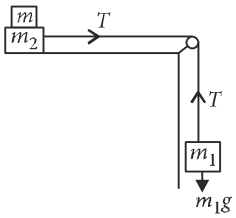
CHAPTER

3

Laws of Motion

1. 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



(a) 18.3 kg
(b) 27.3 kg
(c) 43.3 kg   (d) 10.3 kg   *(2018)*

2. A given object takes n times more time to slide down a 45° rough inclined plane as it takes to slide down a perfectly smooth 45° incline. The coefficient of kinetic friction between the object and the incline is

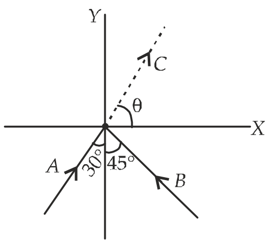
(a) $\sqrt{1-\frac{1}{n^2}}$ (b) $1-\frac{1}{n^2}$

(c) $\frac{1}{2-n^2}$ (d) $\sqrt{\frac{1}{1-n^2}}$ *(Online 2018)*

3. A body of mass 2 kg slides down with an acceleration of 3 m/s^2 on a rough inclined plane having a slope of 30°. The external force required to take the same body up the plane with the same acceleration will be (g = 10 m/s^2)

(a) 6 N   (b) 14 N   (c) 4 N   (d) 20 N
(Online 2018)

4. Two particles A and B of equal mass M are moving with the same speed v as shown in the figure. They collide completely inelastically and move as a single particle C. The angle θ that the path of C makes with the X-axis is given by

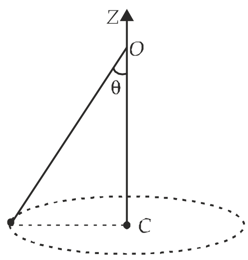


(a) $\tan\theta = \frac{\sqrt{3}+\sqrt{2}}{1-\sqrt{2}}$ (b) $\tan\theta = \frac{1-\sqrt{3}}{1+\sqrt{2}}$

(c) $\tan\theta = \frac{\sqrt{3}-\sqrt{2}}{1-\sqrt{2}}$ (d) $\tan\theta = \frac{1-\sqrt{2}}{\sqrt{2}(1+\sqrt{3})}$

(Online 2017)

5. A conical pendulum of length 1 m makes an angle θ = 45° w.r.t. Z-axis and moves in a circle in the XY plane. The radius of the circle is 0.4 m and its center is vertically below O. The speed of the pendulum, in its circular path, will be (Take g = 10 m s^{-2})



(a) 0.4 m/s   (b) 2 m/s
(c) 0.2 m/s   (d) 4 m/s   *(Online 2017)*

6. A rocket is fired vertically from the earth with an acceleration of $2g$, where g is the gravitational acceleration. On an inclined plane inside the rocket, making an angle θ with the horizontal, a point object of mass m is kept. The minimum coefficient of friction μ_{min} between the mass and the inclined surface such that the mass does not move is

(a) tan2θ   (b) tanθ
(c) 3tanθ   (d) 2tanθ   *(Online 2016)*

7. A particle of mass m is acted upon by a force F given by the empirical law $F = \frac{R}{t^2}v(t)$. If this law is to be tested experimentally by observing the motion starting from rest, the best way is to plot

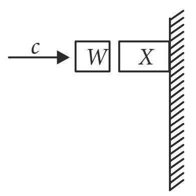
(a) log $v(t)$ against $\frac{1}{t}$ (b) $v(t)$ against t^2

(c) log $v(t)$ against $\frac{1}{t^2}$ (d) log $v(t)$ against t

(Online 2016)

8. Given in the figure are two blocks A and B of weight 20 N and 100 N, respectively. These are being pressed against a wall by a force F as shown. If the coefficient of friction between the blocks is 0.1 and between block B and the wall is 0.15, the frictional force applied by the wall on block B is

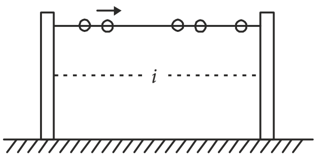
(a) 120 N
(b) 150 N
(c) 100 N
(d) 80 N



(2015)

9. A block of mass m = 10 kg rests on a horizontal table. The coefficient of friction between the block and the table is 0.05. When hit by a bullet of mass 50 g moving with speed v, that gets embedded in it, the block moves and comes to stop after moving a distance of 2 m on the table. If a freely falling object were to acquire speed $\frac{\ }{65}$ after being dropped from height H, then neglecting energy losses and taking g = 10 m s^{-2}, the value of H is close to
(a) 0.2 km (b) 0.3 km (c) 0.4 km (d) 0.5 km
(Online 2015)

10. A large number (n) of identical beads, each of mass m and radius r are strung on a thin smooth rigid horizontal rod of length L ($L >> r$) and are at rest at random positions. The rod is mounted between two rigid supports (see figure). If one of the beads is now given a speed v, the average force experienced by each support after a long time is (assume all collisions are elastic)

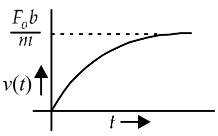


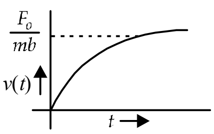
(a) $\frac{7}{i\ -}$
(b) $\frac{7}{i\ -7}$
(c) $\frac{7}{7\text{-}i\ -\ .}$
(d) zero *(Online 2015)*

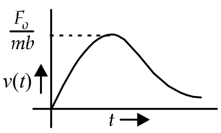
11. A block of mass m is placed on a surface with a vertical cross section given by $y = \frac{x^3}{6}$. If the coefficient of friction is 0.5, the maximum height above the ground at which the block can be placed without slipping is
(a) $\frac{1}{2}$ m (b) $\frac{1}{6}$ m
(c) $\frac{2}{3}$ m (d) $\frac{1}{3}$ m *(2014)*

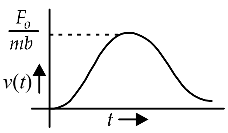
12. Two cars of masses m_1 and m_2 are moving in circles of radii r_1 and r_2, respectively. Their speeds are such that they make complete circles in the same time t. The ratio of their centripetal acceleration is
(a) $m_1 : m_2$ (b) $r_1 : r_2$
(c) 1 : 1 (d) $m_1r_1 : m_2r_2$ *(2012)*

13. A particle of mass m is at rest at the origin at time t = 0. It is subjected to a force $F(t) = F_oe^{-bt}$ in the x direction. Its speed $v(t)$ is depicted by which of the following curves?

(a) 

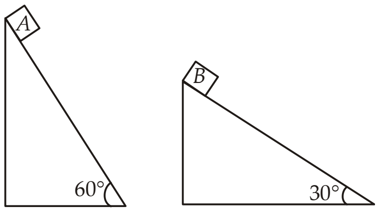
(b) 

(c) 

(d) 

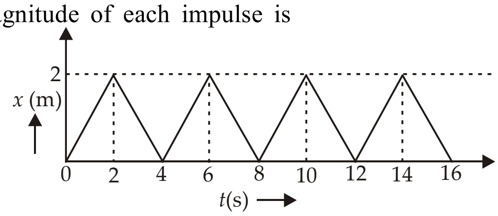
(2012)

14. Two fixed frictionless inclined planes making an angle 30° and 60° with the vertical are shown in the figure. Two blocks A and B are placed on the two planes. What is the relative vertical acceleration of A with respect to B?



(a) 4.9 m s^{-2} in vertical direction
(b) 4.9 m s^{-2} in horizontal direction
(c) 9.8 m s^{-2} in vertical direction
(d) zero *(2010)*

15. The figure shows the position - time (x-t) graph of one-dimensional motion of a body of mass 0.4 kg. The magnitude of each impulse is



(a) 0.2 N s (b) 0.4 N s (c) 0.8 N s (d) 1.6 N s
(2010)

16. A body of mass m = 3.513 kg is moving along the x-axis with a speed of 5.00 m s^{-1}. The magnitude of its momentum is recorded as
(a) 17.57 kg m s^{-1} (b) 17.6 kg m s^{-1}
(c) 17.565 kg m s^{-1} (d) 17.56 kg m s^{-1}. *(2008)*

17. A block of mass m is connected to another block of mass M by a spring (massless) of spring constant k. The blocks are kept on a smooth horizontal plane. Initially the blocks are at rest and the spring is unstretched. Then a constant force F starts acting on the block of mass M to pull it. Find the force of the block of mass m.
(a) $\frac{MF}{(m+M)}$ (b) $\frac{mF}{M}$
(c) $\frac{(M+m)F}{m}$ (d) $\frac{mF}{(m+M)}$ *(2007)*

18. A ball of mass 0.2 kg is thrown vertically upwards by applying a force by hand. If the hand moves 0.2 m which applying the force and the ball goes upto 2 m height further, find the magnitude of the force. Consider g = 10 m/s^2
(a) 22 N (b) 4 N (c) 16 N (d) 20 N.
(2006)

19. A player caught a cricket ball of mass 150 g moving at a rate of 20 m/s. If the catching process is completed in 0.1 s, the force of the blow exerted by the ball on the hand of the player is equal to
(a) 300 N (b) 150 N (c) 3 N (d) 30 N.
(2006)

20. Consider a car moving on a straight road with a speed of 100 m/s. The distance at which car can be stopped is [μ_k = 0.5]
(a) 100 m (b) 400 m (c) 800 m (d) 1000 m
(2005)

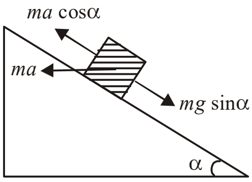
21. A block is kept on a frictionless inclined surface with angle of inclination α. The incline is given an acceleration a to keep the block stationary. Then a is equal to

(a) g

(b) $g \tan\alpha$

(c) $g/\tan\alpha$

(d) $g \operatorname{cosec}\alpha$ *(2005)*



22. A particle of mass 0.3 kg is subjected to a force $F = -kx$ with $k = 15$ N/m. What will be its initial acceleration if it is released from a point 20 cm away from the origin?
(a) 5 m/s^2 (b) 10 m/s^2 (c) 3 m/s^2 (d) 15 m/s^2 *(2005)*

23. A bullet fired into a fixed target loses half its velocity after penetrating 3 cm. How much further it will penetrate before coming to rest assuming that it faces constant resistance to motion?
(a) 1.5 cm (b) 1.0 cm (c) 3.0 cm (d) 2.0 cm *(2005)*

24. The upper half of an inclined plane with inclination ϕ is perfectly smooth while the lower half is rough. A body starting from rest at the top will again come to rest at the bottom if the coefficient of friction for the lower half is given by
(a) $2\tan\phi$ (b) $\tan\phi$ (c) $2\sin\phi$ (d) $2\cos\phi$ *(2005)*

25. A smooth block is released at rest on a 45° incline and then slides a distance d. The time taken to slide is n times as much to slide on rough incline than on a smooth incline. The coefficient of friction is

(a) $\mu_s = 1 - \frac{1}{n^2}$ (b) $\mu_s = \sqrt{1 - \frac{1}{n^2}}$

(c) $\mu_k = 1 - \frac{1}{n^2}$ (d) $\mu_k = \sqrt{1 - \frac{1}{n^2}}$ *(2005)*

26. An annular ring with inner and outer radii R_1 and R_2 is rolling without slipping with a uniform angular speed. The ratio of the forces experienced by the two particles situated on the inner and outer parts of the ring, F_1/F_2 is
(a) 1 (b) $\frac{R_1}{R_2}$ (c) $\frac{R_2}{R_1}$ (d) $\left(\frac{R_1}{R_2}\right)^2$ *(2005)*

27. A block rests on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of static friction between the block and the plane is 0.8. If the frictional force on the block is 10 N, the mass of the block (in kg) is (take g = 10 m/s^2)
(a) 2.0 (b) 4.0 (c) 1.6 (d) 2.5 *(2004)*

28. Two masses m_1 = 5 kg and m_2 = 4.8 kg tied to a string are hanging over a light frictionless pulley. What is the acceleration of the masses when lift free to move?

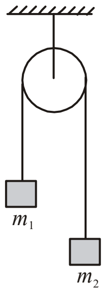
(g = 9.8 m/s^2)

(a) 0.2 m/s^2

(b) 9.8 m/s^2

(c) 5 m/s^2

(d) 4.8 m/s^2. *(2004)*



29. A machine gun fires a bullet of mass 40 g with a velocity 1200 m s^{-1}. The man holding it can exert a maximum force of 144 N on the gun. How many bullets can he fire per second at the most?
(a) one (b) four (c) two (d) three. *(2004)*

30. A rocket with a lift-off mass 3.5×10^4 kg is blasted upwards with an initial acceleration of 10 m/s^2. Then the initial thrust of the blast is
(a) 3.5×10^5 N (b) 7.0×10^5 N
(c) 14.0×10^5 N (d) 1.75×10^5 N. *(2003)*

31. A light spring balance hangs from the hook of the other light spring balance and a block of mass M kg hangs from the former one. Then the true statement about the scale reading is
(a) both the scales read M kg each
(b) the scale of the lower one reads M kg and of the upper one zero
(c) the reading of the two scales can be anything but the sum of the reading will be M kg
(d) both the scales read $M/2$ kg. *(2003)*

32. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block is

(a) $\frac{Pm}{M+m}$ (b) $\frac{Pm}{M-m}$

(c) P (d) $\frac{PM}{M+m}$ *(2003)*

33. A marble block of mass 2 kg lying on ice when given a velocity of 6 m/s is stopped by friction in 10 s. Then the coefficient of friction is
(a) 0.02 (b) 0.03 (c) 0.06 (d) 0.01. *(2003)*

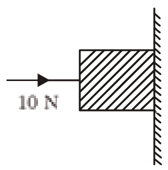
34. A horizontal force of 10 N is necessary to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.2. The weight of the block is

(a) 20 N

(b) 50 N

(c) 100 N

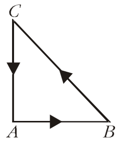
(d) 2 N. *(2003)*



35. A spring balance is attached to the ceiling of a lift. A man hangs his bag on the spring and the spring reads 49 N, when the lift is stationary. If the lift moves downward with an acceleration of 5 m/s^2, the reading of the spring balance will be

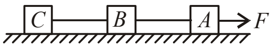
(a) 24 N (b) 74 N (c) 15 N (d) 49 N. *(2003)*

36. Three forces start acting simultaneously on a particle moving with velocity $\vec{v}$. These forces are represented in magnitude and direction by the three sides of a triangle *ABC* (as shown). The particle will now move with velocity



(a) less than $\vec{v}$
(b) greater than $\vec{v}$
(c) $|\vec{v}|$ in the direction of the largest force *BC*
(d) $\vec{v}$, remaining unchanged. *(2003)*

37. Three identical blocks of masses m = 2 kg are drawn by a force F = 10.2 N with an acceleration of 0.6 m s^{-2} on a frictionless surface, then what is the tension (in N) in the string between the blocks B and C?



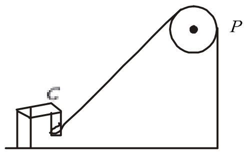
(a) 9.2 (b) 7.8 (c) 4 (d) 9.8 *(2002)*

38. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is $g/8$, then the ratio of the masses is

(a) 8 : 1 (b) 9 : 7 (c) 4 : 3 (d) 5 : 3. *(2002)*

39. One end of a massless rope, which passes over a massless and frictionless pulley P is tied to a hook C while the other end is free. Maximum tension that the rope can bear is 960 N. With what value of maximum safe acceleration (in m s^{-2}) can a man of 60 kg climb on the rope?

(a) 16
(b) 6
(c) 4
(d) 8. *(2002)*



40. When forces F_1, F_2, F_3 are acting on a particle of mass m such that F_2 and F_3 are mutually perpendicular, then the particle remains stationary. If the force F_1 is now removed then the acceleration of the particle is

(a) F_1/m (b) F_2F_3/mF_1
(c) $(F_2 - F_3)/m$ (d) F_2/m. *(2002)*

41. A lift is moving down with acceleration a. A man in the lift drops a ball inside the lift. The acceleration of the ball as observed by the man in the lift and a man standing stationary on the ground are respectively

(a) g, g (b) $g - a, g - a$
(c) $g - a, g$ (d) a, g. *(2002)*

42. The minimum velocity (in m s^{-1}) with which a car driver must traverse a flat curve of radius 150 m and coefficient of friction 0.6 to avoid skidding is

(a) 60 (b) 30 (c) 15 (d) 25 *(2002)*

ANSWER KEY

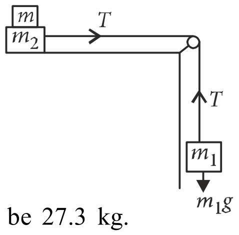
1. (b)	**2.** (b)	**3.** (d)	**4.** (a)	**5.** (b)	**6.** (b)	**7.** (a)	**8.** (a)	**9.** (*)	**10.** (b)	**11.** (b)	**12.** (b)
13. (b)	**14.** (a)	**15.** (c)	**16.** (a)	**17.** (d)	**18.** (d)	**19.** (d)	**20.** (d)	**21.** (b)	**22.** (b)	**23.** (b)	**24.** (a)
25. (c)	**26.** (b)	**27.** (a)	**28.** (a)	**29.** (d)	**30.** (a)	**31.** (a)	**32.** (d)	**33.** (c)	**34.** (d)	**35.** (a)	**36.** (d)
37. (b)	**38.** (b)	**39.** (b)	**40.** (a)	**41.** (c)	**42.** (b)						

Explanations

1. (b) : To stop the moving blocks, here frictional force between m_2 and surface is increased by placing some extra mass m on top of mass m_2.

Condition for stopping moving blocks, $f \geq T$

or $\mu N \geq T$ or $\mu(m + m_2)\, g \geq m_1 g$



For minimum value of m,

$$\mu(m + m_2)g = m_1 g$$

or $m = \dfrac{m_1}{\mu} - m_2 = \dfrac{5}{0.15} - 10$

$= 33.33 - 10 = 23.33$ kg

From given options suitable answer will be 27.3 kg.

2. (b) : Time taken to slide along smooth surface is given by

$$s = \frac{1}{2} g \sin 45° t_1^2 \quad \text{or} \quad t_1 = \sqrt{\frac{2\sqrt{2}\, s}{g}}$$

Time taken to slide along rough surface

$$s = \frac{1}{2} g(\sin 45° - \mu \cos 45°) t_2^2 \quad \text{or} \quad t_2 = \sqrt{\frac{2\sqrt{2}\, s}{g(1-\mu)}}$$

As per question, $t_2 = nt_1$

$$\frac{2\sqrt{2}\, s}{g(1-\mu)} = n^2 \times \frac{2\sqrt{2}\, s}{g} \Rightarrow 1 - \mu = \frac{1}{n^2} \Rightarrow \mu = 1 - \frac{1}{n^2}$$

3. (d) : Downward acceleration on the slope,

$a = g(\sin 30° - \mu \cos 30°)$

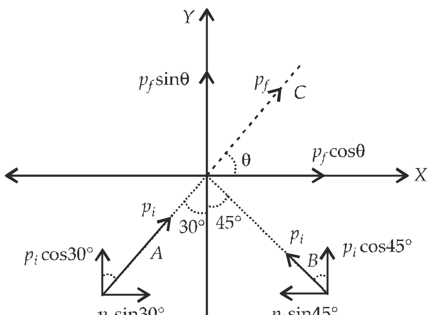
Now body moves up with an acceleration a upward due to external force F,

$F - mg\,(\sin 30° + \mu \cos 30°) = ma$

$F = mg(\sin 30° + \mu \cos 30°) + mg(\sin 30° - \mu \cos 30°)$

$$= 2mg \sin 30° = 2 \times 2 \times 10 \times \frac{1}{2} = 20 \text{ N}$$

4. (a) : During completely inelastic collision both particles A and B stick together.



Here, p_i = initial momentum of each particle

p_f = final momentum of the system

Using conservation of linear momentum,

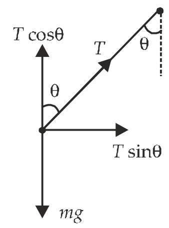
Along X-axis, $p_f \cos\theta = p_i \sin 30° - p_i \sin 45°$ ...(i)

Along Y-axis, $p_f \sin\theta = p_i \cos 30° + p_i \cos 45°$ ...(ii)

Divide eqn. (ii) by eqn. (i), we get

$$\frac{\sin\theta}{\cos\theta} = \frac{\cos 30° + \cos 45°}{\sin 30° - \sin 45°} = \frac{\frac{\sqrt{3}}{2} + \frac{1}{\sqrt{2}}}{\frac{1}{2} - \frac{1}{\sqrt{2}}} \therefore \tan\theta = \frac{\sqrt{3} + \sqrt{2}}{1 - \sqrt{2}}$$

5. (b) : FBD of the pendulum is shown in the figure.



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

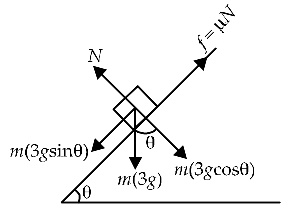
$T \cos\theta = mg$

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

$\theta = 45°$, $r = 0.4$ m $\therefore v^2 = rg$

$v = \sqrt{rg} = \sqrt{0.4 \times 10} = 2$ m/s

6. (b) : Since the rocket is moving vertically upwards with acceleration $2g$, therefore the apparent acceleration experienced by the point object is $g + 2g = 3g$ vertically downwards.



From the figure, $N = 3mg \cos\theta$

Point object does not move on inclined surface,

$\mu N = 3mg\sin\theta$

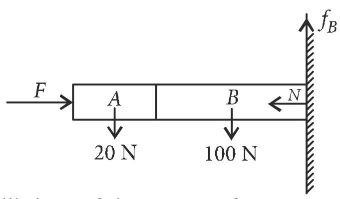
or $\mu 3mg \cos\theta = 3mg \sin\theta$ or $\mu = \tan\theta$

7. (a) : Here, $F = \dfrac{R}{t^2} v(t) \Rightarrow m\dfrac{dv}{dt} = \dfrac{R}{t^2} v(t) \Rightarrow \dfrac{dv}{v(t)} = \dfrac{R}{m}\dfrac{dt}{t^2}$

Integrating both sides, $\displaystyle\int \frac{dv}{v(t)} = \frac{R}{m}\int \frac{dt}{t^2} \Rightarrow \ln v = -\left(\frac{R}{m}\right)\left(\frac{1}{t}\right) + C$

Graph between $\ln v$ and $\left(\dfrac{1}{t}\right)$ is a straight line.

8. (a) : Various forces acting on the system are shown in the figure.



For vertical equilibrium of the system, $f_B = 100 \text{ N} + 20 \text{ N} = 120$ N

9. (*) : System (block + bullet) comes to rest after moving 2 m,

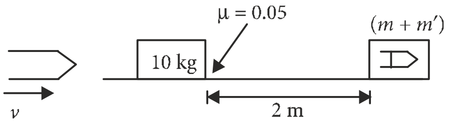
$s = 2$ m, $v_2 = 0$, $v_1 = ?$

$a = -\mu g = -0.05 \times 10 = -0.5$ m s^{-2}

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

$0^2 = v_1^2 - 2(0.5) \times 2$

$v_1 = \sqrt{2}$ m s^{-1}



Using momentum conservation,
Momentum of the system after collision = Momentum of the system before collision.

$\sqrt{7}\,(10 + 50 \times 10^{-3}) = (50 \times 10^{-3}) \times v + 0$

$$\approx \frac{\sqrt{7}\times 65}{:5\times 65^{-8}} = 755\sqrt{7}\ \mathrm{y}\ \ {}^{-6}\ \dashv\{\ \frac{\quad}{65} = 75\sqrt{7}\ \mathrm{y}\ {}^{-6}$$

For a freely falling body, to acquire $' = \frac{\quad}{65} = 75\sqrt{7}\ \mathrm{y}\ {}^{-6}1$ we use $'^{7} = 7\quad e\ 1e\ = \frac{'7}{7}$

$$H = \frac{=55}{75} = 95\ \mathrm{y}\ = 0.04\ \mathrm{km}$$

*None of the given options is correct.

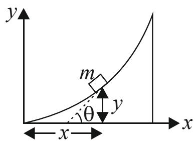
10. (b) : As collisions are elastic and masses are equal, velocities of colliding particles get exchanged.
Change in momentum Δp in each collision with the supports = $2mv$
Time interval between consecutive collisions with one support,

$$\Delta\ = \frac{\text{-}i\ -7\quad .\times 7}{\quad}$$

So, average force experienced by each support,

$$c\quad = \frac{\Delta}{\Delta} = \frac{7}{\text{-}i\ -7\quad .74} = \frac{7}{i\ -7}$$

11. (b) : Block is under limiting friction, so
$\mu = \tan\theta$ ...(i)



Equation of the surface,

$$y = \frac{x^3}{6}$$

Slope, $\frac{dy}{dx} = \frac{x^2}{2}$ ... (ii)

From eqns (i) and (ii), we get

$$\mu = \frac{x^2}{2} \Rightarrow 0.5 = \frac{x^2}{2} \Rightarrow x^2 = 1 \ \Rightarrow\ x = 1 \ \text{ So, } \ y = \frac{1}{6}\text{ m.}$$

12. (b) : Centripetal acceleration, $a_c = \omega^2 r \ \because\ \omega = \frac{2\pi}{T}$

As $T_1 = T_2 \ \Rightarrow\ \omega_1 = \omega_2 \ \because\ \frac{a_{c_1}}{a_{c_2}} = \frac{r_1}{r_2}$

13. (b) : $F(t) = F_o e^{-bt}$ (Given)
$ma = F_o e^{-bt}$

$$a = \frac{F_o}{m}e^{-bt} \ \text{ also } \ \frac{dv}{dt} = \frac{F_o}{m}e^{-bt} \ \text{ or } \ dv = \frac{F_o}{m}e^{-bt}dt$$

Integrating both sides, we get

$$\int_0^v dv = \int_0^t \frac{F_o}{m}e^{-bt}dt \ \Rightarrow\ v = \frac{F_o}{m}\left[\frac{e^{-bt}}{-b}\right]_0^t = \frac{F_o}{mb}[1 - e^{-bt}]$$

14. (a) : The acceleration of the body down the smooth inclined plane is $a = g\sin\theta$
It is along the inclined plane.
where θ is the angle of inclination
∴ The vertical component of acceleration a is
$a_{(\text{along vertical})} = (g\sin\theta)\sin\theta = g\sin^2\theta$
For block A
$a_{A(\text{along vertical})} = g\sin^2 60°$
For block B
$a_{B(\text{along vertical})} = g\sin^2 30°$
The relative vertical acceleration of A with respect to B is
$a_{AB(\text{along vertical})} = a_{A(\text{along vertical})} - a_{B(\text{along vertical})} = g\sin^2 60° - g\sin^2 30°$

$$= g\left(\left(\frac{\sqrt{3}}{2}\right)^2 - \left(\frac{1}{2}\right)^2\right) = \frac{g}{2} = 4.9\ \text{m s}^{-2} \text{ in vertical direction.}$$

15. (c) : Here, mass of the body, $m = 0.4$ kg
Since position-time (x-t) graph is a straight line, so motion is uniform. Because of impulse direction of velocity changes as can be seen from the slopes of the graph.
From graph,

Initial velocity, $u = \frac{(2-0)}{(2-0)} = 1\ \text{m s}^{-1}$

Final velocity, $v = \frac{(0-2)}{(4-2)} = -1\ \text{m s}^{-1}$

Initial momentum, $p_i = mu = 0.4 \times 1 = 0.4$ N s
Final momentum, $p_f = mv = 0.4 \times (-1) = -0.4$ N s
Impulse = Change in momentum = $p_f - p_i$
$= -0.4 - (0.4)$ N s $= -0.8$ N s
|Impulse| = 0.8 N s

16. (a) : Momentum is mv.
$m = 3.513$ kg ; $v = 5.00$ m/s ∴ $mv = 17.57$ kg m s^{-1}
Because the values will be accurate up to second decimal place only, 17.565 = 17.57.

17. (d) : Acceleration of the system $a = \frac{F}{m+M}$

Force on block of mass $m = ma = \frac{mF}{m+M}$.

18. (d) : Work done by hand = Potential energy of the ball

∴ $FS = mgh \Rightarrow F = \frac{mgh}{s} = \frac{0.2\times 10\times 2}{0.2} = 20$ N.

19. (d) : Force × time = Impulse = Change of momentum

∴ Force $= \frac{\text{Impulse}}{\text{time}} = \frac{3}{0.1} = 30$ N.

20. (d) : Retardation due to friction = $\mu_k g \ \because\ v^2 = u^2 + 2as$
∴ $0 = (100)^2 - 2(\mu_k g)s$ or $2\mu_k g = 100 \times 100$

or $s = \frac{100\times 100}{2\times 0.5\times 10} = 1000$ m.

21. (b) : The incline is given an acceleration a. Acceleration of the block is to the right. Pseudo acceleration a acts on block to the left. Equate resolved parts of a and g along incline.
∴ $ma\cos\alpha = mg\sin\alpha$ or $a = g\tan\alpha$.

22. (b) : $F = -kx$ or $F = -15\times\left(\frac{20}{100}\right) = -3$ N
Initial acceleration is over come by retarding force.
or $m \times$ (acceleration a) = 3 or $a = \frac{3}{m} = \frac{3}{0.3} = 10\ \text{m s}^{-2}$.

23. (b) : For first part of penetration, by equation of motion,

$$\left(\frac{u}{2}\right)^2 = (u)^2 - 2f(3) \quad \text{or } 3u^2 = 24f \qquad \text{...(i)}$$

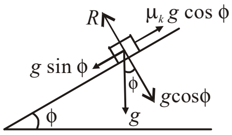
For latter part of penetration,

$$0 = \left(\frac{u}{2}\right)^2 - 2fx \quad \text{or} \quad u^2 = 8fx \qquad \text{...(ii)}$$

From (i) and (ii)

$3 \times (8fx) = 24f$ or $x = 1$ cm.

24. (a) : For upper half smooth incline, component of g down the incline = $g\sin\phi$



$\therefore \quad v^2 = 2(g\sin\phi)\dfrac{l}{2}$

For lower half rough incline,

frictional retardation = $\mu_k g\cos\phi$

$\therefore$ Resultant acceleration = $g\sin\phi - \mu_k g\cos\phi$

$$0 = v^2 + 2\,(g\sin\phi - \mu_k g\cos\phi)\,\frac{l}{2}$$

or $\quad 0 = 2(g\sin\phi)\dfrac{l}{2} + 2g(\sin\phi - \mu_k\cos\phi)\dfrac{l}{2}$

or $\quad 0 = \sin\phi + \sin\phi - \mu_k\cos\phi$ or $\mu_k\cos\phi = 2\sin\phi$ or $\mu_k = 2\tan\phi$.

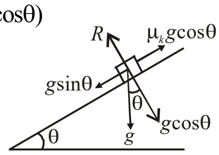
25. (c) : Component of g down the plane = $g\sin\theta$

$\therefore$ For smooth plane,

$$d = \frac{1}{2}(g\sin\theta)t^2 \qquad \text{...(i)}$$

For rough plane,

Frictional retardation up the plane = $\mu_k\,(g\cos\theta)$



$\therefore \quad d = \dfrac{1}{2}(g\sin\theta - \mu_k g\cos\theta)(nt)^2$

$\therefore \quad \dfrac{1}{2}(g\sin\theta)t^2 = \dfrac{1}{2}(g\sin\theta - \mu_k\, g\cos\theta)n^2t^2$

or $\quad \sin\theta = n^2\,(\sin\theta - \mu_k\cos\theta)$

Putting $\theta = 45°$

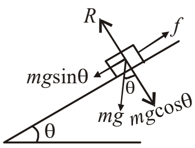
or $\quad \sin45° = n^2\,(\sin45° - \mu_k\cos45°)$

or $\quad \dfrac{1}{\sqrt{2}} = \dfrac{n^2}{\sqrt{2}}(1 - \mu_k) \quad$ or $\quad \mu_k = 1 - \dfrac{1}{n^2}$.

26. (b) : Centripetal force on particle = $mR\omega^2$

$$\therefore \quad \frac{F_1}{F_2} = \frac{mR_1\omega^2}{mR_2\omega^2} = \frac{R_1}{R_2}.$$

27. (a) : For equilibrium of block,



$f = mg\sin\theta$

$\therefore \quad 10 = m \times 10 \times \sin30°$

or $\quad m = 2$ kg.

28. (a) : $\dfrac{a}{g} = \dfrac{(m_1 - m_2)}{(m_1 + m_2)} = \dfrac{(5 - 4.8)}{(5 + 4.8)} = \dfrac{0.2}{9.8}$

or $\quad a = g \times \dfrac{0.2}{9.8} = \dfrac{9.8 \times 0.2}{9.8} = 0.2\ \text{ms}^{-2}$.

29. (d) : Suppose he can fire n bullets per second

$\therefore$ Force = Change in momentum per second

$$144 = n \times \left(\frac{40}{1000}\right) \times (1200) \quad \text{or} \quad n = \frac{144 \times 1000}{40 \times 1200} \quad \text{or} \quad n = 3.$$

30. (a) : Initial thrust = (Lift-off mass) × acceleration = $(3.5 \times 10^4) \times (10) = 3.5 \times 10^5$ N.

31. (a) : Both the scales read M kg each.

32. (d) : Acceleration of block $(a) = \dfrac{\text{Force applied}}{\text{Total mass}}$

or $\quad a = \dfrac{P}{(M + m)}$

$\therefore$ Force on block = Mass of block × a $= \dfrac{MP}{(M + m)}$.

33. (c) : Frictional force provides the retarding force

$\therefore \quad \mu\, mg = ma$

or $\quad \mu = \dfrac{a}{g} = \dfrac{u/t}{g} = \dfrac{6/10}{10} = 0.06$.

34. (d) : Weight of the block is balanced by force of friction

$\therefore$ Weight of the block = $\mu R = 0.2 \times 10 = 2$ N.

35. (a) : When lift is standing, $W_1 = mg$

When the lift descends with acceleration a, $W_2 = m\,(g - a)$

$$\therefore \quad \frac{W_2}{W_1} = \frac{m(g - a)}{mg} = \frac{9.8 - 5}{9.8} = \frac{4.8}{9.8}$$

or $\quad W_2 = W_1 \times \dfrac{4.8}{9.8} = \dfrac{49 \times 4.8}{9.8} = 24$ N.

36. (d) : By triangle of forces, the particle will be in equilibrium under the three forces. Obviously the resultant force on the particle will be zero. Consequently the acceleration will be zero.

Hence the particle velocity remains unchanged. $\vec{v}$.

37. (b) : $\because$ Force = mass × acceleration

$\therefore \quad F - T_{AB} = ma$ and $T_{AB} - T_{BC} = ma$

$\therefore \quad T_{BC} = F - 2\,ma$ or $T_{BC} = 10.2 - (2 \times 2 \times 0.6)$

or $\quad T_{BC} = 7.8$ N.

38. (b) : $\dfrac{a}{g} = \dfrac{(m_1 - m_2)}{(m_1 + m_2)} \quad \therefore \quad \dfrac{1}{8} = \dfrac{(m_1 - m_2)}{(m_1 + m_2)} \quad$ or $\quad \dfrac{m_1}{m_2} = \dfrac{9}{7}$.

39. (b) : $T - 60g = 60a$ or $960 - (60 \times 10) = 60a$

or $\quad 60a = 360 \quad$ or $\quad a = 6\ \text{m s}^{-2}$.

40. (a) : F_2 and F_3 have a resultant equivalent to F_1

$\therefore$ Acceleration $= \dfrac{F_1}{m}$.

41. (c) : For observer in the lift, acceleration = $(g - a)$

For observer standing outside, acceleration = g.

42. (b) : For no skidding along curved track,

$v = \sqrt{\mu R g}$

$\therefore \quad v = \sqrt{0.6 \times 150 \times 10} = 30$ m/s.