Main Booklet Solution

Laws of Motion & Friction

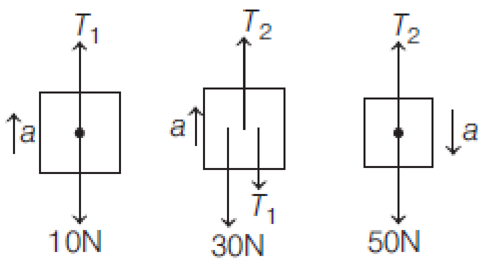
In chapter Exercise – 1 (Problems on Constraints & Simple Pulley System)

1. $v = 2u$ **2.** $u = 2v$ **3.** $u = 2v$ **4.** $u = 4v$

5. $v_1 + v_2 = 2v_3$ **6.** $v_2 + v_3 = 2v_1$ **7.** $2v_1 = v_2 + 2v_3$ **8.** $v_2 = v_3 = 2v_1$

9. $a_2 = 3a_1$ **10.** $3a_1 = 2a_2$ **11.** $5a_1 = 4a_2$

12. $g / 9$



$50 - T_2 = 5a$ ...(i)

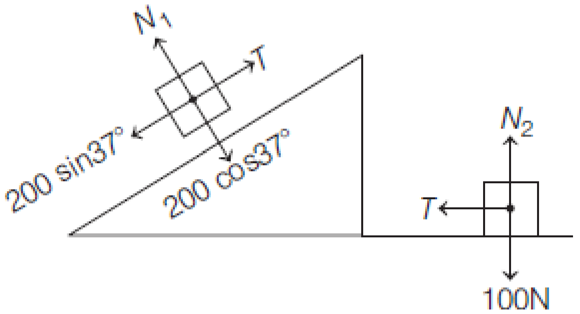
$T_2 - 30 - T_1 = 3a$ ...(ii)

$T_1 - 10 = 1a$ ...(iii)

Solving Eqs. (i), (ii) and (iii), we get

$$a = \frac{g}{9}$$

13. $2g / 5$



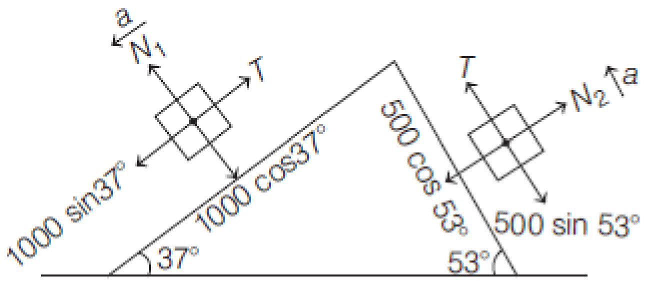
$200 \sin 37^\circ - T = 20a$ ...(i)

$T = 10a$ ...(ii)

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

$\Rightarrow \quad a = 4 \text{ m/s}^2$

14. $2g / 15$



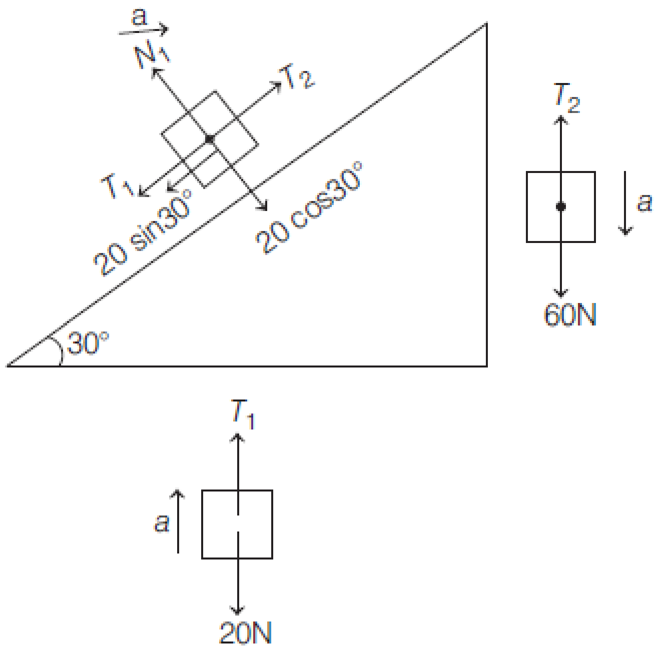
$$1000 \sin 37^\circ - T = 100a \qquad ...(\text{i})$$

$$T - 500 \sin 53^\circ = 50a \qquad ...(\text{ii})$$

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

$$\Rightarrow \quad a = \frac{4}{3}\,\text{m/s}^2$$

15. $3g / 10$



$$60 - T_2 = 6a \qquad ...(\text{i})$$

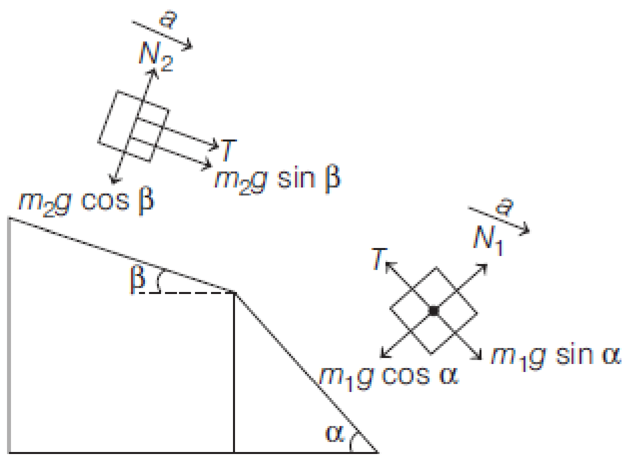
$$T_2 - T_1 - 10 = 2a \qquad ...(\text{ii})$$

$$T_1 - 20 = 2a \qquad ...(\text{iii})$$

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

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

16. $\dfrac{(m_1 \sin\alpha + m_2 \sin\beta)g}{m_1 + m_2}$



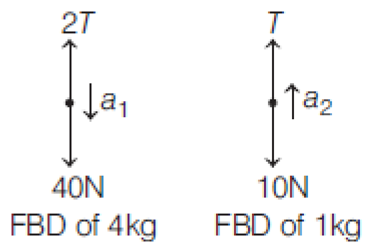
$$m_1 g \sin\alpha - T = m_1 a \qquad ...(i)$$

$$T + m_2 g \sin\beta = m_2 a \qquad ...(ii)$$

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

$$\Rightarrow \quad a = \frac{(m_1 \sin\alpha + m_2 \sin\beta)g}{m_1 + m_2}$$

17. acceleration of 4 kg = 2.5 m/s^2 down, acceleration of 1 kg = 5 m/s^2 up



$$40 - 2T = 4a_1 \qquad ...(i)$$

$$T - 10 = 1a_2 \qquad ...(ii)$$

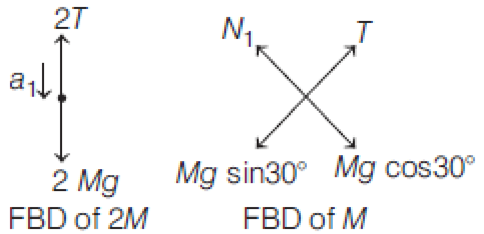
$$2a_1 = a_2 \qquad ...(iii)$$

Solving Eqs. (i), (ii) and (iii), we get

$a_1 = 2.5 \text{ m/s}^2$, down

and $a_2 = 5 \text{ m/s}^2$, up

18. acceleration of $2M = \dfrac{g}{6}$ down, acceleration of $M = \dfrac{g}{3}$ up the plane



$$2Mg - 2T = 2Ma_1 \qquad ...(i)$$

$$T - Mg\sin 30^\circ = Ma_2 \qquad ...(ii)$$

$$2a_1 = a_2 \qquad ...(iii)$$

Solving Eqs. (i), (ii) and (iii), we get

$a_1 = \frac{g}{6}$, down

and $a_2 = \frac{g}{3}$, up the plane

19. acceleration of $2M = \frac{2g}{3}$ down, acceleration of $M = \frac{g}{3}$ up

$2Mg - T = 2Ma_1$ ...(i)

$2T - Mg = Ma_2$ ...(ii)

$2a_2 = a_1$ ...(iii)

$a_2 = \frac{g}{2}$, up and $a_1 = \frac{2g}{3}$, down

20. acceleration of 4 kg $= \frac{2g}{7}$ down, acceleration of 5 kg $= \frac{g}{7}$ up

$50 - 2T = 5a_1$ ...(i)

$T - 40 = 4a_2$ ...(ii)

$a_2 = 2a_1$ ...(iii)

Solving Eqs. (i), (ii) and (iii), we get

$a_1 = -\frac{10}{7}\,\text{m/s}^2 = \frac{10}{7}\,\text{m/s}^2$, up

$a_2 = -\frac{20}{7}\,\text{m/s}^2 = \frac{20}{7}\,\text{m/s}^2$, down

21. acceleration of 3 kg = 20 m/s^2 and acceleration of 5 kg = 10 m/s^2

$170 - 2T = 5a_1$ ...(i)

$T = 3a_2$ ...(ii)

$a_2 = 2a_1$ ...(iii)

Solving Eqs. (i), (ii) and (iii), we get

$a_1 = 10\,\text{m/s}^2$ and $a_2 = 20\,\text{m/s}^2$

22. acceleration of $A = \frac{9F}{34m}$, acceleration of $B = \frac{3F}{17m}$

$F - 2T = 2ma_1$ ...(i)

$3T = 4ma_2$ ...(ii)

$2a_1 = 3a_2$ ...(iii)

Solving Eqs. (i), (ii) and (iii), we get

$a_2 = \frac{3F}{17m}$ and $a_1 = \frac{9F}{34m}$

23. acceleration of $3m$ and m are $\frac{g}{13}$ and $\frac{7g}{13}$, respectively.

$$7T - 3mg = 3ma_1 \quad ...(i)$$

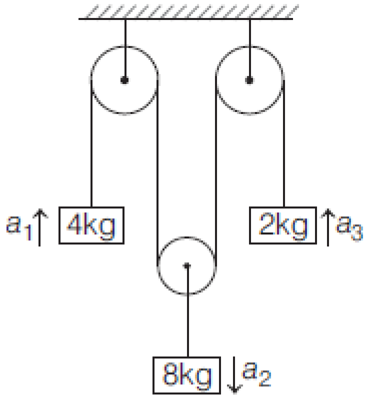
$$mg - T = ma_2 \quad ...(ii)$$

$$7a_1 = a_2 \quad ...(iii)$$

Solving Eqs. (i), (ii) and (iii), we get

$$a_1 = \frac{7g}{13} \text{ and } a_2 = \frac{g}{13}$$

24. acceleration of 8 kg, 4 kg and 2 kg are 2 m/s^2 up, 2 m/s^2 down, 6 m/s^2, respectively.



$$T - 40 = 4a_1 \quad ...(i)$$

$$80 - 2T = 8a_2 \quad ...(ii)$$

$$T - 20 = 2a_3 \quad ...(iii)$$

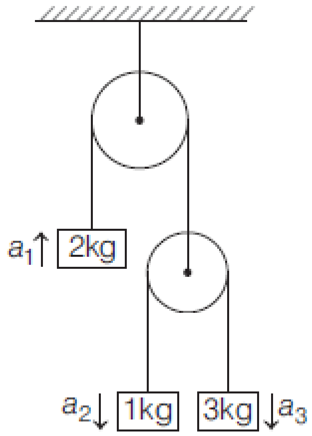
$$2a_2 = a_1 + a_3 \quad ...(iv)$$

$$a_1 = -2\,\text{m/s}^2$$

$$a_2 = +2\,\text{m/s}^2$$

$$a_3 = +6\,\text{m/s}^2$$

25. acceleration of 1 kg, 2 kg and 3 kg are 2 m/s^2 down, 2 m/s^2 and 6 m/s^2 up, respectively.



$$2T - 20 = 2a_1 \quad ...(i)$$

$$10 - T = a_2 \quad ...(ii)$$

$$30 - T = 3a_3 \quad ...(iii)$$

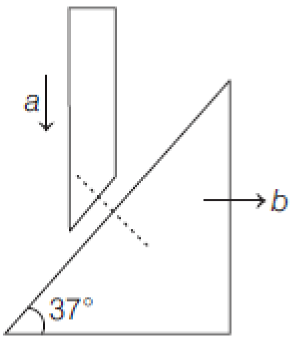
$$2a_1 = a_2 + a_3 \quad ...(iv)$$

Solving Eqs. (i), (ii), (iii) and (iv), we get

$a_1 = 2\,\text{m/s}^2$, $a_2 = -2\,\text{m/s}^2$, $a_3 = 6\,\text{m/s}^2$

In chapter Exercise – 2 (Wedge constraints & Pseudo force (acc. frames))

26. $\frac{4a}{3}\hat{\mathbf{i}}$



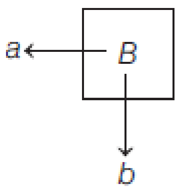
From wedge constraint their acceleration will be same along the common normal at contact.

$\Rightarrow\ a\cos 37^\circ = b\sin 37^\circ \ \Rightarrow\ b = \frac{4a}{3}$

So, $\mathbf{a}_B = \left(\frac{4a}{3}\right)\hat{\mathbf{i}}$

27. $-a\hat{\mathbf{i}} - 4a\hat{\mathbf{j}}$

From string constraint,



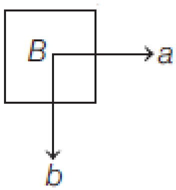
$-4a + b = 0$

$\Rightarrow\ b = 4a$

$\mathbf{a}_B = -a\hat{\mathbf{i}} - 4a\hat{\mathbf{j}}$

28. $a\hat{\mathbf{i}} - 2(a+c)\hat{\mathbf{j}}$

From string constraint,



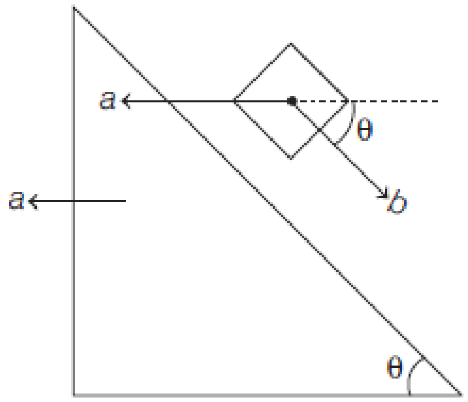
$-2a - 2c + b = 0$

$\Rightarrow\ b = 2(a+c)$

$\mathbf{a}_B = a\hat{\mathbf{i}} - 2(a+c)\hat{\mathbf{j}}$

29. $a(\cos\theta - 1)\hat{\mathbf{i}} - a\sin\theta\,\hat{\mathbf{j}}$

From string constraint,



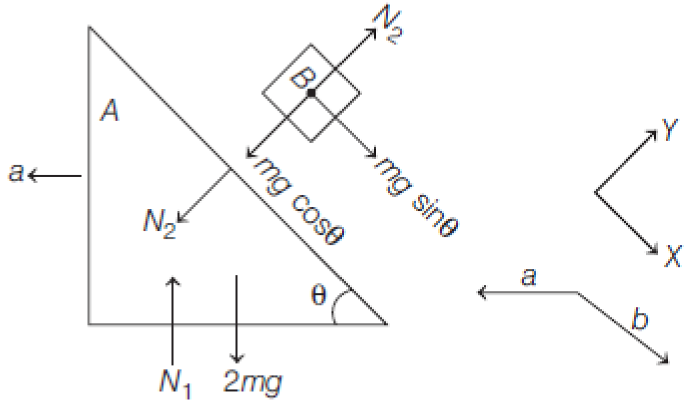
$$-a + b = 0$$

$$\Rightarrow \quad b = a$$

$$\mathbf{a}_B = (b\cos\theta - a)\hat{\mathbf{i}} - b\sin\theta\,\hat{\mathbf{j}}$$

$$= a(\cos\theta - 1)\hat{\mathbf{i}} - a\sin\theta\,\hat{\mathbf{j}}$$

30. $a = \dfrac{b\cos\theta}{3}; b = \dfrac{3g\sin\theta}{3 - \cos^2\theta}$



For A, $\sum F_x = ma_x$

$$\Rightarrow \quad N_2\sin\theta = 2ma \qquad ...(\text{i})$$

For B, $\sum F_x = ma_x$

$$\Rightarrow \quad mg\sin\theta = m(b - a\cos\theta) \qquad ...(\text{ii})$$

$$\sum F_y = ma_y$$

$$\Rightarrow \quad mg\cos\theta - N_2 = ma\sin\theta \qquad ...(\text{iii})$$

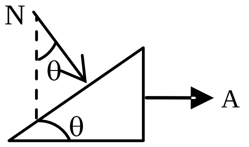
Solving Eqs. (i), (ii) and (iii), we get

$$a = \frac{b\cos\theta}{2}; b = \frac{3g\sin\theta}{3 - \cos^2\theta}$$

31. $a_1\sin 45^0 = a_2\sin 15^0$

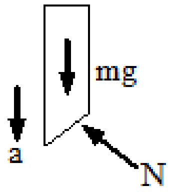
32. $A = \dfrac{mg}{M\cot\theta + m\tan\theta}$ and $a = \dfrac{mg\tan\theta}{M\cot\theta + m\tan\theta}$

Let the acceleration of wedge be 'A'



$N\sin\theta = MA$ ...(1)

Let acceleration of rod be 'a'



$mg - N\cos\theta = ma$ ...(2)

$\tan\theta = y/x$

$y = x\tan\theta$

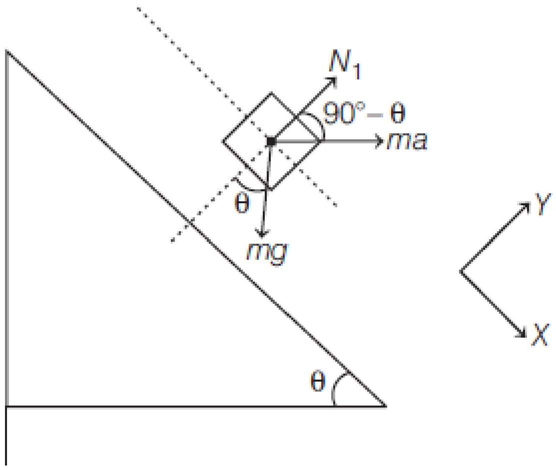
$\dfrac{d^2y}{dt^2} = \dfrac{d^2x}{dt^2}\tan\theta$

$a = A\tan\theta$ ...(3)

Solving (1) (2) & (3), we get

$A = \dfrac{mg}{M\cot\theta + m\tan\theta}$ and $a = \dfrac{mg\tan\theta}{M\cot\theta + m\tan\theta}$

33. $g\cot\theta$



$\sum F_y = 0$

$\Rightarrow$ $N_1 + ma\sin\theta = mg\cos\theta$

$\Rightarrow$ $N_1 = mg\cos\theta - ma\sin\theta$

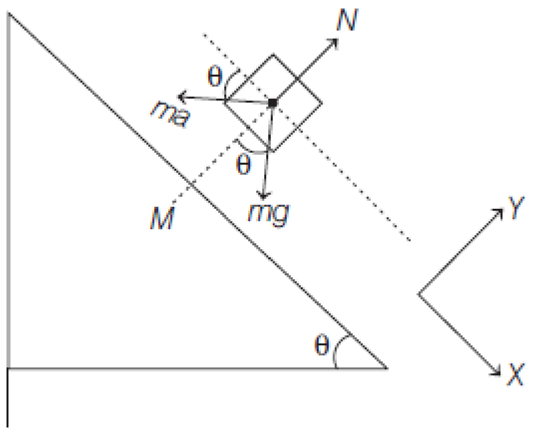
When block loses contact with the wedge

$N_1 = mg\cos\theta - ma\sin\theta = 0$

$\Rightarrow$ $a = g\cot\theta$

34. $(M+m)g\tan\theta$

Lets take acceleration of wedge to be a.



$$\sum F_x = 0$$

$$\Rightarrow \quad mg\sin\theta - ma\cos\theta = 0$$

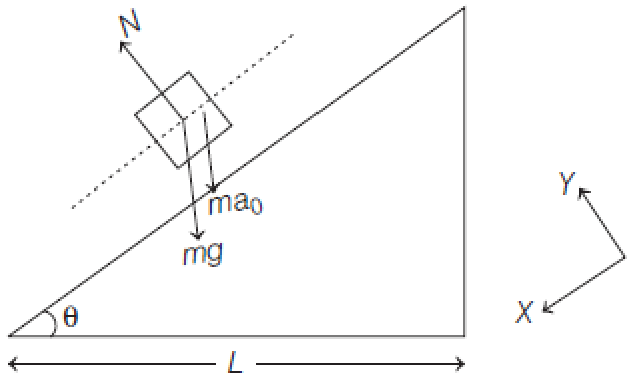
$$\Rightarrow \quad a = g\tan\theta$$

For $(M+m)$ system,

$$\sum F_x = ma$$

$$\Rightarrow \quad F = (M+m)g\tan\theta$$

35. $\sqrt{\left(\dfrac{2L}{(g+a_0)\sin\theta\cos\theta}\right)}$



$$\sum F_x = ma_x$$

$$\Rightarrow \quad (mg+ma_0)\sin\theta = ma_x$$

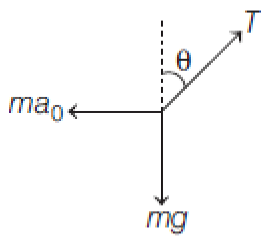
$$\Rightarrow \quad a_x = (g+a_0)\sin\theta$$

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

$$\Rightarrow \quad \frac{L}{\cos\theta} = 0 + \frac{1}{2}(g+a_0)\sin\theta T^2$$

$$T = \sqrt{\frac{2L}{(g+a_0)\sin\theta\cos\theta}}$$

36. $\tan^{-1}\left(\frac{a_0}{g}\right)$



FBD of *m*

$\sum F_x = 0$

$\Rightarrow \quad T\sin\theta = ma_0 \qquad ...(i)$

$\sum F_y = 0$

$\Rightarrow \quad T\cos\theta = mg \qquad ...(ii)$

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

$\Rightarrow \quad \tan\theta = \frac{a_0}{g} \Rightarrow \theta = \tan^{-1}\left(\frac{a_0}{g}\right)$

In chapter Exercise – 3 (Spring force)

37. 10 N

System is in equilibrium. Tension in the string will be 10 N, so spring balance reading will be 10 N.

38. 16 N

$40 - T = 4a \qquad ...(i)$

$T - 10 = 1a \qquad ...(ii)$

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

$a = 6\ \text{m/s}^2$ and $T = 16$ N

Spring balance reading = T = 16 N

39. Each will read 10 kg.

Both of them will read 100 N.

40. 0.2 m

$30 - T_1 = 3a \qquad ...(i)$

$10 + T_1 - T_2 = a \qquad ...(ii)$

$T_2 - 20 = 2a \qquad ...(iii)$

Solving Eqs. (i), (ii) and (iii), we get

$a = \frac{10}{3}\ \text{m/s}^2$ and $T_1 = 20\ \text{N}$

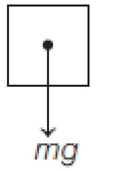
Spring force $= kx = T_1$

$\Rightarrow \quad 100x = 20$

$\Rightarrow \quad x = 0.2\ \text{m}$

41. $g/2$ upwards, g downwards

Just after cutting the string

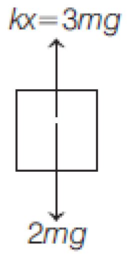


FBD of m

$$F = ma$$

$$\Rightarrow \quad mg = ma$$

$$\Rightarrow \quad a = g \downarrow$$



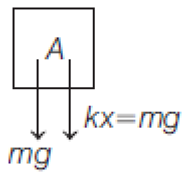
FBD of $2m$

$$F = ma$$

$$\Rightarrow \quad 3mg - 2mg = 2ma$$

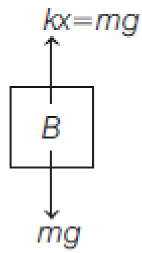
$$\Rightarrow \quad a = \frac{g}{2} \uparrow$$

42. $2g$ downwards, 0



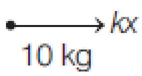
For A, $mg + mg = ma_A$

$$a_a = 2g \downarrow$$



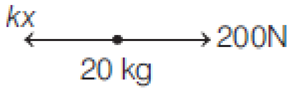
For B, $a_B = 0$

43. 4 ms^{-2}



$$\Rightarrow \quad kx = 10(12)$$

$$\Rightarrow \quad kx = 120 \text{ N}$$



$$200 - kx = 20a$$
$$\Rightarrow \quad 200 - 120 = 20a$$
$$\Rightarrow \quad a = 4 \text{ m/s}^2$$

JEE Main Exercise

1. (D)
Horizontal velocity of ball and person are same so both will cover equal horizontal distance in a given interval of time and after following the parabolic path the ball falls exactly in the hand which threw it up.

2. (B)
$$\vec{a} = \frac{\overrightarrow{v_2} - \overrightarrow{v_1}}{t} = \frac{(-2)-(+10)}{4} = \frac{-12}{4} = -3 \text{ m/s}^2$$

3. (B)
$$F = ma = 10 \times (-3) = -30 \text{ N}$$

4. (B)
Impulse = Force × Time = $-30 \times 4 = -120\, N\text{-}s$

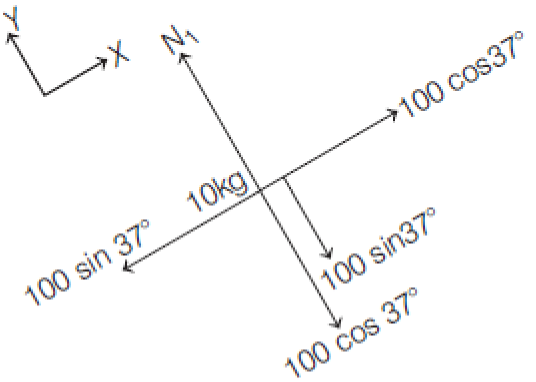
5. (D)
$$R = m(g+a) = m(g+g) = 2mg$$

6. (A)
$$T_1 = m(g+a) = 1 \times \left(g + \frac{g}{2}\right) = \frac{3g}{2}$$
$$T_2 = m(g-a) = 1 \times \left(g - \frac{g}{2}\right) = \frac{g}{2} \quad \therefore \quad \frac{T_1}{T_2} = \frac{3}{1}$$

7. (B)
Apparent weight $= m(g-a) = 50(9.8 - 9.8) = 0$

8. (A)
$$m = \frac{F}{a} = \frac{\sqrt{6^2 + 8^2 + 10^2}}{1} = \sqrt{200} = 10\sqrt{2} \text{ kg}$$

9. (A)



$\sum F_x = ma_x$

$\Rightarrow \quad 100\cos 37^\circ - 100\sin 37^\circ = 10a$

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

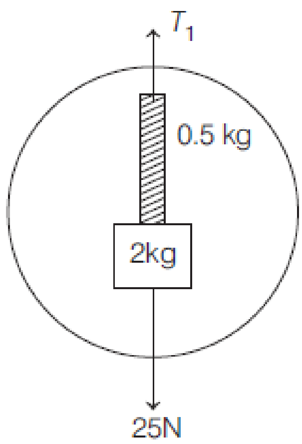
10. (C)

Acceleration of system, $a = \dfrac{F}{m_1 + m_2 + m_3}$

Net force on $m_2 = m_2 a$

$$= m_2\left(\frac{F}{m_1 + m_2 + m_3}\right)$$

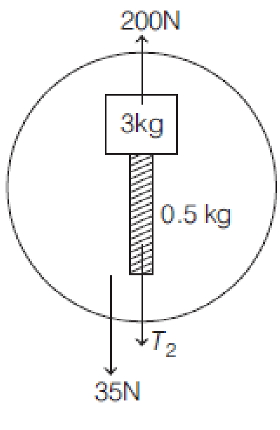
11. (C)



$\sum F_y = ma_y$

$\Rightarrow \quad T_1 - 25 = 2.5(10)$

$T_1 = 50\ \text{N}$



$$\sum F_y = ma_y$$

$\Rightarrow$ $200 - 35 - T_2 = 3.5(10)$

$\Rightarrow$ $T_2 = 130\text{ N}$

12. (C)

$150 - T_1 - T_2 = 15a$ ...(i)

$T_1 = 5a$ ...(ii)

$T_2 = 10a$ ...(iii)

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

$a = 5\text{ m/s}^2$ and $T_2 = 50\text{ N}$

13. (C)

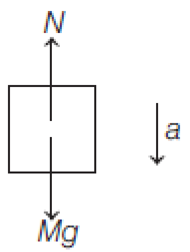
$8g\sin 30^\circ - T = 8a$ ...(i)

$T - 4g = 4a$ ...(ii)

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

$a = 0$

14. (A)



FBD of block

$Mg - N = ma$

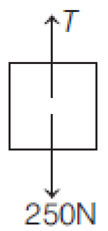
$\Rightarrow$ $Mg - \dfrac{Mg}{4} = Ma \Rightarrow a = \dfrac{3g}{4}$

15. (D)

$T - 6000g = 6000\left(\dfrac{g}{2}\right)$

$\Rightarrow$ $T = 9000g$

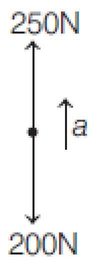
16. (D)



FBD of cage

$\sum F_y = 0$

$\Rightarrow$ $T = 250\text{ N}$

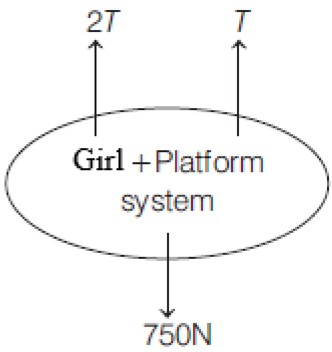


FBD of monkey

$$250 - 200 = 20a$$

$\Rightarrow$ $a = 2.5\ \text{m/s}^2$

17. (B)



$$\sum F_y = ma_y$$

$\Rightarrow$ $3T - 750 = 75(0)$

$\Rightarrow$ $T = 250\ \text{N}$

18. (A)

$m_2 g - 2T = m_2 a_2$ ...(i)

$T = m_1 a_1$ ...(ii)

$a_1 = 2a_2$ ...(iii)

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

$$a_2 = \frac{m_2 g}{4m_1 + m_2}$$

19. (C)

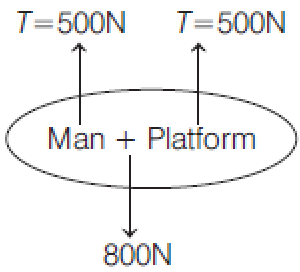
$\Delta p = \sum F \Delta t$

$m\Delta v = 7(1.5) + 5(1.7) + 10(3)$

$\Delta = 4.9\ \text{m/s}$

20. (B)

For (man + platform) system,



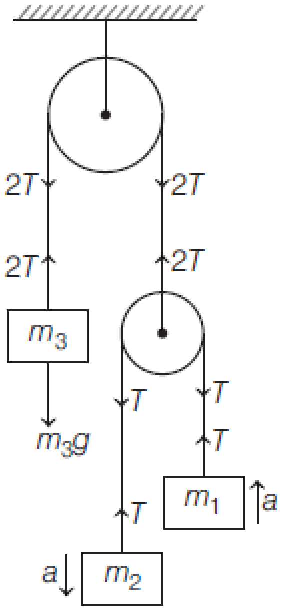
$$\sum F_y = ma_y$$

$\Rightarrow \quad 2T - 800 = 80a$

$\Rightarrow \quad a = 2.5 \text{ m/s}^2$

21. (A)

Since, m_3 is at rest.



$\Rightarrow \quad 2T = m_3 g$

For m_1 and m_2,

$$m_2 g - T = m_2 a \qquad ...(i)$$

$$T - m_1 g = m_1 a \qquad ...(ii)$$

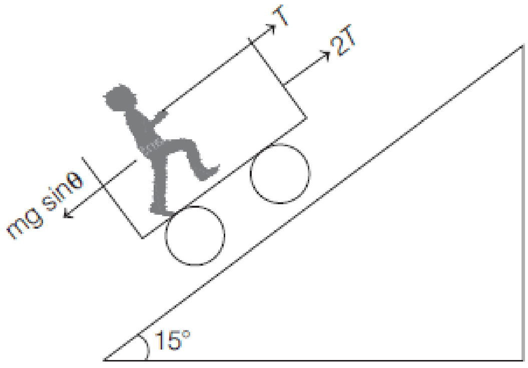
From Eqs. (i) and (ii), we get

$$\frac{m_2 g - T}{m_2} = \frac{T - m_1 g}{m_1}$$

$$T - = \frac{2m_1 m_2 g}{m_1 + m_2} = \frac{m_3 g}{2}$$

$$\Rightarrow \quad m_3 = \frac{4m_1 m_2}{m_1 + m_2}$$

22. (C)



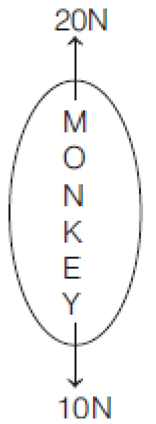
$3T - mg\sin\theta = ma$

$750 - 1000(0.26) = 100a$

$a = 4.9 \text{ m/s}^2$

23. (B)

To just lift the block, tension in the string will be 20 N.



$F = ma$

$\Rightarrow \quad 20 - 10 = 1 \cdot a_1$

$a_1 = 10 \text{ m/s}^2$

When monkey stops moving w.r.t. the string

$20 - T = 2a_2 \qquad \text{...(i)}$

$T - 10 = 1a_2 \qquad \text{...(ii)}$

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

$\Rightarrow \quad a_2 = \frac{10}{3} \text{ m/s}^2$

Change in acceleration $= a_1 - a_2 = 10 - \frac{10}{3} = \frac{20}{3} \text{ m/s}^2$

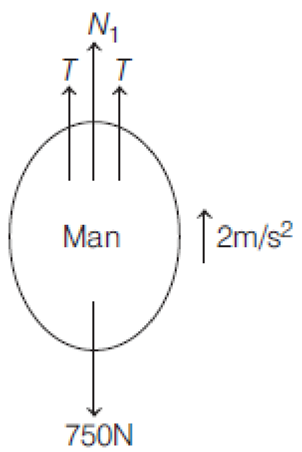
24. (B)

For (man + platform) system

$\Rightarrow \quad \sum F = ma$

$4T - 750 - 250 = 100 \times 2$

$\Rightarrow \quad T = 300 \text{ N}$



For only man, $\sum F = ma$

$\Rightarrow \quad 2T + N_1 - 750 = 75(2)$

$\Rightarrow \quad N_1 = 300 \text{ N}$

Reading $= \frac{N_1}{g} = 30 \text{ kg}$

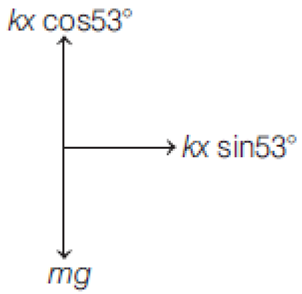
25. (C)

Before burning the string,

$$\sum F_x = 0 \Rightarrow T = kx\sin 53^\circ$$

$$\sum F_y = 0 \Rightarrow kx\cos 53^\circ = mg$$

$$\Rightarrow \quad kx = \frac{5mg}{3}$$



After burning the string,

$$\sum F_x = ma_x$$

$$\Rightarrow \quad kx\sin 53^\circ = ma_x$$

$$\Rightarrow \quad a_x = \frac{4g}{3}$$

$$\sum F_y = ma_y$$

$$\Rightarrow \quad mg - kx\cos 53^\circ = ma_y$$

$$\Rightarrow \quad a_y = 0$$

26. (C)

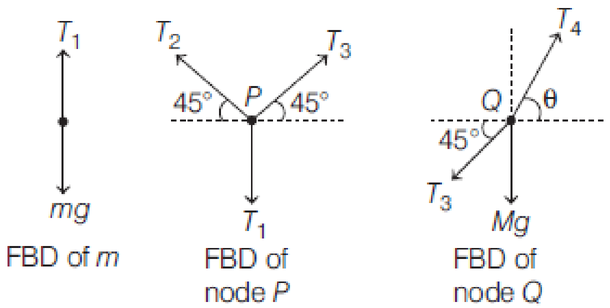
$$T = \frac{2m_1 m_2 g_{\text{eff}}}{m_1 + m_2} = \frac{2(3)(1.5)}{4.5}\left(g + \frac{g}{10}\right)$$

$$= \frac{11g}{5} = 22\,\text{N}$$

$$kx = 2T = 2(22) = 44\,\text{N}$$

Reading of spring balance $= \dfrac{44}{g} = 4.4\,\text{kg}$

27. (A)



Fro m, $\sum F_y = 0 \Rightarrow T_1 - mg = 0$

$$\Rightarrow \quad T_1 = mg$$

For node P, $\sum F_x = 0$

$$\Rightarrow \quad T_3\cos 45^\circ - T_2\cos 45^\circ = 0$$

$\Rightarrow \quad T_3 = T_2$

$\sum F_y = 0$

$\Rightarrow \quad T_2 \sin 45° + T_3 \sin 45° = T_1$

$\Rightarrow \quad 2T_3 \sin 45° = T_1$

$\Rightarrow \quad T_3 \sin 45° = \frac{T_1}{2} = \frac{mg}{2}$

For node Q,

$\sum F_y = 0$

$\Rightarrow \quad T_4 \sin\theta = Mg + T_3 \sin 45° \quad \text{...(i)}$

$\sum F_x = 0$

$\Rightarrow \quad T_4 \cos\theta = T_3 \cos 45° \quad \text{...(ii)}$

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

$$\Rightarrow \quad \tan\theta = \frac{M + \frac{m}{2}}{\frac{m}{2}} = 1 + \frac{2M}{m}$$

28. (10)

Force on particle at 20 cm away $F = kx$

$F = 15 \times 0.2 = 3\,N \qquad [\text{As } k = 15\,N/m]$

$\therefore$ Acceleration = $\frac{\text{Force}}{\text{Mass}} = \frac{3}{0.3} = 10\,m/s^2$

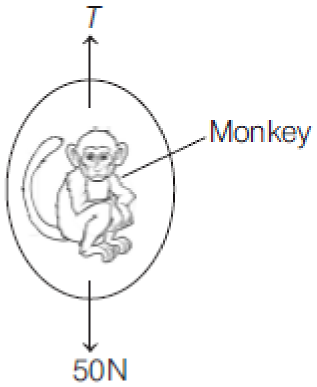
29. (2.5)

Tension the string $= m(g+a) =$ Breaking force

$\Rightarrow 20(g+a) = 25 \times g \Rightarrow a = g/4 = 2.5\,m/s^2$

30. (6)

For clamp, $T \sin 30° = 40 \Rightarrow T = 80\,\text{N}$



For monkey, $T - 50 = 5a$

$a = 6\,\text{m/s}^2$

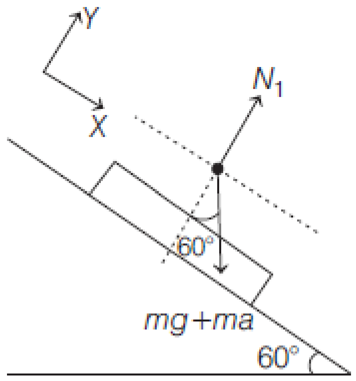
31. (322)

For (A + B + C) system, $\sum F = \sum ma$

$T_D - 100 - 150 - 80 = [10(-2) + 15(0) + 8(1.5)]$

$T_D = 322\,\text{N}$

32. (40)



$$\sum F_y = 0$$

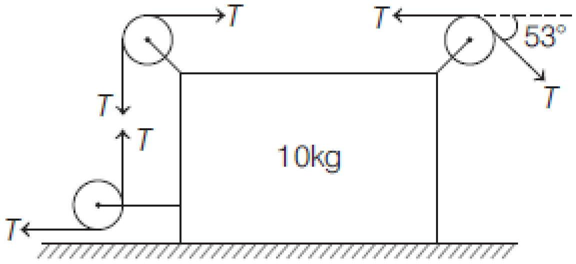
$$\Rightarrow \quad N_1 = (mg + ma)\cos 60^\circ$$

$$\Rightarrow \quad N_1 = 50 \times 16 \times \frac{1}{2}$$

$$N_1 = 400\,\text{N}$$

Reading of weighing machine $= \dfrac{N_1}{g} = 40$ kg

33. (4)



$$T = 100\text{ N}$$

$$\sum F_x = ma_x$$

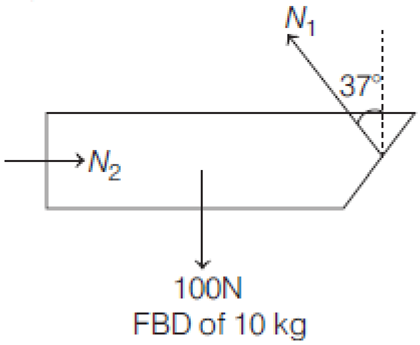
$$\Rightarrow \quad T - T\cos 53^\circ = 10a$$

$$100 - 100\left(\frac{3}{5}\right) = 10a$$

$$\Rightarrow \quad a = 4\text{ m/s}^2 \text{ left}$$

34. (75)

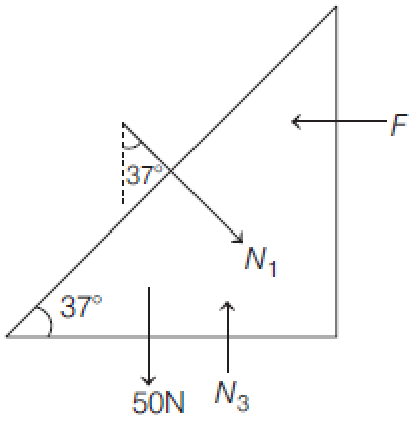
$$\sum F_y = 0$$



$$\Rightarrow \quad N_1 \cos 37^\circ = 100$$

$$\Rightarrow \quad N_1 = \frac{500}{4} = 125\,\text{N}$$

$\sum F_x = 0$



FBD of 5 kg

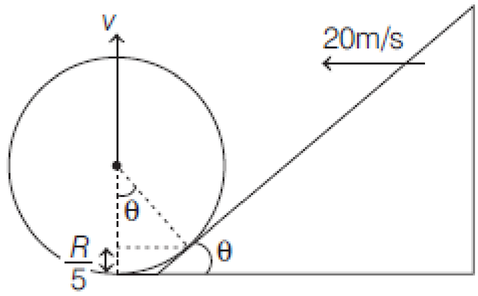
$F = N_1 \sin 37°$

$\Rightarrow \quad F = 125\left(\dfrac{3}{5}\right)$

$\Rightarrow \quad F = 75\text{ N}$

35. (15)

$\cos\theta = \dfrac{4R/5}{R} = \dfrac{4}{5} \Rightarrow \theta = 37°$

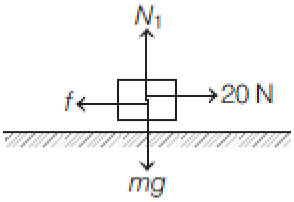


From wedge constraint, $v\cos\theta = 20\sin\theta$

$\Rightarrow \quad v = 20\tan\theta = 20\left(\dfrac{3}{4}\right) = 15\text{ m/s}$

Friction

1. (A)



$$\sum F_y = 0$$

$\Rightarrow$ $N_1 - 40 = 0$

$\Rightarrow$ $N_1 = 40\,\text{N}$

Since, the block is not moving.

$$\sum F_x = 0$$

$\Rightarrow$ $20 - f = 0$

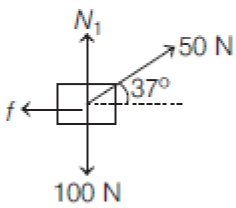
$\Rightarrow$ $f = 20\,\text{N}$ (static)

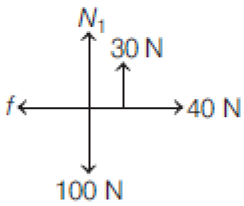
$$f \le f_L$$

$\Rightarrow$ $20 \le \mu_s (N_1)$

$\Rightarrow$ $\mu_S \ge 0.5$

2. (A)





$$\sum F_y = 0$$

$\Rightarrow$ $N_1 + 50\sin 30^\circ - 100 = 0$

$\Rightarrow$ $N_1 = 70\,\text{N}$

$$f_L = \mu_S N$$

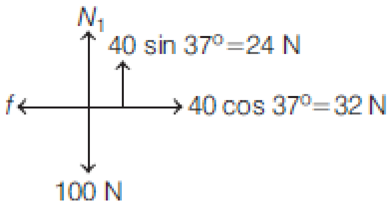
$$= 0.5(70) = 35\,\text{N}$$

$$\sum F_x = ma_x$$

$\Rightarrow$ $40 - 35 = 10a_x$

$\Rightarrow$ $a_x = 0.5\,\text{m/s}^2$

3. (B)



$\sum F_y = 0$

$\Rightarrow$ $+N_1 + 24 - 100 = 0$

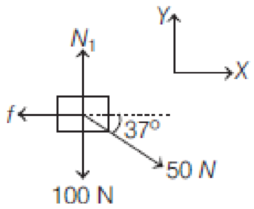
$\Rightarrow$ $N_1 = 76\,\text{N}$

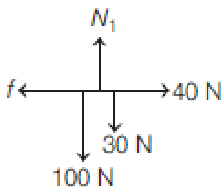
$f_L = \mu_S N = 0.5(76) = 38\,\text{N}$

Since, driving force is less than the limiting friction, the block will not move.
So, $a = 0$.

4. (C)

$\sum F_y = 0$





$\Rightarrow$ $N_1 - 100 - 30 = 0$

$\Rightarrow$ $N_1 = 130\,\text{N}$

$f_L = \mu_S N_1 3$

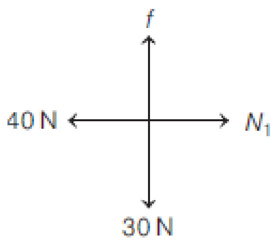
$\Rightarrow$ $f_L = 0.3(130) = 39\,\text{N}$

$\sum F_x = ma_x$

$\Rightarrow$ $40 - 39 = 10a_x$

$\Rightarrow$ $a_x = 0.1\ \text{m/s}^2$

5. (C)



$\sum F_x = 0$

$\Rightarrow$ $N_1 - 40 = 0$

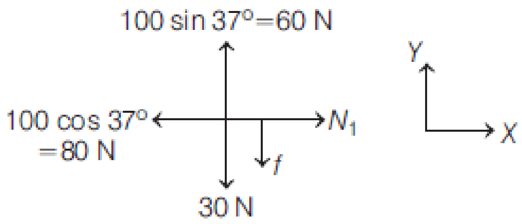
$\Rightarrow$ $N_1 = 40\text{N}$

$f_L = \mu_S N$

$\Rightarrow$ $f_L = 0.8(40) = 32\,\text{N}$

Since, $f_L \geq 30\,\text{N}$, the block won't move.

6. (A)



$$\sum F_x = 0$$

$\Rightarrow \quad +N_1 - 80 = 0$

$\Rightarrow \quad N_1 = 80N$

$$f_L = \mu_S N$$

$$f_L = 0.25(80) = 20 \text{ N}$$

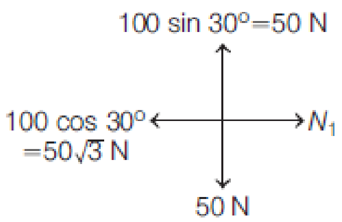
In absence of friction, driving force on the block is 60 – 30 = 30 N up the wall which is more than the limiting friction. So, block will accelerate up the wall.

$$\sum F_y = ma_y$$

$\Rightarrow \quad 60 - 30 - 20 = 3a_y$

$\Rightarrow \quad a_y = \frac{10}{3} \text{ m/s}^2$

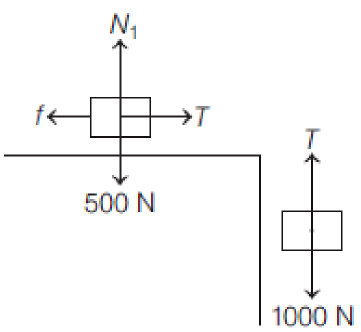
7. (A)



Since, driving force is zero in absence of friction, no friction will act

$\Rightarrow \quad f = 0$ and $a = 0$

8. (A)



For 100 kg block,

$$\sum F_y = 0$$

$\Rightarrow \quad T - 1000 = 0$

$\Rightarrow \quad T = 1000 \text{ N}$

For 50 kg block,

$$\sum F_y = 0$$

$$N_1 - 500 = 0$$

$\Rightarrow \quad N_1 = 500\text{N}$

$\sum F_x = 0$

$\Rightarrow \quad T - f = 0$

$\Rightarrow \quad f = T = 1000\text{ N}$

$f_L = \mu N_1 = \mu(500)$

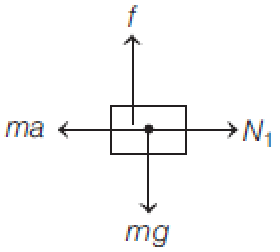
$f \le f_L$

$1000 \le 500(\mu)$

$\Rightarrow \quad \mu \ge 2$

9. (B)

Lets take acceleration of cart as a



$\sum F_x = 0 \Rightarrow N_1 = ma$

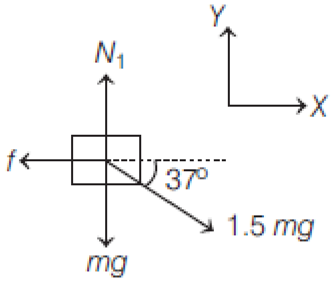
$\sum F_y = 0 \Rightarrow f = mg$

and $f \le f_L$

$\Rightarrow \quad mg \le \mu N_1 \Rightarrow a \ge \dfrac{g}{\mu}$

$\Rightarrow \quad a_{\min} = \dfrac{g}{\mu}$

10. (A)



$\sum F_y = 0$

$\Rightarrow \quad +N_1 - mg - 1.5mg\sin 37^\circ = 0$

$\Rightarrow \quad N_1 = 1.9\,mg$

$\sum F_x = ma_x$

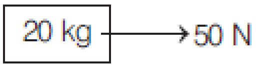
$\Rightarrow \quad 1.5mg\cos 37^\circ - \mu N_1 = m(0)$

$\Rightarrow \quad \mu = \dfrac{1.5mg\cos 37^\circ}{1.9\,mg}$

$\Rightarrow \quad \mu = \dfrac{12}{19}$

11. (A)

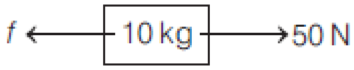
Taking both the block as a system,



$\sum F = ma$

$\Rightarrow \quad 50 = 20a$

$\Rightarrow \quad a = 2.5 \text{ m/s}^2$



For upper 10 kg block,

$50 - f = 10(2.5)$

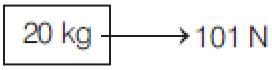
$\Rightarrow \quad f = 25 \text{ N}$

& $\quad f_L = 0.5(100) = 50 \text{ N}$

Since, $f < f_L$

Friction between both the blocks is static & common acceleration is 2.5 m/s^2.

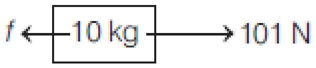
12. (B)



$\sum F = ma$

$\Rightarrow \quad 101 = 20a$

$\Rightarrow \quad a = 5.05 \text{ m/s}^2$



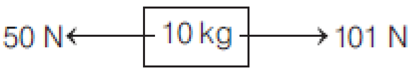
$\sum F = ma$

$\Rightarrow \quad 101 - f = 10(5.05)$

$\Rightarrow \quad f = 50.5 \text{ N}$

Since $f > f_L$; out assumption is wrong.

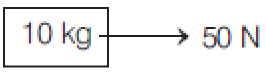
Friction between the blocks will be kinetic.



$\sum F = ma$

$\Rightarrow \quad 101 - 50 = 10a$

$\Rightarrow \quad a = 5.1 \text{ m/s}^2$



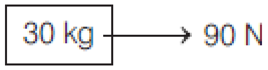
$\sum F = ma$

$\Rightarrow \quad 50 = 10a$

$\Rightarrow \quad a = 5 \text{ m/s}^2$

13. (A)

For system,

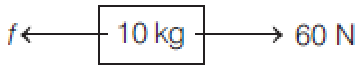


$\sum F = ma$

$\Rightarrow \quad 90 = 30a$

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

For 10 kg block,



$\sum F = ma$

$\Rightarrow \quad 60 - f = 10(3)$

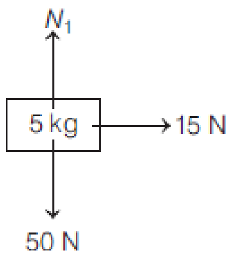
$f = 30\,\text{N}$

& $\quad f_L = 00.5(100) = 50\,\text{N}$

Since, $f < f_L$; out assumption is correct.

Both the blocks will move with common acceleraiton of 3 m/s^2.

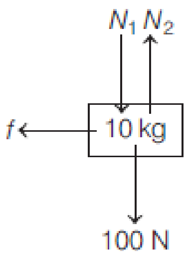
14. (B)



$\sum F = ma$

$\Rightarrow \quad 15 = 5a$

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

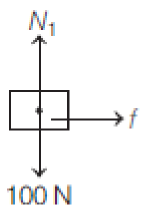


$a = 0$

$f = 0$

15. (C)

FBD of 10 kg block,



$\sum F_y = 0 \Rightarrow N_1 = 100\,\text{N}$

$\sum F_x = ma$

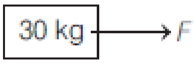
$\Rightarrow \quad f = 10a$

For maximum acceleration,

$10a = f_L = \mu(100)$

$\Rightarrow \quad a_{\max} = 5\,\text{m/s}^2$

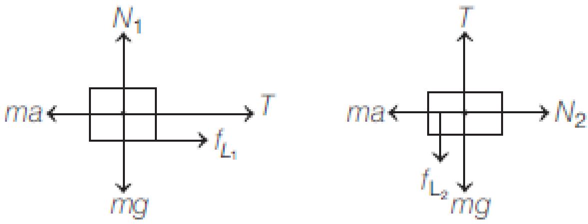
For (20 kg + 10 kg) system,



$\sum F_x = ma$

$\Rightarrow \quad F = 30(5) = 150\,\text{N}$

16. (C)



For keeping smaller blocks at rest w.r.t. the bigger block

$ma = mg + f_{L_2} + f_{L_1}$

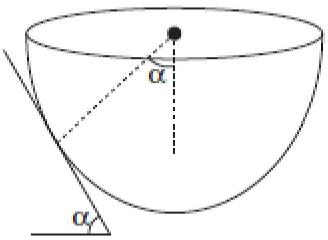
$\Rightarrow \quad ma = mg + \mu N_2 + \mu N_1$

$\Rightarrow \quad ma = mg + \mu(ma) + \mu(mg)$

$\Rightarrow \quad a = \left(\dfrac{1+\mu}{1-\mu}\right) g$

So, $F = (M + 2m)\left(\dfrac{1+\mu}{1-\mu}\right) g$

17. (A)



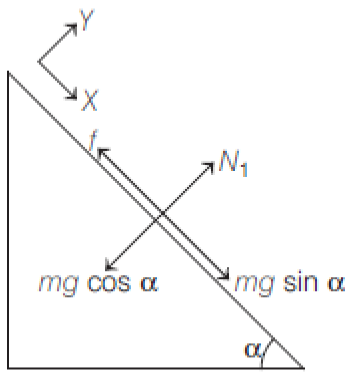
$\sum F_y = 0$

$\Rightarrow \quad N_1 - mg\cos\alpha = 0$

$\Rightarrow \quad N_1 = mg\cos\alpha$

$\sum F_x = 0$

$\Rightarrow \quad mg\sin\alpha = f$



& $\quad f \le f_L$

$\Rightarrow \quad mg\sin\alpha \le \mu mg\cos\alpha$

$\Rightarrow \quad \tan\alpha \le \dfrac{1}{3}$

$\Rightarrow \quad \tan\alpha_{\max} = \dfrac{1}{3}$

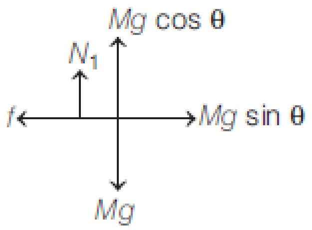
$\Rightarrow \quad \cot\alpha_{\max} = 3$

18. (C)

$\sum F_y = 0$

$\Rightarrow \quad N_1 + Mg\cos\theta - Mg = 0$

$\Rightarrow \quad N_1 = Mg(1-\cos\theta)$



For pulling the block,

$Mg\sin\theta \ge f_L$

$\Rightarrow \quad Mg\sin\theta \ge \mu N_1$

$\Rightarrow \quad Mg\sin\theta \ge \mu Mg(1-\cos\theta)$

$$\Rightarrow \quad \frac{2\sin\left(\frac{\theta}{2}\right)\cos\left(\frac{\theta}{2}\right)}{2\sin\left(\frac{\theta}{2}\right)} \ge \mu$$

$\Rightarrow \quad \cot\left(\dfrac{\theta}{2}\right) \ge \mu$

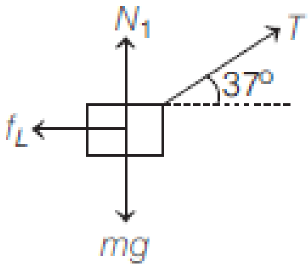
19. (B)

For block *B*,

$\sum F_y = 0$

$\Rightarrow \quad +N_1 + T\sin 37^\circ = mg$

$\Rightarrow \quad N_1 = mg - T\sin 37^\circ$



$$\sum F_x = 0$$

$$\Rightarrow T\cos 37^\circ = f_L$$

$$\Rightarrow \frac{4T}{5} = \mu\left(mg - \frac{3T}{5}\right)$$

$$\Rightarrow \frac{12T}{5} = 100g - \frac{3T}{5}$$

$$\Rightarrow T = \frac{100g}{3}$$

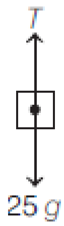
For A,

$$\sum F = ma$$

$$\Rightarrow T - 25g = 25a$$

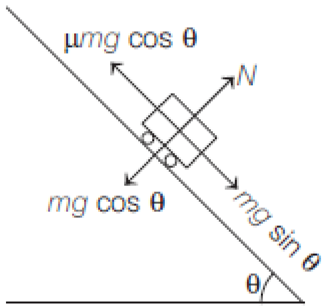
$$\Rightarrow \frac{100g}{3} - 25g = 25a$$

$$\Rightarrow a = \frac{g}{3}$$



20. (C)

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



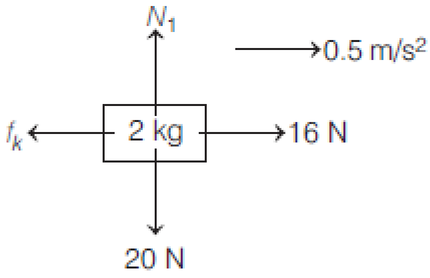
$$v^2 = u^2 + 2as$$

$$\Rightarrow v^2 = (20)^2 + 2\times 10\left[\left(\frac{3}{5}\right) - \left(\frac{1}{2}\right)\left(\frac{4}{5}\right)\right](21)$$

$$v = \sqrt{400+84} = \sqrt{484}\ \text{m/s} = 22\ \text{m/s}$$

21. (A)

For 2 kg block,



$\sum F_y = 0 \Rightarrow N_1 = 20\,\text{N}$

$f_k = \mu N_1 = 20\mu_1$

$\sum F = ma$

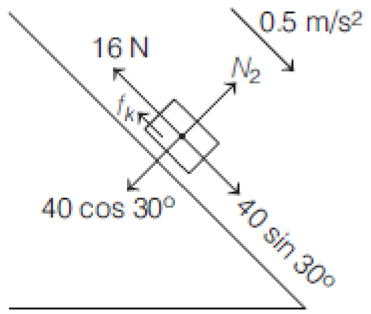
$\Rightarrow 16 - 20\mu_1 = 2(0.5)$

$\Rightarrow \mu_1 = \dfrac{3}{4}$

For 4 kg block,

$\sum F = ma$

$\Rightarrow 40\sin 30^\circ - 16 - f_k = 4(0.5)$



$\Rightarrow f_k = 2\,\text{N}$

$f_k = \mu_k N$

$\Rightarrow 2 = \mu_k(40\cos 30^\circ)$

$\Rightarrow \mu_k = \dfrac{1}{10\sqrt{3}} = 0.0577 = 0.06$

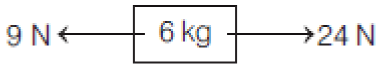
22. (B)

For 6 kg block,

$\sum F = ma$

$\Rightarrow 24 - 9 = 6a$

$\Rightarrow a = 2.5\,\text{m/s}^2$

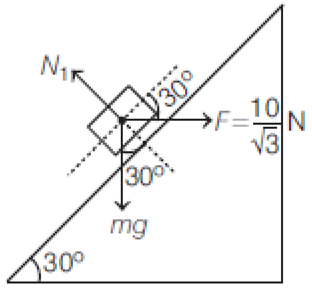


For 3 kg block,

$\Rightarrow F - 24 = 3(2.5)$

$\Rightarrow F = 31.5\,\text{N}$

23. (A)

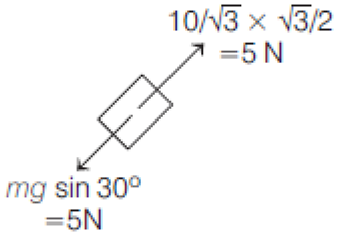


$$\Rightarrow \quad +N_1 - mg\cos 30^\circ - F\sin 30^\circ = 0$$

$$\Rightarrow \quad N_1 = mg\cos 30^\circ + F\sin 30^\circ$$

$$\Rightarrow \quad N_1 = 5\sqrt{3} + \frac{5}{\sqrt{3}} = \frac{20}{\sqrt{3}}\text{ N}$$

$$f_L = \mu N_1 = 0.5\left(\frac{20}{\sqrt{3}}\right) = \frac{10}{\sqrt{3}}\text{ N}$$



Along the inclined plane, in absence of friction, net force is zero.

So, $f = 0$

24. (0.75)

$$F_{\min} = \frac{\mu mg}{\sqrt{\mu^2+1}} = \frac{3mg}{5}$$

$$\Rightarrow \quad 25\mu^2 = 9\mu^2 + 9$$

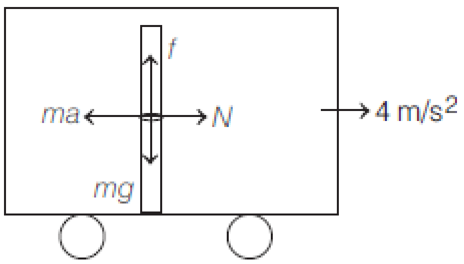
$$\Rightarrow \quad 16\mu^2 = 9$$

$$\Rightarrow \quad \mu = \frac{3}{4} = 0.75$$

25. (0.5)

w.r.t. train $\sum F_x = 0$

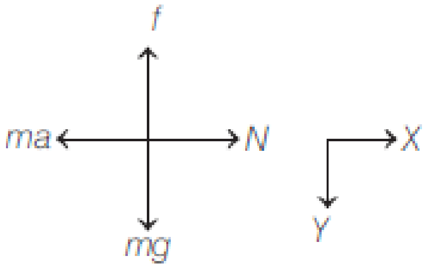
$$N = ma$$



$$\sum F_y = ma_y$$

$$\Rightarrow \quad mg - \mu N = ma_y$$

$$\Rightarrow \quad mg - \mu ma = ma_y$$



$\Rightarrow \quad a_y = g - \mu a$

$\Rightarrow \quad a_y = 10 - \frac{1}{2}(4) = 8 \text{ m/s}^2$

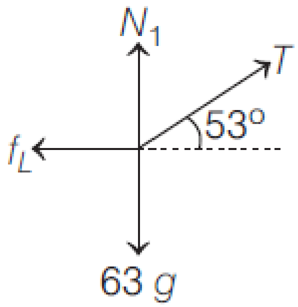
$s_y = u_y t + \frac{1}{2} a_y t^2$

$\Rightarrow \quad 1 = 0 + \frac{1}{2}(8) t^2$

$\Rightarrow \quad t = 0.5 \text{ s}$

26. (35)

For man,



$\sum F_y = 0$

$\Rightarrow \quad N_1 + T \sin 53^\circ = 63g$

$\Rightarrow \quad N_1 = 63g - \frac{4T}{5}$

$\sum F_x = 0$

$\Rightarrow \quad T \cos 53^\circ = f_L$

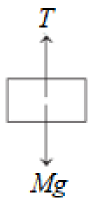
$\Rightarrow \quad \frac{3T}{5} = \mu\left(63g - \frac{4T}{5}\right)$

$\Rightarrow \quad \frac{3T}{5} = \frac{3}{5}\left(63g - \frac{4T}{5}\right)$

$\Rightarrow \quad \frac{9T}{5} = 63g$

$\Rightarrow \quad T = 35g$

For block,



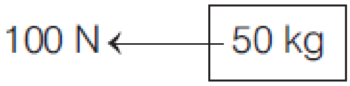
$\sum F_y = Ma_y$

$\Rightarrow \quad T - Mg = 0$

$\Rightarrow \quad M = 35 \text{ kg}$

27. (0.98)

Taking ($A + B$) system,

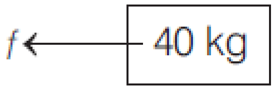


$$\sum F = ma$$

$\Rightarrow$ $100 = 50a$

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

For B,



$$\sum F = ma$$

$\Rightarrow$ $f = 40 \times 2 = 80 \text{ N}$

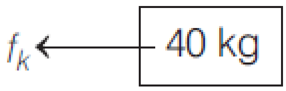
$$f_L = \mu_s N$$

$$= 0.75 \times 98 = 73.5 \text{ N}$$

Since, $f > f_L$, out assumption is wrong.

Friction between the blocks will be kinetic.

For B,



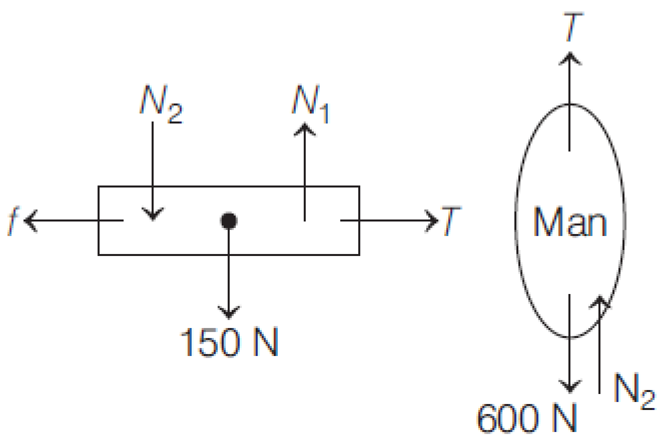
$$\sum F = ma$$

$\Rightarrow$ $f_k = 40a$

$$0.4 \times 10 \times 9.8 = 40a$$

$\Rightarrow$ $a = 0.98 \text{ m/s}^2$

28. (250)



For board,

$$\sum F_x = ma_x$$

$\Rightarrow$ $T - f_L = 0$

$\Rightarrow$ $T = f_L \Rightarrow T = \mu N_1$

$\Rightarrow$ $T = 0.5(N_2 + 150)$ ...(i)

For man,

$$\sum F_y = 0$$

$\Rightarrow \quad T + N_2 - 600 = 0$

$\Rightarrow \quad N_2 = 600 - T \qquad \ldots(\text{ii})$

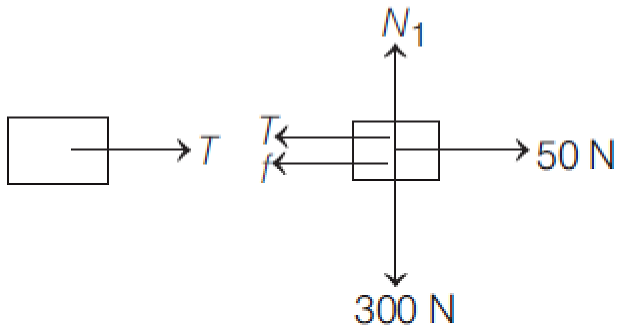
From Eqs. (i) & (ii), we get

$$T = 0.5(600 - T + 150)$$

$\Rightarrow \quad 3T = 750$

$\Rightarrow \quad T = 250\,\text{N}$

29. (0)

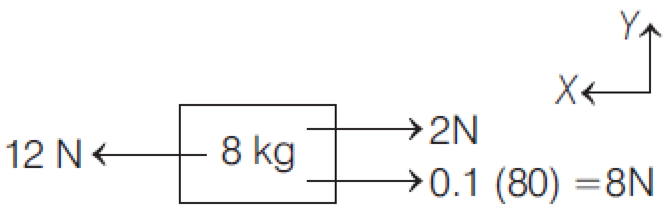


For block *A*,

$$f_L = \mu N = 0.2(300) = 60\,\text{N}$$

Since applied force is less than $f_L, T = 0$ and hence friction on block *B* = 0.

30. (3)



For (4 kg + 4 kg) system,

$$\sum F = ma$$

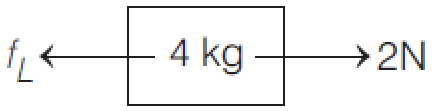
$\Rightarrow \quad 12 - 2 = 8 = 8a$

$\Rightarrow \quad a = 0.25 \text{ m/s}^2$

For upper 4kg block,

$$\sum F = ma$$

$\Rightarrow \quad f_L - 2 = 4(0.25)$



$\Rightarrow \quad f_L = 3N$

and $\quad f_L = 3\,\text{N} = \mu(40) \Rightarrow \mu = \dfrac{3}{40}$

31. **(a)** 0 m/s^2, 0 N **(b)** 0 m/s^2, $f_s = 25\,\text{N}$ **(c)** 0 m/s^2, $f_L = 30$ N **(d)** 1.2 m/s^2, $f_k = 25$ N

$f_L = \mu_s N$

$\Rightarrow$ $f_L = 0.6(50) = 30\,\text{N}$

$f_k = \mu_k N$

$\Rightarrow$ $f_k = 0.5(50) = 25\,\text{N}$

(a) Since, no force is applied, frictional force will be zero.

(b) Since, applied force is less than limiting friction, block won't move and static friction will be equal to the force applied, i.e. 25 N.

(c) Since, $F = f_L$, the block is on verge of motion. So, a = 0 and f_L = 30 N.

(d) Since, $F > f_L$, the block will be set into motion and nature of friction will be kinetic.

$F - f_k = ma$

$\Rightarrow$ 31 – 25 = 5a

$\Rightarrow$ $a = 1.2$ m/s^2

SECTION – I

1. (b)

Impulse, $I =$ change in momentum, ΔP

$$F_{\text{avg}} = \frac{\Delta P}{\Delta t} \qquad \because\ \Delta P_1 = \Delta P_2 \quad \therefore\ I_1 = I_2$$

Given $\Delta t_1 = 3\text{s}$ and $\Delta t_2 = 5\text{s}$

Hence, F_{avg} in case (i), when $\Delta t_2 = 3\text{s}$ is more than (ii) when $\Delta t_2 = 5\text{s}$

2. (b)

Force, $F = \frac{dm}{dt}v = \frac{10}{5}\times 4.5 = 9$ dyne

3. (b)

Initial momentum $\vec{P}_i = 0.15\times 12\left(\hat{i}\right)$

Final momentum $\vec{P}_f = 0.15\times 12\left(-\hat{i}\right)$

$\left|\Delta\vec{P}\right| = 3.6$ kg m/s or $3.6 = F\Delta t$

$3.6 = 100\,\Delta t \qquad\qquad \therefore\ \Delta t = 0.036\,\text{sec}$

4. (c)

$$F = \frac{dp}{dt} = v\frac{dm}{dt} = 10\times 1 = 10\,\text{N}$$

$$a = \frac{F}{m} = \frac{10}{2} = 5\ \text{m/s}^2$$

5. (c)

$$a = \frac{vdv}{dx};\ adx = vdx;\ \int_{0.5}^{1.5} -\frac{kx}{m}dx = \int_4^v v\,dv$$

$$\Rightarrow -\frac{k}{2m}\left[1.5^2 - 0.5^2\right] = \frac{v^2 - 4^2}{2} \ \Rightarrow\ -\frac{12}{2\times 2}[2] = \frac{v^2 - 16}{2}$$

$$\Rightarrow -3\times 4 = v^2 - 16$$

$$\Rightarrow v^2 = 4 \ \Rightarrow\ v = 2\ \text{m/s}$$

6. (d)

Thrust force on rocket is given by

$$F_{\text{thrust}} = \left(V_{\text{rel}}\cdot\frac{dm}{dt}\right)$$

$$\Rightarrow \left(V_{\text{rel}}\cdot\frac{dm}{dt} - mg\right) = ma$$

$$\Rightarrow 500\left(\frac{dm}{dt}\right) - 10^3\times 10 = 10^3\times 20$$

$$\Rightarrow \frac{dm}{dt} = 60 \text{ kg/s}$$

7. (c)

From the Newton's second law of motion,

$$F = ma$$

$$\Rightarrow a = \frac{F}{M} \Rightarrow a = \frac{F_0}{M}\left[1 - \left(\frac{T-t}{T}\right)^2\right]$$

$$\Rightarrow \int_0^v dv = \frac{F_0}{M}\int_0^{2T}\left[1 - \left(\frac{T-t}{T}\right)^2\right]dt$$

$$\Rightarrow V = \frac{F_0}{M}\left[t + \frac{1}{3T^2}(T-t)\right]_0^{2T}$$

$$\Rightarrow V = \frac{F_0}{M}\left\{\left[2T + \frac{1}{3T^2}(T-2T)^3\right] - \left[0 + \frac{T^3}{3T^2}\right]\right\}$$

$$\Rightarrow V = \frac{F_0}{M}\left[\frac{4T}{3}\right]$$

8. (b)

From the Newton's second law,

$$F = \frac{dp}{dt}\frac{d(mv)}{dt} = v\left(\frac{dm}{dt}\right) + \frac{mdv}{dt} \qquad \ldots \text{(i)}$$

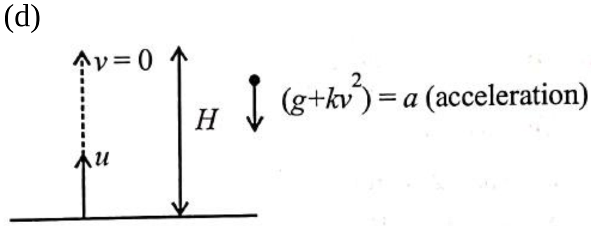
We have given, $\frac{dM(t)}{dt} = bv^2(t)$ … (ii) and $F_{\ell xt} = 0$

Thrust on the satellite,

$$= -v\left(\frac{dm}{dt}\right) = -v\left(bv^2\right) = -bv^3 \text{ [Using (i) and (ii)]}$$

$$= M(t)a = -bv^3 \Rightarrow a = \frac{-bv^3}{M(t)}$$

9. (d)



$\vec{F} = mkv^2 + mg$ ($\because$ mg and mkv^2 act opposite to motion)

$$\vec{a} = \frac{\vec{F}}{-m} = -\left[kv^2 + g\right]$$

$$\Rightarrow v \cdot \frac{dv}{dh} = -\left[kv^2 + g\right] \qquad \left(\because a = v\frac{dv}{dh}\right)$$

$$\Rightarrow \int_u^0 \frac{v \cdot dv}{kv^2 + g} = \int_0^h dh \Rightarrow \frac{1}{2k} \ln\left[kv^2 + g\right]_u^0 = -h$$

$$\Rightarrow \frac{1}{2k} \ln\left[\frac{ku^2 + g}{g}\right] = h$$

10. (a)

Net acceleration

$$\frac{dsv}{dt} = a = -\left(g + \gamma v^2\right)$$

Let time t required to rise to its zenith ($v = 0$) so,

$$\int_{v_0}^0 \frac{-dv}{g + rv^2} = \int_0^t dt \qquad [\text{for } H_{\max}, v = 0]$$

$$\therefore \; t = \frac{1}{\sqrt{\gamma g}} \tan^{-1}\left(\frac{\sqrt{\gamma}\, v_0}{\sqrt{g}}\right)$$

11. (d)

$v^2 = u^2 - 2gh$ or $v = \sqrt{u^2 - 2gh}$

Momentum, $P = mv = m\sqrt{u^2 - 2gh}$

At $h = 0, P = mu$ and at $h = \frac{u^2}{g}$, $P = 0$

Upward direction is positive and downward direction is negative.

12. (b)

From Newton's second law

$$\frac{dp}{dt} = F = kt$$

Integrating both sides we get,

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

$$\Rightarrow 2p = \frac{kT^2}{2} \Rightarrow T = 2\sqrt{\frac{p}{k}}$$

13. (a)

From $F = \frac{R}{t^2} v(t) \Rightarrow m\frac{dv}{dt} = \frac{R}{t^2} v(t)$

Integrating both sides $\int \frac{dv}{v} = \int \frac{\text{P}dt}{mt^2}$

In $v \propto \frac{1}{t}$

14. (a)

From questiuon, mass of body, $m = 5\,\text{kg}$

Velocity at $t = 0$,

$u = (6i - 2\hat{j})\,\text{m/s}$

Velocity at $t = 10\,\text{s}$,

$v = +6\ \hat{j}\ \text{m/s}$

Force, $F = ?$

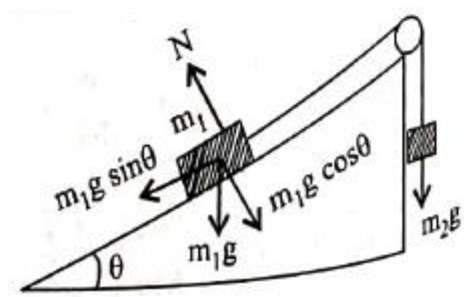
Acceleraiton, $a = \dfrac{v-u}{t} = \dfrac{6\hat{j} - (6\hat{i} - 2\hat{j})}{10} = \dfrac{3\hat{i} + 4\hat{j}}{5}\ \text{m/s}^2$

Force, $F = ma$

$= 5 \times \dfrac{(-3\hat{i} + 4\hat{j})}{5} = (-3\hat{i} + 4\hat{j})\,\text{N}$

15. (c)

For equilibrium conduction, $m_2 g = m_1 g \sin\theta$



$\sin\theta = \dfrac{m_2}{m_1} = \dfrac{3}{5}$

$\cos\theta = \dfrac{4}{5}$

Normal force (N) on $m_1 = 5g\cos\theta$

$= 5 \times 10 \times \dfrac{4}{5} = 40\,\text{N}$,

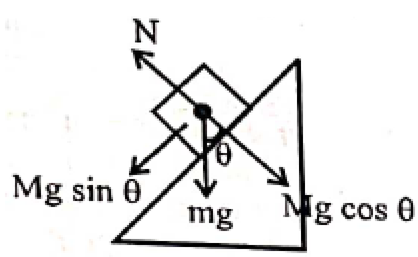
Friction $(f) = m_2 g = 30\,\text{N}$, $F = \sqrt{N^2 + f^2} = 50\,\text{N}$

16. (c)

Acceleration of block on smooth inclined plane,

$a = g\sin\theta$

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



$s = \dfrac{1}{2} g \sin 30^\circ (2)^2$

When the incline is changed to 45°

$s = \dfrac{1}{2} g \sin 45^\circ t^2$

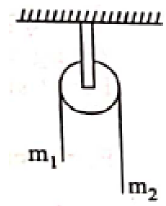
As distance travelled is same

$\therefore \quad \left(\dfrac{1}{2}\right)(4) = \dfrac{1}{\sqrt{2}} t^2$

$\Rightarrow \quad t = 2\sqrt{2} \simeq 1.68$

17. (d)

Acceleration in such system is given as



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

$$\Rightarrow \frac{g}{2} = \frac{(\lambda(L-\ell) - \lambda\ell)}{\lambda L} \quad \Rightarrow \ell = \frac{L}{4} = \frac{L}{x}$$

So, $x = 4$

18. (c)

Given that mass of monkey, m = 50 kg

Acceleration due to gravity, g = 10 m/s^2

Tension (T) = 350 N

Given monkey climbs downward, acceleration of monkey,

a = 4 m/s^2

When monkey climbs upward, acceleration of monkey,

a = 5 m/s^2

(For upward)

$$T = mg = ma$$

$$\Rightarrow T = mg + ma = 50(10+5) = 750\,\text{N}$$

Rope will break while climbing upward

(For downward)

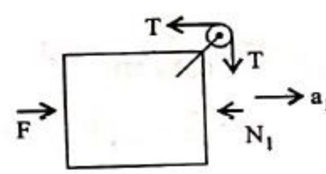
$$T = ma(g - a) = 50(10-4) = 300\,\text{N}$$

Rope will not break while climbing downward

19. (a)

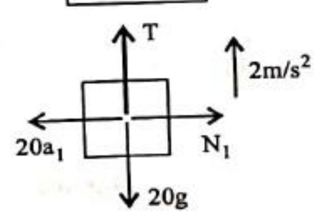
Let a_1 be the acceleration of 100 kg block

FBD of 100 kg block w.r.t. ground



$$F - T - N_1 = 100a_1 \quad ...(i)$$

FBD of 20 block w.r.t. 100 kg

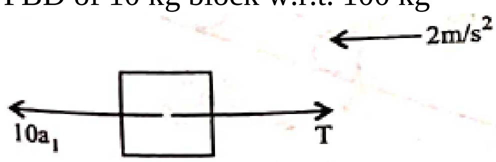


$$T - 20g = 20(2) \Rightarrow T = 40 + 200$$

$$\Rightarrow T = 240 \quad ...(ii)$$

$$N_1 = 20a_1 \quad ...(iii)$$

FBD of 10 kg block w.r.t. 100 kg



$$10a_1 - 240 = 10(2)$$

$$\Rightarrow a_1 = 26 \text{ m/s}^2$$

$$F - 240 - 20(26) = 100 \times 26$$

$$\Rightarrow F = 3360\,\text{N}$$

20. (a)

Let addition force required be $=\vec{F}$ -

$$\vec{F}+5i-6\hat{i}+7\hat{j}-8\hat{j}=0$$

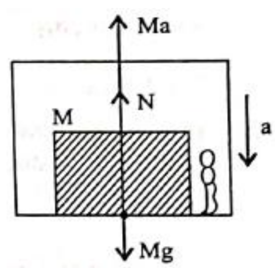
$$\Rightarrow \quad \vec{F}=\hat{i}+\hat{j}, \left|\vec{F}\right|=\sqrt{1^2+1^2}=\sqrt{2}$$

Angle with x-axis: $\tan\theta=\dfrac{y \text{ component}}{x \text{ component}}=\dfrac{1}{1}$

So, $\theta=\tan^{-1}(1)=45°$.

21. (c)

For observer in box



$$N+Ma=Mg$$

$$\Rightarrow \quad N=M(g-a)$$

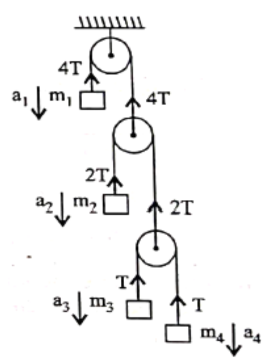
$$\Rightarrow \quad \frac{Mg}{4}=M(g-a)$$

$$\Rightarrow \quad a=\frac{3g}{4}$$

22. (b)

When elevator does downward, then a pseudo force acts on object in upward direction, due to which effective weight of object decreases.

23. (a)



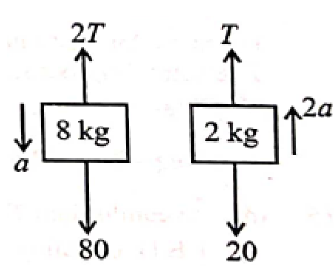
$$\sum\vec{T}\bullet\vec{a}=0$$

$$\Rightarrow -4Ta_1-2Ta_2-Ta_3-Ta_4=0$$

$$\Rightarrow 4a_1+2a_2+a_3+a_4=0$$

24. (d)

From free body diagram,



$$80-2T=8a \qquad \text{...(i)}$$

$$T-20=4a \qquad \text{...(ii)}$$

Multiple equation (ii) by 2 and adding with equation (i) we get

$$(8+8)a=40 \Rightarrow a=\frac{40}{16}=\frac{10}{4}\text{ m/s}^2$$

Using $S=\dfrac{1}{2}at^2 \Rightarrow t^2=\dfrac{2S}{a}$

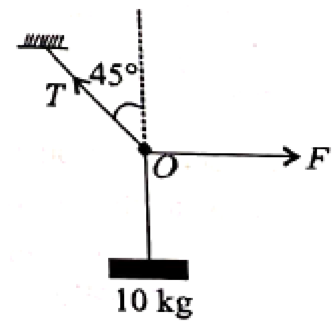
$$\Rightarrow \quad \frac{0.2\times2\times4}{10}=t^2 \Rightarrow t=0.4\sec$$

25. (a)

The free body diagram is by Lami's theorem

$\Rightarrow \quad \frac{mg}{135°} = \frac{F}{135}$

$\Rightarrow \quad F = mg = 100\,\text{N}$



26. (b)

Retardation due to friction $= \frac{\mu Mg}{M} = \mu g$

Now, $s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 2^2}{2g\mu} = \frac{2}{0.4 \times 10} = 0.5\,\text{m}$

27. (a)

From the free diagram shown

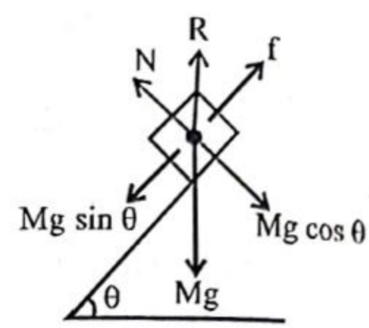
$N = Mg\cos\theta$

$f = Mg\sin\theta$

Contact force, $R = \sqrt{N^2 - f^2}$

$\Rightarrow \quad R = \sqrt{(Mg\cos\theta)^2 + (Mg\sin\theta)^2}$

$= \sqrt{(Mg)^2(\cos^2\theta + \sin^2\theta)} \Rightarrow R = Mg$



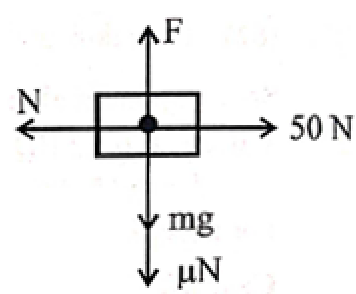
28. (d)

By FBD of block, we have

N = 50 N and $F \le mg + \mu N$

i.e. $F \le 2g + 0.5 \times 50 \le 20 + 25 \le 45\,\text{N}$

So, Maximum force that can be applied is 45 N.



29. (d)

For 4 kg block

$4g - T = 4a \qquad \ldots(\text{i})$

For 40 kg block

$T - 40g + 0.02 = 40a \quad [\because f_k = \mu mg]$

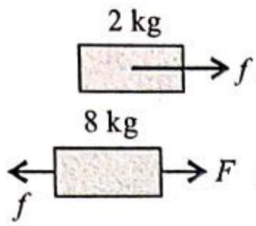
$T - 8 = 40a \qquad \ldots(\text{ii})$

Adding (i) & (ii), we get

$40 - 8 = 44a$

$a = \frac{32}{44} = \frac{8}{11}\,\text{m/s}^2$

30. (c)



$f = 2a$ ...(i)

$F - f = 8a$ ...(ii)

Clearly, from (i) 'a' will be maximum when $f = f_{\text{lim}}$

So, $a_{\max} = \dfrac{f_{\text{lim}}}{2} = \dfrac{\mu \times 2g}{2} = \mu g$

From (ii), $F_{\max} = 8a_{\max} + f_{\text{lim}} = 8\mu g + 2\mu g = 10\mu g = 49\,\text{N}$

31. (b)

For beaker to move with disc

$f_s = m\omega^2 R$

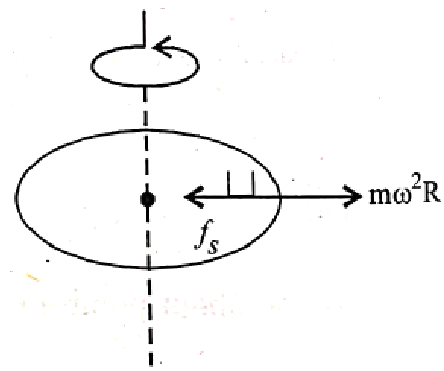
So, R will be maximum, when $f_s = f_{\text{lim}}$

Therefore, $f_{\text{lim}} = m\omega^2 R_{\max}$

$\mu_{mg} = m\omega^2 R_{\max}$

$R_{\max} = \dfrac{\mu g}{\omega^2}$

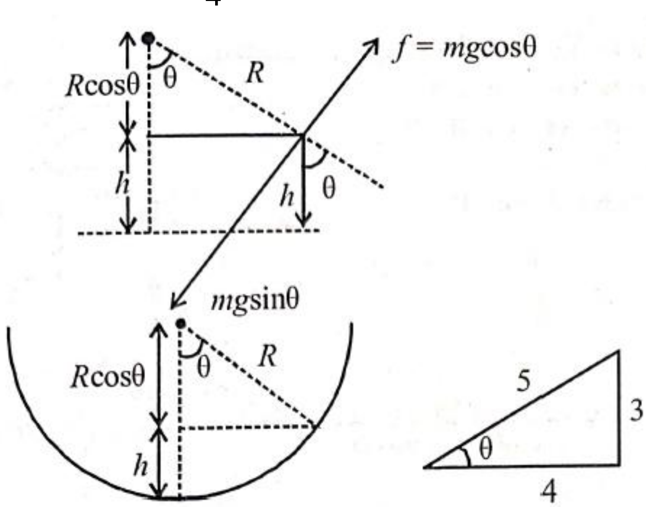
So, $R \le \dfrac{\mu g}{\omega^2}$



32. (a)

For balancing, $mg\sin\theta = f = \mu mg\cos\theta$

$\Rightarrow \quad \tan\theta = \mu = \dfrac{3}{4} = 0.75$



$h = R - R\cos\theta = R - R\left(\dfrac{4}{5}\right) = \dfrac{R}{5}$

$\therefore \quad h = \dfrac{R}{5} = 0.2\text{ m} \qquad [\because \text{ radius, } R = 1\text{ m}]$

33. (c)

$A:\ N = 5g + 20\sin 30°$

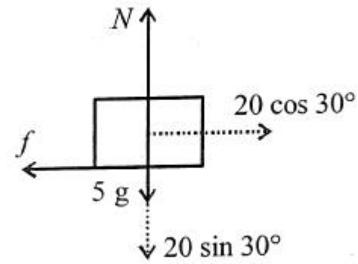
$= 50 + 20 \times \frac{1}{2} = 60\,\text{N}$

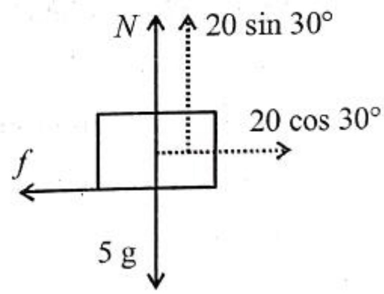
Acceleration, $a_1 = \frac{F - f}{m}$

$= \frac{20\cos 30° - \mu N}{5}$

$= \left[\frac{20 \times \frac{\sqrt{3}}{2} - 0.2 \times 60}{5}\right]$

$= 1.06\ \text{m/s}^2$





$B:\ N = 5g - 20\sin 30°$

$= 50 - 20 \times \frac{1}{2} = 40\,\text{N}$

$a_2 = \frac{F - f}{m} = \left[\frac{20\cos 30° - 0.2 \times 40}{5}\right] = 1.86\ \text{m/s}^2$

Now, $a_2 - a_1 = 1.86 - 1.06 = 0.8\ \text{m/s}^2$

34. (b)

Taking (*A* + *B*) as system

$F - \mu(M + m)g = (M + m)a$

$\Rightarrow\ a = \frac{F - \mu(M+m)g}{(M+m)} \ \Rightarrow\ a = \frac{F - (0.2)4 \times 10}{4} = \left(\frac{F - 8}{4}\right)$

But, $a_{max} = \mu g = 0.2 \times 10 = 2$

$\therefore\ \frac{F - 8}{4} = 2 \ \Rightarrow\ F = 16\,\text{N}$

35. (a)

From figure, $2 + mg\sin 30° = \mu mg\cos 30°$ and $10 = mg\sin 30° + \mu mg\cos 30° = 2\mu mg\cos 30° - 2$

$\Rightarrow\ 6 = \mu mg\cos 30°$ and $4 = mg\sin 30°$

By dividing above two $\Rightarrow\ \frac{3}{2} = \mu \times \sqrt{3}$

$\therefore$ Coefficient of friction, $\mu = \frac{\sqrt{3}}{2}$

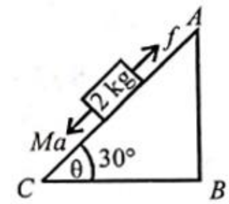
36. (d)

Equation of motion when the mass slides down

$Mg\sin\theta - f = Ma$

$\Rightarrow \quad 10 - f = 6$ ($M = 2$ kg, $a = 3$ m/s^2, $\theta = 30°$ given)

$\therefore \quad f = 4\,\text{N}$



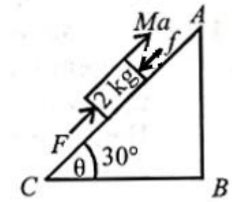
Equation of motion when the block is pushed up

Let the external force required to take the block up the plane with same acceleration be F

$F - Mg\sin\theta - f = Ma$

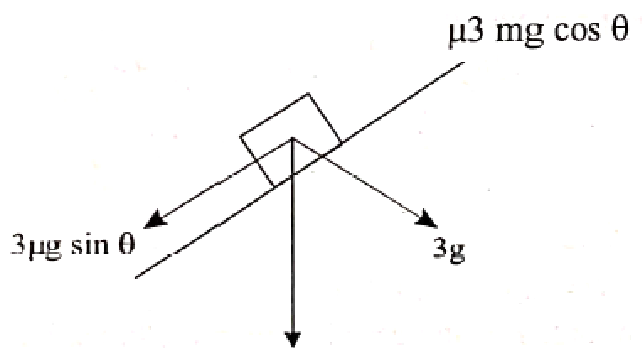
$\Rightarrow \quad F - 10 - 4 = 6$

$F = 20\,\text{N}$



37. (b)

Let μ be the minimum coefficient of friction



At equilibrium, mass does not move so, $3mg\sin\theta = \mu 3mg\cos\theta$

$\therefore \quad \mu_{min} = \tan\theta$

38. (b)

Initial speed at point A, $u = v_0$

Speed at point B, v = ?

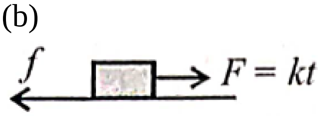
$v^2 - u^2 = 2gh$

$v^2 = v_0^2 + 2gh$

Let ball travels distance 'S' before coming to rest

$$S = \frac{v^2}{2\mu g} = \frac{v_0^2 + 2gh}{2\mu g} = \frac{v_0^2}{2\mu g} + \frac{2gh}{2\mu g} = \frac{h}{\mu} + \frac{v_0^2}{2\mu g}$$

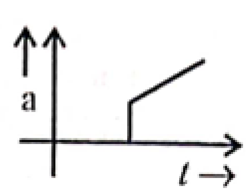
39. (b)



$$a = \frac{kt - \mu mg}{m}$$

$$a = \frac{kt}{m} - \mu g$$

So, a-t graph will be as shown



40. (d)

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

$a = g\sin\theta - 0.3\,xg\,\cos\theta$

$= \frac{g}{\sqrt{2}} - \frac{0.3\,gx}{\sqrt{2}} = 5\sqrt{2} - 0.3\left(5\sqrt{2}\right)x = 5\sqrt{2} - 1.5\sqrt{2x}$

Velocity will increase until $a = 0$ and when $v = v_{max}$, then $a = 0$

$0 = 5\sqrt{2} - 1.5\sqrt{2}x$

$x = \frac{5\sqrt{2}}{1.5\sqrt{2}}$

$x = 3.33\,\text{m}$

41. (c)

Given, position vector of particle

$r = \left(10t\hat{i} + 15t^2\hat{j} + 7k\right)m$

$\therefore$ velocity of particle,

$v = \frac{dr}{dt} = 10\hat{i} + 30t\hat{j}$

Acceleration of particle,

$a = \frac{dv}{dt} = 30\hat{j}$

$\therefore$ Net force applied on the particle,

$F = ma = 30m\hat{j}$

Clearly, net force is applied along Y-axis

42. (c)

Given, $F_1 = 10N, F_2 = 8N,$

$F_3 = 6\text{ N}$, mass, $m = 5\text{ kg}$

According to question, resultant of F_2

And F_3 should be opposite to F_1.

$\Rightarrow$ $a = \frac{F}{m} = \frac{10}{5} = 2m/s^2$

43. (c)

Given,

$v = 10\sqrt{x}$

$m = 500g = \frac{500}{1000}kg$

$\Rightarrow$ $a = v\frac{dv}{dx} \Rightarrow v = 10\sqrt{x}$

$\frac{dv}{dx} = 10 \times \frac{1}{2}x^{-1/2} \Rightarrow \frac{dv}{dx} = \frac{5}{\sqrt{x}}$

$\Rightarrow$ $a = v\frac{dv}{dx} = 10\sqrt{x}.\frac{5}{\sqrt{x}}$

$\Rightarrow \quad a = 50 m/s^2 \Rightarrow f = ma$

$\Rightarrow \quad f = \frac{500}{1000} \times 50 \Rightarrow f = 25\text{ N}$

44. (a)

Mass of particle $= 500\text{ g}$

$= 500 \times 10^{-3} kg = 0.5\text{ kg}$

Velocity of the particle is;

$v = 2t\hat{i} + 3t^2\hat{j}(m/s)$

Acceleration of particle is

$a = \frac{dv}{dt} = 2\hat{i} + 6t\hat{j}\ m/s^2$

So, acceleration of the particle at $t = 1s$ is,

$a(t = 1s) = 2\hat{i} + 6\hat{j}\ m/s^2$

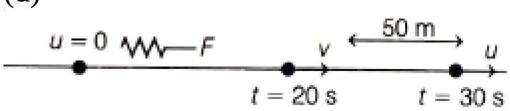
$\therefore$ Force the particle is

$F = ma(\text{at } t = 1s)$

$\Rightarrow \quad F = 0.5(2\hat{i} + 6\hat{j}) = \hat{i} + 3\hat{j}\text{ N}$

Hence, $x = 3$

45. (d)



As particle covers 50m in 10s while moving with a constant velocity $(F = 0, a = 0)$

Velocity of particle is,

$v = \frac{d}{T} = \frac{50}{10} = 5m/s$

Now, for first 20 s of journey,

$u = 0, v = m/s, t = 20\text{ s}$

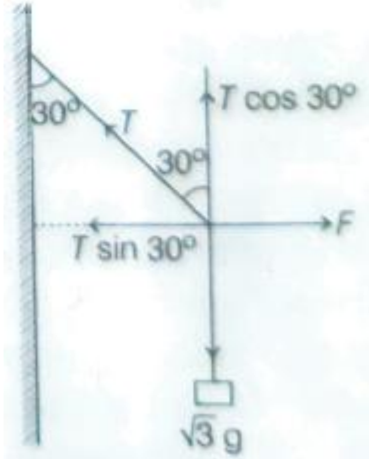
Acceleration, $a = \frac{v-u}{t} = \frac{5}{20} m/s^2$

Magnitude force will be

$F = m \times a = 20 \times \frac{5}{20} = 5N$

46. (d)

From the given free body diagram.



$$T\cos 30^\circ = \sqrt{3}g$$

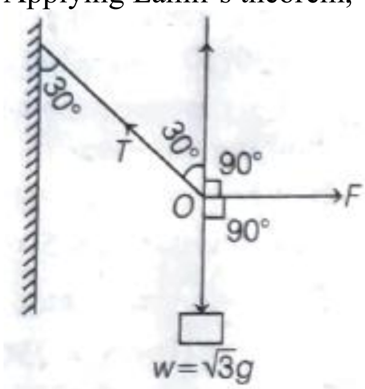
$$\Rightarrow \quad T = \frac{\sqrt{3}}{2} = \sqrt{3}g$$

$$\Rightarrow \quad T = 2g = 2\times 10\left(\because g = 10\text{ ms}^{-2}\right)$$

$$= 20\text{ N}$$

Alternative Solution

Since, three forces T,F and W are acting on a point 0 and the system is in equilibrium, hence Applying Lamil's theorem,



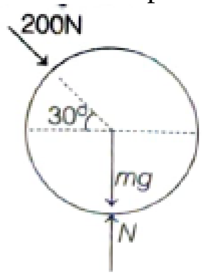
$$\frac{T}{\sin 90^\circ} = \frac{F}{\sin\left(180^\circ - 30^\circ\right)} = \frac{w}{\sin\left(90^\circ + 30^\circ\right)}$$

$$\Rightarrow \quad \frac{T}{\sin 90^\circ} = \frac{w}{\sin\left(90^\circ + 30^\circ\right)}$$

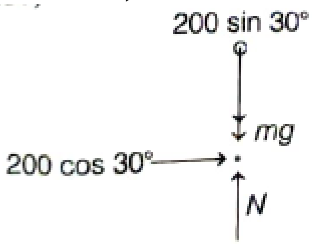
$$\Rightarrow \quad T = \frac{w}{\cos 30^\circ} = \frac{\sqrt{3}g}{\left(\sqrt{3}/2\right)} = 2g = 2\times 10 = 20\text{N}$$

47. (b)

FBD of the sphere



Therefore,



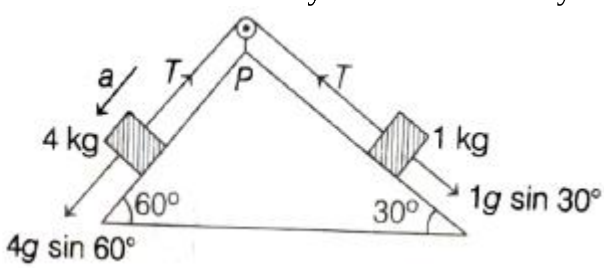
Since, $a_y = 0$

Thus, $N = mg + 200 \sin 30^\circ$

$N = 70 \times 10 + 200 \times \sin 30^\circ$
$= 800$ N

48. (a)

Let a be acceleration of system FBD of the system



On applying Newton's second law, we get

$4 \times a = 4 \times g \sin 60^\circ - T$

$1 \times a = T - 1 \times g \sin 30^\circ$

or, $4a = 20\sqrt{3} - T$ … (i)

And $a = 4\sqrt{3} - 1$ … (ii)

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

$5a = 20\sqrt{3} - 5$

or, $a = 4\sqrt{3} - 1$

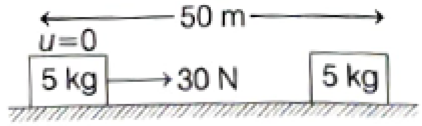
From Eq. (ii),

$4\sqrt{3} - 1 = T - 5$

or, $T = 4\left(\sqrt{3} + 1\right)$ N

49. (a)

The given situation in question is as follows.



Let, the coefficient of kinetic friction be μ.

Acceleration,

$$a = \frac{F - f}{m} = \frac{F - \mu mg}{m}$$

$$a = \frac{30 - \mu \times 5 \times 10}{5}$$

$$= 6 - 10\mu$$

Using second equation of motion,

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

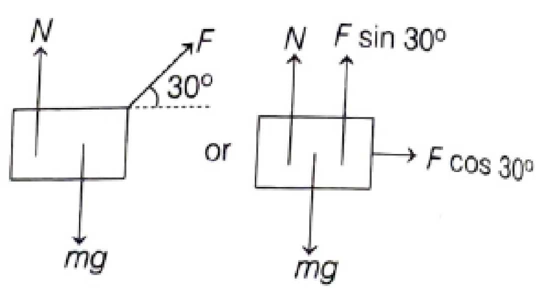
$$\Rightarrow \quad 50 = 0 + \frac{1}{2}(6 - 10\mu) \times 10^2$$

$$\Rightarrow \quad 6 - 10\mu = 1.0$$

$$\Rightarrow \quad \mu = 0.5$$

50. (a)

Drawing FBD of block,



In y-direction,

$$\Sigma F_y = ma_y \qquad (\because a_y = 0)$$

$$N + F\sin 30^\circ = mg$$

Or $\quad N = mg - F\sin 30^\circ$ ….. (i)

in x-direction,

$$\Sigma F_x = ma_x$$

$$\Rightarrow \quad F\cos 30^\circ - \mu N = ma_x$$

As block is on the verge of N from Eq. (i) to Eq.(i) to Eq. (ii), we get

$$F\cos 30^\circ = \mu\left(mg - F\sin 30^\circ\right)$$

$$F\cos 30^\circ = \mu mg - \mu F\sin 30^\circ$$

$$F\left(\cos 30^\circ + \mu\sin 30^\circ\right) = \mu mg$$

$$F = \frac{\mu mg}{\cos 30^\circ + \mu\sin 30^\circ}$$

Given that

$\mu_s = 0.25, m = 10kg, g = 10m/s$

$$F = \frac{0.25 \times 10 \times 10}{\frac{\sqrt{3}}{2} + 0.25 \times \frac{1}{2}}$$

$\Rightarrow \quad F = 25.2N$

51. (c)

Given, $u = 20m/s, t = 5s$

Let, μ be the coefficient of friction, then R = retardation,

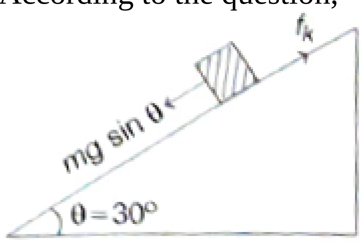
$a = \mu g$

Using, $v = u - at$

$$\Rightarrow 0 = 20 - \mu g \times 5 \Rightarrow \mu = \frac{20}{10 \times 5} = 0.4$$

52. (d)

According to the question,



Acceleration of block

$$= \frac{mg\sin\theta - \mu_k mg\cos\theta}{m}$$

$$= g(\sin\theta - \mu_k \cos\theta) = \frac{g}{4} \text{ [Given]}$$

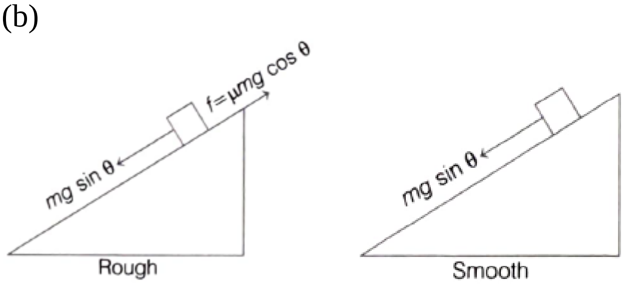
So, $\sin\theta - \mu_k \cos\theta = \frac{1}{4}$

As $\theta = 30^\circ$; we have

$$\frac{1}{2} - \frac{\sqrt{3}}{2}\mu_k = \frac{1}{4}$$

Or $\mu_k = \frac{2 \times 1}{4\sqrt{3}} = \frac{1}{2\sqrt{3}}$

53. (b)



Acceleration in case of smooth inclined plane,

$$a_1 = g\sin\theta = \frac{8}{\sqrt{2}}, \theta = 45^\circ$$

Acceleration over a rough inclined

Plane, $a_2 = g\sin\theta = \mu g\cos\theta$

$= g/\sqrt{2} - \mu g/\sqrt{2} = \frac{g}{\sqrt{2}}(1-\mu)$

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

Time taken, $t = \sqrt{\frac{2s}{a}}$ $(\because u = 0)$

Given, $t_{rough} = nt_{smooth}$

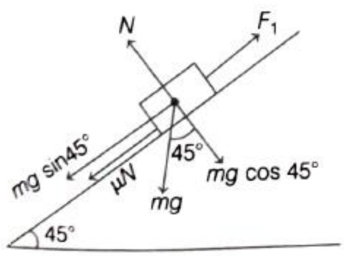
$\sqrt{\frac{2s}{a_2}} = n\sqrt{\frac{2s}{a_1}}$ or $a_1 = n^2 a_2$

$\Rightarrow \frac{g}{\sqrt{2}} = n^2\left(\frac{g}{\sqrt{2}}(1-\mu)\right)$

$\Rightarrow \mu = 1 - \frac{1}{n^2}$

54. (c)

When pushing upwards, friction force will be in downward direction



$F_1 = mg\sin 45^\circ + \mu N$

$= mg\sin 45^\circ + \mu mg\cos 45^\circ$

$F_1 = \frac{mg}{\sqrt{2}} + \frac{\mu mg}{\sqrt{2}}$

When preventing it from sliding,

Friction force will be in upward direction.

$F_2 + \mu N = mg\sin 45^\circ$

$F_2 = mg\sin 45^\circ - \mu mg\cos 45^\circ$

$= \frac{mg}{\sqrt{2}} - \frac{\mu mg}{\sqrt{2}}$

According to given situation,

$F_1 = 2F_2$

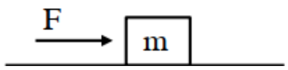
$\frac{mg}{\sqrt{2}} + \frac{\mu mg}{\sqrt{2}} = 2\left(\frac{mg}{\sqrt{2}} - \frac{\mu mg}{\sqrt{2}}\right)$

$3\mu mg = mg$

$\mu = \frac{1}{3} = 0.33$

55. (b)

Given,



From second law of motion,

$$F = ma$$

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

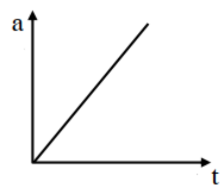
Force applied is linearly depended on time

$F \propto t \Rightarrow F = kt$ (k = constant)

$$a = \frac{kt}{m}$$

Or $a \propto t$

We plot a versus t it will be linear from origin.



SECTION – II

1. (6)

By law of conservation of linear momentum $\vec{P}_i = \vec{P}_f$

$\Rightarrow 60 \times V = (120 + 60) \times 2 \Rightarrow 60V = 360 \Rightarrow V = 6 \text{ m/s}$

2. (12)

Impulse $= \Delta\vec{p}$

$= \vec{P}_f - \vec{P}_i = mv - (-mv) = 2mv = 2 \times 0.4 \times 15 = 12 \text{ Ns}$

3. (500)

$$\vec{a} = \frac{\vec{F}}{m} = 10\hat{i} + 5\hat{j}$$

Displacement of the box along *x*-axis,

$$x = \frac{1}{2} a_x t^2 = \frac{1}{2} \times 10 \times 100 = 500 \text{ m}$$

4. (3)

Along horizontal

$F_1 + 1\cos 45° = 2\sin 45°$

$$F_1 = \frac{2}{\sqrt{2}} - \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{2}}$$

Along vertical

$F_2 = 1\sin 45 + 2\sin 45$

$$F_2 = 3\sin 45 = \frac{3}{\sqrt{2}}$$

So, $\frac{F_1}{F_2}=\frac{1}{3}$. So, $x=3$

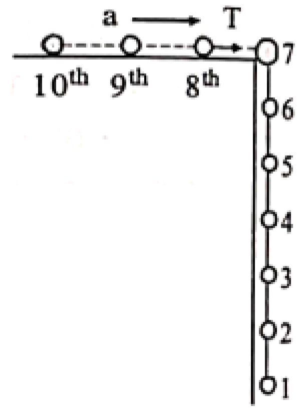
5. (36)

We have, acceleration of system as

$$a=\frac{6mg}{10m}=\frac{3g}{5}$$

taking 8, 9, 10 together

$$T=3ma=3m\times\frac{3g}{5}=\frac{3\times2\times3\times10}{5}=36\text{ N}$$



6. (12)

Let draw FBD of block clearly for equilibrium

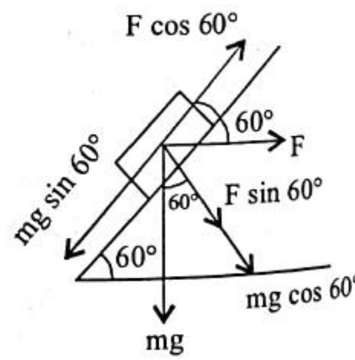
$F\cos60°=mg\sin60°$

$\Rightarrow \frac{F}{mg}=\tan60°$

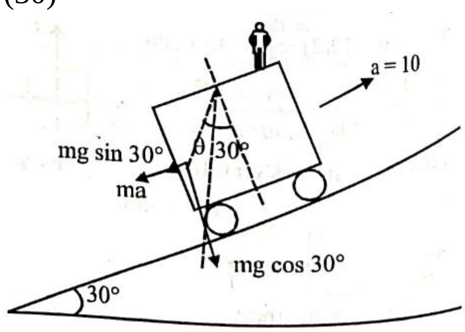
$\Rightarrow \frac{\sqrt{x}}{0.2\times10}=\sqrt{3}$

$\Rightarrow \sqrt{x}=2\sqrt{3}$

$\Rightarrow x=12$



7. (30)



From figure, $\tan\left(30^\circ+\theta\right)=\frac{mg\sin30^\circ+ma}{mg\cos30^\circ}$

$\Rightarrow \tan\left(30°+\theta\right)=\frac{5+10}{5\sqrt{3}}=\frac{1+2}{\sqrt{3}}$

$\Rightarrow \frac{\tan\theta+\frac{1}{\sqrt{3}}}{1-\frac{1}{\sqrt{3}}\tan\theta}$

$\Rightarrow \sqrt{3}\tan\theta+1=3-\sqrt{3}\tan\theta$

$\Rightarrow 2\sqrt{3}\tan\theta=2$

$\Rightarrow \quad \tan\theta = \frac{1}{\sqrt{3}} \qquad \therefore \quad \theta = 30°$

8. (82)

$\vec{P}$ makes angle of 35° with AC

So, component along $AC = 100\cos 35 = 81.9\text{ N} \simeq 82\text{ N}$

9. (3)

Acceleration on smooth inclined plane

$a = g\sin 30° = \frac{g}{2}$

Using $S = ut + \frac{1}{2}at^2$

$\Rightarrow \quad S = \frac{1}{2}\frac{g}{2}T^2 = \frac{g}{2}T^2 \qquad \text{...(i)} \quad (\because u = 0)$

Acceleration on rough inclined plane

$a = g\sin 30° - \mu g\cos 30° = \frac{g}{2} - \frac{\mu g\sqrt{3}}{2}$

$\Rightarrow \quad a = \frac{g}{2}\left(1 - \mu\sqrt{3}\right)$

Using again $S = ut + \frac{1}{2}at^2$

$\Rightarrow \quad S = \frac{1}{4}g\left(1 - \sqrt{3}\mu\right)(\alpha T)^2 \qquad \text{...(ii)}$

By (i) and (ii)

$= \frac{1}{4}gT^2 = \frac{1}{4}g\left(1 - \sqrt{3}\mu\right)\alpha^2 T^2 \quad \Rightarrow \quad 1 - \sqrt{3}\mu = \frac{1}{\alpha^2}$

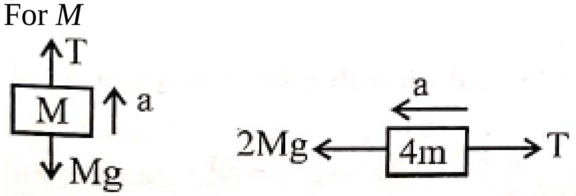
$\Rightarrow \quad \mu = \left(\frac{\alpha^2 - 1}{\alpha^2}\right)\frac{1}{\sqrt{3}} \quad \Rightarrow \quad x = 3.00$

10. (6)

For 4m

$2Mg - T = 4Ma \qquad \ldots \text{(i)}$

For M



$T - mg = Ma \qquad \ldots \text{(ii)}$

Adding (i) & (ii), we get

$Mg = 5Ma \quad \Rightarrow \quad a = \frac{g}{5}$

So, $T = Ma + Mg = \frac{Mg}{5} + Mg = \frac{6}{5}Mg$

11. (3)

From question,

$$t_a = \frac{1}{2} t_d$$

$$\sqrt{\frac{2s}{a_a}} = \frac{1}{2}\sqrt{\frac{2s}{a_d}}$$

Or, $a_a = 4a_d$ ...(i)

$$g\sin\theta + \mu g\cos\theta = 4(g\sin\theta - \mu g\cos\theta)$$

$$\Rightarrow \; 5\mu g\cos\theta = 3g\sin\theta \;\Rightarrow\; \mu = \frac{3\tan\theta}{5}$$

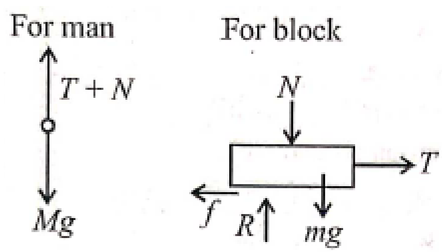
$$\Rightarrow \; \mu = \frac{\sqrt{3}}{5} \qquad [\because \; \theta = 30^\circ]$$

So, $x = 3$

12. (30)

From FBD shown, $T = Mg - N$

$$R = mg + N = (M+m)g - T$$



For no movement of block,

$$T \le \mu R \;\Rightarrow\; T \le \mu[(M+m)g - T]$$

$$\Rightarrow \; T \le \frac{\mu(M+m)g}{1+\mu} \;\Rightarrow\; T = \frac{(0.5)(5+4)\times 10}{1+0.5} = \frac{45}{1.5}$$

$$\therefore \; T_{max} = 30\,\text{N}$$

13. (5)

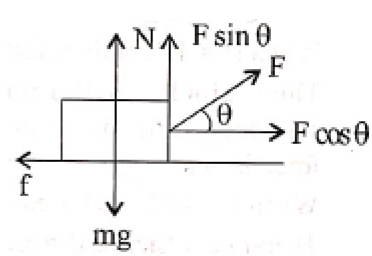
As block is at rest

So, $F\cos\theta = f = \mu N$

$$F\cos\theta = \mu(mg - F\sin\theta)$$

$$F(\cos\theta + \mu\sin\theta) = \mu mg$$

$$F = \frac{\mu mg}{\cos\theta + \mu\sin\theta}$$



For F_{min}

$(\cos\theta + \mu\sin\theta)$ should be maximum i.e. $\frac{d}{d\theta}(\cos\theta + \mu\sin\theta) = 0 \Rightarrow \tan\theta = \mu$

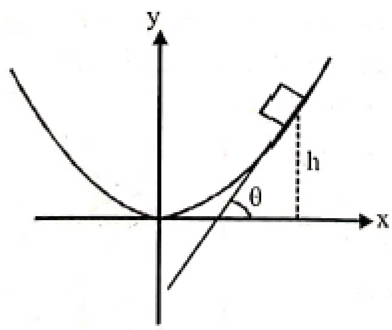
So, $\sin\theta = \frac{\mu}{\sqrt{1+\mu^2}}$ and $\cos\theta = \frac{1}{\sqrt{1+\mu^2}}$

Thus, $F_{\min} = \frac{\mu mg}{\frac{1}{\sqrt{1+\mu^2}} + \frac{\mu.\mu}{\sqrt{1+\mu^2}}} = \frac{\mu mg}{\sqrt{1+\mu^2}}$

Putting the value of μ, m and g

$F_{\min} = 5\,\text{N}$

14. (25)



Block will fall down when $\theta =$ angle of repose i.e.,

$\tan\theta = \mu$

$\therefore \quad \tan\theta = \frac{dy}{dx} = \frac{d}{dx}\left(\frac{x^2}{4}\right) = \frac{x}{2}$ and at time of maximum height $\tan\theta = \mu = 0.5$

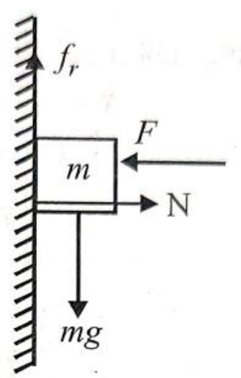
$\Rightarrow \quad x = 1$ and therefore $y = 0.25\,\text{m}$ = 25 cm

(Assuming that *x* and *y* in the equation are given in meter)

15. (25)

F.B.D. of the block is shown in the diagram.

Since, block is at rest,



$\therefore \quad f_r - mg = 0 \qquad ...(i)$

$F - N = 0 \qquad ...(ii)$

$f_r \le \mu N$

In limiting case,

$f_r = \mu N = \mu F \qquad ...(iii)$

Using equation (i) and (iii),

$F = \frac{mg}{\mu} \Rightarrow F = \frac{0.5\times 10}{0.2} = 25\,\text{N}$