Chapter 5

Laws of Motion

Solutions (Set-1)

SECTION - A

School/Board Exam. Type Questions

Very Short Answer Type Questions :

1. What is the CGS unit of force?

Sol. dyne

2. Is it possible that a moving body may be in equilibrium?

Sol. Yes, when it is moving with uniform velocity.

3. Define one newton.

Sol. One newton is that force which acting on a mass of 1 kg produces in it an acceleration of 1 ms^2 in its direction.

4. Name the principle on which rocket works.

Sol. Newton's third law

5. Two bodies of masses 7 kg and 14 kg have identical size, which body has more inertia?

Sol. A body of mass 14 kg.

6. Sand is thrown on the tracks covered with snow. Why?

Sol. To increase friction

7. Why the vehicles are streamlined?

Sol. To overcome air resistance (fluid friction)

8. Action and reaction forces do not balances each other. Why?

Sol. Because they act on two different bodies.

9. Give an example of a body in equilibrium.

Sol. A pendulum just hanged with a string.

10. What do you mean by rolling friction?

Sol. The opposing force that comes into account when one body actually rolls over the surface of other body is called as rolling friction.

Short Answer Type Questions :

11. If the net force acting on a body is zero, will the body remain necessarily in rest position? Explain.

Sol. No, the body may be in the state of uniform motion along a straight line even when the net force acting on the body is zero. Uniform motion means $a = 0$, $F = ma = 0$.

12. A body of mass 0.3 kg is subjected to a force of $F = -kx$ with $k = 15$ Nm^{-1}. What will be its initial acceleration if it is released from a point 20 cm away from the origin?

Sol. $F = -kx = -15 \times 0.20 = -3$ N

$$a = \frac{F}{m} = \frac{-3}{0.3} = -10 \text{ ms}^{-2}$$

13. What do you mean by resultant force? Give an example where resultant force is zero.

Sol. When two or more forces act on a body simultaneously, then the single force which produces the same effect as produced by all the forces acting together is known as the resultant force.

Example for zero resultant force : When two opposite forces having the same magnitude F act on a block placed on a smooth horizontal table, they fail to move the block as resultant force is zero.

14. Define inertia of rest and give any two of its examples.

Sol. Inertia of rest : It is the property of a body by virtue of which it is unable to change its position of rest unless and until an external force acts on it to do so.

Examples :

(i) When the horse starts suddenly, the rider falls backward due to inertia of rest.

(ii) We hit a carpet with a stick to remove the dust particles due to inertia of rest.

15. Why does a car driver tends to get thrown outward when he takes a sharp turn at a high speed?

Sol. This happens due to inertia of direction. When the car is moving in the straight line, the driver tends to continue in straight line motion. When the unbalanced force is applied by the engine to change the direction of motion of the car, the driver slips to one side of the seat due to the inertia of our body.

16. Write difference between balanced and unbalanced force.

Sol.

Balanced	Unbalanced
(i) Resultant force is zero.	Resultant force is non-zero.
(ii) It may not produce acceleration in body.	It produces acceleration in the body.
(iii) It acts on a body at rest or in uniform velocity.	It always occur on accelerated body.

17. Define inertia of motion. Give its two examples.

Sol. It is the property of the body by virtue of which it is unable to change its uniform motion unless and until an external force acts on it to do so.

Examples :

(i) A man jumping from moving bus falls forward due to inertia of motion.

(ii) An athlete runs some distance, before taking a long jump due to inertia of motion.

18. What force should be applied on a body of mass 100 kg to displace it from rest by 100 m in 10 second?

Sol. Here, u = 0, t = 10 s, s = 100 m

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

$$100 = 0 + \frac{1}{2}a(10)^2$$

$\therefore \quad a = \frac{200}{100} = 2 \text{ m/s}^2$

As $F = ma$

$\therefore \quad F = 100 \times 2 = 200$

$\therefore \quad F = 200$ N

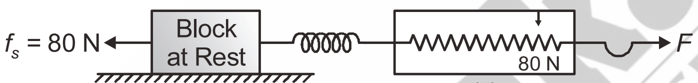
19. Why does a ball thrown upward in a train moving with uniform velocity returns to the thrower?

Sol. This happens because during the upward and downward motion, the ball also moves along horizontal with train due to inertia of motion. Hence, it covers the same horizontal distance as the train does and the ball returns to the thrower.

20. Illustrate the situation in which static friction is a self-adjusting force.

Sol.

(i)

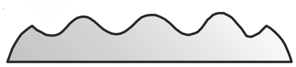


(ii)

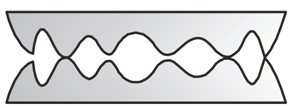
When a block is pulled by some force such that it remains at rest as shown in figure (i). In second case, the block is pulled by some greater force such that the block remains at rest, as shown in figure (ii). This shows that static friction is a self-adjusting force.

21. Discuss friction at atomic level.

Sol. When an apparently plane surface is seen under a powerful microscope its surface is found quite irregular (see the figure). The actual contact area is much smaller than the total surface area (see figure (b)). At these actual points of contact, molecular bonds are formed.



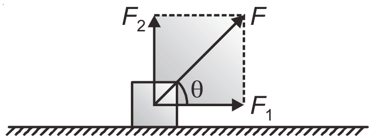
(a)



(b)

When one of the two bodies is pulled over the other, these bonds are broken, the materials are deformed and new bonds are formed. The local deformation sends vibration waves into the bodies. These vibrations finally damp out and the energy appears as heat energy. Lubricating oils prevent the two surfaces from coming into actual contact and hence the friction force is decreased.

22. A body of mass 6.5 kg is acted upon by two perpendicular forces of 12 N and 5 N. Give the magnitude and direction of acceleration of the body.



Sol. $F = \sqrt{F_1^2 + F_2^2} = \sqrt{12^2 + 5^2} = \sqrt{144 + 25}$

$\therefore \quad F = 13$ N

As $F = ma$

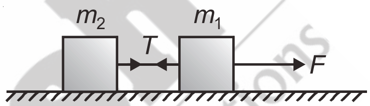
$$\therefore \quad a = \frac{13}{6.5} = 2 \text{ m/s}^2$$

If the force makes angle θ with F_1, then

$$\cos\theta = \frac{F_1}{F} = \frac{12}{13}$$

$$\therefore \quad \theta = \cos^{-1}\left(\frac{12}{13}\right)$$

23. A body of mass m_1 is connected with another body of mass m_2 with a massless string and pulled with force F. Find the acceleration of the system and tension in the string.



Sol. Here, $F - T = m_1 a$ ...(i)

$T = m_2 a$ ...(ii)

Adding (i) and (ii), we get

$F = (m_1 + m_2)a$

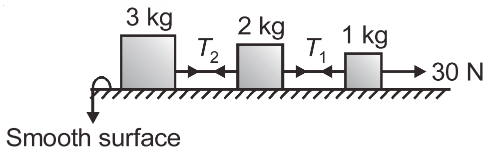
$$\therefore \quad a = \frac{F}{m_1 + m_2} \quad \text{...(iii)}$$

Put the value of (iii) in (ii), we get

$$T = m_2 a = \frac{m_2 F}{m_1 + m_2}$$

$$\therefore \quad T = \frac{m_2 F}{m_1 + m_2}$$

24. Find the value of T_1 and T_2 in the given arrangement.



Sol. $$a = \frac{F}{m_1 + m_2 + m_3}$$

$$\therefore \quad a = \frac{30}{(1 + 2 + 3)} = \frac{30}{6}$$

$\therefore \quad a = 5$ m/s^2

Now, $T_1 = (m_2 + m_3)a$

$\therefore \quad T_1 = (2 + 3)5$

$= 25$ N

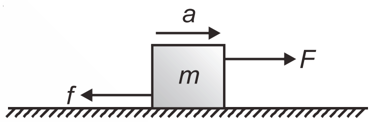
While $T_2 = m_3 a$

$= 3 \times 5$

$= 15$ N

25. What is the frictional force produced by the road if a force of 20 N is given to a block of mass 2 kg produces an acceleration of 5 m/s^2?

Sol. Now, $F - f = ma$



$\therefore \quad 20 - f = 2(5)$

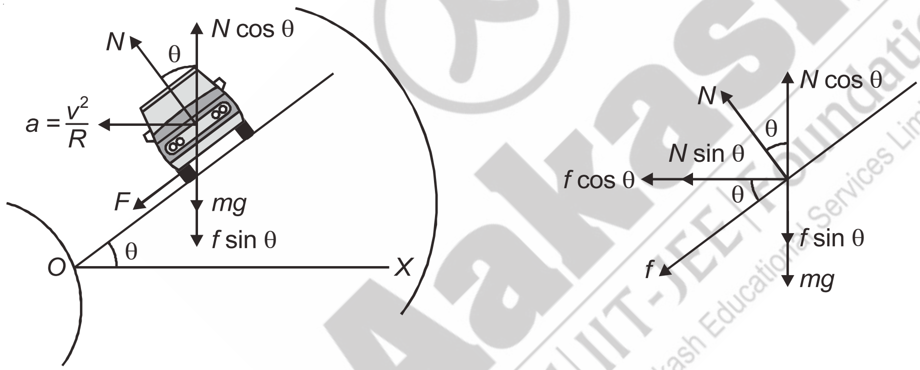
$\therefore \quad f = 20 - 10$

$\therefore \quad f = 10$ N

Hence, the frictional force is 10 N.

26. Draw the free body diagram of a car on a banked road.

Sol.



27. Can a single isolated force exist in nature? Give reason.

Sol. No, according to Newton's third law of motion, to every action, there is always an equal and opposite reaction. So, the forces always exist in pairs. When we talk about a single force, we are first considering only one aspect of the mutual interaction.

28. A bullet of mass 10 g is fired from the gun of mass 1 kg with a speed of 200 m/s. What is the recoil velocity of the gun?

Sol. Here, $m_1 = 10$ g, $m_2 = 1000$ g, $v_1 = 200$ m/s, $v_2 = ?$

As $m_1v_1 + m_2v_2 = 0$

$$\therefore \quad v_2 = \frac{-m_1v_1}{m_2} = \frac{10 \times 200}{1000}$$

$\therefore \quad v_2 = -2$ m/s

Hence, recoil velocity is 2 m/s and negative sign indicates that recoil velocity is in opposite direction to that of the motion of the bullet.

29. The mass of an elevator is 800 kg. Calculate the magnitude of tension produced in the cable of the elevator when

(i) It is stationary.

(ii) It is ascending with an acceleration of 4 ms^{-2}.

(iii) It is descending with same acceleration. (Take g = 10 ms^{-2})

Sol. (i) When elevator is stationary,

$T - mg = 0$

$\therefore \quad T = mg$

$\therefore \quad T = 800 \times 10 = 8000$ N

(ii) When elevator is ascending,

$T - mg = ma$

$\therefore \quad T = mg + ma$

$= m(g + a)$

$= 800(10 + 4)$

$\therefore \quad T = 11{,}200$ N

(iii) When elevator is descending,

$mg - T = ma$

$\therefore \quad T = m(g - a)$

$= 800(10 - 4)$

$= 800 \times 6$

$\therefore \quad T = 4800$ N

30. A rigid body of mass 20 kg is kept on a trolley. The coefficient of friction between the body and the trolley is 0.2. If the trolley starts to move with an acceleration of 1 ms^{-2}, then will the body leave the surface of the trolley? Explain. (Take g = 9.8 ms^{-2})

Sol. Here, $R = mg$

$\therefore \quad R = 20 \times 9.8$

$= 196$ N

Here, the limiting frictional force will be

$f = \mu R$

$= 0.2 \times 196$

$= 39.2$ N

Now, if the body is moving with the trolley with same acceleration as that of trolley, the force on body should be below 39.2 N.

As force on body is

$F = ma$

$= 20 \times 1$

$= 20$ N

Hence, the block will not leave the surface of the trolley.

Long Answer Type Questions :

31. (i) What are impulsive forces? Give two examples.

(ii) How can we measure impulse from force-time graph?

(iii) Write SI unit of impulse.

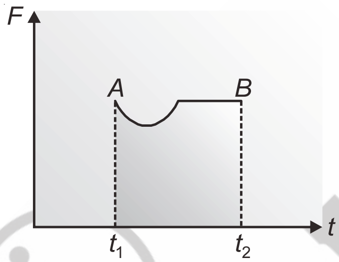
Sol. (i) A large force acting for a short interval of time to produce a large and finite change in momentum is called an impulsive force.

Examples :

(a) A man falls on a concrete floor from some height.

(b) Blow of hammer on a nail.

(ii) The area under the force-time graph *AB* gives the magnitude of the impulse of the given force in the given time interval t_1 to t_2.



(iii) kg ms^{-1}

32. (i) Define one newton and one dyne.

(ii) A bullet penetrates 3 cm in a wooden plank which produces a resistive force to half its velocity. After how much more distance does the resistive force will stop the bullet?

Sol. (i) **One Newton :** It is a force which produces an acceleration of 1 ms^{-2} in a body of mass 1 kg.

One Dyne : It is a force which produces an acceleration of 1 cm s^{-2} in a body of mass 1 g.

(ii) Here, while travelling 3 cm, the resistive force half its velocity. So, the resistive acceleration will be

$$a = \frac{v^2 - u^2}{2s} = \frac{\left(\frac{u}{2}\right)^2 - u^2}{2\times 3\times 10^{-2}}$$

$$\therefore \quad a = \frac{-3u^2}{4\times 2\times 3}\times 10^2$$

$$\therefore \quad a = \frac{-u^2}{8}\times 10^2 \text{ m/s}^2$$

Now, when bullet stops, the resistive force will remain same.

$v^2 = u^2 + 2as$

$$0 = u^2 + 2\left(\frac{-u^2}{8}\times 10^2\right)\times 5$$

$$\therefore \quad s = \frac{-u^2}{\frac{-u^2}{4}\times 10^2}$$

$\therefore \quad s = 4 \times 10^{-2} = 4$ cm

Hence, bullet travels more (4 – 3) cm = 1 cm distance.

33. (i) Define force in terms of acceleration.

(ii) Is it possible a particle acted upon by an unbalanced force is still non-accelerated?

(iii) A force of 20 N produces an acceleration of 4 ms^{-2} in a body of mass m_1 while an acceleration of 10 ms^{-2} in a body of mass m_2. What will be the acceleration if same force is applied when both the bodies are tied together?

Sol. (i) Force is product of mass and an acceleration produced in a body.

(ii) No, it is not possible.

(iii) As $F = ma$

$$\therefore \quad m_1 = \frac{f}{a_1} \text{ and } m_2 = \frac{F}{a_2}$$

$$\therefore \quad m_1 = \frac{20}{4} = 5 \text{ kg}$$

While $m_2 = \frac{20}{10} = 2$ kg

$\therefore \quad m_1 + m_2 = 7$ kg

Again by using,

$F = ma$

$$a = \frac{F}{m_1 + m_2} = \frac{20}{7}$$

$\therefore \quad a = 2.85\ ms^{-2}$

34. Express Newton's second law in component form. Give its significance.

Sol. In rectangular components, force, momentum and acceleration. Vectors may be expressed as

$$\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$$

$$\vec{p} = p_x\hat{i} + p_y\hat{j} + p_z\hat{k}$$

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$

Now, as $\vec{F} = \frac{d\vec{p}}{dt} = m\vec{a}$

$$\therefore \quad F_x\hat{i} + F_y\hat{j} + F_z\hat{k} = \frac{d}{dt}(p_x\hat{i} + p_y\hat{j} + p_z\hat{k})$$

$$= m(a_x\hat{i} + a_y\hat{j} + a_z\hat{k})$$

By equating the components, we get

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

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

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

Significance of component form : It shows that suppose if the applied force makes some angle. With the velocity of the body, it changes the component of velocity along the direction of the force. The component of velocity normal to the force remains unchanged.

35. Forces of $10\sqrt{2}$ N and $5\sqrt{2}$ N are acting on a body of mass $\sqrt{14}$ kg at an angle of 60° to each other. Find the acceleration, distance travelled and the velocity of the mass after 10 s.

Sol. $F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

$\therefore \quad F = \sqrt{(10\sqrt{2})^2 + (5\sqrt{2})^2 + 2\times 10\sqrt{2}\times 5\sqrt{2}\times \cos 60^\circ}$

$\therefore \quad F = \sqrt{100\times 2 + 25\times 2 + 100}$

$\quad = \sqrt{200 + 50 + 100}$

$\therefore \quad F = \sqrt{350} = 5\sqrt{14}$ N

As $a = \dfrac{F}{m}$

$\therefore \quad a = \dfrac{5\sqrt{14}}{\sqrt{14}} = 5\text{ ms}^2$

From equation of motion $s = ut + \frac{1}{2}at^2$, we get

$$s = 0 + \frac{1}{2}\times 5(10)^2 = 250\text{ m}$$

Also, $v = u + at$

$\therefore \quad v = 0 + 5 \times 10 = 50\text{ ms}^{-1}$

36. A ball of mass 100 g falls from a height of 40 m and rebounds to a height of 10 m. What will be the impulse and average force between the ball and the floor if the time during which they are in contact is 0.1 s?

Sol. For downward motion,

$u = 0$, $h = 40$ m, $g = 9.8\text{ ms}^{-2}$

$\therefore \quad v = \sqrt{2gh} = \sqrt{2\times 9.8\times 40}$

$\therefore \quad v = 28\text{ ms}^{-1}$

For upward motion,

$v = 0$, $h = 10$ m, $g = -9.8$ ms^{-2}

$\therefore$ $u^2 = -2gh$

$\therefore$ $u = \sqrt{2 \times 9.8 \times 10} = 14 \text{ ms}^{-1}$

Impulse = Change in momentum = $m(v - u)$

$\therefore$ Impulse = $m(28 - (-14))$

$\therefore$ Impulse = $\frac{100}{1000} \times 42$

= 4.2 kg m/s

Average force = $\frac{\text{Impulse}}{\text{Time}}$

$\therefore$ $f = \frac{4.2}{0.1} = 42 \text{ N}$

37. How does the weight of a person in a elevator will vary if

(i) It moves upward with acceleration a?

(ii) It moves downward with acceleration a?

(iii) It falls freely?

(iv) It is moving with uniform velocity?

(v) It is at rest?

Sol. (i) Here, $T - mg = ma$

$\therefore$ $T = ma + mg$

Apparent weight = $m(a + g)$

So, apparent weight increases.

(ii) Here, $mg - T = ma$

$\therefore$ Apparent weight = $m(g - a)$

So, apparent weight decreases.

(iii) In free fall apparent weight becomes zero.

(iv) In uniform motion, $a = 0$.

So, weight remains same, *i.e.*, $W = mg$.

(v) At rest, $W = mg$, so again weight remains same.

38. (i) What do you mean by isolated system?

(ii) Does the conservation of linear momentum holds good in non-isolated system? Explain.

Sol. (i) Isolated system is a system which is free from any external force, *i.e.*, no external force acts on a system of interacting particles.

(ii) No, conservation of linear momentum holds good only for isolated system, because the external force produces the acceleration which alter the velocity of the particles.

Also as $\vec{F} = \frac{d\vec{p}}{dt}$

So, for $\vec{p}$ to be constant $\vec{F}$ has to be zero.

Hence, when $\vec{F} = 0$

$$\frac{d\vec{p}}{dt} = 0$$

$\therefore$ $\vec{p}$ is constant.

39. A bomb at rest explodes into three fragments of equal masses. Two fragments fly off at right angles to each other with velocities of 5 ms^{-1} and 12 ms^{-1} respectively. Find the speed of the third fragment.

Sol. Here, $\vec{p} = m\vec{v}_1, \vec{p}_2 = m\vec{v}_2, \vec{p}_3 = m\vec{v}_3$

As $\vec{p}_1$ and $\vec{p}_2$ are perpendicular, so the magnitude of their resultant will be

$$p = \sqrt{p_1^2 + p_2^2}$$

$$= \sqrt{(mv_1)^2 + (mv_2)^2}$$

$$= m\sqrt{5^2 + 12^2}$$

= 13 m kg ms^{-1}

By conservation of linear momentum,

$$\vec{p} + \vec{p}_3 = 0$$

$\therefore$ $\vec{p}_3 = -\vec{p}$

$\therefore$ $m\vec{v}_3 = -13\text{ m}$

$\therefore$ $|\vec{v}_3| = |-13|\text{ ms}^{-1}$

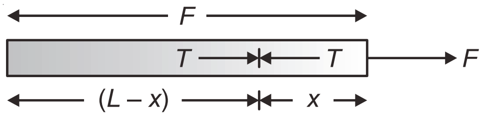
$\therefore$ Speed = 13 ms^{-1}

40. (i) What do you mean by equilibrium of concurrent forces?

(ii) A uniform rope of length *L*, resting on a frictionless horizontal surface is pulled at one end by a force *F*. Find the tension in the rope at a distance *x* from the end where the force is applied.

Sol. (i) When a number of forces acting on a body at a same point and the net force is zero, the body is said to be in equilibrium.

(ii) Let the mass of the uniform rope of length L be M.



Mass per unit length = $\dfrac{M}{L}$

as $a = \dfrac{F}{M}$

Mass of (L – x) length of rope = $M' = \dfrac{M}{L}(L-x)$

As tension T is the only force on the length (L – x) of the rope, so

$$T = M'a = \frac{M}{L}(L-x)\times\frac{F}{M}$$

$$\therefore \quad T = F\left[1-\frac{x}{L}\right]$$

41. (i) Define the two different types of friction when a body moves over a surface.

(ii) A block slides down an incline of 30° with a acceleration of $g/4$. Find the coefficient of kinetic friction.

Sol. (i) **Sliding friction :** It comes into play when one body slides over another body.

Rolling friction : It comes into play when one body rolls over the surface of other body.

(ii) $a = g(\sin\theta - \mu\cos\theta)$

$$\Rightarrow \quad \frac{g}{4} = g(\sin 30^\circ - \mu\cos 30^\circ)$$

$$\Rightarrow \quad \frac{1}{4} = \frac{1}{2} - \frac{\mu\sqrt{3}}{2}$$

$$\Rightarrow \quad \frac{\mu\sqrt{3}}{2} = \frac{1}{4}$$

$$\Rightarrow \quad \mu = \frac{1}{2\sqrt{3}}$$

42. (i) Why does a motorcyclist lean inward when moving along a curved path?

(ii) By how much angle a motorcyclist should lean inwards from the vertical if he goes round a circular track of diameter 125 m with a speed of 90 km/h?

Sol. (i) A motor cyclist bends because the force of friction between the tyres and the road is too small to provide the necessary centripetal force so by bending the horizontal component of the reaction provides the necessary centripetal force.

(ii) $\tan\theta = \dfrac{v^2}{rg}$

where θ is the angle from the vertical.

Now, as $v = 90\times\dfrac{5}{18} = 25\ \text{ms}^{-1}$

and $r = \dfrac{125}{2}$

$\therefore\quad \tan\theta = \dfrac{25\times 25}{\dfrac{125}{2}\times 10}$

$\therefore\quad \theta = 45°$

43. Give some methods of increasing and decreasing friction.

Sol. Methods of increasing friction :

(i) Treading of tyres

(ii) By grooving of shoes

(iii) By putting sand on tracks covered with snow.

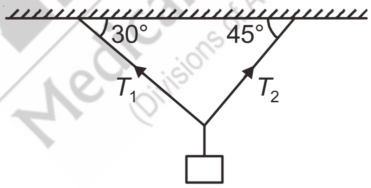
Methods of decreasing friction :

(i) By polishing and greasing

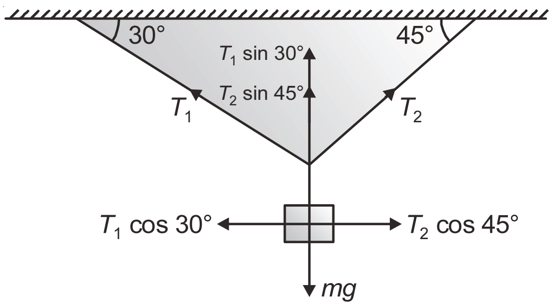
(ii) By streamlining

(iii) By using ball-bearing

44. A body of mass 40 kg is suspended with the help of two strings as shown in the given figure. Find tension T_1 and T_2 in strings.



Sol. FBD of given body will be



In horizontal direction,

$$T_1 \cos 30° = T_2 \cos 45°$$

$$\therefore \quad T_2 = \sqrt{\frac{3}{2}}\, T_1$$

In vertical direction,

$$T_1 \sin 30° + T_2 \sin 45° = mg$$

$$\therefore \quad \frac{T_1}{2} + \sqrt{\frac{3}{2}}\, T_1 \times \frac{1}{\sqrt{2}} = 40 \times 10$$

$$\therefore \quad T_1 = \frac{800}{1+\sqrt{3}} = \frac{800}{2.732}$$

$$\therefore \quad T_1 = 292.82 \text{ N}$$

$$T_2 = \sqrt{\frac{3}{2}} \times 292.82$$

$$= 358.64 \text{ N}$$

45. Why friction is a necessary evil?

Sol. As friction have many advantages and disadvantages, so it is considered as a necessary evil.

Advantages :

(i) We are able to walk.

(ii) Machinery parts rotate through belt and pulley arrangement.

(iii) We are able to write.

Disadvantages :

(i) Wear and tear of the machinery.

(ii) Efficiency of machines decreases.

(iii) Heat produced due to excessive friction in machines damages it.

SECTION - B

Model Test Paper

Very Short Answer Type Questions :

1. Can a body in linear motion be in equilibrium?

Sol. Yes, if the vector sum of the forces acting on it is zero.

2. A boy jumps from the upper story of a house with a load on his back. What is the force of the load on his back when he is in air?

Sol. Zero, as $W = m(g - a) = m(g - g) = 0$

3. A soda water bottle is falling freely. Will the bubbles of the gas rise in the water of the bottle?

Sol. Bubbles will not rise. Water in the bottle is in the state of weightlessness. So, pressure in it does not increase with depth. No upthrust acts on the bubbles, so they do not rise.

4. The distance travelled by a body is directly proportional to time. Is there any external force acting on it?

Sol. $s \propto t$

$s = kt$

$$v = \frac{ds}{dt} = k$$

$$a = \frac{dv}{dt} = 0 \qquad \text{(Body is moving with uniform velocity)}$$

$F = ma = 0$

So, no net external force is acting on it.

5. You can push a brick gently on a smooth floor by applying force with our foot. Our foot gets hurt when we kick the brick. Why?

Sol. When the brick is kicked, time for which force is applied is short, so rate of change of momentum of the brick is large. The brick in turn, applies large force on the foot due to reaction. This force may hurt our foot.

6. Proper inflation of tyres of vehicles saves fuel. Explain.

Sol. When the tyre is properly inflated, the area of contact between the ground and the tyre is reduced. This reduces rolling friction. So, the vehicle covers greater distance for the same quantity of fuel consumed.

7. Is friction a conservative force?

Sol. No, it is a non-conservative force. When direction of motion of a body reverses, the direction of frictional force also reverses. Work has to done against friction both during forward and return journey, *i.e.*, work done against friction along a closed path is not zero, so it is a non-conservative force.

8. Why is it advisable to hold a gun tight to one's shoulder when it is being fired?

Sol. The recoiling gun can hurt the shoulder. When the gun is held tightly against the shoulder, the body and the gun constitutes one system. Total mass becomes large, so the recoil velocity becomes small.

Short Answer Type Questions :

9. Can a single isolated force exist in nature? Give reason.

Sol. No, according to Newton's third law of motion, to every action, there is always an equal and opposite reaction. So, the forces always exist in pairs. When we talk about a single force, we are just considering only one aspect of the mutual interaction.

10. A ball is suspended by a cord from the ceiling of a car. What will be the effect on the position of the ball if

(i) The car moves with uniform velocity?

(ii) The car accelerates?

(iii) The car turns towards left?

Sol. (i) The ball will remain suspended vertically.

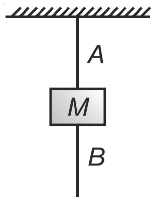
(ii) The ball moves in backward direction.

(iii) The ball moves towards right.

11. Why does Newton's first law of motion appear to be contradicted in our day-to-day life?

Sol. As we roll a ball on the floor, it stops after covering some distance. Motion of the ball is opposed by the force of friction between the ball and the ground and also by air resistance. In the absence of such forces, ball would continue to move.

12. A block of mass M is supported by a cord A from a rigid support, and another cord B is attached to the bottom of the block. If you give a sudden jerk to B, it will break. If you pull on it steadily, A will break. Explain.



Sol. When a sudden jerk is given to B, the upper portion of the system is not able to share the force in short time and the block tends to remain at rest (inertia of rest), so B breaks.

When B is pulled steadily, the force gets sufficient time to reach A which ultimately breaks.

13. A body is dropped from the ceiling of a transparent cabin falling freely towards the earth. Describe the motion of the body as observed by an observer

(i) Sitting in the cabin

(ii) Standing on the earth.

Sol. (i) The body will appear stationary in air.

(ii) The body will appear falling freely under gravity.

14. A man stands in a lift going downward with uniform velocity. He experiences loss of weight at the start but not when the lift is in uniform motion. Explain.

Sol. Apparent weight $R = mg - ma = m(g - a)$. In the start, lift is in acceleration, *i.e.*, $a \neq 0$, so $R < mg$. When lift comes in uniform motion, $a = 0$. So, man experiences his own weight.

15. When brakes are applied to a bicycle, the frictional force provided by the brake shoes is an internal force for the system (bicycle). For retardation, external force must out on the system. The force of friction at the road surface remains the same before and after the brakes are applied (f = mR). How does the bicycle stop?

Sol. When brakes are applied, the wheels are prevented from rolling. During rolling, the friction at the road surface does not cause retardation. When rolling is prevented, wheels have to slip on the road. The friction of the road now causes retardation.

Short Answer Type Questions :

16. Two unequal masses m_1 and m_2 ($m_2 > m_1$) are connected by a string which passes over a frictionless and massless pulley. Find the tension in the string and the acceleration of the masses.

Sol. For body with mass m_2,

$$m_2g - T = m_2a \quad \text{...(i)}$$

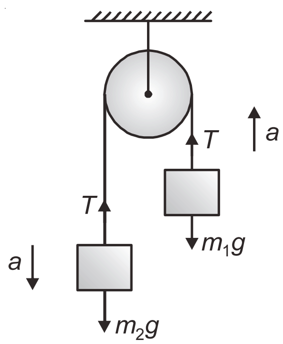
For body with mass m_1,

$$T - m_1g = m_1a \quad \text{...(ii)}$$

All (i) and (ii),

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

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



Put this value in (ii),

$$T - m_1 g = m_1 \times \frac{(m_2 - m_1)g}{m_1 + m_2}$$

$$T_1 = m_1 g\left(1 + \frac{m_2 - m_1}{m_1 + m_2}\right)$$

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

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

17. State Newton's second law of motion. Show that it gives a measure of force. Hence, define 1 N of force.

Sol. The rate of change of momentum of a body is directly proportional to the applied unbalanced external force.

$F = ma$

1 Newton : It is a force which may produce an acceleration of 1 ms^{-2} in a body of mass 1 kg.

18. Find an expression for recoil velocity of a gun.

Sol. Let v_1 = velocity of bullet after firing

v_2 = velocity of gun after firing

m_1 = mass of the bullet

m_2 = mass of the gun

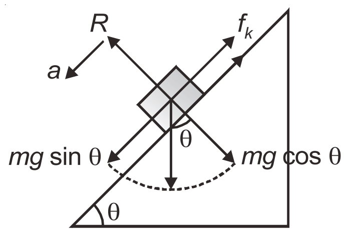
According to the law of conservation of linear momentum,

$m_1 v_1 + m_2 v_2 = 0$

$$\therefore \quad v_2 = \frac{-m_1 v_1}{m_2}$$

19. Obtain an expression for the acceleration of a body sliding down a rough inclined plane.

Sol. When $\tan\theta > \mu_s$ body slips down the plane, the accelerating force on the body,



$F = mg \sin\theta - f_k$

But $f_k = \mu_k R = \mu_k\, mg \cos\theta$

$\therefore \quad ma = mg \sin\theta - \mu_k\, mg \cos\theta$

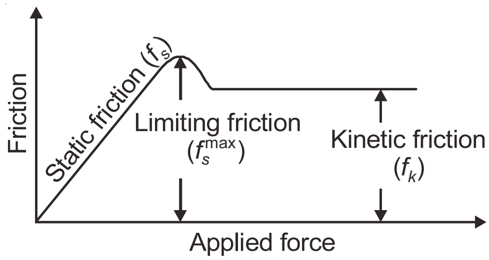
$\therefore \quad a = g(\sin\theta - \mu_k \cos\theta)$

20. Distinguish between static friction, limiting friction and kinetic friction. How do they vary with the applied force, explain by diagram?

Sol. Static friction comes into play between two bodies before one body actually starts moving over the other.

The maximum force of static friction which comes into play when a body just starts moving over the other surface is called limiting friction. While a moving body is acted upon by a kinetic friction.

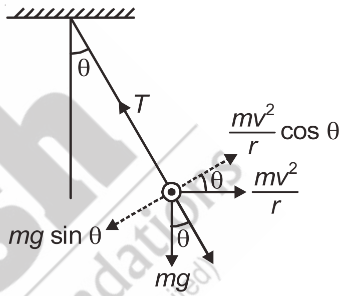
Kinetic friction is always less than the limiting friction



21. An electric bulb suspended from the ceiling of a train by a flexible wire shifts through an angle of 19°48′. When the train goes horizontally round a curved path of radius 200 m. What is the speed of the train?

Sol. Various forces acting on the bulb are shown in figure. Resolving the forces along the length and perpendicular to the wire, we get

$$mg \sin\theta = \frac{mv^2}{r}\cos\theta$$



$$\tan\theta = \frac{v^2}{rg}$$

$$v = \sqrt{rg\tan\theta}$$

$$= \sqrt{200 \times 9.8 \times \tan 19°48'}$$

$$= \sqrt{200 \times 9.8 \times 0.3600}$$

$$= \sqrt{705.6}$$

$$= 26.56 \text{ ms}^{-1}$$

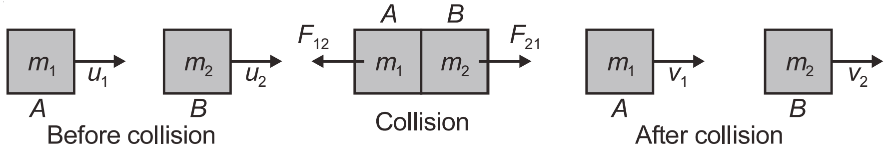
Long Answer Type Questions :

22. State Newton's third law of motion. Derive the law of conservation of momentum from it.

Sol. Newton's third law – "To every action there is an equal and opposite reaction".

According to conservation of linear momentum, if there is no net external force acting on the system, the total momentum remains conserved. In other words, **for an isolated system the initial momentum of the system is equal to the final momentum of the system.**

Consider two objects *A* and *B* of masses m_1 and m_2 moving along the same direction at different velocities $\vec{u}_1$ and $\vec{u}_2$ respectively.



If $|\vec{u}_1| > |\vec{u}_2|$, then they collide and during collision *A* exerts a force $\vec{F}_{21}$ on *B* and simultaneously *B* exerts a force $\vec{F}_{12}$ on, *A*. Let $\vec{v}_1$ and $\vec{v}_2$ are the velocities of two objects *A* and *B* after collision and they are moving along same straight line.

The momentum of *B* before collision,

$$\vec{p}_B = m_2\vec{u}_2$$

The momentum of *B* after collision,

$$\vec{p}\,'_B = m_2\vec{v}_2$$

The rate of change of momentum of *B* is equal to force by *A* on *B* (*i.e.*, F_{21})

$$\therefore \quad \vec{F}_{21} = \frac{m_2\vec{v}_2 - m_2\vec{u}_2}{t} = \frac{m_2(\vec{v}_2 - \vec{u}_2)}{t}$$

Similarly, the rate of change of momentum of *A* is equal to force by *B* on *A* (*i.e.*, F_{12})

$$\therefore \quad \vec{F}_{12} = \frac{m_1(\vec{v}_1 - \vec{u}_1)}{t}$$

According to Newton's third law of motion, the force F_{12} (action) must be equal to F_{21} (reaction).

Therefore, $\vec{F}_{12} = -\vec{F}_{21}$

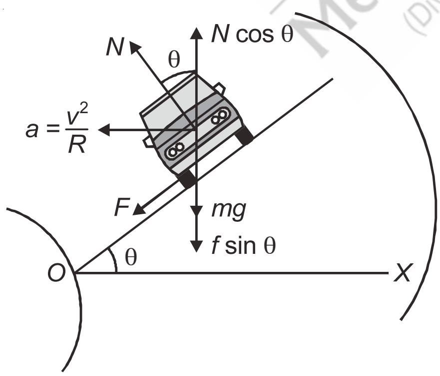
or $$\frac{m_1(\vec{v}_1 - \vec{u}_1)}{t} = -\frac{m_2(\vec{v}_2 - \vec{u}_2)}{t}$$

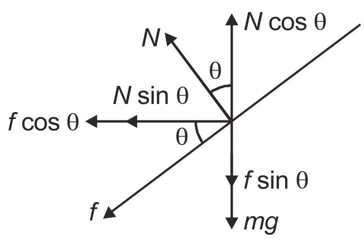
or $$\boxed{m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2}$$

or Total momentum before collision = Total momentum after collision

23. Why are circular roads banked? Deduce an expression for the angle of banking. Draw the free-body diagram. Derive a relation for the optimum velocity of negotiating a curve.

Sol. Motion of a car on a banked road





If we want to increase the maximum possible speed to move on a curved horizontal road, then the road should be banked as shown in the figure (this is the phenomenon of raising outer edge of the curved road above the inner edge) by this we can reduce the contribution of friction to the circular motion of the car.

Now, $N \cos\theta = mg + f \sin\theta$ ...(i) (as there is no acceleration along the vertical direction, which means the net force along vertical direction must be zero)

Centripetal force, $\frac{mv^2}{R}$ provides the horizontal components of N and f.

$$N \sin\theta + f \cos\theta = \frac{mv^2}{R} \quad \text{...(ii)}$$

But as $f \le \mu_s N$

We put $f = \mu_s N$ in (iv) and (v) to get v_{max}.

$$N \cos\theta = mg + \mu_s N \sin\theta \quad \text{...(iii)}$$

and $N \sin\theta + \mu_s N \cos\theta = \frac{mv^2}{R}$ ...(iv)

From (iii),

$$N \cos\theta - \mu_s N \sin\theta = mg$$

$$N = \frac{mg}{\cos\theta - \mu_s \sin\theta} \quad \text{...(v)}$$

Put this value in (iv),

$$\frac{mg(\sin\theta + \mu_s \cos\theta)}{\cos\theta - \mu_s \sin\theta} = \frac{mv_{max}^2}{R}$$

$$\boxed{v_{max} = \left(Rg\,\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}\right)^{1/2}}$$

❑ ❑ ❑

Solutions (Set-2)

Objective Type Questions

(The Law of Inertia Newton's First Law of Motion)

1. An athlete does not come to rest immediately after crossing the winning line due to the

(1) Inertia of rest (2) Inertia of motion

(3) Inertia of direction (4) None of these

Sol. Answer (2)

While running athlete is in the state of motion. So due to inertia of motion athlete does not come to rest.

2. Newton's first law is applicable

(1) In all reference frames (2) Only in inertial reference frames

(3) Only in non-inertial reference frames (4) None of these

Sol. Answer (2)

Newton's law is applicable only in inertial reference frames.

3. When an object is in equilibrium state, then

(1) It must be at rest (2) No force is acting on it

(3) Its net acceleration must be zero (4) All of these

Sol. Answer (3)

Equilibrium $\Rightarrow \vec{F}_{net} = 0$

Using Newton's second law, $\vec{a} = 0$

4. A body of mass 2 kg is sliding with a constant velocity of 4 m/s on a frictionless horizontal table. The force required to keep the body moving with the same velocity is

(1) 8 N (2) 0 N (3) 2×10^4 N (4) $\frac{1}{2}$ N

Sol. Answer (2)

For constant velocity, no force is required so $\vec{F} = 0$

(Newton's Second Law of Motion)

5. From Newton's second law of motion, it can be inferred that

(1) No force is required to move a body uniformly along straight line

(2) Accelerated motion is always due to an external force

(3) Inertial mass of a body is equal to force required per unit acceleration in the body

(4) All of these

Sol. Answer (4)

By Newton's second law

$\vec{F} = m\vec{a}$ …(i)

for (i) Uniform motion means body is moving with constant velocity. By (i) it can be said that only for accelerated motion force is required (2) is true using (i)

(3) Using (i) $\vec{a} = \frac{\vec{F}}{m}$ so this is true

6. If a force of constant magnitude acts in direction perpendicular to the motion of a particle, then its

(1) Speed is uniform (2) Momentum is uniform (3) Velocity is uniform (4) All of these

Sol. Answer (1)

No component of force is in the direction of motion (as $\vec{F} \perp \vec{V}$) so it cannot change the speed of particle. But velocity cannot be constant because force will change the direction of motion.

7. When a force of constant magnitude and a fixed direction acts on a moving object, then its path is

(1) Circular (2) Parabolic (3) Straight line (4) Either (2) or (3)

Sol. Answer (4)

1. To move a particle in circular motion centripetal force is required which has variable direction.
2. Parabolic is possible (example projectile motion)
3. If force is in the direction of motion or just opposite to it, path will be straight line

8. A 10 g bullet moving at 200 m/s stops after penetrating 5 cm of wooden plank. The average force exerted on the bullet will be

(1) 2000 N (2) –2000 N (3) 4000 N (4) –4000 N

Sol. Answer (4)

$m = 10$ g, $u = 200$ m/s, $s = 5$ cm

final velocity $v = 0$

Using $v^2 = u^2 + 2as$

$$a = \frac{u^2}{2s}$$

and for force $F = -ma$ (retarding force)

9. A ball of mass 50 g is dropped from a height of 20 m. A boy on the ground hits the ball vertically upwards with a bat with an average force of 200 N, so that it attains a vertical height of 45 m. The time for which the ball remains in contact with the bat is [Take $g = 10$ m/s^2]

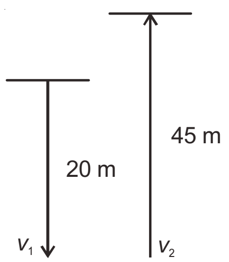
(1) 1/20th of a second (2) 1/40th of a second (3) 1/80th of a second (4) 1/120th of a second

Sol. Answer (3)

Using $v^2 = u^2 + 2as$

$$v_1 = \sqrt{2g\,(20)} = 20 \text{ m/s}$$

$$v_2 = \sqrt{2g(45)} = 30 \text{ m/s}$$



Impulse = $F\Delta t = m(\vec{v}_2 - \vec{v}_1)$

$$\Rightarrow 200\,t = \frac{50}{1000}\,(20 - (-30)$$

$$t = \frac{5}{400} = \frac{1}{80}\text{ s}$$

10. A string tied on a roof can bear a maximum tension of 50 kg wt. The minimum acceleration that can be acquired by a man of 98 kg to descend will be [Take g = 9.8 m/s^2]

(1) 9.8 m/s^2 (2) 4.9 m/s^2 (3) 4.8 m/s^2 (4) 5 m/s^2

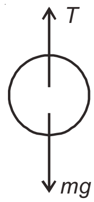
Sol. Answer (3)

T_{max} = 50 g = 50 × 9.8 = 490 N

Using $F_{net} = ma$

98g – 50g = 98a

a = 4.8 m/s^2



11. When a 4 kg rifle is fired, the 10 g bullet receives an acceleration of 3 × 10^6 cm/s^2. The magnitude of the force acting on the rifle (in newton) is

(1) Zero (2) 120 (3) 300 (4) 3000

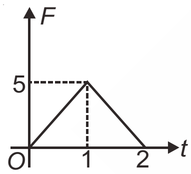
Sol. Answer (3)

Using Newton's third law, bullet will apply the same force in the opposite direction.

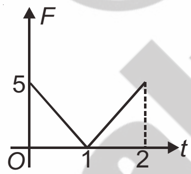
So, using $F = ma$ = $\frac{10}{1000}\times 3\times 10^6\times 10^{-2}$ = 300 N

12. In which of the following graphs, the total change in momentum is zero?

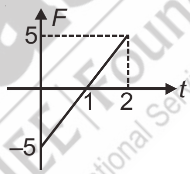
(1)



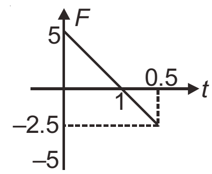
(2)



(3)



(4)



Sol. Answer (3)

Total change in momentum = $\int F.dt$ = Area under Ft curve.

Area above t-axis will be positive and below t-axis will be negative in option (3)

Area $= -\left[\frac{1}{2}\times 5\times 1\right]+\frac{1}{2}\times 5\times 1$ = 0

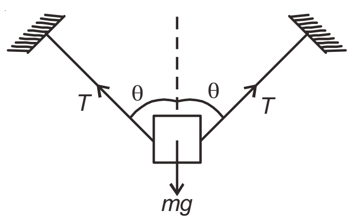
13. A weight Mg is suspended from the middle of a rope whose ends are at the same level. The rope is no longer horizontal. The minimum tension required to completely straighten the rope is

(1) $\frac{Mg}{2}$ (2) $Mg\cos\theta$ (3) $2Mg\cos\theta$ (4) Infinitely large

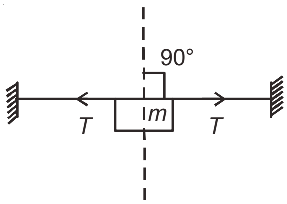
Sol. Answer (4)

$2T\cos\theta = mg$

$T = \frac{mg}{2\cos\theta}$ …(i)



To make this string completely straight

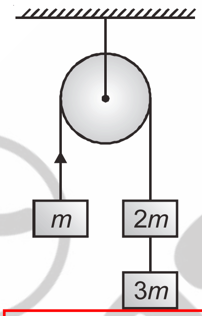


$\theta = 90°$

in (i) put $\theta = 90°$

$$T = \frac{mg}{2\cos 90°} \approx \infty$$

14. In the figure given below, with what acceleration does the block of mass m will move? (Pulley and strings are massless and frictionless)



(1) $\frac{g}{3}$ (2) $\frac{2g}{5}$

(3) $\frac{2g}{3}$ (4) $\frac{g}{2}$

Sol. Answer (3)

For the single pulley system $a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g$

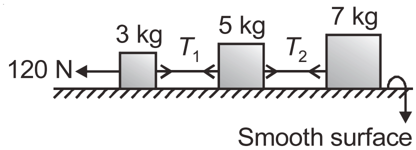
take $2m$ and $3m$ as a system (*i.e.,* single block of $5m$ mass)

$m_1 = 5m$

$m_2 = m$

$$a = \left(\frac{5m - m}{5m + m}\right) g = \frac{2g}{3}$$

15. T_1 and T_2 in the given figure are



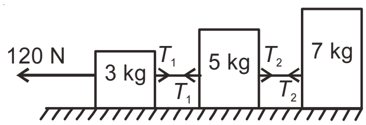
(1) 28 N, 48 N (2) 48 N, 28 N

(3) 96 N, 56 N (4) 56 N, 96 N

Sol. Answer (3)

Acceleration of the system $a = \dfrac{F_{ext}}{M_{Total}} = \dfrac{120}{3+5+7} = 8 \text{ m/s}^2$

Writing equation for 7 kg mass



$T_2 = 7(8)$

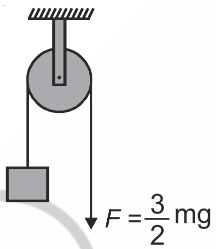
$= 56$ N

Writing equation for 5 kg mass

$T_1 = T_2 + 5\ (a)$

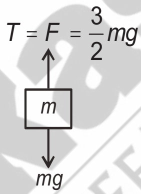
$= 56 + 5\ (8) = 96$ N

16. In the arrangement shown, the mass m will ascend with an acceleration (Pulley and rope are massless)



(1) Zero (2) $\dfrac{g}{2}$ (3) g (4) $2g$

Sol. Answer (2)



$F_{net} = ma$

$\dfrac{3}{2}mg - mg = ma$

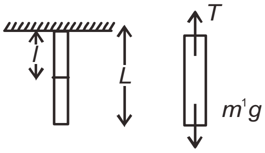
$a = g/2$

17. A uniform rope of mass M and length L is fixed at its upper end vertically from a rigid support. Then the tension in the rope at the distance l from the rigid support is

(1) $Mg\dfrac{L}{L+l}$ (2) $\dfrac{Mg}{L}(L-l)$ (3) Mg (4) $\dfrac{l}{L}Mg$

Sol. Answer (2)

For the lower part



Mass of the lower part is m'

m' = Mass per unit length × length of lower part

$= \dfrac{M}{L}\ (L - l)$

So, Using $\vec{F}_{net} = m\vec{a}$

here $\vec{a} = 0$

$$T - \frac{M}{L}(L - l)\,g = 0$$

$$T = \frac{M}{L}(L - l)\,g$$

18. A man slides down a light rope whose breaking strength is η times the weight of man (η < 1). The maximum acceleration of the man so that the rope just breaks is

(1) $g(1 - \eta)$ (2) $g(1 + \eta)$ (3) $g\eta$ (4) $\frac{g}{\eta}$

Sol. Answer (1)

Given that $T_{max} = \eta\, w$

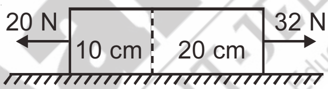
Using $F_{net} = ma$

$$w - T_{max} = \frac{w}{g}a$$

$T_{max} = \eta\, w$

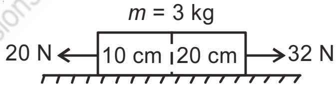
So $a = g(1 - \eta)$

19. Figure shows a uniform rod of length 30 cm having a mass 3.0 kg. The rod is pulled by constant forces of 20 N and 32 N as shown. Find the force exerted by 20 cm part of the rod on the 10 cm part (all surfaces are smooth) is



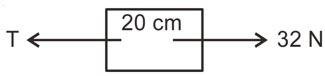
(1) 36 N (2) 12 N (3) 64 N (4) 24 N

Sol. Answer (4)



Acceleration of the system $= \frac{\vec{F}_{net}}{m}$

$$= \frac{32 - 20}{3} = 4\ \text{m/s}^2$$



Free body diagram of 20 cm part

Mass of 20 cm part $m' = \frac{\text{Total mass}}{\text{Total length}} \times (20\text{ cm})$

$$= \frac{3}{30}(20) = 2\text{ kg}$$

Using equation $\vec{F}_{net} = m'a$

$32 - T = 2(4)$

$T = 24$ N

20. In a rocket, fuel burns at the rate of 2 kg/s. This fuel gets ejected from the rocket with a velocity of 80 km/s. Force exerted on the rocket is

(1) 16,000 N (2) 1,60,000 N

(3) 1600 N (4) 16 N

Sol. Answer (2)

For variable mass system $F = \dfrac{u\,dm}{dt} = 80 \times 10^3 \times 2 = 1{,}60{,}000$ N

21. A machine gun fires a bullet of mass 65 g with a velocity of 1300 m/s. The man holding it can exert a maximum force of 169 N on the gun. The number of bullets he can fire per second will be

(1) 1 (2) 2 (3) 3 (4) 4

Sol. Answer (2)

$nmv = F$

n is number of bullets fired per second

$$n\left[\frac{65}{1000}.\,1300\right] = 169$$

$$n = 2$$

22. A balloon has 2 g of air. A small hole is pierced into it. The air comes out with a velocity of 4 m/s. If the balloon shrinks completely in 2.5 s. The average force acting on the balloon is

(1) 0.008 N (2) 0.0032 N

(3) 8 N (4) 3.2 N

Sol. Answer (2)

$$F = \frac{vdm}{dt}$$

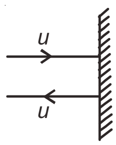
$$= 4\left(\frac{2}{1000 \times 2.5}\right) = 0.0032 \text{ N}$$

23. If n balls hit elastically and normally on a surface per unit time and all balls of mass m are moving with same velocity u, then force on surface is

(1) mun (2) $2\ mun$ (3) $\frac{1}{2}mu^2n$ (4) mu^2n

Sol. Answer (2)

As collision is elastic, velocity after the collision will be – u

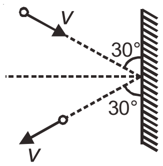


So using $F = \dfrac{dp}{dt}$

$= n\,(mu - (-\,mu)$

$= 2nmu$

24. A particle of mass m strikes a wall with speed v at an angle 30° with the wall elastically as shown in the figure. The magnitude of impulse imparted to the ball by the wall is



(1) mv (2) $\frac{mv}{2}$ (3) $2mv$ (4) $\sqrt{3}\ mv$

Sol. Answer (1)

Impulse = change in momentum

applying equation of change in momentum in horizontal direction

$I = mv\sin30° - (-mv\sin30°)$

$= 2mv\left(\frac{1}{2}\right) = mv$

(Newton's Third Law of Motion Conservation of Momentum)

25. In accordance with Newton's third law of motion

(1) Action and reaction never balance each other

(2) For appearance of action and reaction, physical contact is not necessary

(3) This law is applicable whether the bodies are at rest or they are in motion

(4) All of these

Sol. Answer (4)

(1) Action and reaction act on the different bodies.

(2) Example : Gravitational force, coulomb force

(3) 3rd law is irrespective of the state of motion

26. A bullet of mass 40 g is fired from a gun of mass 10 kg. If velocity of bullet is 400 m/s, then the recoil velocity of the gun will be

(1) 1.6 m/s in the direction of bullet

(2) 1.6 m/s opposite to the direction of bullet

(3) 1.8 m/s in the direction of bullet

(4) 1.8 m/s opposite to the direction of bullet

Sol. Answer (2)

Using conservation of momentum

$P_i = P_f$ …(i)

$P_i = 0$

$P_f = \frac{40}{1000}(400) + 10\,v$

So in (i)

$$0 = \frac{40}{1000}(400) + 10\,v$$

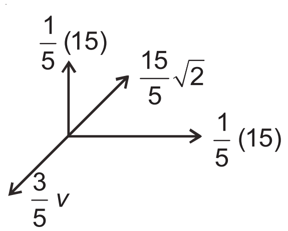
$v = -\,1.6$ m/s

27. A bomb of mass 1 kg initially at rest, explodes and breaks into three fragments of masses in the ratio 1 : 1 : 3. The two pieces of equal mass fly off perpendicular to each other with a speed 15 m/s each. The speed of heavier fragment is

(1) 5 m/s
(2) 15 m/s
(3) 45 m/s
(4) $5\sqrt{2}$ m/s

Sol. Answer (4)

Momentum of the system will be conserved before explosion and after explosion



Using conservation of momentum equation

$$\frac{3}{5}V = \frac{15}{5}\sqrt{2}$$

$$V = 5\sqrt{2}\ \text{m/s}$$

28. A 6 kg bomb at rest explodes into three equal pieces *P*, *Q* and *R*. If *P* flies with speed 30 m/s and *Q* with speed 40 m/s making an angle 90° with the direction of *P*. The angle between the direction of motion of *P* and *R* is about

(1) 143°
(2) 127°
(3) 120°
(4) 150°

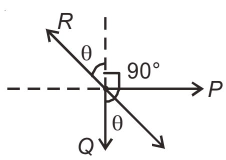
Sol. Answer (2)

$P_p = 30(2) = 60$ kg ms^{-1}

$P_Q = 40\,(2) = 80$ kg ms^{-1}

$$\tan\theta = \frac{60}{80} = 3/4$$

$\theta = 37°$



So angle between *P* and *R* will be 90° + 37° = 127°

29. A particle of mass 2*m* moving with velocity *v* strikes a stationary particle of mass 3*m* and sticks to it. The speed of the system will be

(1) 0.8*v*
(2) 0.2*v*
(3) 0.6*v*
(4) 0.4*v*

Sol. Answer (4)

Collision is completely inelastic using momentum conservation

$2mv + 0 = (2m + 3m)v'$

$v' = \dfrac{2v}{5} = 0.4v$

(Common Forces in Mechanics)

30. A man of mass 50 kg carries a bag of weight 40 N on his shoulder. The force with which the floor pushes up his feet will be

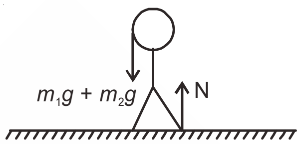
(1) 882 N (2) 530 N (3) 90 N (4) 600 N

Sol. Answer (2)

$N = m_1g + m_2g$

$= 50\,(9.8) + 40$

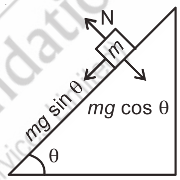
$= 490 + 40 = 530$ N



31. A block of mass m is released on a smooth inclined plane of inclination θ with the horizontal. The force exerted by the plane on the block has a magnitude

(1) mg (2) $\dfrac{mg}{\cos\theta}$ (3) $mg\tan\theta$ (4) $mg\cos\theta$

Sol. Answer (4)



Force enerted by the plane on the block will be N

$N = mg\cos\theta$

32. Which of the following is self-adjusting force?

(1) Static friction (2) Limiting friction

(3) Kinetic friction (4) Rolling friction

Sol. Answer (1)

Static friction is self adjusting force. Its value varies from $0 \le f_s \le \mu_s N$

33. Maximum force of friction is called

(1) Limiting friction (2) Static friction (3) Sliding friction (4) Rolling friction

Sol. Answer (1)

Limiting friction is maximum force of friction.

34. The limiting friction between two bodies in contact is independent of

(1) Nature of the surface in contact

(2) The area of surfaces in contact

(3) Normal reaction between the surfaces

(4) The materials of the bodies

Sol. Answer (2)

35. It is difficult to move a cycle with brakes on because

(1) Rolling friction opposes motion on road

(2) Sliding friction opposes motion on road

(3) Rolling friction is more than sliding friction

(4) Sliding friction is more than the rolling friction

Sol. Answer (4)

Sliding friction > Rolling friction

36. Which is a suitable method to decrease friction?

(1) Polishing (2) Lubrication (3) Ball bearing (4) All of these

Sol. Answer (4)

37. A cubical block rests on a plane of $\mu = \sqrt{3}$. The angle through which the plane be inclined to the horizontal so that the block just slides down will be

(1) 30° (2) 45° (3) 60° (4) 75°

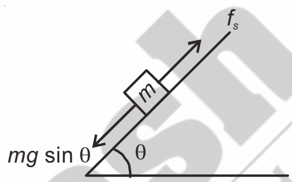
Sol. Answer (3)

$f_s = mg \sin \theta$

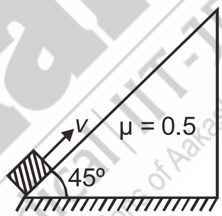
$\mu\, mg \cos \theta = mg \sin \theta$

$\tan \theta = \mu = \sqrt{3}$

$\theta = 60°$



38. A block of mass 1 kg is projected from the lowest point up along the inclined plane. If g = 10 ms^{-2}, the retardation experienced by the block is



(1) $\frac{15}{\sqrt{2}}$ ms^{-2}

(2) $\frac{5}{\sqrt{2}}$ ms^{-2}

(3) $\frac{10}{\sqrt{2}}$ ms^{-2}

(4) Zero

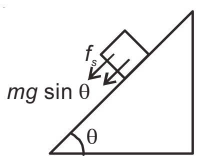
Sol. Answer (1)

Retarding forces will be friction and gravitational force

$a = -(g \sin 45° + \mu\, g \cos 45°)$

$= -\left(\frac{10}{\sqrt{2}} + (0.5)\frac{(10)}{\sqrt{2}}\right)$

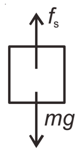
$= \frac{15}{\sqrt{2}}$



39. A child weighing 25 kg slides down a rope hanging from a branch of a tall tree. If the force of friction acting against him is 200 N, the acceleration of child is (g = 10 m/s^2)

(1) 22.5 m/s^2 (2) 8 m/s^2 (3) 5 m/s^2 (4) 2 m/s^2

Sol. Answer (4)



$mg - f_s = ma$

$250 - 200 = 25a$

$a = 2\text{m/s}^2$

40. An object of mass 1 kg moving on a horizontal surface with initial velocity 8 m/s comes to rest after 10s. If one wants to keep the object moving on the same surface with velocity 8 m/s the force required is

(1) 0.4 N (2) 0.8 N (3) 1.2 N (4) Zero

Sol. Answer (2)

To find the frictional force offered by the ground

$v = u + at$

$v = 0$

$0 = 8 - \mu g\,(10)$

$\mu = \dfrac{8}{100} = 0.08$

To move the body with constant velocity on this surface, internal force applied should be equal to friction force $F = \mu mg$

$= (0.08)\,(1)\,(10) = 0.8$ N

41. A heavy box is solid across a rough floor with an initial speed of 4 m/s. It stops moving after 8 seconds. If the average resisting force of friction is 10 N, the mass of the box (in kg) is

(1) 40 (2) 20 (3) 5 (4) 2.5

Sol. Answer (2)

Same like previous question

$\mu = \dfrac{4}{80} = 0.05$

$F = \mu\, mg$

$10 = 0.5m$

$m = 20$ kg

42. If a block moving up an inclined plane at 30° with a velocity of 5 m/s, stops after 0.5 s, then coefficient of friction will be nearly

(1) 0.5 (2) 0.6 (3) 0.9 (4) 1.1

Sol. Answer (2)

Using $v = u + at$

Retardation will be provided by friction as well as gravitational force

$a = \dfrac{u}{t}$

$g \sin 30° + \mu\, g \cos 30° = \dfrac{5}{0.5} = 10$

$\mu = \dfrac{1}{\sqrt{3}} \cong 0.6$

43. A metallic chain 1m long lies on a horizontal surface of a table. The chain starts sliding on the table if 25 cm (or more of it) hangs over the edge of a table. The correct value of the coefficient of friction between the table and the chain is

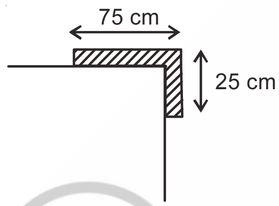
(1) $\frac{1}{3}$

(2) $\frac{2}{3}$

(3) $\frac{1}{4}$

(4) $\frac{1}{5}$

Sol. Answer (1)



$$\frac{M}{4}g = \frac{\mu 3M}{4}g$$

$$\mu = 1/3$$

44. A block of mass m placed on an inclined plane of angle of inclination θ slides down the plane with constant speed. The coefficient of kinetic friction between block and inclined plane is

(1) $\sin\theta$ (2) $\cos\theta$ (3) $\tan\theta$ (4) $\cot\theta$

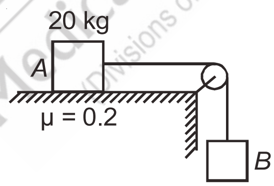
Sol. Answer (3)

Sliding with constant velocity implies that net force acting on the block is zero. So,

$$\mu\, mg \cos\theta = mg \sin\theta$$

$$\mu = \tan\theta$$

45. In the figure shown, the coefficient of static friction between the block A of mass 20 kg and horizontal table is 0.2. What should be the minimum mass of hanging block just beyond which blocks start moving?



(1) 2 kg (2) 3 kg (3) 4 kg (4) 5 kg

Sol. Answer (3)

Tension produced in the string should be just greater than the frictional force acting on the 20 kg block

$T = m_B g$

$T > \mu\, m_A g$

$m_B g > (0.2)\,(20\,(g)$

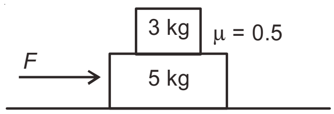
$m_B > 4$ kg

46. Two blocks A and B of masses 5 kg and 3 kg respectively rest on a smooth horizontal surface with B over A. The coefficient of friction between A and B is 0.5. The maximum horizontal force (in kg wt.) that can be applied to A, so that there will be motion of A and B without relative slipping, is

(1) 1.5 (2) 2.5 (3) 4 (4) 5

Sol. Answer (3)

It both are moving together



$$a = \frac{F}{8}$$

For 3 kg block, $f = 3\left(\frac{F}{8}\right)$

$(0.5\ (3)\ g = \frac{3F}{8} \Rightarrow F = 40\text{ N}$

So, $m = 4$ kg

(Equilibrium of a Particle Frame of Reference)

47. When an object is at rest

(1) Force is required to keep it in rest state

(2) No force is acting on it

(3) A large number of forces may be acting on it which balance each other

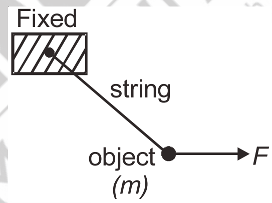
(4) It is in vacuum

Sol. Answer (3)

Object can be at rest only if net force acting on it is zero.

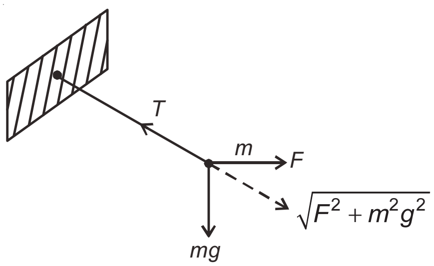
$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 + \dots\dots\dots \vec{F}_n = 0$$

48. In the following figure, the object of mass m is held at rest by a horizontal force as shown. The force exerted by the string on the block is



(1) F (2) mg (3) $F + mg$ (4) $\sqrt{F^2 + m^2g^2}$

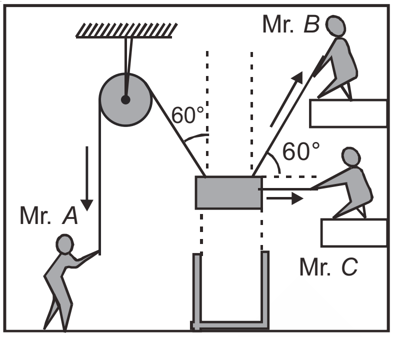
Sol. Answer (4)



For mass m to be at rest, net force on m should be zero

So $T = \sqrt{F^2 + m^2g^2}$

49. Mr. A, B and C are trying to put a heavy piston into a cylinder at a mechanical workshop in railway yard. If they apply forces F_1, F_2 and F_3 respectively on ropes then for which set of forces at that instant, they will be able to perform the said job?



(1) $\sqrt{3}F_1 = F_2 + 2F_3$ (2) $2F_1 = F_2 + F_3$ (3) $2F_2 = \sqrt{3}F_1 - \frac{F_3}{2}$ (4) $F_3 = 2F_1 - \sqrt{3}F_2$

Sol. Answer (1)

Piston is vertically above the cylinder so to drop it inside the cylinder, Net horizontal force must be zero on the piston

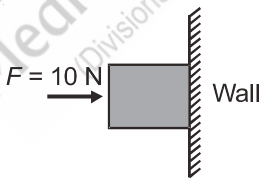
So,

$F_1 \sin 60 = F_2 \cos 60 + F_3$

$$F_1\frac{\sqrt{3}}{2} = \frac{F_2}{2} + F_3$$

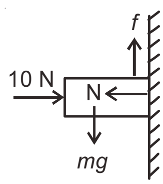
$$\sqrt{3}F_1 = F_2 + 2F_3$$

50. A horizontal force 10 N is necessary to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.2, the weight of the block is



(1) 20 N (2) 50 N (3) 100 N (4) 2 N

Sol. Answer (4)



Normal reaction N = 10 newton

in vertical direction frictional force will balance its weight

$f = mg = W$

$\mu N = (0.2)(10) = 2$ newton

51. A small metallic sphere of mass m is suspended from the ceiling of a car accelerating on a horizontal road with constant acceleration a. The tension in the string attached with metallic sphere is

(1) mg (2) $m(g + a)$ (3) $m(g - a)$ (4) $m\sqrt{g^2 + a^2}$

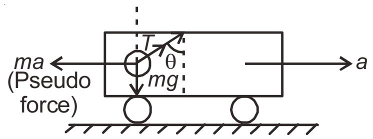
Sol. Answer (4)

$T \cos\theta = mg$ ...(i)

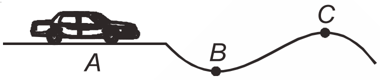
$T \sin\theta = ma$ ...(ii)

Square and add (i) and (ii)

$T = m\sqrt{a^2 + g^2}$



52. A vehicle is moving on a track with constant speed as shown in figure. The apparent weight of the vehicle is



(1) Maximum at A (2) Maximum at B
(3) Maximum at C (4) Same at A, B and C

Sol. Answer (2)

at A $N = mg$

at B $N - mg = \dfrac{mv^2}{r}$

$N = mg + \dfrac{mv^2}{r}$

at C $mg - N = \dfrac{mv^2}{r}$

$N = mg - \dfrac{mv^2}{r}$

So, at B, N is maximum. Hence apparent weight of the vechicle is maximum at B

(Circular Motion Solving Problems in Mechanics)

53. A cyclist riding the bicycle at a speed of $14\sqrt{3}$ m/s takes a turn around a circular road of radius $20\sqrt{3}$ m without skidding. What is his inclination to the vertical?

(1) 30° (2) 45° (3) 60° (4) 75°

Sol. Answer (3)

$\tan\theta = \dfrac{v^2}{rg}$

$= \dfrac{14\times14\times3}{20\sqrt{3}\times10} \simeq \sqrt{3}$

$\theta = 60°$

54. A bus turns a slippery road having coefficient of friction of 0.5 with a speed of 10 m/s. The minimum radius of the arc in which bus turns is [Take g = 10 m/s^2]

(1) 4 m (2) 10 m
(3) 15 m (4) 20 m

Sol. Answer (4)

$$\frac{v^2}{r} = \mu g$$

$$\frac{10 \times 10}{r} = 0.5 \times 10$$

$$r = 20 \text{ m}$$

55. A car is moving on a horizontal circular track of radius 0.2 km with a constant speed. If coefficient of friction between tyres of car and road is 0.45, then maximum speed of car may be [Take g = 10 m/s^2]

(1) 15 m/s

(2) 30 m/s

(3) 20 m/s

(4) 40 m/s

Sol. Answer (2)

$$\frac{v^2}{r} = \mu g$$

$$\frac{v^2}{0.2 \times 10^3} = 4.5$$

$$v = \sqrt{900} = 30 \text{ m/s}$$

56. A boy is sitting on the horizontal platform of a joy wheel at a distance of 5 m from the center. The wheel begins to rotate and when the angular speed exceeds 1 rad/s, the boy just slips. The coefficient of friction between the boy and the wheel is (g = 10 m/s^2)

(1) 0.5 (2) 0.32 (3) 0.71 (4) 0.2

Sol. Answer (1)

$$\frac{v^2}{r} = \omega^2 r = \mu\, g$$

$$m = 0.5$$

57. A train is running at 20 m/s on a railway line with radius of curvature 40,000 metres. The distance between the two rails is 1.5 metres. For safe running of train the elevation of outer rail over the inner rail is (g = 10 m/s^2)

(1) 2.0 mm

(2) 1.75 mm

(3) 1.50 mm

(4) 1.25 mm

Sol. Answer (3)

$$\tan\theta = \frac{h}{d} = \frac{v^2}{rg}$$

$$h = \frac{(1.5)(20)(20)}{40{,}000 \times 10}$$

$$= 1.5 \text{ mm}$$

58. A car is moving on a horizontal circular road of radius 0.1 km with constant speed. If coefficient of friction between tyres of car and road is 0.4, then speed of car may be (g = 10 m/s^2)

(1) 5 m/s
(2) 10 m/s
(3) 20 m/s
(4) All of these

Sol. Answer (4)

Maximum speed for the circular road

$$\frac{v_{\text{maximum}}^2}{r} = \mu g$$

$$V_{\text{maximum}} = \sqrt{\mu r g}$$

$$= \sqrt{0.4 \times 100 \times 10} = \sqrt{400} = 20 \text{ m/s}$$

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