

UNIT 3

Dynamics



1 Explain Newton's first law of motion.

Ans. Newton's first law of Motion States that:

A body continues its state of rest or of uniform motion in a straight line provided no net force acts on it.

First law of motion deals with bodies which are either at rest or moving with uniform speed in a straight line. According to Newton's first law of motion, a body at rest remains at rest provided no net force acts on it. This part of the law is true as we observe that objects do not move by themselves unless someone moves them. For example, a book lying on a table remains at rest as long as no net force acts on it.

Similarly, a moving object does not stop moving by itself. A ball rolled on a rough ground stops earlier than that rolled on a smooth ground. It is because rough surfaces offer greater friction. If there would be no force to oppose the motion of a body then the moving body would never stop.

Since Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as law of inertia.

We have observed that the passengers standing in a bus fall forward when its driver applies brakes suddenly. It is because the upper parts of their bodies tend to continue their motion, while lower parts of their bodies in contact with the bus stop with it. Hence, they fall forward.

2 Explain Newton's 2nd law of motion?

Ans. Newton's 2nd law of motion

Newton's second law of motion deals with situations when a net force is acting on a body. It states that;

When a net force acts on a body, it produces acceleration in the body in the direction of the net force. The magnitude of this acceleration is directly proportional to the net force acting on the body and inversely proportional to its mass.

If a force produces an acceleration a in a body of mass m , then we can state mathematically that

$$a \propto F$$

$$\text{and } a \propto \frac{1}{m}$$

$$\text{or } a \propto \frac{F}{m}$$

$$\text{or } f \propto ma$$

Putting k as proportionally constant, we get

$$F = kma$$

In SI units, the value of k comes out to be 1. Thus, e.q. becomes

$$F = ma$$

SI unit of force is newton (N). According to Newton's second law of motion.

One newtons (1N) is the force that produces an acceleration of 1 ms^{-2} in a body of mass 1 kg.

Thus, a force of one newton can be expressed as

$$1\text{N} = 1 \text{ kg} \times 1 \text{ ms}^{-2}$$

$$\text{or } 1\text{N} = 1 \text{ kg ms}^{-2}$$

3 State and explain Newton's third law of motion:

Ans. Newton's third law of motion

To every action there is always an equal but opposite reaction.

Explanation

Newton's third law of motion deals with the reaction of a body when a force acts on it. Let a body A exerts a force on another body B, the body B reacts against this force and exerts a force on body A. The

force exerted by body A on B is the action force whereas the force exerted by body B on A is called the reaction force. Newton's third law of motion states that:

According to this law, action is always accompanied by a reaction force and the two forces must always be equal and opposite. Note that action and reaction forces act on different bodies.

Consider a book lying on a table. The weight of the book is acting on the table in the downward direction. This is the action. The reaction of the table acts on the book in the upward direction. Consider another example. Take an air-filled balloon. When the balloon is set free, the air inside it rushes out and the balloon moves forward. In this example, the action is by the balloon that pushes the air out of it when set free. The reaction of the air which escapes out from the balloon acts on the balloon. It is due to this reaction of the escaping air that moves the balloon forward.

A rocket also moves on the same principle. When its fuel burns, hot gases escape out from its tail with a very high speed. The reaction of these gases on the rocket causes it to move opposite to the gases rushing out of its tail.

4 Explain law of conservation of momentum.

Ans. Law of Conservation of Momentum

It states that:

The momentum of an isolated system of two or more than two interacting bodies remains constant.

Consider the example of an air-filled balloon case, balloon and the air inside it form a system. Before releasing the balloon, the system was at rest and hence the initial momentum of the system was zero. As soon as the balloon is set free, air escapes out of it with some velocity. The air coming out of it possesses momentum to conserve momentum, the balloon moves in a direction opposite to that of air rushing out.

Consider an isolated system of two spheres of masses m_1 and m_2 as shown in figure. They are moving in a straight line with initial velocities u_1 and u_2 respectively, such that u_1 is greater than u_2 . Sphere of mass m_1 approaches the sphere of mass m_2 as they move.

Initial momentum of mass $m_1 = m_1 u_1$

Initial momentum of mass $m_2 = m_2 u_2$

Total initial momentum of the system before collision = $m_1 u_1 + m_2 u_2$

After sometimes mass m_1 hits m_2 with some force. According to Newton's third law of motion, m_2 exerts an equal and opposite reaction force on m_1 . Let their velocities become v_1 and v_2 respectively after collision. Then

Final momentum of mass $m_1 = m_1 v_1$

Final momentum of mass $m_2 = m_2 v_2$

Total final momentum of the system after collision = $m_1 v_1 + m_2 v_2$

[Total initial momentum of the system before collision] = [Total final momentum of the system after collision]

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

Equation shows that the momentum of an isolated system before and after collisions remains the same which is the law of conservation of momentum. Law of conservation of momentum is an important law and has vast applications.

5 Give relation between force and momentum.

Ans. Force and the Momentum:

Consider a body of mass m moving with initial velocity v_i . Let a force F acts on the body which produces an acceleration a in it. This changes the velocity of the body. Let its final velocity after time t becomes v_f . If P_i and P_f be the initial momentum and final momentum of the body related to initial and final velocities respectively then

$$P_i = mv_i$$

and $P_f = mv_f$

∴ Change in momentum = final momentum - initial momentum

or $P_f - P_i = mv_f - mv_i$

Thus the rate of change in momentum is given by:

$$\begin{aligned} \frac{P_f - P_i}{t} &= \frac{mv_f - mv_i}{t} \\ &= m \frac{v_f - v_i}{t} \end{aligned}$$

Since $\frac{v_f - v_i}{t}$ is the rate of change of velocity equal to the acceleration a produced by the force F .

$$\therefore \frac{P_f - P_i}{t} = ma$$

According to Newton's second law of motion.

$$F = ma$$

$$\text{or } \frac{P_f - P_i}{t} = F$$

Equation also defines force and states Newton's second law of motion as

When a force acts on a body, it produces an acceleration in the body and will be equal to the rate of change of momentum of the body. SI unit of momentum is newton-second (Ns) which is the same as kgms^{-1} .

6 Explain friction and write down to reduce friction.

Ans. Friction

The force that oppose the motion of moving objects is called friction.

Friction is a force that comes into action as soon as a body is pushed or pulled over a surface. In case of solids, the force of friction between two bodies depends upon many factors such as nature of the two surfaces in contact and the pressing force between them. Rub your palm over different surfaces such as table, carpet, polished marble surface, brick, etc. you will find smoother is the surface, easier it is to move your palm over the surface. Moreover, harder you press your palm over the surface, more difficult would it be to move.

Friction is equal to the applied force that tends to move a body at rest. It increases with the applied force. Friction can be increased to certain maximum value. It does not increase beyond this. The maximum value of friction is known as the force of limiting friction (F_s). it depends on the normal reaction (pressing force) between the two surfaces in contact. The ratio between the force of limiting friction F_s and the normal reaction R is constant. This constant is called the coefficient of friction and is represented by μ .

$$\text{Thus } \mu = \frac{F_s}{R}$$

$$\text{or } F_s = \mu R$$

If m be the mass of the block, then for horizontal surface,

$$R = mg$$

$$\text{Hence } F_s = \mu mg$$

Methods of Reducing Friction

The friction can be reduce by:

- (i) Making the sliding surfaces smooth.
- (ii) Making the fast moving objects a streaming shape (fish shape) such as cars, aeroplanes, etc. this causes the smooth flow of air and thus minimizes air resistance at high speeds.
- (iii) Lubricating the sliding surfaces.
- (iv) Using ball bearings or roller bearings. Because the rolling friction is lesser than the sliding friction.

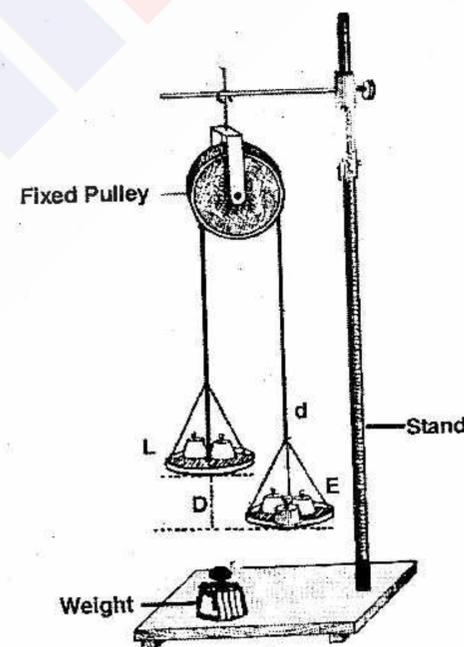
7 Explain tension and acceleration in a string in different cases.

Ans. Tension and Acceleration in a String

Following are the cases for tension and acceleration in a string.

(a) Case I

Vertical Motion of two Bodies Attached to the Ends of a String that Passes over a Frictionless Pulley.



Consider two bodies A and B of masses m_1 and m_2 respectively. Let m_1 is greater than m_2 . The bodies are attached to the opposite ends of an inextensible string. The string passes over a frictionless pulley shown in figure. The body A being heavier must be moving downwards with some acceleration. Let this acceleration be a . at the same

time, the body B attached to the other end of the string moves up with the same acceleration a . As the pulley is frictionless, hence tension will be the same throughout the string. Let the tension in the string be T .

Since the body A moves downwards, hence its weight m_1g is greater than the tension T in the string.

$$\therefore \text{Net force acting on body A} = m_1g - T$$

According to Newton's second law of motion:

$$m_1g - T = m_1a \quad (i)$$

As body B moves upwards, hence its weight m_2g is less than the tension T in the string.

$$\therefore \text{Net force acting on body B} = T - m_2g$$

$$T - m_2g = m_2a \quad (ii)$$

Adding eq. (i) and eq. (ii), we get acceleration 'a'

$$a = \frac{m_1 - m_2}{m_1 + m_2} g \quad (iii)$$

Divide Eq. 2 by Eq. 1, to find tension T in the string.

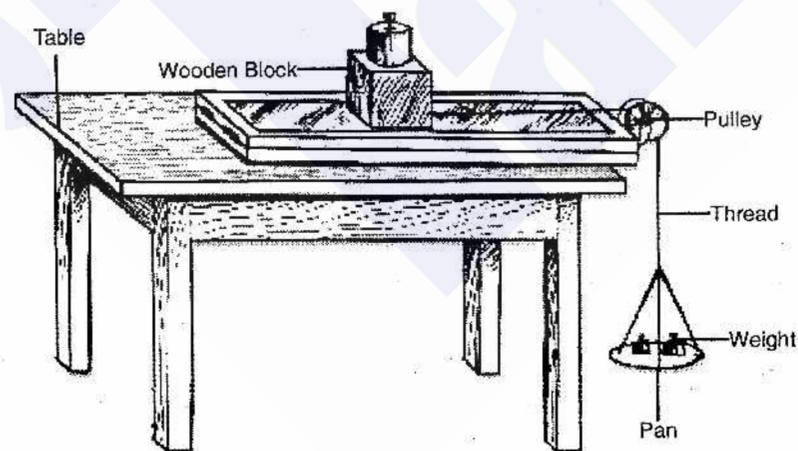
$$T = \frac{2m_1 m_2}{m_1 + m_2} g \quad (iv)$$

The above arrangement is also known as atwood machine. It can be used to find the acceleration g due to gravity using Eq. 3.

$$g = \frac{m_1 + m_2}{m_1 - m_2} \times a \quad (v)$$

Case II

Motion of two Bodies Attached to the ends of a String that Passes over a Frictionless Pulley such that one Body Moves Vertically and the other moves on a smooth Horizontal Surface



Consider two bodies A and B of masses m_1 and m_2 respectively attached to the ends of an

inextensible string as shown in figure. Let the body A moves downwards with an acceleration a . Since the string is inextensible, therefore, body B also moves over the horizontal surface with the same acceleration a . As the pulley is frictionless, hence tension T will be the same throughout the string.

Since body A moves downwards, therefore, its weight m_1g is greater than the tension T in the string.

$$\therefore \text{Net force acting on body A} = m_1g - T$$

According to Newton's second law of motion;

$$m_1g - T = m_1a \quad (i)$$

The forces acting on body B acting downward.

- (i) Weight m_2g of the body B acting downward.
- (ii) Reaction R of the horizontal surface acting on body B in the upwards direction.
- (iii) Tension T in the string pulling the body B horizontally over the smooth surface.

As body B has no vertical motion, hence resultant of vertical forces (m_2g and R) must be zero.

Thus, the net force acting on body B is T .

$$T = m_2a \quad (ii)$$

Adding Eqs (i) and (ii), we get acceleration a as

$$a = \frac{m_1}{m_1 + m_2} g$$

Putting the value of a in equations (i) to get tension T as

$$T = \frac{m_1 m_2}{m_1 + m_2} g$$

EXERCISE

- 3.1. Encircle the correct answer from the given choices.
- Newton's first law of motion is valid only in the absence of:
 - force
 - net force
 - friction
 - momentum
 - Inertia depends on.
 - force
 - net force
 - mass
 - velocity
 - A boy jumps out of a moving bus. There is a danger for him to fall.
 - towards the moving bus
 - away from the bus
 - in the direction of motion
 - opposite to the direction of motion
 - A string is stretched by two equal and opposite forces 10N each. The tension in the string is:
 - zero
 - 5 N
 - 10 N
 - 20 N
 - The mass of a body.
 - decrease when accelerated
 - increase when accelerated
 - decreases when moving with high velocity
 - none of the above
 - Two bodies of masses m_1 and m_2 attached to the ends of an inextensible string

passing over a frictionless pulley such that both move vertically. The acceleration of the bodies is:

- $\frac{m_1 \times m_2}{m_1 + m_2} g$
 - $\frac{m_1 - m_2}{m_1 + m_2} g$
 - $\frac{m_1 + m_2}{m_1 - m_2} g$
 - $\frac{2m_1 m_2}{m_1 + m_2} g$
- Which of the following is the unit of momentum?
 - Nm
 - kgms^{-2}
 - Ns
 - Ns^{-2}
 - When horse pulls a cart, the action is on the cart?
 - cart
 - earth
 - horse
 - earth and cart
 - Which of the following material lowers friction when pushed between metal plates?
 - water
 - fine marble powder
 - air
 - oil

Answers

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

3.2. Define the following terms:

- Inertia
- momentum
- Force
- Force of friction
- Centripetal force

Ans. (i) **Inertia**

Inertia is that characteristic of a body due to which it resists against any change in its state of rest or of uniform motion.

(ii) **Momentum**

The product of mass and velocity of moving body is called momentum.

$$P = mv$$

(iii) **Force**

Force is defined as the agency which changes or tends change the state of rest or of uniform motion of a body.

(iv) **Force of friction:**

The force that produces resistance against relative motion between two surfaces is called force of friction.

(v) **Centripetal force:**

The force that keeps a body to move in a circle is called centripetal force.

3.3 What is the difference between.

- (i) **Mass and weight**
- (ii) **Action and reaction**
- (iii) **Sliding friction and rolling friction**

Ans. (i) Mass:

The amount of matter in a body is called its mass. It is a scalar quantity and always remain constant.

Weight

The force by which the earth attracts a body toward its centre is called its weight. It is vector quantity. It changes with the altitude.

(ii) **Action**

The force exerted by a body on the other body is called action.

Reaction

The force exerted by the other body on the first body in response its action is called reaction.

(iii) **Sliding friction**

When two bodies slide over one another, the force of friction between them is known as sliding friction.

Rolling Friction

When one body rolls over the other, the force of friction between these two bodies is known as rolling friction.

3.4 What is the law of inertia?

Ans. Law of Inertia

According to law of inertia. Everybody continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by an external force impressed upon it.

3.5 Why is it dangerous to travel on the roof of a bus?

Ans. When a bus in running position then every body in the bus is also in motion. So if a

person try to travel on the roof of the bus then he may lose his balance and he may fall down. So it is dangerous to walk on the roof of a bus.

3.6 Why does a passenger move outward when a bus takes a turn?

Ans. When a bus takes a turn, centripetal force is needed to keep it in the curved track. This centripetal force is provided by the friction between the tyres and the road. The passenger sitting in the bus lack the required centripetal force so they move out ward.

3.7 How can you relate a force with the change of momentum of a body?

Ans. Relation between force and change in Momentum

When a force acts on a body, it produces an acceleration in the body and will be equal to the rate of change of momentum of the body.

Consider a body of mass 'm' moving with initial velocity 'Vi'. Let a force 'F' acts on the body which produces an acceleration 'a' in it. Let its final velocity after time 't' become 'Vf'. If 'pi' and 'pf' be the initial momentum and 'pf' final momentum of the body related to initial and final velocities respectively then

$$p_i = mv_i$$

$$p_f = mv_f$$

change in momentum

$$p_f - p_i = mv_f - mv_i$$

so the rate of change in momentum

$$\frac{p_f - p_i}{t} = \frac{mv_f - mv_i}{t}$$

$$\frac{p_f - p_i}{t} = m \left(\frac{v_f - v_i}{t} \right)$$

we know $\frac{v_f - v_i}{t}$, is the rate of change of

velocity so $\frac{v_f - v_i}{t} = a$

So
$$\frac{p_f - p_i}{t} = ma$$

According to Newton's second law of motion $F = ma$

So
$$\frac{p_f - p_i}{t} = F$$

3.8 What will be the tension in a rope that is pulled from its ends by two opposite forces 100N each?

Ans. Total tension = ?

$$\begin{aligned} T &= F_1 + F_2 \\ &= 100 + 100 \\ T &= 200 \text{ N} \end{aligned}$$

3.9. Action and reaction are always equal and opposite. Then how does a body move?

Ans. Action is a force that acts on a body while reaction is the force that is acted by the second body on the first body in response to its action which is equal to the first force but its direction is opposite. So due to the reaction force the first body moves in the opposite direction of the action force. As we push the ground in the backward direction it is our action while the earth pushes us in the forward direction with same force; so we move in the forward direction by the reaction force of the earth.

3.10. A horse pushes the cart. If the action and reaction are equal and opposite then how does the cart move?

Ans. The horse pushes the ground in the backward direction that is the action but inverse the earth pushes the horse in forward direction that is the reaction of the earth. So the cart moves along with horse. The force exerted by the horse on the cart is not action while it is the net force to move the cart.

3.11. What is the law of conservation of momentum?

Ans. According to this law:

The total momentum of an isolated system of two or more than two interacting bodies remains constant.

3.12. Why is the law of conservation of momentum important?

Ans. Importance of law of Conservation of Momentum:

In our daily life the law of conservation helps us to understand the different phenomena such.

(i) When gun is fired the bullet goes in the forward direction while gun recoils in the

backward direction. By reading this law we can find the velocity of the gun with which it will recoil.

(ii) Rockets and jet engines also work on the same principle. In these machines, hot gases produced by burning of fuel rush out with large momentum. The machines gain an equal and opposite momentum. This enables them to move with very high velocities.

3.13. When a gun is fired, it recoils. Why?

Ans. When gun is fired the bullet moves in forward direction that is the action. So as a reaction the gun recoils.

3.14. Describe two situations in which force of friction is needed.

Answer

- (i) We need friction to walk on the ground.
- (ii) Friction is also needed to move and stop the vehicles. In the absence of friction, the vehicles cannot move on the roads. To stop a moving vehicle friction is required, so we use brakes to provide friction.
- (iii) The nails are used to join pieces of wood etc. which stay there only due to friction.

3.15. How does oiling the moving parts of a machine lower friction?

Ans. By oiling the moving parts of machine becomes slippery; so as a result the friction is lowered.

3.16. Describe ways to reduce friction.

Ans. Ways to Reduce the Friction:

The friction can be reduced by:

- (i) Making the sliding surfaces smooth
- (ii) Lubricating the sliding surfaces.
- (iii) Rolling friction is much less than the sliding friction, therefore, sliding friction is converted into rolling friction by the use of ball bearings.
- (iv) The front sides of high speed vehicles, aeroplanes, and ships are shaped wedge like and pointed so that minimum friction is offered by air and water etc.

3.17. Why is rolling friction less than sliding friction?

Ans. When a body is placed on the surface of an other body then there develops cold welds. So, when a body rolls on the surface of an other body; it moves with out rupturing the cold welds. That is why the rolling friction is extremely less than sliding friction.

3.18. What you know about the following:

- (i) **Tension in a string**
- (ii) **Limiting force of friction**
- (iii) **Braking force**
- (iv) **Skidding of vehicles**
- (v) **Seatbelts**
- (vi) **Banking of roads**
- (vi) **Cream separator**

Ans. (i) Tension in a String:

When a weight is suspended by a string. Then an upward force provided by the string on the weight is called tension in the string. It is equal to the weight but opposite in direction.

(ii) Limiting Force of Friction:

The maximum value of friction is known as the force of limiting friction. (F_s)

(iii) Braking Force:

The force which is required to over come the limiting friction is called braking force.

(iv) Skidding of Vehicles:

While taking a turn; if required centripetal force is not provided then as a result the driver fails to take the turn instead he goes straight that is called skidding.

(v) Seatbelts:

The safety belts which are used while driving a bus or car are called seat belts. These belts make the driver safe in any accidental case.

(vi) Banking of Roads:

baking of roads means that the outer edge of a road is raised at a turning point.

(vi) Cream Separator:

A cream separator is a high-speed spinner which is used to separate the fat contents of various products i.e., milk.

3.19. What would happen if all friction suddenly disappears?

Ans. If all friction suddenly disappears then the moving bodies will never stop and bodies at rest will never move.

3.20. Why the spinner of a washing machine is made to spin at a very high speed?

Ans. The spinner of washing machine is made to spin at a very high speed so that the water from wet clothes is forced out through the holes due to lack of centripetal force.

PROBLEMS

3.1. A force of 20 N moves a body with an acceleration of 2 ms^{-2} . What is its mass?

Ans. Solution

$$F = 20 \text{ N}, a = 2 \text{ ms}^{-2}, m = ?$$

$$F = ma$$

$$20 = m \times 2$$

$$m = 10 \text{ kg}$$

3.2. The weight of a body is 147 N. what is its mass? (Take the value of g as 10 ms^{-2})

Ans. Solution:

$$w = 147 \text{ N}, m = ?$$

$$w = mg$$

$$147 = m \times 10$$

$$\frac{147}{10} = m$$

$$m = 14.7 \text{ kg}$$

3.3. How much force is needed to prevent a body of mass 10 kg from falling?

Ans. $m = 10 \text{ kg}$

$$f = ?$$

The force required to prevent from falling will be equal to its weight.

$$F = w = mg$$

$$= 10 \times 10$$

$$F = 100 \text{ N}$$

3.4. Find the acceleration produced by a force of 100 N in a mass of 50 kg.

Ans. Solution:

$$F = 100 \text{ N}, m = 50 \text{ kg}, a = ?$$

$$F = ma$$

$$100 = 50 \times a$$

$$a = 2 \text{ ms}^{-2}$$

- 3.5. A body has weight 20 N. how much force is required to move it vertically upwards with an acceleration of 2 ms^{-2} ?

Ans. $w = 20 \text{ N}$, $F = ?$, $a = 2 \text{ ms}^{-2}$

$$F = ma$$

$$m = \frac{w}{g}$$

$$m = 2 \times 2 = 4 \text{ N}$$

So 4N is the net force. There for total force required to move it vertically will be equal to the weight of the body + net force.

$$F' = 20 + 4 = 24 \text{ N}$$

- 3.6. Two masses 52 kg and 48 kg are attached to the ends of a string that passes over a frictionless pulley. Find the tension in the string and acceleration in the bodies when both the masses are moving vertically.

Ans. $m_1 = 48 \text{ kg}$, $m_2 = 52 \text{ kg}$, $T = ?$

$$a = ?$$

$$a = \left(\frac{m_2 - m_1}{m_1 + m_2} \right) \times g$$

$$a = \frac{(52 - 48)}{52 + 48} \times 10$$

$$a = 0.4 \text{ ms}^{-2}$$

(ii)

$$T = \frac{2 m_1 m_2}{m_1 + m_2} \times g$$

$$T = \frac{2 \times 48 \times 52}{48 + 52} \times 10$$

$$T = 499.2$$

$$T = 500 \text{ N} \quad (\text{approximately})$$

- 3.7. Two masses 26 kg and 24 kg are attached to the ends of a string which passes over a frictionless pulley. 26 kg is lying over a smooth horizonral table. 24 N mass is moving vertically downward. Find the tension in the string and the acceleration in the bodies.

Ans. Solution:

$$m_1 = 26 \text{ kg}, m_2 = 24 \text{ kg}, a = ?$$

$$T = ?$$

$$a = \frac{m_2}{m_1 + m_2} \times g$$

$$a = \frac{24}{(24 + 26)} \times 10$$

$$a = \frac{24}{5} = 4.8 \text{ ms}^{-2}$$

$$T = \frac{m_1 m_2}{m_1 + m_2} \times g = \frac{24 \times 26}{24 + 26} \times 10$$

$$T = \frac{624}{50} \times 10 = \frac{624}{5} = 125 \text{ N}$$

- 3.8. How much time is required to change 22 Ns momentum by a force of 20 N?

Ans. $\Delta P = 22 \text{ Ns}$, $F = 20 \text{ N}$, $T = ?$

$$F = \frac{\Delta P}{T}$$

$$T = \frac{\Delta P}{F} = \frac{22}{20} = 1.1 \text{ sec}$$

- 3.9. How much is the force of friction between a wooden block of mass 5 kg and the horizontal marble floor? The coefficient of friction between wood and the marble is 0.6.

Ans. $m = 5 \text{ kg}$, $\mu = 0.6$, $F_s =$

$$F_s = \mu \times m \times g$$

$$= 0.6 \times 5 \times 10 = 30 \text{ N}$$

- 3.10. How much centripetal force is needed to make a body of mass 0.5 kg to move in a circle of radius 50 cm with a speed 3 ms^{-1} ?

Ans. Solution:

$$m = 0.5 \text{ kg}$$

$$r = 50 \text{ cm} \Rightarrow 0.5 \text{ m}$$

$$v = 3 \text{ ms}^{-1}$$

$$F_c = ?$$

$$F_c = \frac{mv^2}{r}$$

$$F_c = \frac{0.5 \times 3 \times 3}{0.5}$$

$$F_c = 9 \text{ N}$$

