Chapter Five

LAWS OF MOTION



MCQ I

- **5.1** 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.
- **5.2** 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.

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- (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.
- **5.3** A cricket ball of mass 150 g has an initial velocity $\mathbf{u} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \,\mathrm{m \, s^{-1}}$ and a final velocity $\mathbf{v} = -(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \,\mathrm{m \, s^{-1}}$ after being hit. The change in momentum (final momentum-initial momentum) is (in kg m s¹)
 - (a) zero
 - (b) $-(0.45\hat{\mathbf{i}} + 0.6\hat{\mathbf{j}})$
 - (c) $-(0.9\hat{i} + 1.2\hat{j})$
 - (d) $-5(\hat{\mathbf{i}} + \hat{\mathbf{j}})$.
- **5.4** In the previous problem (5.3), the magnitude of the momentum transferred during the hit is
 - (a) Zero (b) 0.75 kg m s^{-1} (c) 1.5 kg m s^{-1} (d) 14 kg m s^{-1} .
- **5.5** 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 law.
- **5.6** 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.
- **5.7** A body of mass 2kg travels according to the law $x(t) = pt + qt^2 + rt^3$ where $p = 3 \,\mathrm{m \, s^{-1}}$, $q = 4 \,\mathrm{m \, s^{-2}}$ and $r = 5 \,\mathrm{m \, s^{-3}}$.

The force acting on the body at t = 2 seconds is

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

- **5.8** 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 $\mathbf{v} = (6\hat{\mathbf{i}} 12\hat{\mathbf{j}})$ m s⁻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
- **5.9** A car of mass m starts from rest and acquires a velocity along east $\mathbf{v} = v \,\hat{\mathbf{i}} \, (v > 0)$ in two seconds. 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.

MCQ II

- **5.10** The motion of a particle of mass m is given by x = 0 for t < 0 s, $x(t) = A \sin 4p t$ for 0 < t < (1/4) s (A > 0), and x = 0 for t > (1/4) s. Which of the following statements is true?
 - (a) The force at t = (1/8) s on the particle is $-16\pi^2 A$ m.
 - (b) The particle is acted upon by on impulse of magnitude $4\pi^2 A m$ at t = 0 s and t = (1/4) s.
 - (c) The particle is not acted upon by any force.
 - (d) The particle is not acted upon by a constant force.
 - (e) There is no impulse acting on the particle.
- **5.11** In Fig. 5.1, the co-efficient of friction between the floor and the body B is 0.1. The co-efficient of friction between the bodies B and A is 0.2. A force **F** is applied as shown

Exemplar Problems-Physics

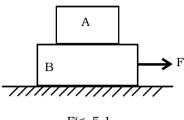
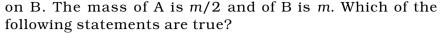
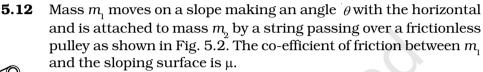


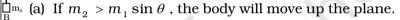
Fig. 5.1

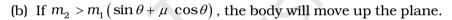


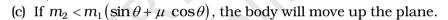
- (a) The bodies will move together if F = 0.25 mg.
- (b) The body A will slip with respect to B if F = 0.5 mg.
- (c) The bodies will move together if F = 0.5 mg.
- (d) The bodies will be at rest if F = 0.1 mg.
- (e) The maximum value of F for which the two bodies will move together is 0.45 mg.

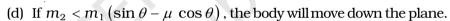


Which of the following statements are true?

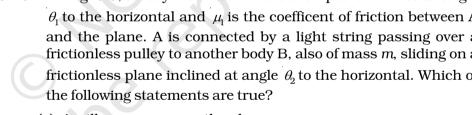


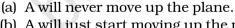


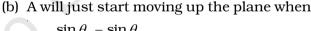




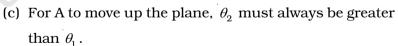
In Fig. 5.3, a body A of mass m slides on plane inclined at angle θ_1 to the horizontal and μ_1 is the coefficent of friction between A and the plane. A is connected by a light string passing over a frictionless pulley to another body B, also of mass m, sliding on a frictionless plane inclined at angle θ_2 to the horizontal. Which of

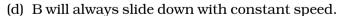






$$\mu = \frac{\sin \theta_2 - \sin \theta_1}{\cos \theta_1}$$





- Two billiard balls A and B, each of mass 50g and moving in opposite directions with speed of 5m s⁻¹ each, collide and rebound with the same speed. If the collision lasts for 10⁻³ s, which of the following statements are true?
 - (a) The impulse imparted to each ball is 0.25 kg m s⁻¹ and the force on each ball is 250 N.

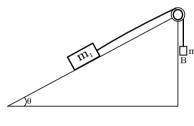


Fig. 5.2

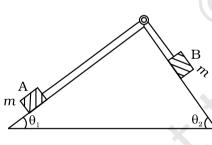


Fig. 5.3

- (b) The impulse imparted to each ball is 0.25 kg $\,$ m $\,s^{\text{--}1}$ and the force exerted on each ball is 25×10^{-5} N.
- (c) The impulse imparted to each ball is 0.5 Ns.
- (d) The impulse and the force on each ball are equal in magnitude and opposite in direction.
- **5.15** A body of mass 10kg is acted upon by two perpendicular forces, 6N and 8N. The resultant acceleration of the body is
 - (a) 1 m s^{-2} at an angle of $\tan^{-1} \left(\frac{4}{3}\right)$ w.r.t. 6N force.
 - (b) 0.2 m s^{-2} at an angle of $tan^{-1} \left(\frac{4}{3}\right)$ w.r.t. 6N force.
 - (c) 1 m s^{-2} at an angle of $\tan^{-1} \left(\frac{3}{4}\right)$ w.r.t.8N force.
 - (d) 0.2 m s^{-2} at an angle of $\tan^{-1} \left(\frac{3}{4}\right)$ w.r.t.8N force.

VSA

- **5.16** A girl riding a bicycle along a straight road with a speed of $5~{\rm m~s^{\text{-}1}}$ throws a stone of mass $0.5~{\rm kg}$ which has a speed of $15~{\rm m~s^{\text{-}1}}$ with respect to the ground along her direction of motion. The mass of the girl and bicycle is $50~{\rm kg}$. Does the speed of the bicycle change after the stone is thrown? What is the change in speed, if so?
- **5.17** A person of mass 50 kg stands on a weighing scale on a lift. If the lift is descending with a downward acceleration of 9 m s⁻², what would be the reading of the weighing scale? $(g = 10 \text{ m s}^{-2})$
- **5.18** The position time graph of a body of mass 2 kg is as given in Fig. 5.4. What is the impulse on the body at t = 0 s and t = 4 s.

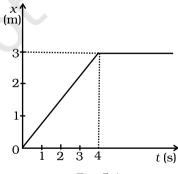


Fig. 5.4

- **5.19** A person driving a car suddenly applies the brakes on seeing a child on the road ahead. If he is not wearing seat belt, he falls forward and hits his head against the steering wheel. Why?
- **5.20** The velocity of a body of mass 2 kg as a function of *t* is given by $\mathbf{v}(t) = 2t \ \hat{\mathbf{i}} + t^2 \hat{\mathbf{j}}$. Find the momentum and the force acting on it, at time t=2s.
- **5.21** A block placed on a rough horizontal surface is pulled by a horizontal force F. Let f be the force applied by the rough surface on the block. Plot a graph of f versus F.
- **5.22** Why are porcelain objects wrapped in paper or straw before packing for transportation?
- **5.23** Why does a child feel more pain when she falls down on a hard cement floor, than when she falls on the soft muddy ground in the garden?
- **5.24** A woman throws an object of mass 500 g with a speed of 25 m s^1 .
 - (a) What is the impulse imparted to the object?
 - (b) If the object hits a wall and rebounds with half the original speed, what is the change in momentum of the object? \\\\\\
- **5.25** Why are mountain roads generally made winding upwards rather than going straight up?

SA

- Fig. 5.5). Thread CD of the same type is attached to the other end of 2 kg mass. Lower thread is pulled gradually, harder and harder in the downward directon so as to apply force on AB. Which of the threads will break and why?
- **5.27** In the above given problem if the lower thread is pulled with a jerk, what happens?
- **5.28** Two masses of 5 kg and 3 kg are suspended with help of massless inextensible strings as shown in Fig. 5.6. Calculate T_1 and T_2 when whole system is going upwards with acceleration = 2 m s² (use q = 9.8 m s⁻²).

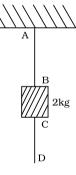


Fig. 5.5

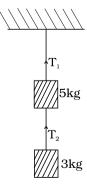
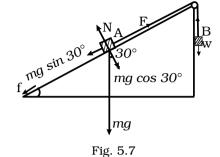
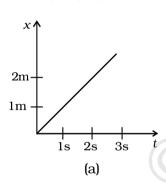


Fig. 5.6

5.29 Block A of weight 100 N rests on a frictionless inclined plane of slope angle 30° (Fig. 5.7). A flexible cord attached to A passes over a frictonless pulley and is connected to block B of weight W. Find the weight W for which the system is in equilibrium.



- **5.30** A block of mass M is held against a rough vertical wall by pressing it with a finger. If the coefficient of friction between the block and the wall is μ and the acceleration due to gravity is g, calculate the minimum force required to be applied by the finger to hold the block against the wall?
- **5.31** A 100 kg gun fires a ball of 1kg horizontally from a cliff of height 500m. It falls on the ground at a distance of 400m from the bottom of the cliff. Find the recoil velocity of the gun. (acceleration due to gravity = 10 m s^{-2})
- **5.32** Figure 5.8 shows (x, t), (y, t) diagram of a particle moving in 2-dimensions.



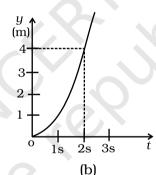


Fig. 5.8

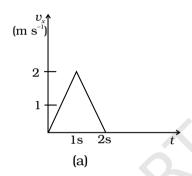
If the particle has a mass of 500 g, find the force (direction and magnitude) acting on the particle.

5.33 A person in an elevator accelerating upwards with an acceleration of 2 m s⁻², tosses a coin vertically upwards with a speed of 20 m s¹. After how much time will the coin fall back into his hand? ($g = 10 \text{ m s}^{-2}$)

LA

- **5.34** There are three forces $\mathbf{F_1}$, $\mathbf{F_2}$ and $\mathbf{F_3}$ acting on a body, all acting on a point P on the body. The body is found to move with uniform speed.
 - (a) Show that the forces are coplanar.
 - (b) Show that the torque acting on the body about any point due to these three forces is zero.

- **5.35** When a body slides down from rest along a smooth inclined plane making an angle of 45° with the horizontal, it takes time T. When the same body slides down from rest along a rough inclined plane making the same angle and through the same distance, it is seen to take time pT, where p is some number greater than 1. Calculate the co-efficient of friction between the body and the rough plane.
- **5.36** Figure 5.9 shows (v_x, t) , and (v_y, t) diagrams for a body of unit mass. Find the force as a function of time.



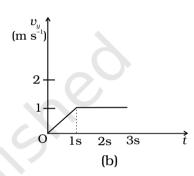


Fig. 5.9

5.37 A racing car travels on a track (without banking) ABCDEFA (Fig. 5.10). ABC is a circular arc of radius 2 R. CD and FA are straight paths of length R and DEF is a circular arc of radius R = 100 m. The co-effecient of friction on the road is $\mu = 0.1$. The maximum speed of the car is 50 m s⁻¹. Find the minimum time for completing one round.

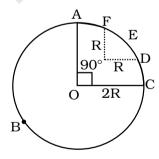


Fig. 5.10

- **5.38** The displacement vector of a particle of mass m is given by $\mathbf{r}(t) = \hat{\mathbf{i}} A \cos \omega t + \hat{\mathbf{j}} B \sin \omega t$.
 - (a) Show that the trajectory is an ellipse.
 - (b) Show that $\mathbf{F} = -m\omega^2 \mathbf{r}$.

- **5.39** A cricket bowler releases the ball in two different ways
 - (a) giving it only horizontal velocity, and
 - (b) giving it horizontal velocity and a small downward velocity. The speed $v_{\rm s}$ at the time of release is the same. Both are released at a height H from the ground. Which one will have greater speed when the ball hits the ground? Neglect air resistance.
- **5.40** There are four forces acting at a point P produced by strings as shown in Fig. 5.11, which is at rest. Find the forces $\mathbf{F_1}$ and $\mathbf{F_2}$.

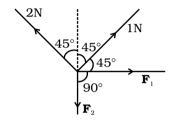


Fig. 5.11

- **5.41** A rectangular box lies on a rough inclined surface. The co-efficient of friction between the surface and the box is μ . Let the mass of the box be m.
 - (a) At what angle of inclination θ of the plane to the horizontal will the box just start to slide down the plane?
 - (b) What is the force acting on the box down the plane, if the angle of inclination of the plane is increased to $\alpha > \theta$?
 - (c) What is the force needed to be applied upwards along the plane to make the box either remain stationary or just move up with uniform speed?
 - (d) What is the force needed to be applied upwards along the plane to make the box move up the plane with acceleration α ?
- **5.42** A helicopter of mass 2000kg rises with a vertical acceleration of 15 m s⁻². The total mass of the crew and passengers is 500 kg. Give the magnitude and direction of the $(g = 10 \text{ m s}^{-2})$
 - (a) force on the floor of the helicopter by the crew and passengers.
 - (b) action of the rotor of the helicopter on the surrounding air.
 - (c) force on the helicopter due to the surrounding air.