UNIT 1

Physical Quantities and Measurement

1 What is science? Write a brief note on the history of science.

Ans. Science

The knowledge gained through observations and experimentations is called science. The word science is derived from the Latin word scientia, which means knowledge.

History of Science

Man has always been inspired by the wonders of nature. He has always been curious to know the secrets of nature and remained in search of the truth and reality. He observes various phenomena and tries to find their answers by logical reasoning.

Until eighteenth century, various aspect of material objects were studied under a single subject called natural philosophy. But as the knowledge increased, it was divided into two main streams; physical sciences – which deal with the study of non-living things and Biological sciences – which are concerned with the study of living things.

We can say that science has made the life of man very easy. Today due to countless inventions of science we can save our time. We can travel large distances in minutes or hours. We can contact with anyone any where in world in seconds.

No doubt, science has lot of benefits but contrary to it science has also many demerits, like deadly weapons, environmental pollution and road accidents etc.

2 Define physics and explain relation between physics and daily life.

Ans. Physics

Physics is a branch of science that deals with matter, energy and their relationship.

Physics and our Daily Life

The rapid progress in science during the recent years has become possible due to the discoveries and inventions in the field of physics. The technologies are the applications of scientific principles. Most of the technologies of our modern society throughout the world are related to Physics. For example, a car is made on the principles of mechanics and a refrigerator is based on the principle of thermodynamics.

In our daily life, we hardly find a device where physics is not involved. Consider pulleys that make it easy to lift heavy loads. Electricity is used not only to get light and heat but also mechanical energy that drives fans and electric motors etc. consider the means of transportation such as cars and aeroplanes; domestic appliance such as air-conditioners, refrigerators, vacuum-cleaners, washing machines, and microwave ovens etc. similarly the means of communication such as radio, TV, telephone and computer are the result of applications of physics. These devices have made our lives much easier, faster and more comfortable than the past. For example, think of what a mobile phone smaller than our palm can do? It allows us to contact people anywhere in the world and to get latest worldwide information. We can take and save pictures, send and receive messages of our friends.. We can also receive radio transmission and can use a calculator as well.

3 Explain branches of physics.

Ans. Following are the main branches of physics.

Mechanics

It is the study of motion of objects, its causes and effects.

Heat

It deals with the nature of heat, modes of transfer and effects of heat.

Sound

It deals with the physical aspects of sound waves, their production, properties and applications.

Light (Optics)

It is the study of physical aspects of light, its properties, working and use of optical instruments.

Electricity and Magnetism

It is the study of the charges at rest and in motion, their effects and their relationship with magnetism.

Atomic Physics

It is the study of the structure and properties of atoms.

Nuclear Physics

It deals with the properties and behaviour of nuclei and the particles within the nuclei.

Plasma Physics

It is the study of production, properties of the ionic state of matter – the fourth state of matter.

Geophysics

It is the study of the internal structure of the earth.

4 Explain Physical quantities and their types.

Ans. Physical Quantities

All measurable quantities are called physical quantities such as length, mass, time, and temperature.

Explanation

A physical quantity possesses at least two characteristics in common. One is its numerical magnitude and the other is the unit in which it is measured.

For Example

If the length of a student is 104 cm then 104 is its numerical magnitude and centimeter is the unit of measurement. Similarly when a grocer says that each bag contains 5 kg sugar, he is describing its numerical magnitude as well as the unit of measurement. It would be meaningless to state 5 or kg only.

Types of Physical Quantities

Physical quantities are of two types.

(a) Base quantities

(b) Derived quantities

(a) Base Quantities

There are seven physical quantities which form the foundation for other physical quantities. These physical quantities are called the base quantities. These are length, mass, time, electric current, temperature, intensity of light and the amount of a substance.

(b) Derived Quantities

Those physical quantities which are expressed in terms of base quantities are called the derived quantities. These include area, volume, speed, force, work, energy, power, electric charge, electric potential, etc.

5 Explain base units and derived units. Give examples.

Ans. Base Units

The units that describe base quantities are called base units. Each base quantity has its SI unit. Table shows seven base quantities, their SI unit and their symbols.

Base quantities, their SI units with symbols

Quantity		Unit	
Name	**Symbol**	**Name**	**Symbol**
Length	l	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Electric current	I	ampere	A
Intensity of light	L	candela	cd
Temperature	T	kelvin	K
Amount of a substance	n	mole	mol

Derived Units

The units used to measure derived quantities are called derived units. Derived units are defined in terms of base units and are obtained by multiplying or dividing one or more base units with each other. The unit of area $(metre)^2$ and the unit of volume $(metre)^3$ are based on the unit of length, which is

metre. Thus the unit of length is the base unit while the unit of area and volume are derived units. Speed is defined as distance covered in unit time; therefore its unit is metre per second. In the same way the unit of density, force, pressure, power etc. can be derived using one or more base units. Some derived units and their symbols are given in the table.

Derived quantities and their SI units with symbols

Quantity		Unit	
Name	**Symbol**	**Name**	**Symbol**
Speed	v	metre per second	ms^{-1}
Acceleration	a	metre per second per second	ms^{-2}
Volume	V	cubic metre	m^3
Force	F	Newton	N or ($kg\ ms^{-2}$)
Pressure	P	pascal	Pa or ($N\ m^{-2}$)
Density	ρ	kilogramme per cubic metre	$kg\ m^{-3}$
charge	Q	coulomb	C or (AS^{-1})

6 What are prefixes? Explain it.

Ans. Prefixes

The words or letters added before a unit and stand for the multiples or sub-multiples of that unit are known as prefixes. For example, kilo, mega, milli, micro, etc.

Explanation

Some of the quantities are either very large or very small. For example, 250,000m, 0.002W and 0.000,002g, etc. SI units have the advantage that their multiples and sub-multiples can be expressed in terms of prefixes. Prefixes are the words or letters added before SI units such as kilo, mega, giga and milli. The prefixes are useful to express very large or small quantities. For example, divide 20,000g by 1000 to express it into kilogram, since kilo represents 10^3 or 1000.

$$\text{Thus} \quad 20{,}000\text{g} = \frac{20{,}000}{1000}\text{ kg} = 20\text{ kg}$$

$$\text{or} \quad 20{,}000\text{g} = 20 \times 10^3\text{g} = 20\text{ kg}$$

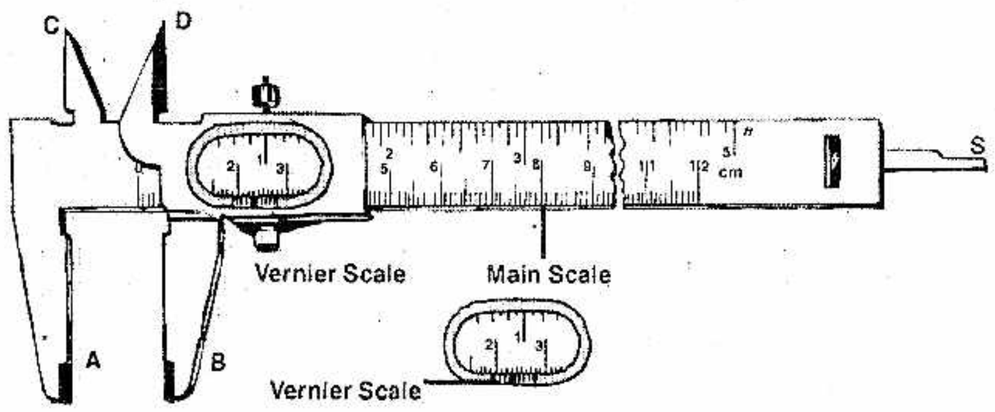
However, double prefixes are not used. For example, no prefix is used with kilogram since it already contains the prefix kilo. Prefixes given in Table are used with both types base and derived units. Let us consider few more examples. Some prefixes are given below.

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

7 Define vernier callipers. Explain its construction and working.

Ans. Vernier Callipers

An instrument used to measure small lengths such as internal or external diameter or length of a cylinder, etc. is called as vernier calipers. A vernier calipers can measure things more accurately than metre rule.



Vernier Callipers

Construction

A vernier calipers consists of two jaws as shown in figure above. One is a fixed jaw with main scale attached to it. Main scale has centimeter and millimetre marks on it. The other jaw is a moveable jaw. It has vernier scale having 10 divisions over it such that each of its division is 0.9 mm.

Least Count

The different between one small division on main scale division and one vernier scale division is 0.1 mm. It is called least count (LC) of the Vernier Calliper. Least count of the Vernier Callipers can also be found as given below:

$$\text{Least count of Vernier Callipers} = \frac{\text{smallest reading on main scale}}{\text{No. of divisions on vernier scale}}$$

$$= \frac{1 \text{ mm}}{10 \text{ divisions}} = 0.1 \text{ mm}$$

$$\text{Hence LC} = 0.1 \text{ mm}$$

$$= 0.01$$

Zero Error and Zero Correction

To find the zero error, close the jaws of veriner callipers gently. If zero line of the vernier scale coincides with the zero of the main scale then the zero error will not exist if zero line of the vernier scale is on the right side of the zero of the main scale will be negative if zero line of vernier scale is on the left side of zero of the main scale then zero error will be positive.

Taking a Reading on Vernier Callipers

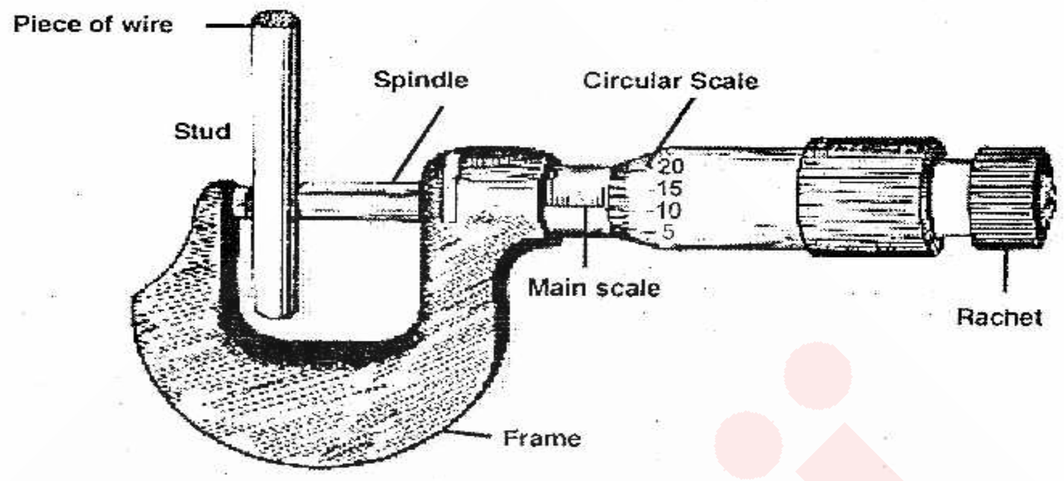
Place the solid cylinder between jaws of the Vernier Callipers and close the jaws till they press the opposite sides of the object gently.

Note the complete divisions of main scale past the vernier scale zero in a tabular form. Next find the vernier scale division that is coinciding with any division on the main scale. Multiply it by least count of vernier callipers and add to in the main scale reading. This is equal to the diameter of the solid cylinder. Add zero correction (Z.C) to get correct measurement.

8 Define screw gauge and explain its working and construction.

Ans. Screw Guage

A screw guage is an instrument that is used to measure small lengths with accuracy greater than a Vernier Calliper. It is also called as micrometer screw gauge.



Construction

A simple screw gauge consists of a U-shaped metal frame with a metal stud at its one end. A hollow cylinder (or sleeve) has a millimeter scale over it along a line called index line parallel to its axis. The hollow cylinder acts as a nut. It is fixed at the end of U-shaped frame opposite to the stud. A Thimble has a threaded spindle inside it.

Pitch of Screw Gauge

As the thimble completes one rotation, the spindle moves 1 mm along the index line. It is because the distance between consecutive threads on the spindle is 1 mm. This distance is called the pitch of screw on the spindle.

Least Count

Least count of screw gauge is 0.01mm. least count of a screw gauge can be found as given below:

$$\text{Least count} = \frac{\text{Pitch of the screw guage}}{\text{No. of divisions on circular scale}}$$

$$= \frac{1 \text{ mm}}{100} = 0.01 \text{ mm} = 0.001 \text{ cm}$$

Working

(i) First of all place the wire between stud and spindle of screw gauge.

(ii) Turn the ratchet so that the object is pressed gently between the stud and spindle.

(iii) Note main scale as well as circular scale readings to find the diameter of given wire.

(iv) Repeat these steps three times to get the average diameter of wire.

Zero Error

To find the zero error, close the gap between the spindle and the stud of the screw gauge by rotating the ratchet in the clockwise direction. If zero of circular scale coincides with the index line, then the zero error will be zero.

Zero error will be positive if zero of circular scale is behind the index line. In this case, multiply the number of divisions of the circular scale that has not crossed the index line with the least count of screw gauge to find zero error.

Zero error will be negative if zero of circular scale has crossed the index line. In this case, multiply the number of divisions of the circular scale that has crossed the index line with the least count of screw gauge to find the least count of screw gauge to find the negative zero error.

9 **Explain the following physical balance, lever balance, electronic balance.**

Ans. **Physical Balance**

A physical balance is used in the laboratory to measure the mass of various objects by comparison. It consists of a beam resting at the center of a fulcrum.

The beam carries scale pans over the hooks on either side. Unknown mass is placed on the left pan. Find some suitable standard masses that cause the pointer to remain at zero on raising the beam.

Lever Balance

A lever balance consists of a system of levers. When lever is lifted placing the object in one pan and standard masses on the other pan, the pointer of the lever system moves. The pointer is brought to zero by varying standard masses.

Electronic Balance

Electronic balances come in various ranges; milligram ranges, gram ranges and kilogramme ranges. Before measuring the mass of a body, it is switched ON and its reading is set to zero. Next place the object to be weighted. The reading on the balance gives you the mass of the body placed over it.

10 **Write a note on accuracy of physical balance, beam balance and lever balance.**

Ans. The details given below show the accuracy of these balance.

(a) **Beam Balance**

Let the balance measures coin's mass = 3.2 g.

A sensitive beam balance may be able to detect a change as small as of 0.1g or 100 mg.

(b) **Physical Balance**

Let the balance measures coin's mass = 3.24g.

Least count of the physical balance may be as small as 0.01g or 10mg. Therefore, its measurement would be more precise than a sensitive beam balance.

(c) **Electronic Balance**

Let the balance measures coin's mass = 3.247 g

Least count of an electronic balance is 0.001g or 1mg. Therefore, its measurement would be more precise than a sensitive physical balance. Thus electronic balance is the most sensitive balance in the above balances.

11 **What is stop watch and how to use it?**

Ans. **Stop Watch**

Stop watch is a type of machine which is used to measure the time interval of an event.

Types

There are two types of stop watch.

(i) Mechanical stop watch

(ii) Digital stop watch

A mechanical stopwatch can measure a time interval up to a minimum 0.1 second. Digital stopwatches commonly used in laboratories can measure a time interval as small as 1/100 second or 0.01 second.

Use of Mechanical Stopwatch

A mechanical stopwatch has a knob that is used to wind the spring that powers the watch. It can also be used as a start-stop and rest button. The watch starts when the knob is pressed once. When pressed second time, it stops the watch while the third press brings the needle back to zero position.

Use of Digital Stopwatch

The digital stopwatch starts to indicate the time lapsed as the start/stop button is pressed. As soon as start/stop button is pressed again, it stops and indicates the time interval recorded by it between start and stop of an event. A rest button restores its initial zero setting.

12 **Explain measuring cylinder and how to use it?**

Ans. **Measuring Cylinder**

A measuring cylinder is a glass or transparent plastic cylinder. It has a scale along its length that indicates the volume in milliliter (mL). Measuring cylinders have different capacities from 100 mL to 2500 mL. They are used to measure the volume of a liquid or powdered substance. It is also used to find the volume of an irregular shaped solid insoluble in a liquid by displacement method. The solid is lowered into a measuring cylinder containing water/liquid. The level of water/liquid rises. The increase in the volume of water/liquid is the volume of the given solid object.

How to use a Measuring Cylinder

While using a measuring cylinder, it must be kept vertical on a plane surface. Take a measuring cylinder. Place it vertically on the table. Pour some water into it. Note that the surface of water is curved. The meniscus of the most liquid curve downwards while the meniscus of mercury curves upwards. The correct method to note the level of a liquid in the cylinder is to keep the eye at the same level as the meniscus of the liquid.

It is incorrect to not the liquid level keeping the eye above the level of liquid. When the eye is above the liquid level, the meniscus appears higher on the scale. Similarly when the eye is below the liquid level, the meniscus appears lower than actual height of the liquid.

Measuring Volume of an Irregular Shaped Solid

Measuring cylinder can be used to find the volume of a small irregular shaped solid that sinks in water. Let us find the volume of a small stone. Take some water in a graduated measuring cylinder. Note the volume V_i of water in the cylinder. Tie the solid with a thread. Lower the solid into the cylinder till it is fully immersed in water. Note the volume V_f of water and the solid. Volume of the solid will be $V_f - V_i$.

13 **Explain significant figures.**

Ans. **Significant Figures**

All the accurately known digits and the first doubtful digit in an expression are called significant figures. It reflects the precision of a measured value of a physical quantity.

Explanation

The accuracy in measuring a physical quantity depends upon various factors:

(i) The quality of the measuring instrument

(ii) The skill of the observer

(iii) The number of observations made

An improvement in the quality of measurement by using better instrument increases the significant figures in the measured result. The significant figures are all the digits that are known accurately and the one estimated digit. More significant figure means greater precision. The following rules are helpful in identifying significant figures:

(i) Non-zero digits are always significant.

(ii) zeros between two significant figures are also significant.

(iii) Final or ending zeros on the right in decimal fraction are significant.

(iv) Zeros written on the left side of the decimal point for the purpose of spacing the decimal point are not significant.

(v) In whole numbers that end in one or more zeros without a decimal point. These zeros may or may not be significant. In such cases, it is not clear which zeros serve to locate the position value and which are actually parts of the measurement. In such a case, express the quantity using scientific notation to find the significant zero.

EXERCISE

1.1 Encircle the correct answer from the given choices.

(i) The number of base units in SI are:

(a) 3 (b) 6
(c) 7 (d) 9

(ii) Which one of the following unit is not a derived unit?

(a) pascal (b) kilogramme
(c) newton (d) watt

(iii) Amount of a substance in terms of numbers is measured in:

(a) gram (b) kilogramme
(c) newton (d) mole

(iv) An interval of 200μs is equivalent to:

(a) 0.2 s (b) 0.02 s
(c) 2×10^{-4} s (d) 2×10^{-6} s

(v) Which one of the following is the smallest quantity?

(a) 0.01 g (b) 2 mg
(c) 100 μg (d) 5000 mg

(vi) Which instrument is most suitable to measure the internal diameter of a test tube?

(a) metre rule
(b) vernier callipers
(c) measuring tap
(d) screw gauge

(vii) A student claimed the diameter of a wire as 1.032 cm using Vernier Callipers. Upto what extent do you agree with it.

(a) 1 cm (b) 1.0 cm
(c) 1.03 cm (d) 1.032 cm

(viii) A measuring cylinder is used to measure:

(a) mass (b) area
(c) volume (d) level of a liquid

(ix) A student noted the thickness of a glass sheet using a screw gauge. On the main

scale, it reads 3 divisions while 8th division on the circular scale coincides with index line. Its thickness is:

(a) 3.8 cm (b) 3.08 mm
(c) 3.8 mm (d) 3.08 m

(x) Significant figures in an expression are:

(a) all the digits
(b) all the accurately known digits
(c) all the accurately known digits and the first doubtful digit
(d) all the accurately known and all the doubtful digits

Answers

(i)	(c)	(ii)	(b)	(iii)	(d)	(iv)	(c)
(v)	(d)	(vi)	(b)	(vii)	(c)	(viii)	(c)
(ix)	(b)	(x)	(c)				

1.2. What is the difference between base quantities and derived quantities? Give three examples of each.

Ans. Base Quantities

The seven physical quantities on the basis of which other quantities are expressed are called base quantities. e.g. length, mass, time and temperature etc.

Derive Quantities

Those quantities that are expressed interm of base quantities are called derived quantities are called derived quantities .e.g volume, speed work and power etc.

1.3. Pick out the base units in the following. Joule, Newton, kilogram, hertz, mole, ampere, metre, Kelvin, coulomb and watt.

Ans. Base Units

(i) kilogram (ii) mole
(iii) ampere (iv) metre
(v) kelvin

1.4. Find the base quantities involved in each of the following derived quantities.

(a) speed (b) volume
(c) force (d) work

Ans. (a) Speed : Base units involved meter and second
(b) Volume : metre
(c) Force : kg, metre, second
(d) Work : kg, metre, second

1.5. Estimate your age in seconds.

Ans. Use the following formula to convert your age into seconds.

Age in seconds = years $\times$ 365 $\times$ 24 $\times$ 3600

1.6. What role SI units have played in the development of science?

Ans. SI units have played very important role in the development of science. Particularly this system is very useful to exchange the scientific and technical information.

1.7. What is meant by vernier constant?

Ans. The difference between one main scale division and one vernier division is called vernier constant.

1.8. What do you understand by the zero error of a measuring instrument?

Ans. If the zero of both the scales of a given instrument do not conside with each other it means the given instrument has zero error. So, our measurement will be less or greater than the correct reading.

1.9. Why is use of zero error necessary in a measuring instrument?

Ans. In order to get the correct measurement the use of zero error is necessary.

1.10. What is a stop watch? What is the least count of a mechanical stopwatch you have used in the laboratories?

Ans. Stopwatch is an instrument which is used to measure the time interval of an event. The least count of mechanical stop watch is 0.1 second.

1.11. Why do we need to measure extremely small interval of time?

Ans. In order to get the more accurate results we need small interval of times.

1.12. What is meant by significant figures of a measurement?

PROBLEMS

1.1 Express the following quantities using prefixes.

(a) 5000 g **(b) 2000000 w**

(c) 52×10^{-10} kg **(c) 225×10^{-8} s**

Ans. (a) 5 kg (b) 2 MW

(c) 5.2 μg (d) 2.25 μs

1.2. How do the prefixes micro, nano and pico relate to each other?

Ans. 10^{-6} micro = 10^{-9} nano = 10^{-12} pico

1.3. Your hair grow at the rate of 1 mm per day. Find their growth rate in nms^{-1}.

Ans. $$\frac{1 \times 10^6}{24 \times 3600}$$

$$= \frac{1000000}{24 \times 3600} = \frac{10000}{864} = 11.57 \text{ nms}^{-1}$$

1.4. Rewrite the following in standard form.

(a) 1168×10^{-27} **(b) 32×10^5**

(c) 725×10^{-5} kg **(d) 0.02×10^{-8}**

Ans. (a) 1.168×10^{-24}

(b) 3.2×10^6

(c) 7.25×10^{-3} kg

(d) 2×10^{-10}

1.5. Write the following quantities in standard form.

(a) 6400 km

(b) 380000 km

(c) 300000000 ms^{-1}

(d) seconds in a day

Ans. (a) 6.400×10^3 km

(b) 3.8×10^5 km

(c) 3×10^8 ms^{-1}

(d) 8.64×10^4s

1.6. On closing the jaws of a vernier callipers, zero of the vernier scale is on the right to its main scale such that 4^{th} division of its vernier scale coincides with one of the main scale division. Find its zero error and zero correction.

Ans. Zero error 0.04 cm

Zero correction – 0.04 cm

1.7. A screw gauge has 50 divisions on its circular scale. The pitch of the screw gauge is 0.5 mm. What is least count.

Ans. $$\text{Least count} = \frac{\text{Pitch}}{\text{No. of circular scaled division}}$$

$$= \frac{0.5}{50} \Rightarrow \frac{1}{100}$$

$$= 0.01 \text{ mm} \Rightarrow 0.001 \text{ cm}$$

1.8. Which of the following quantities have three significant figures?

(a) 3.0066 m (b) 0.00309 kg

(c) 5.05×10^{-27}kg (d) 301.0 sec

Ans. (b) and (c)

1.9. What are the significant figures in the following measurements?

(a) 1.009 cm **(b) 0.00450 kg**

(c) 1.66×10^{-27} kg **(d) 2110 se**

Ans. (a) 4 (b) 3

(c) 3 (d) 4

1.10. A chocolate wrapper is 6.7 cm long and 5.4 cm wide. Calculate its area up to reasonable number of significant figures.

Ans. Area = length × width

$= 6.7 \times 5.4$

$= 36.18 \text{ cm}^2$

Reasonable significant figures = 36 cm^2.