CHAPTER > 05

Laws of Motion

KEY NOTES

Force

- It is the external agent (a push or pull) which changes or tries to change the state of rest or uniform motion of a body in a straight line.
- The SI unit of force is newton (1 N) $=1$ kg-ms^{-2}.
- A stone released from the top of a building accelerates downward due to the gravitational pull of the earth.

  This shows that external agencies (e.g. gravitational and magnetic forces) can exert force on a body even from a distance.
- An external force is required to keep a body in motion.

The Law of Inertia

- Inertia is the property of an object by virtue of which it cannot change its state of rest or motion or direction of motion on its own. Inertia means **resistance to change**.
- The state of rest and the state of uniform linear motion (motion with constant velocity) are equivalent. In both cases, there is no net force acting on the body.

Newton's Laws of Motion

Newton gave three laws of motion

Newton's First Law

- It states that, every body continues to be in its state of rest or of uniform motion in a straight line unless compelled by some external force to act otherwise.
- It can be simply expressed as, if the net external force on a body is zero, its acceleration is zero and acceleration can be non-zero only, if there is a net external force on the body.

Momentum

- Momentum of a body is defined as the product of its mass m and velocity v and is denoted by p.

$$p = mv$$

  It is a vector quantity.
- Greater is the change in momentum in a given time, the greater is the force that needs to be applied.
- The same force for the same time causes the same change in momentum for different bodies.

Newton's Second Law

- It states that, the rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts.

  Thus, $$F = \frac{\Delta p}{\Delta t} = ma$$

  Some important points about second law are given below

  (i) In the second law, $F = 0$ implies $a = 0$. The second law is obviously consistent with the first law.

  (ii) The second law of motion is a vector law.

  It is equivalent to three equations, one for each component of the vectors.

$$F_x = \frac{dp_x}{dt} = ma_x$$

$$F_y = \frac{dp_y}{dt} = ma_y$$

$$F_z = \frac{dp_z}{dt} = ma_z$$

  (iii) It is applicable to a particle and also to a body or system of particles provided **F** is the total external force on the system and a is the acceleration of the system as a whole.

  Any internal forces in the system are not to be included in **F**.

  (iv) The second law of motion is a local relation which means acceleration at an instant does not depend on the history of motion.

- **Impulsive force** is a force which acts on a body for a very short interval of time and produces a large change in its linear momentum.
- **Impulse** of a force is equal to the product of average force and the time interval for which it acts.

$$\text{Impulse} = F_{av} \times t$$

Also, impulse = change in linear momentum.

Newton's Third Law

- It states that, to every action, there is always an equal and opposite reaction.
- The term action and reaction in the third law means nothing else but force.
- Forces always occur in pairs. Force on a body A by B is equal and opposite to the force on the body B by A.

  i.e. (Force on A by B) $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$ (Force on B by A)

  If you are considering the system of two bodies as a whole, then F_{AB} and F_{BA} are internal forces of the system $(A + B)$.
- There is no cause-effect relation implied in the third law. The force on A by B and the force on B by A act at the same instant.

Conservation of Momentum

- According to this law, total linear momentum of a system of particles remains constant or conserved in the absence of any external force.

  i.e. When $\mathbf{F}_{ext} = 0, \frac{d\mathbf{p}}{dt} = 0, \mathbf{p} = \text{constant}$

  i.e. $\mathbf{p}_{initial} = \mathbf{p}_{final}$
- The total momentum of an isolated system of interacting particles is conserved.
- If two bodies A and B have initial momenta $\mathbf{p}_A$ and $\mathbf{p}_B$ and after collision their final momenta are $\mathbf{p}'_A$ and $\mathbf{p}'_B$ then according to conservation law of linear momentum,

$$\mathbf{p}'_A + \mathbf{p}'_B = \mathbf{p}_A + \mathbf{p}_B$$

Equilibrium of a Particle

- Equilibrium of a particle in mechanics refers to the situation when the net external force on the particle is zero.
- Equilibrium under three concurrent forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ requires that the vector sum of the three forces is zero.

  i.e. $\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = 0$

  In component form, $\Sigma F_x = 0$, $\Sigma F_y = 0$ and $\Sigma F_z = 0$.
- In other words, the resultant of any two forces says $\mathbf{F}_1$ and $\mathbf{F}_2$ obtained by parallelogram law of forces must be equal and opposite to the third force $\mathbf{F}_3$.

Common Forces in Mechanics

- In mechanics, we encounter several kinds of forces. Except gravitational force, all common forces in mechanics are contact forces.

Some examples of contact forces are given below

- When bodies are in contact (i.e. book resting on a table, a system of rigid bodies connected by rods, hinges and other type of supports), there are mutual contact forces (for each pair of bodies) satisfying the third law.
- Contact forces also arise, when solids are in contact with fluids.
- When a spring is compressed or extented by an external force, a restoring force is generated. This force is usually proportional to compression or elongation (for small displacements).
- The spring force F is written as $F = -kx$, where x is the displacement and k is the force constant.

Friction

- The component of contact force normal to the surfaces in contact is called **normal reaction**. The component parallel to the surfaces in contact is called **friction**.
- In other words, when one body moves or tries to move over the surface of the another body, then a force comes into play which opposes the relative motion of the objects in contact. This force is called **friction**.
- **Static Friction** Force of friction which comes into play between two bodies before one body has not actually starts moving over the other is called static friction and it is denoted by f_s.
- The limiting value of static friction $f_{s\,(max)}$ is independent of the area of contact and varies with normal force N approximately as $f_{s\,(max)} = \mu_s N$

  where, μ_s is the constant of proportionality depending only on the nature of surfaces in contact. The constant μ_s is called the **coefficient of static friction**.
- Static friction opposes **impending motion.** Impending motion means the motion that would take place (but does not actually take place) under the applied force, if friction were absent.
- **Limiting Friction** Maximum force of static friction which comes into play when a body just starts moving over the surface of another body is called limiting friction.

  Thus, $f_s \le f_{s\,(max)}$.

Kinetic Friction

- Frictional force that opposes relative motion between surfaces in contact is called kinetic or sliding friction and is given by

$$f_k = \mu_k N$$

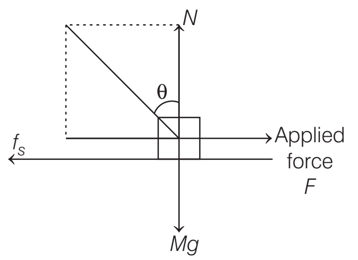
where, μ_k = coefficient of kinetic friction.

- Coefficient of kinetic friction f_k is always less than coefficient of static friction.

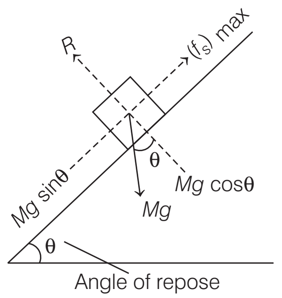
- When the **relative motion** has begun, the acceleration of the body on the rough surface is given by

$$a = \frac{F - f_k}{m}$$

where, F = applied force and f_k = kinetic friction.
- If a body is moving on a rough surface with constant velocity, then $F = f_k$ and if the applied force on the body is removed, then its acceleration is $\frac{-f_k}{m}$.
- **Rolling Friction** Friction which comes into play when a body like a ring or a sphere rolls without slipping over a horizontal surface, is known as rolling friction.
- For the same weight, rolling friction is much smaller than static or sliding friction.
- **Angle of Friction** The angle between the resultant of limiting friction f_s and normal reaction N with the direction of N is called angle of friction θ.



- **Angle of Repose** The minimum angle of inclination of a plane with the horizontal, such that the body placed on the plane just starts to slide down is known as angle of repose.



- In many situations, like in a machine with different moving parts, friction does have a negative role.

  It opposes relative motion and thereby dissipates power in the form of heat, etc.
- **Lubricants** are a way of reducing kinetic friction in a machine. Another way is to use **ball bearings** between two moving parts of a machine.

  Since the rolling friction between ball bearings and the surfaces in contact is very small, power dissipation is reduced.
- Kinetic friction that dissipates power is nevertheless important for quickly stopping relative motion.

  It is made use of by brakes in machines and automobiles.

Dynamics of Circular Motion

- **Centripetal Force** When an object moves on a circular path, a force acts on it, whose direction is towards the **centre of the path,** this force is called centripetal force.

  Centripetal force acting on a particle of mass m on a circular path of radius r is given by

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

- For a stone rotated in a circle by a string, the centripetal force is provided by the tension in the string.

Motion of a Car on Level Road

- When a car of mass m is turning on the level road without skidding, centripetal force on the car must be equal or less than static friction.

i.e. $$F \geq \frac{mv_{\max}^2}{r}$$

$$\mu g \geq \frac{mv_{\max}^2}{r} \qquad [\mu = \text{coefficient of friction}]$$

or $$v_{\max} \leq \sqrt{\mu \cdot rg}$$

∴ Maximum velocity on a curved road to avoid skidding is $v_{\max} = \sqrt{\mu rg}$.

Motion of a Car on Banked Road

- Maximum velocity of a car on banked road is given by

$$v_{\max} = \sqrt{rg\left[\frac{\mu + \tan\theta}{1 - \mu\tan\theta}\right]}$$

where, θ = inclination of road

and r = radius of turn.

If $\mu = 0$, then $v = \sqrt{rg}\tan\theta$.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ Newton's First Law of Motion

1 According to Galileo's experiment for a double inclined plane that are smooth, when a ball is released from rest on one of the planes rolls down and climb up the other of decreased slope, the final height of the ball is
(a) less than the initial height
(b) more than the initial height
(c) equal to the initial height
(d) more or less than the initial height

2 Inertia is also called resistance to change. It means that, if the net external force is zero, then
(a) a body at rest continues to remain at rest
(b) a body in motion continues to move with a uniform velocity
(c) a body in rest starts moving with uniform velocity
(d) Both (a) and (b)

3 Newton's first law is based upon
(a) law of gravitation
(b) law of inertia given by Galileo
(c) Both (a) and (b)
(d) None of the above

4 When a car is stationary, there is no net force acting on it. During pick-up, it accelerates. This happens due to
(a) net external force
(b) net internal force
(c) may be external or internal force
(d) None of the above

5 If a running bus stops suddenly, our feet stop due to friction, but the rest of the body continues to move forward due to
(a) momentum (b) force
(c) inertia (d) impulse

6 Suppose the earth suddenly stops attracting objects placed near surface. A person standing on the surface of the earth will
(a) remain standing (b) fly up
(c) sink into earth (d) Either (b) or (c)

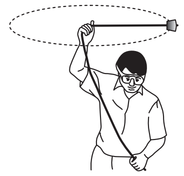
7 An astronaut accidentally gets separated out of his small spaceship accelerating in interstellar space at a constant rate of 100 ms^{-2}. What is the acceleration of the astronaut, the instant after he is outside the spaceship? (Assume that there are no nearby stars to exert gravitational force on him)
(a) 0 (b) 1
(c) ∞ (d) Data insufficient

8 A portion of a meteor moving at a constant rate of 50 kmh^{-1} gets separated from its surface, when it enter earth's atmosphere. Find the velocity of the portion of meteor at the instant after it gets separated.
(a) 100 kmh^{-1} (b) 50 kmh^{-1}
(c) 0 kmh^{-1} (d) 200 kmh^{-1}

TOPIC 2 ~ Newton's Second Law of Motion : Momentum and Impulse

9 A smaller and a bigger iron balls are dropped from a small height on a glass pane placed on a table. Only bigger ball breakes the glass pane, because
(a) bigger ball transfers greater momentum than smaller
(b) bigger ball transfers lesser momentum than smaller
(c) bigger ball transfer equal momentum as smaller
(d) None of the above

10 When a stone is rotated with uniform speed in horizontal plane by means of a string, the magnitude of the momentum is fixed but its direction changes. A force is needed to cause this change in momentum vector. This force is provided by



(a) gravity
(b) our hand through the string
(c) Both gravity and our hand through the string
(d) None of the above

11 A rocket is going upwards with accelerated motion. A man sitting in it feels his weight increased 5 times his own weight. If the mass of the rocket including that of the man is 1.0×10^4 kg, how much force is being applied by rocket engine? (Take, $g = 10\,\text{ms}^{-2}$).

(a) 5×10^4 N (b) 5×10^5 N
(c) 5×10^8 N (d) 2×10^4 N

12 A particle of mass m is moving in a straight line with momentum p. Starting at time $t = 0$, a force $F = kt$ acts in the same direction on the moving particle during time interval T, so that its momentum changes from p to $3p$. Here, k is a constant. The value of T is ***JEE Main 2019***

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

13 A force of 10 N acts on a body of mass 0.5 kg for 0.25s starting from rest. What is its momentum now ? ***JIPMER 2018***

(a) 0.25 N/s (b) 2.5 N/s
(c) 0.5 N/s (d) 0.75 N/s

14 A machine gun fires a bullet of mass 40 g with a velocity of $1200\,\text{ms}^{-1}$. The man holding it can exert a maximum force of 144 N on the gun. How many bullets can be fired per second at the most?

(a) Only one
(b) Three
(c) Can fire any number of bullets
(d) 144×48

15 If a ball of mass 0.1 kg hits the ground from the height of 20m and bounce back to the same height, then find out the force exerted on the ball if the time of impact is 0.04 s. (Take, $g = 10\,\text{m/s}^2$) ***JIPMER 2019***

(a) 100 $(+\hat{\mathbf{j}})$ N (b) 200 $(+\hat{\mathbf{j}})$ N
c) 100 $(-\hat{\mathbf{j}})$ N (c) 1000 $(\hat{\mathbf{j}})$ N

16 While launching a satellite of mass 10^4 kg, a force of 5×10^5N is applied for 20s. The velocity attained by the satellite at the end of 20s, is

(a) 4 km/s (b) 3 km/s
(c) 1 km/s (d) 2 km/s

17 The motion of a particle of mass m is described by $y = ut + gt^2$. Find the force acting on the particle.

(a) Zero (b) mg
(c) 2 mg (d) 3 mg

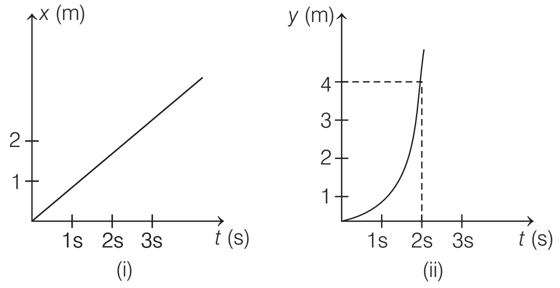
18 A body of mass 1 kg starting from origin with initial velocity of $3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}\,\text{ms}^{-1}$. If a constant force of $2\hat{\mathbf{i}} - 3\hat{\mathbf{j}}$ acts on it, find the coordinate of point it reaches in 3 s.

(a) (18, −1.5) (b) (9, 1.5)
(c) (18, 1.5) (d) (9, −1.5)

19 A bullet of mass 0.04 kg moving with a speed of $90\,\text{ms}^{-1}$ enters a heavy wooden block and stopped after 3s. What is the average resistive force exerted by the block on the bullet?

(a) 1 N (b) 1.2 N
(c) 2 N (d) 3 N

20 Figure shows x-t and y-t diagrams of a particle moving in two-dimensions.



If the particle has a mass of 500 g, find the force (direction and magnitude) acting on the particle.

(a) 8 N along X-axis (b) 12 N along X-axis
(c) 1 N along Y-axis (d) 3 N along Y-axis

21 A batsman hits back at ball straight in the direction of the bowler without changing its initial speed of $12\,\text{ms}^{-1}$. If the mass of the ball is 0.15 kg, find the impulse imparted to the ball. (Assume linear motion of the ball)

(a) 1.8 N-s (b) 3.6 N-s
(c) 3.6 N-m (d) 1.8 N-m

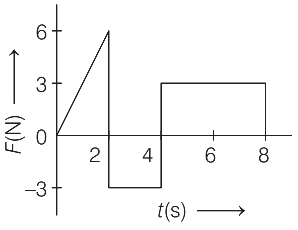
22 A mass of 10 kg is suspended by a rope of length 4 m, from the ceiling. A force F is applied horizontally at the mid-point of the rope such that the top half of the rope makes an angle of 45° with the vertical. Then, F equals (Take, $g = 10\,\text{ms}^{-2}$ and the rope to be massless) ***JEE Main 2020***

(a) 75 N (b) 70 N (c) 100 N (d) 90 N

23 A gun applied a force F on a bullet which is given by $F = (100 - 0.5 \times 10^5\, t)$ N. The bullet emerges out with speed 400 m/s, then find out the impulse exerted till force on the bullet becomes zero. ***AIIMS 2019***

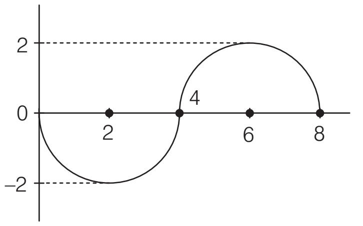
(a) 0.2 N-s (b) 0.3 N-s
(c) 0.1 N-s (d) 0.4 N-s

24 The force F acting on a particle of mass m is indicated by the force-time graph shown below. The change in momentum of the particle over the time interval from 0 to 8s is **CBSE AIPMT 2014**



(a) 24 N-s (b) 20 N-s
(c) 12 N-s (d) 6 N-s

25 The force-time (F-t) graph for linear motion of a body initially at rest is shown in figure. The segments shown are circular, the linear momentum gained in 4 s is **CBSE AIPMT 2012**



(a) 8 N-s (b) 4π N-s
(c) 2π N-s (d) 8π N-s

TOPIC 3 ~ *Newton's Third Law of Motion*

26 Every action has an equal and opposite reaction, which suggests that
(a) action and reaction always act on different bodies
(b) the forces of action and reaction cancel to each other
(c) the forces of action and reaction cannot cancel to each other
(d) Both (a) and (c)

27 Recoiling of gun is an example of
(a) Newton's first law of motion
(b) Netwon's second law of motion
(c) Newton's third law of motion
(d) law of conservation of angular momentum

28 A book is lying on the table. What is the angle between the action of the book on the table and reaction of the table on the book?
(a) 0° (b) 30°
(c) 45° (d) 180°

29 Twelve one-rupee coins are put on top of each other on a table, where mass of each coin is 20g. The reaction of the 7th coin (counted from bottom) on the 8th coin is [take, $g = 10\ \text{m/s}^2$]
(a) 2N (b) 1N
(c) 3 N (d) 4N

TOPIC 4 ~ *Conservation of Momentum and Equilibrium of Particle*

30 In an isolated system, (i.e. a system with no external force) total momentum of interacting particles is conserved. It follows
(a) Newton's first law (b) Newton's second law
(c) Newton's third law (d) Both (b) and (c)

31 A 100 kg gun fires a ball of 1 kg horizontally from a cliff of height 500 m. It falls on the ground at a distance of 400 m from the bottom of the cliff. The recoil velocity of the gun is (take, $g = 10\ \text{ms}^{-2}$)
(a) $0.2\ \text{ms}^{-1}$. (b) $0.4\ \text{ms}^{-1}$
(c) $0.6\ \text{ms}^{-1}$ (d) $0.8\ \text{ms}^{-1}$

32 An explosion breaks a rock into three parts in a horizontal plane. Two of them go off at right angles to each other. The first part of mass 1 kg moves with a speed of $12\ \text{ms}^{-1}$ and the second part of mass 2 kg moves with $8\ \text{ms}^{-1}$ speed. If the third part flies off with 4ms^{-1} speed, then its mass is **CBSE AIPMT 2013**
(a) 3 kg
(b) 5 kg
(c) 7 kg
(d) 17 kg

33 A trolley of mass 200 kg moves with a uniform speed of 36 kmh^{-1} on a frictionless track. A child of mass 20 kg runs on the trolley from one end to the other (10 m away) with a speed of 4 ms^{-1} relative to the trolley in a direction opposite to its motion and ultimately jumps out of the trolley. With how much velocity has the trolley moved from the time the child begins to run?

(a) 10.36 (b) 11.36
(c) 12.36 (d) 14.40

34 Three concurrent coplanar forces 1 N, 2 N and 3 N are acting along different directions on a body can keep the body in equilibrium, if

(a) 2 N and 3 N act at right angle
(b) 1 N and 2 N act at acute angle
(c) 1 N and 2 N act at right angle
(d) Cannot be possible

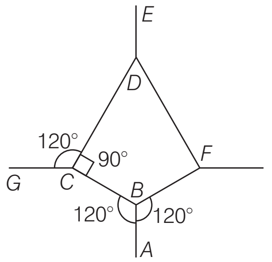
35 Two forces $\mathbf{F}_1 = 3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}$ and $\mathbf{F}_2 = 2\hat{\mathbf{i}} - 3\hat{\mathbf{j}}$ are acting upon a body of mass 2 kg. Find the force $\mathbf{F}_3$, which when acts on the body will make it stable.

(a) $5\hat{\mathbf{i}} + 7\hat{\mathbf{j}}$ (b) $-5\hat{\mathbf{i}} - 7\hat{\mathbf{j}}$
(c) $-5\hat{\mathbf{i}} + 7\hat{\mathbf{j}}$ (d) $5\hat{\mathbf{i}} - 7\hat{\mathbf{j}}$

36 There are four forces acting at a point P produced by strings as shown in figure, which is at rest. The forces F_1 and F_2 (in N) are

(a) 0.7, 2.1 (b) 4.1, 2.1 (c) 2.31, 1.0 (d) 3.0, 1.4

37 Given figure is the part of a horizontally stretched structure. Section AB is stretched with a force of 10 N. The tension in the sections BC and BF, are

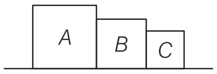


JEE Main 2014

(a) 10 N, 11 N
(b) 10 N, 6 N
(c) 10 N, 10 N
(d) Cannot be calculated due to insufficient data

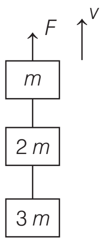
TOPIC 5 ~ *Common Forces in Mechanics (without Friction)*

38 Three blocks A, B and C of masses 4 kg, 2 kg and 1 kg respectively, are in contact on a frictionless surface, as shown in the figure. If a force of 14 N is applied on the 4 kg block, then the contact force between A and B is ***CBSE AIPMT 2015***



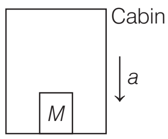
(a) 2 N (b) 6 N (c) 8 N (d) 18 N

39 Three blocks with masses $m, 2m$ and $3m$ are connected by strings, as shown in the figure. After an upward force F is applied on block m, the masses move upward at constant speed v. What is the net force on the block of mass $2m$? (g is the acceleration due to gravity). ***NEET 2013***



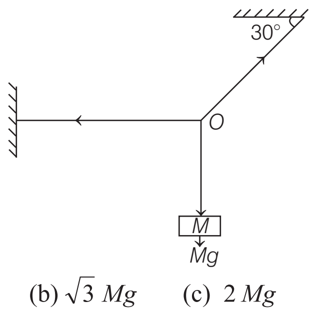
(a) Zero (b) 2 mg (c) 3 mg (d) 6 mg

40 If cabin is descending in vertical direction with acceleration a and reaction by mass M on the floor of cabin is $\frac{9\,Mg}{10}$, then a equals to



(a) g (b) $\frac{g}{10}$
(c) $\frac{9}{10}g$ (d) $\frac{10}{9}g$

41 A mass M is hung with a light inextensible string as shown in the figure. Find the tension of the horizontal string. ***JIPMER 2019***



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

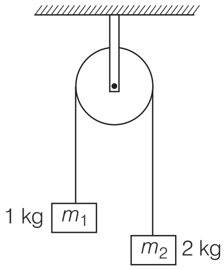
42 Two masses $m_1 = 5$ kg and $m_2 = 10$ kg connected by an inextensible string over a frictionless pulley, are moving as shown in the figure. The coefficient of friction of horizontal surface is 0.15. The minimum weight m that should be put on top of m_2 to stop the motion is ***JEE Main 2018***

(a) 18.3 kg (b) 27.3 kg
(c) 43.3 kg (d) 10.3 kg

43 A mass of 10 kg is suspended vertically by a rope from the roof. When a horizontal force is applied on the mass, the rope deviated at an angle of 45° at the roof point. If the suspended mass is at equilibrium, the magnitude of the force applied is (Take, $g = 10\ \text{ms}^{-2}$) ***JEE Main 2019***

(a) 70 N (b) 200 N (c) 100 N (d) 140 N

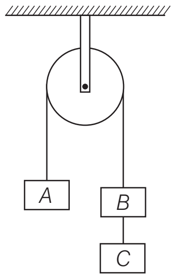
44 Two masses $m_1 = 1$ kg and $m_2 = 2$ kg are connected by a light inextensible string and suspended by means of a weightless pulley as shown in figure.



Assuming that both the masses start from rest, the distance travelled by 2 kg mass in 2 s is (given, $g = 10\ \text{ms}^{-2}$)

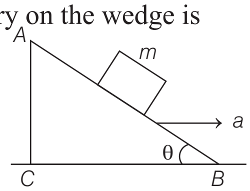
(a) $\frac{20}{9}$ m (b) $\frac{40}{9}$ m (c) $\frac{20}{3}$ m (d) $\frac{1}{3}$ m

45 Three equal weights A, B and C of mass 2 kg each are hanging on a string over a fixed frictionless pulley as shown in the figure. The tension in the string connecting weight B and C is (given, $g = 9.8\ \text{ms}^{-2}$)



(a) zero (b) 9.8 N
(c) 13.3 N (d) 19.6 N

46 A block of mass m is placed on a smooth inclined wedge ABC of inclination θ as shown in the figure. The wedge is given an acceleration a towards the right. The relation between a and θ for the block to remain stationary on the wedge is ***NEET 2018***



(a) $a = g\cos\theta$ (b) $a = \frac{g}{\sin\theta}$

(c) $a = \frac{g}{\text{cosec}\,\theta}$ (d) $a = g\tan\theta$

TOPIC 6 ~ *Friction*

47 If a box is lying in the compartment of an accelerating train and box is stationary relative to the train. What force cause the acceleration of the box?

(a) Frictional force in the direction of train
(b) Frictional force in the opposite direction of train
(c) Force applied by air
(d) None of the above

48 A trolley is carrying a box on its surface having coefficient of static friction equal to 0.3. Now the trolley starts moving with increasing acceleration. Find the maximum acceleration of the trolley, so that the box does not slide back on the trolley.

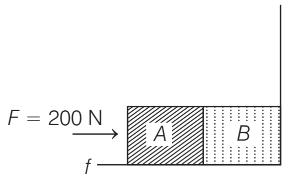
(a) $2\ \text{ms}^{-2}$ (b) $3\ \text{ms}^{-2}$ (c) $4\ \text{ms}^{-2}$ (d) $5\ \text{ms}^{-2}$

49 A boy prevents fall of his book on the ground by pressing it against a vertical wall. If weight of his book is 10 kg and μ_s of the wall is 0.2. Find the minimum force needed by him in his attempt. (given, $g = 10\ \text{ms}^{-2}$)

(a) 300 N (b) 400 N (c) 500 N (d) 600 N

50 Two bodies A and B of masses 5 kg and 10 kg in contact with each other rest on a table against a rigid partition.

The coefficient of friction between the bodies and the table is 0.15. A force of 200 N is applied horizontally at A.

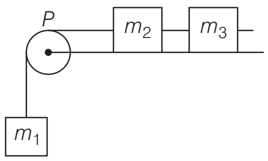


What is the reaction of the partition?

(a) 170 N (b) 204 N

(c) 177.95 N (d) 174 N

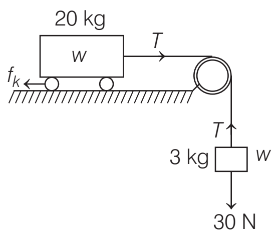
51 A system consists of three masses m_1, m_2 and m_3 connected by a string passing over a pulley P. The mass m_1 hangs freely and m_2 & m_3 are on a rough horizontal table (the coefficient of friction $=\mu$). The pulley is frictionless and of negligible mass. The downward acceleration of mass m_1 is (assume, $m_1 = m_2 = m_3 = m$) ***CBSE AIPMT 2014***



(a) $\frac{g(1-g\mu)}{9}$ (b) $\frac{2g\mu}{3}$

(c) $\frac{g(1-2\mu)}{3}$ (d) $\frac{g(1-2\mu)}{2}$

52 What is the acceleration of the block and the trolley system as in figure, if the coefficient of kinetic friction between the trolley and the surface is 0.04? What is the tension T in the string? (Take, $g = 10\text{ ms}^{-2}$, neglect the mass of the string)



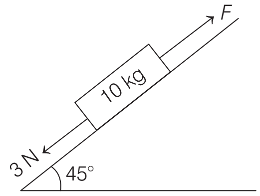
(a) $a = 0.96\text{ ms}^{-2}$, $T = 50$ N

(b) $a = 0.42\text{ ms}^{-2}$, $T = 27.1$ N

(c) $a = 0.96\text{ ms}^{-2}$, $T = 27.1$ N

(d) $a = 0.42\text{ ms}^{-2}$, $T = 42.6$ N

53 A block of mass 10 kg is kept on a rough inclined plane as shown in the figure. A force of 3 N is applied on the block. The coefficient of static friction between the plane and the block is 0.6. What should be the minimum value of force F, such that the block does not move downward? (Take, $g = 10\text{ms}^{-2}$) ***JEE Main 2019***



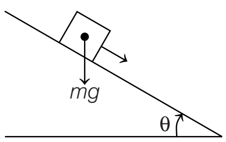
(a) 32 N (b) 25 N (c) 23 N (d) 18 N

54 A box of mass 8 kg is placed on a rough inclined plane of inclination 30°. Its downward motion can be prevented by applying a horizontal force F, then value of F for which friction between the block and the incline surface is minimum, is (take, $g = 10\text{ ms}^{-2}$) ***JIPMER 2018***

(a) $\frac{80}{\sqrt{3}}$ (b) $40\sqrt{3}$ (c) $\frac{40}{\sqrt{3}}$ (d) $80\sqrt{3}$

55 A plank with a box on it at one end is gradually raised about the other end. As the angle of inclination with the horizontal reaches 30°, the box starts to slip and slides 4.0 m down the plank in 4.0 s.

The coefficients of static and kinetic friction between the box and the plank will be, respectively (take, $g = 10\text{ ms}^{-2}$) ***CBSE AIPMT 2015***



(a) 0.6 and 0.6 (b) 0.6 and 0.5

(c) 0.5 and 0.6 (d) 0.4 and 0.3

56 F_1 and F_2 are the minimum and maximum forces needed to keep a body on a rough inclined plane stationary. If θ be the angle of inclination of the surface, so that $\tan\theta = 2\mu$. Find the ratio of F_1 and F_2.

(a) 1 : 2 (b) 2 : 1

(c) 1 : 3 (d) 3 : 1

57 The upper half of an inclined plane of inclination θ is perfectly smooth, while lower half is rough. A block starting from rest at the top of the plane will again come to rest at the bottom, if the coefficient of friction between the block and lower half of the plane is given by ***NEET 2013***

(a) $\mu = \frac{1}{\tan\theta}$ (b) $\mu = \frac{2}{\tan\theta}$

(c) $\mu = 2\tan\theta$ (d) $\mu = \tan\theta$

TOPIC 7 ~ *Dynamics of Circular Motion*

58 A particle of mass 2 kg is moving on a circular path of radius 10 m with a speed of 5 ms^{-1} and its speed is increasing at a rate of 3 ms^{-1}. Find the force acting on the particle.

(a) 5 N (b) 10 N
(c) 12 N (d) 14 N

59 A particle is moving on a circular path of 10 m radius. At any instant of time, its speed is 5 ms^{-1} and the speed is increasing at a rate of 2 ms^{-2}. The magnitude of net acceleration at this instant is

(a) 5 ms^{-2} (b) 2 ms^{-2}
(c) 3.2 ms^{-2} (d) 4.3 ms^{-2}

60 Two stones of masses m and $2m$ are whirled in horizontal circles. The heavier one in a radius of $\frac{r}{2}$ and the lighter one in radius of r. The tangential speed of lighter stone is n times that of the value of heavier stone, when they experience same centripetal forces. The value of n is ***CBSE AIPMT 2015***

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

61 When a car is moving along a circle on a level road the centripetal force is provided by f, where f denotes as ***JEE Main 2014***

(a) $f < \mu_s N = \frac{mv^2}{r}$

(b) $\frac{mv^2}{r} = f \le \mu_s N$

(c) $f = \mu_s N = \frac{mv^2}{r}$

(d) $f = \mu_k N = \frac{mv^2}{r}$

62 If a car is moving in uniform circular motion, then what should be the value of velocity of a car ,so that car will not move away from the circle?

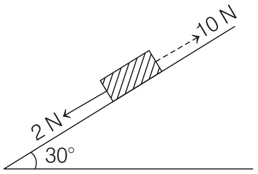
(a) $v < \sqrt{\mu_s Rg}$ (b) $v \le \sqrt{\mu_s Rg}$
(c) $v < \sqrt{\mu_k Rg}$ (d) None of these

63 A car is negotiating a curved road of radius R. The road is banked at an angle θ. The coefficient of friction between the tyres of the car and the road is μ_s. The maximum safe velocity on this road is ***NEET 2016***

(a) $\sqrt{gR\left(\frac{\mu_s + \tan\theta}{1-\mu_s \tan\theta}\right)}$ (b) $\sqrt{\frac{g}{R}\left(\frac{\mu_s + \tan\theta}{1-\mu_s \tan\theta}\right)}$

(c) $\sqrt{\frac{g}{R^2}\left(\frac{\mu_s + \tan\theta}{1-\mu_s \tan\theta}\right)}$ (d) $\sqrt{gR^2\left(\frac{\mu_s + \tan\theta}{1-\mu_s \tan\theta}\right)}$

64 A block kept on a rough inclined plane, as shown in the figure, remains at rest upto a maximum force 2 N down the inclined plane. The maximum external force up the inclined plane that does not move the block is 10 N. The coefficient of static friction between the block and the plane is (Take, $g = 10\ m/s^2$) ***JEE Main 2019***



(a) $\frac{2}{3}$ (b) $\frac{\sqrt{3}}{2}$
(c) $\frac{\sqrt{3}}{4}$ (d) $\frac{1}{2}$

65 A circular racetrack of radius 300 m is banked at an angle of 15°. If the coefficient of friction between the wheels of the race car and the road is 0.2. Find optimum speed of the race car to avoid wear and tear on its tyres and maximum permissible speed to avoid slipping. (Take $g = 9.8\ ms^{-2}$ and $\tan 15° = 0.27$)

(a) $v_o = 48\ ms^{-1}$, $v_{max} = 60\ ms^{-1}$
(b) $v_o = 28.1\ ms^{-1}$, $v_{max} = 38.1\ ms^{-1}$
(c) $v_o = 62.2\ ms^{-1}$, $v_{max} = 73.4\ ms^{-1}$
(d) None of the above

SPECIAL TYPES QUESTIONS

I. Assertion and Reason

Direction (Q. Nos. 66-74) *In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

66 **Assertion** Aristotle stated that an external force is required to keep a body in motion.

Reason Opposing forces are always present in the natural world.

67 **Assertion** A body is momentarily at rest but still some force is acting on it at that time.

Reason When a force acts on a body, it may not have some acceleration.

68 **Assertion** At the microscopic level, all bodies are made up of charged constituents (like nuclei and electrons) and various contact forces exist between them.

Reason These forces are due to elasticity of bodies, molecular collisions and impacts, etc.

69 **Assertion** If force is not parallel to the velocity of the body, but makes some angle with it, it changes the component of velocity along the direction of force.

Reason The component of velocity normal to the force remains unchanged.

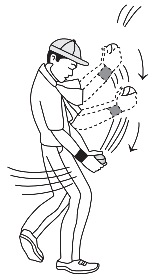
70 **Assertion** If we consider system of two bodies A and B as a whole, $\mathbf{F}_{AB}$ and $\mathbf{F}_{BA}$ are internal forces of the system ($A + B$). They add to give a null force.

Reason Internal forces in a body or a system of particles cancel away in pairs.

71 **Assertion** Newton's third law of motion is applicable only when bodies are in motion.

Reason Newton's third law applies to all types of forces, e.g. gravitational, electric or magnetic forces, etc.

72 **Assertion** A seasoned cricketer allows a longer time for his hands to stop the ball, while catching the ball. His hand is not hurt.



Reason The novice (new player) keeps his hand fixed and tries to catch the ball almost instantly. He needs to provide a much greater force to stop the ball instantly and this hurts.

73 **Assertion** Product of mass and velocity (i.e. momentum) is basic to the effect of force on motion.

Reason Same force for same time causes the same change in momentum for different bodies.

74 **Assertion** It is always necessary that external agency of force is in contact with the object while applying force on object.

Reason A stone released from top of a building accelerates downward due to gravitational pull of the earth.

II. Statement Based Questions

75 Consider the following statements.

I. When we beat a carpet with a stick, dust particles are removed.
II. When we shake a mango tree, the mangoes fall down.
III. When a vehicle suddenly stopped, the passengers tend to fall forward.

Which of the statements are correct for examples of inertia?

(a) Both I and II (b) Both II and III
(c) Both I and III (d) I, II and III

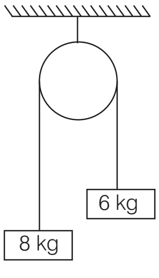
76 To solve a problem in mechanics, we need to consider an assembly of different bodies. In this assembly,

I. different bodies exert force on each other.
II. few selected body experiences force of gravity.

Which of the following statement(s) is/are incorrect?

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

77 In the figure, 8 kg and 6 kg are hanging stationary from a rough pulley and are about to move. They are stationary due to roughness of the pulley. Which of the following statement(s) is/are correct?



I. The force of friction on the rope is 20 N.
II. The force of friction on the rope is 30 N.

(a) Only I (b) Only II
(c) Neither I nor II (d) None of these

78 Study the following statements.

I. When stone is rotated at greater speed in circular path, greater force is required.

II. When stone is rotated in a circle of smaller radius, greater force is required.

III. When stone is rotated at greater speed in a circle of smaller radius, smaller force is required.

Which of the following statement(s) is/are correct?

(a) Both I and II (b) Both II and IV
(c) Both I and III (d) I, II and III

79 Suppose a light-weight vehicle (say, a small car) and a heavy weight vehicle (say, a loaded truck) are parked on a horizontal road. Then, which of the following statement is correct?

(a) Much greater force is needed to push the truck.
(b) Equal force is needed to push the truck and car.
(c) No force is required to move the vehicles.
(d) None of the above

80 If no external force acts on particle, then which of the following statement is incorrect about particle?

(a) Particle may be at rest.
(b) Particle moves with uniform velocity on linear path.
(c) Particle moves with uniform speed on circle.
(d) None of the above

81 Which of the following statement is incorrect regarding the Newton's third law of motion?

(a) To every action, there is always an equal and opposite reaction.
(b) Action and reaction act on the same body.
(c) There is no cause-effect relation between action and reaction.
(d) Action and reaction forces are simultaneous.

82 Which of the following statement is incorrect, when a person walks on a rough surface?

(a) The frictional force exerted by the surface stops him from moving.
(b) The force which the person exerts on the floor keeps him moving.
(c) The reaction of the force which the person exerts on floor keeps him moving.
(d) None of the above

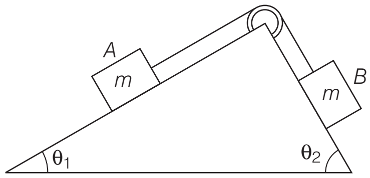
83 Choose the correct statement.

(a) Friction force is generated in pairs.
(b) Centrifugal force is the reaction force of centripetal force.
(c) Centrifugal force is a type of non-pseudo force.
(d) None of the above

84 Which one of the following statement is incorrect?

(a) Frictional force opposes the relative motion. ***NEET 2018***
(b) Limiting value of static friction is directly proportional to normal reaction.
(c) Rolling friction is smaller than sliding friction.
(d) Coefficient of sliding friction has dimensions of length.

85 In the given figure below, a body A of mass m slides on plane inclined at angle θ_1 to the horizontal and μ is the coefficient of friction between A and the plane. A is connected by a light string passing over a frictionless pulley to another body B, also of mass m, sliding on a frictionless plane inclined at an angle θ_2 to the horizontal. Which of the following statement(s) is/are correct?



(a) A will never move up the plane.
(b) A will just start moving up the plane, when

$$\mu = \frac{\sin\theta_2 + \sin\theta_1}{\cos\theta_1}$$

(c) For A to move up the plane, θ_2 must always be greater than θ_1.
(d) B will always slide down with constant speed.

III. Matching Type

86 Match the Column I (example) with Column II (newton's law) and select the correct answer from the codes given below.

	Column I		Column II
A.	Soldier feels backward shock while firing bullet	1.	Newton's first law
B.	Passenger feels forward jerk when bus stops all of sudden	2.	Newton's second law
C.	Bowler withdraw of hands backward while taking catch	3.	Newton's third law

	A	B	C		A	B	C
(a)	3	1	2	(b)	2	1	3
(c)	1	2	3	(d)	3	2	1

87 Match the Column I (type of friction) with Column II (value of μ) and select the correct answer from the codes given below.

	Column I		Column II
A.	Static friction	1.	μ is highest
B.	Rolling friction	2.	μ is moderate
C.	Kinetic friction	3.	μ is lowest

	A	B	C
(a)	3	2	1
(b)	1	2	3
(c)	1	3	2
(d)	2	3	1

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

88 One end of a string of length l is connected to a particle of mass m and the other to a small peg on a smooth horizontal table. If the particle moves in a circle with speed v, the net force on the particle directed towards the centre is (where, T is the tension in the string)

(a) T (b) $T-\frac{mv^2}{l}$ (c) $T+\frac{mv^2}{l}$ (d) 0

89 A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 ms^{-1}. How long does the body take to reverse its velocity?

(a) 10 s (b) 11 s (c) 12 s (d) 13 s

90 A body of mass 5 kg is acted upon by two perpendicular forces 8 N and 6 N. Find the magnitude of the acceleration of the body.

(a) 4 ms^{-2} (b) 2 ms^{-2}
(c) 6 ms^{-2} (d) None of these

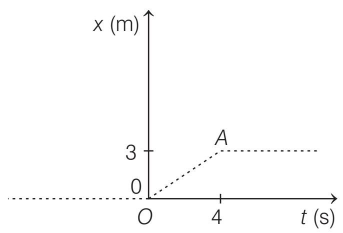
91 A rocket with a lift-off mass 20000 kg is blasted upwards with an initial acceleration of 5.0 ms^{-2}. Calculate the initial thrust (force) of the blast.

(a) 2.96×10^5 N (b) 2.4×10^4 N
(c) 1.8×10^5 N (d) 3×10^8 N

92 A truck starts from rest and accelerates uniformly with 2 ms^{-2}. At $t=10$ s, a stone is dropped by a person standing on the top of the truck (6 m high from the ground). What are the (i) velocity and (ii) acceleration of the stone at $t=11$ s?
(Neglect air resistance).

(a) 22.4 ms^{-1} and 9.8 ms^{-2} (b) 20 ms^{-1} and 4.8 ms^{-2}
(c) 12.8 ms^{-1} and 9.8 ms^{-2} (d) 25 ms^{-1} and 10.2 ms^{-2}

93 Figure below shows the position-time graph of a particle of mass 4 kg. What is the (i) force on the particle for $0<t<4$ s (ii) and impulse at $t=0$ (consider one dimensional motion only)?



(a) 0 N, 3 kg-ms^{-1} (b) 0 N, 0.75 kg-ms^{-1}
(c) 1 N, 2 kg-ms^{-1} (d) 2 N, 4 kg-ms^{-1}

94 Two masses 8 kg and 12 kg are connected at the two ends of a light inextensible string that goes over a frictionless pulley. Find the acceleration of the masses and the tension in the string when the masses are released.

(a) 2 ms^{-2}, 80 N (b) 2 ms^{-2}, 96 N
(c) 4 ms^{-2}, 100 N (d) 4 ms^{-2}, 110 N

95 Two billiard balls each of mass 0.05 kg moving in opposite directions with speed 6 ms^{-1} collide and rebound with the same speed. What is the impulse imparted (in kg-ms^{-1}) to each ball due to the other?

(a) – 0.4 (b) – 0.6
(c) – 0.8 (d) – 1.0

96 A batsman deflects a ball by an angle of 45° without changing its initial speed which is equal to 54 kmh^{-1}. What is the impulse imparted to the ball?
(Mass of the ball = 0.15 kg).

(a) 4.20 kg-ms^{-1} (b) 4.16 kg-ms^{-1}
(c) 2.58 kg-ms^{-1} (d) 4.58 kg-ms^{-1}

97 A stone of mass 0.25 kg tied to the end of a string is whirled round in a circle of radius 1.5 m with speed 40 revmin^{-1} in a horizontal plane. What is the tension in the string ? What is the maximum speed with which the stone can be whirled around, if the string can withstand a maximum tension of 200 N?

(a) 5 N, 32 ms^{-1} (b) 6.6 N, 34.6 ms^{-1}
(c) 6.6 N, 42.8 ms^{-1} (d) 7 N, 24.8 ms^{-1}

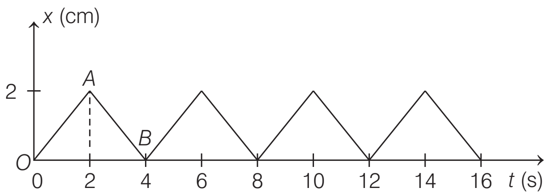
98 A horse cannot pull a cart and run in empty space because

(a) it loses its energy in space
(b) it does not set a reaction force there, which can help it go forward
(c) its body becomes very light there
(d) None of the above

99 It is easier to pull a lawn mower than to push it because

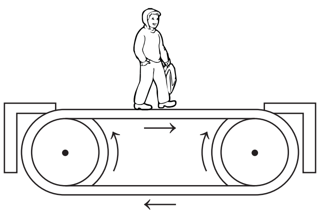
(a) pulling is more comfortable than pushing
(b) one gets extra energy in pulling
(c) pulling makes the lawn mower lights
(d) pulling reduces friction of the surface

100 Figure below shows the position-time graph of a body of mass 0.04 kg. What is the magnitude (in kg-ms^{-1}) of each impulse?



(a) 6×10^{-4} (b) 8×10^{-4}
(c) 10×10^{-4} (d) 2×10^{-4}

101 Figure shows a man of mass 55 kg standing stationary with respect to a horizontal conveyor belt that is accelerating with 1 ms^{-2}. The net force acting on the man is



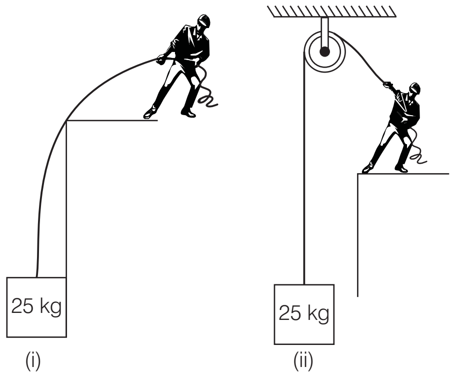
(a) 35 N (b) 45 N
(c) 55 N (d) 65 N

102 A stream of water flowing horizontally with a speed of 15 ms^{-1} gushes out of a tube of cross-sectional area 10^{-2} m^2 and hits a vertical wall nearby. What is the force exerted on the wall by the impact of water, assuming it does not rebound?
(a) 2250 N (b) 2408 N
(c) 2048 N (d) None of these

103 Ten one-rupee coins are put on top of each other on a table. Each coin has mass *m*. Find the magnitude (in *m*gN) and direction of
(i) the force on the 7th coin (counted from the bottom due to all the coins on its top)
(ii) the force on the 7th coin by the 8th coin
(iii) and the reaction of the 6th coin on the 7th coin.
(a) 3, 3, – 4 (b) – 4, 3 , 3
(c) 3, – 4, 3 (d) None of these

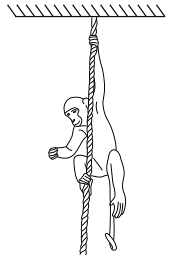
104 An aircraft executes a horizontal loop at a speed of 720 kmh^{-1} with its wings banked at 15°. What is the radius of the loop?
(Take, $g = 10\,\text{ms}^{-2}$ and $\tan 15° = 0.27$)
(a) 14.8 km (b) 14.8 m
(c) 29.6 km (d) 26.9 m

105 A block of mass 25 kg is raised by a 50 kg man in two different ways as shown in figure. What is the action on the floor by the man in the two cases, respectively?



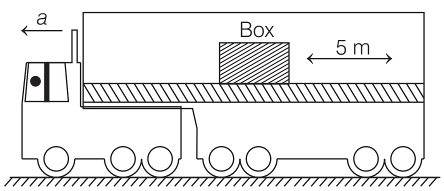
(a) 750 N, 250 N (b) 250 N, 750 N
(c) 450 N, 250 N (d) 250 N, 450 N

106 A monkey of mass 40 kg climbs on a rope which can withstand a maximum tension of 600 N. In which of the following cases will the rope break?
(Ignore the mass of the rope and take, $g = 10$ ms^{-2})



(a) The monkey climbs up with an acceleration of 6 ms^{-2}
(b) The monkey climbs down with an acceleration of 4 ms^{-2}
(c) The monkey climbs up with a uniform speed of 5 ms^{-1}
(d) The monkey falls down the rope nearly freely under gravity

107 The rear side of a truck is open and a box of 40 kg mass is placed 5 m away from the open end as shown in figure. The coefficient of friction between the box and the surface below it is 0.15. On a straight road, the truck starts from rest and accelerates with 2 ms^{-2}. At what distance from the starting point does the box fall off the truck? (ignore the size of the box).



(a) 18.84 m (b) 12.48 m
(c) 16.56 m (d) 15.28 m

108 A disc revolves with a speed of $33\frac{1}{3}$ rev$\min^{-1}$ and has a radius of 15 cm. Two coins A and B are placed at 4 cm and 14 cm away from the centre of the record, respectively. If the coefficient of friction between the coins and the record is 0.15, which of the coins will revolve with the record without slipping?

(a) Coin A will revolve but B will not revolve
(b) Coin B will revolve but A will not revolve
(c) None of the coins will revolve
(d) Both coins will revolve

109 You may have seen in a circus a motorcyclist driving in vertical loops inside a 'death well' (a hollow spherical chamber with holes, so the spectators can watch from outside). What is the minimum speed (is ms^{-1}) required at the uppermost position to perform a vertical loop, if the radius of the chamber is 25 m?

(a) 15.65 (b) 12.48 (c) 14.56 (d) 18.48

110 A man stands in contact against the inner wall of a hollow cylindrical drum of radius 3 m rotating about its vertical axis. The coefficient of friction between the wall and his clothing is 0.15.

What is the minimum rotational speed of the cylinder to enable the man to remain stuck to the wall (without falling) when the floor is suddenly removed?
($R = mr\omega^2$ and $F = mg$)

(a) 4 $rads^{-1}$ (b) 4.7 $rads^{-1}$ (c) 5.2 $rads^{-1}$ (d) 6.2 $rads^{-1}$

NCERT Exemplar

111 A ball is travelling with uniform translatory motion. This means that

(a) it is at rest
(b) the path can be a straight line or circular and the ball travels with uniform speed
(c) all parts of the ball have the same velocity (magnitude and direction) and the velocity is constant
(d) the centre of the ball moves with constant velocity and the ball spins about its centre uniformly

112 A metre scale is moving with uniform velocity. This implies

(a) the force acting on the scale is zero, but a torque about the centre of mass can act on the scale
(b) the force acting on the scale is zero and the torque acting about centre of mass of the scale is also zero
(c) the total force acting on it need not be zero but the torque on it is zero
(d) neither the force nor the torque need to be zero

113 A cricket ball of mass 150 g has an initial velocity $\mathbf{u} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\ ms^{-1}$ and a final velocity $\mathbf{v} = -(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\ ms^{-1}$, after being hit. The change in momentum (final momentum – initial momentum) is (in kg-ms^{-1})

(a) zero (b) $-(0.45\hat{\mathbf{i}} + 0.6\hat{\mathbf{j}})$
(c) $-(0.9\hat{\mathbf{i}} + 1.2\hat{\mathbf{j}})$ (d) $-5(\hat{\mathbf{i}} + \hat{\mathbf{j}})$

114 Conservation of momentum in a collision between particles can be understood from

(a) conservation of energy
(b) Newton's first law only
(c) Newton's second law only
(d) Both Newton's second and third laws

115 A hockey player is moving northward and suddenly turns westward with the same speed to avoid an opponent. The force that acts on the player is

(a) frictional force along westward
(b) muscle force along southward
(c) frictional force along south-west
(d) muscle force along south-west

116 A body of mass 2kg travels according to the law $x(t) = pt + qt^2 + rt^3$ where, $q = 4\ ms^{-2}$, $p = 3\ ms^{-1}$ and $r = 5\ ms^{-3}$. The force acting on the body at $t = 2$ s is

(a) 136 N (b) 134 N (c) 158 N (d) 68 N

117 A body with mass 5 kg is acted upon by a force $\mathbf{F} = (-3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})$ N. If its initial velocity at $t = 0$ is $\mathbf{u} = (6\hat{\mathbf{i}} - 12\hat{\mathbf{j}})\ ms^{-1}$, the time at which it will just have a velocity along the Y-axis is

(a) never (b) 10 s
(c) 2 s (d) 15 s

118 A car of mass m starts from rest and acquires a velocity along east, $v = v\hat{\mathbf{i}}\ (v > 0)$ in 2 s. Assuming the car moves with uniform acceleration, the force exerted on the car is

(a) $\frac{mv}{2}$ eastward and is exerted by the car engine
(b) $\frac{mv}{2}$ eastward and is due to the friction on the tyres exerted by the road
(c) more than $\frac{mv}{2}$ eastward exerted due to the engine and overcomes the friction of the road
(d) $\frac{mv}{2}$ exerted by the engine

Answers

Mastering NCERT with MCQs

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

Special Types Questions

66 (a)	67 (c)	68 (a)	69 (b)	70 (c)	71 (d)	72 (b)	73 (c)	74 (d)	75 (d)
76 (b)	77 (a)	78 (a)	79 (a)	80 (c)	81 (b)	82 (a)	83 (a)	84 (d)	85 (c)
86 (a)	87 (c)								

NCERT & NCERT Exemplar MCQs

88 (a)	89 (c)	90 (b)	91 (a)	92 (a)	93 (a)	94 (b)	95 (b)	96 (b)	97 (b)
98 (b)	99 (d)	100 (b)	101 (c)	102 (a)	103 (a)	104 (a)	105 (a)	106 (a)	107 (a)
108 (a)	109 (a)	110 (b)	111 (c)	112 (b)	113 (c)	114 (d)	115 (c)	116 (a)	117 (b)
118 (b)									

Hints & Explanations

4 (*a*) During pick-up, the car accelerates. This must happen due to a net external force. This is because, the acceleration of the car cannot be accounted for by any internal force. The only conceivable external force along the road is the force of friction. It is the frictional force that accelerates the car as a whole.

5 (*c*) This is because the feet of the passenger comes to rest along with the bus, but the upper part of his body, due to inertia of motion, tends to remain in motion.

6 (*a*) If downward attractive force on the earth stops, the upward self-adjusting force also stops. Due to inertia, the person resists any change to its state of rest. So, the person will remain standing.

7 (*a*) Once the astronaut is out of spaceship, there are no nearby stars to exert gravitational force on him and the small spaceship exert negligible gravitational attraction on him, so the net force acting on the astronaut is zero.

Therefore, net acceleration of the astronaut will be zero.

8 (*b*) When a body gets separated from another moving body, it acquires the velocity of the moving body.

So, when a portion of meteor gets separated, it acquires the velocity of meteor, i.e. 50 kmh^{-1}.

9 (*a*) Since, momentum is directly proportional to mass of the body. Hence when both iron balls are dropped from same height, then bigger ball gain greater momentum than smaller ball at the time of striking the glass pane. Hence, it can transfer greater momentum to the glass pane and so it breaks.

11 (*b*) Given, $m = 1.0 \times 10^4$ kg

As the weight of the man is increased 5 times, so acceleration of the rocket, also increase to 5 times

i.e. $a = 5g = 5 \times 10 = 50\,\text{ms}^{-2}$

Force applied by rocket engine is

$$F = ma = 1.0 \times 10^4 \times 50 = 5 \times 10^5\ \text{N}$$

12 (*b*) Here, $F = kt$

When $t = 0$, linear momentum $= p$

When $t = T$, linear momentum $= 3p$

According to Newton's second law of motion,

applied force, $F = \dfrac{dp}{dt}$

or $\quad dp = F \cdot dt$

or $\quad dp = kt \cdot dt$

Now, integrate both side with proper limit

$$\int_p^{3p} dp = k\int_0^T t\,dt \quad \text{or} \quad [p]_p^{3p} = k\left[\frac{t^2}{2}\right]_0^T$$

or $$(3p - p) = \frac{1}{2}k[T^2 - 0]$$

or $$T^2 = \frac{4p}{k} \quad \text{or} \quad T = 2\sqrt{\frac{p}{k}}$$

13 (*b*) Given, $F = 10\,\text{N}$, $v_i = 0$, $m = 0.5$ kg, $\Delta t = 0.25$ s

$\because$ Change in momentum, $\Delta p = p_f - p_i$ …(i)

Also, $\quad \Delta p = F \cdot \Delta t$ …(ii)

From Eqs. (i) and (ii), we get

$$F \cdot \Delta t = p_f - p_i$$

or $\quad 10\times 0.25 = p_f - mv_i$

$= p_f - 0.5\times 0$

or $\quad p_f = 2.5\text{ N/s}$

14 (*b*) From Newton's second law, $F = n\cdot\left(\dfrac{\Delta p}{\Delta t}\right)$

Here, F = force, n = number of bullets fired per second and $\dfrac{\Delta p}{\Delta t}$ = rate of change of momentum of one bullet.

$$\Rightarrow \quad F = n\left(\frac{mv-0}{\Delta t}\right)$$

Given, $F = 144\text{ N}$, $m = 40\text{ g} = 40\times 10^{-3}$ kg,

$v = 1200\text{ ms}^{-1}$ and $\Delta t = 1\text{ s}$

$$\therefore \quad 144 = n\times\frac{40\times 10^{-3}\times 1200}{1}$$

$$\Rightarrow \quad n = \frac{144}{4\times 12}$$

$$\Rightarrow \quad n = 3$$

15 (*a*) Given, mass of ball, $m = 0.1\text{kg}$

Velocity attained by the ball before hitting the ground,

$$v = \sqrt{2gh}\,(-\hat{\mathbf{j}})$$

$$= \sqrt{2\times 10\times 20}\,(-\hat{\mathbf{j}}) = -20\,\hat{\mathbf{j}}\text{ m/s}$$

Velocity of ball when bounce back to the same height after hitting the ground,

$$v' = -v = -(-20\,\hat{\mathbf{j}}) = 20\,\hat{\mathbf{j}}\text{ m/s}$$

$\therefore$ Change in velocity,

$$\Delta v = v' - v = 20\,\hat{\mathbf{j}} - (-20\,\hat{\mathbf{j}}) = 40\,\hat{\mathbf{j}}\text{ m/s}$$

$\therefore$ Force exerted on the ball,

$$F = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{0.04} \qquad [\text{given, } \Delta t = 0.04\text{ s}]$$

$$= \frac{0.1\times 40\,\hat{\mathbf{j}}}{0.04} = 100\,(\hat{\mathbf{j}})\text{ N}$$

16 (*c*) Given, mass of satellite, $m = 10^4$ kg

$$F = 5\times 10^5\text{ N},\ t = 20\text{ s}, u = 0,\ v = ?$$

Impulse applied on the satellite is equal to the change in momentum.

i.e. $\quad F\cdot t = m(v-u)$

$$5\times 10^5\times 20 = 10^4(v-0)$$

$$\Rightarrow \quad v = \frac{5\times 10^5\times 20}{10^4} = 1000\text{ m/s} = 1\text{ km/s}$$

17 (*c*) From equation of motion, $y = ut + \dfrac{1}{2}at^2 \qquad \ldots\text{(i)}$

where, a is the acceleration.

Given equation, $y = ut + gt^2 = ut + \dfrac{1}{2}\cdot 2gt^2 \qquad \ldots\text{(ii)}$

Comparing Eqs. (i) and (ii), we get

Acceleration, $a = 2g$

Force $= m\times a = m\cdot 2g = 2mg$

18 (*a*) Given, initial velocity, $u = 3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}$

Force, $F = 2\hat{\mathbf{i}} - 3\hat{\mathbf{j}}$

Initial velocity along X-axis and Y-axis are $u_x = 3\text{ms}^{-1}$ and $u_y = 4\text{ ms}^{-1}$, respectively.

Similarly, $F_x = 2\text{ N}$ and $F_y = -3\text{ N}$

If acceleration along X and Y-axes are a_x and a_y, then

$$a_x = \frac{F_x}{m} = \frac{2}{1} = 2\text{ m/s}^2 \qquad [\because F = ma]$$

$$a_y = \frac{F_y}{m} = \frac{-3}{1} = -3\text{ m/s}^2$$

$$s_x = u_x t + \frac{1}{2}a_x t^2 = 3\times 3 + \frac{1}{2}\times 2\times 9 = 18\text{m}$$

$$s_y = u_y t + \frac{1}{2}a_y t^2 = 4\times 3 + \frac{1}{2}\times -3\times 9 = 12 - 13.5$$

$$= -1.5\text{m}$$

So, required x and y-coordinates of point = (18, – 1.5)

19 (*b*) Given, mass of bullet, $m = 0.04$ kg

Initial speed of bullet, $u = 90\text{ ms}^{-1}$

Time, $t = 3$ s

Final velocity of bullet, $v = 0$

If a be the retardation in the bullet in the wooden block, then

From equation of motion, $v = u - at$

$$0 = 90 - a\times 3$$

$$\Rightarrow \quad 3a = 90 \Rightarrow a = 30\text{ m/s}^2$$

$\therefore$ Average resistive force,

$$F = m\cdot a = 0.04\times 30 = 1.2\text{ N}$$

20 (*c*) Given, mass of the particle, $m = 500\text{ g} = 0.5$ kg

***x*- *t* graph** of the particle is a straight line.

Hence, particle is moving with a uniform velocity along X-axis, i.e. its acceleration is zero and hence force acting along X-axis is zero.

***y*-*t* graph** of the particle is curved line.

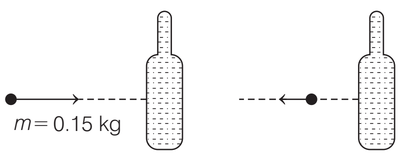
Hence, particle has acceleration along Y-axis.

From equation, $s = ut + \dfrac{1}{2}at^2$

$$4 = 0 + \frac{1}{2}a\cdot 2^2 \Rightarrow a = 2\text{ ms}^{-2}$$

$\therefore$ Force along Y-axis $= m\times a = 0.5\times 2 = 1$ N

21 (*b*) The situation is as depicted below

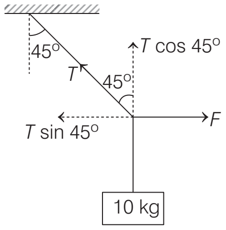


Initial momentum = $mv = 0.15\times 12$ = 1.8 N-s to right

Final momentum = $mv = 0.15\times 12$ = 1.8 N-s to left

$$\text{Impulse} = \text{Change in momentum}$$
$$= \text{Final momentum} - \text{Initial momentum}$$
$$= (1.8 \text{ N-s}) - (-1.8 \text{ N-s})$$
$$= (1.8 \text{ N-s}) + (1.8 \text{ N-s}) = 3.6 \text{ N-s}$$
$$= 3.6 \text{ N-s towards left}$$

22 (*c*) Given situation is as shown below



We resolve tension T in string into vertical and horizontal components.

For equilibrium, $F = T\sin 45°$ ...... (i)

and $Mg = T\cos 45°$ .... (ii)

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{F}{Mg} = \tan 45°$$

or $F = Mg$

$$= 10 \times 10 = 100 \text{ N}$$

23 (*c*) Given, force applied by gun,

$$F = (100 - 0.5 \times 10^5 t) \text{ N}$$

Speed of bullet, $v = 400$ m/s

When $F = 0$, then $100 - 0.5 \times 10^5 t = 0$

$\Rightarrow$ $t = 2 \times 10^{-3}$ s

$$\therefore \text{ Impulse, } I = \int F\,dt = \int_0^{2\times10^{-3}} (100 - 0.5 \times 10^5 t)\,dt$$

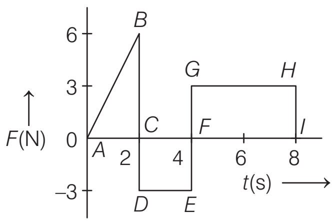
$$= \left[100t - 0.5 \times 10^5 \frac{t^2}{2}\right]_0^{2\times10^{-3}}$$

$$= 100 \times (2 \times 10^{-3} - 0) - \frac{0.5 \times 10^5}{2} \times (4 \times 10^{-6} - 0)$$

$$= 0.2 - 0.1 = 0.1 \text{ N-s}$$

24 (*c*) The area under F-t graph gives change in momentum.

So, for the F-t graph as shown below



For 0 to 2s, Δp_1 = Area under the triangle

$$ABC = \frac{1}{2} \times 2 \times 6 = 6 \text{ kg-ms}^{-1}$$

For 2 to 4s, Δp_2 = Area under the rectangle

$$CFEDC = 2 \times -3 = -6 \text{ kg-ms}^{-1}$$

For 4 to 8s, Δp_3 = Area under the rectangle

$$FIHGF = 4 \times 3 = 12 \text{ kg-ms}^{-1}$$

So, total change in momentum for 0 to 8s,

$$\Delta p_{\text{net}} = \Delta p_1 + \Delta p_2 + \Delta p_3$$
$$= (+6 - 6 + 12) = 12 \text{ kgms}^{-1} = 12 \text{ N-s}$$

25 (*c*) According to figure, radius of semi-circle, $r = 2$

Linear momentum gained = Impulse from 0 to 4 s

= Area enclosed by graph from 0 to 4 s

$$= \frac{\pi r^2}{2} = \frac{\pi(2)^2}{2} = 2\pi \text{ N-s}$$

26 (*d*) Action and reaction force always act on different bodies, because if they work on same body, then net force on the body is zero and there could never be accelerated motion.

So they cannot balance or cancel each other.

Hence, options (a) and (c) are correct.

28 (*d*) Since, action and reaction act in opposite directions on same line, hence angle between them is 180°.

29 (*b*) According to question, 7th coin is under the weight of 5 coins above it.

Hence, reaction of the 7th coin on the 8th coin

= force on the 7th coin due to 8th coin

= weight of 5 coins

$$= 5\,mg = 5 \times 20 \times 10^{-3} \times 10 = 1 \text{ N}$$

$$[\because m = 20 \text{ g} = 20 \times 10^{-3} \text{ kg}]$$

30 (*d*) **Case I** Consider two particles of a system having masses m_1 and m_2 are moving with velocities $\mathbf{v}_1$ and $\mathbf{v}_2$, respectively. Then, total linear momentum of the system

$$\mathbf{p} = m_1 \mathbf{v}_1 + m_2 \mathbf{v}_2 = \mathbf{p}_1 + \mathbf{p}_2$$

If $\mathbf{F}$ is the external force acting on the system, then according to Newton's second law of motion,

$$\mathbf{F} = \frac{d\mathbf{p}}{dt}$$

For an isolated system, $\mathbf{F} = 0 \Rightarrow \dfrac{d\mathbf{p}}{dt} = 0 \Rightarrow \mathbf{p} = \text{constant}$

i.e. $\mathbf{p}_1 + \mathbf{p}_2$ = constant.

Case II Consider two particles of masses m_1 and m_2 moving along a straight line in opposite direction collide to each other, if Δp_1 and Δp_2 be the changes in momenta produced in time Δt, then according to the law of conservation of momentum, if no external force (for isolated system) is applied on the system

$$\Delta p_1 + \Delta p_2 = 0$$

$$\Rightarrow \quad \Delta p_2 = -\Delta p_1$$

$$\Rightarrow \quad \frac{\Delta p_2}{\Delta t} = -\frac{\Delta p_1}{\Delta t}$$

$\Rightarrow$ Force on m_2 = – Force on m_1 $\quad \left[\because F = \dfrac{dp}{dt}\right]$

$$F_2 = -F_1$$

So, in an isolated system, when total momentum of interacting particles is conserved, it follow both, Newton's second and third laws.

Hence, options (b) and (c) are correct.

31 (*b*) Given, mass of the gun, $M = 100\,\text{kg}$

Mass of the ball, $m = 1\,\text{kg}$

Height of the cliff, $h = 500\,\text{m}$

$$g = 10\,\text{ms}^{-2}$$

Time taken by the ball to reach the ground,

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 500\,\text{m}}{10\,\text{ms}^{-2}}} = 10\,\text{s}$$

Horizontal distance covered $= ut$

$\therefore$ $400 = u \times 10$

where, u is the velocity of the ball.

$\Rightarrow$ $u = 40\,\text{ms}^{-1}$

According to law of conservation of linear momentum, initial momentum = final momentum

$$0 = Mv + mu$$

$$v = -\frac{mu}{M} = -\frac{(1\,\text{kg})(40\,\text{ms}^{-1})}{100\,\text{kg}} = -0.4\,\text{ms}^{-1}$$

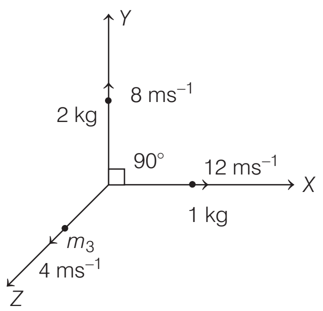
Negative sign shows that the direction of recoil of the gun is opposite to that of the ball.

32 (*b*) From law of conservation of momentum,

we have, $\mathbf{p}_1 + \mathbf{p}_2 + \mathbf{p}_3 = 0$

$m_1\mathbf{v}_1 + m_2\mathbf{v}_2 + \mathbf{p}_3 = 0$ $(\because p = mv)$

From figure given below



$\therefore$ $(1 \times 12\hat{\mathbf{i}}) + (2 \times 8\hat{\mathbf{j}}) + \mathbf{p}_3 = 0$

$\Rightarrow$ $12\hat{\mathbf{i}} + 16\hat{\mathbf{j}} + \mathbf{p}_3 = 0 \Rightarrow \mathbf{p}_3 = -(12\hat{\mathbf{i}} + 16\hat{\mathbf{j}})$

$\therefore$ $p_3 = \sqrt{(12)^2 + (16)^2}$

$= \sqrt{144 + 256} = 20\,\text{kg-ms}^{-1}$

Now, $p_3 = m_3 v_3$

$\Rightarrow$ $m_3 = \dfrac{p_3}{v_3} = \dfrac{20}{4} = 5\,\text{kg}$

33 (*a*) Speed of 200 kg trolley $= \dfrac{36 \times 1000}{60 \times 60} = 10\,\text{ms}^{-1}$

Let v' be the absolute value of velocity of trolley and v_b be the absolute velocity of child after the beginning of journey. Their relative velocity is 4 ms^{-1}.

So, $v' - v_b = 4 \Rightarrow v_b = (v' - 4)$

Momentum before the child begins to run, $p = mv$

Mass of trolley = 200 kg, mass of boy = 20 kg

Total mass of system, $m = (200 + 20)\,\text{kg}$

$\Rightarrow$ $p = (200 + 20) \times 10$

$= 2200\,\text{kg ms}^{-1}$

Momentum after the child starts running

$= 200v' + 20(v' - 4)$

$= 220v' - 80$

Since, no external force is acting on the system, we can apply conservation of linear momentum.

So, $2200 = 220v' - 80$

$220v' = 2280$

$\Rightarrow$ $v' = \dfrac{2280}{220} = 10.36\,\text{ms}^{-1}$

34 (*d*) From the given forces, we can say that first two forces 1 N and 2 N, if are in the same direction, then it would be equal to third force 3 N. But it is given that, all the three forces are in different directions.

So, these is no possibility that these three forces, are in equilibrium.

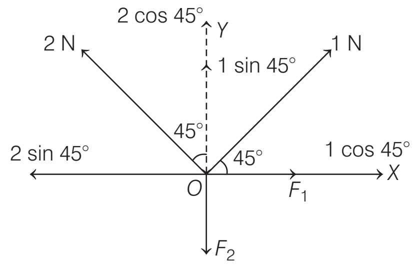
35 (*c*) For stable condition,

$$\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = 0$$

$$(3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}) + (2\hat{\mathbf{i}} - 3\hat{\mathbf{j}}) + \mathbf{F}_3 = 0 \quad \text{(given)}$$

$\Rightarrow$ $\mathbf{F}_3 = -5\hat{\mathbf{i}} + 7\hat{\mathbf{j}}$

36 (*a*) On resolving forces into rectangular components in the given figure as shown below



At equilibrium, $\Sigma F_x = 0$ and $\Sigma F_y = 0$

$\Rightarrow$ $2\cos 45° + \sin 45° = F_2$

and $2\sin 45° = F_1 + \cos 45°$

$\Rightarrow$ $F_1 = 2\sin 45° - \cos 45°$

$= \sqrt{2} - \dfrac{1}{\sqrt{2}}$

$= \dfrac{2-1}{\sqrt{2}} = \dfrac{1}{\sqrt{2}}$

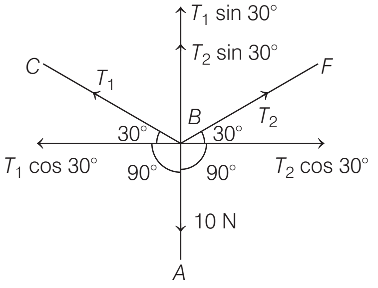
$= 0.707\,\text{N} \simeq 0.7\,\text{N}$

and $F_2 = \sqrt{2} + \dfrac{1}{\sqrt{2}}$

$= \dfrac{2+1}{\sqrt{2}}\,\text{N} = \dfrac{3}{\sqrt{2}}$

$= 2.121\,\text{N} \simeq 2.1\,\text{N}$

37 (*c*) T_1 and T_2 are the tension in the sections BC and BF, then resolution of all forces at B in two perpendicular directions are shown below.



For equilibrium along horizontal direction,

$$T_1 \cos 30° = T_2 \cos 30°$$

Let, $\quad T_1 = T_2 = T$

Again, for equilibrium along vertical direction.

$T_1 \sin 30° + T_2 \sin 30° = 10$

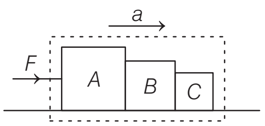
$\Rightarrow \quad 2T \sin 30° = 10$

$$2T \times \frac{1}{2} = 10 \Rightarrow T = 10\,\text{N}$$

So, the tension in both sections BC and BF is 10 N.

38 (*b*) Given, $\quad m_A = 4$ kg,

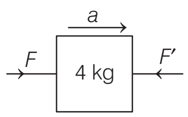
$$m_B = 2\,\text{kg}, m_C = 1\,\text{kg and } F = 14\,\text{N}$$



So, total mass, $M = 4 + 2 + 1 = 7\,\text{kg}$

Now, $\quad F = Ma \Rightarrow 14 = 7a \Rightarrow a = 2\,\text{ms}^{-2}$

FBD of block A,



$$F - F' = 4a$$

$\Rightarrow F' = F - 4a = 14 - 4 \times 2 \Rightarrow F' = 6\,\text{N}$

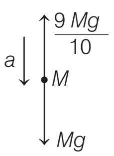
Hence, the contact force between A and B is 6 N.

39 (*a*) Since, all the blocks are moving with constant velocity and we know that, if velocity is constant, acceleration of the body becomes zero.

Hence, the net force on all the blocks will be zero.

40 (*b*) By Newton's third law of motion,

Reaction by floor on mass $M = \dfrac{9Mg}{10}$ (upward)



From figure,

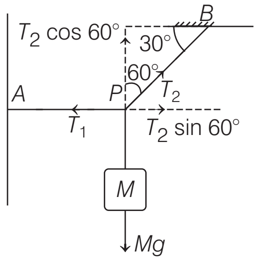
$\mathbf{F}_{\text{net}}$ on cabin of mass M

$$= Mg - \frac{9Mg}{10} = \frac{Mg}{10} \text{ (downward)}$$

By second law, $\dfrac{Mg}{10} = Ma \;\Rightarrow\; a = \dfrac{g}{10}$

41 (*b*) As here is a load at P, so tension in AP and PB will be different as shown in figure. Let these tensions be T_1 and T_2, respectively.

For vertical equilibrium of P,



$$T_2 \cos 60° = Mg$$

i.e. $\quad T_2 = 2\,Mg \quad$ ...(i)

and for horizontal equilibrium of P,

$$T_1 = T_2 \sin 60° = T_2\,(\sqrt{3}/2) \quad \text{...(ii)}$$

Substituting the value of T_2 from Eq. (i), we get

$$T_1 = (2Mg) \times (\sqrt{3}/2) = \sqrt{3}\,Mg$$

42 (*b*) Motion stops when pull due to $m_1 \leq$ force of friction between m and m_2 and surface.

$\Rightarrow \quad m_1 g \leq \mu(m_2 + m)g$

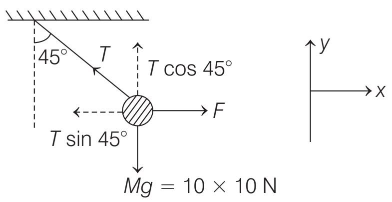
$\Rightarrow \quad 5 \times 10 \leq 0.15(10 + m) \times 10$

$\Rightarrow \quad m \geq 23.33\,\text{kg}$

Here, nearest value is 27.3 kg

So, $\quad m_{\min} = 27.3\,\text{kg}$

43 (*c*) FBD of the given system is follow



Let T = tension in the rope.

For equilibrium condition of the mass,

$\Sigma F_x = 0$ (force in x-direction)

$\Sigma F_y = 0$ (force in y-direction)

When $\Sigma F_x = 0$, then

$\because \quad F = T \sin 45° \quad$ ...(i)

When $\Sigma F_y = 0$, then

$$Mg = T \cos 45° \quad \text{...(ii)}$$

Using Eqs. (i) and (ii),

$$\Rightarrow \quad \frac{F}{Mg} = \frac{T \sin 45°}{T \cos 45°}$$

$$\Rightarrow \quad \frac{F}{Mg} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{\sqrt{2}}} = 1$$

$$\Rightarrow \quad F = Mg = 10 \times 10 = 100\,\text{N}$$

44 (c) Given, $m_1 = 1\,\text{kg}$, $m_2 = 2\text{kg}$, $t = 2\text{s}$ and $g = 10\,\text{ms}^{-2}$

Net force on system $= m_2 g - m_1 g = (m_2 - m_1)g$

Net mass $= (m_1 + m_2)$

$$\therefore \quad a = \frac{\text{Net force}}{\text{Net mass}} = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)g$$

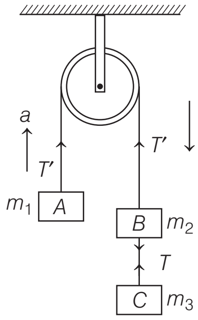
$$= \left(\frac{2-1}{1+2}\right)10 = \frac{10}{3}$$

Distance travelled by 2 kg mass in 2s, $s = \frac{1}{2} \times a \times t^2$

$$= \frac{1}{2} \times \frac{10}{3} \times 4 = \frac{20}{3}\text{ m}$$

45 (c) According to the figure shown,

$$(m_2 + m_3)g - T' = (m_2 + m_3)a \quad \text{...(i)}$$



and $\quad T' - m_1 g = m_1 a \quad$ ...(ii)

Adding Eqs. (i) and (ii), we get

$$a = \left(\frac{m_2 + m_3 - m_1}{m_2 + m_3 + m_1}\right)g \quad \text{...(iii)}$$

Between B and C,

$$m_3 g - T = m_3 a \Rightarrow T = m_3(g - a) \quad \text{...(iv)}$$

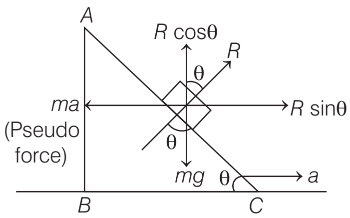
On substituting the value of a from Eqs. (iii) to (iv), we get, the tension between B and C as

$$T = m_3\left[g - \left(\frac{m_2 + m_3 - m_1}{m_2 + m_3 + m_1}\right)g\right] = \frac{2m_1 m_3}{m_1 + m_2 + m_3} \times g$$

Given, $m_1 = m_2 = m_3 = 2\,\text{kg}$ and $g = 9.8\,\text{ms}^{-2}$

$$\Rightarrow \quad T = \frac{2 \times 2 \times 2}{2+2+2} \times 9.8 = 13.3\text{ N}$$

46 (d) According to the question, the FBD of the given condition will be



Since, the wedge is accelerating towards right with a, thus a pseudo force acts in the left direction in order to keep the block stationary. As, the system is in equilibrium.

$$\therefore \quad R \sin\theta = ma \quad \text{...(i)}$$

Similarly, $\quad R\cos\theta = mg \quad$ ...(ii)

Dividing Eq. (i) by Eq (ii), we get

$$\frac{R\sin\theta}{R\cos\theta} = \frac{ma}{mg} \Rightarrow \tan\theta = \frac{a}{g}$$

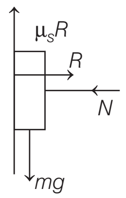
or $\quad a = g\tan\theta$

$\therefore$ The relation between a and g for the block to remain stationary on the wedge is $a = g\tan\theta$.

48 (b) As trolley accelerates forward, a pseudo force called friction acts on the box in reverse direction. It prevent the box to slide in backward direction. But as sliding friction f_s can be increased to a maximum value of μmg. So, maximum acceleration that is possible for the box before it starts sliding $= \frac{f_s}{m} = \mu g$

$= 0.3 \times 10 = 3\text{ms}^{-2}$.

49 (c) The various forces acting on the book are shown in the figure.



At equilibrium,

$$R = N \quad \text{...(i)}$$

$$\mu_s R = mg \quad \text{...(ii)}$$

Given, $m = 10\,\text{kg}$ and $\mu_s = 0.2$

From Eq. (ii), we get

$$0.2R = 10 \times 10$$

$$R = \frac{100}{0.2} = 500\text{N}$$

$\therefore$ Minimum force needed is 500 N.

50 (c) Mass of body A, $m_1 = 5\,\text{kg}$

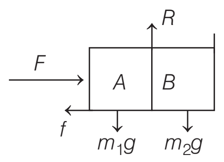
Mass of body B, $m_2 = 10\,\text{kg}$

Coefficient of friction between the bodies and the table,

$$\mu = 0.15$$

Force applied horizontally at A, $F = 200\,\text{N}$

Limiting friction acting to the left as shown below is given by



$$f = \mu R$$

$$= 0.15\,(5 + 10) \times 9.8 = 22.05\text{ N}$$

$$[\because R = (m_1 + m_2)g]$$

$\therefore$ Net force acting on the partition towards the right,

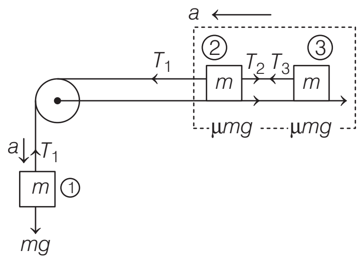
$$F' = F - f = 200 - 22.05 = 177.95\text{ N}$$

According to the Newton's third law of motion,

Reaction of partition = Net force acting on the partition

= 177.95 N (towards the left)

51 (*c*) First of all consider the forces on the blocks as shown below



For the Ist block, $mg - T_1 = m \times a$ ...(i)

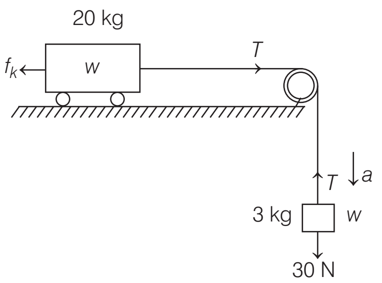
Let us consider 2nd and 3rd block as a system.

So, $T_1 - 2\mu mg = 2m \times a$ ...(ii)

Adding Eqs. (i) and (ii), we get

$$mg(1 - 2\mu) = 3m \times a \Rightarrow a = \frac{g}{3}(1 - 2\mu)$$

52 (*c*) As the string is inextensible and the pulley is smooth, the 3 kg block and the 20 kg trolley both have same magnitude of acceleration *a* as shown below.



Applying second law to the motion of the block in the above figure $30 - T = 3a$ ...(i)

Apply the second law to motion to the trolley,

$$T - f_k = 20\,a$$

Now, $f_k = \mu_k N$

Given, $\mu_k = 0.04$

$N = 20 \times 10 = 200$ N

Thus, the equation for the motion of the trolley is

$$T - 0.04 \times 200 = 20a \Rightarrow T - 8 = 20a \quad \text{...(ii)}$$

Adding Eqs (i) and (ii), we get

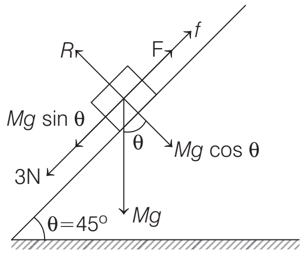
$$a = \frac{22}{23}\text{ ms}^{-2} = 0.96\text{ ms}^{-2}$$

Putting the value of a in Eq. (i), we get

$$T = 30 - 3(0.96) = 27.1\text{ N}$$

Thus, the acceleration of the block and tension in the string is 0.96 ms^{-2} and 27.1 N, respectively.

53 (*a*) Free body diagram, for the given figure is as follows,



For the block to be in equilibrium i.e., so that it does not move downward, then

$$\Sigma f_x = 0$$

$\therefore$ $3 + Mg\sin\theta - F - f = 0$

or $3 + Mg\sin\theta = F + f$

As, frictional force, $f = \mu R$

$\therefore$ $3 + Mg\sin\theta = F + \mu R$ ...(i)

Similarly, $\Sigma f_y = 0$

$$-Mg\cos\theta + R = 0$$

or $Mg\cos\theta = R$ ...(ii)

Substituting the value of 'R' from Eq. (ii) to Eq. (i), we get

$$3 + Mg\sin\theta = \text{F} + \mu(Mg\cos\theta) \quad \text{...(iii)}$$

Here, $M = 10\,\text{kg}, \theta = 45°, g = 10\,\text{m/s}^2$

and $\mu = 0.6$

Substituting these values is Eq. (iii), we get

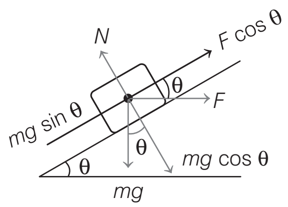
$$3 + (10 \times 10\sin 45°) - (0.6 \times 10 \times 10\cos 45°) = F$$

$$\Rightarrow \quad F = 3 + \frac{100}{\sqrt{2}} - \frac{60}{\sqrt{2}} = 3 + \frac{40}{\sqrt{2}}$$

$$= 3 + 20\sqrt{2} = 31.8\,\text{N} \text{ or } F \simeq 32\,\text{N}$$

54 (*a*) Given, $m = 8$ kg and $\theta = 30°$

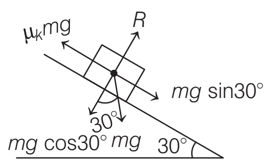
For friction to be minimum, from the diagram below, the component of force should be balanced by the component of weight along the inclined surface.



i.e. $F\cos\theta = mg\sin\theta$

$$\Rightarrow \quad F = mg\tan\theta = 8 \times 10 \times \tan 30° = \frac{80}{\sqrt{3}}$$

55 (*b*) It is given that, a plank with a box on it at one end is gradually raised about the other end. At an angle of inclination 30°, the box starts to slip and slides down 4 m on the plank in 4s as shown in figure.



The coefficient fo static friction,

$$\mu_s = \tan 30° = \frac{1}{\sqrt{3}} = 0.6$$

So, distance covered by a plank, $s = ut + \frac{1}{2}at^2$

Here, $u = 0$, $t = 4$ s and $s = 4$ m

$$\Rightarrow \quad 4 = \frac{1}{2} \times a \times (4)^2$$

$$\Rightarrow \qquad a = \frac{4}{8} = 0.5\,\text{ms}^{-2}$$

From diagram, for motion of block,

$$ma = mg\sin 30° - \mu_k mg$$

where, μ_k = coefficient of kinetic friction.

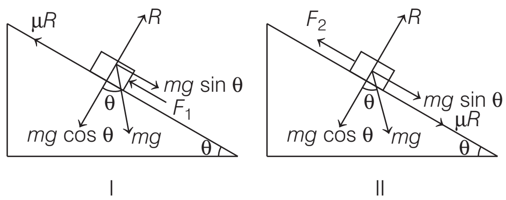
$$\Rightarrow \qquad a = g\sin 30° - \mu_k g$$

$$0.5 = 10 \times \frac{1}{2} - \mu_k \times 10$$

$$\Rightarrow \qquad \mu_k = \frac{5 - 0.5}{10} = 0.45 \simeq 0.5$$

Thus, coefficient of kinetic friction between the box and the plank is 0.5.

56 (c) Forces acting on the body in the two cases are shown below. The only difference is that in the first case (I) force of friction is acting is upward direction and in the second case (II), it is acting in downward direction.



For equilibrium in case I,

$$\mu R + F_1 = mg\sin\theta$$

$$F_1 = mg\sin\theta - \mu R$$

$$= mg\sin\theta - \mu mg\cos\theta \quad [\because R = mg\cos\theta]$$

Similarly, for equilibrium in case II,

$$F_2 = \mu R + mg\sin\theta$$

$$= \mu mg\cos\theta + mg\sin\theta \quad [\because R = mg\cos\theta]$$

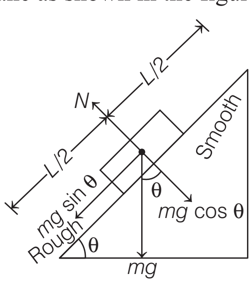
$$\Rightarrow \qquad \frac{F_1}{F_2} = \frac{(mg\sin\theta - \mu mg\cos\theta)}{mg\sin\theta + \mu mg\cos\theta} = \frac{\sin\theta - \mu\cos\theta}{\sin\theta + \mu\cos\theta}$$

Putting $\qquad \mu = \frac{1}{2}\tan\theta$

$$\frac{F_1}{F_2} = \frac{\sin\theta - \frac{1}{2}\sin\theta}{\sin\theta + \frac{1}{2}\sin\theta} = \frac{1 - \frac{1}{2}}{1 + 1/2} = \frac{1}{2} \times \frac{2}{3}$$

$$F_1 : F_2 = 1 : 3$$

57 (c) Let m be the mass of the block and L be the length of the inclined plane as shown in the figure below



Since, initial and final speeds are zero, hence work done by gravitational force

= work done by friction force

$$f_g \cdot L = f_f \cdot \frac{L}{2} \text{ (as only lower half has friction)}$$

here, $f_g = mg\sin\theta$ and $f_f = \mu N = \mu mg\cos\theta$

where, μ = coefficient of friction between block and lower half of the plane.

$$\Rightarrow mg\sin\theta \cdot L = \mu mg\cos\theta \cdot \frac{L}{2}$$

or $$\mu = \frac{mg\sin\theta \cdot L}{mg\cos\theta \cdot \frac{L}{2}} = 2\frac{\sin\theta}{\cos\theta} = 2\tan\theta$$

$$\Rightarrow \qquad \mu = 2\tan\theta$$

58 (a) Given, $m = 2\,\text{kg}$, $r = 10\,\text{m}$ and $v = 5\,\text{ms}^{-1}$

Radial acceleration (centripetal acceleration)

$$= \frac{v^2}{r} = \frac{5 \times 5}{10} = 2.5\,\text{ms}^{-2}$$

Force = Mass × Acceleration = 2 × 2.5 = 5 N

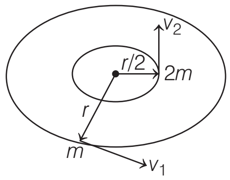
59 (c) Given, $r = 10\,\text{m}$, $v = 5\,\text{ms}^{-1}$ and tangential acceleration, $a_t = 2\,\text{ms}^{-2}$

$$\Rightarrow \text{Radial acceleration, } a_r = \frac{v^2}{r} = \frac{5 \times 5}{10} = 2.5\,\text{ms}^{-2}$$

Net acceleration, $a = \sqrt{a_r^2 + a_t^2} = \sqrt{(2.5)^2 + 2^2}$

$$= \sqrt{10.25} = 3.2\,\text{ms}^{-2}$$

60 (a) The given situation is as shown in figure.



As, the tangential speed of lighter stone is n times that of the value of heavier stone, when they experience same centripetal forces, we get

$$(F_c)_{\text{heavier}} = (F_c)_{\text{lighter}}$$

$$\Rightarrow \qquad \frac{2m(v)^2}{(r/2)} = \frac{m(nv)^2}{r}$$

$$\Rightarrow \qquad n^2 = 4$$

$$\Rightarrow \qquad n = 2$$

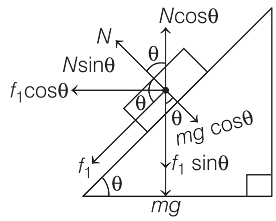
62 (b) For car of mass M moving in circle of radius R, with velocity v, requires a centripetal force which is obtained from friction force ($\mu_s N$) between the tyre of car and road, that satisfies the following condition,

$$\frac{mv^2}{R} \le \mu_s mg \qquad (\because N = mg)$$

$$v \le \sqrt{\mu_s Rg}$$

Thus, when a car is moving along a circle, then its velocity $v \le \sqrt{\mu_s Rg}$, so that it will not move away from the circle.

63 (*a*) According to question, a car is negotiating a curved road of radius R. The road is banked at an angle θ and the coefficient of friction between the tyres of car and the road is μ_s. So, this given situation can be drawn as shown in figure below



Considering the case of vertical equilibrium,

$$N\cos\theta = mg + f_1 \sin\theta$$

$$\Rightarrow \quad mg = N\cos\theta - f_1\sin\theta \quad \ldots(i)$$

Considering the case of horizontal equilibrium,

$$N\sin\theta + f_1\cos\theta = \frac{mv^2}{R} \quad \ldots(ii)$$

Dividing Eq. (ii) by Eq. (i), we get

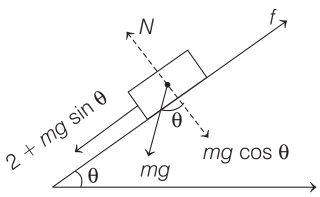
$$\frac{v^2}{gR} = \frac{N\sin\theta + f_1\cos\theta}{N\cos\theta - f_1\sin\theta} = \frac{\sin\theta + \mu_s\cos\theta}{\cos\theta - \mu_s\sin\theta}$$

$$(\because f_1 = \mu_s N)$$

$$\Rightarrow \quad v = \sqrt{gR\left(\frac{\sin\theta + \mu_s\cos\theta}{\cos\theta - \mu_s\sin\theta}\right)}$$

$$= \sqrt{gR\left(\frac{\tan\theta + \mu_s}{1 - \mu_s\tan\theta}\right)}$$

64 (*b*) Block does not move upto a maximum applied force of 2N down the inclined plane.

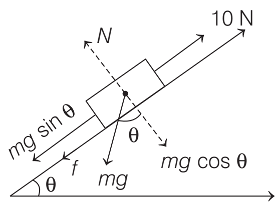


So, equating forces, we have;

$$2 + mg\sin\theta = f$$

$$\text{or} \quad 2 + mg\sin\theta = \mu\, mg\cos\theta \quad \ldots(i)$$

Similarly, block also does not move upto a maximum applied force of 10 N up the plane.



Now, equating forces, we have

$$mg\sin\theta + f = 10\,\text{N}$$

$$\text{or} \quad mg\sin\theta + \mu mg\cos\theta = 10 \quad \ldots(ii)$$

Now, solving Eqs. (i) and (ii), we get

$$mg\sin\theta = 4 \quad \ldots(iii)$$

$$\text{and} \quad \mu\, mg\cos\theta = 6 \quad \ldots(iv)$$

Dividing, Eqs. (iii) and (iv) we get

$$\mu\cot\theta = \frac{3}{2}$$

$$\Rightarrow \quad \mu = \frac{3\tan\theta}{2} = \frac{3\tan 30^\circ}{2} \Rightarrow \mu = \frac{\sqrt{3}}{2}$$

65 (*b*) Given, $\mu_s = 0.2$, $R = 300\,\text{m}$ and $\theta = 15^\circ$

Optimum speed, $v_0 = \sqrt{gR\tan\theta} = \sqrt{9.8 \times 300 \times \tan 15^\circ}$

$$= \sqrt{2940 \times 0.27} = 28.1\ \text{ms}^{-1}$$

and

$$v_{\max} = \sqrt{\frac{gR(\mu_s + \tan 15^\circ)}{1 - \mu_s\tan 15^\circ}}$$

$$= \sqrt{\frac{9.8 \times 300\,(0.2 + 0.27)}{1 - 0.2\,(0.27)}}$$

$$= 38.1\ \text{ms}^{-1}$$

Thus, the optimum speed and maximum permissible speed are 28.1 ms^{-1} and 38.1 ms^{-1}, respectively.

66 (*a*) Aristotle stated that an external force is required to keep a body in motion as it can be observed in our surrounding, i.e. to move a body, we need to push or pull an object. But Aristotle didn't give any reason behind this fact.

The reason behind this fact is that there are a number of opposing forces like frictions, viscosity, etc. are always present in the natural world. To counter these opposing forces, some external force is required to keep a body in motion.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

67 (*c*) A stationary body $(v = 0)$ may still have some acceleration, e.g. when a body is thrown in upward direction, it comes to rest at highest position, but at that time, it still have acceleration equal to acceleration due to gravity g.

Hence, gravitational force is acting at highest position and when a force acts on a body, then its accelerates.

Therefore, Assertion is correct but Reason is incorrect.

68 (*a*) At the microscopic level, all bodies are made up of charged constituents and various contact forces exist between them.

These forces are due to elasticity of bodies, molecular collisions and impacts etc.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

69 (*b*) Force is a vector quantity. Thus, if force is not parallel to the velocity of the body, but makes some angle with it, it changes the component of velocity along the direction of force.

The component of velocity normal to the force remains unchanged, e.g. in projectile motion, horizontal component of velocity does not change under the effect of vertical gravitational force.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

70 (*c*) If force on A by $B = \mathbf{F}_{AB}$ and force on B by $A = \mathbf{F}_{BA}$.

These forces add to give a null force when $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$
Here $\mathbf{F}_{AB}$ and $\mathbf{F}_{BA}$ are internal forces of $(A + B)$ system.

Internal forces in a body do not cancel away as they do not act on the same particle.

Therefore, Assertion is correct but Reason is incorrect.

71 (*d*) According to Newton's third law of motion, it is impossible to have a single force out of mutual interaction between two bodies, whether they are moving or at rest.

It means, third law of motion is applicable to all the bodies either at rest or in motion and this law is also applicable to all types of forces.

Therefore, Assertion is incorrect but Reason is correct.

72 (*b*) Force $= \dfrac{\text{Change in momentum}}{\text{Time interval}} = \dfrac{\Delta p}{\Delta t}$

If time interval is increased, then force decrease (for constant Δp). Therefore, reaction force on the hand is small, i.e. he experience less hurt.
This is what seasoned cricketer does.
New player make Δt small, so force is more, which hurt new player's hand.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

73 (*c*) As we know, momentum, $\mathbf{p} = m\mathbf{v}$

Change in $\mathbf{p}$ can be brought by changing force $\mathbf{F}$ i.e.

As, $\mathbf{F} = \dfrac{d\mathbf{p}}{dt}$ = rate of change of momentum with time.

$$\Rightarrow \quad d\mathbf{p} = \mathbf{F}\,dt$$
$$\Rightarrow \quad md\mathbf{v} = \mathbf{F}dt$$

So, in order to keep, $\mathbf{F}dt$ constant, $md\mathbf{v}$ should be constant, here m and $d\mathbf{v}$ can change from one body to another body.

Thus, same force for same time can cause different change in momentum for different bodies.

Therefore, Assertion is correct but Reason is incorrect.

74 (*d*) It is not always necessary that external agency of force is in contact with the object, while applying force on object.

Force can be applied on a body/particle without contact or with contact, it depends on the agency, applying force. e.g.

Earth pulls (exerts force) from distance. A stone without any physical contact falls due to gravitational pull of the earth.

Therefore, Assertion is incorrect but Reason is correct.

75 (*d*) Dust particles are removed when we beat a carpet with a stick because the carpet is suddenly set into motion, but the dust particles remains at rest due to inertia.

The mangoes fall down, when we shake a mango tree, due to the fact that shaking brings the branches of the tree in motion while mangoes tend to be at rest due to inertia.

Similarly, passengers are in inertia of motion when vehicle is stopped suddenly. So, they fall forward.

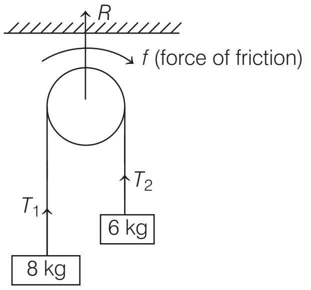
So, all statements are correct for examples of inertia.

76 (*b*) The statement II is incorrect and it be corrected as,

Each body in the assembly experiences the force of gravity.

Rest statement is correct.

77 (*a*) Due to friction, tension at all points on the thread is not alike as shown below.



Here $T_1 - T_2 = f$, also $R = T_1 + T_2$
Given, $\quad T_1 = 8g,\ T_2 = 6g$
$\Rightarrow \quad R = (8+6)g = 14g$
As, $\quad f = T_1 - T_2 = 8g - 6g = 2g = 20\,\text{N}$
So, statement I is correct but II is incorrect.

78 (*a*) When a stone tied with string is rotated in horizontal circle, then centripetal force is required which is given as

$$F = \frac{mv^2}{r}$$
$$\therefore \quad F \propto v^2,\ F \propto \frac{1}{r}$$

From above, it is clear that when stone is rotated with greater speed, then greater force (centripetal force) is required.
Again, when stone is rotated in a circle of smaller radius, greater force is required.
So, statements I and II are correct but III is incorrect.

79 (*a*) Due to inertia, greater force is needed to push the truck than the car, to bring them to the same speed in same time.

Thus, the statement given in option (a) is correct, rest are incorrect.

80 (*c*) The statement given in option (c) is incorrect and it can be corrected as,

When particle moves in a circle even with uniform or constant speed, it faces an external force towards its centre called centripetal force.

This means, in the absence of external force a particle cannot move with uniform speed in a circle.

Rest statements are correct.

81 (*b*) The statement given in option (b) is incorrect and it can be corrected as,

According to Newton's third law of motion, to every action, there is always an equal and opposite reaction.

It clearly shows that exchange of forces happen between the two bodies, i.e. action and reaction does not act on same body.

Rest statements are correct.

82 (*a*) When a person walks on the road, he exerts a force on floor. According to Newton's third law of motion, a reaction force exerts on the person which is being provided by the frictional force.

Thus, the frictional force helps a person to walk on a rough surface.

Thus, the statement given in option (a) is incorrect, rest are correct.

83 (*a*) Friction force or any type of force in nature is always created in pairs. It is ascending to Newton's third law of motion.

But centrifugal force in general is not a reaction force to centripetal force.

This is because, reaction and action force do not act on the same body. Centrifugal force is a pseudo force, which is used when we try to analyse the motion of a body from the frame to rotating body.

Thus, the statement given in option (a) is correct, rest are incorrect.

84 (*d*) The opposing force that comes into play when one body is actually sliding over the surface of the other body is called sliding friction.

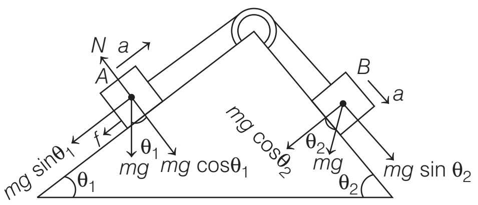
The coefficient of sliding is given as $\mu_S = \dfrac{N}{F_{\text{sliding}}}$

where, N is the normal reaction and F_{sliding} is the sliding force.

As, the dimensions of N and F_{sliding} are same. Thus, μ_S is a dimensionless quantity.

Thus, the statement given in option (d) is incorrect, rest are correct.

85 (*c*) Let A moves up the plane, then B will move downward as shown.



When A just starts moving up

$$mg \sin \theta_1 + f = mg \sin \theta_2$$

where, $f = \mu N = \mu\, mg \cos\theta_1$

$\Rightarrow \quad mg \sin \theta_1 + \mu\, mg \cos \theta_1 = mg \sin \theta_2$

$\Rightarrow \quad \mu = \dfrac{\sin \theta_2 - \sin \theta_1}{\cos\theta_1}$

When A moves upwards,

$$f = mg \sin \theta_2 - mg \sin \theta_1 > 0$$

$\Rightarrow \quad \sin \theta_2 > \sin \theta_1 \Rightarrow \theta_2 > \theta_1$

Thus, the statement given in option (c) is correct, rest are incorrect.

87 (*c*)

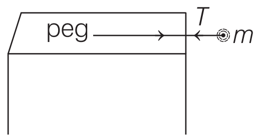
A. Static friction is the frictional force between the surfaces of two objects when they are not in motion with respect to each other. Due to this reason, static friction has the highest value of frictional force and hence μ is highest.

B. Rolling friction takes place when one body rolls over the surface of another body due to which the value of friction is less in case of rolling friction and hence μ is lowest.

C. Kinetic friction takes place when one body slides over the surface of the another body. Value of friction is moderate and lie in between the friction value of rolling and static friction and hence μ is moderate.

Hence, $A \rightarrow 1$, $B \rightarrow 3$ and $C \rightarrow 2$.

88 (*a*) According to question, one end of a string of length l is connected to a particle of mass m and other to a small peg on a smooth horizontal table as shown below.



It is given that tension in the string is T. So, when particle starts moving with speed v in a circle, then the net force on the particle, directed towards its centre is T.

89 (*c*) Given, $m = 20\,\text{kg}$, $v = 15\,\text{ms}^{-1}$ and $F = 50\,\text{N}$

Change in momentum in reversing the velocity

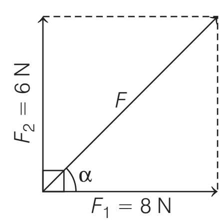
$$= mv - (-mv) = 2mv = 2 \times 20 \times 15 = 600 \text{ units}$$

Impulse of force $= F \times t = 50 \times t$

So, $\quad 50 \times t = 600 \Rightarrow t = \dfrac{600}{50} = 12\text{ s}$

90 (*b*) Mass of the body, $m = 5\,\text{kg}$

Force acting on body, $F_1 = 8\,\text{N}$



and $\quad F_2 = 6\,\text{N}$

Angle between two forces, $\theta = 90°$

Resultant force acting on the body,

$$F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos\theta}$$
$$= \sqrt{(8)^2 + (6)^2 + 2\times 8\times 6\times \cos 90^\circ}$$
$$= \sqrt{64 + 36} = 10\,\text{N} \qquad (\because \cos 90^\circ = 0)$$

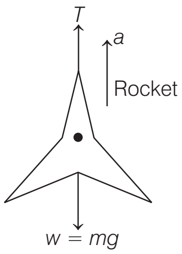
Acceleration, $a = \dfrac{F}{m} = \dfrac{10}{5} = 2\,\text{ms}^{-2}$

$\therefore$ An acceleration of 2 ms^{-2} is acting on a body.

91 (*a*) Initial mass of the rocket, $m = 20000$ kg

Initial acceleration, $a = 5.0\,\text{ms}^{-2}$ in upward direction

Let initial thrust of the blast be T.



$\therefore\ T - mg = ma \Rightarrow T = mg + ma$

$$T = m\times(g + a) = 20000\times(9.8 + 5.0)$$
$$= 2\times 10^4\times 14.8 = 29.6\times 10^4 = 2.96\times 10^5\ \text{N}$$

92 (*a*)

(i) Initial speed of truck, $u = 0$

Acceleration, $a = 2\,\text{ms}^{-2}$ and time, $t = 10$ s

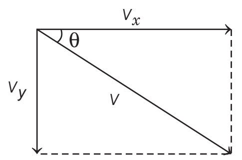
Velocity attained by the truck in 10 s,

$$v = u + at = 0 + 2\times 10 = 20\,\text{ms}^{-1}$$

Horizontal velocity of the stone which remains unchanged, $v_x = 20\,\text{ms}^{-1}$

When stone is dropped from the top of the truck, initial vertical velocity, $u_y = 0$

Velocity attained in vertical direction by the stone in time interval from $t = 10$ s to $t = 11$ s, i.e. in 1 s.



$$v_y = u_y + gt = 0 + 9.8\times 1 = 9.8\,\text{ms}^{-1}$$

$\therefore$ Resultant velocity of the stone,

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(20)^2 + (9.8)^2} = 22.4\,\text{ms}^{-1}$$

(ii) Just after the stone is dropped from the truck, the horizontal force or acceleration acting on stone due to the truck becomes zero ($a_x = 0$) and it falls freely under gravity.

$\therefore$ Acceleration of the stone, $a_y = g = 9.8\,\text{ms}^{-2}$

Thus, the velocity and acceleration of the stone are 22.4 ms^{-1} and 9.8 ms^{-2}, respectively.

93 (*a*) For $0 < t < 4$s, the position-time graph OA is a straight line inclined at an angle from time axis, which is representing uniform motion of the particle, i.e. the particle is moving with a constant speed. Therefore, acceleration and force acting on the particle will be zero.

Impulse at $t = 0$,

$$\text{Impulse} = \text{change in momentum}$$
$$= mv - mu = m(v - u)$$

Before $t = 0$, particle is at rest, hence $u = 0$

After $t = 0$, particle is moving with a constant velocity.

Velocity of the particle = slope of position-time graph.

$$= \frac{3\text{m}}{4\text{s}} = 0.75\,\text{ms}^{-1}$$

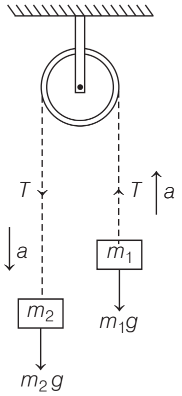
$\therefore$ Impulse = Change in momentum = $4(0.75 - 0)$

$$= 3\,\text{kg-ms}^{-1}$$

94 (*b*) Masses connected at the two ends of a light inextensible string are

$$m_1 = 8\,\text{kg},\ m_2 = 12\,\text{kg}$$

Let T be the tension in the string and masses move with an acceleration a, when released.



For mass m_1,

$$T - m_1 g = m_1 a \qquad \text{...(i)}$$

For mass m_2,

$$m_2 g - T = m_2 a \qquad \text{...(ii)}$$

On adding Eqs. (i) and (ii), we get

$$m_2 g - m_1 g = (m_1 + m_2)\,a$$

$$\therefore \qquad a = \frac{(m_2 - m_1)}{(m_1 + m_2)}\,g \qquad \text{...(iii)}$$

$$= \frac{12 - 8}{12 + 8}\times 10$$

$$= \frac{4}{20}\times 10 = 2\,\text{ms}^{-2}$$

On substituting the value of a in Eq. (i), we get

$$T = m_1 g + m_1 a = m_1\,(g + a)$$
$$= 8\,(10 + 2) = 96\,\text{N}$$

Thus, the acceleration and tension in the string are 2 ms^{-2} and 96 N, respectively.

95 (*b*) Mass of each ball, $m = 0.05$ kg

Speed of each ball, $v = 6\,\text{ms}^{-1}$

Momentum of each ball before collision,

$p_i = mv = 0.05 \times 6 = 0.30\ \text{kg ms}^{-1}$

After collision each ball rebound, therefore momentum of each ball after collision

$$p_f = m(-v) = 0.05 \times (-6) = -0.30\ \text{kg ms}^{-1}$$

Impulse imparted to each ball = Change in its momentum

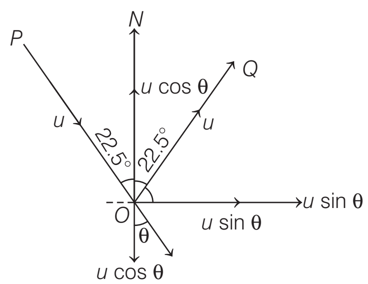
$$= p_f - p_i = -0.30 - (0.30)$$
$$= -0.60\ \text{kg-ms}^{-1}$$

96 (*b*) Mass of the ball, $m = 0.15$ kg

Velocity of the ball, $v = u = 54\ \text{kmh}^{-1}$

$$= 54 \times \frac{5}{18}\ \text{ms}^{-1} \qquad \left(\because 1\ \text{km h}^{-1} = \frac{5}{18}\ \text{ms}^{-1}\right)$$
$$= 15\ \text{ms}^{-1}$$

Let the ball be incident along path *PO* and batsman deflects the ball by an angle of 45° along path *OQ*.



$$\angle PON = \angle NOQ = \frac{45°}{2} = 22.5 = \theta$$

On resolving the initial velocity of the ball along *PO* and final velocity of the ball along *OQ*, into rectangular components. The horizontal component of velocity $u \sin\theta$ remains unchanged while vertical component of velocity is just reversed.

$\therefore$ Impulse imparted to the ball

= Change in linear momentum of the ball

$= mu\cos\theta - (-mu\cos\theta) = 2\,mu\cos\theta$

$= 2 \times 0.15 \times 15 \times \cos 22.5°$

$= 4.5 \times 0.9239\ \text{kg-ms}^{-1} = 4.16\ \text{kg-ms}^{-1}$

97 (*b*) Mass of a stone, $m = 0.25$ kg

Radius of the string, $r = 1.5$ m

Frequency, $\nu = 40\ \text{revmin}^{-1} = \frac{40}{60}\ \text{revs}^{-1} = \frac{2}{3}\ \text{revs}^{-1}$

Centripetal force required for circular motion is obtained from the tension in the string.

$\therefore$ Tension in the string = Centripetal force

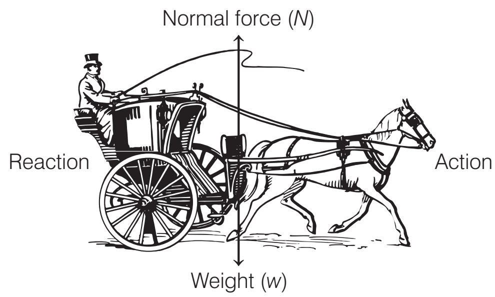
$$T = \frac{mv^2}{r} = \frac{m(r\omega)^2}{r}$$
$$= mr\omega^2 = mr(2\pi\nu)^2 \qquad (\because\ \omega = 2\pi\nu)$$
$$= mr4\pi^2\nu^2$$
$$= 0.25 \times 1.5 \times 4 \times \left(\frac{22}{7}\right)^2 \times \left(\frac{2}{3}\right)^2 = 6.6\ \text{N}$$

Maximum tension which can be withstood by the string

$$T_{\max} = 200\ \text{N}$$
$$\therefore \qquad T_{\max} = \frac{mv_{\max}^2}{r}$$
$$\Rightarrow \qquad v_{\max}^2 = \frac{T_{\max} \times r}{m} = \frac{200 \times 1.5}{0.25} = 1200$$
$$\therefore \qquad v_{\max} = \sqrt{1200} = 34.6\ \text{ms}^{-1}$$

Thus, the tension and maximum speed are 6.6 N and 34.6 ms^{-1}, respectively.

98 (*b*) According to Newton's third law, every action has an equal and reaction. The horse pushes backward on the ground, so the ground pushes forward with an equal force as shown below.



So, for pulling a cart or for running, the horse pushes the earth with its feet and earth makes it move in forward direction. Since in empty space, there is no reaction force, therefore horse cannot run in empty space.

99 (*d*) When we push the lawn mower, a component of our force increase the reaction force of the earth due to which friction force increases considerably. So, it becomes difficult to move the lawn mower.

While is pulling, it reduces the friction, and hence it becomes easier to move the lawn mower.

100 (*b*) Mass of the body, $m = 0.04$ kg

The position-time graph *OA* from $t = 0$ to $t = 2$ s is a straight line, therefore body is moving with a constant velocity.

Velocity of the body, v = Slope of x- t graph

$$= \frac{2-0}{2-0} = 1\ \text{cms}^{-1} = 10^{-2}\ \text{ms}^{-1} \ (\because 1\ \text{cm} = 10^{-2}\ \text{m})$$

Part *AB* of position-time graph is also a straight line, therefore velocity of the body,

$$v' = \frac{0-2}{4-2} = -1\ \text{cms}^{-1} = -10^{-2}\ \text{ms}^{-1}$$

Negative sign shows that the direction of velocity is reversed after 2s and it is being repeated.

Magnitude of the impulse imparted to the ball after every two seconds

$= \text{Change is momentum of the ball}$

$= mv - mv' = m(v - v')$

$= 0.04\,[10^{-2} - (-10^{-2})]$

$= 8 \times 10^{-4}\ \text{kg ms}^{-1}$

101 (*c*) Given, mass of the man, $M = 55\,\text{kg}$

As the man is standing stationary w.r.t. the belt, so

Acceleration of man = Acceleration of belt

$\therefore$ Acceleration of man, $a = 1\,\text{ms}^{-2}$

$\therefore$ Net force on the man,

$$F = Ma = (55\,\text{kg})(1\,\text{ms}^{-2}) = 55\,\text{N}$$

102 (*a*) Speed of the stream of water, $v = 15\,\text{ms}^{-1}$.

Area of cross-section of the tube, $A = 10^{-2}\ \text{m}^2$

Volume of water coming out per second from the tube,

$$V = Av = 10^{-2} \times 15$$
$$= 15 \times 10^{-2}\ \text{m}^3\text{s}^{-1}$$

Density of water $= 10^3\ \text{kgm}^{-3}$

$\therefore$ Mass of the water coming out of the tube per second,

$$m = V \times \rho \qquad \left(\because \text{Density} = \frac{\text{Mass}}{\text{Volume}}\right)$$
$$= 15 \times 10^{-2} \times 10^3\ \text{kg} = 150\,\text{kgs}^{-1}$$

Force exerted on the wall by the impact of water

= Change in momentum per second

$= mv = 150 \times 15 = 2250\ \text{N}$

103 (*a*) (i) Mass of each coin $= m$

Number of total coins $= 10$

(i) Force acting on 7th coin (counted from the bottom)

= weight of the coins above it

= weight of 3 coins

$= 3\,mg$ N (downward)

(ii) Force acting on 7th coin by 8th coin

= weight of the eighth coin + weight of two coin supported by eight coin

$= 3mg$ N (downward)

(iii) Reaction of the sixth coin on the seventh coin

= – (force exerted in sixth coin)

= – (weight of the four coin)

$= -4\,mg$ N (vertically upward)

104 (*a*) Given, $v = 720\,\text{kmh}^{-1} = 720 \times \frac{5}{18}\,\text{ms}^{-1} = 200\,\text{ms}^{-1}$

$$\theta = 15^\circ,\ g = 10\,\text{ms}^{-2}$$

As, $\quad \tan\theta = \dfrac{v^2}{rg}$

$$\therefore \qquad r = \frac{v^2}{\tan\theta g} = \frac{(200\,\text{ms}^{-1})^2}{\tan 15^\circ \times 10\,\text{ms}^{-2}} = \frac{40000}{0.27 \times 10}$$
$$= 14815\,\text{m} = 14.8\,\text{km}$$

105 (*a*) Mass of the block, $m = 25\,\text{kg}$

Mass of the man, $M = 50\,\text{kg}$

Force required to lift the block (F) = Weight of the block

$$F = mg = 25 \times 10 = 250\,\text{N}$$

Weight of the man, $w = Mg = 50 \times 10 = 500\,\text{N}$

Case I If the block is raised by the man as shown in Fig. (i), then force is applied by the man in the upward direction due to which apparent weight of the man increases. Therefore, action on the floor by the man

$$= F + w = 250 + 500 = 750\,\text{N}$$

Case II If the block is raised by the man as shown in Fig. (ii), then force is applied by the man in the downward direction due to which apparent weight of the man decreases. Therefore, action on the floor by the man

$$= mg - F = 500 - 250 = 250\,\text{N}$$

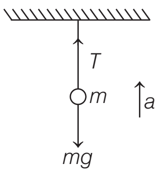
106 (*a*) Mass of the monkey,

$$m = 40\,\text{kg}$$

Maximum tension which can be withstood by the rope,

$$T_{\max} = 600\text{N}$$

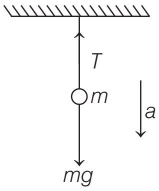
(a) When monkey climbs up with an acceleration, $a = 6\,\text{ms}^{-2}$ as shown, then



$$T - mg = ma$$
$$\Rightarrow \qquad T = mg + ma$$
$$\Rightarrow \qquad T = m(g + a)$$
$$= 40\,(10 + 6) = 640\,\text{N}$$

In this condition $T > T_{\max}$, therefore the rope will break.

(b) When monkey climbs down with an acceleration, $a = 4\ \text{ms}^{-2}$ as shown, then



$$mg - T = ma$$
$$\Rightarrow \qquad T = mg - ma$$
$$= m(g - a)$$
$$= 40\,(10 - 4) = 240\,\text{N}$$

In this condition $T < T_{\max}$, therefore the rope will not break.

(c) When monkey climbs up with a uniform speed of $5\ \text{ms}^{-1}$, then its acceleration a is zero.

$$\therefore \qquad T = mg = 40 \times 10 = 400\ \text{N}$$

In this condition $T < T_{\max}$, therefore the rope will not break.

(d) When monkey falls down freely under gravity, then its acceleration in downward direction is g.

$$\therefore \qquad T = m(g - a)$$
$$= m(g - g) \qquad (\because a = g)$$
$$= 0$$

In this condition, monkey will be in a state of weightlessness and tension in the rope is zero. Therefore, the rope will not break.

Hence, if the acceleration of $6\ \text{ms}^{-2}$, so rope will break.

107 (*a*) Mass of the box, $m = 40\,\text{kg}$

Coefficient of friction between the box and the surface, $\mu = 0.15$

Acceleration of the truck, $a = 2\ \text{ms}^{-2}$.

Force applied by the truck on the box due to its accelerated motion,

$$F = ma = 40 \times 2 = 80\,\text{N}$$

Due to this pseudo force on the box, box tries to move in backward direction, but limiting friction force opposes its motion.

Limiting friction force between the box and the surface, $f = \mu R = \mu mg$

$$f = 0.15 \times 40 \times 9.8 = 58.8\ \text{N}$$

Net force acting on box in backward direction,

$$F' = F - f = 80 - 58.8 = 21.2\,\text{N}$$

Acceleration produced in the box in backward direction,

$$a' = \frac{F'}{m} = \frac{21.2}{40} = 0.53\ \text{ms}^{-2}$$

Using equation of motion for travelling $s = 5\,\text{m}$ to fall off the truck,

$$s = ut + \frac{1}{2}a't^2$$

$$\Rightarrow \quad 5 = 0 \times t + \frac{1}{2} \times 0.53 \times t^2$$

$$\Rightarrow \quad t = \sqrt{\frac{5 \times 2}{0.53}} = \sqrt{\frac{1000}{53}} = 4.34\ \text{s}$$

Distance travelled by the truck in time, $t = 4.34$ s

$$s' = ut + \frac{1}{2}at^2 = 0 \times t + \frac{1}{2} \times 2 \times (4.34)^2$$

$$= (4.34)^2 = 18.84\ \text{m}$$

108 (*a*) Frequency of revolution,

$$\nu = 33\frac{1}{3} = \frac{100}{3}\ \text{revmin}^{-1}$$

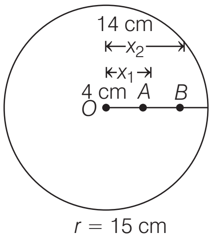
$$= \frac{100}{3 \times 60}\ \text{revs}^{-1} = \frac{5}{9}\ \text{revs}^{-1}$$

$\therefore$ Angular velocity, $\omega = 2\pi\nu$

$$= 2 \times \frac{22}{7} \times \frac{5}{9}$$

$$= \frac{220}{63}\ \text{rads}^{-1}$$

The given situation is as drawn below



Given, radius of the disc, $r = 15\,\text{cm}$

Distance of first coin A from the centre, $x_1 = 4$ cm

Distance of the second coin B from the centre $x_2 = 14$ cm

Coefficient of friction between the coins and the record, $\mu = 0.15$

If force of friction between the coin and the record is sufficient to provide the centripetal force, then coil will revolve with the record.

$\therefore$ To prevent slipping (or to revolve the coin along with record), the force of friction $f \geq$ centripetal force (f_c)

$$\Rightarrow \quad \mu mg \geq mr\omega^2 \quad \text{or} \quad \mu g \geq r\omega^2$$

For first coin A,

$$r\omega^2 = \frac{4}{100} \times \left(\frac{220}{63}\right)^2 = \frac{4 \times 220 \times 220}{100 \times 63 \times 63}$$

$$= 0.488\ \text{ms}^{-2}$$

and $\mu g = 0.15 \times 9.8 = 1.47\ \text{ms}^{-2}$

Here, $\mu g \geq r\omega^2$, therefore this coin will revolve with the record.

For second coin B,

$$r\omega^2 = \frac{14}{100} \times \left(\frac{220}{63}\right)^2 = \frac{14 \times 220 \times 220}{100 \times 63 \times 63} = 1.707\ \text{ms}^{-1}$$

Here, $\mu g < r\omega^2$, therefore centripetal force will not be obtained from the force of friction, hence this coin will not revolve with the record.

109 (*a*) When the motorcyclist is at the uppermost point of the death well, then weight of the cyclist as well as the normal reaction R of the ceiling of the chamber is in downward direction. These forces are balanced by the outward centrifugal force acting on the motorcyclist.

$$\therefore \quad R + mg = \frac{mv^2}{r}$$

where, v = speed of the motorcyclist,

m = mass of (motor cycle + driver)

and r = radius of the death well.

The minimum speed required to perform a vertical loop is given by

weight of the object = centripetal force

$$mg = \frac{mv_{\text{min}}^2}{r}$$

Given, $r = 25\,\text{m}$

$$\therefore \quad v_{\text{min}} = \sqrt{rg} = \sqrt{25 \times 9.8} = 15.65\ \text{ms}^{-1}$$

110 (*b*) Radius of the cylindrical drum, $r = 3\,\text{m}$

Coefficient of friction between the wall and his clothing, $\mu = 0.15$

The normal reaction of the wall on the man acting horizontally provides the required centripetal force.

$$R = mr\omega^2 \qquad \text{...(i)}$$

The frictional force F, acting upwards balances his weight,

i.e. $$F = mg \qquad \text{...(ii)}$$

The man will remain stuck to the wall without slipping, if

$$\mu R \geq F \quad \Rightarrow \quad \mu \times mr\omega_{\min}^2 = mg$$

$$\Rightarrow \qquad \omega_{\min} = \sqrt{\frac{g}{\mu r}} = \sqrt{\frac{10}{0.15 \times 3}}$$

$$= 4.7 \text{ rad s}^{-1}$$

112 (*b*) To solve this question, we have to apply Newton's second law of motion, in terms of force and change in momentum.

We know that, $F = \frac{dp}{dt}$

Given that metre scale is moving with uniform velocity, hence $dp = 0$, then force, $F = 0$.
As all parts of the scale is moving with uniform velocity and total force is zero, hence torque will also be zero.

113 (*c*) Given, $\mathbf{u} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\,\text{ms}^{-1}$ and $\mathbf{v} = -(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\,\text{ms}^{-1}$

Mass of the ball, $m = 150$ g $= 0.15$ kg

$\therefore \quad \Delta\mathbf{p}$ = change in momentum

= Final momentum – Initial momentum

$= m\mathbf{v} - m\mathbf{u} = m(\mathbf{v} - \mathbf{u})$

$= (0.15)[-(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) - (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})]$

$= (0.15)[-6\hat{\mathbf{i}} - 8\hat{\mathbf{j}}]$

$= -(0.15 \times 6\hat{\mathbf{i}} + 0.15 \times 8\hat{\mathbf{j}})$

$= -(0.9\hat{\mathbf{i}} + 1.20\hat{\mathbf{j}})\,\text{kg-ms}^{-1}$

Hence, $\Delta\mathbf{p} = -(0.9\hat{\mathbf{i}} + 1.2\hat{\mathbf{j}})\,\text{kg-ms}^{-1}$

114 (*d*) We know that, for a system

$$F_{\text{ext}} = \frac{dp}{dt} \qquad \text{(from Newton's second law)}$$

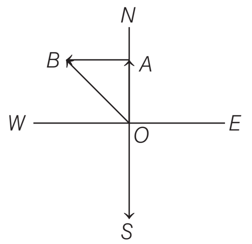
If $\quad F_{\text{ext}} = 0, dp = 0$

$\Rightarrow \quad p$ = constant

Hence, momentum of a system will remain conserve, if external force on the system is zero.

In case of collision between particles, equal and opposite forces will act on individual particles by Newton's third law.
Hence, total force on the system will be zero.

115 (*c*) Consider the adjacent diagram



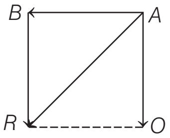
Let, $\mathbf{OA} = \mathbf{p}_1$ = initial momentum of player northward and $\mathbf{AB} = \mathbf{p}_2$ = final momentum of player towards west.

Clearly, $\mathbf{OB} = \mathbf{OA} + \mathbf{AB}$

Change in momentum $= \mathbf{p}_2 - \mathbf{p}_1$

$= \mathbf{AB} - \mathbf{OA} = \mathbf{AB} + (-\mathbf{OA})$

= Clearly resultant AR will be along south-west.



This resultant force is provided by friction, along south-west.

116 (*a*) Given, mass, $m = 2$ kg, $q = 4\,\text{ms}^{-2}$, $p = 3\,\text{ms}^{-1}$ and $r = 5\,\text{ms}^{-3}$

$$x(t) = pt + qt^2 + rt^3$$

$$v = \frac{dx}{dt} = p + 2qt + 3rt^2$$

$$a = \frac{dv}{dt} = 0 + 2q + 6rt$$

At $\quad t = 2\text{s}, \; a = 2q + 6 \times 2 \times r$

$= 2q + 12r$

$= 2 \times 4 + 12 \times 5$

$= 8 + 60 = 68\,\text{ms}^{-1}$

Force, $\quad F = ma = 2 \times 68 = 136\,\text{N}$

117 (*b*) Given, $\quad$ mass, $m = 5$ kg

Acting force, $\mathbf{F} = (-3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\,\text{N}$

Initial velocity at $t = 0$, $\mathbf{u} = (6\hat{\mathbf{i}} - 12\hat{\mathbf{j}})\,\text{ms}^{-1}$

$$\text{Retardation, } \hat{\mathbf{a}} = \frac{\mathbf{F}}{m} = \left(-\frac{3\hat{\mathbf{i}}}{5} + \frac{4\hat{\mathbf{j}}}{5}\right)\text{ms}^{-2}$$

As final velocity is along Y-axis only, its x-component must be zero.
From $v = u + at$, for x-component only,

$$0 = 6\hat{\mathbf{i}} - \frac{3\hat{\mathbf{i}}}{5}t$$

$$t = \frac{5 \times 6}{3} = 10 \text{ s}$$

118 (*b*) Given, mass of the car $= m$

As car starts from rest, $u = 0$

Velocity acquired along east, $v = v\hat{\mathbf{i}}$

Duration, $t = 2$s

We know that, $\quad \mathbf{v} = \mathbf{u} + \mathbf{a}t$

$\Rightarrow \quad v\hat{\mathbf{i}} = 0 + \mathbf{a} \times 2$

$\Rightarrow \quad \mathbf{a} = \frac{v}{2}\hat{\mathbf{i}}$

Force, $\quad \mathbf{F} = m\mathbf{a} = \frac{mv}{2}\hat{\mathbf{i}}$

Therefore, force acting on the car is $\frac{mv}{2}$ towards east.

As external force on the system is only friction, so the force $\frac{mv}{2}$ is by friction on the tyres exerted by the road.