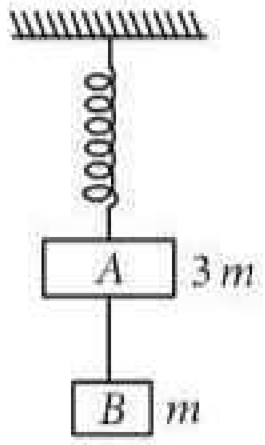
Chapter 4. Laws of Motion

1. Two blocks A and B of masses $3m$ and m respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of A and B immediately after the string is cut, are respectively



(a) $\frac{g}{3}, g$ (b) g, g (c) $\frac{g}{3}, \frac{g}{3}$ (d) $g, \frac{g}{3}$

(NEET 2017)

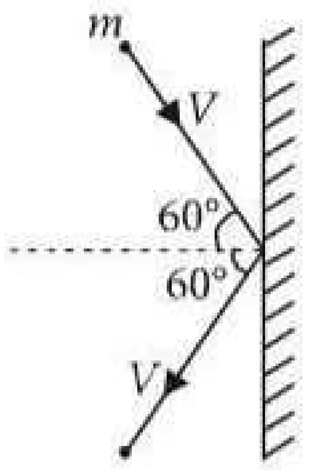
2. One end of string of length l is connected to a particle of mass 'm' and the other end is connected to a small peg on a smooth horizontal table. If the particle moves in circle with speed 'v', the net force on the particle (directed towards centre) will be (T represents the tension in the string)

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

(c) zero (d) T

(NEET 2017)

3. A rigid ball of mass m strikes a rigid wall at 60° and gets reflected without loss of speed as shown in the figure. The value of impulse imparted by the wall on the ball will be



(a) mV (b) $2\,mV$

(c) $\frac{mV}{2}$ (d) $\frac{mV}{3}$

(NEET-II 2016)

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

(a) $\sqrt{\frac{g}{R}\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}}$ (b) $\sqrt{\frac{g}{R^2}\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}}$

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

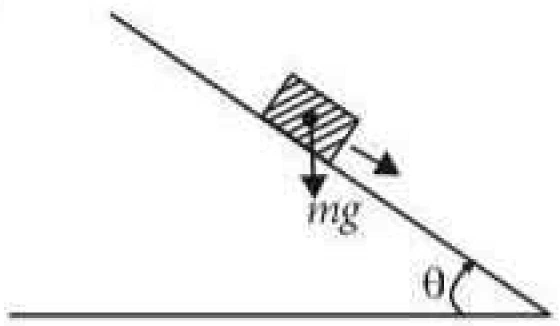
(NEET-I 2016)

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

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

(2015)

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



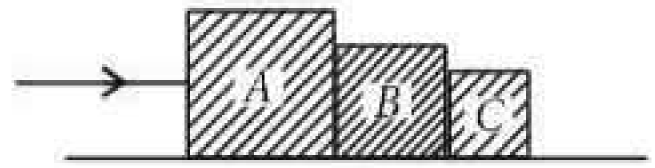
The coefficients of static and kinetic friction between the box and the plank will be, respectively

(a) 0.5 and 0.6 (b) 0.4 and 0.3

(c) 0.6 and 0.6 (d) 0.6 and 0.5

(2015)

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



(a) 8 N (b) 18 N

(c) 2 N (d) 6 N

(2015 Cancelled)

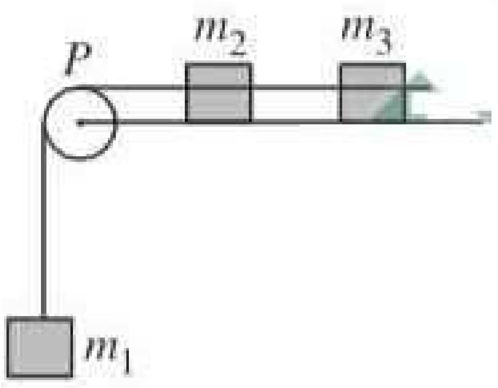
8. A block A of mass m_1 rests on a horizontal table. A light string connected to it passes over a frictionless pully at the edge of table and from its other end another block B of mass m_2 is suspended. The coefficient of kinetic friction between the block and the table is μ_k. When the block A is sliding on the table, the tension in the string is

(a) $\dfrac{m_1m_2(1+\mu_k)g}{(m_1+m_2)}$ (b) $\dfrac{m_1m_2(1-\mu_k)g}{(m_1+m_2)}$

(c) $\dfrac{(m_2+\mu_k m_1)g}{(m_1+m_2)}$ (d) $\dfrac{(m_2-\mu_k m_1)g}{(m_1+m_2)}$

(2015 Cancelled)

9. A system consists of three masses m_1, m_2 and m_3 connected by a string passing over a pulley P. The mass m_1 hangs freely and m_2 and m_3 are on a rough horizontal table (the coefficient of friction = μ). The pulley is frictionless and of negligible mass. The downward acceleration of mass m_1 is (Assume $m_1 = m_2 = m_3 = m$)



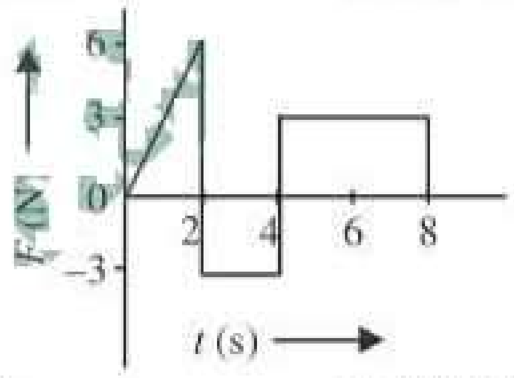
(a) $\dfrac{g(1-g\mu)}{9}$

(b) $\dfrac{2g\mu}{3}$

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

(d) $\dfrac{g(1-2\mu)}{2}$ *(2014)*

10. The force F acting on a particle of mass m is indicated by the force-time graph shown below. The change in momentum of the particle over the time interval from zero to 8 s is



(a) 24 N s (b) 20 N s

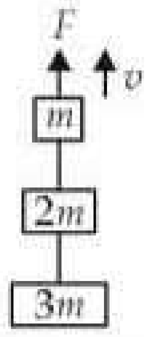
(c) 12 N s (d) 6 N s *(2014)*

11. A balloon with mass m is descending down with an acceleration a (where $a < g$). How much mass should be removed from it so that it starts moving up with an acceleration a?

(a) $\dfrac{2ma}{g+a}$ (b) $\dfrac{2ma}{g-a}$

(c) $\dfrac{ma}{g+a}$ (d) $\dfrac{ma}{g-a}$ *(2014)*

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



(a) $3mg$

(b) $6mg$

(c) zero

(d) $2mg$ *(NEET 2013)*

13. An explosion breaks a rock into three parts in a horizontal plane. Two of them go off at right angles to each other. The first part of mass 1 kg moves with a speed of 12 m s^{-1} and the second part of mass 2 kg moves with 8 m s^{-1} speed. If the third part flies off with 4 m s^{-1} speed, then its mass is

(a) 7 kg (b) 17 kg

(c) 3 kg (d) 5 kg *(NEET 2013)*

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

(a) $\mu = 2\tan\theta$ (b) $\mu = \tan\theta$

(c) $\mu = \dfrac{1}{\tan\theta}$ (d) $\mu = \dfrac{2}{\tan\theta}$

(NEET 2013)

15. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/s. A bob is suspended from the roof of the car by a light wire of length 1.0 m. The angle made by the wire with the vertical is

(a) $\dfrac{\pi}{3}$ (b) $\dfrac{\pi}{6}$ (c) $\dfrac{\pi}{4}$ (d) $0°$

(Karnataka NEET 2013)

16. A person holding a rifle (mass of person and rifle together is 100 kg) stands on a smooth surface and fires 10 shots horizontally, in 5 s. Each bullet has a mass of 10 g with a muzzle velocity of 800 m s^{-1}. The final velocity acquired by the person and the average force exerted on the person are

(a) $-0.08\ ms^{-1}$, 16 N (b) $-0.8\ ms^{-1}$, 8 N
(c) $-1.6\ ms^{-1}$, 16 N (d) $-1.6\ ms^{-1}$, 8 N
(Karnataka NEET 2013)

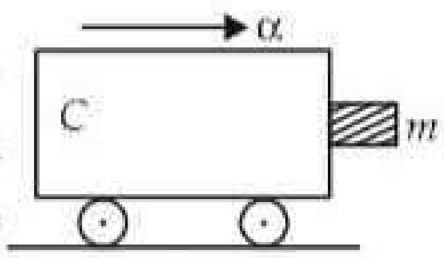
17. A stone is dropped from a height h. It hits the ground with a certain momentum P. If the same stone is dropped from a height 100% more than the previous height, the momentum when it hits the ground will change by
(a) 68% (b) 41%
(c) 200% (d) 100% *(Mains 2012)*

18. A person of mass 60 kg is inside a lift of mass 940 kg and presses the button on control panel. The lift starts moving upwards with an acceleration 1.0 m/s². If $g = 10\ m\ s^{-2}$, the tension in the supporting cable is
(a) 8600 N (b) 9680 N
(c) 11000 N (d) 1200 N *(2011)*

19. A body of mass M hits normally a rigid wall with velocity V and bounces back with the same velocity. The impulse experienced by the body is
(a) MV (b) $1.5MV$
(c) $2MV$ (d) zero *(2011)*

20. A conveyor belt is moving at a constant speed of 2 m s⁻¹. A box is gently dropped on it. The coefficient of friction between them is $\mu = 0.5$. The distance that the box will move relative to belt before coming to rest on it, taking $g = 10\ m\ s^{-2}$, is
(a) 0.4 m (b) 1.2 m
(c) 0.6 m (d) zero *(Mains 2011)*

21. A block of mass m is in contact with the cart C as shown in the figure.



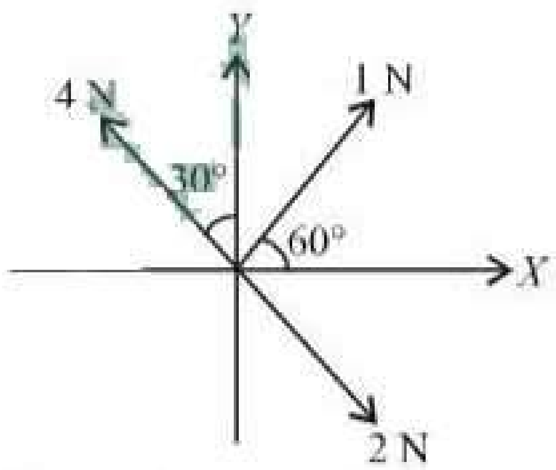
The coefficient of static friction between the block and the cart is μ. The acceleration α of the cart that will prevent the block from falling satisfies
(a) $\alpha > \frac{mg}{\mu}$ (b) $\alpha > \frac{g}{\mu m}$
(c) $\alpha \geq \frac{g}{\mu}$ (d) $\alpha < \frac{g}{\mu}$ *(2010)*

22. The mass of a lift is 2000 kg. When the tension in the supporting cable is 28000 N, then its acceleration is
(a) 4 m s⁻² upwards (b) 4 m s⁻² downwards
(c) 14 m s⁻² upwards (d) 30 m s⁻² downwards
(2009)

23. A body, under the action of a force $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$, acquires an acceleration of 1 m/s². The mass of this body must be
(a) 10 kg (b) 20 kg
(c) $10\sqrt{2}$ kg (d) $2\sqrt{10}$ kg *(2009)*

24. A roller coaster is designed such that riders experience "weightlessness" as they go round the top of a hill whose radius of curvature is 20 m. The speed of the car at the top of the hill is between
(a) 16 m/s and 17 m/s
(b) 13 m/s and 14 m/s
(c) 14 m/s and 15 m/s
(d) 15 m/s and 16 m/s *(2008)*

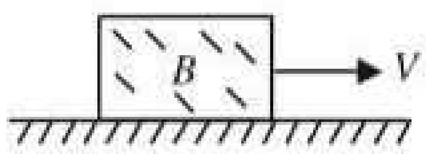
25.



Three forces acting on a body are shown in the figure. To have the resultant force only along the y-direction, the magnitude of the minimum additional force needed is
(a) $\frac{\sqrt{3}}{4}$ N (b) $\sqrt{3}$ N
(c) 0.5 N (d) 1.5 N *(2008)*

26. Sand is being dropped on a conveyer belt at the rate of M kg/s. The force necessary to keep the belt moving with a constant velocity of v m/s will be
(a) $\frac{Mv}{2}$ newton (b) zero
(c) Mv newton (d) $2\ Mv$ newton
(2008)

27. A block B is pushed momentarily along a horizontal surface with an initial velocity V. If μ is the coefficient of sliding friction between B and the surface, block B will come to rest after a time



(a) $g\mu/V$
(b) g/V
(c) V/g
(d) $V/(g\mu)$. *(2007)*

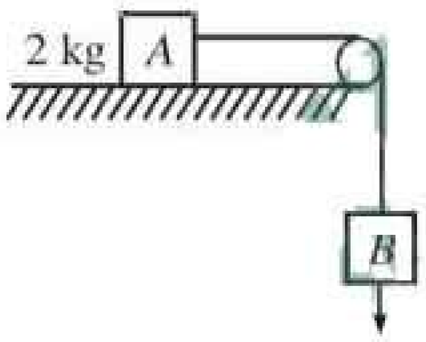
28. A 0.5 kg ball moving with a speed of 12 m/s strikes a hard wall at an angle of 30° with the wall. It is reflected with the same speed at the same angle. If the ball is in contact with the wall for 0.25 seconds, the average force acting on the wall is

(a) 96 N (b) 48 N
(c) 24 N (d) 12 N. *(2006)*

29. A block of mass m is placed on a smooth wedge of inclination θ. The whole system is accelerated horizontally so that the block does not slip on the wedge. The force exerted by the wedge on the block will be (g is acceleration due to gravity)

(a) $mg \cos \theta$ (b) $mg \sin \theta$
(c) mg (d) $mg/\cos \theta$ *(2004)*

30. The coefficient of static friction, μ_s, between block A of mass 2 kg and the table as shown in the figure is 0.2. What would be the maximum mass value of block B so that the two blocks do not move? The string and the pulley are assumed to be smooth and massless. (g = 10 m/s^2)



(a) 2.0 kg
(b) 4.0 kg
(c) 0.2 kg
(d) 0.4 kg *(2004)*

31. A man weighs 80 kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 5 m/s^2. What would be the reading on the scale? (g = 10 m/s^2)

(a) zero (b) 400 N
(c) 800 N (d) 1200 N *(2003)*

32. A monkey of mass 20 kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspended from it but will break if the mass exceeds 25 kg. What is the maximum acceleration with which the monkey can climb up along the rope ?(g = 10 m/s^2)

(a) 5 m/s^2 (b) 10 m/s^2
(c) 25 m/s^2 (d) 2.5 m/s^2 *(2003)*

33. A lift of mass 1000 kg which is moving with acceleration of 1 m/s^2 in upward direction, then the tension developed in string which is connected to lift is

(a) 9800 N (b) 10,800 N
(c) 11,000 N (d) 10,000 N. *(2002)*

34. A block of mass 10 kg placed on rough horizontal surface having coefficient of friction m = 0.5, if a horizontal force of 100 N acting on it then acceleration of the block will be

(a) 10 m/s^2 (b) 5 m/s^2
(c) 15 m/s^2 (d) 0.5 m/s^2. *(2002)*

35. 250 N force is required to raise 75 kg mass from a pulley. If rope is pulled 12 m then the load is lifted to 3 m, the efficiency of pulley system will be

(a) 25% (b) 33.3%
(c) 75% (d) 90%. *(2001)*

36. On the horizontal surface of a truck a block of mass 1 kg is placed (m = 0.6) and truck is moving with acceleration 5 m/sec^2 then the frictional force on the block will be

(a) 5 N (b) 6 N
(c) 5.88 N (d) 8 N. *(2001)*

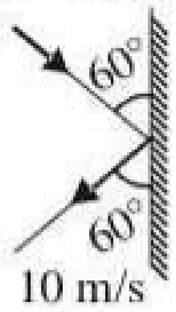
37. A cricketer catches a ball of mass 150 gm in 0.1 sec moving with speed 20 m/s, then he experiences force of

(a) 300 N (b) 30 N
(c) 3 N (d) 0.3 N. *(2001)*

38. A 1 kg stationary bomb is exploded in three parts having mass 1 : 1 : 3 respectively. Parts having same mass move in perpendicular direction with velocity 30 m/s, then the velocity of bigger part will be

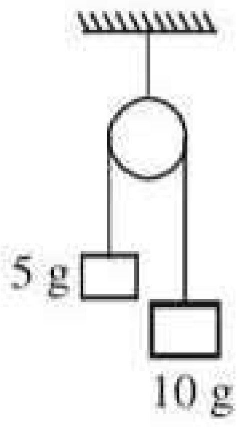
(a) $10\sqrt{2}$ m/sec (b) $\frac{10}{\sqrt{2}}$ m/sec
(c) $15\sqrt{2}$ m/sec (d) $\frac{15}{\sqrt{2}}$ m/sec. *(2001)*

39. A body of mass 3 kg hits a wall at an angle of 60° and returns at the same angle. The impact time was 0.2 sec. The force exerted on the wall



(a) $150\sqrt{3}$ N
(b) $50\sqrt{3}$ N
(c) 100 N
(d) $75\sqrt{3}$ N. *(2000)*

40. Two masses as shown in the figure are suspended from a massless pulley. The acceleration of the system when masses are left free is



(a) $\frac{2g}{3}$ (b) $\frac{g}{3}$
(c) $\frac{g}{9}$ (d) $\frac{g}{7}$. *(2000)*

41. If the force on a rocket, moving with a velocity of 300 m/s is 210 N, then the rate of combustion of the fuel is
(a) 0.07 kg/s (b) 1.4 kg/s
(c) 0.7 kg/s (d) 10.7 kg/s *(1999)*

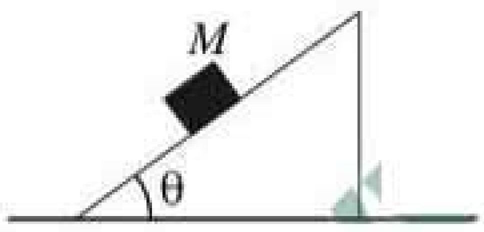
42. A mass of 1 kg is suspended by a thread. It is
(i) lifted up with an acceleration 4.9 m/s^2,
(ii) lowered with an acceleration 4.9 m/s^2.
The ratio of the tensions is
(a) 1 : 3 (b) 1 : 2
(c) 3 : 1 (d) 2 : 1 *(1998)*

43. A bullet is fired from a gun. The force on the bullet is given by

$$F = 600 - 2 \times 10^5 t$$

where, F is in newton and t in seconds. The force on the bullet becomes zero as soon as it leaves the barrel. What is the average impulse imparted to the bullet?
(a) 9 N-s (b) zero
(c) 1.8 N-s (d) 0.9 N-s *(1998)*

44. A mass M is placed on a very smooth wedge resting on a surface without friction. Once the mass is released, the acceleration to be given to the wedge so that M remains at rest is a where



(a) a is applied to the left and $a = g\tan\theta$
(b) a is applied to the right and $a = g\tan\theta$
(c) a is applied to the left and $a = g\sin\theta$
(d) a is applied to the left and $a = g\cos\theta$
(1998)

45. A 5000 kg rocket is set for vertical firing. The exhaust speed is 800 m s^{-1}. To give an initial upward acceleration of 20 m s^{-2}, the amount of gas ejected per second to supply the needed thrust will be (g = 10 m s^{-2})
(a) 185.5 kg s^{-1} (b) 187.5 kg s^{-1}
(c) 127.5 kg s^{-1} (d) 137.5 kg s^{-1} *(1998)*

46. A force of 6 N acts on a body at rest and of mass 1 kg. During this time, the body attains a velocity of 30 m/s. The time for which the force acts on the body is
(a) 7 seconds (b) 5 seconds
(c) 10 seconds (d) 8 seconds. *(1997)*

47. A 10 N force is applied on a body produce in it an acceleration of 1 m/s^2. The mass of the body is
(a) 15 kg (b) 20 kg
(c) 10 kg (d) 5 kg. *(1996)*

48. A force vector applied on a mass is represented as $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and accelerates with 1 m/s^2. What will be the mass of the body?
(a) 10 kg (b) 20 kg
(c) $10\sqrt{2}$ kg (d) $2\sqrt{10}$ kg. *(1996)*

49. A man fires a bullet of mass 200 gm at a speed of 5 m/s. The gun is of one kg mass. By what velocity the gun rebounds backward?
(a) 1 m/s (b) 0.01 m/s
(c) 0.1 m/s (d) 10 m/s. *(1996)*

50. In a rocket, fuel burns at the rate of 1 kg/s. This fuel is ejected from the rocket with a velocity of 60 km/s. This exerts a force on the rocket equal to
(a) 6000 N (b) 60000 N
(c) 60 N (d) 600 N. *(1994)*

51. A block has been placed on a inclined plane with the slope angle θ, block slides down the plane at constant speed. The coefficient of kinetic friction is equal to
(a) sin θ (b) cos θ
(c) g (d) tan θ *(1993)*

52. A monkey is decending from the branch of a tree with constant acceleration. If the breaking strength is 75% of the weight of the monkey, the minimum acceleration with which monkey can slide down without branch is
(a) g (b) $\frac{3g}{4}$
(c) $\frac{g}{4}$ (d) $\frac{g}{2}$ *(1993)*

53. Consider a car moving along a straight horizontal road with a speed of 72 km/h. If the coefficient of static friction between the tyres and the road is 0.5, the shortest distance in which the car can be stopped is (taking g = 10 m/s^2)
(a) 30 m (b) 40 m
(c) 72 m (d) 20 m *(1992)*

54. Physical independence of force is a consequence of
(a) third law of motion
(b) second law of motion
(c) first law of motion
(d) all of these laws *(1991)*

55. A heavy uniform chain lies on horizontal table top. If the coefficient of friction between the chain and the table surface is 0.25, then the maximum fraction of the length of the chain that can hang over one edge of the table is
(a) 20% (b) 25%
(c) 35% (d) 15% *(1991)*

56. When milk is churned, cream gets separated due to
(a) centripetal force (b) centrifugal force
(c) fricitional force (d) gravitational force *(1991)*

57. A particle of mass m is moving with a uniform velocity v_1. It is given an impulse such that its velocity becomes v_2. The impulse is equal to
(a) $m[|v_2| - |v_1|]$ (b) $\frac{1}{2}m[v_2^2 - v_1^2]$
(c) $m[v_1 + v_2]$ (d) $m[v_2 - v_1]$ *(1990)*

58. A 600 kg rocket is set for a vertical fring. If the exhaust speed is 1000 ms^{-1}, the mass of the gas ejected per second to supply the thrust needed to overcome the weight of rocket is
(a) 117.6 kg s^{-1} (b) 58.6 kg s^{-1}
(c) 6 kg s^{-1} (d) 76.4 kg s^{-1} *(1990)*

59. A body of mass 5 kg explodes at rest into three fragments with masses in the ratio 1 : 1 : 3. The fragments with equal masses fly in mutually perpendicular directions with speeds of 21 m/s. The velocity of heaviest fragment in m/s will be
(a) $7\sqrt{2}$ (b) $5\sqrt{2}$
(c) $3\sqrt{2}$ (d) $\sqrt{2}$ *(1989)*

60. Starting from rest, a body slides down a 45° inclined plane in twice the time it takes to slide down the same distance in the absence of friction. The coefficient of friction between the body and the inclined plane is
(a) 0.80 (b) 0.75
(c) 0.25 (d) 0.33 *(1988)*

Answer Key

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

EXPLANATIONS

1. **(a) :** Before the string is cut

$kx = T + 3mg$ ...(i)

$T = mg$ ...(ii)

From eqns. (i) and (ii)

$kx = 4mg$

Just after the string is cut

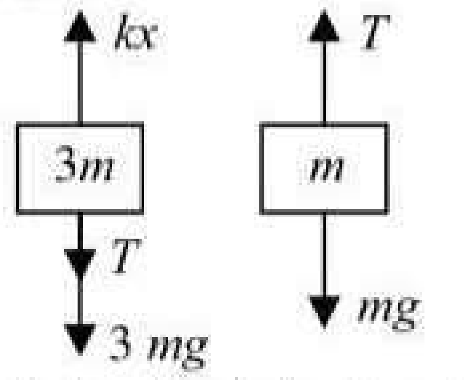
$T = 0$

$$a_A = \frac{kx - 3mg}{3m}$$

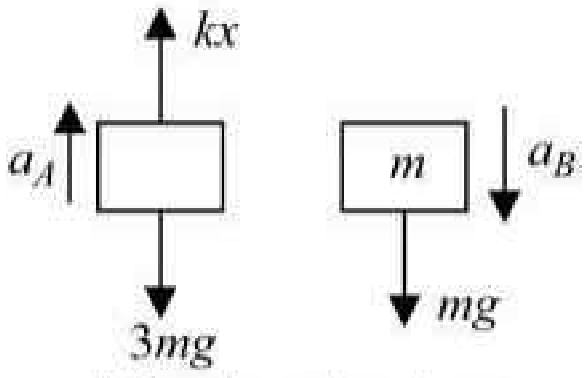
$$a_A = \frac{4mg - 3mg}{3m}$$

$$= \frac{mg}{3m} = \frac{g}{3}$$

and also $a_B = g$.



Before the string is cut



After the string is cut

2. **(d) :** Centripetal force $\left(\frac{mv^2}{l}\right)$ is provided by tension so net force on the particle will be equal to tension T.

3. **(a) :** Given, $p_i = p_f = mV$

Change in momentum of the ball

$= \vec{p}_f - \vec{p}_i$

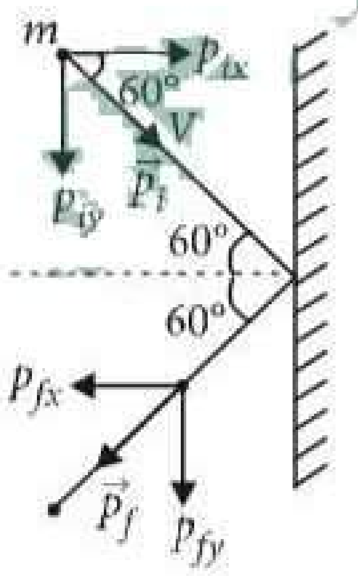
$= (-p_{fx}\hat{i} - p_{fy}\hat{j}) - (p_{ix}\hat{i} - p_{iy}\hat{j})$

$= -\hat{i}(p_{fx} + p_{ix}) - \hat{j}(p_{fy} - p_{iy})$

$= -2p_{ix}\hat{i} = -mV\hat{i}$ $[\because p_{fy} - p_{iy} = 0]$

Here, $p_{ix} = p_{fx} = p_i \cos 60° = \frac{mV}{2}$

$\because$ Impulse imparted by the wall = change in the momentum of the ball = mV.



4. **(d) :**

For vertical equilibrium on the road,

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

$mg = N\cos\theta - f\sin\theta$ ...(i)

Centripetal force for safe turning,

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

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

$$\frac{v^2}{Rg} = \frac{N\sin\theta + f\cos\theta}{N\cos\theta - f\sin\theta}$$

$$\Rightarrow \frac{v_{max}^2}{Rg} = \frac{N\sin\theta + \mu_s N\cos\theta}{N\cos\theta - \mu_s N\sin\theta}$$

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

5. **(c) :** Let v be tangential speed of heavier stone. Then, centripetal force experienced by lighter stone is $(F_c)_{lighter} = \frac{m(nv)^2}{r}$ and that of heavier stone is

$$(F_c)_{heavier} = \frac{2mv^2}{(r/2)}$$

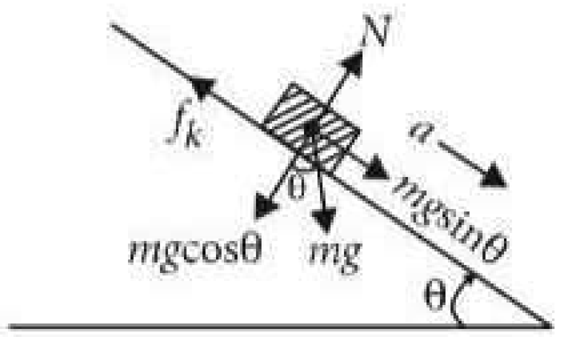
But $(F_c)_{lighter} = (F_c)_{heavier}$ (given)

$$\therefore \frac{m(nv)^2}{r} = \frac{2mv^2}{(r/2)}$$

$$n^2\left(\frac{mv^2}{r}\right) = 4\left(\frac{mv^2}{r}\right)$$

$n^2 = 4$ or $n = 2$

6. **(d) :** Let μ_s and μ_k be the coefficients of static and kinetic friction between the box and the plank respectively.



When the angle of inclination θ reaches 30°, the block just slides,

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

If a is the acceleration produced in the block, then

$ma = mg\sin\theta - f_k$

(where f_k is force of kinetic friction)

$= mg\sin\theta - \mu_k N$ (as $f_k = \mu_k N$)

$= mg\sin\theta - \mu_k mg\cos\theta$ (as $N = mg\cos\theta$)

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

As $g = 10\ ms^{-2}$ and $\theta = 30°$

$\therefore$ $a = (10\ ms^{-2})(\sin 30° - \mu_k \cos 30°)$ ...(i)

If s is the distance travelled by the block in time t, then

$$s = \frac{1}{2}at^2 \qquad (\text{as } u = 0)$$

$$\text{or} \quad a = \frac{2s}{t^2}$$

But $s = 4.0$ m and $t = 4.0$ s (given)

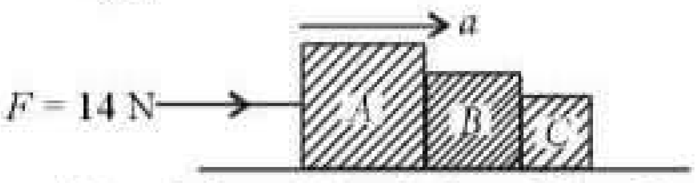
$$\therefore \quad a = \frac{2(4.0\text{ m})}{(4.0\text{ s})^2} = \frac{1}{2}\text{ ms}^{-2}$$

Substituting this value of a in eqn. (i), we get

$$\frac{1}{2}\text{ ms}^{-2} = (10\text{ ms}^{-2})\left(\frac{1}{2} - \mu_k \frac{\sqrt{3}}{2}\right)$$

$$\frac{1}{10} = 1 - \sqrt{3}\mu_k \text{ or } \sqrt{3}\mu_k = 1 - \frac{1}{10} = \frac{9}{10} = 0.9$$

$$\mu_k = \frac{0.9}{\sqrt{3}} = 0.5$$

7. (d) : 

Here, $M_A = 4$ kg, $M_B = 2$ kg, $M_C = 1$ kg, $F = 14$ N

Net mass, $M = M_A + M_B + M_C = 4 + 2 + 1 = 7$ kg

Let a be the acceleration of the system.

Using Newton's second law of motion,

$$F = Ma$$

$$14 = 7a \quad \therefore \quad a = 2\text{ m s}^{-2}$$

Let F' be the force applied on block A by block B *i.e.* the contact force between A and B. Free body diagram for block A

Again using Newton's second law of motion,

$$F - F' = 4a$$

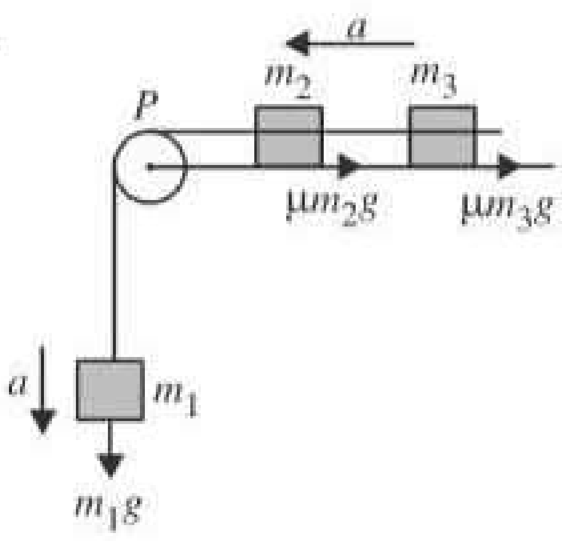
$$14 - F' = 4 \times 2 \quad \Rightarrow 14 - 8 = F' \quad \therefore \quad F' = 6\text{ N}$$

8. (a)

9. (c) : Force of friction on mass $m_2 = \mu m_2 g$

Force of friction on mass $m_3 = \mu m_3 g$

Let a be common acceleration of the system.



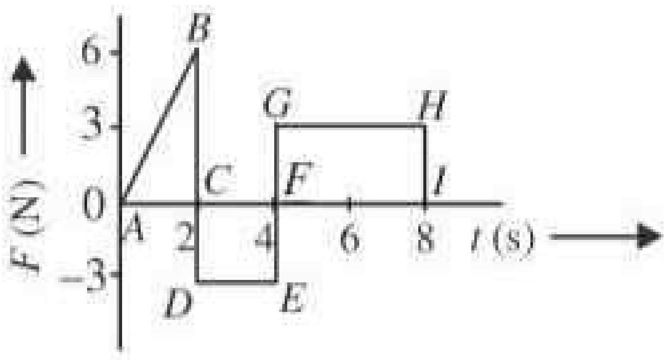
$$\therefore \quad a = \frac{m_1 g - \mu m_2 g - \mu m_3 g}{m_1 + m_2 + m_3}$$

Here, $m_1 = m_2 = m_3 = m$

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

Hence, the downward acceleration of mass m_1 is $\frac{g(1-2\mu)}{3}$.

10. (c) :



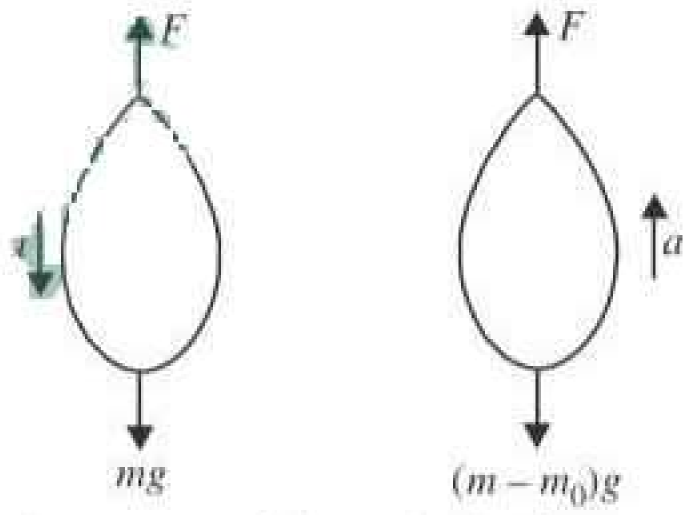
Change in momentum = Area under F-t graph in that interval

= Area of ΔABC – Area of rectangle $CDEF$ + Area of rectangle $FGHI$

$$= \frac{1}{2} \times 2 \times 6 - 3 \times 2 + 4 \times 3 = 12\text{ N s}$$

11. (a) : Let F be the upthrust of the air. As the balloon is descending down with an acceleration a,

$$\therefore \quad mg - F = ma \qquad \text{... (i)}$$



Let mass m_0 be removed from the balloon so that it starts moving up with an acceleration a. Then,

$$F - (m - m_0)g = (m - m_0)a$$

$$F - mg + m_0 g = ma - m_0 a \qquad \text{... (ii)}$$

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

$$m_0 g = 2ma - m_0 a$$

$$m_0 g + m_0 a = 2ma$$

$$m_0(g + a) = 2ma$$

$$m_0 = \frac{2ma}{a + g}$$

12. (c) : Let T_1 be tension in string connecting m and $2m$ and T_2 be tension in string connecting $2m$ and $3m$.

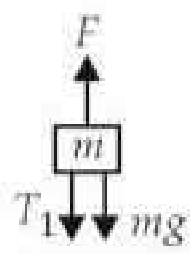
Let a be common acceleration of the system.

$$\therefore \quad a = \frac{F - (m + 2m + 3m)g}{m + 2m + 3m} = \frac{F - 6mg}{6m}$$

As the system moves with constant speed, therefore, $a = 0$

$$\therefore \quad F - 6mg = 0 \text{ or } F = 6mg$$

The free body diagram of block m is as shown in the figure.



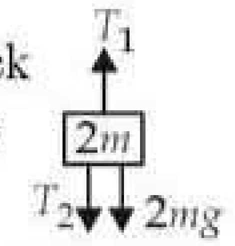
The equation of motion of block of mass m is

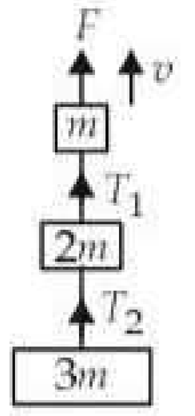
$$F - T_1 - mg = 0$$

$$6mg - T_1 - mg = 0$$

$$T_1 = 5mg \qquad \text{...(i)}$$

The free body diagram of block of mass $2m$ is as shown in the figure.





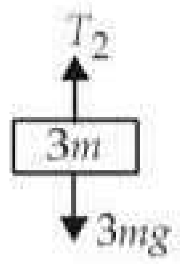
The equation of motion of block of mass $2m$ is

$$T_1 - T_2 - 2mg = 0$$

$$5mg - T_2 - 2mg = 0 \quad \text{(Using (i))}$$

$$T_2 = 3mg$$

The free body diagram of block of mass $3m$ is as shown in the figure.



The equation of motion of block of mass $3m$ is

$$T_2 - 3mg = 0$$

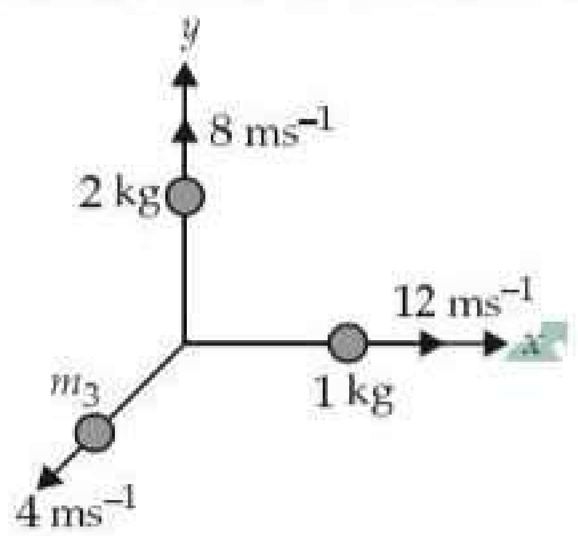
$$T_2 = 3mg$$

Net force on the block of mass $2m$ is

$$F_{net} = T_1 - T_2 - 2mg = 5mg - 3mg - 2mg = 0$$

Alternate solution: As all blocks are moving with constant speed, therefore, acceleration is zero. So net force on each block is zero.

13. (d) : The situation is as shown in the figure.



According to law of conservation of linear momentum

$$\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = 0 \qquad \therefore \; \vec{p}_3 = -(\vec{p}_1 + \vec{p}_2)$$

Here, $\vec{p}_1 = (1\text{ kg})(12\text{ m s}^{-1})\hat{i} = 12\hat{i}\text{ kg m s}^{-1}$

$$\vec{p}_2 = (2\text{ kg})(8\text{ m s}^{-1})\hat{j} = 16\hat{j}\text{ kg m s}^{-1}$$

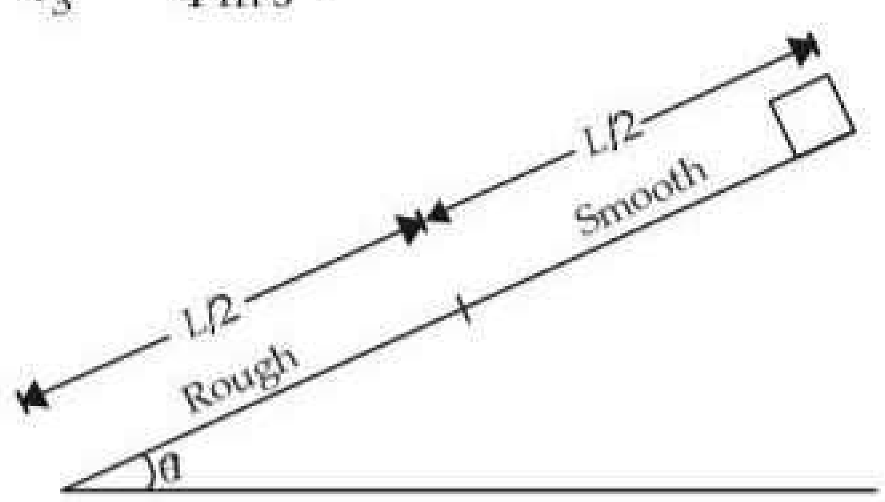
$$\therefore \quad \vec{p}_3 = -(12\hat{i} + 16\hat{j})\text{kg m s}^{-1}$$

The magnitude of p_3 is

$$p_3 = \sqrt{(12)^2 + (16)^2} = 20\text{ kg m s}^{-1}$$

$$\therefore \quad m_3 = \frac{p_3}{v_3} = \frac{20\text{ kg m s}^{-1}}{4\text{ m s}^{-1}} = 5\text{ kg}$$

14. (a) :



Let m be mass of the block and L be length of the inclined plane.

According to work-energy theorem

$$W = \Delta K = 0 \quad \text{(Initial and final speeds are zero)}$$

$\therefore$ Work done by friction + Work done by gravity = 0

$$-\mu mg\cos\theta\frac{L}{2} + mg\sin\theta L = 0$$

$$\frac{\mu}{2}\cos\theta = \sin\theta$$

$$\mu = \frac{2\sin\theta}{\cos\theta} = 2\tan\theta$$

Alternate solution

For upper half smooth plane

Acceleration of the block, $a = g\sin\theta$

Here, $u = 0$ (block starts from rest)

$$a = g\sin\theta,\; s = \frac{L}{2}$$

Using, $v^2 - u^2 = 2as$, we have

$$v^2 - 0 = 2 \times g\sin\theta \times \frac{L}{2}$$

$$v = \sqrt{gL\sin\theta} \qquad \text{...(i)}$$

For lower half rough plane

Acceleration of the block, $a' = g\sin\theta - \mu g\cos\theta$

where μ is the coefficient of friction between the block and lower half of the plane

Here, $u = v = \sqrt{gL\sin\theta}$,

$v = 0$ (block comes to rest)

$$a = a' = g\sin\theta - \mu g\cos\theta,\; s = \frac{L}{2}$$

Again, using $v^2 - u^2 = 2as$, we have

$$0 - (\sqrt{gL\sin\theta})^2 = 2 \times (g\sin\theta - \mu g\cos\theta) \times \frac{L}{2}$$

$$-gL\sin\theta = (g\sin\theta - \mu g\cos\theta)L$$

$$-\sin\theta = \sin\theta - \mu\cos\theta$$

$$\mu\cos\theta = 2\sin\theta$$

$$\mu = 2\tan\theta$$

15. (c) : Let θ is the angle made by the wire with the vertical.

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

Here, $v = 10$ m/s, $r = 10$ m, $g = 10\text{ m/s}^2$

$$\therefore \quad \tan\theta = \frac{(10\text{ m/s})^2}{10\text{ m}(10\text{ m/s}^2)} = 1$$

$$\theta = \tan^{-1}(1) = \frac{\pi}{4}$$

16. (b)

17. (b) : When a stone is dropped from a height h, it hits the ground with a momentum

$$P = m\sqrt{2gh} \quad \text{...(i)}$$

where m is the mass of the stone.

When the same stone is dropped from a height $2h$ (*i.e.* 100% of initial), then its momentum with which it hits the ground becomes

$$P' = m\sqrt{2g(2h)} = \sqrt{2}P \quad \text{(Using (i)) ...(ii)}$$

$$\% \text{ change in momentum} = \frac{P' - P}{P} \times 100\%$$

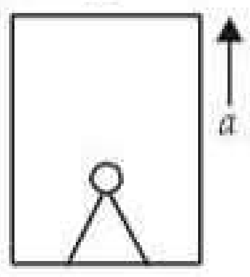
$$= \frac{\sqrt{2}P - P}{P} \times 100\% = 41\%$$

18. (c) : Here, Mass of a person, $m = 60$ kg

Mass of lift, $M = 940$ kg,

$a = 1 \text{ m/s}^2$, $g = 10 \text{ m/s}^2$

Let T be the tension in the supporting cable.



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

$T = (M + m)(a + g) = (940 + 60)(1 + 10) = 11000 \text{ N}$

19. (c) : Impulse = Change in linear momentum

$= MV - (-MV) = 2MV$

20. (a) : Force of friction, $f = \mu mg$

$$\therefore \quad a = \frac{f}{m} = \frac{\mu mg}{m} = \mu g = 0.5 \times 10 = 5 \text{ m s}^{-2}$$

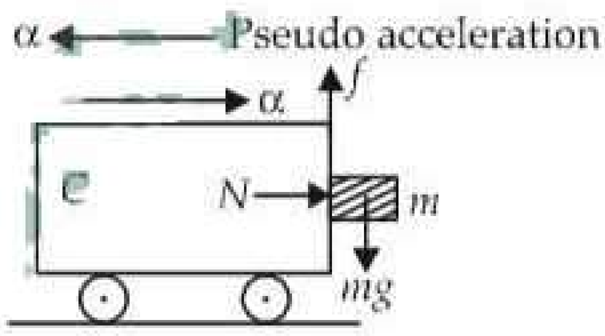
Using $v^2 - u^2 = 2aS$

$0^2 - 2^2 = 2(-5) \times S \Rightarrow \quad S = 0.4 \text{ m}$

21. (c) : Pseudo force or fictitious force, $F_{fic} = m\alpha$

Force of friction, $f = \mu N = \mu m\alpha$

The block of mass m will not fall as long as



$f \geq mg$

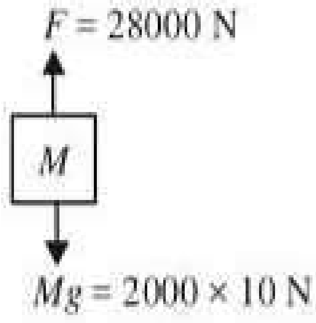
$\mu m\alpha \geq mg$

$\alpha \geq \frac{g}{\mu}$

22. (a) : $F - Mg = Ma$

$8000 = 2000a$

$\therefore$ Acceleration is 4 m s^{-2} upwards.



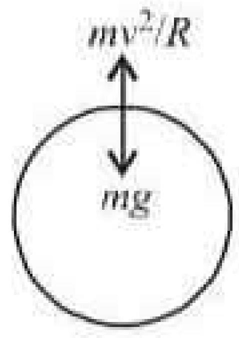
23. (c) : $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$

$$|\vec{F}| = \sqrt{36 + 64 + 100} = \sqrt{200} \text{ N} = 10\sqrt{2} \text{ N}.$$

Acceleration, $a = 1 \text{ m s}^{-2}$

$$\therefore \text{ Mass, } M = \frac{10\sqrt{2}}{1} = 10\sqrt{2} \text{ kg}.$$

24. (c) :

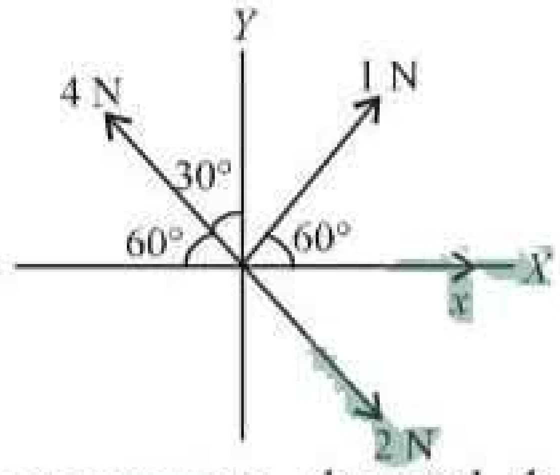


$$mg = \frac{mv^2}{R} \Rightarrow v = \sqrt{Rg}$$

$$v = \sqrt{20 \times 10} = \sqrt{200} = 14.1 \text{ m/s}$$

i.e., Between 14 and 15 m/s.

25. (c) :



Taking x-components, the total should be zero.

$1 \times \cos 60° + 2\cos 60° + x - 4\cos 60° = 0$

$\therefore \quad x = 0.5 \text{ N}$

26. (c) : $F = \frac{d}{dt}(Mv) = v\frac{dM}{dt} + M\frac{dv}{dt}$

As v is a constant,

$$F = v\frac{dM}{dt}. \qquad \text{But } \frac{dM}{dt} = M \text{ kg/s}$$

$\therefore$ To keep the conveyer belt moving at v m/s, force needed $= vM$ newton.

27. (d) : Given $u = V$, final velocity = 0.

Using $v = u + at$

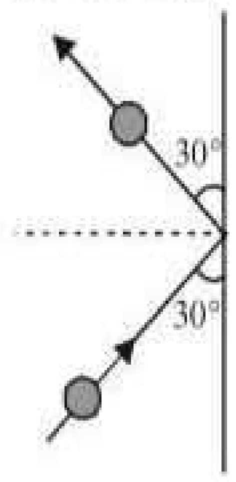
$$\therefore \quad 0 = V - at \quad \text{or,} \quad -a = \frac{0 - V}{t} = -\frac{V}{t}$$

$f = \mu R = \mu mg$ (f is the force of friction)

$\therefore$ Retardation, $a = \mu g$

$$\therefore \quad t = \frac{V}{a} = \frac{V}{\mu g}.$$

28. (c) : Components of momentum parallel to the wall add each other and components of momentum in the perpendicular to the wall are opposite to each other. Therefore change of momentum is final momentum – initial momentum



i.e., ($mv\sin\theta$ after collision – ($-mv\sin\theta$) before collision)

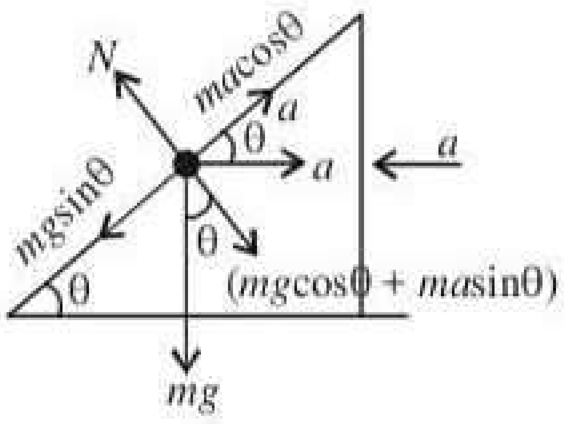
$F \times t$ = change in momentum

$= 2mv\sin\theta$

$$\therefore \quad F = \frac{2mv\sin\theta}{t}$$

$$= \frac{2 \times 0.5 \times 12 \times \sin 30°}{0.25} = 48 \times \frac{1}{2} = 24 \text{ N}.$$

29. (d) : The wedge is given an acceleration to the left.



∴ The block has a pseudo acceleration to the right, pressing against the wedge because of which the block is not moving.

∴ $mg\sin\theta = ma\cos\theta$

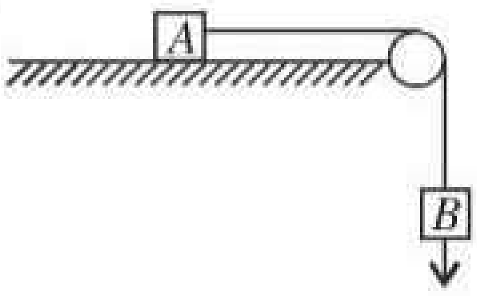
or $a = \dfrac{g\sin\theta}{\cos\theta}$

Total reaction of the wedge on the block is $N = mg\cos\theta + ma\sin\theta$.

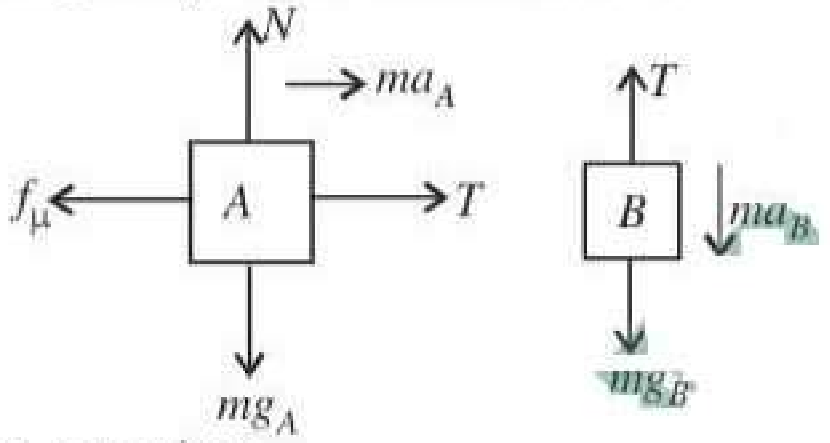
or $\quad N = mg\cos\theta + \dfrac{mg\sin\theta \cdot \sin\theta}{\cos\theta}$

or $\quad N = \dfrac{mg(\cos^2\theta + \sin^2\theta)}{\cos\theta} = \dfrac{mg}{\cos\theta}$.

30. (d) :



Free body diagram of two masses is



We get equations

$T + ma = f_\mu$ or $T = \mu N_A$ (for $a = 0$)

and $T = ma + mg$ or $T = m_B g$ (for $a = 0$)

∴ $\mu N_A = m_B g \Rightarrow m_B = \mu m_A = 0.2 \times 2 = 0.4$ kg.

31. (d) : When the lift is accelerating upwards with acceleration a, then reading on the scale

$R = m(g + a) = 80(10 + 5)\text{ N} = 1200\text{ N}$.

32. (d) : Let T be the tension in the rope when monkey climbs up with an acceleration a. Then,

$T - mg = ma$

$25g - 20g = 20a \Rightarrow a = \dfrac{5 \times 10}{20} = 2.5\text{ m/s}^2$.

33. (b) : For a lift which is moving in upward direction with an acceleration a, the tension T developed in the string connected to the lift is given by

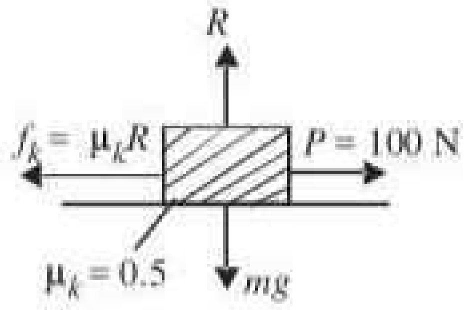
$T = m(g + a)$.

Here $m = 1000$ kg, $a = 1\text{ m/s}^2$, $g = 9.8\text{ m/s}^2$

∴ $T = 1000(9.8 + 1) = 10{,}800$ N.

34. (b) : $m = 10$ kg,

$R = mg$



∴ Frictional force $= f_k$

$= \mu_k R = \mu_k mg$

$= 0.5 \times 10 \times 10$

$= 50$ N [$g = 10\text{ m/sec}^2$]

∴ Net force acting on the body $= F = P - f_k$

$= 100 - 50 = 50$ N.

∴ Acceleration of the block $= a = F/m$

$= 50/10 = 5\text{ m/sec}^2$.

35. (c) : Load $W = Mg = 75 \times 10 = 750$ N

Effort (P) = 250 N

∴ Mechanical advantage

$= \dfrac{\text{load}}{\text{effort}} = \dfrac{W}{P} = \dfrac{750}{250} = 3.$

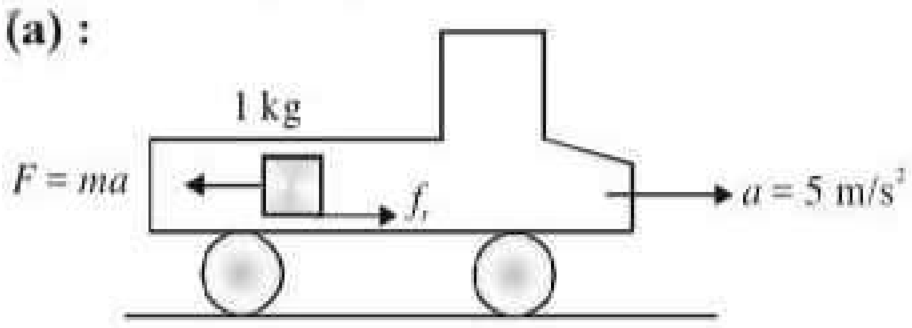
Velocity ratio

$= \dfrac{\text{distance travelled by effort}}{\text{distance travelled by load}} = \dfrac{12}{3} = 4$

Efficiency, $\eta = \dfrac{\text{Mechanical advantage}}{\text{Velocity ratio}}$

$= (3/4) \times 100 = 75\%$.

36. (a) :



$f_{rL} = \mu_s N = \mu_s \times mg = 0.6 \times 1 \times 10 = 6$ N.

where f_{rL} is the force of limiting friction.

Pseudo force $= ma = 1 \times 5$; $F = 5$ N

If $F < f_{rL}$ block does not move. So static friction is present.

Static friction = applied force . ∴ $f_r = 5$ N.

37. (b) : Impulse = Change in momentum

$F \cdot \Delta t = m \cdot v$; $F = \dfrac{m \cdot v}{\Delta t} = \dfrac{150 \times 10^{-3} \times 20}{0.1} = 30$ N.

38. (a) : Apply conservation of linear momentum.

Total momentum before explosion

= total momentum after explosion

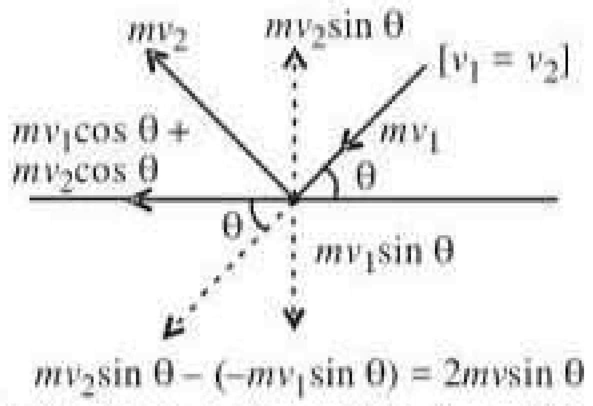
$0 = \dfrac{m}{5}v_1\hat{i} + \dfrac{m}{5}v_2\hat{j} + \dfrac{3m}{5}\vec{v}_3$;

$\dfrac{3m}{5}\vec{v}_3 = -\dfrac{m}{5}[v_1\hat{i} + v_2\hat{j}]$

$\vec{v}_3 = \dfrac{-v_1}{3}\hat{i} - \dfrac{v_2}{3}\hat{j} \qquad \because v_1 = v_2 = 30$ m/sec.

$\vec{v}_3 = -10\hat{i} - 10\hat{j}$; $v_3 = 10\sqrt{2}$ m/sec.

39. (a) :



Change in momentum = $2 \times 3 \times 10 \times \sin 60°$

$$= 60 \times \frac{\sqrt{3}}{2}$$

Force = Change in momentum/Impact time

$$= \frac{30\sqrt{3}}{0.2} = 150\sqrt{3}\text{ N}$$

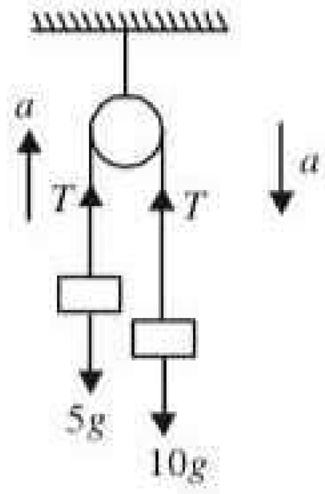
40. (b) : The force equations are

$T - 5g = 5a,$

$10g - T = 10a$

Adding, $10g - 5g = 15a$

or, $a = \frac{5g}{15} = \frac{g}{3}.$



41. (c) : Force $= \frac{d}{dt}(\text{momentum})$

$$= \frac{d}{dt}(mv) = v\left(\frac{dm}{dt}\right) \Rightarrow 210 = 300\left(\frac{dm}{dt}\right)$$

$$\frac{dm}{dt} = \text{rate of combustion} = \frac{210}{300} = 0.7 \text{ kg/s}$$

42. (c) : Upward acceleration, $ma = T_1 - mg$

$T_1 = m(g + a)$

Downward acceleration, $ma = mg - T_2$

or, $T_2 = m(g - a)$

$$\frac{T_1}{T_2} = \frac{g+a}{g-a} = \frac{9.8+4.9}{9.8-4.9} = 3:1.$$

43. (d) : When $F = 0$, $600 - 2 \times 10^5 t = 0$

$$\therefore \quad t = \frac{600}{2\times10^5} = 3\times10^{-3}\text{ s.}$$

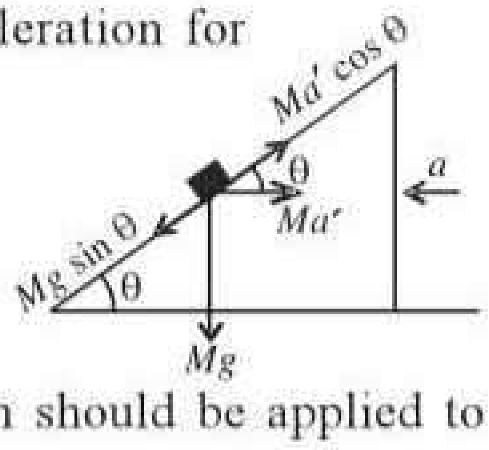
Now, impulse, $I = \int_0^t F dt = \int_0^t (600 - 2\times10^5 t)dt$

$$600t - 2\times10^5\frac{t^2}{2} = 600\times3\times10^{-3} - 10^5\times(3\times10^{-3})^2$$

or, $I = 1.8 - 0.9 = 0.9$ N-s.

44. (a) : The pseudo acceleration for the body $a' = a$

If the pseudo force $Ma\cos\theta = Mg\sin\theta$, then the body will be at rest, $a = g\tan\theta$.



This horizontal acceleration should be applied to the wedge to the left.

45. (b) : Thrust $= M(g + a) = u\frac{dm}{dt}$

$$\frac{dm}{dt} = \frac{M(g+a)}{u} = \frac{5000(10+20)}{800} = 187.5 \text{ kg/s}$$

46. (b) : Force (F) = 6 N; Initial velocity (u) = 0; Mass (m) = 1 kg and final velocity (v) = 30 m/s.

Therefore acceleration (a) $= \frac{F}{m} = \frac{6}{1} = 6$ m/s^2 and final velocity (v) = $30 = u + at = 0 + 6 \times t$

or $t = 5$ seconds.

47. (c) : Force (F) = 10 N and acceleration (a) = 1 m/s^2.

Mass (m) $= \frac{F}{a} = \frac{10}{1} = 10$ kg.

48. (c) : Force $(\vec{F}) = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and acceleration (a) = 1 m/s^2.

$$\text{Mass } (m) = \frac{|\vec{F}|}{a} = \frac{|6\hat{i} - 8\hat{j} + 10\hat{k}|}{1}$$

$$= \sqrt{36+64+100} = \sqrt{200} = 10\sqrt{2} \text{ kg.}$$

49. (a) : Mass of bullet (m_1) = 200 gm = 0.2 kg; Speed of bullet (v_1) = 5 m/sec. and mass of gun (m_2) = 1 kg. Before firing, total momentum is zero.

∴ After firing total momentum is $m_1v_1 + m_2v_2$

From the law of conservation of momentum

$m_1v_1 + m_2v_2 = 0$

or $v_2 = \frac{-m_1v_1}{m_2} = \frac{-0.2\times5}{1} = -1$ m/sec.

50. (b) : Rate of burning of fuel $\left(\frac{dm}{dt}\right)$ = 1 kg/s and velocity of ejected fuel (v) = 60 km/s = 60×10^3 m/s.

Force = Rate of change of momentum

$$= \frac{dp}{dt} = \frac{d(mv)}{dt} = v\frac{dm}{dt} = (60\times10^3)\times1 = 60000\text{ N.}$$

51. (d) : The acceleration is nullified by force of kinetic friction/mass

$mg\sin\theta$ is force downwards.

μ_k is the coefficient of kinetic friction.

$\mu_k mg\cos\theta$ is force acting upwards.

∴ $mg\sin\theta - \mu_k mg\cos\theta$ = mass × acceleration.

acceleration = 0 as v is constant

∴ $\mu_k = \tan\theta$.

52. (c) : Let T be the tension in the branch of a tree when monkey is decending with acceleration a

Thus, $mg - T = ma$

also, T = 75% of weight of monkey

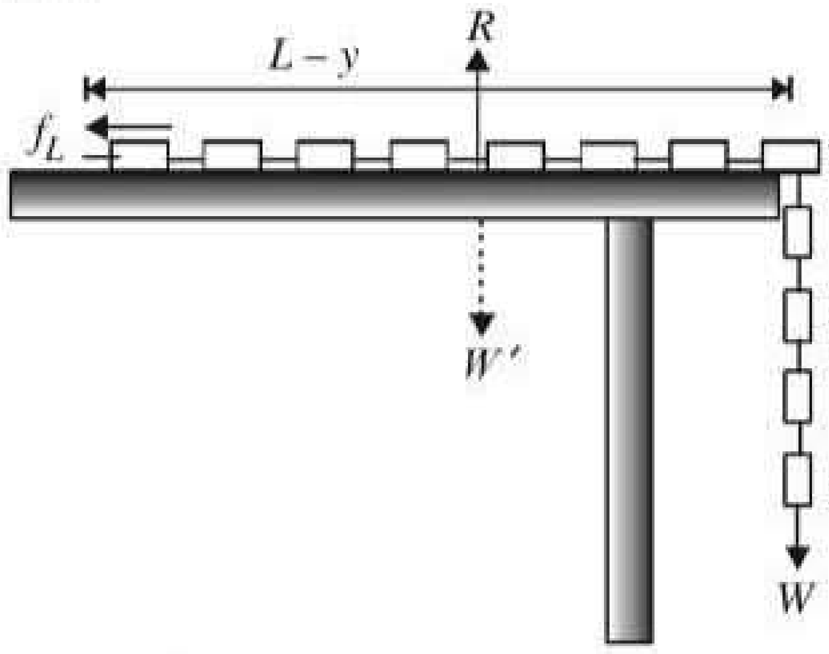
$$T = \left(\frac{75}{100}\right)mg = \frac{3}{4}mg$$

$$\therefore \quad ma = mg - \left(\frac{3}{4}\right)mg = \frac{1}{4}mg \text{ or } a = \frac{g}{4}$$

53. (b)

54. (c) : Newton's first law of motion is related to physical independence of force.

55. (a) : Let M is the mass of the chain of length L. If y is the maximum length of chain which can hang outside the table without sliding, then for equilibrium of the chain, the weight of hanging part must be balanced by the force of friction on the portion on the table.



$$W = f_L \qquad \text{.....(i)}$$

But from figure

$$W = \frac{M}{L} yg \text{ and } R = W' = \frac{M}{L}(L - y)g$$

So that $f_L = \mu R = \mu \frac{M}{L}(L - y)g$

Substituting these values of W and f_L in eqn (i),

we get $\mu \frac{M}{L}(L - y)g = \frac{M}{L} yg$

or $\mu(L - y) = y$ or $y = \frac{\mu L}{\mu + 1} = \frac{0.25L}{1.25} = \frac{L}{5}$

or $\frac{y}{L} = \frac{1}{5} = \frac{1}{5} \times 100\% = 20\%$

56. (b) : When milk is churned, cream gets separated due to centrifugal force.

57. (d) : Impulse is a vector quantity and is equal to change in momentum of the body thus, (same as $F \times t$ where t is short)

$$\text{Impulse} = mv_2 - mv_1 = m(v_2 - v_1)$$

58. (c) : Thrust is the force with which the rocket moves upward given by

$$F = u\frac{dm}{dt}$$

Thus mass of the gas ejected per second to supply the thrust needed to overcome the weight of the rocket is

$$\frac{dm}{dt} = \frac{F}{u} = \frac{m \times a}{u} \text{ or } \frac{dm}{dt} = \frac{600 \times 10}{1000} = 6 \text{ kgs}^{-1}$$

59. (a) : Since 5 kg body explodes into three fragments with masses in the ratio 1 : 1 : 3 thus, masses of fragments will be 1 kg, 1 kg and 3 kg respectively. The magnitude of resultant momentum of two fragments each of mass 1 kg, moving with velocity 21 m/s, in perpendicular directions is

$$\sqrt{(m_1v_1)^2 + (m_2v_2)^2}$$

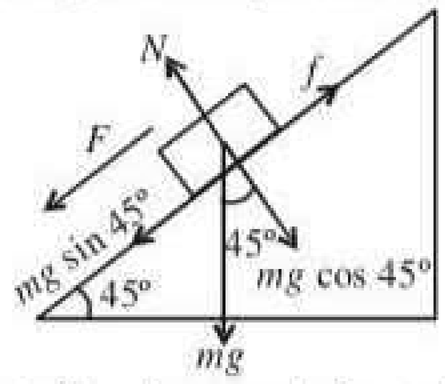
$$m'v' = \sqrt{(21)^2 + (21)^2} = 21\sqrt{2} \text{ kg m/s}$$

According to law of conservation of linear momentum

$$m_3v_3 = m'v' = 21\sqrt{2} \text{ or } 3v_3 = 21\sqrt{2}$$

or $v_3 = 7\sqrt{2}$ m/s

60. (b) : The various forces acting on the body have been shown in the figure. The force on the body down the inclined plane in presence of friction μ is



$$F = mg\sin\theta - f = mg\sin\theta - \mu N = ma$$

or $a = g\sin\theta - \mu g\cos\theta$.

Since block is at rest thus initial velocity $u = 0$

∴ Time taken to slide down the plane

$$t_1 = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2s}{g\sin\theta - \mu g\cos\theta}}$$

In absence of friction time taken will be $t_2 = \sqrt{\frac{2s}{g\sin\theta}}$

Given : $t_1 = 2t_2$.

$$\therefore \quad t_1^2 = 4t_2^2 \text{ or } \frac{2s}{g(\sin\theta - \mu\cos\theta)} = \frac{2s \times 4}{g(\sin\theta)}$$

or $\sin\theta = 4\sin\theta - 4\mu\cos\theta$ or $\mu = \frac{3}{4}\tan\theta = 0.75$