglobin and doubles helix structure of DNA.

Bragg's equation has lead to a new branch of physics called "Crystallization".

Polarization: The process of obtaining the light in which the electric vibration is confined only in one plane is called polarization. An ordinary incandescent bulb emits un-polarized light, as does the sun because its vibrations are randomly oriented in space. The un-polarized beam can be polarized by the following process:

- Selective absorption
- Reflection from different surfaces
- Refraction through crystals
- Scattering by small particles

The un-polaroid light can be polarized light by using certain types of materials called dichroic substances or tourmaline crystal. These materials transmit only those waves, whose vibrations are parallel to a particular direction and will absorb those waves whose vibrations are in other directions. One such commercial polarizing material is "Polaroid". The phenomenon of polarization proves that light is transverse waves. Sunlight also becomes partially polarized because of scattering by air molecules or water vapors in the atmosphere.



Uses of Polarization: The polaroid is used:

- To determine the concentration of an optically active substance such as sugar and tartaric acid in the solution.
- In curtainless window to adjust the amount of light into the room.
- In the headlight of vehicles to control the glare in night driving.
- The polaroid sunglasses reduce the glare produced by the reflection of light from water, glass, snow and rough road surfaces.

Polarisation of Light:

(i) The ordinary light also called as unpolarised light consists of a very large number of vibrations in all planes with equal probability at right angles to the direction of propagation, i.e., **unpolarised light is symmetrical about the direction of propagation.**

(ii) The light which has acquired the property of one-sideness is called **polarised light** of **lack of symmetry of vibration around the direction of wave propagation is called polarisation.**

(iii) Polarisation of light waves shows that they are **transverse waves.**

(iv) When the vibrations are confined only to a single direction in a plane perpendicular to the direction of propagation, it is called a **plane polarised light.**

(v) A plane passing through the direction of propagation and perpendicular to the plane of vibration is called as **plane of polarisation.**

(vi) To obtain the stationary interference pattern, the **following conditions** must be fulfilled:

(a) The two sources should be **coherent**, i.e., they should vibrate in the same phase or there should be a constant phase difference between them.

(b) The two sources must emit continuously waves of same wavelength and frequency.

(c) The separation between two coherent sources should be small.

(d) The distance of the screen from the two sources should be large.

(e) **For good contrast between maxima and minima**, the amplitudes of the two interfering waves should be as nearly equal as possible and the background should be dark.

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{n_2}{n_1} = {}^1n_2$$

where ${}^1n_2$ is called the refractive index of medium 2 with respect to medium 1.

(vii) If the medium 1 is vacuum, then $v_1 = c$ and the index of refraction of the medium w.r.t. the vacuum is:

$$n = c/v$$

It is also called absolute refractive index.

(viii) **The frequency of a light wave remains unchanged as it passes across the boundary separating two mediums**, because there are the same number of wavefronts passing from medium 1 into medium 2.

(ix) Because the speed of light is different in different mediums and frequency remains unchanged on passing from one medium to other, hence wavelength of light gets changed with change in medium. The relation is:

$$\lambda_{medium} = \frac{\lambda_{air}}{n}$$

Thus, **when a light ray from a rarer medium is refracted into a denser medium, its velocity decreases and wavelength decreases but the frequency does not change.**

Real and Apparent Depth:

(i) When one looks into a pool of water, it does not appear to be as deep as it really is. Also when one looks into a slab of glass, the material does not appear to be as thick as it really is. This all happens due to refraction of light.

(ii) If a breaker is filled with water and a point lying at its bottom is observed by someone located in air, then the bottom point appears raised. The apparent depth t_{ap} is less than the actual depth t_{ac}. It can be shown that

$$\text{Apparent depth} = \frac{\text{Actual depth}}{\text{Refractive index (n)}}$$

ASSIGNMENT NO. 9

(1) Michelson interferometer was devised in:
(a) 1987 (b) 1881 (c) 1687 (d) 1789

(2) When one mirror of a Michelson interferometer is move a distance of 0.5 mm, 2000 fringes are observed, the wavelength of light used is:
(a) 2000 A° (b) 1000 cm (c) 5000 A° (d) None of these

(3) A diffraction grating has 500 lines per mm. Its grating element will be:
(a) 500 mm (b) 5×10^{-3} mm (c) 2×10^{-3} mm (d) 5×10^{3} mm

(4) The formula for grating element is:
(a) $d = LN$ (b) $d = \frac{L}{N}$ (c) $d = \frac{N}{L}$ (d) $d = L + N$

(5) In Young's double slit experiment, if the distance between the slits is doubled and distance between the slits and the screen is halved, the fringe width or spacing is:
(a) Half (b) Double (c) Four times (d) One fourth

(6) The wavelength of X-rays is of the order of:
(a) 10 A° (b) 1000 A° (c) 1 A° (d) 100 A°

(7) If 5000 lines per cm are ruled on a diffraction grating, then the slit spacing will be:
(a) 5×10^{-3} A° (b) 0.02 m (c) 2×10^{-4} A° (d) 2×10^{4} A°

(8) Which one of the following cannot be polarized?
(a) Radio waves (b) Ultraviolet rays (c) X-rays (d) Sound waves

(9) The ratio of fringe width for bright and dark fringes is:
(a) 1 : 2 (b) 2 : 1 (c) 1 : 4 (d) 1 : 1

(10) Ratio of intensities of two waves are 4 : 1 then ratio of amplitude of two waves is:
(a) 2 : 1 (b) 1 : 2 (c) 4 : 1 (d) 1 : 4

(11) The index of refraction of diamond is 2.0 velocity of light in diamond in m/sec. is:
(a) 6×10^{8} (b) 3×10^{8} (c) 2×10^{8} (d) 1.5×10^{8}

(12) Wavelength of red colour as compared to that of violet colour is:
(a) Smaller (b) Longer (c) Equal (d) None of these

(13) Angle between ray of light and the corresponding wavefront is:
(a) 0° (b) 60° (c) 90° (d) 120°

(14) If $\lambda = 400$ nm, its value in angstrom unit ($= 10^{10}$ m) is given as:
(a) 4×10^{3} (b) 4×10^{-17} (c) 4×10^{17} (d) 4×10^{-3}

(15) In case of YDS experiment, the distance between adjacent bright fringes is given by:
(a) $\Delta y = \frac{\lambda L}{d}$ (b) $\Delta y = \frac{L}{\lambda d}$ (c) $\Delta y = \frac{d}{\lambda L}$ (d) None of these

(16) The fringe width in YDS experiment can be increased by decreasing:
(a) Width of slits (b) Wavelength of light
(c) Slits separation (d) Distance between slits and screen

(17) If the slits in YDS experiment are made closer, fringe spacing will:
(a) Increase (b) Decrease (c) Remain same (d) None of above

(18) One of the following options represent the conditions for destructive interference:
(a) Path difference $= \frac{\lambda}{2}$ (b) P.D. $= 2\frac{\lambda}{2}$ (c) P.D. $= 3\frac{\lambda}{2}$ (d) Both (a) and (c)

(19) In Michelson's interferometer apparatus, the number of mirrors and number of glass plates used respectively are:
(a) 2, 3 (b) 3, 2 (c) 3, 3 (d) 2, 2

(20) In Michelson's interferometer, a bright fringe will be replaced by next bright fringe if we move the movable mirror by an amount equal to:
(a) λ (b) $\frac{\lambda}{2}$ (c) $\frac{\lambda}{4}$ (d) None of these

(21) Wavelength of light can be found by means of Michelson interferometer using the formula:
(a) $\lambda = \frac{2m}{L}$ (b) $\lambda = \frac{L}{2m}$ (c) $\lambda = \frac{m}{2L}$ (d) $\lambda = \frac{2L}{m}$

(22) In Michelson's interferometer, if the movable mirror is moved a distance of $\frac{\lambda}{4}$, the path difference between the two interfering waves changes by:
(a) $\frac{\lambda}{4}$ (b) $\frac{\lambda}{2}$ (c) λ (d) $\frac{3\lambda}{2}$

(23) If N is number of lines per meter in a diffraction grating of length L, then its grating element will be given as:
(a) $\frac{N}{L}$ (b) $\frac{L}{N}$ (c) $\frac{L}{2N}$ (d) $\frac{2N}{L}$

(24) Light reaches the earth from sun in nearly:
(a) Plane wave front (b) Cylindrical wave front
(c) Spherical wave front (d) All of these

(25) The concept of secondary wavelets from all points on a wavefront was first proposed by:
(a) Newton (b) Huygen (c) Faraday (d) Raman

(26) Light waves coming from two closely spaced pinholes placed in front of a laser light source are:
(a) Coherent (b) Incoherent
(c) Neither coherent nor incoherent (d) Nothing can be predicted

(27) Yellow light emitted by sodium lamp in Young's double slit experiment is replaced by monochromatic blue light of the same intensity:
(a) Fringe width will decrease (b) Fringe width will increase
(c) Fringe width will remain unchanged (d) Fringes will become less intense

(28) In an interference experiment monochromatic light is replaced by white light; we will see:
(a) Uniform illumination on the screen (b) Uniform darkness on the screen
(c) Equally spaced white and dark bands (d) A few coloured bands & then uniform illumination

(29) Two light waves are coherent if they are obtained from a single monochromatic source by:
(a) Division of amplitude only (b) Division of wavefront only
(c) Both of the above (d) None of the above

(30) **Light appears to travel in a straight line because:**
(a) its velocity is very large (b) it is not absorbed by the surroundings
(c) its wavelength is very small (d) it is reflected by the surroundings

(31) **The path difference between two interfering waves at a point on a screen is 11.5 times the wavelength. The point is:**
(a) Dark (b) Bright
(c) Neither bright nor dark (d) Data is inadequate

(32) **The fringe width in Young's double slit experiment increases when:**
(a) Wavelength increases (b) Distance between source and screen decreases
(c) Distance between slits increases (d) the width of the slits increases

(33) **If Young's double slit experiment is immersed in water then the fringe width:**
(a) Decreases (b) Increases
(c) Remains unchanged (d) becomes infinite

(34) **Light travels faster in air than in glass according to:**
(a) Wave theory of light (b) Corpuscular theory of light
(c) Both (a) and (b) (d) Neither (a) nor (b)

(35) **Which one of the following does not explain the wave nature of light?**
(a) Photoelectric effect (b) Interference (c) Diffraction (d) Polarization

(36) **The phenomenon of diffraction can be exhibited by:**
(a) Infrared waves (b) Microwaves (c) X-rays (d) All of these

(37) **A diffraction pattern is obtained using a beam of red light. What happens if the red light is replaced by blue light?**
(a) No change
(b) Diffraction bands become narrower and crowded together
(c) Bands become broader and farther apart
(d) Bands disappear

(38) **The fact that light is transverse wave phenomenon derives its evidential support from the observation that:**
(a) Light is a wave motion (b) Light is characterized by interference
(c) Light shows polarizing effects (d) Light can be diffracted

(39) **The phenomenon which does not take place in sound waves is:**
(a) Scattering (b) Diffraction (c) Interference (d) Polarization

(40) **If light is polarized by reflection, then the angle between reflected and refracted light is:**
(a) π (b) $\frac{\pi}{2}$ (c) 2π (d) $\frac{\pi}{4}$

(41) **Which of these waves can be polarized?**
(a) Sound waves (b) Longitudinal waves on a string
(c) Transverse waves on a string (d) Light waves

(42) **The phenomenon of rotation of plane of plane polarized light is called:**
(a) Double refraction (b) Kerr effect (c) Dichroism (d) Optical activity

(43) **The wave nature of light was proposed by:**
(a) Einstein (b) Maxwell (c) Huygen (d) Newton

(44) **As a plane wavefront propagates, its radius of curvature:**
(a) Increases (b) Decreases
(c) Remains infinity (d) First increases then decreases

(45) **Two narrow sources of light are said to be coherent if they emit waves having:**
(a) The same wavelength (b) The same amplitude
(c) A constant phase relation between them (d) All of these

(46) **In Young's double slit experiment, the condition for constructive interference is:**
(a) $d \sin\theta = m\lambda$ (b) $d \sin\theta = (m + 1/2)\lambda$
(c) $d \sin\theta = (m - 1/2)\lambda$ (d) $2d \sin\theta = m\lambda$

(47) **Two sodium lamps are used to produce sustained interference. Tick the correct statement:**
(a) They can produce (b) They can not produce
(c) They can produce if the intensity of light is low (d) They can produce if the intensity of light is high

(48) **In Young's double slit experiment, the fringe width is:**
(a) Proportional to the wavelength (b) Proportional to the width of slits
(c) Inversely proportional to the wavelength (d) Proportional to the square of wavelength

(49) **The path difference corresponding to a phase difference π is:**
(a) λ (b) $\lambda/2$ (c) $\lambda/4$ (d) 3λ

(50) **The speed of light in air is 3×10^8 m/s. What will be its speed in diamond whose refractive index is 2.4?**
(a) 3×10^8 m/s (b) 3.2×10^8 m/s (c) 1.25×10^8 m/s (d) 7.2×10^8 m/s

(51) **The tip of a needle does not give a sharp image. It is due to:**
(a) Interference (b) Diffraction (c) Polarization (d) Refraction

(52) **In Young's double slit experiment the separation between the slits is halved and the distance between the slits and screen is doubled. The fringe width is:**
(a) Unchanged (b) Halved (c) Doubled (d) Quadrupled

(53) **The theory associated with secondary wavelet is:**
(a) Doppler's effect (b) Relativity theory (c) Huygen's theory (d) None of these

(54) **A polariser is used to:**
(a) Reduce intensity of light (b) Produce polarised light
(c) Increase intensity of light (d) Produce unpolarised light

(55) **At sunrise or sunset, the sun looks redder than at midday because:**
(a) of scattering of light (b) of the effects of refraction
(c) of the effects of diffraction (d) the sun is hottest at these times

(56) **A thin layer of oil on the surface of water looks coloured due to:**
(a) Polarisation of light (b) Reflection of light
(c) Interference of light (d) The transmission of light

(57) **The frequency of light having wavelength 1000 A° is:**
(a) 3×10^3 Hz (b) 3×10^4 Hz (c) 3×10^7 Hz (d) 3×10^{15} Hz

(58) **The difference between 1st bright fringe and 1st dark fringe is equal to:**

(a) $\frac{\lambda L}{2d}$ (b) $\frac{\lambda L}{d}$ (c) $\frac{\lambda L}{4d}$ (d) $\frac{2\lambda L}{d}$

(59) **Diffraction pattern produced by white light through a single slit consists of:**

(a) Parallel bright and dark fringes (b) Circular bright and dark fringes
(c) Coloured fringes of equal width (d) Coloured fringes of varying width

(60) **In the diffraction of X-rays from crystals by Bragg's Law, the condition for constructive interference is:**

(a) $d \sin\theta = n\lambda$ (b) $2d \sin\theta = n\lambda$ (c) $d \sin\theta = 2n\lambda$ (d) $2 \sin\theta = n/\lambda$

(61) **Longitudinal waves do not exhibit:**

(a) Reflection (b) Refraction (c) Diffraction (d) Polarization

(62) **Optically active substances are those substances which:**

(a) Produce polarised light
(b) Produces double refraction
(c) Rotate the plane of polarisation of polarised light
(d) Convert a plane polarised light into circularly polarised light

(63) **The Huygens' theory of light fails to explain:**

(a) Photoelectric effect (b) Inference
(c) Diffraction (d) Reflection and refraction

(64) **For which of the following colours will the fringe width be minimum in the double-slit experiment:**

(a) Violet (b) Red (c) Green (d) Yellow

(65) **What is the frequency of light whose wavelength is 5×10^{-7} m?**

(a) 5×10^{-7} Hz (b) 3×10^{8} Hz (c) 6×10^{-4} Hz (d) 6×10^{14} Hz

(66) **An object is placed between two parallel mirrors. The number of image formed is:**

(a) 2 (b) 4 (c) 8 (d) Infinite

(67) **If the refractive index of water is 1.33 then the speed of light in water will be:**

(a) 225000 km s^{-1} (b) 300000 km s^{-1} (c) 299999 km s^{-1} (d) 333 ms^{-1}

(68) **The equation used to determine the speed of light by Michelson was:**

(a) $c = \frac{16f}{T}$ (b) $c = \frac{16d}{T}$ (c) $c = \frac{16f}{T}$ (d) $c = \frac{16d}{f}$

(69) **Which of the following properties of light does not change with the nature of the medium?**

(a) Velocity (b) Wavelength (c) Amplitude (d) Frequency

(70) **A point source of light placed in a homogeneous medium gives rise to:**

(a) A cylindrical wave front (b) An elliptical wave front
(c) A spherical wave front (d) A plane wave front

ANSWERS

(1)	(b)	(2)	(c)	(3)	(c)	(4)	(b)	(5)	(d)
(6)	(c)	(7)	(d)	(8)	(d)	(9)	(d)	(10)	(a)
(11)	(d)	(12)	(b)	(13)	(c)	(14)	(a)	(15)	(a)
(16)	(c)	(17)	(a)	(18)	(d)	(19)	(d)	(20)	(b)
(21)	(d)	(22)	(b)	(23)	(b)	(24)	(a)	(25)	(b)
(26)	(a)	(27)	(a)	(28)	(d)	(29)	(c)	(30)	(c)
(31)	(a)	(32)	(a)	(33)	(a)	(34)	(a)	(35)	(a)
(36)	(d)	(37)	(b)	(38)	(c)	(39)	(d)	(40)	(a)
(41)	(d)	(42)	(d)	(43)	(c)	(44)	(c)	(45)	(d)
(46)	(a)	(47)	(b)	(48)	(a)	(49)	(b)	(50)	(c)
(51)	(b)	(52)	(d)	(53)	(c)	(54)	(b)	(55)	(a)
(56)	(c)	(57)	(d)	(58)	(a)	(59)	(d)	(60)	(b)
(61)	(d)	(62)	(c)	(63)	(a)	(64)	(a)	(65)	(d)
(66)	(d)	(67)	(a)	(68)	(b)	(69)	(c)	(70)	(c)

SOLUTION

(11)

$$n = \frac{C}{V}$$

$$V = \frac{C}{n}$$

$$V = \frac{3\times10^8}{2}$$

$$= 1.5\times10^8 \text{ m/s}$$

(d) is correct

(22) The path difference will be $2\left(\frac{\lambda}{4}\right) = \frac{\lambda}{2}$

(b) is correct

(33)

$$\mu = \frac{C}{V} = \frac{f\lambda}{f\lambda'}$$

$$\mu = \frac{\lambda}{\lambda'}$$

For water $\mu = 1.33$

$$1.33 = \frac{\lambda}{\lambda'}$$

$$\frac{4}{3} = \frac{\lambda}{\lambda'}$$

$$\Rightarrow \lambda' = \frac{3}{4}\lambda$$

For young's double slot experiment

$$\Delta y = \frac{L\lambda}{d}, \quad \Delta y' = \frac{L\lambda'}{d}$$

$$\frac{\Delta y'}{\Delta y} = \frac{\frac{L\lambda'}{d}}{\frac{L\lambda}{d}}$$

$$\frac{\Delta y'}{\Delta y} = \frac{\lambda'}{\lambda} < 1$$

$\therefore$ fringe width decreases.

(a) is correct

Chapter 10

OPTICAL INSTRUMENTS

MCAT UNIT 4

KEY POINTS

Optical Instruments: The branch of physics which deals with the principle of refraction and reflection of light is called optical instruments.

Lens: Lens is a piece of transparent refracting medium bounded by one or two spherical surfaces. There are two types of lenses:

- Convex lens
- Concave lens

Convex Lens: A lens which converges the parallel rays of light to a point is called convex or converging lens. Convex lens is thicker at the centre and thinner at the edges. There are three types of convex lens

- Double convex lens
- Plano convex lens
- Concavo convex lens

Concave Lens: A lens which diverges the parallel rays of light is called concave or diverging lens. Concave lens is thinner at the centre and thicker at the edges. There are three types of convex lens:

- Double concave lens
- Plano concave lens
- Convexo concave lens

Centre of Curvature: The center of the spherical surface of the lens is called center of curvature.

Radius of Curvature: The radius of the spherical surface of the lens is called radius of curvature.

Optical Centre: A point which lies inside of the lens or on the surface of the lens through which a light ray passes undeviated is called optical centre of the lens.

Principle Focus: The point at which the parallel rays converges in case of convex lens or from which they appear to diverge in case of concave lens is called the focus of the lens. A convex lens has real focus whereas a concave lens has virtual focus.

Principle Axis: The line joining the optical centre of the lens and the focus is called principle axis.

Focal Length: The distance between the optical centre and the focus of the lens is called focal length. The focal length of convex lens is positive that of a concave lens is negative. The focal length is one half of the radius of curvature of the spherical surface of the lens i.e., $f = R/2$.

Pole: The point where the principle axis touches the surfaces of the lens is called pole. A lens has two poles. The distance between the two poles of the lens is called width of the lens.

Aperture: The diameter of the circular boundary of the lens is called aperture.

Power of a Lens: The reciprocal of the focal length of a lens is called its power.

i.e., $$P = \frac{1}{f}$$

The power of a convex lens is taken as positive that of a concave lens is taken as negative. The unit of power of the lens is called diopter. The power of a lens is said to be one diopter, if the focal length of the lens is one metre. i.e.,

$$\text{One diopter} = \frac{1}{f = 1 \text{ metre}} \Rightarrow 1\text{ D} = 1\text{ m}^{-1}$$

Combination of the Lenses: If 'n' lenses are combined to form a single lens, then its power is given by:

$$P = P_1 + P_2 + P_3 + \ldots\ldots + P_n$$

For the combination of two convex lenses, we have:

$$P = P_1 + P_2$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow f = \frac{f_1 f_2}{f_1 + f_2}$$

For the combination of two concave lenses, we have:

$$P = P_1 + P_2$$

$$\frac{1}{f} = -\frac{1}{f_1} - \frac{1}{f_2} \Rightarrow f = -\frac{f_1 f_2}{f_1 + f_2}$$

If a convex lens of focal length f_1 and a concave lenses of focal length f_2 are combined, then we have:

$$P = P_1 + P_2$$

$$\frac{1}{f} = \frac{1}{f_1} - \frac{1}{f_2} \Rightarrow f = \frac{f_1 f_2}{f_2 - f_1}$$

If $f_1 > f_2$, then this combination behaves as convex lens and if $f_1 < f_2$, then this combination behaves as concave lens.

Lens Aberrations or Defect in Lenses: There are two types of defect in a lens.

Chromatic Aberration:

- When white light passes through a lens, it disperses the light into seven colours.
- The lens cannot focus all the colours at one point. As a result the coloured image is formed. This defect is called chromatic aberration.

Remedy:

- This defect can be removed by using a combination of a convex and a concave lenses. Their focal lengths are so adjusted that the combination does not produce any dispersion.
- Lenses which are free from dispersion are called achromatic lenses.

Spherical Aberration:

- When parallel rays of light pass through a lens of large aperture, then rays passing through the lens near edges converge more than the rays which pass through the central part of the lens. This defect is called spherical aberration.
- As a result the blurred image is formed.

Remedy:

- This defect can be removed by using only the central portion of a lens.
- Making the two surfaces of the lens of different curvature.
- By using a convex and a concave lens of different shapes.

Least Distance of Distinct Vision: The minimum distance from of the eye at which an object appears to be distinct is called least distance of distinct vision or near point. For a normal eye, it is equal to 25 cm. However, it can change with age.

Magnification: The ratio of size of image to the size of object is called magnification. It is given by:

$$M = \frac{\text{Size of the image}}{\text{Size of the object}} = \frac{I}{O}$$

In case of image formed by a lens, it can be written as:

$$M = \frac{\text{Distance of the image from the lens}}{\text{Distance of the object from the lens}} = \frac{q}{p}$$

Thus $$M = \frac{I}{O} = \frac{q}{p}$$

Since magnification is a ratio of two sizes, so it has no units and no dimension. The magnification is positive for real image and is negative for virtual image.

Visual Angle: It is the angle subtended by an object at the eye. The apparent size of an object depends upon the visual angle subjected by it at the eye.

Angular Magnification: It is the ratio of the angles subtended by the image as seen through the optical device to that subtended by the object at the naked eye. Mathematically, it can be written as:

$$M = \frac{\theta_i}{\theta_o}$$

Resolving Power: It is the ability of an optical instrument to reveal the minor details of the object under examination. Mathematically, it is given by $R = \frac{1}{\alpha_{min}}$. Where α_{min} is the minimum angle which two point sources (images) subtend at the instrument so that their images are seen as two district spots of light rather than one. Raleigh showed that the resolving power of a convex lens is

$$\alpha_{min} = \frac{1.22\lambda}{D}$$

Thus, $$R = \frac{D}{1.22\lambda}$$

Where λ = Wavelength of light

D = Diameter of lens

The resolving power of a diffraction grating is given by:

$$R = \frac{\lambda}{\lambda_2 - \lambda_1} = \frac{\lambda}{\Delta\lambda}$$

Where $\Delta\lambda = \lambda_2 - \lambda_1$ and $\lambda = \lambda_1 \approx \lambda_2$

If N is the number of lines on the grating, the resolving power of the grating in mth-order diffraction is given by:

$$R = N \times m$$

Lens Formula: The formula is given by:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Distance of object 'p' is positive for real object and is negative for virtual object. Distance of image 'q' is positive for real image and is negative for virtual image. Focal length of the lens 'f' is positive for convex lens and negative for concave lens.

Important Rays for Image Formation: There are three important rays used for the image formation and any two of them should intersect actually or virtually to form the real or virtual image.

- A ray which passes through the optical centre of a lens is undeviated.
- A ray parallel to the principle axis of a lens, passes through (or appear to come from) the focus of a lens.
- A ray which passes through the focus becomes parallel to the principle axis of the lens.

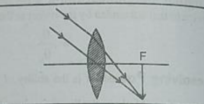
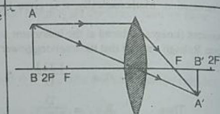
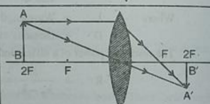
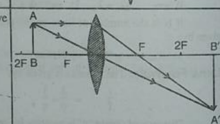
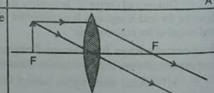
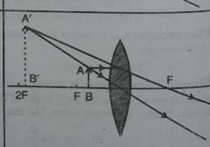
Microscope: It is an optical instrument used to see the magnified image of small objects. There are two types of microscopes.

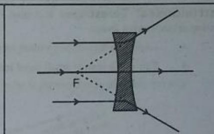
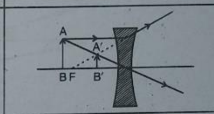
- Simple microscope
- Compound microscope

Simple Microscope: A double convex lens can be used as a simple microscope or magnifier, when the object is placed within the focal length of the lens. In this case, the lens forms virtual, erect and magnified image at least distance of distinct vision. The magnification produced by lens is given by

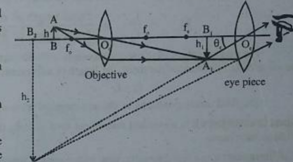
$$M = 1 + \frac{d}{f}$$

A convex lens of short focal length is preferred for high magnification.

Position of object	Position of image	Real / virtual	Inverted / erect	Magnification and size of image	Sign of magni-faction	Ray Diagram
at infinity (u = ∞)	at focus (v = f)	real	inverted	m < 1 greatly diminished	negative	
beyond 2f(u > 2f)	between f and 2f (f < v < 2f)	real	inverted	m < 1 diminished	negative	
at 2f (u = 2f)	at 2f(v = 2f)	real	inverted	m = 1 same size	negative	
between f and 2f (f < u < 2f)	beyond 2f(v > 2f)	real	inverted	m > 1 magnified	negative	
at f(u = f)	at infinity (v = ∞)	real	inverted	m = ∞ magnified	negative	
between optical centre and focus (u < f)	at a distance greater than the object distance and on the same side as object (v > u)	virtual	erect	m > 1 magnified	negative	

at infinity (v = ∞)	at focus (v = f)	virtual	erect	m < 1 diminished	positive	
between infinity and optical centre	between optical centre and focus	virtual	erect	m < 1 diminished	positive	

Compound Microscope: Compound microscope is used, whenever high magnification is required. If consists of two convex lenses.



- Objective lens of small focal length and small aperture
- Eye-piece lens of large focal length and large aperture.

The ray diagram of compound microscope is shown in figure. The magnification of the compound microscope is equal to the product of magnification of objective and eye piece.

i.e., $M = M_1 \times M_2$

Where $M_1 = \frac{q_1}{P_1}$ = Magnification produced by objective

and $M_2 = 1 + \frac{d}{fe}$ = Magnification produced by eye piece.

The magnification of the compound microscope is given by:

$$M = \frac{q_1}{p_1}\left(1+\frac{d}{fe}\right)$$

As $p_1 \approx f_0$ and $q_1 \approx L_0$, then $M = \frac{L_o}{f_o}\left(1+\frac{d}{fe}\right)$

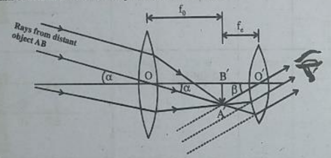
The final image produced by the compound microscope is virtual and inverted.

Telescope: It is an optical instrument used to see a clear image of distant objects. The image of a distant object viewed through a telescope appears larger because it subtends a bigger visual angle than when viewed with the naked eye.

Astronomical Telescope: It is used to see astronomical objects in space such as Moon and stars, etc. If consists of two convex lenses.

- Objective lens of large focal length and large aperture
- Eye-piece lens of small focal length and small aperture.

The ray diagram of astronomical telescope is shown in figure.



The magnifying power of astronomical telescope is given by:

$$M = \frac{f_o}{f_e} = \frac{\text{Focal length of objective}}{\text{Focal length of eye piece}}$$

The magnification of telescope increases with the increase in the value of f_o and decrease with increase in the value of f_e. In normal adjustment, the length of astronomical telescope is given by

$$L = f_o + f_e$$

The final image produced by the astronomical telescope is virtual and inverted.

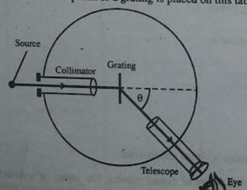
Spectrometer: It is an optical instrument used to study the spectra from different sources of light. It consists of three main parts.

Collimator: It is a fixed metallic tube with a convex lens at one end and an adjustable slit at other end.

- The distance of slit from the lens can be changed.
- It produces the parallel rays of light.

Turntable:

- It is a circular table which can rotate about a fixed vertical axis.
- A circular scale, graduated in half degrees, is attached with it.
- A prism or a grating is placed on this table to disperse the light.



Schematic diagram of a spectrometer

Spectrometer

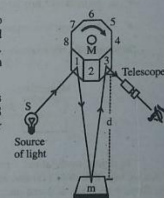
Telescope:

- It is an ordinary telescope fitted with a cross-wire placed at the focus of objective.
- It can be rotated about the same vertical axis as the turn table.
- A vernier scale is attached with the telescope which rotates with the telescope.

Uses of Spectrometer: A spectrometer is used to:

- Determine the angle of deviation of light by a prism.
- Determine the refractive index of transparent material.
- The wavelength of light used.

Speed of Light: Galileo was the first person to make an attempt to measure its speed. Michelson performed an experiment to determine the speed of light. The experiment set up of the Michelson experiment is shown in figure. An eight-sided polished mirror M is mounted on the shaft of a motor which rotates it.



When the time taken by light in moving from M to m and back to M is equal to the time taken by face 2 to move to the position of face-3, the source S becomes visible in the telescope. Michelson derived the following relation for the speed of light

$$C = 16fd$$

Where f = Frequency of rotation of mirror M

And d = Distance between mirrors m and M.

Michelson measured the speed of light in vacuum to be equal to:

$$c = 3.0 \times 10^8 \ ms^{-1}$$

The speed of light in other medium is always less than 'c'. It depends upon the nature of medium.

Introduction to Fibre Optics: Alexander Graham Bell invented a device known as 'Photo Phone' shortly after his invention of telephone. With this device, Bell transmits a voice message via a beam of light. During the recent post the idea of transmission of light through thin optical fibres has been revived and is now being used in communication technology.

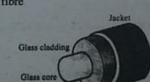
Optical Fibre: Optical fibre consists of thin glass fibres through which information are transmitted as pulses of light. It can carry information, whether it is an audio signal, a television signal or a computer data by visible or invisible infrared light. Propagation of light in an optical fibre requires that the light should be totally confined within the fibre. This may be done by:

- Total internal reflection, and
- Continuous refraction

Types of Optical Fibre: There are three types of optical fibres

- Single mode step index fibre
- Multimode step index fibre
- Multimode graded index fibre

Single Mode Step Index Fibre: Single mode or mono mode step index fibre has a very thin core about 5μm diameter and has a relatively larger cladding as shown in figure. A strong monochromatic light (ie a laser light) is used to send information through it. It can carry more than 14 TV channels or 14000 phone calls.



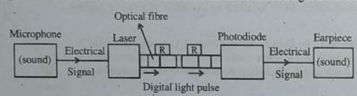
Multi-mode Step Index Fibre: This type of fibre has a core of relatively larger diameter of about 50μm. It is mostly used for carrying white light. But due to dispersion effects, it is useful for a short distance only. Its core has refractive index 1.52 and cladding 1.48.

Multimode Graded Index Fibre: This type of fibre has core which ranges in diameter from 50 to 1000 μm. There is no noticeable boundary between core and cladding and refractive index decreases gradually from core and cladding. It is useful for long distance application in which white light is used.

Single Transmission and Conversion to Sound: A fibre optic communication system consists of three major components:

- A transmitter that converts electrical signals to light signals.
- An optical fibre for guiding the signals.
- A receiver that captures the light signals at other end of the fibre and reconverts them to electric signals.

In transmitter, the lasers and LEDs are used which emit an invisible infrared light of wavelength 1.3 μm.



In digital modulation, a pulse of light represents the number 1 and the absence of light represents zero. Thus we says that once (1s) and zeros (0s) are moving down the path. When the light signal is traveling through the fibre, it becomes dim and must be regenerated by devices called repeaters that are placed at 100 km apart. At the end of the fibre, a photodiode captures the light signals, which are then amplified and decoded them to reconstruct the original signal transmitted.

Losses of Power: In an optical fibre, the signal may be lost by:

- Scattering and absorption by the impurity atoms.
- Spreading or dispersion of light into different wavelengths.

ASSIGNMENT NO. 10

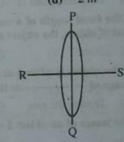
(1) **The limit to which a microscope can be used to resolve details of an object depends upon:**
(a) Wider objective and light of short wavelength
(b) Narrow objective and light of short wavelength
(c) Narrow objective and light of longer wavelength
(d) None of these

(2) **Snell's law is described as:**
(a) $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (b) $n_2 \sin\theta_1 = n_1 \sin\theta_2$ (c) $n_1 \sin\theta_2 = n_2 \sin\theta_1$ (d) None of these

(3) **When $\theta_2 = 90°$ and $\theta_1 = \theta_c$ then Snell's law becomes:**
(a) $\sin\theta_c = n_1 n_2$ (b) $\sin\theta_c = \frac{n_2}{n_1}$ (c) $\sin\theta_c = \frac{n_1}{n_2}$ (d) None of these

(4) **Power of any lens would be one dipotre when its focal length is:**
(a) 1.0 m (b) 1 cm (c) 10 cm (d) 2 m

(5) **The figure shows an equi-convex lens of focal length f. If the lens is cut along PQ. The focal length of each half will be:**



(a) $\frac{f}{2}$ (b) f
(c) 2f (d) $\frac{3f}{2}$

(6) **The unit of power of a lens is:**
(a) Metre (b) Watt (c) Newton (d) Dioptre

(7) **The minimum distance between an object and its real image in a convex lens is:**
(a) 2f (b) 2.5f (c) 3f (d) 4f

(8) **The image formed by a convex lens of focal length 10 cm is twice the size of the object. The position of the object will be:**
(a) 20 cm (b) 30 cm (c) 50 cm (d) 15 cm

(9) **In Michelson's experiment, the equation used to find the speed of light is:**
(a) c = 16 fd (b) c = 16 f/d (c) c = 16d/f (d) c = fd/16

(10) **The diameter of single mode step fibre core is:**
(a) 10 μm (b) 30 μm (c) 5 μm (d) 100 μm

(11) **The focal length 'f' and radius of curvature are related by:**
(a) f = 2R (b) R = 2f (c) R = f (d) None of the above

(12) **The focal length of objective of telescope is 60 cm. To obtain magnification of 20 focal length of eye piece should be:**
(a) 5 cm (b) 4 cm (c) 3 cm (d) 2 cm

(13) **In compound microscope the magnification of object is M_o and magnification of eyepiece is Me. The magnifying power of compound microscope is:**
(a) $M_o + M_e$ (b) $M_o \times M_e$ (c) $M_e - M_e$ (d) M_o/M_e

(14) To increase the resolving power of telescope we should use:
(a) Wider objective (b) Wider eyepiece (c) Shorter objective (d) Shorter eyepiece

(15) Which mirror should be used to obtain a parallel beam of light from a small lamp?
(a) Plane mirror (b) Convex mirror
(c) Concave mirror (d) Any one of the above

(16) Which one of the following phenomena cannot be explained by the wave theory of light?
(a) Refraction (b) Total internal reflection
(c) Diffraction (d) Photoelectric effect

(17) In vacuum light travels at a speed of 3×10^8 ms^{-1}, what is the speed of light in glass of refractive index 1.5?
(a) 1.5×10^8 ms^{-1} (b) 2×10^8 ms^{-1} (c) 3×10^8 ms^{-1} (d) 4.5×10^8 ms^{-1}

(18) An object is placed between two parallel mirrors. The number of image formed is:
(a) 2 (b) 4 (c) 8 (d) Infinite

(19) A convex lens acts as diverging lens when the object is placed:
(a) Between F and 2F (b) At 2F (c) With focal length (d) Beyond 2F

(20) If the focal length of a convex lens is 5 cm, then to get real and inverted image of the same size as that of object, the object should be placed at:
(a) 5 cm (b) 10 cm (c) 15 cm (d) 20 cm

(21) If the object is placed at 12 cm distance from a convex lens of focal length 6 cm, then we get an image of ———— as that of object.
(a) Double the size (b) Same size (c) Half the size (d) None of these

(22) The image of an object 5 mm length is only 1 cm high. The magnification produced by lens is:
(a) 1 (b) 0.2 (c) 2 (d) 0.1

(23) The focal length of convex lens having magnifying power of 5.55 is:
(a) 5.5 cm (b) 5 cm (c) 4.5 cm (d) 6 cm

(24) Raleigh formula for resolving power is given by:
(a) $R = \frac{\lambda}{\Delta\lambda}$ (b) $R = N \times m$ (c) $\alpha_{min} = 1.22\frac{\lambda}{D}$ (d) None of these

(25) A grating with high resolving power can distinguish ———— difference in wavelengths.
(a) Smaller (b) Larger (c) Zero (d) None of these

(26) A lens of 2 cm focal length is to be used as magnifying glass. Its magnification is:
(a) 13.5 (b) 12.5 (c) 0.5 (d) 2.5

(27) The eye-piece of a compound microscope acts as:
(a) Converging lens (b) Converging mirror (c) Magnifying glass (d) None of these

(28) When the mirror rotates in Michelson method, any of its faces takes the position of very next face, then the angle subtended at the centre is:
(a) 30° (b) 45° (c) 60° (d) 75°

(29) The property of light which makes light possible to be transmitted into inaccessible places is:
(a) Interference (b) Diffraction (c) Polarization (d) None of these

(30) The refractive index of a given piece of transparent quartz is greatest for:
(a) Red light (b) Violet light (c) Green light (d) Yellow light

(31) A completely transparent material will be invisible in vacuum when the refractive index μ is:
(a) Unity (b) More than unity (c) Less than unity (d) Equal to 1.33

(32) Which of the following does not change when light goes from one medium to another?
(a) Frequency (b) Wavelength (c) Speed (d) Intensity

(33) Critical angle of light passing from glass to air is minimum for:
(a) Red (b) Green (c) Yellow (d) Violet

(34) If the speed of light in vacuum is c, then its velocity in a medium of refractive index 1.5 is:
(a) $1.5 \times c$ (b) $c \times \left(\frac{8}{9}\right)$ (c) $\frac{c}{1.5}$ (d) $c \times \left(\frac{9}{8}\right)$

(35) The focal length f and radius of curvature R of a spherical mirror of small aperture are related by the relation:
(a) $f = R$ (b) $f = 2R$ (c) $2f = R$ (d) Acceleration

(36) A convex mirror has a focal length f. A real object placed at a distance f in front of it from the pole, produces an image at:
(a) Infinity (b) f (c) $\frac{f}{2}$ (d) 2f

(37) What is the power of a diverging lens of focal length 40 cm?
(a) +2.5 D (b) −2.5 D (c) −3.5 D (d) +4.0 D

(38) Two lenses have powers +2 D and − 4 D respectively. The power of combination is:
(a) −2 D (b) +2 D (c) −4D (d) +4 D

(39) A convex lens is dipped in a liquid, whose refractive index is equal to the refractive index of the lens. Then is focal length will:
(a) become zero (b) become infinite
(c) remain unchanged (d) become small but non-zero

(40) When the length of a microscope increases its magnifying power:
(a) Decreases (b) Increases (c) does not change
(d) may increase or decrease depending on the observer and the place of observation.

(41) Large aperture of telescope is used for:
(a) greater magnification (b) greater resolution
(c) reducing lens aberration (d) ease of manufacture

(42) Magnifying power of an astronomical telescope for normal vision with usual notation is:
(a) $-\frac{f_o}{f_e}$ (b) $-f_o \times f_e$ (c) $-\frac{f_e}{f_o}$ (d) $-f_o + f_e$

(43) Loss in the ability of eye to focus on near and far objects with advancing age is called:
(a) Presbyopia (b) Astigmatism (c) Hypermetropia (d) Myopia

(44) The least distance of distinct vision is 25 cm. If the focal length of a convex lens is 10 cm. It acts as simple microscope of maximum magnification:
(a) 2.5 (b) 3 (c) 3.5 (d) 5

(45) Magnification of a lens is negative when image is:
(a) Real and erected (b) Virtual and erected (c) Real and inverted (d) Virtual and inverted

(46) **To obtain a parallel beam of a headlight of a car it must be fitted with a:**
(a) Convex lens (b) Concave lens (c) Convex mirror (d) Plane mirror

(47) **A compound microscopic has two lenses. The magnifying power of one is 5 and the combined magnifying power is 100. The magnifying power is 100. The magnifying power of the other is:**
(a) 10 (b) 20 (c) 50 (d) 25

(48) **A glass lens is dipped in water. Its power will:**
(a) Remain unchanged (b) Decrease (c) Increase (d) Become infinite

(49) **A double convex air bubble in water behaves as a:**
(a) Convergent lens (b) Divergent lens (c) Plane glass slab (d) Concave mirror

(50) **The final image produced by a compound microscope is:**
(a) Real and inverted (b) Real and erect
(c) Virtual and inverted (d) Virtual and erect

(51) **The position of a cross wire in a microscope is where:**
(a) The first image due to objective is formed (b) The final image due to microscope is formed
(c) The focal point of eyepiece lies (d) The focal point of objective lies

(52) **The scientist who made first attempt to measure the speed of light was:**
(a) Newton (b) Galileo (c) Michelson (d) Faraday

(53) **A long-sighted person cannot see clearly:**
(a) Distant objects (b) Close objects
(c) Both distant and close objects (d) None of these

(54) **A short-sighted person uses spectacles fitted with:**
(a) Convex lenses (b) Concave lenses (c) Cylindrical lenses (d) Plano-convex lenses

(55) **Critical angle of a medium depends upon the:**
(a) Refractive index of the denser medium (b) Speed of light in air
(c) Relative refractive index of the two medium (d) Intensity of the beam of light

(56) **In Michelson's experiment, the angle subtended by a side of eight-sided mirror at the center is:**
(a) $\pi/4$ (b) $\pi/8$ (c) $\pi/2$ (d) π

(57) **When light wave suffers reflection at the interface between air and glass, the change of phase of the reflected wave is equal to:**
(a) Zero (b) π (c) 2π (d) $\pi/2$

(58) **If the refractive index of medium increases, then the velocity of the light through it:**
(a) Decreases (b) Increases
(c) Remains unchanged (d) First decreases then increases

(59) **Multimode step index fiber is used for:**
(a) Long distance (b) Short distance
(c) Neither long nor short distances (d) Both long and short distances

(60) **In old system, repeaters are placed typically apart at a distance of:**
(a) 20 km (b) 25 km (c) 30 km (d) 40 km

(61) **With a step index fiber, the overall time difference may be about:**
(a) 30 ns/km (b) 33 ns/km (c) 35 ns/km (d) 50 ns/km

(62) **In fibre optics, the speed of light is inversely proportional to:**
(a) Frequency (b) Wavelength (c) Refractive index (d) Amplitude

(63) **When light enters glass (or any other medium) it suffers a change in:**
(a) Wavelength only (b) Frequency only
(c) Velocity only (d) Both velocity and wavelength

(64) **Resolving power of the diffraction grating is:**
(a) $N \times m$ (b) $N^2 \times m$ (c) $N \times m^2$ (d) N/m

(65) **A transparent refracting medium bounded by two curved surfaces, is called:**
(a) Glass (b) Mirror (c) Prism (d) Lens

(66) **The reciprocal of focal length of a lens expressed in metres is called:**
(a) Focus (b) Aperture (c) Power (d) Optical centre

(67) **The diameter of single mode step fibre core is:**
(a) 10 µm (b) 30 µm (c) 5 µm (d) 100 µm

(68) **The light emitted from LED has a wavelength:**
(a) 1.3 µm (b) 1.2 µm (c) 1.4 µm (d) 1.5 µm

(69) **Information carrying capacity of fiber optics is called:**
(a) Capacity (b) Confinement (c) Bandwidth (d) None

(70) **Which of the following optical fibers is used for long distance transmission without dispersion effect?**
(a) Single mode step index (b) Multimode step index
(c) Multimode graded index (d) Any of them

ANSWERS

(1)	(a)	(2)	(a)	(3)	(b)	(4)	(a)	(5)	(c)
(6)	(d)	(7)	(d)	(8)	(d)	(9)	(a)	(10)	(c)
(11)	(b)	(12)	(c)	(13)	(b)	(14)	(a)	(15)	(c)
(16)	(d)	(17)	(b)	(18)	(d)	(19)	(c)	(20)	(b)
(21)	(b)	(22)	(c)	(23)	(a)	(24)	(c)	(25)	(a)
(26)	(a)	(27)	(c)	(28)	(b)	(29)	(b)	(30)	(b)
(31)	(a)	(32)	(a)	(33)	(d)	(34)	(c)	(35)	(c)
(36)	(c)	(37)	(b)	(38)	(a)	(39)	(b)	(40)	(a)
(41)	(b)	(42)	(a)	(43)	(a)	(44)	(c)	(45)	(b)
(46)	(c)	(47)	(b)	(48)	(b)	(49)	(b)	(50)	(c)
(51)	(a)	(52)	(c)	(53)	(b)	(54)	(b)	(55)	(a)
(56)	(a)	(57)	(b)	(58)	(a)	(59)	(b)	(60)	(c)
(61)	(b)	(62)	(c)	(63)	(d)	(64)	(d)	(65)	(d)
(66)	(c)	(67)	(c)	(68)	(a)	(69)	[illegible]	(70)	(c)

SOLUTION

(5) If f' be the focal length of each half then on combining the two halves we will get 'f'. Therefore,

$$\frac{1}{f} = \frac{1}{f'} + \frac{1}{f'}$$

$$\frac{1}{f} = \frac{2}{f'}$$

$$f' = 2f$$

(c) is correct

(14) As $M = \frac{f_0}{f_e}$

(a) is correct

(17) $n = \frac{C}{V}$

$$\Rightarrow V = \frac{C}{n}$$

$$V = \frac{3 \times 10^8}{1.5}$$

$$V = 2 \times 10^8 \ ms^{-1}$$

(b) is correct

(18) The number of images observable between two parallel mirror is ∞

As $N = \frac{360}{\theta}$

$$N = \frac{360}{0} = \infty$$

(d) is correct

(28) $\frac{360^\circ}{8} = 45^\circ$

(b) is correct

(31) Conditions for invisibility

(i) Transparent

(ii) Colourless

(iii) μ-same as that of medium in which it is to be placed.

(a) is correct

(37) As power of lens is reciprocal for focal length in meter is

$$f = 40 \text{ cm} = 0.4 \text{ m}$$

$$p = \frac{1}{f} = \frac{1}{0.4}$$

$$p = 2.5 \text{ p}$$

As lens is diverging

$$\therefore p = -2.5 \text{ p}$$

(b) is correct

(47) $M = M_1 \times M_2$

$$100 = 5 \times M_2$$

$$M_2 = 20$$

(b) is correct

Chapter 11

HEAT AND THERMODYNAMICS

MCAT UNIT 7-8

KEY POINTS

Thermodynamics: It deals with transformation of heat energy into mechanical energy (work). It deals with various phenomena of energy and related properties of matter.

Heat: It is amount of energy that flows from a hot body to a cold body when they are in thermal contact with each other". Thus, heat is a form of energy associated with molecular motion.

Temperature: Temperature is degree of hotness or coldness of a body. It is physical quantity which determines the direction of flow of heat from one body to another when they are in thermal contact with each other. It describes the level of thermal energy in a body. It is the measure of average translational K.E of molecules of a gas.

(i) Temperature is a **macroscopic** physical quantity related to our sense of hot and cold.

(ii) Our temperature sense is not always reliable. For example, on a cold winter day, in the same room, an iron chair seems to be much colder to our touch than does a wooden chair, although both are at the same temperature.

(iii) Temperature is basically a **measure of degree of hotness or coldness of a body.**

(iv) The natural flow of heat is from higher temperature to lower temperature.

(v) Temperature of a body is directly proportional to the kinetic energy of the random motion of the molecules or atoms of the substance.

(vi) Two bodies are said to be in **thermal equilibrium** with each other when no heat flows from one body to the other, i.e., when both the bodies are at the same temperature.

(vii) Temperature of a body cannot be lowered up to any extent while it can be raised up to any value. Theoretical lowest temperature is considered to be absolute zero. Highest possible temperature achieved in laboratory is about 10^8 K while lowest possible temperature attained is 10^{-8} K.

(viii) Branch of physics dealing with production and measurement of temperatures close to 0 K is known as **cryogenics** while that dealing with the measurement of very high temperatures is called as **pyrometry**.

Different Types of Temperature Scales:

(i) The Kelvin temperature scale is also known as thermodynamic scale. The SI unit of temperature is Kelvin and is defined as (1/273.16) of the temperature of the triple point of water. The triple point of water is that point on a P-T diagram where the three phases of water, the solid, the liquid and the gas, can coexist in equilibrium.

(ii) In addition to Kelvin temperature scale, there are other temperature scales also like Celsius, Fahrenheit, Reaumer, Rankine, etc. Temperature on one scale can be converted into other scale by using the following identity:

$$\frac{\text{Reading on any scale} - \text{Lower fixed point (LFP)}}{\text{Upper fixed point (UFP)} - \text{Lower fixed point (LFP)}} = \text{Constant for all scales}$$

Hence,

$$\frac{t^\circ C - 0^\circ}{100^\circ - 0^\circ} = \frac{t^\circ F - 32^\circ}{212^\circ - 32^\circ} = \frac{5^\circ R - 0^\circ}{80^\circ - 0^\circ}$$

$$= \frac{5^\circ Ra - 460^\circ}{472^\circ - 460^\circ} = \frac{tK - 273.15}{373.15 - 273.15}$$

(iii) **Different temperature scales:**

S. No.	Names of the scale	Symbol for each degree	Lower fixed point (LFP)	Upper fixed point (UFP)	Number of divisions on the scale
1.	Celsius	°C	0°C	100°C	100
2.	Fahrenheit	°F	32°F	212°F	180
3.	Reaumur	°R	0°R	80°R	80
4.	Rankine	°Ra	460 Ra	672 Ra	212
5.	Kelvin	K	273.15 K	373.15 K	100

Thermometry:

(i) In thermometry, two arbitrary fixed points, **ice and steam points** (i.e., FP and BP of water at 1 atmosphere) are taken to define the temperature scale, e.g., in celsius scale, FP of water is assumed to be 0°C while BP of water 100°C, and the temperature interval between them is divided into 100 equal parts. So, if the thermometric properties at temperatures 0°C, 100°C and t_c°C and x_0 x_{100} and x respectively then,

$$\frac{t_c - 0}{100 - 0} = \frac{x - x_0}{x_{100} - x_0} \quad \text{or} \quad t_c = \frac{x - x_0}{x_{100} - x_0} \times 100°C$$

(ii) The thermometric property x may be
(a) length of liquid in a capillary;
(b) pressure of gas at constant volume;
(c) volume of gas at constant pressure;
(d) resistance of a given platinum wire.

Some Important Points Regarding Thermometers:

(i) Hydrogen cannot be used as a thermometric substance above 500°C because it starts diffusing.
(ii) In liquid thermometers, mercury is preferred over other liquids as its expansion is large and uniform and it has high thermal conductivity and low specific heat.
(iii) Gas thermometers are more sensitive than liquid thermometers as expansion of gases is more than that of liquids.
(iv) Usually platinum is used in resistance thermometers as it has high melting point and for it α is constant.
(v) Below −200°C, the hydrogen and nitrogen cannot be used because they start liquefying.
(vi) Thermoelectric thermometers have low thermal capacity and high thermal conductivity, so can be used to measure quickly changing temperatures.
(vii) Alcohol thermometer is preferred to the mercury thermometer due to the large value of the coefficient of cubic expansion.
(viii) The mercury thermometers with cylindrical bulbs are more sensitive than those with spherical bulbs.

Heat:

(i) Heat is a form of energy. It is basically that energy which is transferred from one body to other due to difference of their temperatures.
(ii) Dimensional formula of heat is $[ML^2T^{-2}]$. The SI unit of heat is joule while in CGS system the unit of heat is calorie.
(iii) (a) A calorie is the amount of heat required to raise the temperature of one gram of water through 1°C (more precisely from 14.5°C to 15.5°C).
(b) 1 kilocalorie (kcal) = 1000 cal = amount of heat required to raise the temperature of 1 kg of water by 1°C.
(c) FPS unit of heat is **British Thermal Unit** (Btu). 1 Btu = 252 cal = amount of heat required to raise the temperature of 1 lb (pound) of water through 1°F.
(d) 1 cal = 4.186 joule

(iv) Generally, the temperature of a body rises when heat is supplied to it. However, following two situations are also found to exist:
(a) **When heat is supplied to a body either at its melting point or boiling point**, the temperature of body does not change. In this situation, heat supplied to the body is used up in changing its state.
(b) When liquid in a thermos flask is vigorously shaken or gas in a cylinder is suddenly compressed, temperature of liquid or gas gets raised even without supplying heat. In this situation, work done on the system becomes a source of heat energy.

Latent Heat:

(i) When a substance changes from one state to another state (say from solid to liquid or liquid to gas or from liquid to solid or gas to liquid) then energy is either absorbed or liberated. This heat energy is called **latent heat**.
(ii) No change in temperature is involved when the substance changes its state. That is, **phase transformation is an isothermal change**. Ice at 0°C melts into water at 0°C. Water at 100°C boils to form steam at 100°C.
(iii) The amount of heat required to change the mass m of the substance is written as: $\Delta Q = mL$, where L is the latent heat. Latent heat is also called as **Heat of Transformation**.
(iv) Any material has two types of latent heats:
(a) **Latent heat of fusion:** For a change from solid to liquid (melting) or for a change from liquid to solid (freezing).
(b) **Latent heat of vaporisation:** For a change from liquid to vapour (boiling) or for a change from vapour to liquid (condensation).
(v) **The latent heat of fusion** is the heat energy required to change 1 kg of the material in its solid state at its melting point to 1 kg of the material in its liquid state. It is also the amount of heat energy released when at melting point 1 kg of liquid changes to 1 kg of solid. For water at its normal freezing temperature or melting point (0°C), the latent heat of fusion (or latest heat of ice) is:

$$L_F = L_{ice} \approx 80 \text{ cal/g} \approx 60 \text{ kJ/mol} = 336 \text{ kilojoule/kg}$$

(vi) **The latent heat of vaporisation** is the heat energy required to change 1 kg of the material in its liquid state at its boiling point to 1 kg of the material in its gaseous state. It is also the amount of heat energy released when 1 kg of vapour changes into 1 kg of liquid. For water at its normal boiling point or condensation temperature (100°C), the latent heat of vaporisation (latent heat of steam) is:

$$L_V = L_{steam} \approx 540 \text{ cal/g} \approx 40.8 \text{ kJ/mol} \approx 2260 \text{ kilojoule/kg}$$

(vii) In the process of melting or boiling, heat supplied is used to increase the internal potential energy of the substance and also in doing work against external pressure while internal kinetic energy remains constant. This is the reason that **internal energy of steam at 100°C is more than that of water at 100°C.**
(viii) In case of change of state:
(a) if the molecules come closer, energy is released;
(b) if the molecules move apart, energy is absorbed.

Transmission of Heat: Heat can be transmitted from one place to another by three different mechanisms:
(i) Conduction (ii) Convection (iii) Radiation

(i) **Conduction** is the process of transmission of heat in a body from the hotter part to the colder part without any bodily movement of constituent atoms or molecules of the body.
(ii) **Convection** is the process of transmission of heat in a body from hotter part to the colder part through the actual bodily movement of constituent atoms or molecules of the body.
(iii) **Radiation** is the process of transmission of heat from one body to another body through electromagnetic waves even through vacuum, irrespective of their temperatures. Heat from the sun reaches the earth by radiation.

Steady State: When one end of a rod is heated, then initially the temperature of various points of the rod changes continuously and the rod is said to exist in a **variable state**. After some time, a state is reached, when the temperature of each cross-section becomes steady. This state is known as **steady state**. In this state, any heat received by any cross-section is partly conducted to the next section and partly radiated, i.e., no heat is absorbed by the cross-section.

Thermometric Property: It is the property of a matter that changes with temperature. Examples of thermometric properties are:

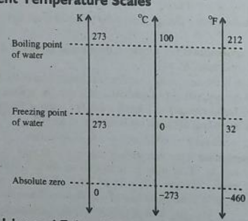
- Expansion on heating and contraction on cooling.
- Variation in the colour with temperature.
- Variation in the shape of the object with temperature.
- Variation in the resistance and conductance of the wire with temperature.

Thermometer: It is a device to measure the temperature of the body. It based on some thermometric properties.

Scales of Temperature: The three scales commonly used are:

- Centigrade or Celsius scale
- Fahrenheit scale
- Kelvin or absolute scale

Comparison of Different Temperature Scales



Relations between Celsius and Fahrenheit Scales:

$$°C = \frac{5}{9}(°F - 32) \quad \Rightarrow \quad °F = \frac{9}{5}°C + 32$$

Relations between Celsius and Absolute Scales:

$$K = °C + 273 \quad \Rightarrow \quad °C = K - 273$$

Relations between Fahrenheit and Absolute Scales:

$$K = \frac{5}{9}(°F - 32) + 273 \quad \Rightarrow \quad °F = \frac{9}{5}(K - 273) + 32$$

Assumptions of Kinetic Theory of Gases:

(i) A gas consists of a large number of identical, tiny, spherical, neural and elastic particles called molecules.

(ii) In a gas molecules are moving in all possible directions with all possible speeds in accordance with **Maxwell's distribution law.**

(iii) The space occupied by the molecules is much smaller than the volume of the gas.

(iv) There is no force of attraction among the molecules.

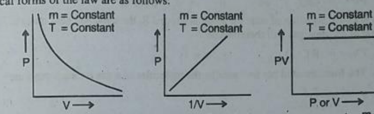
(v) The pressure of a gas is due to elastic collision of gas molecules with the walls of the container.

(vi) The time of contact of a moving molecule with the walls of the container is negligible as compared to the time interval between two successive collisions on the same wall of the container.

Gas-laws:

(i) **Boyle's Law:** According to it for a given mass of an ideal gas at constant temperature, the volume of a gas is inversely proportional to its pressure, i.e., $V \propto \frac{1}{P}$ if mass of gas and T = constant.

Graphical forms of the law are as follows:

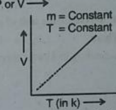


(ii) **Charles' law:** According to it for a given mass of an ideal gas at constant pressure, volume of a gas is directly proportional to its absolute temperature, i.e.,

$$V \propto T$$

If m and P = Constant

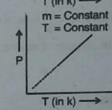
Graphical form of the law is shown in adjoining figure.



(iii) **Gay-Lussac's law:** According to it, for a given mass of an ideal gas at constant volume, pressure of a gas is directly proportional to its absolute temperature, i.e.,

$$P \propto T \quad \text{if m and V = Constant}$$

This is shown graphically in adjoining figure.



(iv) **Avogadro's law:** According to it, at same temperature and pressure, equal volumes of all the gases contain equal number of molecules, i.e.,

$$N_1 = N_2 \quad \text{if P, V and T are same}$$

(v) **Graham's law:** According to it, at constant pressure and temperature, the rate of diffusion of a gas is inversely proportional to the square root of its density, i.e.,

$$\text{Rate of diffusion} \propto \frac{1}{\sqrt{\rho}} \quad \text{if P and T = Constant}$$

(vi) **Dalton's law:** According to it, the pressure exerted by a gaseous mixture is equal to the sum of partial pressure of each component present in the mixture, i.e.,

$$P = P_1 + P_2 + \ldots\ldots$$

Ideal Gas Equation:

(i) A relation connecting macroscopic properties pressure, volume and temperature of a gas describes the state, i.e., physical condition of the system and is called equation of state.

(ii) For a system containing N particles of a gas, when macroscopic properties P, V and T are studied through experiments, it was found that:

$$V \propto N \quad ; \text{ if P and T are constant}$$

$$V \propto \frac{1}{P} \quad ; \text{ if N and T are constant}$$

and

$$V \propto T \quad ; \text{ if P and N are constant}$$

Combining all these, we get:

$$V \propto \frac{NT}{P} \quad \text{i.e.,} \quad \frac{PV}{NT} = \text{Constant} = k$$

The constant k is called Boltzmann's constant.

(iii) As number of moles, $m = \frac{m}{M} = \frac{N}{N_A}$ $(\because N = \mu N_A)$

Hence, $\frac{PV}{\mu T} = N_A k = R$ $(\because N_A k = R)$

i.e., $PV = \mu RT$ with $R = 8.31$ J/mol K

This equation is called equation of state for an ideal gas and R, the universal gas constant. The equation of state for 1 mole of an ideal gas will therefore be:

$$PV = RT \qquad (\because \mu = 1)$$

Pressure of Gas: The force exerted per unit area by the molecules of a gas is called pressure.

i.e., $P = F/A$

In SI-system, the unit of pressure is Pascal (P_a).

Where $1 P_a = 1 Nm^{-2}$

According to kinetic theory of the gas, pressure exerted by the gas is given by

$$P = \frac{2}{3} N_o < \frac{1}{2} m v^2 >$$

Where $N_o = \frac{N}{V}$ is the number of molecules per unit volume.

The pressure of an ideal gas can be written as:

$$P = \frac{1}{3} \rho < v^2 >$$

Where ρ = Density of the gas and

Interpretation of Temperature: According to kinetic theory, the absolute temperature of an ideal gas is:

$$T = \frac{2}{3K} < \frac{1}{2} m v^2 >$$

Where $K = \frac{R}{N_A}$ is the Boltzman constant. Its value is $1.38 \times 10^{-23} JK^{-1}$.

Boyle's Law: The volume of a given mass of a gas is inversely proportional to the pressure provided the absolute temperature of the gas remains constant.

$$P \propto \frac{1}{V} \Rightarrow PV = \text{Constant}$$

In general, the Boyle's law can be written as:

$$P_1V_1 = P_2V_2 = \text{Constant}$$

If mass is not constant then:

$$\frac{P_1V_1}{m_1} = \frac{P_2V_2}{m_2} = \text{Constant}$$

Charle's Law: The volume of a given mass of a gas is directly proportional to the absolute temperature provided the pressure of the gas remains constant.

$$V \propto T \Rightarrow \frac{V}{T} = \text{Constant}$$

In general, the Charle's law can be written as:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \text{cons tan t}$$

Gas Equation: By combining the Boyle's and Charles' law, we obtained gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \text{constant}$$

Avogadro's Hypothesis and Universal Gas Constant: Under the same conditions of temperature and pressure, equal volumes of gas contain the same number of moles or kilo moles. The ideal gas equation is:

$$PV = nRT$$

Where n is the number of kilo moles of the gas and R is a constant and its value is the same for all gases. The value of universal gas constant is 8314 J / Kmol K or 8.314 J / mol K. The volume of 1 mole of a gas at S.T.P is 22.4 litres. One mole of any gas at S.T.P contains 6.02×10^{23} molecules.

Internal Energy: The sum of all forms of microscopic kinetic and potential energies of the molecules of a substance is termed as internal energy. The internal energy is directly proportional to temperature. When we heat a substance, the heat is converted to internal energy. The change in internal energy of the system depends on initial and final states of the system and is independent of the path followed.

i.e., $\Delta U = U_b - U_a$

Where U_a and U_b are the internal energies of the system at states a and b respectively.

The internal energy is similar to gravitational P.E. So like the gravitational potential energy, it is the change in internal energy and not its absolute value which is important.

Work and Heat: Both heat and work correspond to transfer of energy by some means. If the piston moves upward through a small distance Δy, then work done by the gas is:

$$W = P\Delta V$$

The work done by the gas is equal to area under the P-V diagram.

Thermal Expansion: The expansion on heating is called thermal expansion. The increase in length on heating is called linear expansion. The increase in length when heated through temperature ΔT is given by:

$$\Delta L = \alpha L_o \Delta T$$

The coefficient of linear expansion 'α' is defined as the change in length per unit original length per kelvin rise in temperature.

$$\alpha = \frac{\Delta L}{L_o \Delta T}$$

SI unit of coefficient of linear expansion is K^{-1}. If L_0 is the length of the rod at $0\,^0C$ then its length at temperature T is given by:

$$L = L_o(1 + \alpha\Delta T)$$

The increase in volume on heating is called volume expansion. The coefficient of volume expansion 'β' is defined as the change in volume per unit original volume per kelvin rise in temperature.

$$\beta = \frac{\Delta V}{V_o \Delta T}$$

SI unit of coefficient of volume expansion is K^{-1}. If V_0 is the volume of the box at $0\,^0C$ then its volume at temperature T is given by:

$$V = V_o(1 + \beta\Delta T)$$

The coefficient of volume expansion 'β' is three times the coefficient of linear expansion.

i.e., $\beta = 3\alpha$

Effect of Thermal Expansion: While laying railway tracks, some gaps are to be left between successive lengths of rails to allow for expansion during summer. In the construction of a bridge, the ends of the steel girders are not fixed but are placed on the rollers so that they expand or contract freely. Cement floors or concrete roads are laid in small pieces with gaps in between to allow for expansion in summer.

App[illegible]ations of Thermal Expansion: Thermal expansion has very useful applications. Most of the applications employ a bimetallic strip. It is a thin strips of different metals welded together. In bimetallic strip, one metal expands or contracts more than the other when heated or cooled. Bimetallic strip is used in bimetallic thermometer, thermostat that are used in electric iron and geyser.

Molar Specific Heat of a Gas:

Specific Heat: The amount of heat required to raise the temperature of 1 kg of substance through 1 k. It is denoted by C and is given by

$$c = \frac{\Delta Q}{m\Delta T}$$

The SI-unit of specific heat is $J\ Kg^{-1}\ K^{-1}$.

Molar Specific Heat: The amount of heat required to raise the temperature of 1 mole of substance through 1 K". It is denoted by C and is given by:

$$C = \frac{\Delta Q}{n\Delta T}$$

The SI-unit of molar specific heat is $J\ mol^{-1}K^{-1}$. One kilogram of different substance contains different number of molecules. Therefore, the specific heat of different substance will be different. One mole of every substance contain equal number of molecules (ie $N_A = 6.02 \times 10^{23}$). Therefore the molar specific heat of different substance will nearly be same with few exceptions only.

Molar Specific Heat at Constant Volume: The amount of heat required to raise the temperature of one mole of gas through 1k at constant volume. It is denoted by C_V and is given by

$$C_v = \frac{\Delta Q_v}{\Delta T}$$

Molar Specific Heat at Constant Volume: The amount of heat required to raise the temperature of one mole of gas through 1k at constant pressure. It is denoted by C_p and is given by

$$C_p = \frac{\Delta Q_p}{\Delta T}$$

The molar specific heat at constant pressure C_p is greater than the molar specific heat at constant volume C_V by an amount equal to universal gas constant R.

$$C_p - C_V = R$$

The ratio of C_p and C_V is constant and is equal to γ.

$$\gamma = \frac{C_p}{C_v}$$

Where
$\gamma = 1.67$ for monoatomic gas
$\gamma = 1.4$ for diatomic gas
$\gamma = 1.3$ for polyatomic gas

Thermodynamics:

(i) The branch of Physics, which deals with the conversion of heat into other forms of energy, is known as Thermodynamics.

(ii) A system whose state is completely defined by the variables like Pressure (P), Volume (V), Temperature (T), Internal energy (U), is called a **thermodynamic system.**

(iii) The variables P, V, T, U whose knowledge specifies the state of a thermodynamical system, are called as **thermodynamic variables.**

(iv) All the variables P, V, T, U are not independent as relations, like $PV = \mu RT$, $U = \frac{3}{2}\mu RT$, connecting these variables, exist.

(v) One can select pressure P and volume V as two independent thermodynamical variables. A knowledge of these two determines the state of a thermodynamical system because other variables can be worked out from the knowledge of P and V.

(vi) A P-V diagram for a system is called an **indicator diagram**. Each dot in a P-V diagram represents a possible state of the system.

(vii) A curve drawn between two points on the indicator diagram shows a **thermodynamic process.**

(viii) **The area under a curve on P-V diagram shows work done on or by the system.**

(ix) **Work done on or by a gas or system depends upon both the initial state, final state and the path adopted between these two states.**

(x) Like work done, heat exchanged by the system or a gas also depends upon both the initial state, the final state and the path.

(xi) **Change in internal energy of a gas depends only upon the initial and the final state but not on the path.** It is a **unique function** of the point on the indicator diagram.

Different Types of Thermodynamical Processes:

(i) **Isobaric process:**

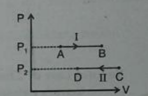
(a) It is a thermodynamic process in which pressure is kept constant.

(b) The equation of state for the process is: **(V/T) = constant.**

(c) **In isobaric compression,** temperature decreases and internal energy flows out in the form of heat energy, while in **isobaric expansion,** temperature increases and heart flows into the system.

(d) The amount of heat energy ΔQ transferred is given by:

$$\Delta Q = \mu C_p \Delta T \qquad (\mu = \text{number of moles})$$



(e) In the adjoining figure, graphs I and II represent isobaric expansion and compression respectively.

(f) **The slope of the isobaric curve on a P-V diagram is zero.**

(g) Isobaric expansion of the volume of a gas is given by:

$$V_1 = V_0(1 + \gamma_v t)$$

where $\gamma_v = (1/273)$ per °C = Coefficient of volume expansion

(ii) **Isochoric (isometric) process:**

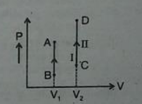
(a) It is a thermodynamic process in which the volume of the system is kept constant.

(b) The equation of state for the process is: **(P/T) = constant.**

(c) For increasing (decreasing) the pressure of a gas at constant volume, its temperature must be increased (decreased) by adding (taking out) heat energy into (from) the system.

(d) For isochoric process:

$$\Delta Q = \mu C_v \Delta T$$



(e) In the adjoining figure, graphs I and II represent isometric decrease in pressure at volume V_1 and isometric increase in pressure at volume V_2 respectively.

(f) **The slope of the isometric curve is infinite on a P-V diagram.**

(g) Isometric expansion of the pressure of a gas is given by:

$$P_t = P_0(1 + \gamma_p t)$$

where $\gamma_p = (1/273)$ per °C = 0.0037 per °C = Coefficient of pressure expansion

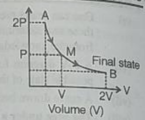
(iii) **Isothermal process:**

(a) It is a thermodynamical process in which the temperature of the system remains constant.

(b) The equation of state for the process is: **PV = constant.**

(c) During isothermal expansion of a gas, its volume increases while pressure decreases, while in isothermal compression, the volume decreases while pressure increases.

(d) The isothermal curve on P-V diagram is like a **hyperbola** and is shown in the adjoining figure.



(e) The slope of the isothermal curve at any point M is given by:

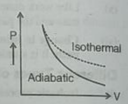
$$\frac{dP}{dV} = -\left(\frac{P}{V}\right)$$

It is negative and is equal in magnitude to the ratio of P and V at that point.

(f) In an isothermal process, heat may go into or may come out of the system to maintain constant temperature.

(iv) **Adiabatic process:**

(a) It is a process in which heat exchanged by the system to or from the surroundings is zero, i.e., $\Delta Q = 0$.

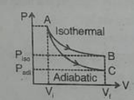


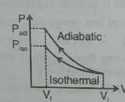
(b) The equation of state for this process is: $\mathbf{PV^{\gamma} = constt.}$ where γ is the ratio of specific heats of the gas.

(c) The adiabatic curve on the P-V diagram is shown in the adjoining figure. The slope of the curve at any point is given by:

$$\frac{dP}{dV} = -\gamma\left(\frac{P}{V}\right)$$

Slope of adiabatic curve is more in magnitude in comparison to the slope of the isothermal curve.





Second Law of Thermodynamics:

(i) **Kelvin's statement:** It is impossible for an engine operating in a cyclic process to extract heat from a reservoir and convert it completely into work, i.e., whole of heat can never be converted into work though whole of work can be converted into heat, i.e., **a perfect heat engine can never be constructed.**

(ii) **Clausius statement:** It is impossible for a self-acting machine unaided by an external agency to transfer heat from a cold to hot reservoir, i.e., **heat by itself cannot pass from a colder to hotter body**.

Carnot Heat Engine:

(i) **Engine:** It consists of four parts: (a) a cylinder with perfectly insulating walls and a perfectly conducting base containing a perfect gas as working substance and fitted with an insulating frictionless piston; (b) a source of infinite thermal capacity maintained at a constant higher temperature T_H; (c) a sink of infinite thermal capacity maintained at constant lower temperature T_L, and (d) a perfectly non-conducting stand for cylinder.

(ii) **Carnot cycle:** It consists of four operations in succession: (a) isothermal expansion at higher temperature T_H (b) adiabatic expansion between temperatures T_H and T_L (c) isothermal compression at constant lower temperature T_L and (d) adiabatic compression between temperatures T_L and T_H.

(iii) **Efficiency of the engine:** $\eta = 1 - \frac{T_L}{T_H} = 1 - \frac{Q_2}{Q_1}$

(a) η depends only on temperatures of source and sink and is independent of all other factors.

(b) All reversible heat engines working between same temperatures are equally efficient and no heat engine can be more efficient than Carnot engine.

(c) As on kelvin scale, temperature can never be negative and T_H and T_L are finite, efficiency of a heat engine is always lesser than unity, i.e., whole of heat can never be converted into work which is in accordance with second law.

Law of Heat Exchange: In any heat transfer, the total heat lost by hot body is equal to the total heat gained by cold body.

i.e., Heat lost hot body = Heat gained cold body

First Law of Thermodynamics: In any thermodynamic process, when heat is added to a system, this energy appears as an increase in the internal energy stored in the system plus the work done by the system on its surroundings". According to law of conservation of energy, we can write:

$$Q = (U_2 - U_1) + W \quad \text{or} \quad Q = \Delta U + W$$

Where $\Delta U = U_2 - U_1$ is change in internal energy of the system.

Draw Back of First Law of Thermodynamics: First law of thermodynamics tells us that heat energy can be converted into equivalent amount of work, but it is silent about the conditions under which this conversion takes place and about the direction of flow of heat.

Applications of First Law of Thermodynamics:

Isothermal Process: A process in which temperature of the system remains constant is called isothermal process.

i.e., $T = \text{Constant} \Rightarrow \Delta U = 0$

For isothermal process, first law of thermodynamics becomes:

$$Q = W$$

When the gas expends isothermally, the work (W) is done by the gas, so heat Q must be supplied to it. When the gas is compressed isothermally, the work is done on the gas. Thus the gas rejects heat Q to keep its temperature constant. The P-V graph of an isothermal process is a curve known as isotherm. It is like a hyperbola. In an isothermal process, the Boyle's law is applicable.

i.e., $P_1V_1 = P_2V_2 = \text{Constant}$

It means that when a gas expends or compresses isothermally, the product of its pressure and volume during the process remains constant.

Isochoric Process: A process in which volume of the system remains constant is called isochoric process.

i.e., $V = \text{Constant} \Rightarrow \Delta W = 0$

For isochoric process, first law of thermodynamics becomes:

$$Q = \Delta U$$

The heat supplied to gas during isochoric process increases the temperature of the gas only. The P-V graph of an isochoric process is a curve known as isochor. It is a straight line parallel to pressure axis.

Isobaric Process: A process in which pressure of the system remains constant is called isobaric process.

i.e., $P = \text{Constant}$

For isobaric process, first law of thermodynamics becomes

$$Q = \Delta U + W$$

When the gas is heated at constant pressure, a part of the heat supplied is used to increase the temperature of the gas and the remaining part is used by the gas to do work on its surroundings during expansion. The P-V graph of an isobaric process is a curve known as isobar. It is a straight line parallel to volume axis.

Adiabatic Process: A process in which no heat enters or leaves a system is called an adiabatic process.

i.e., $\text{Heat} = Q = 0 \Rightarrow \Delta S = 0 \Rightarrow \text{Entropy} = \text{Constant}$

When a gas expands adiabatically, the temperature of the gas decreases because work is done at the cost of internal energy, so cooling takes place in the system. When gas is compressed adiabatically, its temperature increases because work is done on the gas, so heating effect takes place in the system. In case of adiabatic changes, the following relation is satisfied.

$$PV^{\gamma} = \text{Constant}$$

The P-V graph of an adiabatic process is a curve known as adiabat.

Examples of Adiabatic Process: Adiabatic change takes place rapidly:

- The rapid escape of air from a burst tyre.
- The rapid expansion and compression of air through which a sound wave is passing.
- Cloud formation in the atmosphere.

An adiabat is steeper than an isotherm.

Reversible and Irreversible Processes:

Reversible Process: The process which can be retraced in exactly reverse order with out producing any change in the surroundings is called reversible process.

Examples: Although no actual change is completely reversible, however

- The process of liquefaction and evaporation of a substance performed slowly, are practically reversible.
- The slow compression of a gas in a cylinder is reversible process as the compression can be changed to expansion by slowly decreasing the pressure on the piston to reverse the operation.

Irreversible Process: A process which cannot be retraced in the backward direction by reversing the controlling factors is called an irreversible process.

All changes which occur suddenly are irreversible.

Examples:

- Dissipation of energy in friction is irreversible process.
- Dissipation of energy through conduction, convection and radiation are irreversible process.
- The explosions and collisions are highly irreversible process.

Cycle: A process which brings the system back to its initial condition is called a cycle. In cyclic process, there is no change in the values of state variable such as P, V, T, U and S.

Reversible Cycle: A reversible cycle is the one in which all the changes are reversible.

Heat Engine: A device which converts heat energy into mechanical work is called heat engine. Every heat engine absorbs heat from a hot body called source, converts a part of it into useful mechanical work and rejects the remaining part of heat to a cold body called sink. The efficiency of a heat engine is given by:

$$\eta = 1 - \frac{Q_2}{Q_1}$$

Since, $Q_2 \neq 0$, therefore the efficiency of heat engine cannot be 100 %.

Importance of Second Law of Thermodynamics: The second law of thermodynamics is concerned with the circumstances in which heat can be converted into work and direction of flow of heat. The second law deals with the practical problems regarding the conversion of heat energy into work.

Second Law of Thermodynamics: It can be stated in a number of different ways.

Kelvin's Statement: It is impossible to devise a process which may convert heat extracted from a single reservoir, entirely into work without leaving any change in the working system.

Clausius Statement: It is impossible to flow heat from a lower temperature to a higher temperature without the expenditure of external energy. This statement of second law is applied in the design of refrigerator and air conditioner.

Refrigerator: A heat engine that operates in reverse order and transfers heat from a cold reservoir to a hot reservoir is called a refrigerator. The coefficient of performance of a heat engine is defined as:

$$E = \frac{T_2}{T_1 - T_2}$$

If T_2 is greater than coefficient of performance of the refrigerator and air conditioner decreases.

Carnot Engine and Carnot's Theorem: Sadi Carnot in 1840 introduced an ideal engine which is free from friction and other heat losses and has maximum possible efficiency. This engine is called Carnot engine.

Carnot Cycle: A Carnot cycle consists of two isothermal and two adiabatic processes:

- Isothermal Expansion
- Adiabatic Expansion
- Isothermal Compression
- Adiabatic Compression

Thermal and mechanical equilibrium is maintained all the time so that each process is perfectly reversible. The area under the PV diagram of the Carnot engine represents the total work done by the engine in one cycle.

Efficiency of Carnot Engine: The efficiency of the Carnot engine is defined as:

$$\eta = \frac{\text{Output}}{\text{Input}} = \frac{\text{Work done}}{\text{Heat absorbed}}$$

$$\eta_c = 1 - \frac{Q_2}{Q_1}$$

As $$\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$$

In this case, we have:

$$\eta_c = 1 - \frac{T_2}{T_1}$$

The efficiency is usually expressed in percentage, in this case

$$\text{Percentage efficiency} = \eta = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

The efficiency of Carnot engine depends on the temperature of hot and cold reservoirs. It is independent of the nature of working substance.

The efficiency of the engine is 100 %, when sink is at absolute zero, but it is impossible to achieve the temperature of absolute zero, so the efficiency of Carnot engine is less then one or 100 %.

Carnot Theorem: No heat engine can be more efficient than a Carnot engine operating between the same two temperatures". **(OR)** All Carnot's engines operating between the same two temperatures have the same efficiency, irrespective of the nature of working substance". Actually, all real heat engines are less efficient then Carnot engine due to friction and other heat losses.

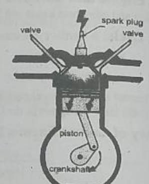
Thermodynamic Scale of Temperature: The Carnot cycle provides us the basis to define a temperature scale that is independent of material properties. This is known as thermodynamic scale of temperature. The thermodynamic scale of temperature is defined by choosing 273. 16 K as the absolute temperature of the triple point of water as one fixed point and absolute zero, as the other. The unit of thermodynamic scale is Kelvin. 1 Kelvin is defined as $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water. The unknown temperature T in Kelvin can be determined by using Carnot cycle $\frac{Q}{Q_3} = \frac{T}{T_3}$.

$$\Rightarrow \quad T = 273.16 \frac{Q}{Q_3}$$

This scale is independent of the property of the working substance, hence it can be applied at very low temperature.

Triple Point: It is a state in which ice, water and vapours co-exist in equilibrium and it occurs uniquely at one particular pressure and temperature. The temperature 273.16 K is chosen as triple point of water.

Petrol Engine: All the engines are based on principle of a Carnot cycle. A typical four stroke petrol engine also under goes four successive processes in each cycle.



- Charging stroke
- Compression Stroke
- Power Stroke
- Exhaust Stroke

The actual efficiency of properly tuned engine is usually not more than 25 % to 30 % because of friction and other heat losses.

Diesel Engine: No spark plug is needed in the diesel engine. Diesel is sprayed into the cylinder at maximum compression. Because air is at very high temperature immediately after compression, the fuel mixture ignites on contact with the air in the cylinder and pushes the piston out ward. The efficiency of diesel engine is about 35 % to 40%.

Entropy: The concept of entropy was introduced by Rudolph Clausius to give quantitative basis for the second law of thermodynamics and for the development of thermodynamics. The entropy is thermal property of system which remains constant when no heat enters or leaves the system. Entropy is a state variable and it describes the unavailability of the energy from the system to do work. Entropy is a measure of degree of disorder of the system. If a system absorbs or rejects heat ΔQ at absolute temperature T, the change in entropy of the system is given by

$$\Delta S = \frac{\Delta Q}{T}$$

The change in entropy ΔS is positive when heat ΔQ is added to a system and negative when heat ΔQ is removed from the system. The SI unit of entropy is J/K or JK^{-1}. Link potential energy or internal energy, the absolute value of entropy cannot be determined. However the change in entropy of the system can be measured.

Second Law of Thermodynamics in Terms of Entropy: If a system undergoes a natural process, it will go in the direction that causes an increase in entropy of the system and its surrounding. In all natural process where heat flows from one system to another, there is always a net increase in entropy. This is another statement of 2^{nd} law of thermodynamics.

Law of Increase of Entropy: Entropy of the universe during any process either remains constant or increase.

i.e. $\Delta S_{universe} \geq 0$

Law of Degradation of Energy: In all real processes, when heat flows from one system to another, the opportunity to convert some heat into work is lost. When heat flows from one system to another, the energy is degraded from higher level where more energy is available for useful work to a lower level at which less or no energy is available for work". Entropy of a system remains constant during reversible process whereas it increases during an irreversible process. With the passage of time when the entropy of the universe becomes maximum, the temperature of all bodies becomes same. At this stage, the flow of heat from one body to another is stopped. This is called the heat death of the universe. The increase of entropy of universe represents the passage of time. Therefore, we can say that entropy can be considered as time arrow.

Environment Crisis as Entropy Crisis: The environmental crisis is an entropy or disorder crisis resulting from our futile efforts to ignore the second law of thermodynamics. According to second law of thermodynamics, any increase in the order in a system will produce an even greater increase in entropy or disorder in the environment.

- Thermal pollution of the environment means increase in the entropy.
- In addition to thermal pollution, the most energy transformation processes such as heat engines used for transportation and for power generation cause air pollution.
- In effect, all forms of energy production have some undesirable effects and in some cases all problems cannot be anticipated in advance.

ASSIGNMENT NO. 11

(1) **The centigrade and Fahrenheit scales will have the same reading when the temperature is:**
(a) 70° (b) −80° (c) −40° (d) 120°

(2) **The Fahrenheit and Kelvin scale will have the same reading when temperature is:**
(a) 370° (b) 574.25° (c) 414.5° (d) 388°

(3) **Fahrenheit scale was originally used in:**
(a) Meteorology (b) Clinical thermometer
(c) Clinical thermometer and meteorology (d) None of these

(4) **A gas which strictly obeys the gas laws under all conditions of temperature and pressure is called:**
(a) Real gas (b) Ideal gas (c) Inert gas (d) None of these

(5) **The motion of molecules in gases is:**
(a) Orderly (b) Random (c) Circular (d) All of these

(6) **At constant temperature, if the density of the gas is increased, its pressure will:**
(a) Decrease (b) Increase (c) Remains unchanged (d) None of these

(7) **If a molecule with momentum mv strikes a wall and rebound then the change in momentum will be:**
(a) −2 mv (b) Zero (c) 2 mv (d) mv

(8) **Given that $P = 10^4 N/m^2$, area of the piston = 0.1 m^2 and distance moved by the piston = 10^{-1} cm, then the work done by the gas is:**
(a) 1 J (b) 10^5 J (c) 10^4 J (d) 10 J

(9) **If C_v denotes molar specific heat at constant volume and ΔT is the change in temperature, then $C_v\Delta T$ gives:**
(a) Volume (b) Pressure (c) Energy (d) Entropy

(10) **If temperature of the sink is decreased, efficiency of a carnot engine:**
(a) Remains constant (b) Decreases (c) Increases (d) None of these

(11) **One degree of thermodynamic scale is equal to ———— of the temperature of triple point of water.**
(a) $\frac{1}{273}$th (b) $\frac{1}{100}$th (c) $\frac{1}{273.16}$th (d) $\frac{1}{32}$th

(12) **The unknown temperature T on thermodynamic scale in kelvin is given by the formula:**
(a) $T = 273.16\frac{Q}{Q_3}$ (b) $T = 32\frac{Q}{Q_3}$ (c) $T = 100\frac{Q}{Q_3}$ (d) $T = 273\frac{Q}{Q_3}$

(13) **A certain engine converts 20% of available heat energy into work. Then its efficiency will be:**
(a) 20% (b) 80% (c) 50% (d) None of these

(14) **Number of spark plugs needed in diesel engine is:**
(a) Four (b) Five (c) Six (d) None of these

(15) **Most motorbikes have ———— cylinder/s engine but cars usually have cylinders on the same crankshaft.**
(a) Four, six (b) One, four (c) Two, five (d) None of these

(16) **A constant volume gas thermometer works on:**
(a) Archimedes' principle (b) Pascal's law (c) Boyle's law (d) Charles' law

(17) **The ratio of coefficients of cubical expansion and linear expansion is:**
(a) 1 : 1 (b) 3 : 1 (c) 2 : 1 (d) None of these

(18) **When a copper ball is heated, the largest percentage in crease will occur in its:**
(a) Diameter (b) Area (c) Volume (d) Density

(19) **Sea animals are safe in winter in cold countries because of:**
(a) their body conditions (b) High specific heat of water
(c) Low conductivity of water (d) Anomalous expansion of water

(20) **The volume expansion coefficient is:**
(a) Equal to temperature
(b) Proportional to square root of temperature
(c) Inversely proportional to square root of temperature
(d) Inversely proportional to temperature

(21) **Heat is transferred most rapidly by the process of:**
(a) Conduction (b) Convection (c) Radiation (d) Combustion

(22) **When water is heated from 0°C to 10°C, its volume:**
(a) Increases (b) Decreases (c) Does not change (d) Data is insufficient

(23) **First law of thermodynamics concerns conservation of:**
(a) Heat (b) Work (c) Momentum (d) Energy

(24) **When 110 J of heat is added to a gaseous system, internal energy increases by 40 J; the amount of work done is:**
(a) 150 J (b) 70 J (c) 110 J (d) 40 J

(25) **Molar specific heat at constant volume C_V for a monoatomic gas is:**
(a) $\frac{3}{2}R$ (b) $\frac{5}{2}R$ (c) $\frac{6}{2}R$ (d) $\frac{4}{2}R$

(26) **A sink, that is a system where heat is rejected, is essential for the conversion of heat into work. From which law the above inference follows?**
(a) Zeroth (b) First (c) Second (d) Third

(27) **The first operation involved in a Carnot cycle is:**
(a) Isothermal expansion (b) Adiabatic expansion
(c) Isothermal compression (d) Adiabatic compression

(28) **An ideal heat engine exhausting heat at 77°C is to have a 30% efficiency. It must take heat at:**
(a) 127°C (b) 227°C (c) 327°C (d) 673°C

(29) **The work done in an adiabatic change in a particular gas depends upon only:**
(a) Change in volume (b) Change in pressure
(c) Change in temperature (d) None of these

(30) **The gas law $\frac{PV}{T}$ = Constant is true for:**
(a) Isothermal changes only (b) Adiabatic changes only
(c) Both isothermal and adiabatic changes (d) Neither for isothermal nor for adiabatic changes

(31) **The physical quantity which described the level of thermal energy in a body is:**
(a) Temperature (b) Heat energy (c) Pressure (d) Volume

(32) **The pressure exerted by the gas is directly proportional to:**
(a) Velocity of the molecule (b) Density of the gas
(c) Square of the density (d) Square root of the density

(33) **For an ideal gas system, the internal energy is directly proportional to:**
(a) Pressure (b) Volume (c) Density (d) Temperature

(34) **The change in internal energy of the system is positive, when the temperature of the system:**
(a) Increases (b) Decreases (c) Remains constant (d) None of the above

(35) **Water boils at 100°C, the corresponding temperature at Fahrenheit scale is:**
(a) 180°F (b) 200°F (c) 212°F (d) 273°F

(36) **A Celsius degree is larger than a Fahrenheit degree by:**
(a) 5/9 (b) 9/5 (c) 9/10 (d) 9/8

(37) **Absolute zero is considered as that temperature at which:**
(a) All liquids become gases (b) All gases become liquids
(c) Water freezes (d) All gases partially liquefied

(38) **At constant volume, the graph between P and T is:**
(a) Hyperbola (b) Parabola (c) Straight line (d) Ellipse

(39) **At constant temperature, if the pressure of the given mass of gas is doubled, then the density of the gas becomes:**
(a) Double (b) 1/4 of the original value
(c) 1/2 of the original value (d) Remains constant

(40) **An inflated tire suddenly bursts. As a result of this, the temperature of air:**
(a) Increases (b) Decreases
(c) May increase or decrease (d) Remains constant

(41) **When the gas expends isothermally, the work is:**
(a) Done on the gas (b) Done by the gas (c) Zero (d) Negative

(42) **The SI-unit of molar specific heat is:**
(a) $J\,mol\,K^{-1}$ (b) $J\,mol^{-1}K^{-1}$ (c) $J\,mol^{-1}K$. (d) $J\,mol^{-1}$

(43) **The co-efficient of linear expansion of platinum is $9 \times 10^{-6}\,C^{-1}$. Its coefficient of volume expansion is:**
(a) $3 \times 10^{-6}\,C^{-1}$ (b) $9 \times 10^{-6}\,C^{-1}$ (c) $18 \times 10^{-6}\,C^{-1}$ (d) $27 \times 10^{-6}\,C^{-1}$

(44) **The SI unit of entropy is:**
(a) $J\,K^{-1}$ (b) $J\,s^{-1}$ (c) $J\,K\,s^{-1}$ (d) $J\,K^{-2}$

(45) **The natural process tends to proceed towards a state of greater:**
(a) Order (b) Disorder
(c) Both order and disorder (d) Neither order nor disorder

(46) **Which of the following is not the function of state?**
(a) Internal energy (b) Entropy (c) Enthalpy (d) Mass

(47) **Entropy of universe during any natural process:**
(a) Increases (b) Increases or remains constant
(c) Decreases (d) Decreases or remains constant

(48) **When a sphere is heated, then the greatest increase is in its:**
(a) Radius (b) Circumference (c) Surface area (d) Volume

(49) **Net change in entropy of a system in a Carnot's cycle is:**
(a) Positive (b) Negative (c) Maximum (d) Zero

(50) **Area under the p-v graph of Carnot engine represents the:**
(a) Heat absorbed (b) Heat rejected (c) Total work done (d) All of the above

(51) **Temperature of gas is a measure of:**
(a) the average translational kinetic energy of the gas molecules
(b) the average potential energy of the gas molecules
(c) the average distance of the gas molecules
(d) the size of the gas molecules

(52) **A thermometric liquid which can be used to measure temperature between –40°C to 40°C is:**
(a) Water (b) Alcohol (c) Mercury (d) Phenol

(53) **The temperature at which the reading of a Fahrenheit thermometer will be double that of Centigrade thermometer is:**
(a) 160° (b) 180° (c) 32° (d) 100°

(54) **For measuring temperature near absolute zero, the thermometer used is:**
(a) Thermoelectric thermometer (b) Radiation thermometer
(c) Magnetic thermometer (d) Resistance thermometer

(55) **The absolute zero is the temperature at which:**
(a) Water freezes (b) All substances exist in solid state
(c) Molecular motion ceases (d) None of the above

(56) **Absolute zero (0 K) is that temperature at which:**
(a) Matter ceases to exist (b) Ice melts and water freezes
(c) Volume and pressure of a gas becomes zero (d) None of the above

(57) **The temperature on Celsius scale is 25°C. What is the corresponding temperature on the Fahrenheit scale?**
(a) 40°F (b) 77°F (c) 50°F (d) 45°F

(58) **The root mean square speed of the molecules of different ideal gases, maintained at the same temperature, are:**
(a) Same (b) Different (c) Zero (d) Infinity

(59) **'P' is the pressure and 'd' is the density of gas at constant temperature, then:**
(a) $P \propto \frac{1}{d}$ (b) $P \propto \frac{1}{d^2}$ (c) $P \propto d$ (d) $P \propto d^2$

(60) **The number of molecules per cc of a gas at S.T.P. is:**
(a) 2.68×10^{17} (b) 2.68×10^{19} (c) $22400 \times 6 \times 10^{23}$ (d) 6×10^{23}

(61) **In winter, the temperature of the inside wall of a room as compared to the temperature of air in the room is:**
(a) Lower (b) Higher (c) Same
(d) May be lower or higher depending upon atmospheric pressure

(62) **Pressure of a gas can be written as:**
(a) $1/3\ \rho V$ (b) $1/3\ V^2$ (c) $1/3\ \rho V^2$ (d) $1/3\ \rho^2 V$

(63) **One Kelvin is defined as:**
(a) 1/100 of boiling point of water (b) 1/273.16 of melting of ice
(c) 1/273.16 of boiling point of water (d) 1/273.16 of temperature of triple point of water

(64) **The value of Boltzmann's constant is:**
(a) 1.38×10^{-23} J/K (b) $1.38 \times 10^{+23}$ J/K
(c) 1.38×10^{-23} J/mole-K (d) 1.38×10^{-23} J/K mole-K

(65) **For a gas obeying Boyle's law if the pressure is doubled, the volume becomes:**
(a) Double (b) One half (c) Three fold (d) Remains the same

(66) **If co-efficient of linear expansion of a solid body is α, its co-efficient of cubical expansion will be approximately:**
(a) 2α (b) 3α (c) 2.5α (d) 4α

(67) **The SI units of specific heat are:**
(a) K cal $kg^{-1} K^{-1}$ (b) Cal $gm^{-1} C^{-1}$ (c) K. Cal $kg^{-1} C^{o-1}$ (d) J $kg^{-1} K^{-1}$

(68) **In an adiabatic process:**
(a) $Q = \Delta U + W$ (b) $Q = \Delta U$ (c) $Q = W$ (d) $Q = 0$

(69) **A system does 600 J of work and at the same time has its internal energy increased by 320 J. How much heat has been supplied?**
(a) 280 J (b) 920 J (c) 600 J (d) 20 J

(70) **No entropy change takes place in:**
(a) Isothermal process (b) Adiabatic process (c) Isobaric process (d) Isochoric process

ANSWERS

(1)	(c)	(2)	(b)	(3)	(c)	(4)	(b)	(5)	(b)
(6)	(b)	(7)	(a)	(8)	(a)	(9)	(c)	(10)	(c)
(11)	(c)	(12)	(a)	(13)	(a)	(14)	(d)	(15)	(b)
(16)	(d)	(17)	(b)	(18)	(c)	(19)	(d)	(20)	(d)
(21)	(c)	(22)	(d)	(23)	(d)	(24)	(b)	(25)	(a)
(26)	(c)	(27)	(a)	(28)	(b)	(29)	(c)	(30)	(c)
(31)	(a)	(32)	(b)	(33)	(d)	(34)	(a)	(35)	(c)
(36)	(b)	(37)	(b)	(38)	(c)	(39)	(a)	(40)	(b)
(41)	(b)	(42)	(b)	(43)	(d)	(44)	(a)	(45)	(b)
(46)	(d)	(47)	(b)	(48)	(d)	(49)	(d)	(50)	(c)
(51)	(c)	(52)	(c)	(53)	(b)	(54)	(c)	(55)	(c)
(56)	(c)	(57)	(b)	(58)	(a)	(59)	(c)	(60)	(b)
(61)	(a)	(62)	(c)	(63)	(d)	(64)	(a)	(65)	(b)
(66)	(b)	(67)	(d)	(68)	(d)	(69)	(b)	(70)	(b)

SOLUTION

(1) Let x be the required value

$$\frac{C}{100} = \frac{F-32}{180}$$
$$\frac{x}{100} = \frac{x-32}{180}$$
$$x = \frac{10}{18}(x-32)$$
$$x = \frac{5}{9}(x-32)$$
$$9x = 5x - 160$$
$$9x - 5x = -160$$
$$4x = \frac{-160}{4}$$
$$x = -40^\circ$$

(c) is correct

(6) As the expression for the pressure of gas

$$P = \frac{1}{3}\rho < V^2 >$$
$$P \propto \rho$$

(b) is correct

(8)
$$P = 10^4\ Nm^{-2}$$
$$A = 0.1\ m^2$$
$$\Delta y = 10^{-1}\ cm$$
$$\Delta y = \frac{10^{-1}}{100} = 10^{-3}\ m$$
$$\Delta V = A\,.\,\Delta y$$
$$\Delta V = (0.1)(10^{-3})$$
$$\Delta V = 10^{-4}\ m^3$$
$$W = P\Delta V$$
$$= 10^4(10^{-4})$$
$$W = 1\ J$$

(a) is correct

(17) As $\beta = 2\alpha$

$\therefore$ 3 : 1

(b) is correct

(30) $\frac{PV}{T}$ = Constant is true for all types of thermodynamics process

(c) is correct

ENTRY TEST

PHYSICS PART-II

Chapter 12

ELECTROSTATICS

KEY POINTS

Some Important Points Concerning Charge:

(i) The branch of physics concerning with the study of electric charges at rest is known as **electrostatics**.

(ii) Charges are two types, viz., positive charge and negative charge.

(iii) Charging a body implies transfer of charge (electrons) from one body to another. Positively charged body means loss of electrons, i.e., deficiency of electrons. Negatively charged body means excess of electrons. This also shows that **mass of a negatively charged body > mass of a positively charged identical body**.

(iv) **Conservation of charge:** In an isolated system, total charge (sum of positive and negative) remains constant, e.g.,

(a) $\gamma \rightarrow e^{+} + e^{-}$ (b) ${}_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4}$

(v) **Quantization of charge:**

(a) Charge on any body always exists in integral multiples of a fundamental unit of electric charge. This unit is equal to the magnitude of charge on electron ($1\ e = 1.6 \times 10^{-19}$ coulomb). So $Q = \pm ne$, where n is an integer and e is the charge of the electron.

(b) Millikan's oil drop experiment proved the quantization of charge or **atomicity of charge**.

(vi) Like charges repel each other while unlike charges attract each other. **Repulsion is a sure test of electrification**. A charged body may attract a neutral body or an oppositely charged body but it always repels a similarly charged body.

(vii) A body can be charged by means of (a) friction (b) conduction and (c) induction.

Electrostatics: The branch of Physics which deals with charges at rest is called electrostatics.

Coulomb's Law: Coulomb's force between two point charges is directly proportional to product of charges and inversely proportional to square of distance between them. Mathematically, $F = K\frac{q_1q_2}{r_2}$. Where K is constant and its value depends upon:

(i) System of units (ii) Medium between the charges

Coulomb gives the quantitative nature of force between two point charges in 1874 A.D. To find electrostatic force between two point charges coulomb used an apparatus called torsional balance. Coulomb's force always act along the line joining point charges. $K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^{9}\ Nm^2C^{-2}$. Permittivity of free space $\epsilon_0 = 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}$. Coulomb's force is a mutual force i.e., it forms action-reaction pair. When a dielectric (insulator) is placed between two point charges then coulomb's force decreases by a factor ϵ_r is $F_{med} = \frac{1}{4\pi\epsilon_0\epsilon_r}\frac{q_1q_2}{r^2}$. For air ϵ_r (relative permittivity) = 1.

(i) The force of attraction or repulsion between two point charges is directly proportional to the product of charges and inversely proportional to the square of the distance between them, i.e.,

$$F = \frac{q_1q_2}{d^2} \quad ; \quad F_{air} = \frac{1}{4\pi\varepsilon^0}\frac{q_1q_2}{d^2}$$

where ε_0 represents the permittivity of free space.

(ii) The SI unit of permittivity of the medium is coulomb^2/N-m^2 or farad/m, while dimensional formula is $[M^{-1}L^{-3}T^4A^2]$. Permittivity of free space is equal to 8.85×10^{-12} F/m.

(iii) Permttivity of the medium is the property of the medium that determines the number of electric lines of force passing through it.

(iv) $F_{medium} = \frac{1}{4\pi\varepsilon}\left(\frac{q_1q_2}{d^2}\right) = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\left(\frac{q_1q_2}{d^2}\right)$

So $\varepsilon_r = \frac{F_{air}}{F_{medium}}$ where, $\varepsilon_r = (\varepsilon/\varepsilon_0)$ = relative permittivity of the medium, ε_r is also known as dielectric constant (K) of the medium. It has got no units and no dimensions. **The dielectric constant of a metal is infinity.**

(a) Coulomb's electrostatic force may be attractive or repulsive but gravitational force is always attractive.

(b) Coulomb's electrostatic force depends on the medium between the two charges but gravitational force is independent of the medium between the two bodies.

(c) The ratio of the coulomb's force between two protons to the gravitational force between them separated by the same distance is 10^{39}.

Fields of Force: To describe the mechanism by which electric force is transmitted, there are two theories.

(i) Action at a distance effect.

(ii) Field theory or Field effect, Michael Faraday (1791–1867) introduced the concept of an electric field.

Electric intensity is force per unit charge placed at that point in the field of a charge.

$$\vec{E} = \frac{\vec{F}}{q} \quad \Rightarrow \quad \vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

$$\text{or} \quad E = K\frac{q}{r^2} \quad \Rightarrow \quad E \propto \frac{1}{r^2}$$

Electric intensity is a vector quantity.

Its unit is N/C.

Electric Field Lines: Electric field lines originate from positive charges and end on negative charges. The tangent to a field line at any point gives the direction of the electric field at that point. The lines are closer where field is strong, the lines are farther apart where field is weak. No two lines cross each other. The number of lines per unit area passing perpendicularly through an area is proportional to the magnitude of the electric field.

Electric Lines of Force:

(i) The line or a curve along which a test positive charge would travel if it is free to move in an electric field is known as electric line of force.

(ii) Electric field lines emerge from a positive charge and terminate into a negative charge.

(iii) Tangent to the field line at any point gives the direction of field at the point.

(iv) Electric lines of force never cross each other.

(v) The density of field lines is proportional to the strength of the field.

(vi) Near an isolated positive charge, the electric lines of force are directed radially outward, while near an isolated negative charge, the electric lines of force are directed radially inwards.

(vii) Electric field lines do not exist inside a conductor.

(viii) Electric field lines are always perpendicular to charged conducting surface.

(ix) Electric field lines never form closed loops.

(x) Electric field lines are always perpendicular to equipotential surface.

(xi) **In a uniform electric field, the electric lines of force are equidistant, parallel straight lines.**

(xii) The number of lines of force passing through unit area normal to direction of lines of force is known as intensity of the electrical field ($E = \phi/A$). If the lines of force are closer, the intensity of electric field is more and if the lines of force are far apart, the intensity of electric field is less.

(xiii) If a metallic solid sphere is placed in a uniform electric field, then the lines of force are normal to the surface at every point but they cannot pass through the conductor.

Applications of Electrostatics: Xerography (photocopier), inkjet printers and spray painting of car. Selenium is a photoconductor. Aluminium is an excellent conductor.

Electric Flux: No. of electric lines passing through a certain element of area is called flux.

$$\phi = \vec{E}\cdot\vec{A}$$

This formula is valid only for flat surface. Flux is a scalar quantity. S.I. unit of flux is Nm^{2}C^{-1} or JmC^{-1}.

When plane of surface is perpendicular to field line or vector area $\vec{A}$ is parallel to $\vec{E}$ i.e., angle between $\vec{E}$ and vector area $\vec{A}$ is 0°.

$$\therefore \quad \phi = EA\cos 0° \quad \Rightarrow \quad \phi = EA$$

∴ Flux is maximum.

When plane of surface is parallel to $\vec{E}$ or vector area $\vec{A}$ is perpendicular to $\vec{E}$ then $\theta = 90°$.

$$\therefore \quad \phi = EA\cos 90° = EA(0) = 0$$

∴ Flux is minimum.

When $\vec{A}$ is neither perpendicular nor parallel to field lines but is inclined at angle θ with lines, then

$$\phi = EA\cos\theta$$

Where θ is angle between vector area $\vec{A}$ and $\vec{E}$. Flux through a surface enclosing a charge is:

$$\phi_e = \frac{q}{\epsilon_0}$$

Total flux through a closed surface does not depend upon the shape of the closed surface. It depends upon the medium and the charge enclosed.

Gauss's Law: The flux through any closed surface is $\frac{1}{\epsilon_0}$ times the total charge enclosed in it, called Gauss's law.

$$\phi_e = \frac{1}{\epsilon_0}(Q)$$

Intensity of field inside a hollow charged sphere is zero i.e., $\vec{E} = \vec{0}$. Surface charge density $\sigma = \frac{Q}{A}$. Its unit is C/m^2. Electric intensity due to an infinite sheet of charge (positive) is:

$$E = \frac{\sigma}{2\epsilon_0} \quad \text{or} \quad \vec{E} = \frac{\sigma}{2\epsilon_0}\hat{r}$$

$\hat{r}$ is directed away from sheet. Electric intensity due to an infinite sheet of charge (negative) is:

$$E = -\frac{\sigma}{2\epsilon_0} \quad \text{or} \quad \vec{E} = -\frac{\sigma}{2\epsilon_0}\hat{r}$$

$\hat{r}$ is directed towards the sheet. Electric intensity between two oppositely charged parallel plates is:

$$E = \frac{\sigma}{\epsilon_0} \quad \text{or} \quad \vec{E} = \frac{\sigma}{\epsilon_0}\hat{r}$$

$\hat{r}$ is directed from positive to negative plate.

Electric Potential: The potential difference between two points A and B in an electric field is defined as the work done in carrying a unit positive charge from A to B against electric field while keeping the charge in equilibrium.

$$V = \frac{W}{q}$$

Its unit is J/C which is called volt. A potential different of 1 volt exists between two points if work done in moving a unit positive charge from one point to other, keeping equilibrium, is one joule, i.e., 1V = 1J/1C. Electric potential is a scalar quantity. Electric potential at any point (Absolute potential) in an electric field is equal the work done in bringing a unit positive charge from infinity to that point keeping it in equilibrium. The quantity $\frac{\Delta v}{\Delta r}$ gives the maximum value of the rate of change of potential with distance because rate of change of potential with distance because the charge has been moved along a field line along which the distance between the two plates is minimum. It is known as potential gradient.

$$E = \frac{-\Delta v}{\Delta r}$$

Negative sign shows direction of $\vec{E}$ is along the decreasing potential. Other unit of electric intensity is V/m. Electric potential at a point due to a point charge or absolute potential is (at a pt. r from q)

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

Electron Volt: The amount of energy acquire or lost by an electron as it transverses a potential difference of one volt.

$$\therefore \quad 1\,eV = 1.6 \times 10^{-19}\,J$$

Electron volt is unit of energy in atomic physics.

Comparison between Electric and Gravitational Forces:

- Both are conservative.
- Both forces vary inversely with square of the distance between charges or two masses.
- Gravitational force is a very weak force as compared to electrostatic force.
- Electrostatic force could be attractive or repulsive but gravitational force is only attractive.
- Electrostatic force is medium dependent while gravitational force lacks this property.

Charge on an Electron by Millikan's Method: Millikan's oil drop method is used to find charge on an electron (1909). Minimum value of charge on a charged body is 1.6×10^{-19} C.

Capacitor MCAT: A capacitor is a device that can store charge.

$$Q = CV$$

Ability of a capacitor to store charge is called capacitance.

$$C = \frac{Q}{V}$$

S.I unit of capacitance is C/V called farad. One farad is the capacitance of a capacitor which stores one coulomb of charge when potential difference across the capacitor is 1 volt.

$$\therefore \quad 1\,F = \frac{1\,C}{1\,V}$$

Capacitance of a Parallel Plate Capacitor MCAT: Capacitance of a parallel plate capacitor is:

$$C_{air} = \frac{A\epsilon_0}{d}$$

Capacitance of a capacitor increases by a factor ϵ_r if a dielectric is placed between its plates. Capacitance increases due to presence of dielectric due to electric polarization of dielectric. When a dielectric is placed between plates of a charged capacitor, potential difference decreases.

$$\text{As} \quad C = \frac{Q}{V}$$

So C increases. The molecules of the dielectric under the action of electric field become dipoles and the dielectric is said to be polarized.

Energy Store in a Capacitor MCAT: A capacitor can also store energy in electric field.

$$E = \frac{1}{2}CV^2$$

Energy stored in terms of electric field.

$$E = \frac{1}{2}\epsilon_r\epsilon_0 E^2 Ad$$

$$\text{Energy density} = \frac{1}{2}\epsilon_r\epsilon_0 E^2$$

Charging and Discharging of Capacitor MCAT: For a R-C series circuit RC = t (time constant). In one time constant a capacitor is charges or discharges 63% (0.63 times of its equilibrium value). For larger values of R and C a capacitor charges or discharges slowly. For smaller values of R and C a capacitor charges or discharges rapidly.

Series Grouping of Capacitors MCAT:

(i) If a number of capacitors are connected end to end, so that all the capacitors will get the same charge Q, then they are said to be connected in series, i.e.,

$$Q_1 : Q_2 : Q_3 = 1 : 1 : 1$$

(ii) In series grouping, if V_1, V_2, V_3 are the potential differences across the capacitors, then applied potential difference

$$V = V_1 + V_2 + V_3$$

(iii) Hence, $\frac{Q}{C_s} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$ or $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

(iv) Here, effective capacitance C_s is even less than the least of the least of the individual capacitances.

(v) $V_1 : V_2 : V_3 = \frac{1}{C_1} : \frac{1}{C_2} : \frac{1}{C_3}$

(vi) If n identical capacitors, each of capacity C, are joined in series, then the effective capacitance is given by: $C_s = (C/n)$.

Parallel Grouping of Capacitors MCAT:

(i) If a number of capacitors are connected between the same two terminals, so that the potential difference across every one of them is same, then they are said to be connected in parallel, i.e.,

$$V_1 : V_2 : V_3 = 1 : 1 : 1$$

(ii) Here, $q = q_1 + q_2 + q_3$ or $C_pV = C_1V + C_2V + C_3V$ or $C_p = C_1 + C_2 + C_3$.

(iii) Here, the effective capacitance C_p is equal to the sum of their individual capacities.

(iv) $q_1 : q_2 : q_3 = C_1 : C_2 : C_3$

(v) If n capacitors of capacity C are connected in parallel, then the equivalent capacity is given by: $C_p = nC$.

(vi) If C_p is the effective capacity when n identical capacitors are connected in parallel and C_s is their effective capacity when connected in series, then $(C_p/C_s) = n^2$.

Electric Capacitance MCAT:

(i) The capacitance of a conductor is defined as the ratio of the charge given to the conductor to the potential raised due to it, i.e., C = Q/V (Q is measured in coulomb and V in volt).

(ii) The SI unit of capacitance is farad. If one coulomb of charge given to a conductor raises its potential by 1 volt, then the electrical capacitance is said to be 1 farad.

(iii) 1 millifarad = 10^{-3} farad; 1 microfarad = 10^{-6} farad and 1 picofarad = 10^{-12} farad.

(iv) The dimensional formula for electrical capacitance is $[M^{-1}L^{-2}T^{-4}A^2]$.

(v) The electrical capacitance of a spherical conductor is $4\pi\varepsilon_0 R$ or $R/9 \times 10^9$, where R is the radius of conductor.

(vi) The electrical capacitance of the earth is $(6.3 \times 10^6)/(9 \times 10^9) = 7 \times 10^{-4}$ farad.

(vii) If two spherical conductors, one of solid sphere and the other of hollow sphere of equal radii are charged to the same potential, then the charges on them are in the ratio 1 : 1, since their electrical capacitances are same.

(viii) **Electric potential energy stored in a charged capacitor:**

(a) The capacitor stores charge as well as electric potential energy, which is given by:

$$U = \frac{Q^2}{2C} = \frac{1}{2}QV = \frac{1}{2}CV^2$$

(b) The energy is stored in the electric field between the plates of a charged capacitor.

(c) The energy stored per unit volume in the electric field between the plates is called **energy density** (u). It is given by:

$$u = \frac{1}{2}\varepsilon_0 E^2 = \frac{\sigma^2}{2\varepsilon_0}$$

where σ represents surface charge density on the plates of capacitor.

(ii) Force of attraction between oppositely charged plates of a capacitor is given as:

$$F = \frac{Q^2}{2\varepsilon_0 A} \quad \text{or} \quad F = \frac{1}{2}\varepsilon_0 E^2 A$$

Force per unit area, i.e., $\frac{F}{A} = \frac{\sigma^2}{2\varepsilon_0}$.

Electric Potential Energy:

(i) There is always a mutual potential energy of charge, due to an electric force between them.

(ii) The electric potential energy of a system of fixed point charges is equal to the work done by an external agent to assemble the system, bringing each charge in from an infinite distance.

(iii) A charged particle placed in an electric field has potential energy because of its interaction with the electric field.

(iv) It two charges q_1 and q_2 are separated by a distance r, then the potential energy of the system is $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$.

Equipotential Surface MCAT:

(i) The locus of all points which are at the same potential is known as **equipotential surface.**

(ii) No work is required to move a charge one point to another on equipotential surface.

(iii) Near an isolated point charge the equipotential surface is a sphere.

(iv) The work required to move a unit positive charge around a charge Q along a circle of radius r is equal to zero.

(v) The electric lines of force are always normal to the equipotential surface, since E should not have a component along the equipotential surface.

(vi) The surface of a charged conductor is always an equipotential surface whatever may be its shape.

Some Important Points Concerning Electric Potential:

(i) The absolute electric potential at any point in the electric field is defined as the work done per unit positive charge required to move the test charge from infinity to that point.

(ii) SI unit of potential or potential difference is volt or joule/coulomb and dimensional formula is $[M^1L^2T^{-3}A^{-1}]$.

(iii) Potential difference between two points A and B in an electric field is defined as the work required to move a unit positive charge from the point A to the point B against the intensity of the electric field.

$$V_B - V_A = \frac{W_{AB}}{q_0} \quad \text{(where } q_0 \text{ is the test charge)}$$

(a) If W_{AB} is +ve, $V_B > V_A$ (b) If W_{BA} is −ve, $V_B < V_A$ and (c) If W_{AB} is zero, $V_B = V_A$.

(iv) The potential at a point due to positive charge is positive potential while due to negative charge, it is negative potential.

(v) When a positive charge is placed in an electric field, it experiences a force which drives it from points of higher potential to points of lower potential. On the other hand, a negative charge experiences a force driving it from lower to higher potential.

(vi) The work done is moving a charge between two points in an electric field is independent of the path followed between these two points, since the electric field is a conservative field.

(vii) (a) If a charged particle is accelerated through a potential difference of V volts, then the kinetic energy acquired by the particle is given by:

$$eV = (1/2)\,mv^2$$

(b) If a proton or an electron is accelerated from rest through the same potential difference, then they gain an equal amount of kinetic energy (= 1 eV).

(c) The ratio of the kinetic energies acquired by two charged particles accelerated from rest through the same potential difference are in the ratio of their charges, i.e., $(KE)_1 : (KE)_2 = q_1 : q_2$.

ASSIGNMENT NO. 12

(1) **The value of K in SI system of units:**
(a) $9\times10^9\ Nm^2/c^2$ (b) $9\times10^{10}\ Nm^2/c^2$ (c) $9\times10^{-9}\ Nm^2/c^2$ (d) $9\times10^9\ NC/m^2$

(2) **The value of permittivity of free space:**
(a) $8.85\times10^{-12}\ C^2/Nm^2$ (b) $8.85\times10^{-12}\ C^2m^2/N$
(c) $8.85\times10^{-12}\ Nm^2/C$ (d) $8.85\times10^{-11}\ Nm^2/C^2$

(3) **The number of electrons in one coulomb charge is equal to:**
(a) 6.2×10^{18} electrons (b) Zero electrons
(c) 1.6×10^{-22} electrons (d) 6.2×10^{21} electrons

(4) **The electrostatic force of repulsion between two electrons at 1 metre is:**
(a) 9×10^9 N (b) 1.44×10^{-9} N (c) 2.30×10^{-28} N (d) 1 N

(5) **The SI units of permittivity are:**
(a) $N.m/C^2$ (b) $C^2/N.m^2$ (c) $N.m^2/C^2$ (d) N.m/C

(6) **The electric force between two charges placed in air is 2 Newton. When placed in a medium of $\epsilon_r = 80$, the force reduced to:**
(a) 0.029 N (b) 0.025 N (c) 0.03 N (d) 0.04 N

(7) **The value of ϵ_r for various dielectrics is always:**
(a) Larger than unity (b) Less than unity (c) Equal to unity (d) None of above

(8) **A metallic hallow sphere of 8cm diameter is charged with 4×10^{-8} C. The potential on its surface will be:**
(a) 90 volts (b) 9 volts (c) 9000 volts (d) 900 volts

(9) **An important part of inkjet printer is:**
(a) Deflection plates (b) Toner (c) Drum (d) None of these

(10) **The electric intensity at a distance of 1m from the point charge is 1 μC is:**
(a) 9×10^9 N/C (b) 9×10^6 N/C (c) 9×10^3 N/C (d) 9 N/C

(11) **The SI unit of electric flux is:**
(a) Nm^2/C^2 (b) Nm/C^2 (c) Nm^2/C (d) Nm/C

(12) **If a oil droplet between two oppositely charged parallel plates is suspended then:**
(a) $F_g > F_e$ (b) $F_g < F_e$ (c) $F_g = F_e$ (d) None of these

(13) **In case of a parallel plate capacitor, $\frac{1}{2}\epsilon_r\epsilon_0 E^2$ gives:** MCAT
(a) Energy density (b) Energy per unit volume
(c) Energy stored in a capacitor (d) Both (a) and (b)

(14) **The potential at a point situated at a distance of 50 cm from a charge of 5 μC is:**
(a) 9×10^4 volts (b) 9×10^2 volts (c) 9×10^{-2} volts (d) 9×10^{-4} volts

(15) **A charge of 0.10 C accelerated through a potential difference of 1000 volt acquires K.E.**
(a) 100 J (b) 200 J (c) 100 eV (d) 400 J

(16) **A force of 0.01 N is exerted on a charge 1.2×10^{-5} C at a certain point. The electric field at that point is:**
(a) 1.2×10^4 N/C (b) 1.2×10^4 C/N (c) 8.3×10^2 N/C (d) 8.3×10^{-2} N/C

(17) **Two metallic sphere of radius 2 cm and 4 cm get equal quantity of charge. Which has greater surface charge density?**
(a) 2^{nd} sphere (b) Both have same (c) First sphere (d) None of these

(18) **Which one of the following correctly names two types of conductor in both of which the motion of positive ions contributes to the transfer of charge?**
(a) Metals and liquid electrolytes (b) n-type semiconductors and liquid electrolytes
(c) n-type semiconductors and ionised gases (d) Liquid electrolytes and ionised gases

(19) **There are two charges of 1 μC and 5 μC placed at certain distance. The ratio of the forces acting on each other will be:**
(a) 1 : 5 (b) 1 : 1 (c) 5 : 1 (d) 1 : 25

(20) **Two opposite charges, each of magnitude 10^{-9} μC are separated by a distance 9 m. The electric potential at a point mid way between them is:**
(a) 4 V (b) 0 (c) 9×10^{-9} V (d) 9×10^{9} V

(21) **A particle carrying a charge of 2e falls through a potential difference of 3 V. The energy acquired by it is:**
(a) 6.0 eV (b) 9.6×10^{-19} J (c) 1.5 eV (d) 0.66 eV

(22) **Unit of dielectric constant of a medium is:** MCAT
(a) Coulomb/Newton-metre (b) Newton-metre^2/Coulomb^2
(c) Coulomb^2/(Newton-metre)^2 (d) None of the above

(23) **The electric field due to a charge at a distance of 3 m from it is 500 N/coulomb. The magnitude of the charge is:**
(a) 2.5 μC (b) 1.5 μC (c) 2.0 μC (d) 0.5 μC

(24) **The dielectric constant K of an insulator can be:** MCAT
(a) −1 (b) Zero (c) 0.5 (d) 5

(25) **When a proton is accelerated through 1 V. then its KE will be:**
(a) $\left(\frac{1}{1840}\right)$ eV (b) 1840 eV (c) 1 eV (d) 1840 C^2 eV

(26) **The kinetic energy of an electron, which is accelerated in the potential difference of 100 V is:**
(a) 1.6×10^{-17} J (b) 1.6×10^{-14} J (c) 1.6×10^{-10} J (d) 1.6×10^{-8} J

(27) **Gauss' law in electrostatics is true, when the charges enclosed in the Gaussian surface are:**
(a) Stationary only (b) Moving only
(c) Moving or stationary (d) None of these

(28) **Which of the following is equivalent to a volt?**
(a) erg/cm (b) N/coul-m^2 (c) joule/coulomb (d) erg/ampere

(29) **If an electron has an initial velocity in a direction different from that of an electric field, the path of the electron is:**
(a) a straight line (b) a circle (c) an ellipse (d) a parabola

(30) **The capacity of an isolated conducting sphere of radius R is proportional to:** MCAT
(a) R^2 (b) $\left(\frac{1}{R^2}\right)$ (c) $\left(\frac{1}{R}\right)$ (d) R

(31) **The force between the plates of a parallel plate capacitor of a potential difference V between the plates is:** MCAT
(a) $\frac{CV^2}{2d}$ (b) $\frac{C^2V^2}{2d^2}$ (c) $\frac{C^2V^2}{D^2}$ (d) $\frac{V^2d}{C}$

(32) **A condenser of capacity 50 μF is charges to 10 volt. The energy stored is:** MCAT
(a) 1.25×10^{-3} J (b) 3.75×10^{-3} J (c) 2.5×10^{-3} J (d) 5×10^{-4} J

(33) **A charge of 0.10 C accelerated through a potential difference of 1000 volt acquires K.E.**
(a) 100 J (b) 200 J (c) 100 eV (d) 400 J

(34) **Two charges are placed a finite distance apart. if a glass slab is placed between them, force between them will:**
(a) be zero (b) increase (c) decrease (d) remain the same

(35) **A hollow insulated conduction sphere is given a positive charge of 10 μC. What will be the electric field at the centre of the sphere if its radius is 2 metre?**
(a) 5 μC m^{-2} (b) 20 μC m^{-2} (c) 8 μC m^{-2} (d) Zero

(36) **The electric potential at any point inside a charged hollow spherical conductor is:**
(a) Zero (b) Greater than potential on its surface
(c) The same as on its surface (d) Less than the potential on its surface

(37) **In order to obtain the maximum capacity from a given set of capacitors, they should be connected in:** MCAT
(a) Series (b) Parallel (c) Mixed grouping
(d) An electrical circuit consisting of an equal number of cells

(38) **Three capacitors, each of capacity 3 μF are given. A capacitance of 2 μF can be obtained by connecting:** MCAT
(a) them in series (b) them in parallel
(c) two in parallel and one in series (d) two in series and one in parallel

(39) **If a body has a charge of 10^{-12} coulomb:**
(a) the body has 6.25×10^6 excess of electrons (b) the body has 625×10^6 excess of electrons
(c) the body has 6.25×10^6 deficiency of electrons (d) the body has 6.25×10^3 deficiency of electrons

(40) **The ratio of gravitational force of interaction to the electric force of interaction between two electrons is of the order of:**
(a) 10^{-36} (b) 10^{-38} (c) 10^{-42} (d) 10^{-43}

(41) **The dielectric constant K of an insulator cannot be:** MCAT
(a) 3 (b) 6 (c) 8 (d) ∞

(42) **Equal charges are given to two spheres of different radii. The potential will:**
(a) be more on the smaller sphere (b) be more on the bigger sphere
(c) be equal on both the spheres (d) depend on the nature of the material of the sphere

(43) **There is a solid sphere of radius R having uniformly distributed charge throughout it. What is the relation between electric field E and distance r from the centre ($r < R$)?**
(a) $E \propto r^{-2}$ (b) $E \propto r^{-1}$ (c) $E \propto r$ (d) $E \propto r^2$

(44) **Select the correct statement:**
(a) the total charge of the universe is constant
(b) the total number of the charged particles is constant
(c) the total positive charge of the universe remains constant
(d) the total negative charge of the universe remains constant

(45) **When a body is connected to the earth, then electrons from the earth, flow into the body. It means that the body is:**
(a) Uncharged (b) An insulator (c) Positively charged (d) Negatively charged

(46) **Flux coming out from a unit positive charge placed in air is:**
(a) ε_0 (b) ε_0^{-1} (c) $(4\pi\varepsilon_0)^{-1}$ (d) $4\pi\varepsilon_0$

(47) **You are travelling in a car during a thunderstorm. In order to protect yourself from lightning you would prefer to:**
(a) Remain in the car (b) Take shelter under a tree
(c) Get out and lie flat on the ground (d) Touch the nearest electrical pole

(48) **Two charged conductors are connected with a wire. The flow of charge from one conductor to the other will not be there only if both conductors have:**
(a) Same capacity (b) Same charge (c) Equal potential (d) None of these

(49) **A proton is charged to potential 1 volt. Then its energy will be:**
(a) 1840 eV (b) 1/1840 eV (c) 1 eV (d) 1.6 eV

(50) **Electric field intensity at a point in between two parallel sheets with like charges of same surface charge densities:**
(a) Zero (b) σ/ε_0 (c) $\sigma/2\varepsilon_0$ (d) $2\sigma/\varepsilon_0$

(51) **If an electron is brought towards another electron, the electric potential energy of the system:**
(a) Increases (b) Decreases (c) Becomes zero (d) Remains constant

(52) **Some charge is being given to a conductor; then its potential is:**
(a) Maximum at surface (b) Maximum at centre
(c) Same throughout the conductor (d) Maximum somewhere between surface and centre

(53) **The force between 2 charges 0.06 cm apart is 5 N. Then the force when they are brought 0.01 cm closer will be:**
(a) 7.2 N (b) 180 N (c) 4.8 N (d) 66 N

(54) **When two charged conductors are brought into contact, the electric charge on them is shared:**
(a) Equally (b) In proportion to their capacities
(c) Inversely as their capacities (d) None of the above

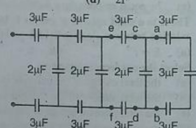
(55) **The capacitance of a parallel plate condenser does not depend upon:** MCAT
(a) Area of the plates (b) Medium between the plates
(c) Distance between the plates (d) Metal of the plates

(56) **Assuming the earth as a sphere of radius R = 6400 km, the capacitance of the earth is:** MCAT
(a) Infinite (b) Zero (c) 771 μF (d) 171 μF

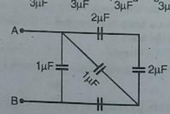
(57) **The capacitance of a parallel plate capacitor is 2 μF and the charge on its positive plate is 2 μC. If the charges on its plates are doubled, the capacitance of the capacitor:** MCAT
(a) Becomes 4 μF (b) Becomes 1 μF (c) Remains 2 μF
(d) Cannot be ascertained in the absence of information on potential

(58) **Force acting upon a charged particle kept between the plates of a charged capacitor is F. If one of the plates of the capacitor is removed, force acting on the same particle will become:** MCAT
(a) 0 (b) $\frac{F}{2}$ (c) F (d) 2F

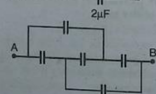
(59) **The resultant capacitance between A and B in the figure is:** MCAT
(a) 1 μF (b) 10 μF
(c) 50 μF (d) 1.5 μF



(60) **Total capacity of the system of capacitors shown in the following figure between the points A and B is:** MCAT
(a) 1 μF (b) 2 μF
(c) 3 μF (d) 4 μF



(61) **Five identical capacitors, each with capacitance C are connected as shown in the figure. Then the equivalent capacitance between A and B is:** MCAT
(a) C (b) 5C
(c) C/5 (d) 3C



(62) **If a dielectric is placed between two point charges, magnitude of Coulomb's force is:**
(a) $\frac{1}{4\pi}\frac{q_1q_2}{r^2}$ (b) $\frac{1}{4\pi\epsilon_0\epsilon_r}\frac{q_1q_2}{r^2}$ (c) $\frac{1\epsilon_r}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$ (d) $\frac{1}{4\pi\epsilon_0\epsilon_r}\frac{q_1}{r^2}$

(63) **If vector area $\vec{A}$ is held perpendicular to field lines, then flux is:**
(a) Maximum (b) Zero (c) No change (d) None of these

(64) **1 volt =**
(a) $\frac{1\ J}{1\ C}$ (b) $\frac{1\ N}{1\ C}$ (c) $\frac{1\ C}{1\ J}$ (d) None of these

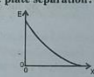
(65) **If a dielectric is placed between the plates of a capacitor, its capacitance will:** MCAT
(a) Increase (b) Decrease (c) Becomes double (d) None of these

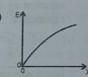
(66) **The minimum charge on any object cannot be less than:** MCAT
(a) 1.8×10^{-19} C (b) 3.2×10^{-19} C (c) 1.6×10^{-19} C (d) 9.1×10^{-11} C

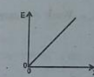
(67) **As 1 ohm × 1 farad = 1 second. For MΩ × PF =** MCAT
(a) second (b) ms (c) μs (d) Ms

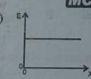
(68) **The apparatus used by Coulomb is:**
(a) Cavendish (b) Torsion balance (c) Physical balance (d) Gold leaf electroscope

(69) **Two parallel conducting plates are connected to a battery, one plate to the positive terminal and the other plate to the negative. The plate separation is gradually increased, the plates remaining connected to the battery. Which graph shows how the electric field E between the plates depends on the plate separation?** MCAT

(a)


(b)


(c)


(d)


ANSWERS

(1)	(a)	(2)	(a)	(3)	(a)	(4)	(c)	(5)	(c)
(6)	(b)	(7)	(a)	(8)	(c)	(9)	(a)	(10)	(c)
(11)	(c)	(12)	(c)	(13)	(d)	(14)	(a)	(15)	(a)
(16)	(c)	(17)	(c)	(18)	(d)	(19)	(b)	(20)	(b)
(21)	(a)	(22)	(d)	(23)	(d)	(24)	(d)	(25)	(c)
(26)	(a)	(27)	(a)	(28)	(c)	(29)	(d)	(30)	(d)
(31)	(a)	(32)	(c)	(33)	(a)	(34)	(c)	(35)	(d)
(36)	(c)	(37)	(b)	(38)	(c)	(39)	(c)	(40)	(d)
(41)	(d)	(42)	(a)	(43)	(c)	(44)	(a)	(45)	(c)
(46)	(b)	(47)	(a)	(48)	(c)	(49)	(c)	(50)	(a)
(51)	(a)	(52)	(c)	(53)	(a)	(54)	(b)	(55)	(d)
(56)	(c)	(57)	(c)	(58)	(b)	(59)	(a)	(60)	(b)
(61)	(a)	(62)	(b)	(63)	(b)	(64)	(a)	(65)	(a)
(66)	(c)	(67)	(c)	(68)	(b)	(69)	(d)		

SOLUTION

(6)
$$F' = \frac{F}{\epsilon_r}$$
$$F' = \frac{2}{80}$$
$$F' = 0.025\ N$$

(b) is correct

(8)
$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r} \qquad d = 8\ cm$$
$$V = 9\times10^9\frac{(4\times10^{-8})}{4\times10^{-2}} \qquad r = \frac{d}{2}$$
$$V = 9000\ V \qquad = \frac{8}{2}$$
$$= 4\ cm$$

(c) is correct

(24) Because k for insulator always greater than 1.

(d) is correct

(31)
$$Work = F\,.\,d$$
$$\Rightarrow F = \frac{Work}{d} \qquad Work = Energy$$
$$F = \frac{E}{d}$$
$$F = \frac{\frac{1}{2}CV^2}{d}$$
$$F = \frac{CV^2}{2d}$$

(a) is correct

(43)
$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$
$$V \propto \frac{1}{r}$$

(a) is correct

(47) According to Gauss's law
$$Flux = \frac{1}{\epsilon_0}(Charge)$$

(b) is correct

(57) Capacitance of a sphere.
$$C = 4\pi\epsilon_0 R$$
$$C = 4(3.14)(8.85\times10^{-25})(6400\times10^3)$$
$$C = 771\ \mu F$$

(c) is correct

(62) A balanced Wheatstone bridge with the middle capacitor as dummy capacitor. So the effective capacitance.
$$\frac{C}{2}+\frac{C}{2} = C$$

(a) is correct

Chapter 13

CURRENT ELECTRICITY

MCAT UNIT 10

KEY POINTS

Electric Current:

(i) The electric current I through a given area of a conductor is the rate of flow of electric charge through the area.

(ii) Electric current is a **Scalar** quantity.

(iii) Conventionally, the direction of electric current is taken along the direction of motion of positive charges. Positive charge moving to the right means current to the right and negative charge moving to the left means current to the right.

(iv) If a charge q passes through any cross-sectional area of the conductor in time t, the electric current I is given by:
$$I = \frac{q}{t} = \frac{\text{(Charge transferred)}}{\text{(Time taken)}}$$

(v) If charge q is in coulomb and t is in seconds then I is in ampere. If q is in ab-coulomb and t is in seconds, then I is in ab-ampere or CGS e.m. unit of current $\left(1\text{ ampere} = \frac{1}{10}\text{ e.m.u. of current}\right)$.

(vi) One amp = (one coulomb/sec) = 6.25×10^{18} electrons/sec.

(vii) When n electrons move across a section of the conductor normal to the direction of flow in t sec, then the current I is given by:
$$I = \frac{ne}{t}$$

(viii) An electric current is due to the drift of:

(a) Electrons in a conductor.
(b) Positive and negative ions in an electrolyte.
(c) Electrons and ions in gases in discharge tubes.
(d) Electrons and holes in a semiconductor.
(e) Mostly electrons in an n-type semiconductor.
(f) Mostly holes in a p-type semiconductor.

Current Electricity: The branch of Physics which deals with charges in motion called current electricity.

Electric Current: The rate of flow of charge is called electric current. If a net charge ΔQ passes through any cross-section of a conductor in time Δt then
$$I = \frac{\Delta Q}{\Delta t}$$

Electric current is a scalar quantity and its unit is ampere i.e.,
$$1\ A = \frac{1\ C}{1\ s}$$

In metallic conductors, charge carriers are electron. In electrolyte, charge carriers are positive and negative ions. In gases charge carriers are electrons and ions. Conventional current is due to flow of positive charges. Electronic current is due to flow of negative charges.

Drift Velocity: The velocity of the free electrons in the direction of drift or effectively in the direction opposite to that of the electric field in metal is known as drift velocity of free electrons. Drift velocity of electrons is 10^{-3} m/s. At room temperature velocity of free electrons is due to their thermal motion which is several hundred kilometers per second.

Source of Current: To have constant current the potential difference across the conductor should be maintained constant. This is achieved by connecting the ends of the wire to the terminals of a device called a source of current. Cells convert chemical energy into electrical energy. Primary cells are non-rechargeable. Secondary cells are rechargeable. Generators convert mechanical energy into electrical energy. Thermocouples convert heat energy into electrical energy. Solar cells convert sunlight into electrical energy.

Effects of Current:

Heating Effect: It is found that heat H produced by a current I in the wire of resistance R during a time interval t is given by:

$$H = I^2Rt$$

The heating effect of current is utilized in electric heater, kettle, toaster and electric iron etc.

Magnetic Effect: The passage of current produces magnetic field in the surrounding space. The strength of the magnetic field depends upon the value of current and the distance from the current element. Magnetic effect is utilized in the defection and measurement of current. All the machines involving electric motors also use the magnetic effect of current.

Chemical Effect: Certain liquids such as dilute sulphuric acid or copper sulphate solution conduct electricity due to some chemical reactions that take place within them. The study of this process is known as electrolysis. The chemical changes produced during the electrolysis of a liquid are due to chemical effects of the current. It depends upon the nature of the liquid and the quantity of electricity passed through the liquid.

Ohm's Law: The current flowing through a conductor is directly proportional to the potential difference across its ends provided the physical state such as temperature etc., of the conductor remains constant.

$$I \propto V \quad \Rightarrow \quad I = \frac{1}{R}V \quad \Rightarrow \quad V = IR$$

Opposition offered by conductor to flow of current is called resistance of conductor.

$$R = \frac{V}{I}$$

Resistance of conductor depends upon the nature, dimensions and the physical state of conductor. Unit of resistance is ohm (Ω).

$$1\,\Omega = \frac{1\,V}{1\,A}$$

Graph between V and I is a straight line if temperature is constant.

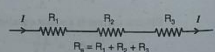
A conductor which obey ohm's law is called ohmic. Those devices which do not obey ohm's law are called non-ohmic. e.g.,

(i) Tungsten filament lamp. (ii) Semi-conductor diode.

Resistance of a conductor increases if its temperature increases.

Series and Parallel Combination of Resistances:

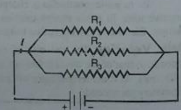
Series Combination of Resistances: In series condition of resistance current is same but voltage is different. Also equivalent resistance is greater than the largest individual resistance.



$$R_e = R_1 + R_2 + R_3$$

Parallel Combination of Resistances: In parallel combination of resistors, current is different but voltage is same. Also equivalent resistance is less than the smallest individual resistance.

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



Resistivity: Resistivity or specific resistance ρ is the resistance of a meter cube a material.

$$R = \rho\frac{L}{A}$$

Its S.I unit is (ohm-m) Ω-m.

Conductivity: Reciprocal of resistivity is called conductivity.

$$\sigma = \frac{1}{\rho}$$

Its unit is (ohm-m). (mho m^{-1})

Conductance: Reciprocal of resistance is called conductance. Its unit is mho or Ω^{-1} or Siemen.

Dependence of Resistance upon Temperature: The fractional change in resistance per kelvin is known as temperature coefficient of resistance.

$$\alpha = \frac{R_t - R_0}{R_0\Delta T}$$

Substance	ρ (Ωm)	α (K^{-1})
Silver	1.52×10^{-8}	0.00380
Copper	1.54×10^{-8}	0.00390
Gold	2.27×10^{-8}	0.00340
Aluminium	2.63×10^{-8}	0.00390
Tungsten	5.00×10^{-8}	0.00460
Iron	11.00×10^{-8}	0.00520
Platinum	11.00×10^{-8}	0.00520
Constanton	49.00×10^{-8}	0.00001
Mercury	94.00×10^{-8}	0.00091
Nichrome	100.0×10^{-8}	0.00020
Carbon	3.5×10^{-5}	−0.0005
Germanium	0.5	−0.05
Silicon	29-2300	−0.07

Its unit is K^{-1}. If resistance decreases with increase in temperature then these substances have negativity temperature coefficient. e.g., Ge, Si. There are some substances like germanium, silicon etc., whose resistance decreases with increase in temperature. i.e.; these substances have negative temperature coefficients.

Colour Code for Carbon Resistances:

Resistivity: Carbon resistors are most common in electronic equipment. They consist of a high-grade ceramic rod or cone (called the substrate) on which a thin resistive film of carbon is deposited. The numerical value of their resistance is indicated by a colour code. It consists of bands of different colours printed on the body of the resistors. The colour used in this code is given in table. It is easy to remember colours and their respective numbers with help this sentence.

B-B-Roy-Goes-Briton-Via Germany-West

Colour	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9
Silver	0.01
Gold	0.1

First Band: The first band indicates the first digit in the numerical value of the resistance e.g., red = 2 is first digit.

Second Band: The second band gives the second digit e.g., violet = 7 is the second digit.

Third Band: The third band is multiplier of 10 to given power i.e., it gives the number of zeros after the first two digit e.g., orange = 3, we put three zero.

Fourth Band: The fourth band gives resistance tolerance. Its colour is either silver or gold e.g., silver and tolerance is ±10%. Gold band shows a tolerance of ±5%.

No Fourth: If there is no fourth band, tolerance is understood to be ±20%. **Tolerance** by tolerance, we means the possible variation from the marked value. For example, a 10000 ohm resistor with a tolerance of ±10% will have an actual resistance anywhere between 9000Ω and 11,000Ω.

Rheostat: Rheostat is wire wound variable resistor. Rheostat has three terminals. Two fixed one variable. Rheostat can be used as variable resistor and potential divider. Thermister is a heat sensitive resistor. Thermisters with high negative temperature coefficient are very accurate for measuring low temperature (10 K). Thermisters are used as temperature sensors.

Thermister: A thermistor is a heat sensitive resistor. Most thermistors have negative temperature coefficient of resistance i.e., the resistance of such thermistors decreases when their temperature is increased. Thermistors with positive temperature coefficient are also available. Thermistors with high negative temperature coefficient are very accurate for measuring low temperature especially near 10 K. The higher resistance at low temperature enables more accurate measurement possible. Thermistors have wide applications as temperature sensors i.e., they convert changes of temperature into electrical voltage which is duly processed.

Electrical Power and Power Dissipation in Resistors: The rate at which the battery is supplying electrical energy is called electrical power of the battery.

$$P = VI$$

Power dissipation in resistors P = VI.

$$P = I^2R \quad \text{and} \quad P = \frac{V^2}{R}$$

Its unit is watt.

Electromotive Force (EMF) and Potential Difference: The emf E of the source is defined as the energy supplied to a unit positive charge by the cell in moving from negative to positive terminal of cell.

$$E = \frac{\Delta W}{\Delta q}$$

Its unit is volt (J/C).

The opposition offered by electrolyte to flow of current is called internal resistance (r). Internal resistance does not remain constant. Its value increases. Terminal potential difference:

$$V_t = E - Ir$$

(i) $V_t = E$ if $r = 0$ but r never zero.
(ii) $V_t = E$ if circuit is open i.e., $I = 0$.
(iii) V_t is always less than E by a factor Ir.
(iv) V_t is greater than E if small battery is charged by larger battery.

When internal resistance = external resistance then P_{out} is maximum.

Maximum Power Output: If V is the potential difference across R, the loss of potential energy per second is VI. This loss of energy per second appears in other forms of energy and is known as power delivered to R by current I.

Power delivered to R is $P_{out} = VI$

$= I^2R \quad (\because V = IR)$

As $I = \dfrac{E}{R + r}$

$$P_{out} = \frac{E^2R}{(R + r)^2} = \frac{E^2R}{(R - r)^2 + 4Rr}$$

where R = r, the denominator of the expression of P_{out} is least and so P_{out} is a maximum. Thus we can see that maximum power is delivered to resistance (load), when the internal resistance of the source equals the load resistance. Therefore;

$$\text{Maximum } P_{out} = \frac{E^2}{4R}$$

Kirchhoff's Rules: Ohm's law and rules of series and parallel combination of resistance are quite useful to analyze simple electrical circuits consisting of more than one resistance. However such a method fails in the case of complex networks consisting of a number of resistors, and a number of voltage sources. Problems of such networks can be solved by a system of analysis, which is based upon two rules, known as Kirchhoff's rules. Sum of all the currents meeting at a point (node) in the circuit is zero. i.e., $\sum I = 0$. This is Kirchhoff's 1st rule. This is also called Kirchhoff's current rule and Kirchhoff's point rule. Kirchhoff's 1st rule obey law of conservation of charge. The algebraic sum of potential changes for a complete circuit is zero. This is called Kirchhoff's 2nd rule. Also called Kirchhoff's voltage rule. Whenever a positive charge enters a cell from negative terminal, it gains energy and if charge enters from positive terminal it loses energy.

Wheatstone Bridge: Wheatstone bridge is a circuit used to find unknown resistance.

Condition for balance point is $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$.

Balance point means galvanometer shows no deflection even after the switch is closed.

Galvanometer shows no deflection because when $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$ is satisfied then potential at B and D is same.

Slide wire bridge and post office box are practical applications of wheatstone bridge.

Potentiometer: A very simple instrument which can measure and compare potential differences accurately, without drawing any current, is called a potentiometer. The potential difference across any length of a wire of uniform area of cross-section is directly proportional to its length when constant current flows through it i.e., $E \propto l$. An ideal voltmeter has infinite resistance. Other accurate potential difference measuring instruments are C.R.O. and digital voltmeter because they do not draw any current from air unit. Potentiometer can be used to measure potential difference, as a potential divider, to compare emf of two cells, to find internal resistance of a cell.

Resistance and Conductance:

(i) Resistance R of a given conductor, at a constant temperature, is directly proportional to its length and inversely proportional to its area of cross-section A.

$$R \propto \frac{l}{A} \quad \text{or} \quad R = \rho\frac{l}{A}$$

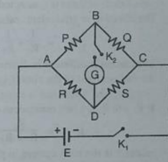
where ρ is called the specific resistance of the material.

(ii) Resistance of a conductor depends upon the temperature, nature and dimensions of the material of the conductor.

(iii) Unit of resistance in MKS system is **ohm** while in CGS e.m. system is ab-ohm. One ohm = 10^9 ab-ohm.

(iv) The specific resistance ρ of a conductor depends upon the temperature and nature of the material of the conductor. It is independent of the dimensions of the conductor.

Wheatstone's Bridge:



(i) In Wheatstone's bridge, four resistance P, Q, R and S are connected such that P and Q are in series and so are R and S. And P + Q branch is in parallel with R + S branch as shown in the adjoining circuit diagram when key K_2 is open. When the bridge is balanced and no current flows in arm BD.

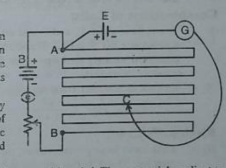
(ii) When QS > PR, current flows from B to D.

(iii) When QS < PR, current flows from D to B.

(iv) The bridge is most sensitive when all the four resistors are of the same order.

(v) Metre bridge, post office box and Carey Foster's bridge are practical applications of Wheatstone's bridge.

Potentiometer:



(i) A potentiometer generally consists of ten wires of uniform area of cross-section stretched on a wooden board between two thick copper strips. Each wire is 100 cm long. The wire is usually made of constant or manganin. A metre scale is fitted parallel to its length.

(ii) A steady current is set up in the wire by means of a battery B. This maintains a uniform potential gradient (fall of potential per unit length) along the length of the wire. In the figure, E is the e.m.f. of the source which is balanced between points A and C.

(iii) Let R be the total resistance of the potentiometer wire having a total length l. Then potential gradient = $I \times \dfrac{R}{l}$.

(iv) Any potential difference less than the total potential difference maintained across the potentiometer wire can be balanced against a convenient length of the potentiometer wire. The potential difference balanced is proportional to the length of the wire which balances the potential difference.

(v) The unit of specific resistance in MKS system is ohm × metre, in CGS e.m. system is ab-ohm × cm.

(vi) The conductance G is the reciprocal of resistance, i.e., G = 1/R. The unit of conductance in MKS system is mho and in CGS e.m. system ab-mho while in SI system is siemen. One siemen = one mho = 10^{-9} ab-mho.

(vii) **Electrical conductivity** of a material is defined as the reciprocal of the resistivity, i.e., $s = \dfrac{1}{\rho} = \dfrac{1}{RA}$. Its unit is $(\text{ohm-metre})^{-1}$ or mho/metre.

Res. ances in Series:

(i) In series combination, resistances are connected end to end in succession.

(ii) The effective or total resistance R is given by:

$$R = R_1 + R_2 + R_3 + \ldots\ldots$$

(iii) The current is same in every part of the circuit.

(iv) The potential difference V across the combination is equal fo the sum of individual potential differences across different resistances

$$V = V_1 + V_2 + V_3 + \ldots\ldots$$

(v) Applied potential difference is divided among the resistances directly in their ratio

$$V_1 : V_2 : V_3 : \ldots\ldots = R_1 : R_2 : R_3 : \ldots\ldots$$

(vi) The equivalent conductance G is given by:

$$\frac{1}{G} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3} + \ldots\ldots$$

Resistances in Parallel:

(i) In parallel combination of resistances, one end of each resistance is connected at one point and the other end of each of them is connected to another point.

(ii) The effective or equivalent resistance R is given by:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$$

(iii) The current is different in different resistances. The sum of the currents in difference resistance is equal to the main current of the circuit, i.e., $I = I_1 + I_2 + I_3 + \ldots\ldots$

(iv) The potential difference is same across each resistance.

(v) If R_1 and R_2 are two resistances connected in parallel having currents I_1 and I_2 flowing in them, then

$$I_1 = \frac{R_2}{R_1 + R_2} I \quad \text{and} \quad I_2 = \frac{R_1}{R_1 + R_2} I$$

where I is the total current in the two branches. **In parallel combination of resistances, currents are shared in the inverse ratio of resistances.**

Combinations of Cells:

(i) Two cells of e.m.f. E_1 and E_2 and internal resistances r_1 and r_2, when connected in series **correctly**, then equivalent e.m.f. $E = E_1 + E_2$ and equivalent internal resistance $r = r_1 + r_2$. However, if the two cells are connected wrongly then equivalent e.m.f., $E = E_1 - E_2$ but the equivalent internal reistance will remain same, i.e., $r = r_1 + r_2$.

(ii) If n cells, each of e.m.f. E and internal resistance r are connected in series with external resistance R, then current

$$I = \frac{nE}{R + nr}$$

Kirchhoff's Laws:

(i) **First Law:** In an electric circuit, the algebraic sum of the currents meeting at any point in the circuit is zero, i.e., $\sum I = 0$. In this law, the current flowing towards the point are given positive signs while currents flowing away from the point are given negative signs. This means that the sum of current flowing towards the point is equal to the sum of currents flowing away from the point. **The first law is based on the law of conservation of charge.**

(ii) **Second Law:** In any closed mesh in a circuit, the algebraic sum of the products of currents and resistances in each part of the mesh taken around in a given order is equal to the algebraic sum of the e.m.f.'s in that mesh, i.e.,

$$\sum IR = \sum E$$

In this law, the product of current and resistance in any part is given positive sign when we traverse it in the direction of current, and negative sign when in the opposite direction. Similarly, the e.m.f. of the cell is taken as positive when we traverse from the negative pole to the positive pole of the cell, and negative when in opposite direction.

(iii) The second law is basically based on the law of conservation of energy.

ASSIGNMENT NO. 13

(1) A current of 1 ampere is passing through a conductor, the charge passing through it in one minute is:

(a) 40 coulomb (b) 60 coulomb (c) 2 coulomb (d) None of these

(2) The magnitude of the drift velocity is of the order of:

(a) 10^{-3} m/s (b) 10^{-4} m/s (c) 10^{-6} m/s (d) 10^{3} m/s

(3) For non-ohmic devices, the graph between V and I is:

(a) Not a straight line (b) A straight line (c) A curve (d) All of above

(4) The fourth band is a:

(a) Gold band (b) Silver band (c) Brown band (d) Both (a) and (b)

(5) Gold band shows a tolerance of:

(a) ± 10% (b) ± 20% (c) ± 5% (d) 10%

(6) Silver band shows a tolerance of:

(a) ± 10% (b) ± 20% (c) ± 5% (d) 10%

(7) If there is no fourth band, tolerance is shows as:

(a) ± 10% (b) ± 20% (c) ± 5% (d) 10%

(8) The wire used in the construction of a rheostat is of the material:

(a) Iron (b) Silver (c) Gold (d) Manganin

(9) When the current is being drawn from the battery:

(a) $V = E + Ir$ is applied (b) $V = E - Ir$ is applied

(c) It is being discharged (d) Both (a) and (c)

(10) When the current is drawn from a cell, its terminal potential difference and emf are:

(a) Different (b) Same (c) Both zero (d) None of them

(11) The resistance of a conductor through which a current of one ampere is flowing when a potential difference across its ends is one volt is:

(a) One volt (b) One ohm (c) One ampere (d) One coulomb

(12) The SI unit of the temp coefficient of resistivity of a material is:

(a) K (b) K^{-1} (c) Ohm K (d) Ohm

(13) Three resistors of resistance 2, 3 and 6 Ohms are connected in parallel then their equivalent resistance is:

(a) 11.0 ohms (b) 1.0 ohm (c) 5.0 ohms (d) 70 ohms

(14) When three resistances 2Ω, 4Ω and 6Ω connected in parallel the equivalent resistance is:

(a) $\frac{11}{12}\Omega$ (b) $\frac{12}{11}\Omega$ (c) 12 Ω (d) 0 Ω

(15) Two resistances R_1 and R_2 are connected in parallel. The equivalent resistance of the combination is equal to:

(a) $\frac{R_1R_2}{R_1 + R_2}$ (b) $\frac{R_1 + R_2}{R_1 R_2}$ (c) $R_1 + R_2$ (d) $R_2 - R_2$

(16) In a closed circuit, the e.m.f and internal resistance of cell are E and r respectively. If the external resistance in the circuit is R then the Ohm's law has the form:

(a) $I = \frac{E}{R}$ (b) $I = \frac{E}{Rr}$ (c) $I = \frac{E}{r}$ (d) $I = \frac{E}{R + r}$

(17) Which one of the following is the unit of potential gradient:
(a) Volt × Metre (b) Volt/Amp (c) Volt/Metre (d) $Volt/Amp^2$

(18) Secondary cells are:
(a) Non-chargeable (b) Rechargeable (c) Both (a), (b) (d) Like primary cells

(19) If three resistors are connected parallel to each other then their equivalent resistance is:
(a) Greater than larger individual resistance (b) Less than smaller individual resistance
(c) Equal to larger value (d) Equal to smaller value

(20) Heat generated by a 40 watt bulb in one hour is:
(a) 4800 J (b) 40 J (c) 144000 J (d) 14400 J

(21) A 100 watt bulb is operated by 200 volt, the current flowing through bulb is:
(a) 1 A (b) 0.5 A (c) 2.5 A (d) 3.5 A

(22) The resistance of a 60 watt bulb in a 120 volt line is:
(a) 20 ohm (b) 0.5 ohm (c) 240 ohm (d) 2 ohm

(23) 1.0×10^7 electrons pass through a conductor in certain interval of time. The amount of charge will be:
(a) 1.6×10^{-12} Coulomb (b) 1.6×10^{-26} Coulomb
(c) 6.0×10^{25} Coulomb (d) 1.6×10^{26} Coulomb

(24) The amount of charge passing through a wire in certain interval of time is 1.6 pico coulombs. The number of electrons are then:
(a) 10^7 (b) 10^{15} (c) 10^{10} (d) 10^{16}

(25) The resistances of 2, 3, 4 Ω are provided. Their equivalent resistance will be the minimum when they are connected:
(a) In series (b) In parallel
(c) In series and in parallel (d) Any of above

(26) Three resistances each of 3 Ω are connected in parallel. Their equivalent resistance is:
(a) 9 Ω (b) 66 Ω (c) 1 Ω (d) 1/9 Ω

(27) A battery of 50 volts is attached to a circuit containing resistances of 5 Ω, 10 Ω and 10 Ω arranged in series. The current in the circuit is:
(a) 2 amps (b) 5 amps (c) 40 amps (d) 20 amps

(28) If 2 V are needed to cause a current of 0.2 A to flow in a conductor, its resistance is:
(a) 0.1 Ω (b) 0.4 Ω (c) 1.0 Ω (d) 10 Ω

(29) The resistivity of a 1 m length of wire of iron as compared to the wire of same material of double the length is:
(a) Same (b) Smaller (c) Greater (d) Much greater

(30) The work done by a cell in moving 10 coulombs of charge around a loop is 20 J. The emf of the cell is;
(a) 200 N (b) 200 V (c) 2 V (d) 0.5 V

(31) Filament resistance in a 500 W, 200 V light bulb is:
(a) 80 Ω (b) 50 Ω (c) 2.5 Ω (d) 0.4 Ω

(32) The ampere-sec stands for the unit of:
(a) Power (b) Current (c) Energy (d) Charge

(33) For which of the following dependence of drift velocity v on electric field E is ohm's law obeyed?
(a) $v \propto E$ (b) v = Constant (c) $v \propto E^{1/2}$ (d) $v \propto E^2$

(34) The terminal potential difference of a cell when short circuited is:
(a) E (b) $\frac{E}{2}$ (c) Zero (d) $\frac{E}{3}$

(35) A wire of resistance R is cut into n equal parts. These parts are then connected in parallel. The equivalent resistance of the combination will be:
(a) nR (b) $\frac{R}{n}$ (c) $\frac{n}{R}$ (d) None of these

(36) A cell of e.m.f E volt, internal resistance r ohm is being charges with a current of I amp, then the terminal potential difference is:
(a) E (b) $E - Ir$ (c) $E + Ir$ (d) $E \pm Ir$

(37) A steady current flows in a conductor of variable cross-sectional area. Out of the following physical quantities the one which remains constant along the length of the conductor is:
(a) Drift speed (b) Current density (c) Current (d) Electric field

(38) When the length of the potentiometer wire is increased, then the accuracy in the determination of the null point:
(a) Increases (b) Decreases
(c) Remains unchanged (d) Sometimes increases and sometimes decreases

(39) To draw maximum current from a combination of cells how should the cells be grouped?
(a) Series (b) Parallel (c) Mixed
(d) Depends upon the relative values of external and internal resistance

(40) Total number of electrons present in 4 amp current following for 1 sec is:
(a) 2.5×10^{19} (b) 2.5×10^{20} (c) 1.25×10^{13} (d) 6×10^8

(41) A wire having very high value of conductance is said to be:
(a) Very good conductor (b) An insulator
(c) Moderately good conductor (d) None of these

(42) In order to have a constant current through a wire, the potential difference across its ends should be:
(a) Increasing (b) Decreasing (c) Zero (d) Maintained constant

(43) Electrolysis is the study of conduction of electricity through:
(a) Liquids (b) Solids (c) Gasses (d) All

(44) During electrolysis process, density of $CuSO_4$ solution:
(a) Remains constant (b) Decreased (c) Increased (d) None of these

(45) The resistance of a one metre cube of a conductor is called:
(a) Resistivity (b) Inductivity (c) Permitivity (d) Conductivity

(46) If the resistivity of the conductor is large then it is:
(a) An insulator (b) A poor conductor (c) A good conductor (d) A conductor

(47) Three resistors of resistance 2, 3 and 6 Ohms are connected in parallel then their equivalent resistance is:
(a) 11.0 ohms (b) 1.0 ohm (c) 5.0 ohms (d) 70 ohms

(48) In which one of the following substances, the resistance decreases with increase in temp:
(a) Copper (b) Silver (c) Carbon (d) None of these

(49) A conductor of resistance 8 ohm is bent in the form of a circle. What will be the resistance between two points on any diameter of circle?
(a) 1 ohm (b) 2 ohm (c) 8 ohm (d) 16 ohm

(50) Through an electrolyte, an electric current is due to drift of:
(a) Free electrons (b) Free electrons and holes
(c) Protons (d) Positive and negative ions

(51) A 60 W lamp carries a current of 0.5 A. The total charge passing through it in one hour will be:
(a) 1800 C (b) 2400 C (c) 3000 C (d) 3600 C

(52) **The particles that conduct electricity through a solution of an electrolyte are called:**
(a) Electrons (b) Protons (c) Ions (d) Atoms

(53) **Through a semiconductor an electric current is due to drift of:**
(a) Free electrons (b) Free electrons and holes
(c) Positive and negative ions (d) Protons

(54) **The terminal potential difference of a cell is greater than its emf, when it is:**
(a) Being charged (b) On open circuit
(c) Being discharged (d) Being either charged or discharged

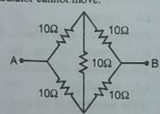
(55) **Unit of resistance is:**
(a) volt/amp (b) $volt^2/amp$ (c) $volt/amp^2$ (d) volt

(56) **The terminal potential difference of a cell when connected through an external resistance equal to its internal resistance is:**
(a) E (b) Zero (c) E/2 (d) E/3

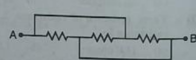
(57) **In a circuit containing two unequal resistors connected in parallel:**
(a) the current is the same in both the resistors
(b) a large current flows through the large resistor
(c) the voltage drop across both the resistances is the same
(d) the smaller resistance has smaller conductance

(58) **Which of the following statement is true?**
(a) Insulators do not contain electrons
(b) Some of the electrons in a conductor are free to move through the material
(c) Conductors always contain more electrons than insulators
(d) The atoms in a conductor can move about but those in an insulator cannot move.

(59) **The equivalent resistance between the points A and B in the following figure is:**
(a) 10 Ω (b) 20 Ω
(c) 40 Ω (d) 5 Ω



(60) **Three equal resistors, each equal to R, are connected as shown in the following figure; then the equivalent resistance between points A and B is:**
(a) R (b) 3R
(c) R/3 (d) 2R/3



(61) **The resistance of a metallic wire becomes 8 times when:**
(a) Length is doubled (b) Length is tripled
(c) Length is doubled and radius is halved (d) Length is halved and radius is doubled

(62) **When wheatstone bridge is balanced then galvanometer shows:**
(a) Maximum deflection (b) Zero deflection
(c) In between (a), (b) (d) None of these

(63) **Kirchhoff's first rule is a manifestation of law of conservation of:**
(a) Energy (b) Charge (c) Momentum (d) K.E.

(64) **A wire of resistance R is cut into two equal parts, its resistance becomes R/2, what happens to resistivity:**
(a) Double (b) Same (c) Half (d) One fourth

(65) **If a 40 watt bulb is on for 2 hours, how much heat is generated?**
(a) 280×10^5 J (b) 288×10^3 J (c) 80 J (d) 400 J

(66) **Terminal potential difference is greater than emf of the cell when:**
(a) Circuit is open (b) Circuit is closed
(c) Small battery is charged by bigger battery (d) None of these

(67) **For electrolysis, the vessel containing two electrodes and electrolyte is known as:**
(a) Voltmeter (b) Voltameter (c) Photometer (d) None of these

(68) **The product of resistance and conductance is:**
(a) 1 (b) Resistivity (c) Conductance (d) Zero

(69) **Which equation is used to define resistance?**
(a) Energy = $(current)^2$ × resistance × time (b) Potential difference = current × resistance
(c) Power = $(current)^2$ × resistance (d) Resistivity = resistance × area + length

(70) **The current in a resistor is 8.0 mA. What charge flows through the resistor in 0.020 s?**
(a) 0.16 mC (b) 1.6 mC (c) 4.0 mC (d) 0.40 C

ANSWERS

(1)	(b)	(2)	(a)	(3)	(a)	(4)	(d)	(5)	(c)
(6)	(a)	(7)	(b)	(8)	(d)	(9)	(b)	(10)	(a)
(11)	(b)	(12)	(b)	(13)	(b)	(14)	(b)	(15)	(a)
(16)	(d)	(17)	(a)	(18)	(b)	(19)	(b)	(20)	(c)
(21)	(b)	(22)	(c)	(23)	(a)	(24)	(a)	(25)	(b)
(26)	(b)	(27)	(a)	(28)	(d)	(29)	(a)	(30)	(c)
(31)	(a)	(32)	(d)	(33)	(a)	(34)	(c)	(35)	(d)
(36)	(c)	(37)	(c)	(38)	(a)	(39)	(b)	(40)	(a)
(41)	(a)	(42)	(d)	(43)	(a)	(44)	(a)	(45)	(a)
(46)	(b)	(47)	(b)	(48)	(c)	(49)	(b)	(50)	(b)
(51)	(a)	(52)	(c)	(53)	(b)	(54)	(a)	(55)	(a)
(56)	(c)	(57)	(c)	(58)	(c)	(59)	(a)	(60)	(c)
(61)	(c)	(62)	(b)	(63)	(b)	(64)	(b)	(65)	(b)
(66)	(c)	(67)	(b)	(68)	(a)	(69)	(b)	(70)	(a)

SOLUTION

(16) As R and r are in series their equivalent resistance is R + r.

According to Ohm's law:

$$E = IR_{eq}$$

$$\Rightarrow I = \frac{E}{R_{eq}}$$

$$I = \frac{E}{R+r}$$

(d) is correct

(20)

$$\text{Heat} = \text{Power} \times \text{Time}$$

$$H = P \times t$$

$$H = 40 \times 3600$$

$$H = 144000\ J$$

(c) is correct

(29) As resistivity is the resistance of a cubic meter wire therefore it will remain same.

(a) is correct

(35) When n resistors each of resistance R are connected in parallel then

$$\frac{R_s}{R_p} = n^2$$

(d) is correct

(40)

$$I = \frac{Q}{t} \qquad \text{But } Q = ne$$

$$e = 1.6 \times 10^{-19}$$

$$I = \frac{ne}{t} \qquad t = 1\ \text{sec.}$$

$$I = 4\ \text{amp.}$$

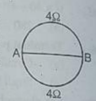
$$4 = \frac{n \times 1.6 \times 10^{-19}}{(1)}$$

$$\frac{4}{1.6 \times 10^{-19}} = n$$

$$n = 2.5 \times 10^{19}$$

(a) is correct

(49) Now two resistance are connected in parallel therefore their equivalent resistor across diameter AB is



$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{4}$$

$$\frac{1}{R_{eq}} = \frac{1+1}{4}$$

$$= \frac{2}{4} = \frac{1}{2}$$

$$R_{eq} = 2\Omega$$

(b) is correct

(56) As we know that:

$$V_T = E - Ir$$

$$\text{Then } I = \frac{E}{R+r}$$

Therefore,

$$V_T = E - \frac{E}{R+r} \cdot r \qquad (R = r)$$

$$V_T = E - \frac{E}{2r} \cdot r$$

$$V_T = \frac{E}{2}$$

(c) is correct

(59) In wheatstone circuit centre resistor is dummy.

(a) is correct

(60) The three resistance are in parallel.

$$\therefore \frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R}$$

$$\frac{1}{R_{eq}} = \frac{3}{R}$$

$$\Rightarrow R_{eq} = \frac{R}{3}$$

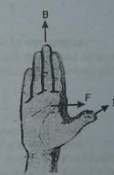
(c) is correct

Chapter 14

ELECTROMAGNETISM

MCAT UNIT 11

KEY POINTS



Electromagnetism: The branch of Physics which deals with study of magnetic field due to moving charges, called electromagnetism.

Magnetism: It is the branch of physics which deals with the properties of magnet.

(i) A magnetic field is formed around a current carrying wire according to Hans Orested.

(ii) The lines of force are circular and their direction depends upon the direction of current.

(iii) The magnetic field produced as long as the current following the current flowing through the wire.

(iv) The direction of magnetic field is determined by right hand rule.

Force on a Current Carrying Conductor in a Uniform Magnetic Field:

$$\vec{F} = I(\vec{L} \times \vec{B}) \quad \text{or} \quad F = ILB \sin\alpha$$

where α is angle between $\vec{L}$ and $\vec{B}$.

This force depends upon:

(i) $F \propto L$ (ii) $F \propto I$ (iii) $F \propto \sin\alpha$ (iv) $F \propto B$

Direction of magnetic force is from strong to weak magnetic field. Direction of magnetic force is given by:

(i) Right hand grip rule. (ii) Right hand palm rule.

(iii) Right hand rule of vector product. (iv) Fleming's left hand rule.

Cross (×) means into page. Dot (•) means out of page.

If current carrying conductor is placed perpendicular to $\vec{B}$ then F_m is maximum. If current carrying conductor is placed parallel to $\vec{B}$ then $F_m = 0$. Magnetic induction is defined as the force acting on one metre length of the conductor placed at right angle to the magnetic field when 1 A current is passing through it. S.I. unit of magnetic induction is tesla (T). A magnetic field is said to have a strength of one tesla if it exerts a force of 1 N on one metre length of the conductor placed at right angle to the field when a current of 1 A passes through the conductor. Thus $1\ T = 1\ NA^{-1}m^{-1}$. Other unit of magnetic induction is gauss (G).

$$1\ G = 10^{-4}\ T$$

Magnetic Flux and Flux Density: Number of magnetic lines passing through a surface placed perpendicular to $\vec{B}$, is called magnetic flux. (OR) Scalar product of $\vec{B}$ and vector area $\vec{A}$.

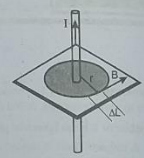
$$\phi = \vec{B} \cdot \vec{A} \quad \Rightarrow \quad f = BA\cos\theta$$

Magnetic flux is a scalar quantity. If plane of surface is perpendicular to $\vec{B}$, i.e., $\vec{B}$ and vector area $\vec{A}$ are parallel then $\theta = 0°$ and flux is maximum. If plane of surface is parallel to $\vec{B}$ i.e., $\vec{B}$ and $\vec{A}$ are perpendicular then $\theta = 90°$ and flux is zero. Unit of magnetic flux is NmA^{-1} which is called weber (wb). Magnetic flux per unit area of a surface perpendicular to $\vec{B}$ ($\vec{B}$ and $\vec{A}$ are parallel) is called magnetic flux density. Unit of magnetic flux density is wb/m^2 or $Nm^{-1}A^{-1}$ (T).

Ampere's Law: According to ampere:

$$B \propto I \Rightarrow B \propto \frac{1}{r}$$

$$B \propto \frac{I}{r} \Rightarrow B = \frac{\mu_0}{2\pi} \cdot \frac{I}{r}$$



Ampere proved that sum of the quantities $\vec{B} \cdot \vec{\Delta l}$ for all path elements into which the complete loop has been divided equals μ_o times the total current enclosed by the loop.

$$\sum_{r=1}^{N} (\vec{B} \cdot \vec{\Delta l})_r = \mu_o \text{ (Current enclosed)}$$

Where μ_o (permeability of free space) $= 4\pi \times 10^{-7}\ wbA^{-1}m^{-1}$

A solenoid is a long, tightly wound, cylindrical coil of wire. When current passes through solenoid it behaves as a bar magnet. Magnetic field inside the solenoid is uniform and much stronger. Magnetic field outside the solenoid is weak that can be neglected. To find magnetic field due to a current carrying solenoid Amperean region is considered. Magnetic field due to current carrying soleonoid.

$$B = \mu_o n I$$

where $n = \frac{N}{l} \Rightarrow B = \mu_o \frac{NI}{l}$ N = Total number of turns, l = Length of solenoid

Direction of $\vec{B}$ is along the axis the solenoid and is given by right hand rule "hold the solenoid in the right hand with fingers curling in the direction of the current, the erect thumb will point in the direction of the field".

Force on a Moving Charge in a Magnetic Field

$$\vec{F} = q(\vec{V} \times \vec{B})$$

For positive charge:

$$\vec{F} = +e(\vec{V} \times \vec{B})$$

For electron:

$$\vec{F} = -e(\vec{B} \times \vec{V}) \quad \text{or} \quad \vec{F} = e(\vec{B} \times \vec{V})$$

If charge is at rest i.e., V = 0 then $F_m = 0$. If charge is projected perpendicular to $\vec{B}$ then F_m is maximum. If charge is moving parallel or antiparallel to $\vec{B}$ then F_m is zero. If electron and proton are projected in a magnetic field they will deflect in opposite direction.

Lorentz Force: When a charge particle q is moving with velocity $\vec{V}$ in a region where there is an electric field $\vec{E}$ and magnetic field $\vec{B}$, the total force $\vec{F}$ is the vector sum of the electric field $q\vec{E}$ and magnetic force $q(\vec{V} \times \vec{B})$ i.e.,

$$\vec{F} = q\vec{E} + q(\vec{V} \times \vec{B})$$

This is known as Lorentz force. No work is done by magnetic force, it is only a deflecting force.

e/m of an Electron: To find e/m of an electron, electron move in a circular path. Centripetal force is provided by magnetic force.

$$F_m = F_c \Rightarrow eVB = \frac{mv^2}{r} \Rightarrow e/m = \frac{V}{Br}$$

The radius r is measured by making the electron's trajectory visible. (Teltron tube). To find velocity v of the electrons, two methods are used:

(i) Potential difference method. (ii) Velocity selector method

Formula for $e/m = \frac{2V}{B^2r^2}$ where V = Potential difference. Unit of e/m is C/kg.

Cathode Ray Oscilloscope: C.R.O. is a high speed graph plotting device. C.R.O. is used for displaying, the waveform of a given voltage. We can measure the voltage, its frequency and phase.

Torque on a Current Carrying Coil:

$$\tau = NIBA \cos \alpha$$

where α is angle between plane of coil and $\vec{B}$. If plane of coil is perpendicular to $\vec{B}$ then $\alpha = 90°$.

$$\therefore \quad \tau = 0$$

If plane of coil is parallel to $\vec{B}$ then $\alpha = 0°$ and τ is maximum ($\tau = NIBA$).

Galvanometer: Galvanometer is an electrical device used to detect the passage of current. Principle of galvanometer is, when a conductor is placed in a magnetic field, it experience a force as soon as a current passes through it. Due to this force a torque acts upon the conductor if it is in the form of a coil.

$$\tau = NIBA \cos \alpha$$

Pole pieces of the magnet are made concave to make the field radial and stronger. Applied torque (deflecting couple) = NIBA. Restorying torque:

$$\tau \propto \theta \Rightarrow \tau = C\theta$$

where C is the torsional couple and is defined as couple for unit twist.

When coil comes to rest:

$$\tau_{applied} = \tau_{rest} \Rightarrow NIBA = C\theta$$

$$I = \frac{C\theta}{BAN} \quad \text{or} \quad I \propto \theta$$

For observing angle of deflection 'θ' two methods:

(i) Lamp and scale arrangement. (ii) Pivoted type galvanometer.

We define current senstivity of a galvanometer as the current in microamperes, required to produce one millimetre deflection on a scale placed one metre away from the mirror of the galvanometer. Such galvanometer in which the coil comes to rest quickly after the current passed through it or the current is stopped flowing through it, is called stable or dead beat galvanometer.

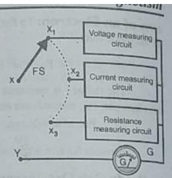
Ammeter: Ammeter is an electrical instrument to measure current in amperes. Ammeter is always connected in series. Ammeter is also called low resistance galvanometer. A galvanometer can be converted into ammeter by connecting a shunt parallel to galvanometer. Resistance of ammeter is less than shunt.

$$R_s = \frac{I_g R_g}{I - I_g}$$

Voltmeter: Voltmeter is an electrical device to measure potential difference between two points in volts. Voltmeter is always connected parallel. A galvanometer can be converted to a voltmeter by connecting a high resistance in series with galvanometer. It is also called high resistance galvanometer.

$$R_h = \frac{V}{I_g} - R_g$$

Avometer: It is an instrument which can measure current in amperes, potential difference in volts and resistance in ohms. It basically consists of a sensitive moving coil galvanometer which is converted into a multirange ammeter, voltmeter of ohmeter accordingly as a current measuring circuit or a voltage measuring circuit or a resistance measuring circuit is connected with the galvanometer with the help of a switch known as function switch. Here X, Y are the main terminals of the AVO meter which are connected with the circuit in which measurement is required. FS is the function selector switch which connects the galvanometer with relevant measuring circuit.



Moving Coil Galvanometer:

(i) It is used for the measurement of current.

(ii) It is based on the principle that when a current carrying conductor is placed in the magnetic field it experiences a force whose direction is given by Fleming's left hand rule.

(iii) It essentially consists of a rectangular coil of large number of turns of fine insulated copper wire would over a non-magnetic metallic frame which is suspended by a very long and thin phosphor bronze wire between the pole pieces of a permanent magnet.

(iv) The current to be measured is conducted to the coil through the suspension wire. The current deflects the coil in the radial magnetic field between the soft iron cylinder and concave pole pieces. The amount of deflection serves as a measure of current. The deflection is measured with the help of a mirror attached to the phosphor bronze wire using lamp and scale arrangement.

(v) The current I is directly proportional to deflection ϕ

$$I \propto \phi \quad \text{or} \quad I = K\phi$$

where K is a constant of the galvanometer and is known as galvanometer constant.

where C = Elastic torsional constant of the suspension wire, N = Number of turns in the coil, A = Area per turn of the coil and B = Magnetic induction of radial magnetic field.

(vi) The current sensitivity, $S = \frac{\phi}{I} = \frac{1}{K} = \frac{NAB}{C}$

For higher sensitivity:

(a) Area of the moving coil should be large. In practice length *l* of the coil is increased as increase in breadth tends to decrease B.

(b) Number of turns in the coil should be increased but this is done up to a certain limit as increase in number of turns leads to increase in the resistance of the galvanometer.

(c) Magnetic induction B should be made large. For this, laminated ferro-cobalt steel permanent magnet is used.

ASSIGNMENT NO. 14

(1) To convert a galvanometer into an ammeter, we connect with it a:
(a) Shunt resistance (b) Low value parallel
(c) Low value by pass resistor (d) All of above

(2) To convert a galvanometer into a voltmeter, we connect with it a:
(a) Shunt resistance (b) A high value series resistance
(c) Parallel resistance (d) None of these

(3) The resistance of shunt is:
(a) Verge large (b) Very small (c) Both (a) and (b) (d) None of these

(4) When the ohmmeter measures the infinite resistance, its pointer lies at:
(a) Center of the scale (b) Left end of the scale
(c) Right end of the scale (d) None of these

(5) A proper combination of a galvanometer and a series resistance acts as:
(a) Voltmeter (b) Ammeter (c) Ohmmeter (d) None of these

(6) Which of the following is correct?
(a) $1\ T = 10^3\ G$ (b) $1\ T = 10^4\ G$ (c) $1\ T = 10^{-4}\ G$ (d) None of these

(7) Two parallel wires carrying current in opposite direction:
(a) Repel each other (b) Attract each other
(c) No effect on each other (d) None of these

(8) Which one of the following is not deflected by magnetic field?
(a) α-particle (b) β-particle (c) Neutrons (d) None of these

(9) If an electron enters the magnetic field at right angle from left and $\vec{B}$ is into paper, electron will be deflected:
(a) Upward (b) Downward (c) No deflection (d) None of these

(10) A solenoid 15 cm, long has 300 turns, I = 5A, B =
(a) $1.3 \times 10^{-2}\ wbm^{-2}$ (b) $1.3 \times 10^{2}\ wb\ m^{-2}$ (c) $1.3 \times 10^{-2}\ G$ (d) $1.3 \times 10^{-2}\ wb$

(11) The sensitvity of galvanometer can be increased by decreasing:
(a) Area of coil (b) Magnetic field
(c) Number of turns of coil (d) Torsional constant

(12) In a velocity selector, particle pass through it if:
(a) $\vec{F}_e = \vec{F}_B$ (b) $\vec{F}_e = \vec{F}_g$ (c) $\vec{F}_e = \vec{F}_B^{\,2}$ (d) $\vec{F}_e = -\vec{F}_B$

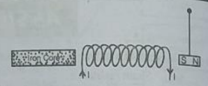
(13) Unit of permeability of free space is:
(a) $wbA^{-1}m^{-1}$ (b) NmA^{-1} (c) $Nm^{o}A^{-2}$ (d) Both (a) and (b)

(14) In finding the value of e/m, apparatus used is:
(a) Cavendish (b) Teltron tube (c) Mass spectrograph (d) None of these

(15) In finding the value of e/m, velocity of electron can be calculated by using:
(a) Potential difference (b) Velocity selector (c) Both (a), (b) (d) None of these

(16) In case of torque on a current carrying coil α is angle between:
(a) $\vec{B}$ and $\vec{A}$ (b) $\vec{B}$ and coil (c) $\vec{B}$ and plane of coil (d) None of these

(17) **The diagram shows a small magnet hanging on a thread near the end of a solenoid carrying a steady current I. What happens to the magnet as the iron core is inserted into the solenoid?**



(a) It moves towards the solenoid.
(b) It moves towards the solenoid and rotates through 180°.
(c) It moves away from the solenoid.
(d) It moves away from the solenoid and rotates through 180°.

(18) **The acceleration of an electron of mass m and charge e, moving with uniform speed v at right angles to a magnetic field of flux density B, is given by:**
(a) $\frac{Bev}{m}$ (b) $\frac{Be}{m}$ (c) $\frac{Bv}{m}$ (d) Bevm

(19) **Given that $\vec{B} = 40\hat{i} - 18\hat{k}$. The vector $\vec{B}$ lies in:**
(a) XY plane (b) YZ plane (c) XZ plane (d) Any of these

(20) **Tesla can also be written as:**
(a) NAm^{-1} (b) $NA^{-1}m^{-1}$ (c) $N^{-1}Am^{-1}$ (d) $NA^{-1}m$

(21) **Unit of E is NC^{-1} and that of B is $NA^{-1}\,m^{-1}$. The unit of $\frac{E}{B}$ comes out to be:**
(a) ms^{-2} (b) kg (c) ms^{-1} (d) ampere

(22) **Synchronization controls of CRO are used to synchronize the:**
(a) Voltages (b) Frequencies (c) Periods (d) Both (b) and (c)

(23) **Time period of sinusoidal voltage applied to CRO can be measured by using time calibration of:**
(a) X-axis (b) Y-axis (c) Z-axis (d) Any of these

(24) **Magnetic field is produced by the flow of current in a straight wire. This phenomenon was discovered by:**
(a) Faraday (b) Maxwell (c) Coulomb (d) Oersted

(25) **Dimensions of magnetic flux are:**
(a) $[MLT^{-2}A^{-2}]$ (b) $[ML^2T^{-2}A^{-2}]$ (c) $[ML^2T^{-1}A^{-2}]$ (d) $[ML^2T^{-2}A^{-1}]$

(26) **A charge q is moving with a velocity parallel to a màgnetic field. Force on the charge due to magnetic field is:**
(a) qvB (b) $\frac{qB}{v}$ (c) 0 (d) $\frac{Bv}{q}$

(27) **Particles having positive charges occasionally come with high velocity from the sky towards the earth. On account of magnetic field of the earth, they would be deflected towards:**
(a) North (b) South (c) East (d) West

(28) **A Current carrying loop is placed in a uniform magnetic field. The torque acting on it does not depend upon:**
(a) Shape of the loop (b) Area of the loop (c) Value of current (d) Magnetic field

(29) **A free charged particle moves through a magnetic field. The particle may undergo a change in:**
(a) Speed (b) Energy (c) Direction of motion (d) None of these

(30) **If a long copper rod carries a direct current, the magnetic field associated with the current will be:**
(a) Only inside the rod (b) Only outside the rod
(c) Both inside and outside the rod (d) Neither inside nor outside the rod

(31) **One tesla is equal to:**
(a) 10^8 gauss (b) 10^{-4} gauss (c) 10^4 gauss (d) 10^{-7} gauss

(32) **A conducting circular loop of radius r carries a constant current I. It is placed in a uniform magnetic field $\vec{B}$ such that $\vec{B}$ is perpendicular to the plane of the loop. The magnetic force acting on the loop is:**
(a) IrB (b) $2\pi rIB$ (c) Zero (d) πrIB

(33) **In a moving coil galvanometer the deflection of the coil θ is related to the electric current I by the relation:**
(a) $I \propto \tan\theta$ (b) $I \propto \theta$ (c) $I \propto \theta^2$ (d) $I \propto \sqrt{\theta}$

(34) **The restoring couple in the moving coil galvanometer is due to:**
(a) Current in the coil (b) Magnetic field of the magnet
(c) Material of the coil (d) Twist produced in the suspension wire

(35) **Which of the following is likely to have the largest resistance?**
(a) Moving coil galvanometer (b) Ammeter of range 1 A
(c) Voltmeter of range 10 V (d) A copper wire of length 1 m and diameter 3 mm

(36) **To measure total charge displaced through its terminals, we use:**
(a) an ammeter (b) a tangent galvanometer
(c) a ballistic galvanometer (d) a magnetometer

(37) **Which of the following is likely to have the least resistance?**
(a) a galvanometer (b) an ammeter (c) a milli ammeter (d) a voltmeter

(38) **A current carrying conductor placed in a magnetic field parallel to it. The force experienced by the conductor is:**
(a) F = O (b) F = BIL (c) F = BIL sin θ (d) F = BIL cos θ

(39) **μ_o is the permeability of free space, its value is:**
(a) $4\pi \times 10^{-7}$ Wb Am (b) $4\pi \times 10^{-7}\ Wb^{-1}\,m^{-1}$
(c) $4\pi \times 10^{-5}\ Wb\,A^{-1}m^{-1}$ (d) $4\pi \times 10^{-7}\ Wb\,A^{-1}m^{-1}$

(40) **The magnetic force experienced by a charge particle moving in a magnetic field will be maximum when it moves:**
(a) Parallel to magnetic field (b) Anti-parallel to magnetic field
(c) Perpendicular to magnetic field (d) None of these

(41) **If the magnetic field is directed along the normal to the area, then magnetic flux is:**
(a) Zero (b) Maximum (c) Minimum (d) None of them

(42) **The magnetic field inside the solenoid can be increased by:**
(a) Increasing number of turns (b) Decreasing current
(c) Increasing current (d) Both (a) and (c)

(43) **Nm/A is commonly called:**
(a) Gauss (b) Volt (c) Ampere (d) Weber

(44) **If a charge is free to move in an electric field then acceleration produced in it will be:**
(a) $a = \frac{qE}{m}$ (b) $a = qEm$ (c) $a = \frac{q}{Em}$ (d) $a = \frac{m}{qE}$

(45) **The e/m of an electron can be calculated by using the formula:**
(a) $\frac{e}{m} = \frac{Vr}{Br}$ (b) $\frac{e}{m} = \frac{2v}{B^2r^2}$ (c) $\frac{e}{m} = \frac{2Ve}{m}$ (d) None of these

(46) **The expression for torque acting on a current carrying coil placed in a uniform magnetic field is equal to:**
(a) $\tau = BIA\cos\alpha$ (b) $\tau = BA\cos\alpha$ (c) $\tau = BIA\sin\alpha$ (d) $\tau = IB\cos\alpha$

(47) The sensitivity of the galvanometer can be increased by increasing the:
(a) Area of the coil (b) Strength of magnetic field
(c) Number of turns of the coil (d) All of these

(48) What is the current in a wire of 10 cm long at right angle to a magnetic field of 0.5 T when force acting on the wire is 5 N:
(a) I = 10 A (b) I = 50 A (c) I = 500 A (d) I = 100 A

(49) When a charged particle moves through a magnetic field, the field changes the particle:
(a) Mass (b) Energy (c) Speed (d) Direction of motion

(50) In CRO when beam of electrons falls on a screen it makes a visible spot because the screen is:
(a) Rough (b) Fluorescent (c) Polished (d) Clear

(51) Such a galvanometer in which the coil comes to rest quickly after the current passed through it is called:
(a) Stable galvanometer (b) Sensitive galvanometer
(c) Both (a) and (b) (d) Tangent galvanometer

(52) The magnetic field at a point due to current carrying conductor is directly proportional to:
(a) Resistance of the conductor (b) Thickness of the conductor
(c) Current flowing through the conductor (d) Distance from the conductor

(53) The work done by magnetic field on a moving charge is:
(a) $Bqvl$ (b) $\frac{Bqv}{l}$ (c) Positive (d) Zero

(54) The resistance of an ideal ammeter and an ideal voltmeter is respectively:
(a) Zero, infinite (b) Low, high (c) High, low (d) Infinite, zero

(55) An electric charge in uniform motion produces:
(a) An electric field only (b) A magnetic field only
(c) Both electric and magnetic fields (d) No such field at all

(56) The force acting on a charge q moving with a velocity v in a magnetic field of induction B is given by:
(a) $q/(\vec{v} \times \vec{B})$ (b) $(\vec{v} \times \vec{B})/q$ (c) $q(\vec{v} \times \vec{B})$ (d) $(\vec{v} \cdot \vec{B})q$

(57) A charged particle moving in a magnetic field experiences a resultant force:
(a) In the direction of field
(b) In the direction opposite to that of field
(c) In the direction perpendicular to both the field and its velocity
(d) None of the above

(58) The direction of magnetic field produced by a linear current is given by:
(a) Right hand thumb rule (b) Fleming's left hand rule
(c) Joule's law (d) Ampere's law

(59) A current is passed through a straight wire. The magnetic field established around it has its lines of force:
(a) Circular and endless (b) Oval in shape and endless
(c) Straight (d) All are true

(60) Energy in a current carrying coil is stored in the form of:
(a) Electric field (b) Magnetic field (c) Dielectric strength (d) Heat

(61) A current flows in a conductor from east to west. The direction of the magnetic field at a point above the conductor is towards:
(a) East (b) West (c) North (d) South

(62) If electron velocity is $2\hat{i} + 3\hat{j}$ and it is subjected to magnetic field of $4\hat{k}$, then its:
(a) Speed will change (b) Path will change (c) Both (a) and (b) (d) None of these

(63) S.I unit of magnetic induction is:
(a) Weber (b) Tesla (c) Gauss (d) Weber m^{-1}

(64) When angle between vector area and magnetic lines is 0° then flux will be:
(a) Maximum (b) Minimum (c) Zero (d) None of these

(65) In galvanometer restoring torque is:
(a) $C\theta$ (b) NIBA (c) $C^2\theta$ (d) None of these

(66) A charge particle moving parallel to $\vec{B}$ follows:
(a) Circular path (b) Parabolic path (c) Straight path (d) Eliptical path

(67) The velocity of helium nucleus travelling in a curved path in the magnetic field is V. The velocity of proton moving in the same curved path in the same magnetic field is:
(a) 4V (b) 2V (c) V (d) $\frac{V}{2}$

(68) If cathode rays are projected at right angles to magnetic field, their trajectory is:
(a) Ellipse (b) Circle (c) Parabola (d) Unaltered

(69) Work done by a magnetic force is:
(a) Maximum (b) Minimum (c) Zero (d) None of these

(70) Value of shunt resistance is:
(a) $R_s = \frac{I_g R_g}{I - I_g}$ (b) $R_s = \frac{IR_g}{I_g - I}$ (c) $R_s = \frac{I_g R}{I_g - I}$ (d) None of these

ANSWERS

(1)	(d)	(2)	(b)	(3)	(b)	(4)	(a)	(5)	(a)
(6)	(b)	(7)	(a)	(8)	(c)	(9)	(b)	(10)	(b)
(11)	(d)	(12)	(d)	(13)	(d)	(14)	(b)	(15)	(c)
(16)	(c)	(17)	(a)	(18)	(a)	(19)	(c)	(20)	(b)
(21)	(c)	(22)	(d)	(23)	(a)	(24)	(d)	(25)	(d)
(26)	(c)	(27)	(c)	(28)	(a)	(29)	(c)	(30)	(c)
(31)	(c)	(32)	(c)	(33)	(b)	(34)	(d)	(35)	(c)
(36)	(c)	(37)	(b)	(38)	(a)	(39)	(d)	(40)	(c)
(41)	(b)	(42)	(d)	(43)	(d)	(44)	(a)	(45)	(b)
(46)	(a)	(47)	(d)	(48)	(d)	(49)	(d)	(50)	(b)
(51)	(b)	(52)	(c)	(53)	(d)	(54)	(a)	(55)	(c)
(56)	(c)	(57)	(c)	(58)	(a)	(59)	(a)	(60)	(b)
(61)	(c)	(62)	(b)	(63)	(b)	(64)	(a)	(65)	(b)
(66)	(c)	(67)	(b)	(68)	(b)	(69)	(c)	(70)	(a)

SOLUTION

(8) Neutrons are chargeless therefore it will not deflect.

(c) is correct

(10)
$$B = \mu_0 n I \qquad n = \frac{N}{l}$$
$$l = 15\text{ cm} = \frac{15}{30} = 0.15\text{ m}$$
$$n = \frac{300}{0.15} = 2000\ , \quad I = 5A$$
$$B = 4\pi \times 10^{-7}(2000)(5)$$
$$B = 1.3 \times 10^{-2}\ \text{Wbm}^{-2}$$

(b) is correct

(18)
$$F = ma \Rightarrow a = \frac{F}{m}$$
$$F = qVB\sin\theta \qquad \theta = 90^\circ$$
$$F = eVB$$
$$a = \frac{eVB}{m}$$

(a) is correct

(21)
$$\frac{E}{B} = \frac{NC^{-1}}{NA^{-1}m^{-1}} \qquad \sec = \frac{C}{A}$$
$$= m\,.\,C^{-1}A \qquad s^{-1} = AC^{-1}$$
$$= ms^{-1}$$

(c) is correct

(44)
$$F_e = qE$$
$$F_e = ma$$
$$a = \frac{qE}{m}$$

(a) is correct

(67)
$$qVB = \frac{mV^2}{r} \Rightarrow V = \frac{qrB}{m}$$
$$\frac{V_P}{V_{He}} = \frac{\frac{erB}{m}}{\frac{2erB}{4m}} = \frac{2}{1}$$
$$\frac{V_P}{V} = \frac{2}{1} \Rightarrow V_P = 2V$$

(68)
$$\vec{F} = q\vec{V} \times \vec{B} = -e\vec{V} \times \vec{B}$$
$$\vec{F} \perp \vec{V}$$

Trajectory is circular.

Chapter 15

ELECTROMAGNETIC INDUCTION / ELECTROMAGNETISM

MCAT UNIT 11

KEY POINTS

In 1831 Michael Faraday in England and Joseph Henry in U.S.A. observed that an emf is setup in a conductor when it moves across a magnetic field, the moving conductor was connected to a galvanometer it would show an electric current flowing through the circuit as long as conductor is kept moving in the magnetic field. The emf produced in conductor is called induced emf and current generated is called the induced current. This phenomenon is known as electromagnetic induction. The induced current can be increased by:

(i) Using a stronger magnetic field. (ii) Moving the loop faster.

(iii) Replacing the loop by a coil of many turns.

The greater the rate of change of flux, the larger is the induced emf.

Motional emf: The emf induced by the motion of a conductor across a magnetic field is called motional emf.

$$\varepsilon = -VBL\sin\theta$$

No motional emf is developed in the stationary rod. No motional emf is developed when rod is moving parallel or antiparallel to $\vec{B}$.

Faraday's Law: The emf induced is directly proportional to rate of change of magnetic flux.

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$$

Lenz's Law: The direction of induced current is always so as to oppose the change which causes the current. Lenz's law is also a statement of conservation of energy.

Mutual Induction: The phenomenon in which a changing current in one coil induces an emf in another coil is called the mutual induction.

$$\varepsilon_s = -M\frac{\Delta I_p}{\Delta t}$$

Where M is mutual inductance of the two coils. It depends upon the number of turns of the coils, their area of cross-section, their closeness together and the nature of the core material. Mutual inductance M may be defined as the ratio of average emf induced in the secondary to the time rate of change of current in the primary.

$$M = \frac{\varepsilon_s}{\frac{\Delta I_p}{\Delta t}}$$

Unit of M is VsA^{-1} called henry (H).

$$1\,H = \frac{1\,V}{1\,A/1\,s}$$

Self Induction: The phenomenon in which a changing current in a coil induces an emf in itself is called self induction.

$$\varepsilon_L = -L\frac{\Delta I}{\Delta t}$$

where L is called self inductance of coil. Self inductance L is the ratio of average emf to the rate of change of current in the coil.

$$L = \frac{\varepsilon_L}{\frac{\Delta I}{\Delta t}}$$

Unit of self inductance is VsA^{-1} called henry (H).

Energy Stored in an Inductor: Energy can be stored in the magnetic field of an inductor.

$$U_m = \frac{1}{2}LI^2$$

Energy stored in terms of magnetic field is:

$$U_m = \frac{1}{2}\frac{B^2}{\mu_o}Al$$

Energy density can be defined as energy stored per unit volume inside the solenoid.

$$U_m = \frac{1}{2}\frac{B^2}{\mu_o}$$

Alternating Current Generator: A current generator is a device that converts mechanical energy into electrical energy. Its principle is based on Faraday's law of electromagnetic induction. Carbon brushes and slip rings are used.

$$\varepsilon = \varepsilon_o \sin 2\pi ft \quad \Rightarrow \quad I = I_o \sin 2\pi ft$$

A number of coils are wound around a cylinder which is rotated in the magnetic field. This assembly is called an armature.

D.C. Generator: Alternating current generators are not suitable for many applications, for example, to run a D.C. motor. In 1834 William Sturgeon invented a simple device called a commutator that prevents the direction of current from changing. Therefore a D.C. generator is similar to the A.C. generator in construction with the difference that "slip rings" are replaced by "split rings". The "split rings" are two halves of a ring that act as a commutator.

D.C. Motor: A motor is a device which converts electrical energy into mechanical energy. We already know that a wire carrying current placed in a magnetic field experiences a force. This is the basic principle of an electric motor. In construction a D.C motor is similar to a D.C generator, having a magnetic field, a commutator and an armature. The magnetic field in the motor, is provided by a permanent magnet of an electromagnet. The windings of the electromagnet are usually called the field coils. The field coils may be in series or in parallel to the armature coils.

Back EMF Effect in Motors: A motor is just like a generator running in reverse. When the coil of the motor rotates across the magnetic field by the applied potential difference V, an emf ε is induced in it. The induced emf is in such a direction that opposes the emf running the motor. Due to this reason the induced emf is called back emf of the motor. The magnitude of the back emf increases with the speed of motor. Since V and ε are opposite in polarity, the net emf in the circuit is $V - \varepsilon$. If R is the resistance of the coil and I the current drawn by the motor, by Ohm's law:

$$V = \varepsilon + IR \quad \Rightarrow \quad I = \frac{V-\varepsilon}{R}$$

When motor is just started back emf is almost zero.

Transformer: A transformer is an electrical device to change a given alternating emf into a larger or smaller alternating emf. It works on the principle of mutual induction between two coils. Transformation equation is:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

If $N_s > N_p$ then $V_s > V_p$ and transformer is called step up. If $N_s < N_p$ then $V_s < V_p$ and transformer is called step down.

For ideal transformer:

$$\frac{V_s}{V_p} = \frac{I_p}{I_s}$$

Hence currents are inversely proportional to the respective voltages. Step up transformer is used at power generation centre to minimize power loss due to heating effect. In a transformer power is lost due to eddy currents and magnetic hysteresis. The induced currents circulating inside a piece of metal are known as eddy currents. Hysteresis loss is the energy expended to magnetize and demagnetize the core material in each cycle of the A.C. Efficiency of transformer is:

$$E_{\%} = \frac{\text{Output power}}{\text{Input power}} \times 100\%$$

Transformer:

(i) The transformer was inverted by Henry. It works on the principle of **mutual induction** and is used in AC only. It suitably changes the peak value of AC voltage.

(ii) A transformer consists of a (a) primary coil of turns N_p, (b) secondary coil of turns N_s and (c) a laminated soft iron core.

(iii) If V_p and V_s denote the voltage across the primary coil and the secondary coil respectively, the $(V_s/V_p) = (N_s/N_p)$.

(iv) In an actual transformer:

Output power ≤ Input power

but in an ideal transformer.

Output power = Input power

i.e., $V_sI_s = V_pI_p$

(I_p and I_s are the currents in primary and secondary coils respectively)

or $\frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p}$

(v) There are two types of transformers:

(a) **Step-up transformers:** Here, $N_s > N_p$, so $V_s > V_p$ and $I_s < I_p$.

(b) **Step-down transformers:** Here, $N_s < N_p$, so $V_s < V_p$ and $I_s > I_p$.

(vi) Magnetic susceptibility of these materials is negative and small. It is independent of temperature.

(vii) All magnetic materials show diamagnetism, i.e., **diamagnetism is a universal property.**

(viii) **In general, atoms with paired electrons exhibit diamagnetism.**

ASSIGNMENT NO. 15

(1) It is possible to transmit A.C power over long distances without much power loss by:

(a) Commutators (b) Transformer (c) D.C motor (d) Thermistors

(2) The efficiency of a transformer can be calculated by:

(a) $\eta = \frac{P_{out}}{P_{in}} \times 100$ (b) $\eta = \frac{P_{in}}{P_{out}} \times 100$ (c) $\eta = \frac{P_{out} \times P_{in}}{100}$ (d) $\eta = \frac{100}{P_{out} \times P_i}$

(3) The power loss in transformer takes place due to:

(a) Eddy current (b) Hysteresis (c) Magnetic field (d) Both (a) and (b)

(4) For an ideal transformer:

(a) Power input = Power output (b) Power input is less than power output
(c) Power input is greater than power output (d) Power output is greater than power input

(5) In step down transformer, the number of turns in:

(a) Primary are more (b) Primary are less
(c) Primary and secondary are equal (d) None of these

(6) A transformer works on:

(a) A.C only (b) D.C only (c) High voltage only (d) Both A.C and D.C

(7) A coil has an inductance of 0.02 Henry. When a current in the coil is changing at the rate of 150 A/S then the induced emf will be:

(a) 3 volt (b) 0.3 volt (c) 1.5 volt (d) 0.2 volt

(8) In a step down transformer, the input voltage is 200 V and the output voltage is 5 volts the turn ratio of the transformer is:

(a) 1 : 20 (b) 1 : 40 (c) 20 : 1 (d) 40 : 1

(9) A 25 watt and 100 watt bulbs are joined in series and connected to the mains. Which bulb will glow brighter?

(a) 100 watt (b) 25 watt
(c) First 25 and then 100watt (d) None of these

(10) When the back emf in a current is zero, it draws.

(a) Zero current (b) Maximum current (c) Minimum current (d) Steady average current

(11) A loop of wire is suspended between poles of a magnet with its plane parallel to pole faces. What happens if A.C. is used?

(a) Coil oscillate (b) Coil rotate (c) Coil remain at rest (d) Both (a), (b)

(12) Motional e.m.f. in the stationary rod is:

(a) $VBL \sin\theta$ (b) $-VBL \sin\theta$ (c) Both (a), (b) (d) Zero

(13) 1 Henry =

(a) VSA^{-1} (b) $VS^{-1}A^{-1}$ (c) $V^{-1}SA$ (d) VSA^{-2}

(14) When motor just started, back e.m.f. is almost:

(a) Maximum (b) Minimum (c) Zero (d) None of these

(15) For ideal transformer, V_s is ———— proportional to I_s.

(a) Directly (b) Inversely (c) Both (a), (b) (d) None of these

(16) Lenz's law is in accordance with law of conservation of:

(a) Mass (b) Momentum (c) Charge (d) Energy

(17) The phenomenon in which changing current in one coil induces an e.m.f. in another coil is called:

(a) Mutual inductance (b) Self induction (c) Mutual induction (d) All of these

(18) A dynamo converts:

(a) Electrical energy into mechanical energy (b) Mechanical energy into electrical energy
(c) Magnetic energy into electrical energy (d) None of these

(19) Unit of energy density is:

(a) $\frac{T^2}{wbm^{-1}A^{-1}}$ (b) $\frac{J}{m^3}$ (c) Both (a), (b) (d) $\frac{kg}{m^3}$

(20) $\frac{V_s}{V_p} = \frac{N_s}{N_p}$. This relation is true only when ———— of transformer.

(a) Input is open (b) Output is open
(c) Both input and output are closed (d) Both input and output are open

(21) If $\frac{N_s}{N_p} = 50$, $I_p = 20$ A, $V_p = 220$ V, $V_s = ?$

(a) 1100 V (b) 11000 V (c) 500 V (d) 1000 V

(22) The back e.m.f. in a motor is 120 V when motor is turning of 1680 rev/min. What is back e.m.f. when motor turns 3360 rev/min?

(a) 240 V (b) 240 J (c) 240 C/J (d) Both (a), (c)

(23) Plane of a coil makes an angle of 20° with the lines of magnetic field. The angle between $\vec{B}$ and vector area of the plane of coil is:

(a) Also 20° (b) 70° (c) 90° (d) 180°

(24) If the area of a single loop of wire placed in a magnetic field with its plane perpendicular to the field of 0.5 T and its area is changed at the rate of 0.5 ms^{-1}, then the magnitude of emf induced is:

(a) One volt (b) 0.25 volt (c) 0.125 volt (d) 0.625 volt

(25) The mutual inductance of two coils is 1.5 mH. If the current in the primary changes at the rate of 6000 As^{-1}, then emf induced in the secondary will be:

(a) 9 V (b) 4 V (c) 9 N (d) 4 MV

(26) The current in a single loop coil is changed at the rate of 25 As^{-1}. If self inductance of the coil is 2 H, an emf induced will be:

(a) 12.5 V (b) 50 V (c) 0.08 V (d) 27 V

(27) **A current rises from zero to its maximum value of 2 A in certain interval of time in a coil of self inductance 5 mH. The energy stored in the magnetic field around the coil is:**

(a) 10 J (b) 5 J (c) 10 mJ (d) 5 mJ

(28) **An A.C. generator operates at 50 Hz. The number of revolutions completed by its coil in one second is:**

(a) 50 rev s^{-1} (b) 314.3 rev s^{-1} (c) 31.43 rev s^{-1} (d) Both (a) and (b)

(29) **The turn ratio of a step-up transformer is 50. The voltage ratio and current ratio respectively will be:**

(a) 50, 50 (b) 50, 0.02 (c) 0.02, 50 (d) 50 volts, 0.02 amp

(30) **A step down transformer has a turn ratio of 50 : 1. An alternating voltage of 300 V is applied to its primary coil. The secondary voltage will be:**

(a) 6 volts (b) 9 volts (c) 12 volts (d) 1500 volts

(31) **It is possible to transmit A.C. power over long distances without much power loss by:**

(a) Transformers (b) Commutators (c) Armatures (d) Thermistors

(32) **An induced emf is produced when a magnet is plunged into a coil. The strength of the induced emf is independent of:**

(a) the strength of the magnet (b) Number of tarns of coil
(c) the resistivity of the wire of the coil (d) Speed with which the magnet is moved

(33) **A moving conductor coil produces an induced emf. This is in accordance with:**

(a) Lenz's law (b) Faraday's law (c) Coulomb's law (d) Ampere's law

(34) **Which one of the following can produce maximum induced emf?**

(a) 50 ampere DC (b) 50 ampere, 50 Hz AC
(c) 50 ampere, 500 Hz AC (d) 100 ampere DC

(35) **When two inductors L_1 and L_2 are connoted in parallel, the equivalent inductance is:**

(a) $L_1 + L_2$ (b) Between L_1 and L_2
(c) Less that both L_1 and L_2 (d) None of these

(36) **When the number of turns in a coil is doubled without any change in the length of the coil, its self – inductance becomes:**

(a) Four times (b) Doubled (c) Halved (d) Squared

(37) **If N is the number of turns in a coil, the value of self –inductance varies as:**

(a) N^0 (b) N (c) N^2 (d) N^{-2}

(38) **A metallic ring is attached to the wall room. Then the north pole of a magnet is brought near the ring, the induced current in the ring is:**

(a) zero (b) in clockwise direction
(c) in anticlockwise direction (d) infinite

(39) **The armature current in a DC motor is maximum when the motor has:**

(a) Picked up maximum speed (b) Just started
(c) Intermediate speed (d) Just been switched off

(40) **The working of a dynamo is based on the principle of:**

(a) Heating effect of current (b) Magnetic effect of current
(c) Chemical effect of current (d) Electromagnetic induction

(41) **A solenoid of length 1 meter has self-inductance L henry. If number of turns are doubled, its self inductance:**

(a) Remains same (b) Becomes 3L henry (c) Becomes 4L henry (d) Becomes $\frac{L}{\sqrt{2}}$ henry

(42) **The average emf induced in a coil when a current changes from 0 to 2 A in 0.05 sec is 8 V, The self-inductance of the coil is:**

(a) 0.1 H (b) 0.2 H (c) 0.4 H (d) 0.8 H

(43) **A 50 mH coil carries a current of 2A. The energy stored in its magnetic field is:**

(a) E = 0.005 J (b) E = 10 J (c) E = 0.1 J (d) E = 50 J

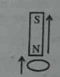
(44) **Energy stored per unit volume inside a solenoid is:**

(a) $\frac{1}{2}\frac{E^2}{\mu_o}$ (b) $\frac{1}{2}\frac{B^2}{\mu_o}$ (c) $\frac{B^2}{\mu_o}$ (d) $\frac{EB}{2\mu_o}$

(45) **Lenz's law does not violate the principle of:**

(a) Conservation of mass (b) Conservation of energy
(c) Conservation of charge (d) Conservation of momentum

(46) **If the north pole of a magnet moves away from a metallic ring. Then the current flows:**



(a) Clockwise (b) Anticlockwise
(c) First clockwise and then anticlockwise (d) None of above

(47) **In case of a motor, if V is the applied emf and ε is the back emf then net emf in the circuit is:**

(a) $V - \varepsilon$ (b) $V + \varepsilon$ (c) $V \times \varepsilon$ (d) $\frac{\varepsilon}{V}$

(48) **Eddy currents are the induced currents which are setup:**

(a) In a direction perpendicular to the flux (b) Along the flux lines
(c) Out of flux area (d) None of these

(49) **In a step down transformer, the input voltage is 200 V and the output voltage is 5 volts the turn ratio of the transformer is:**

(a) 1 : 20 (b) 1 : 40 (c) 20 : 1 (d) 40 : 1

(50) **In a step-up transformer, the turns ratio is 1 : 2. A Leclanche cells (e.m.f. = 1.5 V) is connected across the primary. The voltage across the secondary is:**

(a) 3.0 V (b) 0.75 V (c) 0 V (d) 1.5 V

(51) **In a transformer, the number of turns in primary and secondary are 500 and 2000 respectively. If current in primary is 48 A, the current in the secondary is:**

(a) 12 A (b) 24 A (c) 48 A (d) 144 A

(52) **Which of the following factor/factors is/are responsible for deciding the mutual inductance of two coils?**

(a) the number of turns of each coil (b) the resistance of each coil

(c) Current through each coil (d) Separation between the coils

(53) **SI unit of magnetic flux is:**

(a) weber m^{-2} (b) weber (c) weber per m (d) weber per m^4

(54) **Lenz's law:**

(a) is the same as the right hand palm rule

(b) determines the magnitude of an induced emf

(c) bears no relation to the law of conservation of energy

(d) is useful in deciding the direction of an induced emf

(55) **In a transformer, the immediate cause of the induced alternating current in the secondary coil is:**

(a) a varying magnetic field (b) a varying electric field

(c) the iron core of the transformer (d) a motion of the primary coil

(56) **In a step-up transformer the current in the secondary windings is:**

(a) more than the current in the primary (b) equal to current in the primary

(c) of opposite polarity than in the primary (d) of the same polarity as in the primary

(57) **A metallic ring with a cut is held horizontally and a magnet is allowed to fall vertically through the ring; then the acceleration of the magnet is:**

(a) equal to g (b) less than g

(c) more than g (d) sometimes less and sometimes more than g

(58) **When current I passes through an inductor of self-inductance L, energy stored in it is (1/2) LI^2. This is stored in the:**

(a) Current (b) Voltage (c) Magnetic field (d) Electric field

(59) **Self-induction of a solenoid is:**

(a) Directly proportional to the current flowing through the coil

(b) Directly proportional to its length

(c) Directly proportional to the area of cross-section

(d) Inversely proportional to the area of cross-section

(60) **Two identical coils of insulated wire are hung freely, facing each other. If they are fed exactly in the same way with an alternating current, they will:**

(a) Repel each other (b) Attract each other

(c) Rotate in anticlockwise direction (d) Rotate in clockwise direction

(61) **An electric bulb in series with a large inductor when connected across a DC source takes a little time before reaching a stable glow. If an iron core is inserted into the inductor, the delay will:**

(a) Increase (b) Decrease (c) Remain the same

(d) May change in either direction depending upon the values of inductance and resistance

(62) **The coefficient of mutual inductance between two coils depends upon:**

(a) Medium between coils only (b) Separation between coils only

(c) Both (a) and (b) (d) None of (a) and (b)

(63) **If rotational velocity of a dynamo armature is doubled, then induced emf will become:**

(a) Half (b) Two times (c) Four times (d) Unchanged

(64) **Two conducting coils are placed coaxially. A cell is placed in one coil, then they will:**

(a) Attract each other (b) Repel each other

(c) Both of (a) and (b) (d) they will not experience any force

(65) **If the number of turns of a self-inductor and the length is doubled, the new inductance will become:**

(a) 4 L (b) 2 L (c) 8 L (d) L

(66) **Eddy currents are favourable in which of the following electrical instruments?**

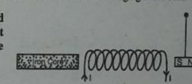
(a) Induction furnace (b) Electric motor (c) Transformer (d) AC generator

(67) **Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon:**

(a) Currents in the coils (b) Materials of the wires of the coils

(c) Relative position and orientation of the coils (d) Rates at which the currents are changing in the coils

(68) **The diagram shows a small magnet hanging on a thread near the end of a solenoid carrying a steady current I. What happens to the magnet as the iron core is inserted into the solenoid?**



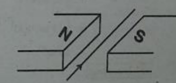
(a) It moves towards the solenoid

(b) It moves towards the solenoid and rotates through 180°

(c) It moves away from the solenoid

(d) It moves away from the solenoid and rotates through 180°

(69) **The diagram shows a wire, carrying a current I, placed between the poles of a magnet. In which direction does the force on the wire act?**



(a) Downwards.

(b) Upwards.

(c) Towards the N pole of the magnet.

(d) Towards the S pole of the magnet.

(70) **Four particles independently move at the same speed in a direction perpendicular to the same magnetic field which particle deflected the most?**

(a) A copper ion (b) A helium nucleus (c) An electron (d) A proton

ANSWERS

(1)	(b)	(2)	(a)	(3)	(d)	(4)	(a)	(5)	(a)
(6)	(a)	(7)	(a)	(8)	(d)	(9)	(b)	(10)	(d)
(11)	(c)	(12)	(d)	(13)	(a)	(14)	(c)	(15)	(b)
(16)	(d)	(17)	(c)	(18)	(b)	(19)	(a)	(20)	(b)
(21)	(b)	(22)	(a)	(23)	(b)	(24)	(b)	(25)	(a)
(26)	(b)	(27)	(c)	(28)	(a)	(29)	(b)	(30)	(a)
(31)	(a)	(32)	(c)	(33)	(b)	(34)	(c)	(35)	(c)
(36)	(b)	(37)	(c)	(38)	(c)	(39)	(b)	(40)	(d)
(41)	(c)	(42)	(b)	(43)	(c)	(44)	(b)	(45)	(b)
(46)	(a)	(47)	(a)	(48)	(a)	(49)	(d)	(50)	(c)
(51)	(a)	(52)	(a)	(53)	(b)	(54)	(d)	(55)	(a)
(56)	(c)	(57)	(a)	(58)	(c)	(59)	(c)	(60)	(b)
(61)	(a)	(62)	(c)	(63)	(b)	(64)	(b)	(65)	(c)
(66)	(a)	(67)	(c)	(68)	(a)	(69)	(a)	(70)	(c)

SOLUTION

(11) $\tau = BINA \cos\alpha$

Here $\alpha = 90°$

$\tau = 0$

(c) is correct

(27) $\text{Energy} = \frac{1}{2}LI^2$

$E = \frac{1}{2}(5\text{ mH})(2)^2$

$= \frac{1}{2}(5\text{ mH})(4)^2$

$= 10\text{ mJ}$

(c) is correct

(28) As $1\text{ rev s}^{-1} = 1\text{ Hz}$

(a) is correct

(29) $\frac{N_s}{N_p} = \frac{V_s}{V_p}$

But $\frac{V_s}{V_p} = \frac{I_p}{I_s}$

Therefore,

$\frac{N_s}{N_p} = \frac{I_p}{I_s}$

(b) is correct

(50) Because transformer works for alternating current not direct current.

(c) is correct

(59) For solenoid

$L = \mu_0 n^2 Al$

$n = \frac{N}{l} \Rightarrow n^2 = \frac{N^2}{l^2}$

$L = \mu_0 \frac{N^2}{l^2} Al$

$L = \frac{\mu_0 N^2 A}{l^2}$

(c) is correct

(63) $\varepsilon = NA\omega B$

$\varepsilon \propto \omega$

Chapter 16

ALTERNATING CURRENT

KEY POINTS

Alternating Current: Alternating current is that which is produced by a voltage source whose polarity keeps on reversing with time. The main reason for the world wide use of A.C. is that it can be transmitted to long distances easily and at a very low cost. The value of voltage or current that exists in a circuit at any instant of time t measured from some reference point is known as its instantaneous value.

$$V = V_0 \sin\frac{2\pi}{T}t \quad \text{or} \quad V = V_0 \sin 2\pi ft$$

The highest value reached by the voltage or current in one cycle is called its peak value. V_0 or I_0. The sum of the positive and negative peak values usually written as p-p value (peak to peak).

Root mean square (rms) value: rms values of on A.C. is the value of the steady current which when flowing through the same resistor produces heat at the same rate as the mean rate of heat produced by A.C.

$$V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707\,V_0$$

Similarly, $I_{rms} = 0.707\,I_0$

A.C. ammeter and A.C. voltmeter read rms value.

As $V = V_0 \sin\omega t$ or $V = V_0' \sin\theta$

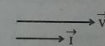
This angle θ which specifies the instantaneous value of the alternating voltage or current is known as its phase.

A.C. Circuits: The basis circuit element in a D.C. circuit is a resistor (R). The basic circuit elements in an A.C. circuit are resistor (R), an inductor (L) and a capacitor (C). The current and voltages in A.C. circuits are controlled by R, L and C.

A.C. Through a Resistor:

$V = V_0 \sin\omega t$

$I = \frac{V}{R} \Rightarrow I = I_0 \sin\omega t$



In this case V and I are in phase.

Vector or phasor diagram is:

When V and I are in phase then power dissipation in resistors.

$$P = VI, \quad P = \frac{V^2}{R}, \quad P = I^2R$$

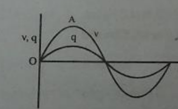
A.C. Through a Capacitor:

As $V = V_0 \sin\omega t$

Also $q = CV$

$\therefore$ $q = CV_0 \sin\omega t$

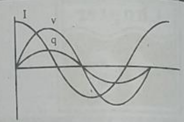
$\therefore$ V and q are in phase.



As current I is the rate of change of q with time, i.e.,

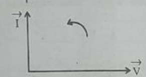
$$I = \frac{\Delta q}{\Delta t} \text{ (Slope of q-t graph)}$$

Slope of q-t graph of 'O' is maximum and decreases onward, becomes zero at A. Therefore current I is maximum at O and zero at A.



$\therefore$ I leads V by $\frac{\pi}{2}$.

Phasor diagram is:



Capacitive reactance is:

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

Unit of capacitive reactance is ohm. A capacitor blocks D.C. but not A.C.

A.C. Through an Inductor:

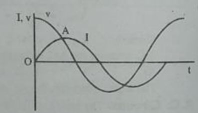
As $I = I_0 \sin 2\pi f t$

If L is the inductance of the coil, the changing current sets up a back emf in coil.

$$\varepsilon_L = L\frac{\Delta I}{\Delta t} \text{ (magnitude)}$$

As $V = \varepsilon_L$

$\therefore$ $V = L\frac{\Delta I}{\Delta t}$



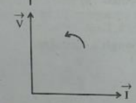
Here $\frac{\Delta I}{\Delta t}$ is slope of I-t graph.

Slope is maximum at O. $\therefore$ V is maximum, slope is zero at A.

$\therefore$ V is zero.

Hence V is leading I by $\pi/2$.

Phasor diagram is:



$$X_L = \omega L \Rightarrow X_L = 2\pi f L$$

Since an inductor coil does not consume energy, it is used for controlling A.C. Such a coil is known as choke. An inductor block A.C. but not D.C.

Impedance: The combined effect of resistance R capacitive reactance X_C and inductive reactance X_L in an A.C. circuit is known as impedance (Z).

Also $Z = \frac{V}{I}$

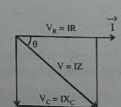
Unit of Z is ohm.

R-C Series Circuit:

$$\text{Impedance } Z = \frac{V}{I} = \sqrt{R^2 + \frac{1}{(\omega C)^2}}$$

I leads the applied voltage by an angle θ such that:

$$\tan\theta = \frac{1}{\omega CR} \Rightarrow \theta = \tan^{-1}\frac{1}{\omega CR}$$

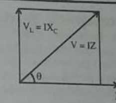


R-L Series Circuit:

$$\text{Impedance } Z = \frac{V}{I} = \sqrt{R^2 + (\omega L)^2}$$

V leads I by:

$$\theta = \tan^{-1}\frac{\omega L}{R}$$



Power in A.C. Circuits: When V and I are not in phase then:

$$P = VI\cos\theta$$

i.e., I and V cos θ are in phase.

Here cos θ is known as power factor.

When A.C. pass through R then V and I are in phase i.e., $\theta = 0°$.

$\therefore$ Power factor $= \cos 0° = 1$

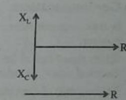
$\therefore$ Power dissipation is maximum.

When A.C. pass through C and L then phase difference between V and I is 90°.

$\therefore$ Power factor $= \cos 90° = 0$

$\therefore$ No power is dissipated.

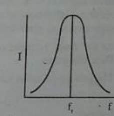
Series Resonance Circuit: A circuit in which R, L and C are connected in series with an alternating voltage source is called series resonance circuit. It is also called acceptor circuit.



At resonance $X_L = X_C$.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

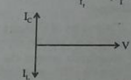
The impedance of the circuit at resonance is resistor so I and V are in phase. The power factor is 1. The impedance is minimum and equal to R. At resonance V_L and V_C may be much larger than the source voltage.



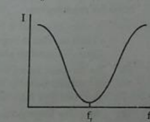
Parallel Resonance Circuit: A circuit in which L and C are connected parallel with an alternating voltage source. It is also called rejector circuit and tank circuit.

At resonance:

$$X_L = X_C$$
$$I_L = I_C$$
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

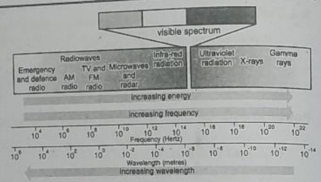


At resonance frequency, the circuit impedance is maximum. It is resistive and its value is $\frac{L}{Cr}$. At resonance the current is minimum and I and V, are in phase, so power factor is 1. At resonance, I_L and I_C may each be larger then the source current I.



Three Phase A.C. Supply: In three phase A.C. generator, instead of one coil, there are three coils inclined at 120° to each other, each connected to its own pair of slip rings. Thus three alternating voltages are generated. The phase difference between these voltages is 120°. Voltage across any two lines is 400 V. In metal detectors L-C parallel circuit is used. In metal detectors concept of beats is used.

Electromagnetic Waves: In 1864 Maxwell formulated a set of equations known as Maxwell equations. Maxwell proved that light waves are electromagnetic. To generate electromagnetic wave electrical charges must accelerate. A radio transmitting antenna provides a good example of generating electromagnetic waves by accelerating charges. L-C parallel circuit is connected with receiving antenna.



Modulation: Modulation is the process of combining the low frequency signal with a high frequency radio wave called carrier wave. Amplitude modulation is used in medium, long and short wave broad casting. Frequency range is from 540 KHz to 1600 KHz. Frequency modulation is used for v.h.f radio and u.h.f. TV sound signals. Frequency range is from 88 MHz to 108 MHz. F.M. radio waves are affected less by electrical interference then A.M. radio waves and hence provide a higher quality transmission of sound. F.M. has short range then A.M.

Radio Communication:

(i) In radio communication, an audio signal from a broadcasting station is sent over a great distance to a receiver.

(ii) Audio signal cannot be sent directly over the air for appreciable distance, even after converting into electrical signal. At audio frequencies, the signal power is quite small and radiation is not practicable.

(iii) The radiation of electrical energy is practicable only at high frequencies, e.g., above 20 kHz. Therefore, if audio signal is to be transmitted properly, some means must be devised which will permit transmission to occur at high frequencies while it simultaneously allows the carrying of audio signal. This is achieved by superimposing electrical audio signal on high frequency carrier wave. This process is called **Modulation.**

(iv) At the radio receiver, the audio signal is extracted from the modulated wave by the process called **Demodulation.**

(v) The process of radio communication involves three steps, viz.:

(a) Transmitter (b) Transmission of radio waves (c) Radio receiver

Modulation:

(i) The process of changing some characteristics (e.g., amplitude, frequency or phase) of a carrier wave in accordance with the intensity of the signal is known as modulation.

(ii) Modulation permits the transmission to occur at high frequency while it simultaneously allow the carrying of the audio singla.

(iii) **Need for modulation:**

(a) In order to radiate a frequency of 20 kHz directly into space, we would need an antenna length of 15,000 m. This is impractical. On the other hand, if a carrier wave of 1000 kHz is used to carry the signal, we need an antenna length of 300 m only.

(b) As the audio signal frequencies are small, therefore these cannot be transmitted over large distances if radiated directly into space (because of their small energy). But, when the audio signal is modified by a high frequency carrier wave, it permits the transmission over large distances.

(c) At audio frequencies, radiation is not practicable because of poor efficiency. However, efficient radiation of electrical energy is possible at high frequencies, thus making wireless communication feasible.

Type of Modulation:

(a) Amplitude modulation (b) Frequency modulation (c) Phase modulation

ASSIGNMENT NO. 16

(1) For q – t graph, slope shows:

(a) Current (b) Voltage (c) e.m.f. (d) None of these

(2) For A.C. through a capacitor, current ———— voltage.

(a) Lags by $\frac{\pi}{2}$ (b) Leads by $\frac{\pi}{2}$ (c) $\tan^{-1}\frac{1}{\omega CR}$ (d) $\tan^{-1}\frac{\omega^2}{R}$

(3) When A.C. pass through an inductor, voltage leads the current by:

(a) Half cycle (b) Quarter cycle (c) Full cycle (d) None of these

(4) Since an inductor does not consume energy coil is used for controlling A.C. Such a coil is called:

(a) Resistor (b) Choke (c) Starter (d) None of these

(5) When 10 V are applied to an A.C. circuit, the current flowing in it is 100 mA. Its impendence is:

(a) 100 Ω (b) 200 Ω (c) 10 Ω (d) 300 Ω

(6) In a R-C series circuit, current ———— applied voltage by θ =

(a) Lead, $\tan^{-1}\frac{1}{\omega CR}$ (b) Lead, $\frac{\pi}{2}$ (c) Lags, $\tan^{-1}\frac{1}{\omega CR}$ (d) Lags, $\frac{\pi}{2}$

(7) Series resonance circuit is also called:

(a) R-L-C series circuit (b) Acceptor circuit (c) Both (a) and (b) (d) None of these

(8) The resonance frequency is:

(a) $\frac{1}{2\pi\sqrt{2LC}}$ (b) $\frac{1}{4\pi\sqrt{LC}}$ (c) $\frac{0.0159}{\sqrt{LC}}$ (d) None of these

(9) For L-C parallel circuit, power factor is:

(a) Zero (b) One (c) Two (d) Three

(10) If capacitance of L-C parallel circuit is made four times then f = ————.

(a) Twice (b) Four times (c) One fourth (d) One half

(11) If a glass plate is placed between plates of a capacitor, in series with a lighted bulb, the brightness of the bulb.

(a) Remains same (b) Decreases (c) Increases (d) Bulb turns off

(12) The electromagnetic spectrum contains:

(a) Radio waves (b) X-rays (c) Microwaves (d) All of these

(13) Who proved that light waves are electromagnetic?

(a) Faraday (b) Einstein (c) Maxwell (d) Enderson

(14) The power dissipated in a resistor is the same for a constant potential difference V as for a sinusoidal potential difference with peak value V_0. Which of the following is the correct relationship between V and V_0?

(a) $V_0 = \frac{V}{2}$ (b) $V_0 = \frac{V}{\sqrt{2}}$ (c) $V_0 = V$ (d) $V_0 = \sqrt{2}V$

(15) An alternating current of root-mean-square value 2A in a given resistor dissipates energy at the same rate as a steady direct current I in another resistor of the same value. What is the value of I?

(a) $\sqrt{2}$ A (b) 2A (c) $2\sqrt{2}$ A (d) 4A

(16) **Use of eddy currents is done in the following except:**
(a) Moving coil galvanometer (b) Electric brakes
(c) Induction motor (d) Dynamo

(17) **The peak voltage of 220 V AC mains in volt is:**
(a) 155.6 (b) 220 (c) 311.0 (d) 440

(18) **A device for generating an alternating current of a desired frequency is known as:**
(a) An oscillator (b) A rectifier (c) An amplifier (d) None of these

(19) **The average power dissipation in a pure capacitor in AC circuit is:**
(a) $\frac{1}{2}CV^2$ (b) CV^2 (c) $2CV^2$ (d) Zero

(20) **In an AC circuit containing only capacitance, the current:**
(a) Leads voltage by 180° (b) Remains in phase with voltage
(c) Leads voltage by 90° (d) Lags voltage by 90°

(21) **In L-C-R series AC circuit, the phase angle between current and voltage is:**
(a) Any angle between 0 and $\pm\frac{\pi}{2}$ (b) $\frac{\pi}{2}$
(c) π (d) Any angle between 0 and π

(22) **In purely resistive A.C circuit the current:**
(a) Lags behind the emf (b) In phase with emf (c) Leads emf (d) None of these

(23) **A 10 μF capacitor is connected across a 200 V, 50 Hz AC supply. The peak current through the circuit is:**
(a) 0.6 amp (b) $0.6\sqrt{2}$ amp (c) $(0.6\sqrt{2})$ amp (d) $(0.6\pi\sqrt{2})$ amp

(24) **With increase in frequency of an A.C. supply the impedance of LRC series circuit:**
(a) Remains constant (b) Increases (c) Decreases
(d) Decreases at first becomes minimum and then increases

(25) **In a circuit containing an inductance of zero resistance, the current lags behind the applied alternating voltage by a phase angle:**
(a) 90° (b) 45° (c) 30° (d) 0°

(26) **The power loss in an AC circuit will be minimum, when:**
(a) Resistance high, inductance is high (b) Resistance is high, inductance is low
(c) Resistance is low, inductance is low (d) Resistance is low, inductance is high

(27) **The average power dissipation in pure inductance is:**
(a) $\frac{1}{2}LI^2$ (b) $2LI^2$ (c) $\frac{LI^4}{4}$ (d) Zero

(28) **A choke coil is preferred to a rheostat in AC circuit as:**
(a) it consumes almost zero power (b) it increases current
(c) it increases power (d) it increases voltage

(29) **A circuit using an inductor and a capacitor in series has maximum current. If L= 0.5 H and C = 8 μF, then the angular frequency of input AC voltage will be:**
(a) 500 (b) 5×10^5 (c) 4000 (d) 5000

(30) **In an LCR series AC circuit, the current:**
(a) is always in phase with the voltage (b) Always lags the generator voltage
(c) Always leads the generator voltage (d) None of the above statements is true

(31) **Energy required to establish a current of 4 A in a self-inductance L = 200 mH:**
(a) 0.16 J (b) 0.80 J (c) 0.40 J (d) 1.6 J

(32) **If the frequency of an AC is made 4 time of its initial value, the inductive reactance will:**
(a) be 4 times (b) be 2 times (c) be half (d) Remain the same

(33) **In non-resonant circuit, what will be the nature of the circuit for frequencies higher than the resonant frequency?**
(a) Resistive (b) Capacitive (c) Inductive (d) None of these

(34) **When voltage V and current I are in phase the power is expressed as:**
(a) $P = VI\sin\theta$ (b) $P = I^2R$ (c) $P = VR$ (d) $P = VI\cos\theta$

(35) **Impedance is the combined effect of:**
(a) Resistance and inductance (b) Resistance and reactance
(c) Inductance and capacitance (d) None of these

(36) **The phase angle θ in an R.L series circuit is expressed as:**
(a) $\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$ (b) $\theta = \tan\left(\frac{\omega L}{R}\right)$ (c) $\theta = \tan^{-1}\left(\frac{R}{\omega L}\right)$ (d) None of these

(37) **In frequency modulation, the amplitude of carrier waves is:**
(a) Increases (b) Remains constant (c) Decreases (d) None of these

(38) **In an AC circuit, power is consumed only in:**
(a) Resistance (b) Inductance (c) Capacitor (d) Inductance & capacitor

(39) **The average value of alternating current over a complete cycle is:**
(a) $\sqrt{2l}$ (b) $\frac{I_0}{\sqrt{2}}$ (c) $\sqrt{I_v}$ (d) Zero

(40) **The root mean square value of A.C is equal to:**
(a) Twice the peak value (b) Half the peak value
(c) $\frac{1}{\sqrt{2}}$ times peak value (d) Equal to peak value

(41) **A coil and an electric bulb are connected in series with an AC source. On introducing a soft iron bar in the coil, the intensity of light of bulb will:**
(a) Remain the same (b) Increase (c) Decrease (d) Fluctuate

(42) **An inductance of 2 henry is connected in a D.C. circuit. Then the value of inductive reactance is:**
(a) 2 ohm (b) 100 ohm (c) 440 ohm (d) Zero

(43) **The minimum and maximum values of power factor in an A.C. circuit are respectively:**
(a) 0 and 1 (b) 0.1 and 1 (c) 1 and 2 (d) 1 and 1.5

(44) **A resistance of 4 ohm and an inductive reactance $\sqrt{48}$ ohm are in series in an AC circuit. The impedance of the circuit is:**
(a) 4 ohm (b) $\sqrt{48}$ ohm (c) $(4+\sqrt{48})$ ohm (d) 8 ohm

(45) **At resonance, the phase difference between current and voltage in an AC circuit is:**
(a) 0° (b) 45° (c) 90° (d) 180°

(46) **Which of the following statements is correct?**
(a) A capacitor offers infinite resistance to DC
(b) Radio-frequency choke is air-cored
(c) Audio frequency choke is iron-cored
(d) All of these

(47) **At an angular frequency of 10,000 rad s^{-1}, the capacitive reactance of a 1.0 μF capacitor is:**
(a) 10 Ω (b) 100 Ω (c) 1000 Ω (d) 10,000 Ω

(48) **Resonance frequency of LC circuit is:**
(a) $\frac{1}{2\pi}\sqrt{(LC)}$ (b) $\frac{1}{2\pi LC}$ (c) $\frac{1}{2\pi}\sqrt{(L/C)}$ (d) $\frac{1}{2\pi\sqrt{(LC)}}$

(49) **With increase in frequency of an AC supply, the inductive reactance:**
(a) Decreases
(b) Increases directly proportional to frequency
(c) Increases as square of frequency
(d) Decreases inversely with frequency

(50) **With increase in frequency of an AC supply, the capacitive reactance:**
(a) Varies inversely with frequency
(b) Varies directly with frequency
(c) Varies directly as square of frequency
(d) Remains constant

(51) **With increase in frequency of an AC supply, the impedance of an LCR series circuit:**
(a) Remains constant (b) Increases (c) Decreases
(d) Decreases at first, becomes minimum and then increases

(52) **The graph between voltage and time is known as ———— of alternating voltage.**
(a) Distance (b) Work (c) Waveform (d) Acceleration

(53) **If frequency of rotating coil of an A.C. generator is f Hz then frequency of e.m.f. produced in Pakistan is:**
(a) 50 Hz (b) 60 Hz (c) f Hz (d) None of these

(54) **Root mean square value of current is:**
(a) $I_{rms}=\frac{I_o}{\sqrt{3}}$ (b) $I_{rms}=\frac{I_o}{\sqrt{2}}$ (c) $I_{rms}=\sqrt{2}\,I_o$ (d) $I_{rms}=0.808\,I_o$

(55) **When A.C. pass through a resistor, phase difference between current and voltage:**
(a) 90° (b) 180° (c) 0° (d) 45°

(56) **When voltage and current are in phase then power dissipated is:**
(a) VI (b) I^2R (c) $\frac{V^2}{R}$ (d) All of these

(57) **For A.C. through a capacitor q and v are:**
(a) In phase (b) Out of phase (c) q lags v by $\frac{\pi}{2}$ (d) q leads v by $\frac{\pi}{2}$

(58) **A direct current of 2A and an alternating current having a maximum value of 2A flow through two identical resistance. The ratio of heat produced in two resistance will be:**
(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 4 : 1

(59) **In case of inductor, in third quarter power is:**
(a) Positive (b) Negative (c) Both (a), (b) (d) None of these

(60) **In a R-C series circuit, impedance is:**
(a) $\sqrt{R^2+(X_C)^2}$ (b) $\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}$ (c) $\sqrt{R^2+X_L^2}$ (d) Both (a), (b)

(61) **In a R-L series circuit, impedance is:**

(a) $\sqrt{R^2 + (\omega L)^2}$ (b) $\sqrt{R^2 + (x_C)^2}$ (c) Both (a), (b) (d) None of these

(62) **A 100 μF capacitor will offer a reactance of:**

(a) 60 Ω (b) 90 Ω (c) 32 Ω (d) 42 Ω

(63) **The impedance of a circuit consists of 3 ohm resistance and 4 ohm reactance. The power factor of the circuit is:**

(a) 0.4 (b) 0.6 (c) 0.8 (d) 1.0

(64) **Main advantage of having a three phase A.C. supply is that load is divided into ________ parts.**

(a) 2 (b) 4 (c) 3 (d) None of these

(65) **The frequency for which 5 μF capacitor has a reactance of $\frac{1}{1000}$ Ω is given by:**

(a) $\frac{100}{\pi}$ μHt (b) $\frac{100}{\pi}$ Hz (c) $\frac{1}{1000}$ H (d) 1000 Hz

(66) **The process of combining low frequency signal with a high frequency radio wave is called:**

(a) Damping (b) Doping (c) Modulation (d) All of these

(67) **Electromagnetic waves emitted from antenna are:**

(a) Stationary (b) Longitudinal (c) Transverse (d) All of these

(68) **A sinusoidal alternating current of peak value I_0 passes through a heater of resistance R. What is the mean power output of the heater?**

(a) $\frac{I_0^2 R}{2}$ (b) $\frac{I_0^2 R}{\sqrt{2}}$ (c) $I_0^2 R$ (d) $\sqrt{2} I_0^2 R$

(69) **A sinusoidal alternating current has a peak value I_0. Which expression is correct for the root-mean-square current I_{rms}?**

(a) $I_{rms} = \frac{I_0}{2}$ (b) $I_{rms} = I_0(0.707)$ (c) $I_{rms} = \sqrt{2I_0}$ (d) $I_{rms} = 2I_0$

ANSWERS

(1)	(a)	(2)	(b)	(3)	(b)	(4)	(b)	(5)	(a)
(6)	(a)	(7)	(c)	(8)	(c)	(9)	(b)	(10)	(d)
(11)	(b)	(12)	(d)	(13)	(c)	(14)	(d)	(15)	(c)
(16)	(d)	(17)	(c)	(18)	(d)	(19)	(d)	(20)	(c)
(21)	(a)	(22)	(b)	(23)	(b)	(24)	(d)	(25)	(a)
(26)	(d)	(27)	(d)	(28)	(a)	(29)	(a)	(30)	(d)
(31)	(d)	(32)	(a)	(33)	(c)	(34)	(b)	(35)	(b)
(36)	(a)	(37)	(b)	(38)	(a)	(39)	(d)	(40)	(c)
(41)	(c)	(42)	(d)	(43)	(a)	(44)	(d)	(45)	(a)
(46)	(d)	(47)	(b)	(48)	(d)	(49)	(b)	(50)	(a)
(51)	(d)	(52)	(c)	(53)	(c)	(54)	(b)	(55)	(c)
(56)	(d)	(57)	(a)	(58)	(c)	(59)	(b)	(60)	(d)
(61)	(a)	(62)	(c)	(63)	(b)	(64)	(c)	(65)	(b)
(66)	(c)	(67)	(c)	(68)	(a)	(69)	(b)		

SOLUTION

(5)
$$V = IZ$$
$$\Rightarrow Z = \frac{V}{I}$$
$$Z = \frac{10}{100 \times 10^{-3}}$$
$$Z = 100\,\Omega$$

(a) is correct

(14)
$$V_{rms} = \frac{1}{\sqrt{2}} V_0$$
$$\sqrt{2}\, V_{rms} = V_0$$

(d) is correct

(17)
$$V_{rms} = 0.707\, V_0$$
$$V_0 = \frac{V_{rms}}{0.707}$$
$$V_0 = \frac{220}{0.707}$$
$$V_0 = 311.0$$

(c) is correct

(29)
$$\omega = \frac{1}{\sqrt{LC}}$$
$$\omega = \frac{1}{\sqrt{0.5 \times 8 \times 10^{-6}}}$$
$$\omega = 500$$

(a) is correct

(31)
$$E = \frac{1}{2} LI^2$$

(d) is correct

(42) Inductive reactance is only for A.C. not D.C.

(d) is correct

(58)
$$H_{(dc)} = I^2Rt = (2)^2 Rt$$
$$H_{(ac)} = I^2Rt = \left(\frac{I_0}{\sqrt{2}}\right)^2 Rt = \frac{2^2}{2} Rt$$
$$\frac{H_{(dc)}}{H_{(ac)}} = \frac{2}{1}$$

(c) is correct

(63) Power factor $\cos\theta$
$$= \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_C)^2}} = \frac{3}{\sqrt{3^2 + 4^2}} = \frac{3}{5} = 0.6$$

(b) is correct

(65)
$$X_C = \frac{1}{2\pi fC}$$
$$\frac{1}{1000} = \frac{1}{5 \times 10^{-6} \times 2\pi f}$$
$$f = \frac{1}{\pi} \times 100 \times 10^6\ \text{Hz}$$
$$\Rightarrow \frac{1}{\pi} \times 100\ \text{MHz}$$

(b) is correct

(67) Power for resistance
$$P = I_0^2 R$$
$$\text{Mean power} = \frac{0 + P}{2}$$
$$= \frac{0 + I_0^2 R}{2}$$
$$= \frac{I_0^2 R}{2}$$

(a) is correct

Chapter 17

PHYSICS OF SOLIDS

MCAT UNIT 6

KEY POINTS

What makes steel hard, lead soft, iron magnetic and copper electrically conducting. It depends upon the structure, the particular order and bonding of atoms in a material.

Crystalline Solids: The solids in which there is a regular arrangement of molecules. e.g., Metals such as copper, iron and zinc, ionic compound, such as sodium chloride, ceramics such as zirconia. Has a definite melting point. For every crystal, there is a temperature at which the vibrations become so great that the structure suddenly breaks up, and the solid melts. The transition from solid to liquid is discontinuous.

Amorphous or Glassy Solids: There is no regular arrangement of molecules. e.g., Plastic, glass. Has no definite melting point.

Polymeric Solids: It has a structure that is intermediate between order and disorder. They can be classified as partially or poorly crystalline solid. e.g., Polythene, polystrene and nylon etc. A crystalline solid consists of three dimensional pattern that repeats itself over and over again. This smallest three dimensional basic structure is called unit cell. Pattern of NaCl have a cube shape. The ability of the body to return to its original shape, after the removal of deforming force, is called elasticity.

Stress: Force applied on unit area to produce any change in the shape, volume or length of a body, is called stress $\sigma = F/A$.

S.I. unit is N/m^2 called Pascal (Pa). When a stress changes length, it is called tensile stress. When stress changes the volume, it is called compressional stress. When stress changes the shape, it is called shear stress.

Strain: Strain is a measure of the deformation of a solid when stress is applied to it. If strain is due to tensile stress, it is called tensile strain.

$$\therefore \quad \text{Strain} = \frac{\Delta l}{l}$$

If strain is due to compressional stress it is called compressional strain.

$$\text{Strain} = \frac{\Delta V}{V}$$

If strain is due to shear stress, it is called shear strain.

$$\text{Strain}\ \gamma = \frac{\Delta a}{a} = \tan\theta$$

For small value of θ, $\gamma = \theta$. No unit of strain.

Elastic Constants for Some Materials			
Material	Young's Modulus 10^9 Nm^{-2}	Bulk Modulus 10^9 Nm^{-2}	Shear Modulus 10^9 Nm^{-2}
Aluminium	70	70	30
Bone	15	–	80
Brass	91	61	36
Concrete	25	–	–
Copper	110	140	44
Diamond	1120	540	450
Glass	55	31	23
Ice	14	8	3
Lead	15	7.7	5.6
Mercury	0	27	0
Steel	200	160	84
Tungsten	390	200	150
Water	0	2.2	0

Elastic Constants: The ratio of stress to strain is a constant for a given material, provided the external applied force is not too great. This is called modulus of elasticity.

$$\text{Modulus of elasticity} = \frac{\text{Stress}}{\text{Strain}}$$

Its unit is N/m^2 or Pa. In case of linear deformation, the ratio is called Young's Modulus.

$$Y = \frac{F/A}{\Delta l/l}$$

For three dimensional deformation, when volume is involved, then the ratio of applied stress to volumetric strain is called Bulk Modulus.

$$K = \frac{F/A}{\Delta V/V}$$

When the shear stress and shear strain are involved then their ratio is called shear modulus.

$$G = \frac{F/A}{\tan\theta}$$

Elastic Limit and Yield Strength: If stress is increased beyond the elastic limit of the material, the specimen becomes permanently changed and does not recover its original shape or dimension after the stress is removed. This kind of behaviour is called plasticity. The UTS is defined as the maximum stress that a material can withstand and can be regarded as the nominal strength of material. Once the point corresponding to UTS is crossed the material breaks at a point responding the fracture stress. Substances which undergo plastic deformation until they break are known as ductile substances. e.g., Lead, copper and wrought iron. Substances which break just after the elastic limit is reached are known as brittle. e.g., Glass and high carbon steel.

Strain Energy in Deformed Materials:

$$W = \frac{1}{2} l_1 F \qquad \text{...... (i)}$$

This is the amount of energy stored in wire. l_1 is the extension produced in the wire due to force F_1. Eq. (i) can be expressed in terms of modulus of elasticity E.

$$W = \frac{1}{2}\left(\frac{EAl_1^2}{L}\right)$$

Electrical Properties of Solids: Metals with conductivity of the order of 10^7 $(\Omega m)^{-1}$. Some solids have very low conductivities ranging between 10^{-10} and 10^{-20} $(\Omega m)^{-1}$ are called insulators. e.g., Wood, diamond etc. Solids with intermediate conductivities from 10^{-6} to 10^{-4} $(\Omega m)^{-1}$ are called semiconductors. e.g., Ge, Si etc. Free electron theory based on Bohr model of electron distribution in an atom failed to explain the electrical behaviour of three types of materials.

Energy Band Theory: In insulators, an empty conduction band, a full valence band and a large energy gap (several eV) between them. In conductors, valence and conduction band overlap each other. There is no physical distinction between the two bands. In semiconductors, partially filled conduction band, and valence band. A very narrow forbidden energy gap (1 eV). At 0K Ge or Si is a perfect insulator. At room temperature. Ge or Si becomes a semiconductor.

Intrinsic and Extrinsic Semiconductor: A semiconductor in its extremely pure form is known as intrinsic semiconductor. Doping is the process in which a small amount of impurity (in the ratio of 1 to 10^6) is added to a pure semiconductor. The doped semiconductor materials are called extrinsic semiconductors. When a silicon crystal is doped with a pentavalent element. e.g., Arsenic, antimony, phosphorous etc. four valence electrons of the impurity atom from covalent bond with four neighbouring Si atoms while fifth valence electron

provides a free electron. Such a extrinsic semiconductor is called n-type semi-conductor. When a silicon crystal is doped with a trivalent element. e.g., Aluminium, born, gellium, indim etc. three valence electrons of the impurity atom covalent bond with three neighbouring Si atoms, while the are missing electron in the covalent bond with the fourth neighbouring Si atom is called a hole which in fact is vacancy where an electron can be accommodated. Such semi-conductor is called p-type semiconductor. The current flowing through the semiconductor is carried by both free electrons and holes.

Superconductors: Some materials whose resistivity becomes zero below a certain temperature called critical temperature. Such materials are called superconductors. First superconductor was discovered in 1911 by Kamerlingh Onnes in 1911. Electrical resistance of mercury disappears suddenly as the temperature is reduced below 4.2 K. Some metals such as aluminium (T_c = 1.18 K), tin (T = 3.72 K) and lead (T_c = 7.2 K) are also become superconductors. In 1986 a new class of ceramic materials was discovered that becomes superconductor at temperature as high as 125 K. Any superconductor with a critical temperature above 77 K, the boiling point of liquid nitrogen is referred as a high temperature superconductor. Yttrium barium copper oxide ($YBa_2Cu_3.O_7$) become superconductor at 163 K or −110°C. Superconductors are used in MR1, magnetic levitation trains, powerful but small electric motors and faster computer chips.

Magnetic Properties of Solid: An atom in which there is a resultant magnetic filed behaves like a tiny magnet and is called a magnetic dipole. Magnetism is due to the spin and orbital motion of the electrons surrounding the nucleus. It is impossible to obtain an isolated north pole. If orbits and the spin axes of the electrons in an atom are so oriented that their field support each other and the atom behaves like a tiny magnet. Substances with such atoms are called paramagnetic substances. e.g., Al, manganese, platinum. If there is no resultant field as the magnetic fields produced by both orbital and spin motions of the electrons might add upto zero, called diamagnetic substances. e.g., atoms of water, copper bismuth, antimony. If atoms cooperate with each other in such a way so as to exhibit a strong magnetic affect, called ferromagnetic substances. e.g., Fe, Co, Ni, Chromium dioxide, Alnico (an iron aluminium nickle-cobalt alloy). Domains are of macroscopic size of the order of millimetres or less but large enough to contain 10^{12} to 10^{16} atoms. Iron is a soft magnetic material. Steel is a hard magnetic material. Above curie temperature iron is paramagnetic but not ferromagnetic. Curie temperature for iron is about 750°C.

Hysteresis Loop: The phenomenon in which magnetism lags behind magnetizing current is called hysteresis. When the current is reduced to zero, the material still remains strongly magnetized, called retantivity. To demagnetize the material the magnetizing current is reversed and increased to reduce the magntization to zero. This is known as coercive current. Once the material is magnetized, its curve never passes through origin. Coercivity of steel is more than iron. The area of the loop is a measure of the energy needed to magnetize and demagnetize each cycle.

Paramagnetic Materials:

(i) Materials which are feebly attracted by magnets are known as paramagnetic materials. Examples: aluminium, sodium, platinum, manganese, $CuCl_2$, $FeCl_3$, oxygen, etc.

(ii) These materials get magnetised in the direction of the magnetic field.

(iii) A paramagnetic rod suspended in a uniform magnetic field becomes parallel to the direction of the field.

(iv) In a non-uniform magnetic field, they move towards region of higher field.

(v) Relative permeability of these materials is just greater than one and positive.

(vi) Magnetic susceptibility is small and positive (10^{-1} to 10^{-3}).

(vii) The magnetic susceptibility is inversely proportional to absolute temperature. This is called **Curie law**, $\chi = (C/T)$, where C is called **Curie's constant**.

(viii) The magnetic susceptibility decreases with increasing magnetising field.

(ix) In general, atoms with finite magnetic moment are paramagnetic. Such materials have unpaired electrons in their valence orbits.

Ferromagnetic Materials:

(i) Substances which are strongly attracted by magnets are known as ferromagnetic substances. Examples: iron, nickel, cobalt, gadolinium.

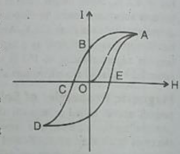
(ii) A ferromagnetic rod, when suspended in a uniform magnetic field, aligns itself along the direction of the field.

(iii) In a non-uniform magnetic field, a ferromagnetic material moves towards regions of higher magnetic field.

(iv) The relative permeability of these materials is very large (10^2 to 10^6).

(v) The magnetic susceptibility of these materials is positive and very high (10^2 to 10^6).

Hysteresis Loop:



(i) Hysteresis loop or cycle is a plot of intensity of magnetisation (I) against magnetising field (H) over closed loop ABCDEA.

(ii) Curve OA indicates the variation of I with H till the saturation point A is reached.

(iii) Curve AB indicates the variation of I as H is decreased to zero.

(iv) Curve BCD indicates the variation of I as H is increased in reverse direction.

(v) Curve DE indicates the variation of I as H is decreased to zero but in reverse direction.

(vi) Curve EA indicates the variation of I as H is increased in the original direction.

(vii) It can be seen that when H is zero, the value of I does not become zero, but has a value of OB. **This lagging of I behind H is called hysteresis.**

(viii) **Retentivity:** The residual magnetism present inside the specimen even when the external magnetising force is made zero is called **retentivity. Or, Retentivity is the capacity of the material to retain its magnetism when the magnetising force is removed**. The intercept OB is a measure of retentivity.

(ix) **Coercivity:** Coercivity is the capacity of the material to retain its magnetism inspite of any demagnetising process. The intercept OC is a measure of retentivity.

(x) **The area of the hysteresis loop is a measure of work done or energy dissipation or hysteresis loop.**

(xi) (a) **For soft iron:** Coercivity is less, retentivity is more, hysteresis loss is less, susceptibility is more and permeability is more.

(b) **For steel:** Coercivity is more, retentivity is less, hysteresis loss is more, susceptibility is less and permeability is less.

(xii) Soft iron is used in transformers, moving coil galvanometers, electromagnets, etc., while steel is used for permanent magnets.

Bonding in Solids: A chemical bond is defined as the attractive force which holds the atoms together in molecules. Depending upon the rearrangement of the valence electrons, bonds are categorised as follows:

(i) **Ionic bond:**

(a) Ionic bond is formed between two atoms by transfer of one or more of valence electrons from one atom to the other.

(b) Ionic bond is very strong, hence ionic compounds have high melting points and boiling points.

(c) The ionic compounds in dry state do not conduct electricity. However, when dissolved in water, they conduct electricity.

(ii) **Covalent bond:**

(a) A covalent bond is formed due to mutual sharing of valence electrons by the combining atoms.

(b) Covalent bond is not as strong as the ionic bond and hence covalent compounds have lower melting points.

(c) Covalent compounds are quite hard.

(iii) **Metallic bond:**

(a) A metal can be assumed as an array of positive ions surrounded by an electron gas. The electrostatic force between the electrons and ions dominates over mutual repulsion between different electrons and different positive ions and thus holds the metal together.

(b) This bond is weak, non-directional.

Energy Bands in Solids:

(i) A solid can be treated as a densely packed system obtained by brining together isolated single atoms. An isolated single atom possesses a number of discrete energy levels that can be occupied by electrons of the atom. Ordinarily, the electrons exist in the ground state, when excited electrons can shift to higher energy levels. Usually only the valence electrons can participate in these excitations. When two atoms can participate in these excitations. When two atoms interact, each previous single energy level is split into two levels. For N atoms, the splitting is N-fold. In case of solids N is very large, the number of splitting is very large. Since the value of energy for different level splittings remains approximately the same, the overall effect of bringing a large number of atoms is to form bands of continuous energy levels, separated by gaps where no electron states exist. The gap is called **forbidden energy gap**.

(ii) The band formed by a series of energy levels containing the valence electrons is known as **valence band**. The valence band may be partially or completely filled up depending upon the nature of the crystal.

(iii) The next higher permitted band is called as the **conduction band**. This band may be empty or partially filled. In conduction band, the electrons can more freely.

Distinction between Conductors, Insulators and Semi-conductors:

(i) **Conductors:**

(a) The substances having high electrical conductivity are known as conductors, e.g., metals.

(b) The valence band and conduction band overlap in case of conductors.

(c) In conductors, charge carriers responsible for the conduction of electricity are **free electrons.**

(d) The electrical conductivity of conductors is of the order of 10^8 (ohm × metre)$^{-1}$.

(e) The conductivity of a metal decreases with rise in its temperature.

(f) Metallic conductors have positive temperature coefficient of resistance.

(g) The resistance of conductor increases due to addition of impurities.

(ii) **Insulators:**

(a) The substances having poor electrical conductivity are known as insulators, e.g., glass, wood, paper, mica, diamond, ceramic, plastic, etc.

(b) In insulators, the valence band is completely filled while conduction band is completely empty.

(c) The electrical conductivity of insulators is very low in the range 10^{-16} to 10^{-6} $ohm^{-1} m^{-1}$.

(d) There exists a large forbidden energy gap (= 6 eV for diamond) between valence band and conduction band.

(e) In insulators, no free electrons are available for conduction.

(f) Insulators have zero temperature coefficient of resistance.

(iii) **Semiconductors:**

(a) The substances whose electrical conductivity lies between conductors and insulators are called semiconductors, e.g., carbon, silicon, germanium, cadmium sulphide, gallium arsenide.

(b) The electrical conductivity lies between that of good conductors like copper and good insulators like polythene.

(c) The conductivity of semiconductors is of the order of 1 (ohm-m)$^{-1}$.

(d) The conductivity of semiconductor is $\simeq 10^{10}$ times that of insulator and $\simeq 10^{-3}$ times that of conductor.

(e) The conductivity of semiconductor increases with increase in temperature.

(f) In semiconductors, electrical conduction is due to electrons and holes.

(g) Semiconductors have negative temperature coefficient of resistance.

(h) The resistance of semiconductors decrease due to the addition of impurities.

(i) In semiconductors there is a small energy gap ($\simeq 1$ eV) between the valence band and the conduction band.

(j) **At absolute zero temperature, conduction band is completely empty and the semiconductor behaves as an insulator.**

Intrinsic Semiconductor:

(i) A semiconductor in pure form is called **intrinsic semiconductor**.

(ii) Intrinsic semiconductor has four electrons in the outermost orbit of atom and atoms are held together by covalent bond.

Crystalline and Amorphous Solids:

(i) The solids in which the atoms are arranged in a definite, regular and long range order, are said to be **crystalline**.

(ii) The solids in which the atoms are arranged in indefinite, irregular and short range order are said to be **amorphous**.

Properties of Crystalline Solids:

(i) They have sharp melting point, on account of equal strengths of all interatomic bonds.

(ii) They have characteristic geometrical shape, on account of negligibly small thermal motion of atoms.

(iii) They have a homogeneous composition.

(iv) Atoms in a crystalline solid have minimum potential energy (i.e., most negative).

(v) They have flat surface.

(vi) They may be anisotropic as regards thermal conductivity, refractive index, electrical conductivity, mechanical strength.

Properties of Amorphous Solids:

(i) These solids do not have sharp melting points.

(ii) They have no characteristic geometrical shape.

(iii) They may not have a homogeneous composition.

(iv) Different atoms in the amorphous solids may not be in stable equilibrium.

(v) They are isotropic as regards thermal conductivity, refractive index, electrical conductivity, mechanical strength.

(vi) Different interatomic bonds may not have equal strengths.

Crystal Lattice: A crystal structure is a periodic arrangement of atoms in space and is obtained by associating with every lattice point a unit assembly or basis of atoms, identical in composition, arrangement and orientation. Thus, crystal structure = space lattice + basis.

Unit Cell: A unit cell is the smallest block or smallest structural unit of the arrangement of atoms in a crystal from which the entire structure can be built by repetition in three dimensions. It can be selected in various ways.

Diamagnetic Materials:

(i) Materials which are repelled by magnets are known as diamagnetic materials. Examples: Bismuth, zinc, copper, silver, gold, diamond, NaCl, water, nitrogen, hydrogen, etc.

(ii) These materials get magnetised in a direction opposite to that of the magnetic field.

(iii) A diamagnetic rod suspended in a uniform magnetic field becomes perpendicular to the direction of the field.

(iv) In a non-uniform magnetic field, they move from regions of higher concentration to regions of lower concentration.

(v) Relative permeability of these materials is less than one but positive.

Rigid Body: When the external forces do not produce any deformation in the body, the body is called a rigid body. Diamond is the nearest approach to a rigid body.

Elasticity:

(i) Elasticity of a material is its property by virtue of which it resists strain when deforming forces are applied on it and recovers from strain when deforming forces are removed.

(ii) When the body regains its original shape and size completely after the removal of deforming forces then the body is said to be **perfectly elastic**, e.g., Quartz fibre.

(iii) If the body does not have any tendency to recover its original shape and size, the body is said to be **perfectly plastic**, e.g., plasticine.

(iv) Truely speaking, the behaviour of bodies lie between these two extreme limits.

Stress:

(i) When external forces are exerted on a body, the body gets distorted, i.e., different poritions of the body move relative to each other. Due to these displacements atomic forces (restoring forces) are set up inside the body to restore the original form. **The restoring force per unit area set up inside the body is called stress.** This is measured by the magnitude of deforming force per unit area of the body when the equilibrium is established. If F is the force applied to an area of cross-section A, then stress = (F/A).

(ii) **When the stress is applied normal to a surface.** This is called as **normal stress.** It produces a change in length of a wire or a change in volume of a body. The normal stress to a wire or body may be **compressive** or **tensile** according as it produces a decrease or increase in the length of a wire or volume of the body.

(iii) When the stress is applied tangential to a surface, it is called **tangential** or **shearing stress**.

(iv) Dimensional formula of stress is $[ML^{-1}T^{-2}]$ and CGS and MKS units are dyne/cm^2 and newton/m^2 respectively.

(v) Stress is a **tensor** quantity.

(vi) Though both stress and pressure are defined as force per unit area but even then they differ from each other due to following reasons:

- (a) Pressure is always normal to the area while stress can be either normal or tangential.
- (b) Pressure on a body is always compressive while stress can be either compressive or tensile.
- (c) Pressure is a scalar while stress is a tensor.

Strain:

(i) The deforming forces acting on a body cause a relative displacement of its various parts and the body is then said to be strained. Either a change in length or a change in volume or change in shape occurs. The relative change produced in the body due to the influence of external forces is called **strain**.

(ii) Strain has no dimension as it is a pure number.

(iii) (a) The changes in length per unit length is called as **linear strain**.

- (b) The change in volume per unit volume is called as **volume strain**.
- (c) If there is a change in shape, the strain is called **shearing strain** or **shear**. It is measured by the angle through which a line originally perpendicular to the fixed surface is turned.

ASSIGNMENT NO. 17

(1) **Curie temperature is:**
(a) Different for chromium oxide and cobalt (b) Same for chromium oxide and cobalt
(c) Same for iron and cobalt (d) None of these

(2) **The steel makes a good permanent magnet and is called:**
(a) Soft (b) Hard (c) In between (d) None of these

(3) **Ferromagnetic substance have the small regions are called:**
(a) Magnets (b) Patches (c) Domains (d) None of these

(4) **The curie temp for iron is about:**
(a) 800°C (b) 740°C (c) 750°C (d) 650°C

(5) **The process of introduces a small amount of impurity into the pure semi conductor is called:**
(a) Overlapping (b) Mixing (c) Doping (d) None of these

(6) **Which of the following are example of diamagnetic substances?**
(a) Antimony (b) Cobalt (c) Copper (d) Both (a) and (c)

(7) **Which of the following is not a ferromagnetic substances?**
(a) Copper (b) Steel (c) Iron (d) Cobalt

(8) **The permeability of diamagnetic materials:**
(a) Less than one (b) Greater than one (c) Equal to one (d) Zero

(9) **The area of hysteresis loop is proportional to the work done in:**
(a) Magnetizing of the substance (b) Reversing the magnetic field
(c) Demagnetizing the substance (d) None of these

(10) **If a material sets up a magnetic field which opposes the applied magnetic field it is said to be:**
(a) Electromagnetic (b) Diamagnetic (c) Paramagnetic (d) None of these

(11) **The domain theory of magnet is important to explain the behaviour of:**
(a) Diamagnets (b) Paramagnets (c) Ferromagnets (d) All of these

(12) **A pentavalent impurity in Si:**
(a) a free electron and a free hole (b) a free hole
(c) a free electron (d) No free particle

(13) **Unit of Bulk modulus is:**
(a) No unit (b) N/m^2 (c) N/P_a (d) $P_a(m)$

(14) **Formula for strain energy in deformed materials is:**
(a) $\frac{1}{2}\frac{EAl_1^2}{L}$ (b) $\frac{EAl_1^2}{2}$ (c) $\frac{1}{3}\frac{EAl_1}{L}$ (d) $\frac{1}{2}\frac{EAl_1}{L^2}$

(15) **At 0 K a piece of silicon is a:**
(a) Conductor (b) Semi-conductor (c) Insulator (d) All

(16) **Gallium belongs to ———— group.**
(a) 4^{th} (b) 2^{nd} (c) 7^{th} (d) 3^{rd}

(17) **Polythene, polystyrene and nylon etc., are examples of:**
(a) Crystalline (b) Amorphous (c) Polymers (d) None of these

(18) **Polymers have ———— specific gravity compared with even the lightest of metals.**
(a) High (b) Low (c) Zero (d) None of these

(19) **The strength to weight ratio of plastic material (chair) is ———— then steel material (chair).**
(a) Greater (b) Lesser (c) Same (d) None of these

(20) **Net charge on n-type material is:**
(a) Positive (b) Negative (c) Neutral (d) All

(21) **Energy needed to magnetize and demagnetize is given by:**
(a) Hysteresis curve (b) Area of loop (c) Coercivity (d) None of these

(22) **Yttrium bearium copper oxide ($YBa_2Cu_3O_7$) become superconductor at:**
(a) 163 K (b) −110°C (c) Both (a), (b) (d) None of these

(23) **Which of following has the highest elasticity?**
(a) Rubber (b) Steel (c) Glass (d) All

(24) **Which of the following has bulk modulus?**
(a) Water (b) Gas (c) Honey (d) All

(25) **Out of the following the one which can penetrate through a 20 cm thick steel plate is:**
(a) γ-rays (b) β-rays (c) α-rays (d) Positive rays

(26) **Crystalline substances mostly exist in:**
(a) Liquid state (b) Gaseous state (c) Solid state (d) Plasma sate

(27) **Solids have a definite shape on account of:**
(a) Crystalline structure (b) Small atomic kinetic energy
(c) Large atomic kinetic energy (d) Large atomic potential energy

(28) **Which of the following is not an amorphous substance?**
(a) Glass (b) Polymers (c) Copper (d) Rubber

(29) **Conductors, insulators and semiconductors differ from each other due to property of:**
(a) Ability of the current they carry (b) Formation of crystal lattice
(c) Binding energy of their electrons (d) Mutual width of their energy gaps

(30) **Which of the following is an example of cubic crystal?**
(a) Calcite (b) Potassium chromate (c) Mercury chloride (d) None of these

(31) **In an extrinsic semiconductor, the ratio of impurity atoms to that of pure atoms is:**
(a) $1:10^8$ (b) $10^8:1$ (c) $1:10^6$ (d) $10^6:1$

(32) **The forbidden energy gap in semiconductors:**
(a) Lies just below the valence band
(b) Lies just above the conduction band
(c) is the same as the valence band
(d) Lies between the valence band and the conduction band

(33) **In a good conductor, the energy gap between the conduction band and valence band is:**
(a) Infinity (b) Wide (c) Narrow (d) Zero

(34) **With rise in temperature the electrical conductivity of intrinsic semiconductor:**
(a) Increases (b) Decreases
(c) First increases and then decreases (d) First decreases and then increases

(35) **What is the hardest natural substance known?**
(a) Steel (b) Chromium (c) Tungsten (d) Diamond

(36) **There is no hole current in good conductors, because they:**
(a) are full of electron gas (b) have large forbidden gap
(c) have no valence band (d) have overlapping valence and conduction bands

(37) **When a semiconductor is heated its resistance:**
(a) Decreases (b) Increases (c) Remains the same
(d) May increase or decrease depending upon semiconductor

(38) **The most commonly used semiconductors are:**
(a) Germanium and silicon (b) Germanium and copper
(c) Silicon and glass (d) Glass and ebonite

(39) **Conductors, semiconductors and insulators differ in:**
(a) Work function (b) Width of forbidden energy gap
(c) Binding energy of electrons (d) Mobility of electrons

(40) **In an insulator, the number of electrons in the valence shell, in general, is:**
(a) Less than 4 (b) More than 4 (c) Equal to 4 (d) None of these

(41) **The drift velocity of holes as compared to that of electrons is:**
(a) Less (b) More (c) Equal (d) More or equal

(42) **The change in the shape of a regular body is due to:**
(a) Metallic strain (b) Longitudinal strain (c) Bulk strain (d) Shearing strain

(43) **Energy stored per unit volume in a stretched wire is:**
(a) $\frac{1}{2}$ Stress × Strain (b) Stress × Strain (c) Load × Stress (d) $\frac{1}{2}$ Load × Extension

(44) **The structure of unit cell is:**
(a) One dimensional (b) Two dimensional (c) Three dimensional (d) All of these

(45) **The maximum stress which a body can bear is called:**
(a) UTS (b) Elastic stress (c) Permanent stress (d) Strain stress

(46) **In hysteresis when magnetization become zero it is:**
(a) Coercivity (b) Retentivity (c) Saturation (d) Remanance

(47) **The substance which have partially filled conduction bands are called:**
(a) Conductors (b) Insulators (c) Semi-conductor (d) Super conductor

(48) **An example of donor impurity is:**
(a) Phosphorus (b) Indium (c) Boron (d) Gallium

(49) **The material whose resistivity becomes zero below a certain temperature:**
(a) Conductor (b) Semi-conductor (c) Super conductor (d) Insulator

(50) **Magnetic field produced by spinning nucleus is:**
(a) Much weaker (b) Much stronger (c) No field (d) All of these

(51) **Domains contains nearly:**
(a) $10^{8} - 10^{10}$ atoms (b) $10^{12} - 10^{16}$ atoms (c) $10^{15} - 10^{20}$ atoms (d) None

(52) **The breaking stress for a wire of unit cross-section is called:**
(a) Yield point (b) Tensile strength (c) Elastic fatigue (d) Y-modulus

(53) **Which of the following quantities does not have the unit of force per unit area?**
(a) Stress (b) Strain (c) Young's modulus (d) Pressure

(54) **The Young's Modulus of a perfectly rigid body is:**
(a) Zero (b) Unit (c) Infinity (d) May have any value

(55) **The area enclosed by a hysteresis loop is a measure of:**
(a) Retentivity (b) Suscesptibility (c) Permeability (d) Energy loss

(56) **The permeability of ferromagnetic substance is:**
(a) Positive and small (b) Positive and large (c) Negative and small (d) Negative and large

(57) **Unbalance spin of electron in the atoms is the cause of:**
(a) Diamagnetism (b) Paramagnetism (c) Ferromagnitism (d) Anti-ferromagnetism

(58) **A small solid ball of a substance is repelled by a pole magnet. The substance may be:**
(a) Bismuth (b) Aluminium (c) Copper (d) Sodium

(59) **The type of bonding in Ge crystal is:**
(a) Ionic (b) Metallic (c) Covalent (d) van der Waals'

(60) **If band gap between valence and conduction band material is 5 eV, the material is:**
(a) An insulator (b) Good conductor
(c) Semiconductor (d) Such materials are non-existent

(61) **In an intrinsic semiconductor:**
(a) Only electrons are responsible for flow of current
(b) Both holes and electrons carry current
(c) Both holes and electrons carry current with electrons being majority carriers
(d) Only holes are responsible for flow of current

(62) **Out of the following, the intrinsic semiconductor is:**
(a) Copper (b) Silicon (c) Arsenic (d) Boron

(63) **The temperature coefficient of resistance of a semiconductor is:**
(a) Positive always (b) Negative always (c) Zero (d) Infinite

(64) **The resisitivity of intrinsic semiconductor at 0 K is:**
(a) ∞ (b) Zero (c) 1 (d) Equal to that at 0°C

(65) **The conductivity of a pure semiconductor can be increased by:**
(a) Increasing temperature (b) Mixing trivalent impurity
(c) Mixing pentavalent impurity (d) All of the above

(66) **Metals such as copper, iron, zinc are ———— solids.**
(a) Crystalline (b) Amorphous (c) Polymeric (d) All

(67) **Conductivity of metals is of the order of:**
(a) $10^{-7}\ \Omega m^{-1}$ (b) $10\ \Omega m^{-1}$ (c) $10^{7}\ (\Omega m)^{-1}$ (d) $10^{-7}\ (\Omega m^{-1})$

(68) **The speed of bullet train can be:**
(a) 500 km/h (b) 500 km/s (c) 500 m/s (d) 5 km/h

(69) **Aluminium behaves as super conductor at:**
(a) 1.18 K (b) 7.8 K (c) 125 K (d) None of these

(70) **Material which has hysteresis loop of small area is suitable for:**
(a) Electromagnet (b) Permanent magnet (c) Core of transformer (d) All

ANSWERS

(1)	(a)	(2)	(b)	(3)	(c)	(4)	(c)	(5)	(c)
(6)	(d)	(7)	(a)	(8)	(a)	(9)	(d)	(10)	(b)
(11)	(c)	(12)	(c)	(13)	(b)	(14)	(a)	(15)	(c)
(16)	(d)	(17)	(c)	(18)	(b)	(19)	(a)	(20)	(c)
(21)	(b)	(22)	(c)	(23)	(b)	(24)	(d)	(25)	(a)
(26)	(c)	(27)	(b)	(28)	(c)	(29)	(d)	(30)	(d)
(31)	(c)	(32)	(d)	(33)	(d)	(34)	(a)	(35)	(d)
(36)	(c)	(37)	(a)	(38)	(a)	(39)	(b)	(40)	(b)
(41)	(a)	(42)	(d)	(43)	(a)	(44)	(c)	(45)	(a)
(46)	(a)	(47)	(c)	(48)	(a)	(49)	(c)	(50)	(a)
(51)	(b)	(52)	(b)	(53)	(b)	(54)	(c)	(55)	(d)
(56)	(b)	(57)	(c)	(58)	(a)	(59)	(c)	(60)	(a)
(61)	(b)	(62)	(b)	(63)	(b)	(64)	(a)	(65)	(d)
(66)	(a)	(67)	(c)	(68)	(a)	(69)	(a)	(70)	(c)

Chapter 18

ELECTRONICS

MCAT UNIT 9

KEY POINTS

p-n Junction and its Characteristics: A pn-junction is formed when a crystal of germanium or silicon is grown in such away that its one half is doped with a trivalent impurity and other half with pentavalent impurity. Its n-region contains free electrons as majority charge carries and p-region contains holes. There is a charge less region is formed around the junction in which charge carriers are not present. This is called depletion region. A potential difference develops across the depletion region, its value is 0.7 V in case of silicon and 0.3 V for germanium. The potential barrier is created due to potential difference.

Forward Biased and Reverse Biased pn-junction: When an external potential difference is applied across a pn-junction such that p-side is positive and n-side is negative and current begins to flow across the junction then the junction is said to be forward biased. The ratio of ΔV_f and ΔI_f $\left(r_f = \frac{\Delta V_f}{\Delta I_f}\right)$ is known as forward resistance of pn-junction. When the positive terminal of source voltage is connected to n-region and negative terminal to p-region and no current flows across the junction then it is said to be reverse biased. A few microampere current flows across the junction due to flow of minority charge carriers known as reverse current or leakage current. pn-junction is also known as semi-conductor diode in reverse biased the resistance offered by diode is of the order of several mega ohms.

Rectification: Conversion of alternating current into direct current is called rectification. In half wave rectification only one half of alternating current cycle is converted into direct current. One diode is used for this, during the positive half cycle of input alternating voltage the diode is forward biased and during negative half cycle it is reverse biased. When both halves of the input voltage cycle are utilized it is known as full wave rectification. Its circuit consists of four diodes connected in a bridge type arrangement.

Specially Designed pn-junction: Light emitting diode (LED) are made from special semi-conductors such as gallium arsenide and gallium arsenide phosphide. During forward bias conduction a photon of visible light is emitted. Photo diode is used for detection of light. It is operated in reverse biased condition. It can turn its current ON and OFF in nano-seconds. It is used for automatic switching, logic circuits, detection of light etc. Photovoltaic cell consists of a thick n-type region covered by a thin p-type layer. It has no external bias. When it is exposed to light it causes a current flow through the external circuit, the current is proportional to intensity of light.

Transistors: A transistor consists of a single crystal of germanium or silicon which is grown in such a way that it has three regions. The central region is p-type which is sandwiched between two n-type regions. It is known as npn transistor. If n-type central region is sandwiched between two p-type regions it forms a pnp transistor. These regions are called base, emitter and collector. The base is very thin of the order of 10^{-6} m. The emitter has greater concentration of impurity as compared to the collector. In normal operation of transistor batteries V_{BB} and V_{CC} are connected in such a way that its emitter-base junction is forward biased and collector base junction is reverse biased. V_{CC} is of much higher value than V_{BB}. An electronic current I_E flows from emitter into base and a very small part of it current I_B flows out of the base and rest of it I_C flows out of the collector.

$$I_E = I_C + I_B$$

The ratio of collector current I_C to base current I_B is nearly constant called current gain of transistor β.

$$\beta = \frac{I_C}{I_B}$$

The transistors are basically used as amplifiers. The voltage gain of the amplifier is given as:

$$\frac{V_{out}}{V_{IN}} = \beta \frac{R_C}{r_{ie}}$$

A transistor can also be used as a switch, the collector and emitter behave as the terminals of the switch. The base and emitter act as control terminals.

Operational Amplifier: Instead of making amplifier circuit by discrete components the whole amplifier is integrated on a small silicon chip and enclosed a capsule. Pins connected with working terminals such as input, output and power supply projected outside the capsule. Such an integrated amplifier is known as operational amplifier (op-amp). It has two input terminals. One is known as inverting input (–) and other non-inverting input (+). A signal that is applied at the inverting input appears after amplification at the output terminal with phase shift of 180°. The input resistance is the resistance between (+) and (–) inputs of amplifier. Its value is very high of the order of several mega ohms. No current flows between the two input terminals. The resistance between the output terminal and ground is called output resistance. Its value is only a few ohms. The ratio of output voltage V_o to the voltage difference between non-inverting and inverting inputs $(V_+ - V_-)$.

$$A_{OL} = \frac{V_o}{V_+ - V_-} = \frac{V_o}{V_i}$$

OP-Amp as Inverting and Non-inverting Amplifier: When input signal V_i which is to be amplified is applied at inverting terminal (–) through resistance R_1. V_+ is grounded and V_- virtually at ground potential then gain is given by:

$$G = -\frac{R_2}{R_1}$$

The gain is independent what is happening inside the amplifier. In case of non-inverting amplifier the input signal V_i is applied at non-inverting terminal (+). The gain of amplifier is given by:

$$G = 1 + \frac{R_2}{R_1}$$

The OP-Amp can also be used as comparator. The comparator as a night switch can be operated.

Digital Systems and Fundamental Logic Gates: A digital system deals with quantities or variables which have only two discrete values or states. For example open or closed, yes or no, true or false, off or on. The mathematical manipulation of these quantities can be represented by binary digits 1 and 0. We require a special algebra known as Boolean algebra for the manipulation of the quantities which have values 1 and 0. Boolean algebra is based upon three basic operations:

(i) AND operation (ii) OR operation (iii) NOT operation

The electronic circuits which implement the various logic operations are known as logic gates. In these gates the high and low states i.e., 1 and 0 states are simulated by certain voltage levels. If voltage of 3.5 V is applied to a gate it will accept it as high or 1. If a voltage of 0.5 V is applied the gate will recognize it as 0 or low. The Boolean equation for OR-gate is given as:

$$X = A + B$$

The output has a value 1 when at least one of its inputs A and B is at 1. The Boolean equation for AND gate is given as:

$$X = A . B$$

Its output X is 1 only when both of its inputs A and B are at 1. The Boolean equation for NOT-gate is in the following:

$$X = \bar{A}$$

It performs the operation of inversion that is why it is also known as inverter. It changes a logic level to its opposite level i.e., it changes 1 to 0 and 0 to 1. The Boolean equation for NOR-gate is given as:

$$X = \overline{A + B}$$

In this gate the output of OR-gate is inverted. The Boolean equation of NAND gate is as:

$$X = A\bar{B} + \bar{A}B$$

The value of X will be 0. When the two inputs have same values and it is 1 when the inputs have different values. The Boolean equation for exclusive NOR-gate (XNOR) is given as:

$$X = \overline{A\bar{B} + \bar{A}B}$$

Its output will be 1 when its two inputs are identical and 0 when the two inputs are different.

Logic Gates:

(i) The electronic circuits in which current and voltage signals vary continuously with time are called **analogue electric circuits**.

(ii) The electronic circuits in which current and voltage signals have only two levels (either **on** or **off**) are called **digital circuits**.

(iii) A switch which can be closed or opened is known as a **gate**. The gate has two possible states. Mathematically, the two possible states. Mathematically, the two states are expressed by number 1 (one) and 0 (zero).

(iv) 1 (one) may be used to represent the gate as **on, true, yes, closed, high** ... and 0 (zero) may be used to represent the gate as **off, false, no, opened, low** ....

(v) The circuits which are used to perform switching action are known as **logic circuits** or **logic gates**.

(vi) The most basic gates are called the OR gate, the AND gate and the NOT gate.

(vii) A table that shows all the input/output possibilities for a logic gate is called a **truth table** or the table of combinations.

Extrinsic Semiconductors:

(i) The addition of foreign impurity to an intrinsic semiconductor in controlled quantities to promote conductivity is termed as **doping**.

(ii) A doped intrinsic semiconductor is called as extrinsic semiconductor.

(iii) Extrinsic semiconductors are of two types:

(a) p-type semiconductor (b) n-type semiconductor

n-type Extrinsic Semiconductor:

(i) When a small amount of pentavalent impurity (examples: phosphorus, arsenic, antimony, etc.) is added to an intrinsic semiconductor, we obtain an n-type extrinsic semiconductor.

(ii) The impurity atoms in n-type extrinsic semiconductor are called **donor atoms**, as they donate an **extra** electron to pure semiconductor or host lattice.

(iii) In the n-type semiconductor, the number of electrons in the conduction band > number of holes in the valence band.

(iv) In the n-type semiconductor, electrons are called as **majority** charge carriers, whereas holes are called as **minority** charge carriers.

(v) In n-type semiconductor, the Fermi level shifts towards the conduction band.

(vi) There is no charge on n-type semiconductor because it is formed by the combination of free negatively charged electrons and fixed positively charged donor ions.

p-type Extrinsic Semiconductor:

(i) When a small amount of trivalent impurity (examples: gallium, indium, boron, boron, etc.) is added to an intrinsic semiconductor, we obtain a p-type extrinsic semiconductor.

(ii) The impurity atoms in p-type extrinsic semiconductor are called **acceptor atoms**, as they accept an electron from the host lattice.

(iii) In the p-type semiconductor, the number of holes in the valence band > number of electrons in the conduction band.

(iv) In the p-type semiconductor, **holes** are **majority** charge carriers while electrons are **minority charge** carriers.

(v) In p-type semiconductor, the Fermi level shifts towards the valence band.

(vi) There is no charge on p-type semiconductor also, because it is formed by the combination of free positively charged holes and fixed negatively charged acceptor ions.

p-n Junction Diode:

(i) If a p-type semiconductor is suitable joined to an n-type semiconductor, the junction is called p-n junction and the device so formed is called p-n junction diode.

(ii) At the junction on both sides a region is formed which is depleted of charge carriers. This region is called depletion region whose thickness is about 10^{-6} m.

(iii) An electric field is developed across the junction which is in a direction to oppose the further diffusion of electrons from n-side.

(iv) The potential developed across the barrier layer is called **barrier potential**. It is 0.7 volts for silicon diode and 0.3 volts for germanium diode.

(v) When no external source is connected to diode, it is called unbiased.

(vi) It has two electrodes, hence it is called diode.

(vii) **Forward bias:**

- (a) When p-side is connected to positive terminal and n-side to negative terminal of battery, the diode is said to be forward biased.
- (b) When battery voltage exceeds the barrier potential (0.7 volt for silicon and 0.3 volt for germanium), majority of charge carrier start crossing the junction.
- (c) The electrons from n-side drift towards the junction and cross it and holes move in the opposite direction.
- (d) The resistance of the junction in forward bias is quite low ($= 26\ \Omega$ if $I = 10^{-3}$ amp).
- (e) Under proper forward biasing of a p-n junction diode the width of the depletion layer decreases or the barrier potential decrease and the diode conducts.
- (f) When p-side is at higher potential than n-type, then also the diode conducts.

(viii) **Reverse bias:**

- (a) When p-side is connected to negative terminal and n-side to positive terminal of battery the diode is said to be reverse biased.
- (b) The battery acts as a reverse bias to majority charge carriers but as a forward bias to minority charge carriers.
- (c) The minority charge carriers move across the junction. This constitutes reverse saturation current which is very small of the order of 1 μA.
- (d) The resistance of the junction in reverse bias is 10 kΩ.
- (e) Under reverse biasing of a p-n junction diode, the width of depletion region increases or the barrier potential increases.

(ix) **Breakdown and breakdown voltage:**

- (a) If the applied reverse voltage is increased gradually, then a stage is reached when covalent bonds in semiconductor are broken and a large number of charge carriers (electron-hole pairs) are generated which give rise to a sharp increase in reverse current. This phenomenon is called **breakdown**.
- (b) The voltage at which breakdown occurs is called **breakdown voltage**.

(x) p-n junction diode is a one-way device which offers a low resistance when forward biased and behaves like an insulator when reverse biased. Thus, it can be used as a **rectifier** i.e., for converting alternating current into direct current.

(xi) An **ideal diode** when forward biased offers **zero resistance** and acts as a short circuit. On the other hand, an **ideal diode** when reverse biased offers **infinite resistance** and acts as an open circuit.

(xii) The ratio of the change in junction voltage ΔV to that in junction current ΔI is called as **dynamic resistance** R_d of diode.

(xiii) **Knee voltage** is defined as the forward voltage at which the current through the junction starts increasing rapidly.

Transistor:

(i) The transistor is a semiconductor device. When a layer of p-type material is sandwiched between two layers of n-type material, the transistor is known as n-p-n transistor. Similarly, when a layer of n-type material is sandwiched between two layers of p-type material, the transistor is known as p-n-p transistor.

(ii) The transistor has three regions: (a) Emitter (b) Base and (c) Collector. Emitter is heavily doped in comparison to other regions and its main function is to supply majority charge carriers. The collector is moderately doped and it's function is to collect majority charge carriers. The base is very lightly doped as compared to emitter or collector and is kept quite thin.

(iii) In most of the transistors, the collector region in made physically larger than emitter region. This is due to the fact that collector has to dissipate much greater power. Due to this difference, collector and emitter are not interchangeable.

(iv) As regards the symbols, arrowhead is always at the emitter which indicates the conventional direction of current flow.

(v) For transistor biasing, the emitter base junction is always forward biased while the collector base junction is always reverse biased.

(vi) Holes are majority charge carriers in a p-n-p transistor. Thus, only hole current plays an important role in the working of a p-n-p transistor.

(vii) Electrons are majority charge carrier in an n-p-n transistor. So, electrons are chiefly responsible for conduction of current in an n-p-n transistor.

(viii) A transistor can be connected in a circuit in the following three different configurations:

(a) Common base (CB) (b) Common emitter (CE) (c) Common collector (CC)

(ix) Emitter current is always equal to the sum of base current and collector current, i.e., $I_e = I_b + I_c$.

ASSIGNMENT NO. 18

(1) **The gate, which performs the operation of inversion is called:**
(a) NOT gate (b) AND gate (c) OR gate (d) XOR gate

(2) **The gate, which changes the logic level to its opposite level is called:**
(a) NOR gate (b) AND gate (c) OR gate (d) NOT gate

(3) **If both the inputs given to a gate are 1, such that the output is 0 then it is:**
(a) NAND gate (b) NOR gate (c) XOR gate (d) All of these

(4) **If both the inputs given to a gate are 0 such that the out put is 1 then it is:**
(a) NAND gate (b) NOR gate (c) XN, OR gate (d) All of these

(5) **XNOR gate can be made by combining:**
(a) OR, NOR, NOT gate (b) OR, AND, NOT gates
(c) OR, NAND, NOT gates (d) NOR, AND, NOT gates

(6) **Breakdown voltage is:**
(a) 25 V (b) 15 V (c) 35 V (d) 5 V

(7) **The value of reverse current for Ge is:**
(a) 1 μA (b) 1 mA (c) 1 A (d) 1 MA

(8) **Device used for conversion of D.C. to A.C. is:**
(a) Oscillator (b) Rectifier (c) Amplifier (d) None

(9) **p-n junction when reversed biased acts as a:**
(a) Capacitor (b) On switch (c) Off switch (d) None

(10) **Pulsating D.C. can be made smooth by using a circuit known as:**
(a) Filter (b) Tank (c) Accepter (d) All

(11) **A photodiode can switch its current on OR off in:**
(a) nano second (b) milli second (c) micro second (d) centi second

(12) **Photodiode is used in:**
(a) Automatic switch (b) Optical communication equipment
(c) Light meters (d) All

(13) **Current gain of a transistor which has collector current of 10 mA and a base current of 40 μA is:**
(a) 25 (b) 250 (c) 2500 (d) 25000

(14) **In case of common emitter amplifier, phase difference between input and out:**
(a) 0° (b) 120° (c) 180° (d) 90°

(15) **When transistor acts as OFF switch then voltage across collector and emitter is ———— V_{CC}.**
(a) Less than (b) Greater than (c) Equal to (d) None

(16) **The photovoltaic cell is always:**
(a) Forward biased (b) Reverse biased (c) No biasing is required (d) None

(17) **Under ideal conditions, the collector current is:**
(a) Equal to base current (b) Nearly equal to emitter current
(c) Less than base current (d) Always zero

(18) **One use of a single p-n junction semiconductor in an electrical circuit is a:**
(a) Rectifier (b) Transistor (c) Battery (d) Diode

(19) **The output from a full wave rectifier is:**
(a) An ac voltage (b) A dc voltage
(c) Zero (d) A pulsating unidirectional voltage

(20) **When n-type semiconductor is heated:**
(a) Number of electrons increases while holes decreases
(b) Number of holes increases while electrons decreases
(c) Holes and electrons remains same
(d) Holes and electrons increases equally

(21) **Zener diode is used for:**
(a) Rectification (b) Amplification (c) Stabilization (d) Modulation

(22) **In a semi-conducting diode, the revere biased current is due to drift of free electrons and holes caused by:**
(a) Thermal excitations only (b) Impurity atoms only
(c) Both (a) and (b) (d) Neither (a) nor (b)

(23) **In the reverse biased p-n junction, the current is of the order of:**
(a) Ampere (b) Milliampere (c) Microampere (d) Nanoampere

(24) **To measure light intensity we use:**
(a) LED with forward bias (b) LED with reverse bias
(c) Photodiode with reverse bias (d) Photodiode with forward bias

(25) **On increasing the reverse bias to a large value in a p-n junction diode current:**
(a) Increases slowly (b) Remains fixed (c) Suddenly increases (d) Decreases slowly

(26) **Rectifier is used to convert:**
(a) Electrical energy into mechanical energy (b) Heat energy into electrical energy
(c) High voltage into low voltage (d) AC into DC

(27) **In an n-p-n transistor p-type crystal acts as:**
(a) Emitter only (b) Base only
(c) Collector only (d) Either emitter or collector

(28) **The emitter base junction in the transistor is:**
(a) Forward biased (b) Reverse biased
(c) Either forward or reverse biased (d) Neither forward nor reverse biased

(29) **The current gain of common-base transistor amplifier is:**
(a) Less than one (b) More than one (c) Equal to one (d) Zero

(30) **In common-base transistor amplifier, the phase difference between output voltage and input voltage is:**
(a) Zero (b) 180° (c) 90° (d) 45°

(31) **For a common base transistor amplifier the numerical value is least for:**
(a) Voltage gain (b) Power gain (c) Resistance gain (d) Current gain

(32) **The base of the transistor is made thin and is doped with least impurity atoms, because:**
(a) About 95% charge carriers may cross (b) 100% charge carriers may cross
(c) the transistor may be saved from high currents (d) None of these

(33) **A logic gate is an electronic circuit which:**
(a) Makes logic decisions (b) Allows electron flow only in one direction
(c) Allows hole flow only in one direction (d) Alternates between 0 an 1 value

(34) **Digital circuits can be made by respective use of:**
(a) AND gates (b) OR gates (c) NOT gates (d) NAND gates

(35) **Which logic function has the output low only when both inputs are high?**
(a) OR (b) NOR (c) AND (d) NAND

(36) **In a half wave rectifier the rms value of ac component of the waves:**
(a) Zero (b) Equal to dc value (c) More than dc value (d) Less than dc value

(37) **A PN junction has a thickness of the order of:**
(a) 10^{-12} m (b) 10^{-6} m (c) 1 mm (d) 1 cm

(38) **A hole in a p-type semi-conductor is:**
(a) A donor level (b) An excess electron (c) Missing electron (d) A missing atom

(39) **If PN junction is forward biased its resistance is:**
(a) Zero (b) Infinity (c) A few ohm (d) A few kilo ohms

(40) **A part of transistor which is heavily doped to produces large number of majority carriers is:**
(a) Emitter (b) Base (c) Collector (d) May be any one

(41) **How is the emitter base junction in the transistor biased?**
(a) Forward (b) Reverse
(c) May be forward or reverse (d) None

(42) **The potential barrier of silicon diode is:**
(a) 0.3 V (b) 0.5 V (c) 0.7 V (d) 0.9 V

(43) **If collector current is 10 mA and base current of 10 μA. What is the current gain of transistor?**
(a) 250 (b) 500 (c) 1000 (d) None of these

(44) **An op-amplifier can be used as:**
(a) Inverting amplifier (b) Night switch (c) Comparator (d) All

(45) **The output of two input OR gate is zero only when:**
(a) Both are one (b) Both are zero (c) Either input is 1 (d) None

(46) **The semi-conductor used for fast counting in electronic circuit is:**
(a) Photodiode (b) LED (c) Photovoltaic cell (d) Solar cell

(47) **For normal transistor operation I_E is given as:**
(a) $I_E = I_C$ (b) $I_E = I_C + I_B$ (c) $I_E = I_B$ (d) None

(48) **The value of open loop gain value for the amplifier is:**
(a) Zero (b) Infinity (c) Very high (d) Very low

(49) **The gate will recognized the voltage as 1 if the applied voltage to gate is:**
(a) 1.5 V (b) 0.5 V (c) 3.5 V (d) 0.7 V

(50) **In the depletion region of an unbiased PN junction diode there are:**
(a) Only electrons (b) Only holes
(c) Both holes and electrons (d) Ions

(51) **In a transistor, the conventional current flows from base to emitter. The transistor is:**
(a) NPN (b) PNP (c) FET (d) None of these

(52) **In full wave rectifier with input frequency 50 Hz the ripple in the output is mainly of frequency:**
(a) 25 Hz (b) 50 Hz (c) 100 Hz (d) Zero

(53) **What is the voltage gain in a common emitter amplifier where input resistance is 3 Ω and load resistance 24 Ω, $\beta = 0.6$?**
(a) 8.4 (b) 4.8 (c) 2.4 (d) 480

(54) **How many NAND gates are used to form AND gate?**
(a) 1 (b) 2 (c) 3 (d) 4

(55) **Photodiode operates when it is:**
(a) Forward biased (b) Reverse biased (c) Unbiased (d) None

(56) **The open loop gain of an op-amp is of the order of:**
(a) 10^3 (b) 10^4 (c) 10^5 (d) 10^6

(57) **In a forward biased p-n junction diode, current inside the junction diode is due to drift of:**
(a) Free electrons (b) Both types of majority carriers
(c) Both types of minority carriers (d) Donor atoms

(58) **A p-n junction diode cannot be used for:**
(a) Rectification (b) Amplification
(c) Obtaining light radiation (d) Detecting light intensity

(59) **In a semiconductor diode, p-side is earthed and to n-side is applied a potential of −2 volt; the diode shall:**
(a) Conduct (b) Not conduct (c) Conduct partially (d) Break down

(60) **In the symbol for a transistor, the arrow head points in the direction of flow of:**
(a) Holes (b) Electrons (c) Majority carriers (d) Minority carriers

(61) **The current gain of common-emitter transistor amplifier is:**
(a) Less than one (b) More than one (c) Equal to one (d) Zero

(62) **In common-emitter transistor amplifier, the phase difference between output vooltage and input voltage is:**
(a) Zero (b) 180° (c) 90° (d) 45°

(63) **The emitter of a transistor is doped the heaviest because it:**
(a) Acts as a supplier of charge carriers (b) Dissipates maximum power
(c) has a large resistance (d) has a small resistance

(64) **At room temperature, potential difference develops across the depletion region in case of silicon:**
(a) 0.3 V (b) 0.7 V (c) 0.8 V (d) 0.9 V

(65) **Width of depletion region is:**
(a) 10^{-8} m (b) 10^{-7} m (c) 10^{-6} m (d) 10^{-4} m

(66) **In photovoltaic cell current is ———— proportional to intensity of light.**
(a) Directly (b) Inversely (c) Both (a), (b) (d) None

(67) **Silicon transistors are preferred because:**
(a) High operating temperature (b) Low leakage current
(c) Suited to high frequency circuits (d) All

(68) **If $R_C = 10$ kΩ, $r_{ie} = 1$ kΩ, $\beta = 50$ then gain of common emitter amplifier:**
(a) 500 (b) 50 (c) 5 (d) None

(69) **If $R_1 = 10$ kΩ and $R_2 = 100$ kΩ then gain of inverting amplifier is:**
(a) 10 (b) −10 (c) 100 (d) None

(70) **Electronic circuits which implement various logic operations are called:**
(a) Logic gates (b) Boolean algebra (c) Amplifier gain (d) None

ANSWERS

(1)	(a)	(2)	(d)	(3)	(d)	(4)	(d)	(5)	(d)
(6)	(a)	(7)	(a)	(8)	(a)	(9)	(c)	(10)	(a)
(11)	(a)	(12)	(d)	(13)	(b)	(14)	(c)	(15)	(c)
(16)	(c)	(17)	(b)	(18)	(a)	(19)	(d)	(20)	(d)
(21)	(c)	(22)	(a)	(23)	(d)	(24)	(c)	(25)	(c)
(26)	(d)	(27)	(b)	(28)	(a)	(29)	(a)	(30)	(a)
(31)	(d)	(32)	(a)	(33)	(a)	(34)	(d)	(35)	(d)
(36)	(c)	(37)	(b)	(38)	(c)	(39)	(c)	(40)	(a)
(41)	(a)	(42)	(c)	(43)	(c)	(44)	(d)	(45)	(b)
(46)	(a)	(47)	(b)	(48)	(c)	(49)	(c)	(50)	(c)
(51)	(a)	(52)	(c)	(53)	(b)	(54)	(b)	(55)	(b)
(56)	(c)	(57)	(c)	(58)	(b)	(59)	(a)	(60)	(a)
(61)	(b)	(62)	(b)	(63)	(a)	(64)	(b)	(65)	(c)
(66)	(a)	(67)	(d)	(68)	(a)	(69)	(b)	(70)	(a)

SOLUTION

(13) Current gain $= \beta$

$$\beta = \frac{I_C}{I_B} = \frac{10\times10^{-3}}{40\times10^{-6}} = 250$$

(b) is correct

(49) Because

$0 \rightarrow 0.8\ V$ 0

$2 \rightarrow 5\ V$ 1

(c) is correct

(52) In full wave rectifier frequency will becomes double.

$\therefore$ 100 Hz

(c) is correct

(53) $G = \beta \cdot \frac{R_C}{r_{ie}}$

$G = 0.6\left(\frac{24}{3}\right)$

$G = 4.8$

(b) is correct

(69) Gain of inverting amplifier

$G = -\frac{R_2}{R_1}$

$G = -\frac{109\ k\Omega}{10\ k\Omega}$

$G = -10$

(b) is correct

Chapter 19

DAWN OF MODERN PHYSICS

MCAT UNIT 12

KEY POINTS

Relative Motion: The change of position of a body with respect to a second body or reference point that is fixed is known as relative motion.

Frame of Reference: Any coordinate system relative to which measurements are taken is known as frame of reference.

Inertial or Non-accelerated Frame of Reference: A frame of reference which is at rest or moving with uniform velocity with respect to other frame of reference is called inertial or non-accelerated frame of reference. (OR) An inertial frame of reference is defined as a coordinates system in which the law of inertia is valid.

Non-inertial or Accelerated Frame of Reference: If a frame of reference is moving with certain acceleration with respect to other frame of reference, then it is called non-inertial or accelerated frame of reference. (OR) A non-inertial frame of reference is defined as a coordinate system in which law of inertia is valid.

Theory of Relativity: The theory of relativity is concerned with the way in which observers who are in a state of relative motion describe physical phenomena.

There are two types of theory of relativity.

(1) ***General Theory of Relativity:*** The theory of relativity which treats problems involving non-inertial or accelerated frame of reference.

(2) ***Special Theory of Relativity:*** The special theory of relativity treats problems involving inertial or non-accelerated frame of reference. This theory is formulated by Einstein in 1905.

Postulates of Special Theory of Relativity:

(1) The laws of physics are the same in all inertial frames.

(2) The speed of light in free space has the same value for all observes, regardless of their state of motion.

Results of Special Theory of Relativity:

(1) ***Time Dilation:*** According to special theory of relativity, time is not absolute quantity. It depends upon the motion of the frame of reference. Suppose an observes at rest measures the time interval between two events is t_o. If the observe is moving with respect to frame of events with velocity v or frame of reference is moving with respect to observer with a uniform velocity v, the time measured by the observer would not be t_o but it would be 't' such that:

$$t = \frac{t_o}{\sqrt{1-\frac{V^2}{C^2}}} \qquad \text{As} \quad \sqrt{1-\frac{V^2}{C^2}} < 1 \qquad \text{So} \quad t > t_o$$

(2) ***Length Contraction:*** The length of the object or distance between the two points measured by an observer who is relatively at rest is called proper length denoted by l_o. If an object and an observer are in relative motion with speed v, then the contracted length 'l' is given by:

$$l = l_o\sqrt{1-\frac{V^2}{C^2}} \qquad \text{As} \quad \sqrt{1-\frac{V^2}{C^2}} < 1 \qquad \text{So} \quad l > l_o$$

(3) *Mass Variation:* According to special theory of relativity mass of an object is a varying quantity and depends upon the speed of object. An object whose mass when measured at rest is m_o will have an increased mass 'm' when observed to be moving at speed v. It is given by:

$$m = \frac{m_o}{\sqrt{1-\frac{V^2}{C^2}}} \qquad \text{So} \quad \sqrt{1-\frac{V^2}{C^2}} < 1 \qquad \Rightarrow \qquad m > m_o$$

If $V = C$, then $m = \infty$.

Any infinity mass would require an infinity force to accelerate it, which are not available, so an object cannot be accelerated to the speed of light 'C' in free space.

Note: *In our daily life, we deal with extremely small speeds, compared to the speed of light. Even the Earth's orbital speed is only 30 kms^{-1}. On the other hand the speed of light in free space is $3 \times 10^8\ ms^{-1}$.*

(4) *Mass Energy Relation:* According to special theory of relativity, mass and energy are different quantities but are interconvertible. The total energy 'E' and mass 'm' of an object are related by the expression.

$$E = m_oC^2$$

The rest mass energy of a particle is given by:

$$E_o = m_oC^2$$

The K.E. in this case is given by:

$$K.E. = mC^2 - m_oC^2 \qquad \Rightarrow \qquad K.E. = (m - m_o)C^2$$

NAVSTAR Navigation System: Results of special theory of relativity are brought into practical use in modern system of navigation satellites called NOVSTAR.

With this system, location and speed of the aircraft anywhere on the Earth can now be determined to an accuracy of about 2 cms^{-1}. If relativity effects are not taken into account, speed calculated would differ by 20 cms^{-1} from the actual value.

After an hour's flight of an aircraft, its location can be predicted to about 50 m with relativistic effects and 720 m with using relativistic effects.

Black Body: A body which absorbs all the radiations falling upon it, is called a black body and when heated, it emits the radiations.

Black Body Radiations: The radiations emitted by black body are called black body radiations or temperature radiations.

Results of Black Body Spectrum:

(1) At a given temperature, the energy is not uniformly distributed in the radiation spectrum of the body.

(2) At a given temperature T, the emitted energy has maximum value for a certain wavelength λ_{max} and the product $\lambda_{max} \times T$ is constant.

$$\lambda_{max} \times T = \text{Constant}$$

The value of the constant is about 2.9×10^{-3} mK wavelength.

(3) For all wavelengths, an increase in temperature causes an increase in energy emission. The radiation intensity increases with increase in wavelength and at particular wavelength λ_{max}, it has a maximum value. With further increase in wavelength, the intensity of radiation decreases.

(4) The area under each curve represents the total energy (E) radiated overall wavelength at a particular temperature. It is found that area is directly proportional to the fourth power of Kelvin temperature 'T'. Thus

$$E \propto T^4 \quad \text{or} \quad E = \sigma T^4$$

Where σ is called Stefen's constant. Its value is $5.67 \times 10^{-8}\ Wm^2K^{-4}$ and the above relation is known as Stefen-Boltzman law.

Plank's Assumption: Max. Planck in 1900, a German physicist suggested that energy is radiated or absorbed in discrete packets, called quanta rather than all possible energies. Each quantum is associated with radiation of a single frequency. The energy of each quantum is proportional to its frequency i.e.,

$$E \propto f \quad \text{or} \quad E = hf$$

Where 'h' is Planck's constant. Its value is 6.63×10^{-34} Js.

Photon: A beam of light with wavelength 'λ' consists of stream of photons travelling at speed 'C' and carries energy E = hf. The momentum 'P' of a photon is related to energy as:

$$E = PC$$

$$\text{Thus} \quad PC = hf \quad \text{or} \quad P = \frac{hf}{C} = \frac{h}{\lambda}$$

Photoelectric Effect: The emission of electrons from a metal surface when exposed to light of suitable frequency is called photoelectric effect.

Maximum Energy of Photoelectrons: The maximum K.E of photoelectrons is given by:

$$K.E_{max} = V_oe \quad \text{or} \quad \frac{1}{2}mV_{max}^2 = V_oe$$

Where m = Mass of electron

e = Change on electron

V_o = Stopping potential

Results of Photoelectric Effect:

(1) The electrons are emitted with different energies. The maximum energy of photoelectrons depends on the particular metal surface and frequency of incident light.

(2) There is a minimum frequency below which no electrons are emitted, however intense the light may be. This frequency is called **threshold frequency**.

(3) The threshold frequency 'f_o' varies from metal to metal.

(4) Electrons are emitted instantaneously, the intensity of light determines only their number.

Einstein's Photoelectric Equation: Incident photon energy – Work function = Max. K.E of photoelectrons

$$\boxed{hf - \phi = \frac{1}{2}mV_{max}^2}$$

when $K.E_{max} = 0$

then $f = f_o$

So $\boxed{hf_o = \phi}$

Thus we can also write Einstein's photoelectric equation.

$$\boxed{hf - hf_o = (K.E)_{max}}$$

Work Function: Minimum energy required to eject the electron from metal surface.

Photo Cell: A device which convert light energy into electrical energy.

Its working based on photoelectric effect.

It consists of an evacuated glass tube containing a thin anode rod and a cathode of some suitable metal surface. Sodium or potassium cathode is suitable for visible light.

Cesium coated oxidized silver cathode is suitable for infra-red light and some other metal can emit ultraviolet radiations.

Applications of Photo Cell:

(i) Security system
(ii) Counting system
(iii) Automatic door system
(iv) Automatic street lighting
(v) Exposure meter for photography
(vi) Sound track of movies

Compton Effect: The phenomenon in which the wavelength of the scattered X-rays is larger then incident X-rays is known as Compton effect. **(OR)** The phenomenon in which a photon of frequency 'f' is scattered by an electron and the scattered photon has a frequency $f' < f$ is called Compton effect.

Explanation:

Compton studied the scattering of X-rays by loosely bound electrons from a graphite target and measured the change in wavelength of photon or Compton's shift as:

$$\Delta\lambda = \frac{h}{m_o c}(1 - \cos\theta)$$

The factor $\frac{h}{m_o c}$ has dimensions of length and is called Compton's wavelength. Its value is 2.43×10^{-12} m.

If $\theta = 90°$ then:

$$\Delta\lambda = \frac{h}{m_o c}$$

So Compton shift is equal to Compton's wavelength.

Pair Production (Materlization of Energy): The conversion of a photon into an electron and a positron pair. When the photon traverses a strong electric field, such as that surrounding the nucleus is called pair production.

Condition for Pair Production: The pair production will occur if the energy of photon is greater than:

$$2m_o C^2 = 1.02 \text{ MeV}$$

Equation for Pair Production:

$$\text{Energy of photon} = \begin{bmatrix}\text{Energy required for}\\ \text{pair production}\end{bmatrix} + \begin{bmatrix}\text{Kinetic energy}\\ \text{of the particle}\end{bmatrix}$$

i.e.,

$$hf = 2m_o C^2 + (K.E)e^- + (K.E)e^+$$

Annihilation of Matter: The reverse process of pair production is called annihilation of matter. When a electron and positron come together, they annihilate each other according to the relation:

$$e^- + e^+ \longrightarrow \gamma + \gamma$$

Energy of energy γ-ray photon is 0.51 MeV.

Positron: Positron is anti-particle of electron. The existence of positron was predicted in 1932 by Antersen.

Similarly proton and a anti-proton annihilation has also been observed at Lowrence Berkeley Laboratory.

Wave-nature of Particle: Light possesses dual nature so particle can show wave-like particles. The wavelength associated with a particle of mass 'm' moving with velocity v is:

$$\lambda = \frac{h}{mv}$$

This equation is known as de-Broglie wavelength.

Davisson and Germer Experiment: The de-Broglie equation is confirmed by Davisson and Germer.

According to Davisson and Germer:

$$\lambda = \frac{h}{\sqrt{2mVe}}$$

$$\boxed{\lambda = 1.66 \times 10^{-10} \text{ m}}$$

This value is experimentally.

According to Bragg's equation:

$$2d \sin\theta = m\lambda$$

$$\boxed{\lambda = 1.65 \times 10^{-10} \text{ m}}$$

This value is theoretically.

Wave Particle Duality: Interference and diffraction phenomena confirms the wave nature of light, while photoelectric effect proves the particle nature of light. Similarly, the experiments of Davisson and Germer and G.P. Thomson reveal wave-like nature of electrons and in experiment of J.J Thomson to find e/m, we had to assume particle-like nature of the electron. In the same way we are forced to assume both wave-like and particle-like properties of all matter.

In other words matter and radiation have a dual "wave-particle" nature and this new concept is known as wave-particle duality.

Electron Microscope:

Principle: Working principle of an electron microscope is based on the wave-nature of moving electrons. Since the wavelength associated with an electron is thousand of time shorter than the wavelength of visible light, so its magnifying power is far greater than that of optical microscope. It is the wave nature of electrons which makes the electron microscope to show minor details not visible with optical microscope.

Working: In an electron microscope, electric and magnetic fields are used to focus electrons by means of electromagnetic forces.

The electrons are accelerated to high energies by applying voltage from KV to several mega volts. Such high voltages give extremely short wavelength.

High voltages also give the electron sufficient energy to penetrate specimen of reasonable thickness.

Resolution: A resolution of 0.5 to 1 nm is possible with 50 kv microscope as compared to best optical resolution of 0.2 m.

Scanning Electron Microscope: A three dimensional image of excellent quality can be achieved by modern versions called scanning electron microscope.

Uncertainty Principle: Position and momentum of a particle cannot both be measured simultaneously with perfect accuracy even with an ideal instrument. There is always a fundamental uncertainty associated with the duality of matter and radiation. This was first proposed by Warner Heisenberg in 1927 and hence known as Heisenberg uncertainty principle.

Statement: It states that the product of uncertainty Δp in the momentum of the body at some instant and the uncertainty in its position Δx at the same instant is approximately equal to Planck's constant.

Explanation: In order to see an electron, we use a light of wavelength 'λ'. The light consists of photons. When one of these photons hits the electron, the photon will be scattered and the original momentum of the electron will be changed.

One cannot predict the exact change in the momentum of the electron. But one can say that change of momentum of the electron will be of the same order as the momentum of the photon.

Hence $$\Delta p = \Delta(mv) \approx \frac{h}{\lambda} \quad \text{...... (i)}$$

This equation gives the uncertainty in the momentum. In order to reduce the uncertainty in momentum, one must use light of large wavelength.

Now the uncertainty in determining the position of the electron will be of the order of wavelength of light. Hence the uncertainty in position can be given as:

$$\Delta x \approx \lambda \quad \text{...... (ii)}$$

Multiply (i) and (ii), we get:

$$\Delta x \,.\, \Delta p \simeq h$$

This is the mathematical form of the principle.

Other Form of Uncertainty Principle:

Statement: The product of the uncertainty in a measured amount of energy and the time available for the measurement is approximately equal to Planck's constant. Mathematically, it can expressed as:

$$\Delta E \,.\, \Delta t = h$$

Thus more accurately we determined the energy of a particle, the more uncertain we will be of the time during which it has that energy.

According to Heisenberg more careful calculations, he found that at the very best.

$$\Delta x \,.\, \Delta p \geq h$$

and

$$\Delta E \,.\, \Delta t \geq h$$

where

$$h = \frac{h}{2\pi} = \frac{6.63 \times 10^{-34}\ \text{Js}}{2 \times 3.14} = 1.05 \times 10^{-34}\ \text{Js}$$

Planck's Quantum Theory: Wave-Particle Duality:

(i) Planck gave quantum theory while explaining the radiation spectrum of a black body. According to Planck's theory, energy is always exchanged in integral multiples of a quanta of light or **photon**.

(ii) Each photon has an energy E that depends only on the frequency v of electromagnetic radiation and is given by:

$$E = h\nu \qquad \text{...... (1)}$$

where $h = 6.6 \times 10^{-34}$ joule-sec, is Planck's constant. In any interaction, the photon either gives up all of its energy or none of it.

(iii) From Einstein's mass-energy equivalence principle, we have

$$E = mc^2 \qquad \text{...... (2)}$$

Using equations (1) and (2), we get

$$mc^2 = h\nu \quad \text{or} \quad m = \frac{h\nu}{c^2} \qquad \text{...... (3)}$$

where m represents the mass of a photon in motion. The velocity v of a photon is equal to that of light, i.e., $v = c$.

(iv) According to theory of relativity, the rest mass m_0 of a photon is given by:

$$m_0 = m\sqrt{1 - \frac{v^2}{c^2}}$$

Here, $m = \frac{h\nu}{c^2}$ or $v = c$

Hence $m_0 = 0$ ...... (4)

i.e., **rest mass of photon is zero, i.e., energy of photon is totally kinetic.**

(v) The momentum p of each photon is given by:

$$p = mc = \frac{h\nu}{c^2} \times c = \frac{h\nu}{c} = \frac{h}{c/\nu} = \frac{h}{\lambda} \qquad \text{...... (5)}$$

The left hand side of the above equation involves the particle aspect of photons (momentum) while the right hand side involves the wave aspect (wavelength) and the Planck's constant is the bridge between the two sides. This shows that **electromagnetic radiation exhibits a wave-particle** duality. In certain circumstances, it behaves like a wave, while in other circumstances it behaves like a particle.

(vi) The wave-particle is not the sole monopoly of e.m. waves. **Even a material particle in motion according to be Broglie will have a wavelength**. The de Broglie wavelength λ of the matter waves is also given by:

$$\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

where K is the kinetic energy of the particle.

Photoelectric Effect:

(i) When light of suitable frequency (electromagnetic radiation) is allowed to fall on a metal surface, electrons are emitted from the surface. These electrons are known as **photoelectrons** and the effect is known as **photoelectric effect**. Photoelectric effect was first discovered by Hertz. In photoelectric effect, light energy is converted into electrical energy.

(ii) **Laws of photoelectric effect**

(a) The kinetic energy of the emitted electron is independent of intensity of incident radiation. But the photoelectric current increases with the increase of intensity of incident radiation.

(b) The kinetic energy of the emitted electron depends on the frequency of the incident.

Planck's Quantum Theory: According to Planck's quantum theory, the light moves in the form of small bundles or packets called **photons**. The energy of each photon is hv, where v is the frequency of light and h is **Planck's constant.**

Modern Theory: Dual Nature of Light:

(i) According to modern theory, **light consists of both particles and wave properties, i.e., a dual nature.**

(ii) The wave properties are manifested in the phenomenon of interference, diffraction and polarisation where light interacts with light.

(iii) The particle nature is more prominent in the phenomenon where light interacts with matter as in phenomena of photoelectric effect, Compton effect Raman effect, etc.

Einstein's Theory of Photoelectric Effect:

(i) Einstein explained the laws of photoelectric effect on the basis of Planck's quantum theory of radiation.

(ii) Einstein treated photoelectric effect as a collision between a photon and an atom in which photon is absorbed by the atom and an electron is emitted.

(iii) According to law of conservation of energy,

$$h\nu = h\nu_0 + \frac{1}{2}mv^2$$

where hv is the energy of the incident photon; $h\nu_0$ is the minimum energy required to detach the electron from the atom (work function or ionisation energy) and (1/2) mv^2 is the kinetic energy of the emitted electron.

(iv) The above equation is known as Einstein's photoelectric equation. Kinetic energy of the emitted electron,

$$= \frac{1}{2}mv^2 = h(\nu - \nu_0) = h\nu - W$$

(v) **Explanation of laws of photoelectric effect:**

(a) The KE of the emitted electron increases with the increase of frequency of incident radiation since W (work function) is constant for a given emitter. KE is directly proportional to $(\nu - \nu_0)$.

(b) Keeping the frequency of incident radiation constant if the intensity of incident light is increased, more photons collide with more atoms and more photoelectrons are emitted. The KE of the emitted electron remains constant since the same photon collides with the same atom (i.e., the nature of the collision does not change). With the increase in the intensity of incident light photoelectric current increases.

ASSIGNMENT NO. 19

(1) **The process of pair production takes place if the energy of photon is:**
(a) Greater than $2m_oc^2$ (b) Less than $2m_oC^2$ (c) Equal to $2m_oC^2$ (d) None of these

(2) **The reverse process of pair production is called:**
(a) Materialization of energy (b) Compton effect
(c) Annihilation of matter (d) None of these

(3) **Positron was discovered by:**
(a) Dirac (b) Anderson (c) Wilson (d) None of these

(4) **The condition $hf > 2m_oc^2$ refers to the process of:**
(a) Compton effect (b) Pair production (c) Photoelectric effect (d) Annihilation of matter

(5) **The equation $e^- + e^+ \rightarrow \gamma + \gamma$ refers to:**
(a) Compton effect (b) Pair production (c) Annihilation of matter (d) Fusion process

(6) **In annihilation of matter, the two photons are produced traveling:**
(a) In opposite direction (b) In same direction (c) At on angle of 180° (d) Both (a) and (c)

(7) **Every particle with corresponding anti-particle with:**
(a) The same mass (b) Opposite charge (c) Different mass (d) Both (a) and (b)

(8) **Tick the correct equation in case of Davison and Germer experiment:**
(a) $\frac{1}{2}mv^2 = ve$ (b) $mv = \sqrt{2mve}$ (c) $\lambda = \frac{h}{\sqrt{2mve}}$ (d) None of these

(9) **Uncertainty principle states that:**
(a) $\Delta x . \Delta E = h$ (b) $\Delta x . \Delta P \approx h$ (c) $\Delta E . \Delta P = h$ (d) None of these

(10) **Heisenberg uncertainty principle is used in:**
(a) Wave mechanics (b) Classical mechanics (c) Both (a) and (b) (d) Quantum mechanics

(11) **Strictly speaking, the Earth is:**
(a) Inertial frame of reference (b) Non-inertial frame of reference
(c) Both (a), (b) (d) None

(12) **The length contraction happens:**
(a) Along the direction of motion (b) Perpendicular to direction of motion
(c) Both (a), (b) (d) None

(13) **For a black body, the product of λ_{max} and T is equal to:**
(a) Wien's constant (b) Planck's constant (c) Davison constant (d) Dirac constant

(14) **Unit of Stephen's constant is:**
(a) $W\,m\,K^{-2}$ (b) $W\,m^{-2}\,K^{-4}$ (c) $W\,m\,K^{-4}$ (d) None

(15) **Stopping potential of photoelectrons:**
(a) Increase with increase in intensity (b) Decrease with increase in intensity
(c) Independent of intensity (d) None

(16) **The energy of photon of radio waves is about:**
(a) 10^{-4} eV (b) 10^{-6} J (c) 10^{-8} eV (d) 10^{-10} eV

(17) **The inverse of photoelectric effect is:**
(a) Emission of γ-rays (b) X-rays (c) Thermionic emission (d) None

(18) **Pair production occurs only when energy of photon is at least equal to:**
(a) 1.02 eV (b) 1.02 MeV (c) 1.2 MeV (d) All

(19) **Interplanar distance (spacing) for nickel crystal:**
(a) 0.91×10^{10} m (b) 0.91×10^{-10} m (c) 0.91×10^{-6} m (d) None

(20) **A three dimensional image of remarkable quality can be achieved by:**
(a) Electron microscope (b) Scanning electron microscope
(c) Optical microscope (d) All

(21) **Value of ħ =**
(a) 1.05×10^{34} J (b) 1.05×10^{-34} Js (c) 1.05×10^{-34} Ns (d) All

(22) **Which one of the following radiations has the strongest photon?**
(a) Microwaves (b) X-rays (c) γ-rays (d) None

(23) **Rest mass of photon is:**
(a) Zero (b) Infinite (c) 9.11×10^{-31} kg (d) None

(24) **Energy for 1 kg of mass is:**
(a) 1×10^{6} eV (b) 5.6×10^{35} eV (c) 9×10^{16} eV (d) None

(25) **The photoelectric effect is described as the ejection of electrons from the surface of a metal, when:**
(a) it is heated to a high temperature (b) Light of suitable frequency falls on it
(c) Electrons of suitable velocity impinge on it (d) it is placed in a strong magnetic field

(26) **The Idea of the quantum nature of light has emerged in an attempt to explain:**
(a) the thermal radiations of a black body (b) the interference of light
(c) Radioactivity (d) Thermionic emission

(27) **Planck's constant has the dimensions of:**
(a) Energy (b) Mass (c) Frequency (d) Angular momentum

(28) **Work function is the energy required:**
(a) to produce X-rays (b) to excite an atom
(c) to explore an atom (d) to eject an electron just out of the surface

(29) **In photoelectric effect, the number of photoelectrons emitted is proportional to:**
(a) Intensity of incident beam (b) Frequency of incident beam
(c) Velocity of incident (d) Work function of photo cathode

(30) **What is the momentum of a photon having frequency 1.5×10^{13} Hz?**
(a) 3.3×10^{-29} kg-m/s (b) 3.3×10^{-24} kg-m/s (c) 6.6×10^{-234} kg-m/s (d) 6.6×10^{-30} kg-m/s

(31) **Of the following, the one which does not travel with the speed of light is:**
(a) X-rays (b) Ultraviolet light (c) Infrared light (d) Matter waves

(32) **The wavelength of de Broglie waves associated with a particle at rest is:**
(a) $\frac{h}{mv}$ (b) $\frac{mv}{h}$ (c) Zero (d) ∞

(33) **A photon travels with a velocity equal to:**
(a) c (b) 2c (c) $\frac{c}{2}$ (d) ∞

(34) **Neglecting variation of mass with velocity, the wavelength proportional to:**
(a) $E^{1/2}$ (b) E (c) $E^{-1/2}$ (d) E^{-2}

(35) **The photoelectric effect is based upon the conservation of:**
(a) Momentum (b) Mass (c) Energy (d) Angular momentum

(36) **The frequency of incident light falling on a photosensitive metal plate is doubled, the K.E of the emitted photoelectrons is:**
(a) Double the earlier value (b) Unchanged
(c) More than doubled (d) Less than doubled

(37) **Of the following properties, the photon does not possess:**
(a) Rest mass (b) Momentum (c) Energy (d) Frequency

(38) **Of the following having the same KE, the one which has the largest wavelength, is:**
(a) An alpha particle (b) A neutron (c) A proton (d) An electron

(39) **The energy of a photon corresponding to the visible light of maximum wavelength is approximately:**
(a) 1 eV (b) 1.6 eV (c) 3.2 eV (d) 7 eV

(40) **The de-Broglie wave corresponding to particle of mass m and velocity v has a wavelength associated with it:**
(a) $\frac{h}{mv}$ (b) hmv (c) $\frac{mh}{v}$ (d) $\frac{m}{hv}$

(41) **The rest mass of electron is m_o. What would be its mass if it moves with a speed of 0.8 C.**
(a) $\frac{3m_o}{5}$ (b) $\frac{5m_o}{3}$ (c) $\frac{4m_o}{5}$ (d) $\frac{2m_o}{\sqrt{5}}$

(42) **If a charged particle is accelerated to move at relativistic velocity which of following will remain unchanged?**
(a) Mass (b) Charge (c) Charge to mass ratio (d) None

(43) **If the velocity of light would have been half of its present value the energy released in a given atomic explosion would change by:**
(a) Increased 4 times (b) Decreased 4 times (c) Remains same (d) Decreased by $\frac{1}{4}$ times

(44) **The momentum of photon having energy "E" is:**
(a) $\frac{E}{c}$ (b) $\frac{E}{c^2}$ (c) $\frac{E}{h}$ (d) Zero

(45) **A particle having rest mass m is accelerated and attained a speed C (velocity of light). Its mass becomes:**
(a) Zero (b) m (c) 2m (d) Infinity

(46) **The SI unit of Plank's constant:**
(a) Js^{-1} (b) J.s (c) Js^{-2} (d) No unit

(47) **Compton shift is maximum at:**
(a) 0° (b) 45° (c) 90° (d) 180°

(48) **The value of Wien's constant is:**
(a) 9.8 mK (b) 2.9×10^{-3} mK (c) 6.63×10^{34} mK (d) 3×10^{8} mK

(49) **If the momentum of particle is doubled than its de-Broglie wavelength:**
(a) Doubles (b) Halves (c) Remains same (d) None of these

(50) **The number of photons at wavelength 546 nm emitted per second by an electric bulb of power 100 W is:**
(a) 1000 (b) 3×10^{20} (c) 3×10^{18} (d) 3×10^{34}

(51) **If the energy of photon is 10 eV and work function is 5 eV then stopping potential will be:**
(a) 50 V (b) 2 V (c) 5 V (d) 15 V

(52) **The numerical value of Compton wavelength is:**
(a) 3.43×10^{-12} m (b) 1.43×10^{-12} m (c) 2.43×10^{-12} m (d) 0.43×10^{-12} m

(53) **The nature of radiation emitted by body depends upon:**
(a) Mass (b) Temperature (c) Volume (d) Pressure

(54) **The de-Broglie wavelength of an electron moving with a speed of 6.6×10^5 m/s is approximately:**
(a) 10^{-11} m (b) 10^{-9} m (c) 10^{-7} m (d) 10^{-5} m

(55) **Wavelength of photon remains constant while passing through medium what other quantity associated remain constant:**
(a) Speed (b) Frequency (c) Momentum (d) All of these

(56) **When a photon collide with an electron which of the following increases:**
(a) Energy (b) Frequency (c) Wavelength (d) All of these

(57) **The idea of matter wave was given by:**
(a) Planck (b) de-Broglie (c) Einstein (d) Heisenberg

(58) **The phenomenon of photoelectric effect was first explained by:**
(a) Hallwach (b) Einstein (c) Planck (d) Bohr

(59) **The photoelectric effect can be understood on the basis of:**
(a) Wave theory of light only (b) Quantum theory of light only
(c) Electromagnetic theory of light only (d) None of the above

(60) **A photon of frequency ν has a momentum associated with it. If c is the velocity of light, this momentum is:**
(a) $h\nu/c^2$ (b) $h\nu/c$ (c) ν/c (d) $h\nu c$

(61) **If an electron and a proton have the same de Broglie wavelength then:**
(a) the proton has greater momentum (b) the electron has greater momentum
(c) both have zero momentum (d) both have equal momentum

(62) **If the intensity of radiation incident on a photocell be increased four times, then number of photoelectrons and energy of photoelectrons emitted become:**
(a) Four times, doubled (b) Doubled, remains unchanged
(c) Remains unchanged, doubled (d) Four times, remains unchanged

(63) **According to special theory of relativity mass is:**
(a) Constant (b) Variable (c) Both (a), (b) (d) None

(64) **A source of light is placed at a distance of 1 m from a photocell and cut off potential is found to be V_o. If the distance is doubled, the cut off potential will be:**
(a) $2V_o$ (b) $\frac{V_o}{2}$ (c) V_o (d) $\frac{V_o}{4}$

(65) **The units of Plank's constant in C.G.S system of units are:**
(a) $eg\ s^{-1}$ (b) $sec\ (erg)^{-1}$ (c) erg second (d) erg per second

(66) **Dimensions of $\frac{h}{m_o c}$:**
(a) $[LTM^{-1}]$ (b) $[M^oLT^o]$ (c) $[MLT^{-2}]$ (d) None

(67) **The work function of a photoelectric material is 3.3 eV. The threshold frequency will be equal to:**
(a) 8×10^{14} Hz (b) 8×10^{10} Hz (c) 5×10^{20} Hz (d) 4×10^{14} Hz

(68) **In a photoelectric effect, monochromatic light is incident on a metal surface. If the intensity of light is twice the intensity but of same wavelength, K.E. of emitted electron becomes:**
(a) Double (b) Half (c) Unchanged (d) None

(69) **The velocity of a particle of mass 'm' of de-Broglie wavelength λ is:**
(a) $\frac{2h}{m\lambda}$ (b) $\frac{h}{m\lambda}$ (c) $\frac{2m\lambda c^2}{h}$ (d) $\frac{m\lambda}{c}$

(70) **Complete the electromagnetic spectrum microwaves, ________, visible, ultraviolet.**
(a) Infrared (b) X-rays (c) γ-rays (d) Short radio waves

ANSWERS

(1)	(a)	(2)	(c)	(3)	(b)	(4)	(b)	(5)	(c)
(6)	(c)	(7)	(d)	(8)	(c)	(9)	(b)	(10)	(d)
(11)	(b)	(12)	(a)	(13)	(a)	(14)	(b)	(15)	(c)
(16)	(d)	(17)	(b)	(18)	(b)	(19)	(b)	(20)	(b)
(21)	(b)	(22)	(c)	(23)	(a)	(24)	(b)	(25)	(a)
(26)	(a)	(27)	(d)	(28)	(d)	(29)	(a)	(30)	(a)
(31)	(d)	(32)	(d)	(33)	(a)	(34)	(c)	(35)	(c)
(36)	(c)	(37)	(a)	(38)	(d)	(39)	(b)	(40)	(a)
(41)	(b)	(42)	(b)	(43)	(d)	(44)	(a)	(45)	(d)
(46)	(b)	(47)	(d)	(48)	(b)	(49)	(c)	(50)	(b)
(51)	(c)	(52)	(c)	(53)	(b)	(54)	(b)	(55)	(d)
(56)	(c)	(57)	(b)	(58)	(b)	(59)	(b)	(60)	(b)
(61)	(d)	(62)	(d)	(63)	(b)	(64)	(c)	(65)	(c)
(66)	(b)	(67)	(a)	(68)	(c)	(69)	(b)	(70)	(a)

SOLUTION

(22) Because γ-rays has shortest wavelength and highest frequency.

(c) is correct

(24)
$$m = 1\,kg$$
$$E = mc^2$$
$$E = (1)(3\times10^8)^2$$
$$E = 9\times10^{16}\,J$$
$$E = \frac{9\times10^{16}}{1.6\times10^{-19}}\,eV$$
$$E = 5.6\times10^{35}\,eV$$

(b) is correct

(34)
$$\lambda = \frac{h}{mv} = \frac{h}{P} = \frac{h}{\sqrt{2mE}}$$
But
$$E = \frac{1}{2}mv^2 = \frac{m^2v^2}{2m}$$
$$E = \frac{P^2}{2m}$$
$$P = \sqrt{2mE}$$
$$\Rightarrow \lambda = .E^{-1/2}$$

(c) is correct

(50)
$$n.hf = Pt \qquad l = fr$$
$$\Rightarrow n = \frac{Pt}{hf} \qquad f = \frac{l}{r}$$
$$\Rightarrow n = \frac{Pt}{\frac{hc}{r}}$$
$$\Rightarrow n = \frac{Pt\times r}{hc}$$
$$n = \frac{100\times1\times540\times10^{-9}}{6.02\times10^{-34}\times3\times10^{8}}$$
$$n = 3\times10^{20}$$

(b) is correct

(65)
$$E = hf$$
$$\Rightarrow h = \frac{E}{f}$$
Unit of h in C.G.S are $\frac{erg}{sec^{-1}}$ = erg sec.

(c) is correct

(67)
$$E = hf$$
$$\Rightarrow f = \frac{E}{h} = \frac{3.3\times1.6\times10^{-19}}{6.6\times10^{-34}}$$
$$f = 8\times10^{14}\,Hz$$

(a) is correct

(69) According to de-Brogle's
$$\lambda = \frac{h}{mv}$$
$$v = \frac{h}{m\lambda}$$

(b) is correct

Chapter 20

ATOMIC SPECTRA

KEY POINTS

The branch of physics that deals with the investigation of wavelengths and intensities of electromagnetic radiation emitted or absorbed by atoms is called spectroscopy. Black body radiation spectrum is an example of continuous spectra. Molecular spectra is the example of band spectra. Atomic spectra is an example of discrete or line spectra. Atomic spectra when an atomic gas or vapour at much less than atmospheric pressure is suitably excited by passing an electric current through it the emitted radiation has spectrum which contains certain specific wavelengths only. The impression on the screen is in the form of lines it referred as line spectrum. The spectrum of any element contains wavelengths that exhibit definite regularities and these were classified into certain groups called the spectral series. First series was identified by J.J Balmer in 1885 in the spectrum of hydrogen called Balmer series. In 1896 the results obtained by Balmer were expressed by J.R Rydberge in the following expression.

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$$

Where R_H is Rydberge's constant. Its value is $1.0974\times10^7\,m^{-1}$. The Balmer series contain wavelengths in the visible portion of the hydrogen spectrum. In ultraviolet region the Lyman series contains the wavelengths given by the formuia.

$$\frac{1}{\lambda} = R_H\left(\frac{1}{1^2}-\frac{1}{n^2}\right) \qquad n = 2, 3, 4, \ldots\ldots$$

In infrared region three spectral series have been found whose lines have the wavelengths specified by the following formula:

- Paschen series $\frac{1}{\lambda} = R_H\left(\frac{1}{3^2}-\frac{1}{n^2}\right)$ $\quad n = 4, 5, 6, \ldots\ldots$
- Brackett series $\frac{1}{\lambda} = R_H\left(\frac{1}{4^2}-\frac{1}{n^2}\right)$ $\quad n = 5, 6, \ldots\ldots$
- Pfund series $\frac{1}{\lambda} = R_H\left(\frac{1}{5^2}-\frac{1}{n^2}\right)$ $\quad n = 6, 7, \ldots\ldots$

Bohr's Model of the Hydrogen Atom: Neils Bohr, in 1913 formulated a model of hydrogen atom based on three postulates.

Postulate-I: An electron bound to the nucleus in an atom can move around the nucleus in certain circular orbits without radiating energy. These orbits are called the discrete stationary states of the atom.

Postulate-II: Only those stationary orbits are allowed for which orbital angular momentum is equal to an integral multiple of $\frac{h}{2\pi}$.

$$mvr = \frac{nh}{2\pi}$$

Here n = 1, 2, 3, ……, it is called principal quantum number.

Postualte-III: Whenever an electron makes a transition that is jumps from high energy state to a lower energy state a photon of energy hf is emitted.

$$hf = E_n - E_p$$

With the development of de-Broglie's hypothesis same justification could be seen in postulate II.

Quantized Radii: The velocity "V_n" of an electron moving in a stationary circular orbit of radius "r_n" in hydrogen atom.

$$V_n = \frac{nh}{2\pi m r_n}$$

Centripetal and Coulomb's forces are given as:

$$F_c = \frac{mv_n^2}{r_n} \Rightarrow F_e = \frac{Ke^2}{r_n^2}$$

Radius of nth orbit:

$$r_n = \frac{n^2h^2}{4\pi^2Kme^2}$$

$$r_n = n^2 r_1 \qquad \because r_1 = \frac{h^2}{4\pi^2Kme^2}$$

r_1 is first Bohr orbit radius having value 0.053 nm. The radii of different stationary orbits of the electrons in the hydrogen atom are given by:

$$r_n = r_1, 4r_1, 9r_1, \ldots\ldots$$

The speed of electron in the nth orbit:

$$V_n = \frac{2\pi Ke^2}{nh}$$

Quantizied Energies: Total energy "E_n" of the electron in Bohr orbit is the sum of kinetic energy and potential energy.

$$E_n = K.E + U$$

$$= \frac{1}{2}mv_n^2 + \left(\frac{-Ke^2}{r_n}\right) = -\frac{1}{n^2}\left(\frac{2\pi^2K^2me^4}{h^2}\right) = -\frac{E_o}{n^2} \qquad \because E_o = \frac{2\pi^2K^2me^4}{h^2}$$

The value of E_o is 13.6 eV.

The allowed energy levels of a hydrogen atom are:

$$E_n = -E_o, \frac{-E_o}{4}, \frac{-E_o}{9}, \frac{-E_o}{16}, \ldots\ldots$$

The energy required to completely remove an electron from the first Bohr orbit is called ionization energy. The minimum potential through which the external electron should be accelerated so that it can supply the requisite ionization energy is known as ionization potential. The electron in the hydrogen atom is in the lowest energy state corresponding to n = 1 and this state is called the ground state or normal state. When electron is in higher orbit it is said to be in the excited state. The potential through which an external electron should be accelerated so that on collision it can excite the electron from ground state is known as excitation potential.

Inner Shell Transitions and Characteristic X-rays MCAT: In heavy atoms the electrons are assumed to be arranged in concentric shells K, L, M, N etc. The inner shell electrons are tightly bound and large amount of energy is required for their displacement from their normal energy levels. After excitation when an atom returns to its normal state, photons of larger energy are emitted. The transition of inner shell electrons in heavy atoms gives rise to the emission of high energy photons or X-rays. The X-rays consists of series of specific wavelengths or frequencies are called characteristic X-rays.

Production of X-rays MCAT: X-ray tube is a high vacuum tube which consists of filament, cathode, tungsten target, anode cooling coils. The kinetic energy with which the electron strike the target is given by:

$$K.E. = Ve$$

The K_α X-ray photon of energy $hf_{K\alpha}$ is given as:

$$hf_{K\alpha} = E_L - E_K$$

The energies depend upon the type of target material. The characteristic X-rays appear as discrete lines of a continuous spectrum. The continuous spectrum is due to an effect known as bremsstrahlung or braking radiation.

Properties, Uses and Biological Effects of X-rays MCAT: X-rays can penetrate several centimeter into solid matter. One can visualize the interiors of the materials opaque to ordinary light. The darkening of the film is proportional to the radiation exposure. In flesh light elements like carbon, hydrogen and oxygen predominate and allow greater amount of incident X-rays to pass through them. One widely used system is computerized axial tomography the corresponding instrument is called CAT-scanner. The density differences of the order of one percent can be detected with CAT scans. X-ray photons are absorbed in tissues, they break molecular bonds and create highly reactive free radicals (H and OH). X-rays are useful for selective destruction of cancer cell.

Uncertainty within the Atom MCAT: According to Heisenberg principle:

$$\Delta p \, \Delta x = \frac{h}{2\pi}$$

If the electron to be confined to a nucleus (10^{-14} m) in diameter, its speed would have to be greater than 10^{10} ms^{-1}, greater than speed of light. When it moves in the circular path of radius (5×10^{-11} m) outside the nucleus then its speed comes out to be 1.46×10^7 ms^{-1}.

Laser MCAT: Light amplification by stimulated emission of radiation. The incident photon is absorbed by an atom in the ground state E_1 there by having the atom in the excited state E_2. This process is called stimulated or induced absorption. In the excited state the atom may decay by spontaneous emission. In stimulated or induced emission the incident photon of energy $hf = E_2 - E_1$ induces the atom to decay by emitting a photon that travels in the direction of incident photon. A metastable state is an excited state in which an excited electron is unusually stable and from which the electron spontaneously falls to lower state only after relatively longer time. When state E_2 contains more atoms than state E_1, this situation is known as population inversion.

Helium Neon Laser MCAT: Its discharge tube is filled with 85% helium and 15% neon gas. The neon is the lasing or active medium in this tube. The metastable states of helium and neon are 20.61 eV and 20.66 eV level. Spontaneous emission from neon atoms initiate laser action and stimulated emission causes electrons in the neon is drop from 20.66 eV to 18.70 eV level and red laser light of wavelength 632.8 nm corresponding to 1.96 eV energy is generated.

Uses of Laser in Medicine and Industry MCAT: It is used for welding of detached retinas. The narrow intense beam of laser can be used to destroy tissue in a localized area. It has been used to destroy cancerous cell. The heat of laser seals off capillaries and lymph vessels to prevent spread of the disease. Laser beam can be used for welding metals and drilling tiny holes in hard materials. It is potential energy source for inducing fusion optical fibres. Laser beam can be used to generate three dimensonal images of objects, in a process called holography.

Band Spectrum: It is given by incandescent vapours or gases in molecular state. It is on account of the individual behaviour of molecules. Band spectrum is the characteristic of the compound. No two different compounds give identical band spectra.

Continuous Spectrum: It is given by incandescent solids and liquids. It is on account of the collective behaviour of atoms or molecules.

Absorption Spectrum: When white light from an incandescent source passes through transparent gas, liquid or solid at a lower temperature before falling on the slit of the spectrometer, then we see an absorption spectrum.

Absorption spectrum is also of three types:

(a) **For line absorption**, the transparent absorbing material must be in the form of atomic vapours or gas.

(b) **For band absorption**, the absorbing material must be in the form of molecular vapours or gas.

(c) **For continuous absorption**, the transparent absorbing material must be a solid or a liquid.

In general, the number of emission lines is larger than the absorption lines.

For n levels, the number of possible emission lines = $\frac{n(n-1)}{2}$ and the number of possible absorption lines = (n − 1).

Fraunhofer Lines: These are the dark lines observed in the **solar spectrum**. These dark lines were discovered by Wolaston. When white light from the photosphere passes through the chromospheres which contains vapours absorb the light of those wavelengths which they themselves would emit when being incandescent.

Introduction MCAT:

(i) X-rays were discovered by Roentgen.

(ii) When fast moving electrons strike a target of suitable material (having high atomic weight and high melting point), X-rays are produced.

(iii) X-ray tubes are mainly of two types, namely

(a) the gas filled or Roentgen X-ray tube.

(b) the modern Coolidge tube or hot filament tube.

(iv) X-rays are electromagnetic waves of very small wavelength ranging from 100 Å to 0.1 Å.

(v) X-rays are not deflected by electric and magnetic fields.

Important Properties of X-rays MCAT:

(i) They are invisible.

(ii) They travel in straight lines with the speed of light.

(iii) They undergo reflection, refraction, interference, diffraction and polarisation.

(iv) They produce illumination on falling on fluorescent materials.

(v) They show continuous spectrum, hence we conclude that like light rays. X-rays are also electromagnetic waves.

(vi) They ionise the gases through which they pass.

(vii) They penetrate through different depths into different substances, e.g., wood, thin metal sheets, flesh, etc. depending upon their wavelength.

(viii) They do not pass through heavy metals and bones.

(ix) They are very active and may eject photoelectrons from metals (show photoelectric effect).

(x) They affect photographic plates.

(xi) They are not deviated by prisms or lenses.

(xii) They can be used to detect possible cracks, air cavities and other flaws in the interior of metal castings.

Intensity Control in X-ray Tube MCAT:

(i) Intensity implies the number of X-ray photons produced from the target.

(ii) The intensity of X-rays is proportional to the number of electrons emitted per sec from the filament and this can be increased by increasing the filament current in the Coolidge tube.

Quality Control in X-ray Tube MCAT:

(i) Quality of X-rays implies the penetrating power of X-rays. Penetrating power is proportional to the potential difference between the filament and target.

(ii) The quality of X-rays can be controlled by varying the potential difference between the cathode and the target.

(iii) Depending on the penetrating power, X-rays are of two types:

(a) **Soft X-rays:** X-rays having wavelength of 4 Å or above are called soft X-rays due to their low penetrating power.

(b) **Hard X-rays:** X-rays having low wavelength of the order of 1 Å have high frequency and are called hard X-rays due to their high penetrating power.

Spectral Series of Hydrogen Atom:

(i) **Lyman series:**

(a) For this series $n_1 = 1, n_2 = 2, 3, 4, \ldots\ldots, \infty$:

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$$

(b) This series lies in the ultraviolet region.

(c) Series limit line of Lyman series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{1} - \frac{1}{\infty}\right] = R \quad \text{or} \quad \lambda = \frac{1}{R}$$

(d) The first member of the Lyman series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{1} - \frac{1}{4}\right] = \frac{3R}{4} \quad ; \quad \lambda = \frac{4}{3R}$$

(ii) **Balmer series:**

(a) For this series $n_1 = 2, n_2 = 3, 4, 5, \ldots\ldots, \infty$:

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$$

(b) This series lies in the visible part of the spectrum.

(c) Series limit line of Balmer series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{\infty}\right] \quad \text{or} \quad \lambda = \frac{4}{R}$$

(d) The first member of the Balmer series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right] \quad \text{or} \quad \lambda = \frac{36}{5R}$$

(iii) **Paschen series:**

(a) For this series $n_1 = 3, n_2 = 4, 5, 6, \ldots\ldots, \infty$:

$$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]$$

(b) This series lies in the near infrared region.

(c) Series limit line of Paschen series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{9} - \frac{1}{\infty}\right] = \frac{R}{9} \quad ; \quad \lambda = \frac{9}{R}$$

(d) The first member of Paschen series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{9} - \frac{1}{16}\right] = \frac{7R}{144} \quad \text{or} \quad \lambda = \frac{144}{7R}$$

(iv) **Brackett series:**

(a) For this series $n_1 = 4, n_2 = 5, 6, \ldots\ldots, \infty$:

$$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_2^2}\right]$$

(b) This series lies in infrared region.

(c) Series limit line of Brackett series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{16} - \frac{1}{\infty}\right] = \frac{R}{16} \quad ; \quad \lambda = \frac{16}{R}$$

(d) The first member of Brackett series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{16} - \frac{1}{25}\right] = \frac{9R}{16 \times 25} \quad \text{or} \quad \lambda = \frac{16 \times 25}{9R}$$

(v) **Pfund series:**

(a) For this series $n_1 = 5$, $n_2 = 6, 7, 8, \ldots\ldots, \infty$:

$$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n_2^2}\right]$$

(b) This series lies in the far infrared region.

(c) Series limit line of Pfund series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{25} - \frac{1}{\infty}\right] = \frac{R}{25} \quad ; \quad \lambda = \frac{25}{R}$$

(d) The first member of the Pfund series is given by:

$$\frac{1}{\lambda} = R\left[\frac{1}{25} - \frac{1}{36}\right] = \frac{11R}{25 \times 36} \quad \text{or} \quad \lambda = \frac{25 \times 36}{11R}$$

Some Important Points:

(i) The ground state energy of the hydrogen atom is taken as the unit of energy in atomic physics. It is known as **Rydberg** (1 Rydberg = 13.6 eV).

(ii) The energy of the electron in various permitted orbits of the hydrogen atom is given by:

$$E_n = -\frac{me^4}{8\varepsilon_0^2 n^2 h^2} = -\frac{13.6}{n^2}\,\text{eV}$$

(iii) The negative sign appearing in the expression for energy indicates that the electron does not have enough energy to escape from the nucleus. Energy is required to remove the electron from the influence of the nucleus.

(iv) As the value of n increases, though the numerical value of energy decreases but its actual value increases because of the negative sign. Thus the energy of the outer orbit is more than the energy of the inner orbit.

(v) In the limit $n = \infty$, $E = 0$ and the electron is no longer bound to the nucleus to form an atom.

(vi) The energies specified by the above expression for energy are called energy levels of the hydrogen atom.

(vii) **Excitation:** It is the process of raising an electron within an atom from a lower energy state to a higher energy state.

(viii) **Excited state:** The state of an atom when an electron has been raised to a higher orbit then it occupies in the ground state, is called an excited state.

(ix) **Ground state:** The lowest energy state of an atom when the atom is most stable, is called ground state.

(x) **Ionisation:** If during the process of excitation the electron is completely removed from the atom, the atom is said to be ionised. The process of removal of the electron from an atom is called ionisation.

(xi) **Ionisation energy:** The energy required to remove an electron from an atom is called ionisation energy. The ionisation energy required to ionise a hydrogen atom is $= 0 - (-13.6) = 13.6$ eV.

(xii) **Ionisation potential:** The potential difference through which an electron is moved to gain ionisation energy is called ionisation potential. The ionisation potential of hydrogen atom is 13.6 volt.

Types of Spectra: Spectra and mainly of two kinds, emission spectrum and absorption spectrum.

(i) **Emission spectrum:** When light from an incandescent source is made to fall on the slit of a spectrometer, then we see an emission spectrum of the source. Emission spectrum is of three types:

(ii) **Line spectrum:** It is given by incandescent vapours or gases in atomic state. It is on account of the individual behaviour of atoms. Line spectrum is characteristic of the element. No two different elements give identical line spectra.

ASSIGNMENT NO. 20

(1) **Quality of x-rays depends upon:** MCAT

(a) Accelerating voltage (b) Filament current
(c) Material of the target (d) Both (a) and (c)

(2) **X-rays exhibit the phenomenon of:** MCAT

(a) Diffraction (b) Interference (c) Polarization (d) All of the above

(3) **The reverse process of photo-electric effect is called:** MCAT

(a) Annihilation of matter (b) Compton effect
(c) Pair production (d) X-rays

(4) **The transitions of inner shell electrons in heavy atoms give rise to the emission of:** MCAT

(a) High energy photon or x-rays (b) High energy γ-rays
(c) Low energy photons or x-rays (d) High energy β-rays

(5) **The duration of a laser pulse is 10^{-8} see. The uncertainty in its energy will be:**

(a) $\Delta E = \frac{h}{\Delta t}$ (b) $\Delta E = h\,\Delta t$ (c) $\Delta E = \frac{\Delta t}{h}$ (d) None of these

(6) **Characteristic x-rays are produced from:** MCAT

(a) Heavy element (b) Light element (c) Inner shell (d) Both (a) and (c)

(7) **In the production of laser beam for each incident photon, we will have two photons going:** MCAT

(a) In the same direction (b) In opposite direction
(c) At right angle to each other (d) In arbitrary direction

(8) **Reflecting mirrors in laser is used to:** MCAT

(a) Further stimulation (b) For producing more energetic lasers
(c) Both (a) and (b) (d) None of these

(9) **In He-Ne laser, the laser action is produced by:** MCAT

(a) Ne only (b) He-Ne both (c) Electrons of He (d) Electrons of Ne

(10) **The excited atoms returns to their ground state in:** MCAT

(a) 10^{-10} sec. (b) 10^{-8} sec. (c) 10^{-6} sec. (d) 10^{-11} sec.

(11) **Life time of metastable states is:** MCAT

(a) 10^{-6} sec or more (b) 10^{-3} sec or more (c) 10^{-5} sec or more (d) None of these

(12) **If the speed of light were 2/3 of its present value, the energy released in a given atomic explosion will be decreased by a fraction of:**

(a) $\frac{2}{3}$ (b) $\frac{4}{9}$ (c) $\frac{5}{9}$ (d) $\frac{2}{9}$

(13) **Helium-Neon laser discharge tube contains neon:** MCAT

(a) 82% (b) 15% (c) 25% (d) 85%

MCAT

(14) **Laser can be made by creating:**
(a) Population inversion (b) Metastable state (c) Assembly (d) All of the above

(15) **What is speed of electron in the first Bohr orbit?**
(a) 2.19×10^6 m/s (b) 1.6×10^6 m/s (c) 2.2×10^{-6} m/s (d) 3×10^8 m/s

(16) **The dual nature of light is exhibited by:**
(a) Diffraction and photoelectric effect (b) Diffraction and reflection
(c) Refraction and interference (d) Photoelectric effect

(17) **The size of the atom is approximately equal to:**
(a) 10^{-4} cm or 10^{-6} metre (b) 10^{-6} cm or 10^{-8} metre
(c) 10^{-8} cm or 10^{-10} metre (d) 10^{-12} cm or 10^{-14} metre

(18) **According to Bohr's postulates which of the following quantities takes discrete values?**
(a) Kinetic energy (b) Potential energy (c) Angular momentum (d) Momentum

(19) **According to Bohr principle, the relation between main quantum number (n) and radius of orbit (r) is:**
(a) $r \propto \frac{1}{n}$ (b) $r \propto n$ (c) $r \propto n^2$ (d) $r \propto \frac{1}{n^2}$

(20) **The radius of electron's second stationary orbit in Bohr's atom is R. The radius of the third orbit will be:**
(a) 3 R (b) 2.25 R (c) 9 R (d) $\frac{R}{3}$

(21) **According to Bohr when electron jumps from any higher orbit to third orbit, the spectral lines so emitted are called:**
(a) Balmer series (b) Paschan series (c) Lyman series (d) P. fund series

(22) **The ratio of the energies of the hydrogen atom in its first to second excited states is:**
(a) $\frac{1}{4}$ (b) $\frac{4}{9}$ (c) $\frac{9}{4}$ (d) 4

(23) **Of the various series of the hydrogen spectrum, the one which lies wholly in the ultraviolet region is:**
(a) Lyman series (b) Balmer series (c) Paschen series (d) Brackett series

(24) **The speed of an electron in the orbit of hydrogen atom in the ground state is:**
(a) c (b) $\frac{c}{10}$ (c) $\frac{c}{2}$ (d) $\frac{c}{137}$

(25) **Hydrogen atoms are excited from ground state to the state of principal quantum number 4. Then the number of spectral lines observed will be:**
(a) 3 (b) 6 (c) 5 (d) 2

(26) **The angular momentum of an electron in a hydrogen atom is proportional to:**
(a) $\frac{1}{\sqrt{r}}$ (b) $\frac{1}{r}$ (c) $\sqrt{r}$ (d) r^2

(27) **The required energy to detach one electron from Balmer series of hydrogen spectrum is:**
(a) 13.6 eV (b) 10.2 eV (c) 3.4 eV (d) −1.5 eV

(28) **The total energy of the electron in the hydrogen atom in the ground state is −13.6 eV. The K.E of this electron is:**
(a) 13.6 eV (b) 0 (c) −13.6 eV (d) 6.8 eV

(29) **Which of the following electromagnetic waves have the smallest wavelength?**
(a) γ-rays (b) X-rays (c) UV-rays (d) Infrared rays

(30) **An electromagnetic radiation has an energy of 13.2 KeV. Then the radiation belongs to the region of:**
(a) Visible light (b) Ultraviolet (c) Infrared (d) Microwave

(31) **The shortest wavelength of X-rays emitted from an X-ray tube depends on the:** MCAT
(a) Current in the tube (b) Voltage applied to the tube
(c) Nature of the gas in the tube (d) Atomic number of the target

(32) **The wavelength of X-rays is nearer to the order of:** MCAT
(a) 10^{-2} m (b) 10^{-4} m (c) 10^{-8} m (d) 10^{-10} m

(33) **The characteristic of the target element that determines the frequency of characteristic X-rays, is:** MCAT
(a) its mass number (b) its atomic number (c) its melting point (d) its conductivity

(34) **On increasing the number of electrons striking the anode of an X-ray tube, which one of the following parameters of the resulting X-ray would increase?** MCAT
(a) Penetration power (b) Frequency (c) Wavelength (d) Intensity

(35) **The voltage applied across an X-ray tube is nearly:** MCAT
(a) 10 volt (b) 100 volt (c) 10,000 volt (d) 10^6 volt

(36) **X-rays were discovered by:** MCAT
(a) Roentgen (b) Becquerel (c) Marie Curie (d) Van Lave

(37) **Which of the following lies wholly in ultraviolet region?**
(a) Lyman series (b) Paschen series (c) Brackett series (d) Balmer series

(38) **The Balmar series of hydrogen results when electron jumps from higher orbits to:**
(a) 1st orbit (b) 2nd orbit (c) 3rd orbit (d) 4th orbit

(39) **What is the ratio of the velocity of electron in third Bohr's orbit to the velocity in 2nd orbit?**
(a) $\frac{9}{4}$ (b) $\frac{2}{3}$ (c) $\frac{3}{2}$ (d) $\frac{4}{9}$

(40) **Dimension of Rydberge constant is:**
(a) LT^{-1} (b) $L^{-1}T$ (c) L^{-1} (d) None of these

(41) **To find longest wavelength radiation in Balmer series the value of 'n' used is:**
(a) 2 (b) 3 (c) 4 (d) ∞

(42) **The ionization energy of hydrogen is:**
(a) 13.6 eV (b) −13.6 eV (c) 3.4 eV (d) Zero

(43) **By CAT scans we can detect the density difference of the order of:**
(a) 1% (b) 15% (c) 10% (d) 50%

(44) **The longest wavelength of light which ionizes a hydrogen atom is:**
(a) 0.74 Å (b) 400 Å (c) 720 Å (d) 912 Å

(45) **The ratio of minimum to maximum wavelength in Balmer series is:**
(a) 5 : 9 (b) 5 : 36 (c) 1 : 4 (d) 3 : 4

(46) **X-rays and γ-rays of same energies may be distinguished by:** **MCAT**
(a) Method of production (b) Their intensities
(c) Ionizing power (d) Their velocities

(47) **Atomic hydrogen is excited to the 8th energy level. How many spectral lines can be observed in spectrum?**
(a) 8 (b) 16 (c) 28 (d) 64

(48) **Compton effect is associated with:**
(a) γ-rays (b) Positive rays (c) β-rays (d) X-rays

(49) **Which of the following types of electromagnetic waves have the longest wavelength?** **MCAT**
(a) X-rays (b) Infrared (c) Radio waves (d) Visible light

(50) **Which of the following radiation series is found in the visible region?**
(a) Lyman (b) Paschen (c) Pfund (d) Balmer

(51) **The ground state energy of H-atom is 13.6 eV. The energy needed to ionise H-atom from its second excited state is:**
(a) 1.51 eV (b) 3.4 eV (c) 13.6 eV (d) 12.1 eV

(52) **Line spectrum is obtained whenever the incandescent vapours at low pressure of the excited substance are in their:**
(a) Atomic state (b) Molecular state (c) Nuclear state (d) None of these

(53) **In black and white televisions, pictures on the screen are produced due to bombardment of:**
(a) X-ray photons on a white screen (b) X-ray photons on a white fluorescent screen
(c) Electrons on a white screen (d) Electrons on a fluorescent white screen

(54) **The value of Rydberg constant is:**
(a) $1.0974 \times 10^{-7}\ m^{-1}$ (b) $1.0974 \times 10^{7}\ m^{-1}$ (c) $1.0974 \times 10^{7}\ m^{-2}$ (d) $10.0974 \times 10^{7}\ m^{-1}$

(55) **According to Bohr's theory of the hydrogen atom. Only those orbits around the nucleus are allowed along with angular momentum of electron is:**
(a) $n(2\pi/h)$ (b) $2\pi/nh$ (c) $nh/2\pi$ (d) $n/2\pi h$

(56) **The velocity of moving electron in nth orbit is given by the relation:**
(a) $v_n = nh/2\pi mr_n$ (b) $v_n = n/\pi mr_n$ (c) $v_n = nh\pi m/r_n$ (d) $v_n = n^2\pi mr_n/h$

(57) **If the radius of first orbit of hydrogen atom is 0.53°A, the radius of second orbit will be:**
(a) 2.120 A° (b) 0.2120 A° (c) 21.200 A° (d) 0.142 A°

(58) **In an electronic transition, atom cannot emit:** **MCAT**
(a) γ-rays (b) Infra-red radiation (c) Visible light (d) Ultra-violet rays

(59) **The shortest wavelength radiation in Balmer series is:**
(a) 3645 A° (b) 3055 A° (c) 8235 A° (d) 5230 A°

(60) **The maximum frequency $f_{max.}$ of x-rays produced by the electrons accelerated by a potential of V_o volts can be expressed by:** **MCAT**
(a) $f_{max.} = h/Ve$ (b) $f_{max.} = Ve/h$ (c) $f_{max.} = hV$ (d) $f_{max.} = V/hc$

ANSWERS

(1)	(d)	(2)	(d)	(3)	(d)	(4)	(a)	(5)	(a)
(6)	(d)	(7)	(a)	(8)	(a)	(9)	(a)	(10)	(b)
(11)	(b)	(12)	(b)	(13)	(b)	(14)	(d)	(15)	(a)
(16)	(c)	(17)	(c)	(18)	(c)	(19)	(c)	(20)	(b)
(21)	(b)	(22)	(c)	(23)	(a)	(24)	(d)	(25)	(b)
(26)	(c)	(27)	(a)	(28)	(a)	(29)	(a)	(30)	(d)
(31)	(d)	(32)	(d)	(33)	(d)	(34)	(c)	(35)	(d)
(36)	(a)	(37)	(a)	(38)	(b)	(39)	(b)	(40)	(c)
(41)	(b)	(42)	(a)	(43)	(a)	(44)	(d)	(45)	(a)
(46)	(a)	(47)	(c)	(48)	(d)	(49)	(c)	(50)	(d)
(51)	(a)	(52)	(a)	(53)	(d)	(54)	(c)	(55)	(a)
(56)	(b)	(57)	(d)	(58)	(a)	(59)	(a)	(60)	(b)

SOLUTION

(5) According to uncertainty principle

$$\Delta E \,.\, \Delta t = h$$

$$\Delta E = \frac{h}{\Delta t}$$

(a) is correct

(15)

$$n = 1$$

$$V_n = \frac{2\pi Ke^2}{nh}$$

$$= \frac{2(3.14)\,9\times10^9\,(1.6\times10^{-19})^2}{1(6.63\times10^{-34})}$$

$$= 2.19\times10^6 \text{ m/s}$$

(a) is correct

(20)

$$r_n = n^2 r_0$$

For 2^{nd} orbit $n = 2$

$$r_2 = 4r_0$$

But $r_2 = R$

Therefore,

$$R = 4r_0$$

Now $r_3 = 9r_0$

$$r_3 = \frac{9}{4}(4r_0)$$

$$r_3 = 2.25\,R$$

(b) is correct

(22) As $E_n = -\frac{13.6}{n^2}\text{ eV}$

For first excited state $n = 2$

$$E_2 = -\frac{13.6}{2^2}\text{ eV}$$

For second excited state $n = 3$

$$E_3 = -\frac{13.6}{3^2}\text{ eV}$$

$$\frac{E_2}{E_3} = \frac{9}{4}$$

(c) is correct

(26) As $mVr = \frac{nh}{2\pi}$

But $r = \frac{n^2h^2}{4\pi^2me^2}$

$$\Rightarrow \quad n^2h^2 = 4\pi^2me^2r$$

$$nh = \sqrt{4\pi^2me^2r}$$

$$mVr = \frac{\sqrt{4\pi^2me^2r}}{2\pi}$$

$$mVr = \sqrt{me^2}\,.\,\sqrt{r}$$

$$mVr \propto \sqrt{r}$$

(c) is correct

(46)

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.63\times10^{-34}\times3\times10^8}{\lambda}$$

$$13.6\times1.6\times10^{-19} = \frac{1.989\times10^{-25}}{\lambda}$$

$$2.176\times10^{-18} = \frac{1.989\times10^{-25}}{\lambda}$$

$$\lambda = \frac{1.989\times10^{-25}}{2.176\times10^{-18}}$$

$$\lambda = 8.685\times10^{-8}\text{ m}$$

$$\lambda = 868\times10^{-10}\text{ m}$$

$$\lambda = 868\text{ A}^\circ$$

(d) is correct

Chapter 21

NUCLEAR PHYSICS

MCAT UNIT 13

KEY POINTS

Structure of the Nucleus: Rutherford, during his α-particle foil experiment said that positive charge of an atom is contained a sphere of radius 10^{-12} cm and also determined the total charge of the nucleus. Rutherford when bombarded nitrogen with α-particle, hydrogen nuclei were emitted, Rutherford called them nucleus.

Nucleon: The particles like proton, neutron present in the nucleus of atom are called nucleon.

Mass Number (A): It is equal to the sum of protons and neutrons present in the nucleus of an atom. It is denoted by A.

Atomic Number (Z): It is equal to the number of protons present in the nucleus or the number of electrons revolving around the nucleus. It is denoted by Z. For example:

$${}^{12}_{6}C \;,\; A = 12,\; Z = 6$$

$${}^{14}_{7}N \;,\; A = 14,\; Z = 7$$

$${}^{235}_{92}U \;,\; A = 235,\; Z = 92$$

Some atomic masses	
Particle	**Mass (u)**
e	0.00055
n	1.008665
^1H	1.007276
^2H	2.014102
^3He	3.01605
^3He	3.01603
^4He	4.002603
^7Li	7.016004
^{10}Be	10.013534
^{14}N	14.0031
^{17}O	16.991

Nuclear Mass: A mass unit is defined as $\frac{1}{12^{th}}$ of the mass of the carbon atom ${}_6C^{12}$. Now the number of molecules in one mole of carbon is 6.02×10^{23} (Avogadro number) and since carbon is monoatomic therefore it has 6.02×10^{23} atoms and mass equal to 12 g. Hence

Mass of 6.02×10^{23} atoms of carbon $= 12$ g

$$\text{Mass of 1 atom of carbon} = \frac{12}{6.02\times10^{23}}\text{ g} = \frac{12}{6.02\times10^{26}}\text{ kg} = 12\text{ a.m.u.}$$

$$\text{So} \quad 12\text{ a.m.u.} = \frac{12}{6.02\times10^{26}}\text{ kg}$$

$$1\text{ a.m.u.} = \frac{12}{12\times6.02\times10^{26}}\text{ kg} = 1.66\times10^{-27}\text{ kg}$$

On a unified atomic scale:

Mass of proton = 1.007276 u
Mass of neutron = 1.008665 u
Mass of electron = 0.00055 u

Isotopes and their Detection by Aston's Mass-Spectrograph: Isotopes are the atoms of same element having same atomic number but different mass number. For example hydrogen has got three isotopes i.e., ${}^1_1H$, ${}^2_1H$, ${}^3_1H$, for carbon ${}^{12}_6C$, ${}^{14}_6C$, for uranium ${}^{238}_{92}U$, ${}^{235}_{92}U$, ${}^{236}_{92}U$ is used as fuel in nuclear reactors. Isotopes of an element are found by mass-sectrograph. When the positive ions are accelerated through a voltage 'V' then they gain energy given by the relation i.e.,

$$Ve = \frac{1}{2}mv^2 \quad \text{...... (i)}$$

$$v = \sqrt{\frac{2Ve}{m}} \quad \text{...... (ii)}$$

When these fast moving ions enters perpendicularly the vacuum chamber placed in a magnetic field, they begin to move along circular path. The necessary centripetal force required for their circular motion is being provided by the magnetic force.

$$Bev = \frac{mv^2}{r} \quad \text{or} \quad r = \frac{mv}{Be} \qquad \ldots\ldots \text{(iii)}$$

Putting the value of 'v' from equation (ii) in equation (iii), we get:

$$r = \sqrt{\frac{2Vm}{B^2e}} \qquad \ldots\ldots \text{(iv)}$$

'r' is the radius of the circular path of the ions moving in the magnetic field. As V, B, e are constant quantities hence the radius of circular path of ions of an element depends only upon their mass.

Mass Defect and Binding Energy: The mass of the nucleus is always less than the total mass of the protons and neutrons that make up the nucleus. The difference of the two masses is called man defect.

$$\Delta m = Zm_p + (A - Z)m_n - m_{nucleus}$$

The missing mass is converted to energy in the formation of the nucleus and is called as Binding Energy.

$$B.E = (\Delta m)c^2$$

$$= Zm_pc^2 + (A - Z)m_nc^2 - mc^2_{nucleus}$$

Binding energy is responsible for stability of the nucleus.

$$\boxed{1 \text{ a.m.u.} = 931.5 \text{ MeV}}$$

As we know that:

$$1 \text{ a.m.u.} = 1.6606 \times 10^{-27} \text{ kg}$$

According to Einstein mass-energy relation:

$$E = mc^2$$

Where c = Velocity of light = 2.998×10^8 m/s

Hence

$$E = (1.6606 \times 10^{-27})(2.998 \times 10^8)^2 \text{ J}$$

$$E = \frac{1.6606 \times 10^{-27+16} \times (2.998)^2}{1.602 \times 10^{-19}}$$

$$E = 931.5 \text{ MeV}$$

So

$$1 \text{ a.m.u.} = 931.5 \text{ MeV}$$

Radioactivity: All those elements whose atomic number is greater than 82 are unstable. They are disintegrating themself and emitting either α or β or γ-rays. This phenomenon is called radioactivity.

Nuclear Transmutation: When the radioactive element decays and a new element is formed or conversion of one type of an atom into another is called transmutation.

Alpha Decay: When an element emits an alpha particle then its mass number decreases by four and atomic number decreases by two i.e.,

$${}_ZX^A \longrightarrow {}^{A-4}_{Z-2}Y + {}_2He^4\ (\alpha)$$

For example:

$${}^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$$

Beta Decay: When an element emits a β-particle then its mass number does not change but atomic number increases by one i.e.,

$${}_ZX^A \longrightarrow {}^{Z+1}_{A}Y + {}^{0}_{-1}\beta$$

For example:

$${}^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$$

Gamma Decay: Gamma rays are photons with high energy. When a γ-ray photon is emitted by an element then neither the mass number nor its atomic number changes rather an atom returns to its normal state from an excited state i.e.,

$${}^{*A}_{Z}X \longrightarrow {}^{A}_{Z}X + \gamma\text{-rays}$$

Half Life: The time period during which the present number of radioactive atoms are reduced to half is called half life.

The rate of decay of a radioactive element is directly proportional to the total number of radioactive nuclei present i.e.,

$$-\frac{\Delta N}{\Delta t} \propto N \quad \Rightarrow \quad -\frac{\Delta N}{\Delta t} = \lambda N$$

Where 'N' is the total number of atoms present, $-\frac{\Delta N}{\Delta t}$ is the rate of decay and 'λ' is the decay constant.

If 'N' is the total number of radioactive atoms and one see of their half life then,

After first half-life, $\frac{N}{2}$ atoms will decay.

After 2^{nd} half-life, $\frac{N}{4}$ atoms will decay.

After third half life, $\frac{N}{8}$ atoms will decay and so on.

After 3 half lives $\frac{7N}{8}$ atoms have decayed and $\frac{N}{8}$ atoms are left.

Half life and decay constant are related with each by the following relation i.e.,

$$\text{Half life} = \frac{0.693}{\text{Decay constant}}$$

$$\boxed{T = \frac{0.693}{\lambda}}$$

So if the decay constant 'λ' of any radioactive element is known, its half life can be found.

Interaction of Radiation with Matter: The interaction of the nuclear radiations i.e., α-particle, β-particle, γ-rays, with matter depends upon the following three factors:

(1) The mass of the particle. (2) The energy of the particle. (3) The charge of the particle.

Interaction of α-particles with Matter: α-particle is a positively charged particle. It is equivalent to a helium atom which has lost its two electrons. The range of α-particle is very small because of its high ionization power. Nearly 35 eV is used to produce a pair of ions. An α-particle with energy 7.7 MeV can produce 2×10^5 ion pairs. They can produce flourescence in substances like Zinc sulphide or Barium platinocyanide.

Interaction of β-particle with Matter: β-particles are electrons moving with high speeds. Its penetrating power of different materials is greater than α-particles because of their less ionization power. It can cause flourescence with substance like Zinc sulphide and Barium platinocyanide.

Interaction of γ-ray with Matter: They are neutral in character i.e., they do not carry any charge so they are not deflected by any electric or magnetic field. Their penetration power is greater than the penetration of α and β particles but their ionizing power is very small. They produce photoelectric effect, Compton's effect and pair production. Lead is the most suitable shield against γ-ray radiation. In solids the exponential decrease in intensity with increase in depth is given by:

$$I = I_o e^{-\mu x}$$

where

I_o = Initial intensity

I = Reduced intensity

μ = Linear absorption coefficient

x = Thickness of a sheet

Radiation Detectors: Many devices are being used for the detection of nuclear radiations like α-particles, β-particles and γ-rays. The working principle of all the radiation detectors is mainly based on the ionizing properties of mainly based on the ionizing properties of these radiations. We shall discuss three detectors here in this chapter.

(1) Wilson Cloud Chamber (2) Geiger-Muller Counter (3) Solid State Detector

(1) ***Wilson Cloud Chamber:*** It is a device which was invented by C.T.R. Wilson in 1911. It is used for the detection of α, β and γ rays on the basis of their ionizing power.

When the radioactive source is placed near the window no. 2, as soon the radiation enter the chamber, they cause ionization. The unionized alcohol vapours condense on the ions and small droplets are formed along the tracks of the α or β-particles and γ-rays. The chamber is illuminated by the light source and these tracks are photographed as shown below.

(2) ***Geiger-Muller Counter:*** Geiger counter is a very versatile, handy and an accurate device for the detection of nuclear radiations. Its working principle is based on the ionization power of the radiations entering the Geiger tube.

It consists of a stiff central wire acting as an anode in a hollow metal cylinder acting as a cathode filled with a suitable mixture of gas at about 0.1 atmospheric pressure. A high potential difference (about 400 V for neon-bromine filled tubes) but slightly less than that necessary to produce discharge through the gas is maintained between the electrodes. When radiation enters the tube, ionization is produced and the free electrons attracted towards positively charged central wire. The entire electron pulse takes less tan 1 μs. However, positive ions, being very massive than the electrons, take several hundred times as long to reach the outer cathode. During this time, called the dead time ($\sim 10^{-4}$ s) of the counter, further incoming particles cannot be counted.

Geiger counter is not suitable for fast counting. Scintillation counter or solid state detectors are fast enough, more accurate and more efficient.

(3) ***Solid State Detector:*** A solid state detector is a specially designed p-n junction operating under a reversed bias in which electron-hole pairs are produced by the incident radiation to cause a current pulse flow through the external circuit. The detector is made from a p-type silicon or Germinium.

The energy needed to produce and electron hole pair is about 3 eV to 4 eV which makes the device useful for detecting low energy particles. The collection time of electrons and holes is much less than gas filled counters and hence a solid state detector can count very fast. This detector is used for detecting α or β-particles but a specially designed device can be used for γ-rays.

Nuclear Reactions: While studying radioactivity, we have seen that an α-particle is emitted from radium-226 and radon-222 is obtained. This nuclear change is represented by the following equation:

$$ {}^{226}_{88}\mathrm{Ra} \longrightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He} $$

Rutherford performed and experiment on the nuclear reaction in 1918. He bombarded α-particle on nitrogen.

$$ {}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H} $$

Before and after any nuclear reaction the number of protons and neutrons must remain same because protons and neutrons can neither be destroyed nor can they be created.

$$ {}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H} $$

Number of protons $= 7 + 2 = 8 + 1$

Number of neutrons $= 7 + 2 = 9 + 0$

Rutherford's nuclear reaction of ${}^{14}_{7}\mathrm{N}$ and α-particle will proceed in the backward direction as:

$$ {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H} \longrightarrow {}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} $$

James Chadwick discovered neutron in 1932. Reaction is shown below:

$$ {}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{12}_{6}\mathrm{C} + n_0^1 $$

Nuclear Fission: Such a reaction in which a heavy nucleus like that of uranium splits up into two nuclei of equal size along with the emission of energy during the reaction is called fission reaction.

Fission reaction of ${}^{235}_{92}\mathrm{U}$ can be represented by the equation:

$$ {}^{235}_{92}\mathrm{U} + n_0^1 \longrightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3n_0^1 + Q $$

By comparing the total energy on the left side of the equation with total energy on right side, we find that in the fission of one uranium nucleus about 200 MeV energy is given out.

When a uranium nucleus breaks up, into barium and krypton, then an energy at the rate of 0.9 MeV per nucleon is given out. This means that an energy $235 \times 0.9 = 211.5$ MeV is given out in the fission of one uranium nucleus.

Two possible fission reactions of uranium are given below as an example.

$$ {}^{235}_{92}\mathrm{U} + n_0^1 \longrightarrow {}^{132}_{50}\mathrm{Sn} + {}^{101}_{42}\mathrm{Mo} + 3n_0^1 + Q $$

and

$$ {}^{235}_{92}\mathrm{U} + n_0^1 \longrightarrow {}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + 2n_0^1 + Q $$

Critical Mass and Critical Volume: In fission chain reaction, such a mass of uranium in which one neutron, out of all the neutrons produced in one fission reaction, produces further fission is called critical mass. The volume of this mass of uranium is called critical volume.

Nuclear Reactor: It is a device in which nuclear fission chain reaction takes place at a constant rate in a controlled manner. Therefore it is used for the production of atomic energy for industrial and other useful purposes.

The important parts of nuclear reactor are:

(1) Core (2) Moderators (3) Control rods
(4) Cooling system (5) Heat exchanger (6) Biological shield

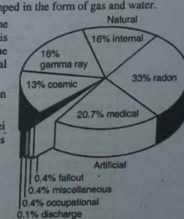
The most important and vital part of a reactor is called core. It contains uranium and one of the moderator, such as graphite and heavy water. Uranium fuel is taken in the form of thick rods, surrounded with moderator.

For self-sustained chain reaction the fast neutrons produced in a fission reaction must be slowed down. This is achieved d by placing uranium in a medium known as moderator. Graphite is generally used as moderator in nuclear reactors.

In case of too many neutrons, control rods of boron or cadmium are used which are effective neutron absorbers. When the chain reaction is too fast the control rods can be inserted to some suitable depth for making them slow down.

Cooling system consists of pipes along which the coolant is pumped in the form of gas and water.

The hot gas is led from the reactor into a heat exchanger. Here the heat is transferred to water circulating through pipes so that the water is converted into steam. This steam is used to drive turbines. The turbine shaft is connected to an electrical generator that produces electrical power.



A wall of concrete which absorbs radiations emitted due to fission of the fuel is used, which protects the workers from their dangerous effect.

Fusion Reaction: Such a nuclear reaction in which two light nuclei merge to form a heavy nucleus is called fusion reaction. Some examples of fusion reactions are given below:

$$ {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{4}_{2}\mathrm{He} + 24\ \mathrm{MeV} $$

$$ {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{3}_{1}\mathrm{He} + {}^{1}_{1}\mathrm{H} + 4.0\ \mathrm{MeV} $$

$$ {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + 3.3\ \mathrm{MeV} $$

$$ {}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + 17.6\ \mathrm{MeV} $$

Nuclear Reactions in the Sun: The sun is composed of primarily of hydrogen. The fusion reactions taking place in sun are given below:

$$^{1}_{1}H + ^{1}_{1}H \longrightarrow ^{2}_{1}H + ^{0}_{-1}e + \text{Energy}$$
$$^{2}_{1}H + ^{1}_{1}H \longrightarrow ^{3}_{2}He + \gamma + \text{Energy}$$
$$^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + ^{1}_{1}H + ^{1}_{1}H + \text{Energy}$$

It has been estimated that in this p-p chain reaction, 25.7 MeV energy is given out i.e., 6.4 MeV per nucleon energy is obtained which is much greater than the energy given out per nucleon (1 MeV) during a fission reaction.

Radiation Exposure: We are constantly being exposed to the radiations originating from both natural and man made sources.

(1) **Cosmic Radiations:** Major portion of the natural radiations reaching our Earth is in the form of the cosmic rays consists of high energy charged particles and electromagnetic radiations. Ozone layer around Earth is a very good shield against the coming radiations. A depletion in ozone layer in the upper atmosphere have been recently detected and increase in the intensity of cosmic rays reaching the Earth can cause skin cancer.

(2) **Building Material Exposure:** Many building materials contain small amount of radioactive isotopes. Radioactive radon gas enters buildings from the ground. Good ventilation can reduce radon level inside the building. Similarly,

(3) Nuclear radiations are being emitted by the radioactive elements present in rocks and one soil.

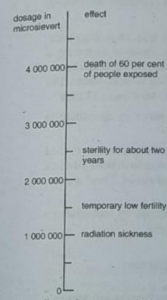
(4) Naturally occurring radio nuclides like Potassium-40 and Carbon-14 are accumulated in the diet and make their way into the body where they emit β-particles.

(5) Dry tobacco leaves are also radioactive so a cigarette smoker is exposed to these harmful radiations due to inhaling of the smoke.

We cannot avoid exposure to radiation, however, the best advice is to avoid unnecessary exposure to any kind of ionizing radiation.

Table: Average radiation doses from a number of common sources of ionizing radiation

Types of Exposure	mSv
Watching television for a year	10
Radiation from nuclear power stations for a year	10
Wearing a radioactive luminous watch for a year (now not very common)	30
Having a chest X-ray	200
Radiation from a brick house per year	750
Maximum dose allowed to general public from artificial sources per year	1000
Working for a month in a uranium mine	1000
Typical dose received by a member of the general public in a year from all sources	2500
Maximum dose allowed to workers exposed to radiation per year	50000



The effects of exposure to high levels of ionizing radiation

Table

Isotope	Half-life	Gamma energies / Mev	Example of use
Sodium ^{24}Na	15 hours	1.37, 2.75	Plasma volume
Iron ^{59}Fe	45 days	1.29, 1.10, 0.19	Iron in plasma
Techneliu ^{99}Te	6 hours	0.14	Thyroid uptake scans
Iodine ^{131}I	8 days	0.72, 0.64, 0.36, 0.28, 0.08	Kidney tests
Iodine ^{125}I	60 days	0.035	Plasma volume vein flow

Biological Effects of Radiation:

Becquerel (Bq): The strength of the radiation source is indicated by its activity measured in becquerel (Bq).

1 becquerel = One disintegration per second

Curie (Ci): It is a big unit of activity 'A'.

1 curie = 3.7×10^{10} disintegration/second

Absorbed Dose (D): The energy 'E' absorbed from ionizing radiation per unit mass of the absorbing body. Mathematically:

$$D = \frac{E}{m}$$

SI unit of absorbed Dose is "Gray". It is denoted by Gy.

$1\ Gy = 1\ J\ kg^{-1}$

The old unit of absorbed Dose is radian, where:

1 rad = 0.01 Gy

Equivalent Dose "D_e": The product of absorbed dose and "Relative Biological Effectiveness" (RBE) is called equivalent Dose.

$D_e = D \times RBE$

SI unit of equivalent dose is sievert (Sv).

$1\ Sv = 1\ Gy \times RBE$

An old unit, the rem is equal to 0.01 Sv.

1 rem = 0.01 Sv

Penetrating high energy radiations are very harmful to human organism when exposed to them. Biological effects are generally of two types:

(1) Somatic effect (2) Genetic effect

Somatic effects affect an individual directly some of the common somatic effects of radiations are skin burns, loss of hairs, ulceration etc. These effects also cause cancer.

In genetic effect genes are damaged. A "gene" is an entity concerned with the transmission and development or determination of hereditary characters. Genetic damaged may appear after long time and even the effects may be passed on the future generations.

Biological and Medical Uses of Radiation: Radioisotopes are used widely in different branches of science.

Uses of Radioisotopes: These are used to study the chemical reactions of complex type. In Biology these chemical reactions take place inside plants and in animals. Quality of fertilizers can be improved by mixing a small amount of radioactive isotopes. The improved varieties of certain crops like rice, chickens, wheat and cotton have be developed through the use of radioisotopes. Used to improve plant structure. Used to treat cancer. The most important isotope which is used for this purpose is Cobalt-60 which emits γ-rays of 1.33 MeV and 1.17 MeV.

Tracer Techniques: Tracers are widely used in medicine to detect malignant tumours, in agriculture to study the uptake of fertilizer by a plant, to identify faults in the underground pipes etc.

Medical Diagnostics and Therapy: Radioactive iodine can be used to check that a person's thyroid gland is working properly. A hyperactive gland absorbs more than twice the amount of normal thyroid gland. A similar method can be used to study the circulation of blood using radioactive isotope Sodium-24. These are also used to treat cancerous cells.

Radiography: The technique of producing a photographic image of an opaque specimen by transmitting a beam of X-rays or γ-rays through it on to an adjacent photographic film is called radiography.

Basic Forces of Nature: We know the basic forces are:

(1) Gravitational force (2) Magnetic force (3) Electric force
(4) Weak nuclear force (5) The strong nuclear force

The electric and magnetic forces were unifined to get an electromagnetic force by Faraday and Maxwell. This unification leaves behind four fundamental forces.

(1) The strong nuclear force. (2) The electromagnetic force. (3) The weak nuclear force.
(4) The gravitational force.

Scientists continued their efforts for unification of forces, 100 years after the unification of electric and magnetic forces. In 1979, Glashow, Weinberg and Abdus Salam unified electromagnetic and weak forces and won Noble Prize in Physics.

Building Block's of Matter: Subatomic particles are divided into three groups:

(1) Photons (2) Leptons (3) Hadrons

Hadrons: Hadrons are particles that experience the strong nuclear force. In addition to it protons, neutrons and mesons are hadrons.

(1) Baryons: The particles equal in mass or greater than protons are called baryons.

(2) Mesons: The particles lighter than protons are called mesons.

(3) Leptons: "Particles that do not experience strong nuclear force". Electrons, mesons, and neutrons are Leptons.

Quarks Table

Name	Symbol	Charge
Up	u	$+\frac{2}{3}e$
Down	d	$-\frac{1}{3}e$
Strange	s	$-\frac{1}{3}e$
Charm	c	$+\frac{2}{3}e$
Top	t	$+\frac{2}{3}e$
Bottom	b	$-\frac{1}{3}e$

Antiquarks Table

Symbol	Charge
$\bar{u}$	$-\frac{2}{3}e$
$\bar{d}$	$+\frac{1}{3}e$
$\bar{s}$	$+\frac{1}{3}e$
$\bar{c}$	$-\frac{2}{3}e$
$\bar{t}$	$-\frac{2}{3}e$
$\bar{b}$	$+\frac{1}{3}e$

Fission:

(i) The splitting of the heavy nucleus into two medium nuclei is known as nuclear fission.

(ii) Nuclear fission was discovered by Otto Hahn and Strassmann in the year 1938.

(iii) The reaction representing the basic fission process of uranium nucleus is written as follows:

$$_{92}U^{235} + {}_0n^1 \longrightarrow {}_{92}U^{236} \longrightarrow X + Y + \text{Neutrons}$$

Here, $_{92}U^{236}$ is a highly unstable isotope and X and Y are the fission fragments.

(iv) The average number of neutrons produced in the fission of uranium is 2.5.

(v) The neutrons released during the fission process are called prompt neutrons.

(vi) Fission fragments while becoming stable emit some neutrons called delayed neutrons. The delayed neutrons are about 1% of the prompt neutrons. The velocity of prompt neutrons is more than the velocity of delayed neutrons.

(vii) U^{235} is more easily fissionable than U^{238}. Fast neutrons are required for the fission of U^{238} while slow neutrons are needed for the fission of U^{235}. Naturally available uranium has 0.7% of U^{235} and 99.3% of U^{238}.

(viii) Easily fissionable element is plutonium, $_{94}Pu^{239}$, which is an artificially formed element.

Energy Released in Fission:

(i) The energy released in the fission of one U^{235} atom is about $200\ MeV = 3.2 \times 10^{-11}$ J.

(ii) The energy released in the fission of 1 g of U^{235} is

$$= \frac{6.023 \times 10^{23}}{235} \times 200\ MeV = 5.128 \times 10^{23}\ MeV$$

$$= 8.2 \times 10^{10}\ J = 2.28 \times 10^4\ kWh$$

Chain Reaction:

(i) A chain reaction is a self-propagating process in which a number of neutrons multiply rapidly during fission till the whole of the fissile material is disintegrated.

(ii) The chain reaction occurs if loss of neutrons by non-fission capture of neutrons and escape of neutrons without being captured is less than the surplus of neutrons produced by fission.

(iii) To start a chain reaction a minimum mass of the fissile material is required. This mass is called **critical mass** or **critical size**.

(iv) Uncontrolled chain reaction is the principle of the atom bomb.

(v) The energy released in the explosion of an atom bomb is equal to the energy released by 2000 ton of TNT and the temperature at the place of explosion is of the order 10^7 °C.

(vi) Controlled chain reaction is the principle of nuclear reactor or **thermopile**.

Nuclear Reactor:

(i) Nuclear reactor was first devised by **Fermi**.

(ii) **Apsara** was the first Indian nuclear reactor.

(iii) A nuclear reactor consists of five main elements:

- (a) **Fuel:** The commonly used fuels are isotopes of uranium, U^{235}, U^{235}; isotopes of thorium, Th^{232}; isotopes of plutonium, P^{239}, Pu^{240} and Pu^{241}.
- (b) **Moderator:** Moderator slows down the highly energetic neutrons. Examples: Heavy water, graphite, beryllium.
- (c) **Control rods:** The function of control rods is to absorb the excess of neutrons and thus controls the chain reaction. Examples: cadmium rods, boron rods.
- (d) **Neutron reflector:** This prevents the leakage of neutrons. Materials of high scattering cross-section and low absorption cross-section are good reflectors.
- (e) **Coolants:** The cooling system removes the heat evolved in the reactor core. Examples: ordinary water; heavy water, helium, CO_2, liquid sodium, potassium, mercury, etc.

(iv) **Breeder reactor:** In a breeder reactor more nuclear fuel would be produced than consumed. In this reactor non-fissionable uranium-238 is converted into fissionable plutonium-239.

(v) **Breeder reactor:** If n atoms undergo fission in a time t seconds and E be the energy released in each fission, then power $P = (nE/t)$.

Nuclear Fusion:

(i) Fusion is a process in which lighter nuclei combine to form a heavy nucleus. When two deuterium nuclei are fused together, a single helium nucleus is formed.

$$ {}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4 + 24 \text{ MeV} $$

(ii) For fusion very high temperature of the order of 10^7 to 10^8 K is required and so the reaction is called **thermonuclear reaction**.

(iii) Fusion energy is greater than fission energy.

(iv) If the temperature is more than that of the sun, then hydrogen nuclei combine to form helium by carbon-nitrogen cycle.

(v) More energy is released due to proton-proton cycle than carbon-nitrogen cycle.

(vi) **Hydrogen bomb** is based on the principle of nuclear fission. The very high temperature required for fusion is supplied by an atom bomb. This bomb is more disastrous than atom bomb.

Radiation Units:

(i) **Roentgen (r):** It is the dose of radiation that produces 1.6×10^{12} pairs of ions in one gram of air. Also, one roentgen (r) = 2.58×10^{-4} coulomb/kg.

(ii) Rad is also a unit of radiation: 1 rad = 10^{-2} J/kg.

Nucleus and its Constituents:

(i) Nucleus of an atom is positively charged. Its radius is about 5×10^{-5} metre.

(ii) Nucleus consists of protons and neutrons which are collectively called nucleons.

(iii) Nucleus was discovered by Rutherford while its constituents proton and neutron were discovered by Ruther ford and Chadwick respectively.

(iv) Atomic number Z of an atom gives the number of protons in the nucleus while the mass number A provides the total number of nucleons (neutrons plus protons) in the nucleus of the atom.

(v) Usually, the nucleus of an element Z with atomic number Z and mass number A is denoted as ${}_ZX^A$.

(vi) Charge of proton is 1.6×10^{-19} C while mass of proton is $m_p = 1.67208 \times 10^{-27}$ kg = 1.00728 amu.

(vii) Neutron has no charge while mass of neutron is $m_n = 1.67431 \times 10^{-27}$ kg = 1.008665 amu.

Nuclear Size:

(i) Size of the nucleus is of the order of fermi (1 fermi = 10^{-15} m).

(ii) The radius of the nucleus is given by: $R = R_0A^{1/3}$, where $R_0 = 1.3$ fermi and A is the mass number.

(iii) The size of the nucleus is of the order of 10^{-15} m for hydrogen and 7×10^{-14} m for the heaviest nucleus.

(iv) The size of the atom is of the order of 10^{-10} m.

Density of Nuclear Matter:

(i) **Isobars:** Isobars are the nuclei with the same mass number A but different atomic number Z. Examples: ${}_8O^{16}$ and ${}_7N^{16}$. The isobars are the atoms of different elements and have different physical and chemical properties.

(ii) **Isotones:** Isotones have the same neutron number but different atomic number and mass number. Examples: ${}_6C^{14}$, ${}_7N^{15}$ and ${}_8O^{16}$. The isotones are atoms of different elements and have different physical and chemical properties.

(iii) **Isomers:** Isomers have the same atomic number and same mass number but their nuclei exist in different energy states. These nuclei exist in different energy states. These nuclei are distinguished by their different life times.

Forces between Nucleons:

(i) **Electrostatic coulomb forces:**

- (a) The coulombic forces exist between protons only.
- (b) As the atomic number increases, the size of the nucleus increases and therefore the coulombic forces increase.
- (c) These forces cause instability of the nucleus.

(ii) **Nuclear forces:**

- (a) These forces exist between any two nucleons.
- (b) These are the strongest known forces in nature.
- (c) These are attractive forces and cause stability of the nucleus.
- (d) Nuclear forces are short range forces. These do not exist at large distances greater than one fermi.
- (e) These forces are charge independent.
- (f) These are saturable forces.
- (g) According to Yukawa, nuclear forces are due to exchange of meosons.
- (h) Anderson and Nedder Meyer discovered the meson.
- (i) π^*, π^- and π^0-mesons are the particles which continuously exchange between proton and proton or neutron and neutron or a proton and a neutron.

(iii) **Hard core forces:**

- (a) These are repulsive forces.
- (b) These forces come into existence when the distances between the nucleons is 0.5 fermi.
- (c) Due to these forces the density of the nucleus remains constant.

(iv) **Tensor forces:**

- (a) These forces are due to spinning of nucleus.
- (b) A spinning nucleus behaves like a magnetic dipole. There exists a force between two dipoles. This force is called tensor force which prevails up to a distance of 3 fermi.

Stability of Nucleus:

(i) The nucleus is more stable when the number of protons is equal to the number of neutrons.

(ii) The nuclei having even number of protons or even number of neutrons are more stable.

(iii) If number of protons or number of neutrons in a nucleus is equal to one of the magic numbers, then the nucleus is stable. Magic numbers are 2, 8, 14, 20, 28, 50, 82, 126.

Atomic Mass Unit (amu): It is equal to (1/12)th the mass of the carbon nucleus.

$$1 \text{ amu} = 1.67 \times 10^{-27} \text{ kg}$$

Mass Energy Equivalence:

(i) Einstein established that **mass is also a form of energy**. The mass m of a particle is equivalent to its energy given by: $E = mc^2$, where c is the velocity of light.

(ii) Energy is released in the form of γ-rays of frequency v given by: $E = mc^2 = hv$.

(iii) The amount of energy released when 1 g of matter is annihilated $= 9 \times 10^{13}$ joules $= 2.5 \times 10^7$ kWh.

(iv) The amount of energy equivalent to 1 amu is 931 MeV.

(v) The amount of energy released when an electron is annihilated is 0.51 MeV.

(vi) Binding energy per nucleon $= \frac{\Delta mc^2}{A}$ joule/nucleon or $\frac{\Delta m \times 931}{A}$ MeV/nucleon.

Law of Radioactive Disintegration:

(i) This law was given by Rutherford and Soddy.

(ii) If N is the number of atoms present at a given instant t, then the rate of disintegration $(-dN/dt)$ is proportional to N, i.e.,

$$\frac{dN}{dt} = -\lambda N$$

where λ is called as the disintegration constant or decay constant.

(iii) If N_0 is the initial number of atoms present, then $N = N_0 e^{-\lambda t}$.

Activity of a Radioactive Substance:

(i) Half-life period (T) of a radioactive element is defined as the time taken by the element to reduce to half of its initial amount.

(ii) Average life or mean life is:

$$T_{av} = \frac{\text{Sum of the life times of all atoms}}{\text{Total number of atoms}} \quad \text{or} \quad T_{av} = \frac{1}{\lambda}$$

(iii) $T = 0.693\, T_{av}$ or $T_{av} = 1.44\, T$

Units of Radioactivity:

(i) The SI unit of radioactivity is Becquerel (bq).

1 becquerel = 1 disintegration/sec or 1 dps

(ii) 1 curie or 1 Ci $= 3.7 \times 10^{10}$ dps $= 3.7 \times 10^{10}$ bq

(iii) 1 rutherford or 1 Rd $= 10^6$ dps $= 10^6$ bq

Examples of Artificial Radioactivity: When aluminium is bombarded with α-particle, radio phosphorus and neutron are emitted.

Uses of Radioisotopes:

(i) Radio phosphorus-32 is used for the treatment of skin diseases, blood cancer, lukemia.

(ii) Radio iodine-134 is used for the treatment of thyroid gland.

(iii) Radio sodium-24 is used for removing defects in blood circulation.

(iv) Radio cobalt-60 is used for the treatment of cancer.

(v) Radio carbon-14 is used for determining the age of fossils and plants.

Introduction:

(i) Radioactivity was discovered by **Henry Becquerel** in the year 1896.

(ii) All the elements with atomic number greater than 82 are naturally radioactive.

(iii) The radioactivity may be defined as the spontaneous disintegration of the atoms of heavy elements with the emission of α-particles, β-particles and γ-rays.

(iv) Rate of disintegration of radioactive elements is not affected by the external conditions of temperature, pressure, electric or magnetic fields.

(v) A particular radioactive element can emit either α-particle or β-particle but never both. However, γ-rays can be emitted by a pure g-emitter or by α-emitter or β-emitter.

(vi) The conversion of lighter elements into radioactive elements by the bombardment of fast moving particles is called artificial or induced radioactivity.

(vii) Madame Curie and Pierre Curie discovered two elements **polonium** and **radium**.

(viii) Rutherford demonstrated experimentally that radiations emitted by radioactive elements are of three types, called as α, β and γ-radiations.

Properties of α, β and γ-rays:

S.No.	Properties	α-rays	β-rays	γ-rays
1.	Nature	Helium nucleus	Fast moving electrons	Electromagnetic radiations or photons
2.	Nature of charge	Positive	Negative	No charge
3.	Magnitude of charge	3.2×10^{-19} coulomb	1.6×10^{-19} coulomb	Zero
4.	Mass	$4 \times 1.67 \times 10^{-27}$ kg	9.1×10^{-31} kg	Rest mass is zero
5.	Velocity	Between 1.4×10^7 m/s to 2.2×10^7 m/s	1% to 99% of velocity of light	3×10^8 m/s
6.	Effect of electric and magnetic fields	Deflected	Deflected	Not deflected
7.	Range	3 to 8 cm in air or 1/100 mm of aluminium	5 mm of Al or 1 mm of lead	30 cm of iron
8.	Penetrating power	Maximum	100 times of α-rays	1000 times of α-rays
9.	Ionising power	Maximum	Lesser	Minimum

ASSIGNMENT NO. 21

(1) **The term "dead time" in G.M counter means the time or the order of:**
(a) More than 1 millisec (b) Less than 1 millisec
(c) More than 1 millisec (d) None of these

(2) **In solid-state detector, the reverse bias is applied through the two:**
(a) Conducting layers of silver (b) Conducting layers of gold
(c) Conducting layers of aluminum (d) Conducting layers of plastic

(3) **In sold state detector, the energy needed to produce an electron hole pair is about:**
(a) 3 Mev to 4 Mev (b) 3 eV to 4 eV (c) Both (a) and (b) (d) None of these

(4) **The phenomenon of nuclear fission is used in the construction of:**
(a) Atomic bombs (b) Hydrogen bomb (c) Both (a) and (b) (d) None of these

(5) **In fission reaction, heavy water is used as:**
(a) Heat exchanger (b) Coolant (c) Moderator (d) None of above

(6) **The Wilson cloud chamber is based on the principle that supper saturated vapors condense more readily on:**
(a) Ions and dust particles (b) Dust particles
(c) Ions (d) None of these

(7) **Wilson cloud chamber is a device used as:**
(a) Path of ionizing particle (b) Accelerating +vely charged particle
(c) Accelerating −vely charged particle (d) None of these

(8) **In Wilson Cloud chamber, the α-particle leave:**
(a) Thin and discontinuous tracks (b) No tracks
(c) Thick, straight and continuous tracks (d) None of these

(9) **Geiger counter was designed by:**
(a) Mosely (b) Michelson (c) Geiger and Muller (d) Faraday

(10) **Geiger Muller counter is suitable for:**
(a) Slow counting (b) Fast counting (c) Both (a) and (b) (d) None of these

(11) **Specially designed solid state detector can be used to detect:**
(a) γ-rays (b) x-rays (c) α-particles (d) β-particles

(12) **A solid state detector is basically:**
(a) A p-n-p transistor (b) A n-p-n transistor
(c) A reverse p-n junction (d) A forward p-n-junction

(13) **The potential difference between the top and bottom of a cloud chamber is of the order of:**
(a) 290 v (b) 400 v (c) 1 kv (d) None of above

(14) **The potential difference between anode and cathode in a neon-bromine filled G.M counter is:**
(a) 290 v (b) 400 v (c) 1 kv (d) 1 MV

(15) **Which one of the following detectors can count fast and operate at low voltage:**
(a) Solid state detector (b) G.M counter
(c) Wilson cloud chamber (d) None of these

(16) **In G.M counter, the positive ions take time to reach the cathode is:**
(a) 10^{-2} s (b) 10^{-3} μs (c) 10^{-4}s (d) 10^{-6} s

(17) **The capture of a neutron by a nucleus results in the formation of:**
(a) Deutron (b) Proton (c) Helium (d) Radio Isotope

(18) **Atomic mass scale 1u is equal to:**
(a) 1.66×10^{18} kg (b) 1.66×10^{-19} kg (c) 1.66×10^{-27} kg (d) 1.66×10^{27} kg

(19) **One joule of energy absorbed per kilogram of a body is:**
(a) Roentgen (b) Grey (c) Rem (d) Curie

(20) **The total energy transferred to a body by means of radiation is measured in units of:**
(a) Becquerels (b) Grey (c) Rem (d) Roentgen

(21) **The SI unit of radiation dose is:**
(a) Roentgen (b) Curie (c) Grey (d) Rem

(22) **The number of fundamental forces present in nature are:**
(a) 3 (b) 2 (c) 5 (d) 4

(23) **During fusion of hydrogen into helium:**
(a) Energy is released (b) Energy is absorbed
(c) Mass is increased due to energy absorption (d) Mass is reduced due to energy released

(24) **The mass spectrograph of naturally occurring neon, showing:**
(a) 1 isotope (b) 2 isotope (c) 3 isotope (d) 4 isotope

(25) **X-rays and γ-rays of the same energy may be distinguished:**
(a) their velocity (b) their ionizing power (c) their intensity (d) method of production

(26) **Which one of the following is not a mode of radioactive?**
(a) Electron emission (b) Alpha decay (c) Proton emission (d) Ionized hydrogen atoms

(27) **The wavelength of γ-rays (in metre is of the order of:**
(a) 10^{-7} (b) 10^{-10} (c) 10^{-12} (d) 10^{-15}

(28) **After 2 hours $\left(\frac{1}{16}\right)$th of the initial amount of a certain radioactive isotope remains undecayed. The half-life of the isotope is:**
(a) 60 minutes (b) 45 minutes (c) 30 minutes (d) 15 minutes

(29) **When uranium ($_{92}U^{238}$) decays to lead ($_{82}Pb^{206}$), the number of alpha particles and beta particles emitted are:**
(a) 6 and 6 respectively (b) 8 and 8 respectively (c) 6 and 8 respectively (d) 8 and 6 respectively

(30) **The unit of radioactivity is:**
(a) Curie (b) Rutherford (c) Both (a) and (b) (d) None of these

(31) Half-life of a radioactive element depends upon:

(a) Amount of the element present (b) Temperature
(c) Pressure (d) None of the above

(32) The nuclei $_6C^{13}$ and $_7N^{14}$ can be described as:

(a) Isotones (b) Isobars (c) Isotopes of carbon (d) Isotopes of nitrogen

(33) The rate of decay of a radioactive element:

(a) is constant (b) Decreases inversely with time
(c) Increases directly with time (d) Decreases exponentially

(34) A radioactive substance has a half-life of four months Three-fourths of the substance will decay in:

(a) Three months (b) Four months (c) Eight months (d) Twelve months

(35) Particles which can be added to the nucleus of an atom without changing its chemical properties are called:

(a) Neutrons electrons (b) Electrons (c) Protons (d) alpha-particles

(36) Nuclear reactions, we have the conservation of:

(a) Mass (b) Energy only
(c) Momentum only (d) Mass, energy and momentum

(37) Atoms having equal number of neutrons as well as equal number of protons but with nucleons in different energy states are called:

(a) Isotopes (b) Isobars (c) Isotones (d) Isomers

(38) If the matter in proton is completely converted into energy, it will be about:

(a) 9310 MeV (b) 100.78 MeV (c) 931 MeV (d) 10078 MeV

(39) One atomic mass unit is equal to:

(a) $\left(\frac{1}{12}\right)$ mass of one C atom (b) $\left(\frac{1}{16}\right)$ mass of O_2 molecule
(c) $\left(\frac{1}{14}\right)$ mass of N_2 molecule (d) $\left(\frac{1}{9}\right)$ mass of F_2 molecule

(40) The mass number of He is 4 and that for sulphur is 32. The radius of sulphur nucleus is larger than that of helium by times:

(a) $\sqrt{8}$ (b) 4 (c) 2 (d) 8

(41) For nuclear forces to be effective, the distance should be:

(a) 10^{-10} m (b) 10^{-13} m (c) 10^{-15} m (d) 10^{-20} m

(42) What was the fissionable material used in the bomb dropped at Nagasaki (Japan) in the year 1945?

(a) Uranium (b) Neptunium (c) Berkelium (d) Plutonium

(43) Which is of the following uranium atoms undergo fission readily?

(a) U^{238} (b) U^{237} (c) U^{236} (d) U^{235}

(44) Control rods used in nuclear reactors are made of:

(a) Stainless steel (b) Graphite (c) Cadmium (d) Plutonium

(45) One atomic mass unit is equal to:

(a) 1.67×10^{-27} pound mass (b) 1.67×10^{-27} slug
(c) 1.67×10^{-27} kg (d) 1.67×10^{-27} g

(46) Nuclei having the same nuclear mass but different nuclear charge are called:

(a) Isotones (b) Isomers (c) Isobars (d) Isotopes

(47) One particle having zero mass and zero charge, which is emitted with beta decay, is called:

(a) Positron (b) Electron (c) Neutrino (d) Neutron

(48) The rate of decay (disintegration per unit time) of a radioactive substance:

(a) is constant (b) Decreases exponentially with time
(c) Varies inversely as time (d) Decreases linearly with time

(49) The binding energy per nucleon is:

(a) Greatest for heavy nuclei (b) Least for heavy nuclei
(c) Greatest for light nuclei (d) Greatest for medium weight nuclei

(50) Controlled fission reactions are maintained in a:

(a) Cyclotron (b) Linear accelerator (c) Nuclear reactor (d) Stellerator

(51) Alpha particles are highly ionizing because of:

(a) their high charge and low speeds (b) their greater mass
(c) their larger energy (d) their constituents

(52) A radioactive decay rate of 3.7×10^{10} disintegrations per second defines the unit of measurement known as the:

(a) Rutherford (b) Rontgen (c) Curie (d) Becquerel

(53) The total energy transferred to a body by means of radiation is measured in units of:

(a) Rutherfords (b) Rontgens (c) Curies (d) Becquerels

(54) Which of the following radiations are suitable for the treatment of flesh just under skin?

(a) Alpha radiations (b) Beta radiations (c) Gamma radiations (d) X-rays

(55) Fraction of decaying atoms per unit time is:

(a) Decay constant (b) Life-time (c) Half-life (d) None

(56) SI unit of radiation dose is:

(a) Becquerel (b) Curie (c) Gray (d) All

(57) Disintegration of nucleus obeys the laws of conservation of:

(a) Charge only (b) Mass only (c) Both charge & mass (d) None of above

(58) The nuclear fission reaction is the practical example of an:

(a) Exothermic reaction (b) Endothermic reaction (c) Chemical reaction (d) All of above

(59) The quantity called absorbed radiation dose 'D' is defined by:

(a) $\frac{E}{m}$ (b) $\frac{E}{C}$ (c) $\frac{m}{c}$ (d) $\frac{C}{E}$

(60) The γ-rays radiographs are used in:

(a) Agricultural industry (b) Medical industry (c) Support industry (d) All of above

(61) Subatomic particles are divided into:

(a) Two groups (b) Three groups (c) Four groups (d) Infinite groups

(62) **The lightest element which exhibits radioactivity is:**
(a) Hydrogen (b) Deuteron (c) Tritium (d) Helium

(63) **In radioactive element, β-ray emits from:**
(a) Nucleus (b) Outer orbit (c) Inner orbit (d) None of these

(64) **Which one of the following statements is true of both α-particles and X-rays?**
(a) They cause ionisation of the air when they pass through it
(b) They can be detected after passing through a few millimetres of aluminium
(c) They can be deflected by electric fields
(d) They can be deflected by magnetic fields

(65) **The radiation having maximum penetration power is:**
(a) X-rays (b) γ-rays (c) α-rays (d) Cathode rays

(66) **Heavy radioactive elements eventually turn into:**
(a) Barium (b) Hydrogen (c) Lead (d) Radium

(67) **Emission of β-rays in a radioactive decay results in a daughter element showing a:**
(a) Change in mass but not in charge (b) Change in charge but not in mass
(c) Change in both (d) Change in neither

(68) **A radioactive element $_ZX^A$ emits an α-particle and changes into:**
(a) $_{Z-2}Y^A$ (b) $_ZY^{A-4}$ (c) $_{Z-2}Y^{A-4}$ (d) $_{Z+2}Y^A$

(69) **When a β-particle is emitted from a nucleus, the effect on its neutron-proton ratio is:**
(a) Increased (b) Decreased (c) Remains same (d) First (a) & then (b)

(70) **What is a curie?**
(a) Measurement of radioactivity (b) Measurement of temperature
(c) Measurement of magnetism (d) Measurement of electric field

(71) **The mother and daughter elements, with the emission of γ-rays, are called:**
(a) Isotopes (b) Isobars (c) Isomers (d) Isodiaphers

(72) **The average life (T) and the decay constant λ of the radioactive nucleus are related as:**
(a) $T\lambda = 1$ (b) $T = 0.693/\lambda$ (c) $T/\lambda = 1$ (d) $T = c/\lambda$

(73) **A nucleus with an excess of neutrons may decay radioactively with the emission of:**
(a) A neutron (b) A proton (c) An electron (d) A positron

(74) **The penetrating power of x-rays increases with:**
(a) Decreases in their velocity (b) Increases in their velocity
(c) Increases in their intensity (d) Decrease in their intensity

(75) **Such type of radiation which can burn the human skin in called:**
(a) Far-infrared (b) Infrared (c) Ultra-violet (d) Microwaves

(76) **Nuclear force is:**
(a) Attractive and long range force (b) Repulsive and long range force
(c) Attractive and short range force (d) Repulsive and short range force

(77)
(a) Binding energy of nucleus (b) Packing fraction
(c) Average energy of nucleus (d) Average energy of reaction

(78) **The binding energy of Deutron is:**
(a) 22.24 MeV (b) 2.224 MeV (c) 0.224 MeV (d) 222.4 MeV

(79) **The reciprocal of decay constant (λ) of a radioactive element is:**
(a) Half life (b) Mean life (c) Total life (d) Curie

(80) **The half-life of a radio-active element depends on:**
(a) Temperature (b) Pressure
(c) Nature of element (d) Amount of radioactive substance

(81) **The radioactive decay obeys the law:**
(a) $N_o = N(1 + e^{\lambda t})$ (b) $N = N_0 e^{\lambda t}$ (c) $N = N_0 e^{-\lambda t}$ (d) $N_o = Ne^{-\lambda t}$

(82) **Energy liberated when one atom of $_{92}U^{235}$ undergoes fission reaction is:**
(a) 140 MeV (b) 28 MeV (c) 200 MeV (d) 60 MeV

(83) **The moderator used in a nuclear reactor is:**
(a) Aluminium (b) Sodium (c) Calcium (d) Graphite

(84) **The range of 7.7 MeV α-particle in air is about:**
(a) 10 cm (b) 20 cm (c) 17 cm (d) 7 cm

(85) **A 3 MeV β-particle can penetrate through an aluminium foil about:**
(a) 65 mm (b) 0.65 mm (c) 6.5 mm (d) 0.065 mm

(86) **Geiger Muller counter always uses:**
(a) Argon and alcohol (b) Bromine mixed with neon
(c) Different gases at different pressures (d) Argon only

(87) **The maximum safe limit does person working in nuclear power station is:**
(a) 0.1 rem per week (b) 4 rem per week (c) 5 rem per week (d) 3 rem per week

(88) **The most useful tracer is:**
(a) Iodine-131 (b) Strontium-90 (c) Carbon-14 (d) Cobalt-60

(89) **One joule of energy absorbed per kilogram of body is:**
(a) Rem (b) Roentgens (c) Grey (d) Becquerel

(90) **The types of quarks are:**
(a) 2 (b) 3 (c) 4 (d) 6

(91) **The strong nuclear force acts on the:**
(a) Mesons only (b) π-mesons only (c) Photons only (d) Hadrons only

(92) **Which one of the following belongs to Leptones group?**
(a) Electrons (b) Neutrino (c) Muons (d) All of them

ANSWERS

(1)	(a)	(2)	(b)	(3)	(b)	(4)	(a)	(5)	(b)
(6)	(c)	(7)	(a)	(8)	(c)	(9)	(c)	(10)	(a)
(11)	(a)	(12)	(c)	(13)	(c)	(14)	(b)	(15)	(a)
(16)	(c)	(17)	(d)	(18)	(c)	(19)	(b)	(20)	(d)
(21)	(c)	(22)	(a)	(23)	(a)	(24)	(c)	(25)	(d)
(26)	(c)	(27)	(c)	(28)	(c)	(29)	(d)	(30)	(c)
(31)	(d)	(32)	(a)	(33)	(d)	(34)	(c)	(35)	(a)
(36)	(d)	(37)	(d)	(38)	(c)	(39)	(a)	(40)	(c)
(41)	(c)	(42)	(d)	(43)	(d)	(44)	(c)	(45)	(c)
(46)	(c)	(47)	(c)	(48)	(b)	(49)	(d)	(50)	(c)
(51)	(a)	(52)	(c)	(53)	(b)	(54)	(b)	(55)	(a)
(56)	(c)	(57)	(c)	(58)	(a)	(59)	(a)	(60)	(b)
(61)	(b)	(62)	(c)	(63)	(a)	(64)	(c)	(65)	(b)
(66)	(c)	(67)	(b)	(68)	(c)	(69)	(b)	(70)	(a)
(71)	(c)	(72)	(b)	(73)	(c)	(74)	(c)	(75)	(c)
(76)	(c)	(77)	(b)	(78)	(b)	(79)	(b)	(80)	(c)
(81)	(c)	(82)	(c)	(83)	(d)	(84)	(d)	(85)	(c)
(86)	(b)	(87)	(a)	(88)	(c)	(89)	(c)	(90)	(d)
(91)	(d)	(92)	(d)						

SOLUTION

(28)

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{t/T}$$

$$\frac{\frac{1}{16} \times N_0}{N_0} = \left(\frac{1}{2}\right)^{120/T}$$

$$\frac{1}{16} = \left(\frac{1}{2}\right)^{120/T}$$

$$\left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{120/T}$$

Comparing power

$$4 = \frac{120}{T}$$

$$T = \frac{120}{4}$$

$$T = 30 \text{ min.}$$

(c) is correct