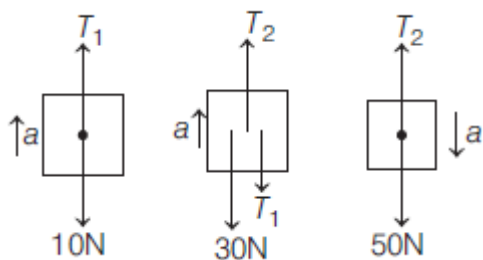


In chapter Exercise – 1 (Problems on Constraints & Simple Pulley System)

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. $g / 9$



$$50 - T_2 = 5a \quad \dots(i)$$

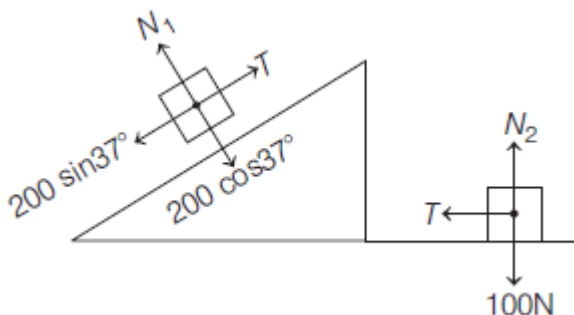
$$T_2 - 30 - T_1 = 3a \quad \dots(ii)$$

$$T_1 - 10 = 1a \quad \dots(iii)$$

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

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

13. $2g / 5$



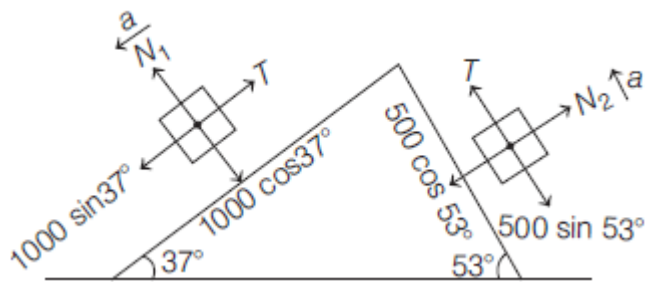
$$200 \sin 37^\circ - T = 20a \quad \dots(i)$$

$$T = 10a \quad \dots(ii)$$

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

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

14. $2g / 15$



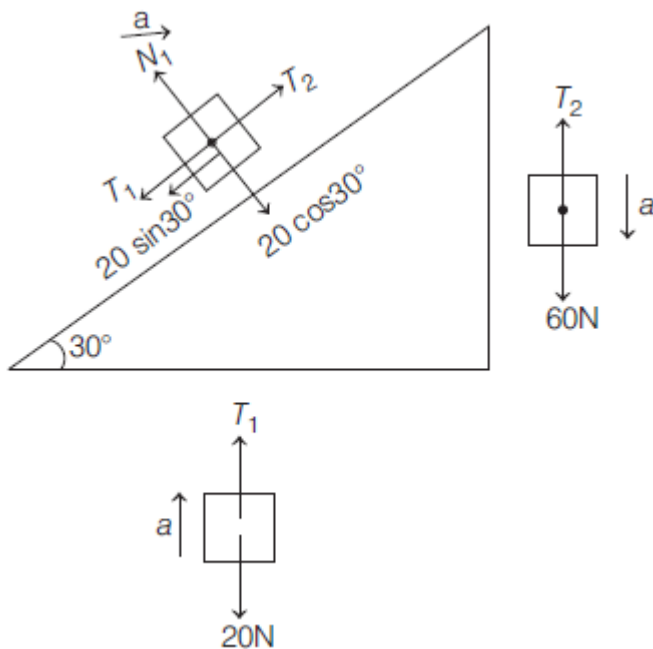
$$1000 \sin 37^\circ - T = 100a \quad \dots(i)$$

$$T - 500 \sin 53^\circ = 50a \quad \dots(ii)$$

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

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

15. $3g / 10$



$$60 - T_2 = 6a \quad \dots(i)$$

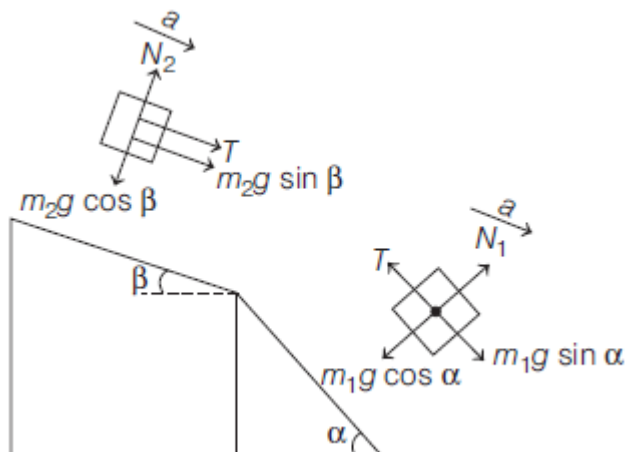
$$T_2 - T_1 - 10 = 2a \quad \dots(ii)$$

$$T_1 - 20 = 2a \quad \dots(iii)$$

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

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

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



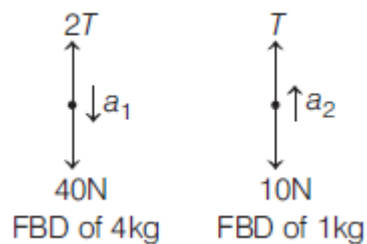
$$m_1 g \sin \alpha - T = m_1 a \quad \dots(i)$$

$$T + m_2 g \sin \beta = m_2 a \quad \dots(ii)$$

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

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

17. acceleration of 4 kg = 2.5 m/s² down, acceleration of 1 kg = 5 m/s² up



$$40 - 2T = 4a_1 \quad \dots(i)$$

$$T - 10 = 1a_2 \quad \dots(ii)$$

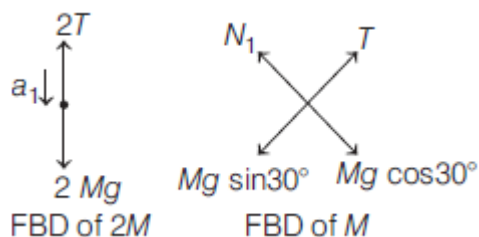
$$2a_1 = a_2 \quad \dots(iii)$$

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

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

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

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



$$2Mg - 2T = 2Ma_1 \quad \dots(i)$$

$$T - Mg \sin 30^\circ = Ma_2 \quad \dots(ii)$$

$$2a_1 = a_2 \quad \dots(iii)$$

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

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

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

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

$$2Mg - T = 2Ma_1 \quad \dots(\text{i})$$

$$2T - Mg = Ma_2 \quad \dots(\text{ii})$$

$$2a_2 = a_1 \quad \dots(\text{iii})$$

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

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

$$50 - 2T = 5a_1 \quad \dots(\text{i})$$

$$T - 40 = 4a_2 \quad \dots(\text{ii})$$

$$a_2 = 2a_1 \quad \dots(\text{iii})$$

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

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

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

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

$$170 - 2T = 5a_1 \quad \dots(\text{i})$$

$$T = 3a_2 \quad \dots(\text{ii})$$

$$a_2 = 2a_1 \quad \dots(\text{iii})$$

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

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

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

$$F - 2T = 2ma_1 \quad \dots(\text{i})$$

$$3T = 4ma_2 \quad \dots(\text{ii})$$

$$2a_1 = 3a_2 \quad \dots(\text{iii})$$

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

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

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

$$7T - 3mg = 3ma_1 \quad \dots(\text{i})$$

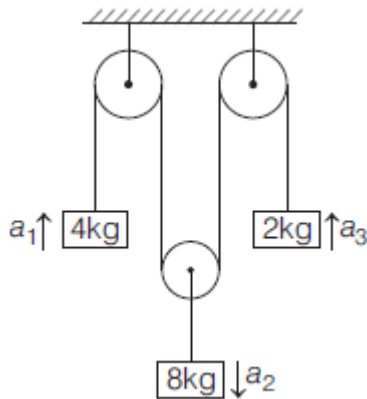
$$mg - T = ma_2 \quad \dots(\text{ii})$$

$$7a_1 = a_2 \quad \dots(\text{iii})$$

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.



$$T - 40 = 4a_1 \quad \dots(\text{i})$$

$$80 - 2T = 8a_2 \quad \dots(\text{ii})$$

$$T - 20 = 2a_3 \quad \dots(\text{iii})$$

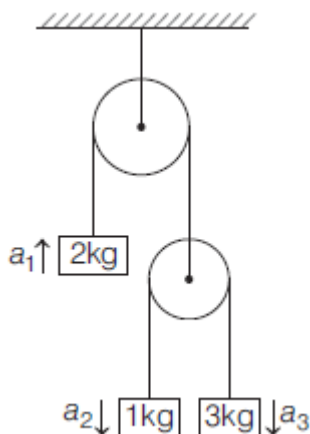
$$2a_2 = a_1 + a_3 \quad \dots(\text{iv})$$

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

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

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

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.



$$2T - 20 = 2a_1 \quad \dots(\text{i})$$

$$10 - T = a_2 \quad \dots(\text{ii})$$

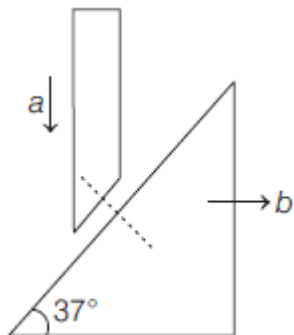
$$30 - T = 3a_3 \quad \dots(\text{iii})$$

$$2a_1 = a_2 + a_3 \quad \dots(\text{iv})$$

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



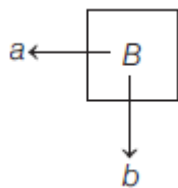
From wedge constraint their acceleration will be same along the common normal at contact.

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

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

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

From string constraint,



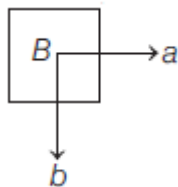
$$-4a + b = 0$$

$$\Rightarrow b = 4a$$

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

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

From string constraint,



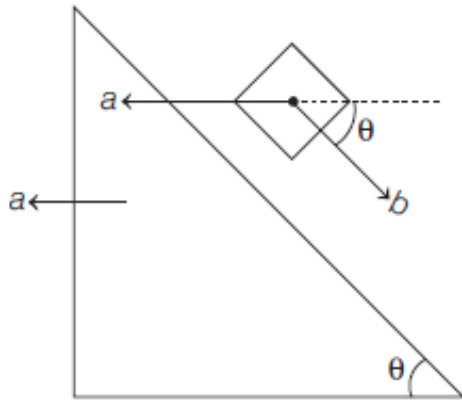
$$-2a - 2c + b = 0$$

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

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

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

From string constraint,

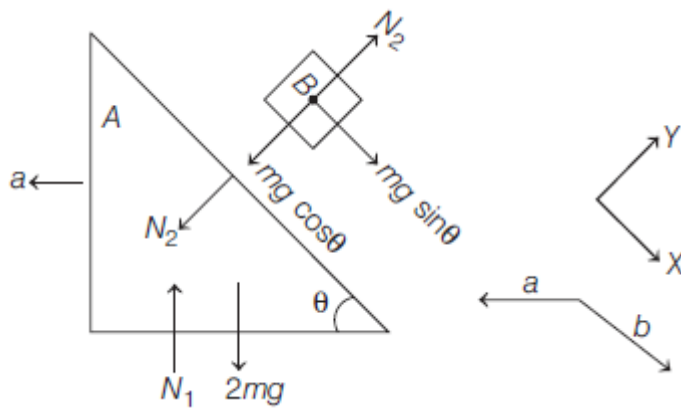


$$-a + b = 0$$

$$\Rightarrow b = a$$

$$\begin{aligned} \mathbf{a}_B &= (b\cos\theta - a)\hat{i} - b\sin\theta\hat{j} \\ &= a(\cos\theta - 1)\hat{i} - a\sin\theta\hat{j} \end{aligned}$$

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



For A, $\sum F_x = ma_x$

$$\Rightarrow N_2 \sin\theta = 2ma \quad \dots(i)$$

For B, $\sum F_x = ma_x$

$$\Rightarrow mg \sin\theta = m(b - a \cos\theta) \quad \dots(ii)$$

$$\sum F_y = ma_y$$

$$\Rightarrow mg \cos\theta - N_2 = ma \sin\theta \quad \dots(iii)$$

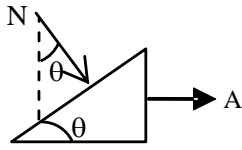
Solving Eqs. (i), (ii) and (iii), we get

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

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

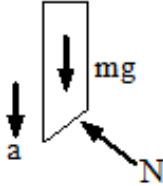
32. $A = \frac{mg}{M \cot \theta + m \tan \theta}$ and $a = \frac{mg \tan \theta}{M \cot \theta + m \tan \theta}$

Let the acceleration of wedge be 'A'



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

Let acceleration of rod be 'a'



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

$\tan \theta = y / x$

$y = x \tan \theta$

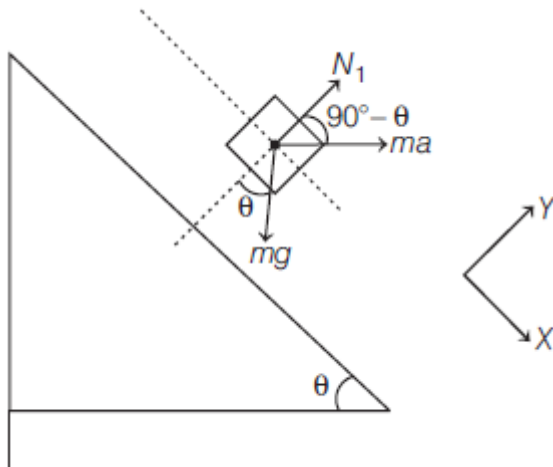
$\frac{d^2 y}{dt^2} = \frac{d^2 x}{dt^2} \tan \theta$

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

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

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

33. $g \cot \theta$



$\Sigma F_y = 0$

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

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

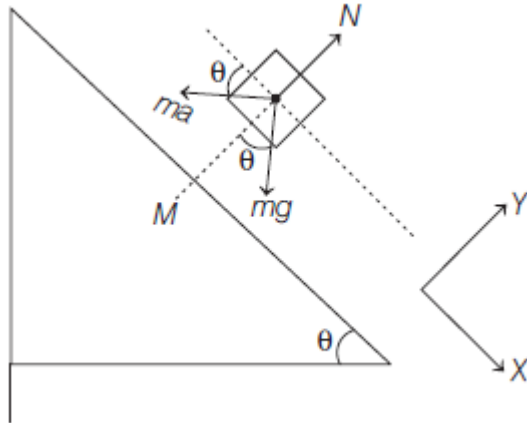
When block loses contact with the wedge

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

$\Rightarrow a = g \cot \theta$

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

Lets take acceleration of wedge to be a .



$$\sum F_x = 0$$

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

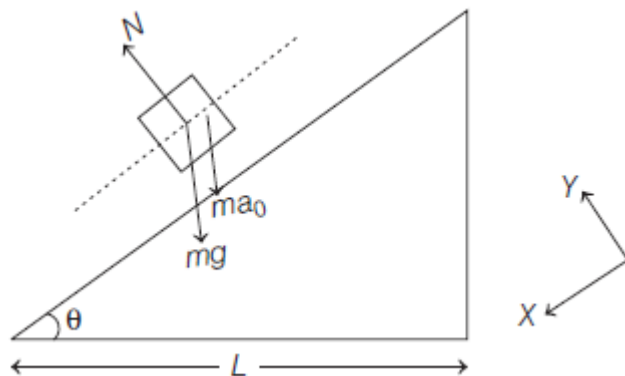
$$\Rightarrow a = g \tan \theta$$

For $(M + m)$ system,

$$\sum F_x = ma$$

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

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



$$\sum F_x = ma_x$$

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

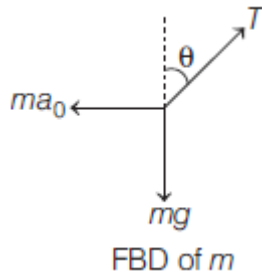
$$\Rightarrow a_x = (g + a_0) \sin \theta$$

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

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

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

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



$$\sum F_x = 0$$

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

$$\sum F_y = 0$$

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

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

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

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

$$40 - T = 4a \quad \dots(i)$$

$$T - 10 = 1a \quad \dots(ii)$$

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

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

Spring balance reading = $T = 16 \text{ N}$

39. Each will read 10 kg.

Both of them will read 100 N.

40. 0.2 m

$$30 - T_1 = 3a \quad \dots(i)$$

$$10 + T_1 - T_2 = a \quad \dots(ii)$$

$$T_2 - 20 = 2a \quad \dots(iii)$$

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

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

Spring force = $kx = T_1$

$$\Rightarrow 100x = 20$$

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

41. $g/2$ upwards, g downwards
Just after cutting the string



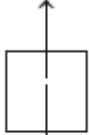
mg
FBD of m

$$F = ma$$

$$\Rightarrow mg = ma$$

$$\Rightarrow a = g \downarrow$$

$$kx = 3mg$$



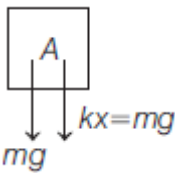
$2mg$
FBD of $2m$

$$F = ma$$

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

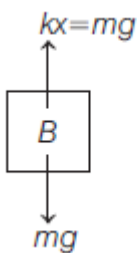
$$\Rightarrow a = \frac{g}{2} \uparrow$$

42. $2g$ downwards, 0



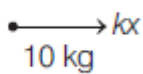
For A, $mg + mg = ma_A$

$$a_a = 2g \downarrow$$



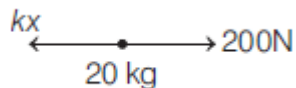
For B, $a_B = 0$

43. 4 ms^{-2}



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

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



$$200 - kx = 20a$$

$$\Rightarrow 200 - 120 = 20a$$

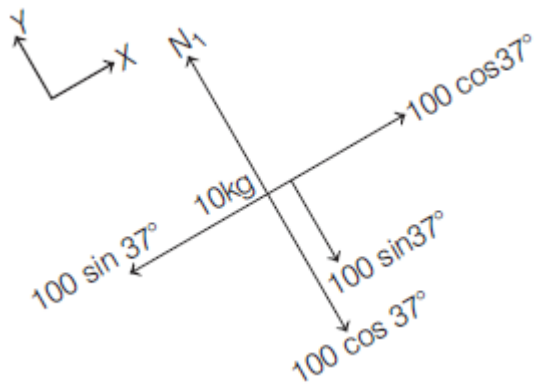
$$\Rightarrow a = 4 \text{ m/s}^2$$

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)
$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t} = \frac{(-2) - (+10)}{4} = \frac{-12}{4} = -3 \text{ m/s}^2$$
3. (B)
$$F = ma = 10 \times (-3) = -30 \text{ N}$$
4. (B)
Impulse = Force \times Time = $-30 \times 4 = -120 \text{ N}\cdot\text{s}$
5. (D)
$$R = m(g + a) = m(g + g) = 2mg$$
6. (A)
$$T_1 = m(g + a) = 1 \times \left(g + \frac{g}{2}\right) = \frac{3g}{2}$$

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



$$\sum F_x = ma_x$$

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

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

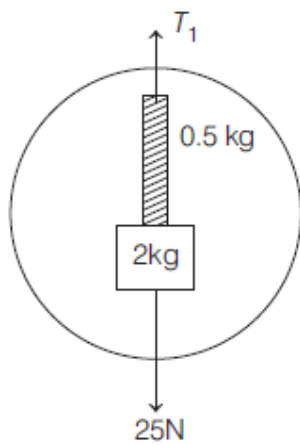
10. (C)

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

$$\text{Net force on } m_2 = m_2 a$$

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

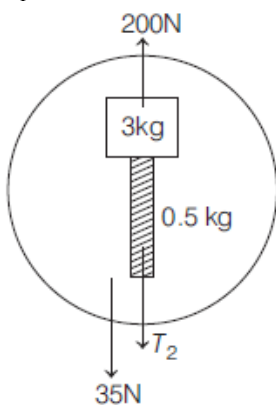
11. (C)



$$\sum F_y = ma_y$$

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

$$T_1 = 50 \text{ N}$$



$$\Sigma F_y = ma_y$$

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

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

12. (C)

$$150 - T_1 - T_2 = 15a \quad \dots(i)$$

$$T_1 = 5a \quad \dots(ii)$$

$$T_2 = 10a \quad \dots(iii)$$

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

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

13. (C)

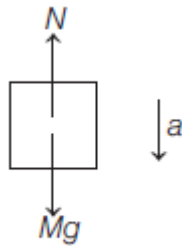
$$8g \sin 30^\circ - T = 8a \quad \dots(i)$$

$$T - 4g = 4a \quad \dots(ii)$$

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

$$a = 0$$

14. (A)



FBD of block

$$Mg - N = ma$$

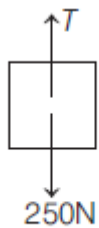
$$\Rightarrow Mg - \frac{Mg}{4} = Ma \Rightarrow a = \frac{3g}{4}$$

15. (D)

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

$$\Rightarrow T = 9000g$$

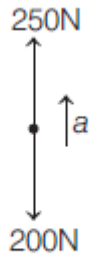
16. (D)



FBD of cage

$$\Sigma F_y = 0$$

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

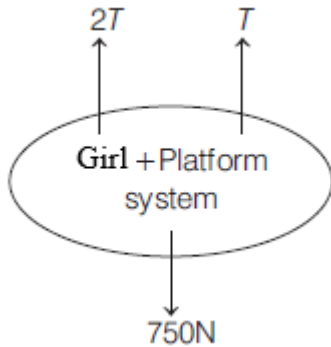


FBD of monkey

$$250 - 200 = 20a$$

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

17. (B)



$$\Sigma F_y = ma_y$$

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

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

18. (A)

$$m_2 g - 2T = m_2 a_2 \quad \dots(i)$$

$$T = m_1 a_1 \quad \dots(ii)$$

$$a_1 = 2a_2 \quad \dots(iii)$$

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

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

19. (C)

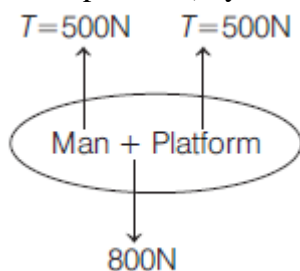
$$\Delta p = \Sigma F \Delta t$$

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

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

20. (B)

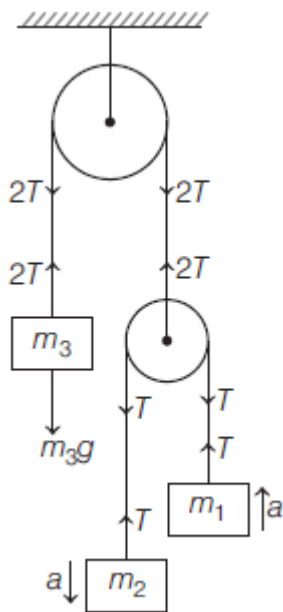
For (man + platform) system,



$$\begin{aligned}\Sigma F_y &= ma_y \\ \Rightarrow 2T - 800 &= 80a \\ \Rightarrow a &= 2.5 \text{ m/s}^2\end{aligned}$$

21. (A)

Since, m_3 is at rest.



$$\Rightarrow 2T = m_3g$$

For m_1 and m_2 ,

$$m_2g - T = m_2a \quad \dots(i)$$

$$T - m_1g = m_1a \quad \dots(ii)$$

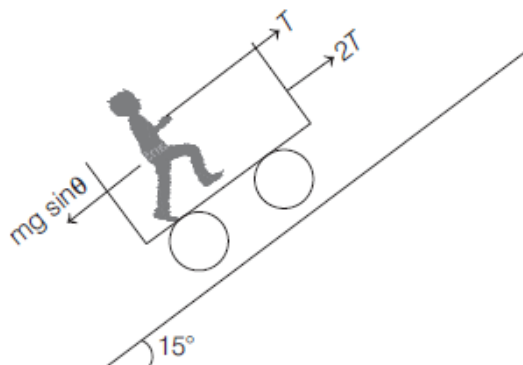
From Eqs. (i) and (ii), we get

$$\frac{m_2g - T}{m_2} = \frac{T - m_1g}{m_1}$$

$$T = \frac{2m_1m_2g}{m_1 + m_2} = \frac{m_3g}{2}$$

$$\Rightarrow m_3 = \frac{4m_1m_2}{m_1 + m_2}$$

22. (C)

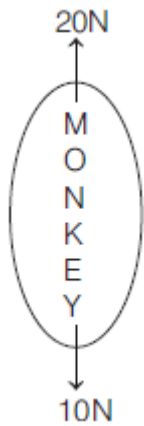


$$3T - mg \sin \theta = ma$$

$$750 - 1000(0.26) = 100a$$

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

23. (B)
To just lift the block, tension in the string will be 20 N.



$$F = ma$$

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

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

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

$$20 - T = 2a_2 \quad \dots(\text{i})$$

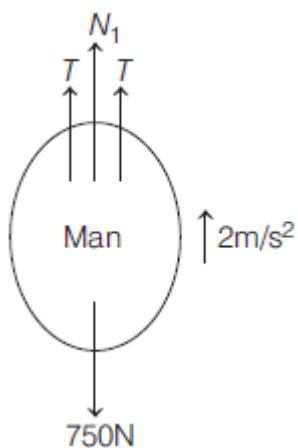
$$T - 10 = 1a_2 \quad \dots(\text{ii})$$

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

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

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

24. (B)
For (man + platform) system
 $\Rightarrow \Sigma F = ma$
 $4T - 750 - 250 = 100 \times 2$
 $\Rightarrow T = 300 \text{ N}$



For only man, $\Sigma F = ma$

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

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

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

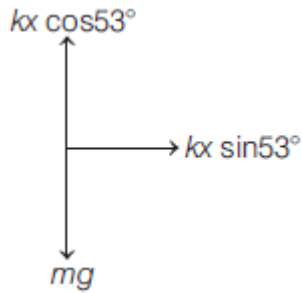
25. (C)

Before burning the string,

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

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

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



After burning the string,

$$\Sigma F_x = ma_x$$

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

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

$$\Sigma F_y = ma_y$$

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

$$\Rightarrow a_y = 0$$

26. (C)

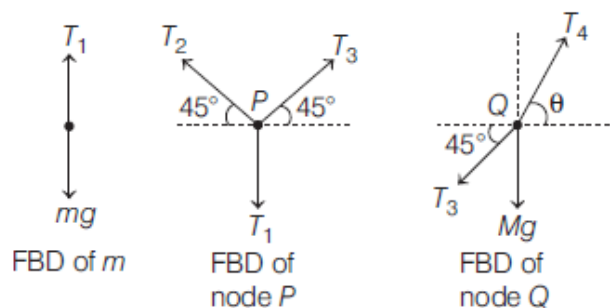
$$T = \frac{2m_1 m_2 g_{\text{eff}}}{m_1 + m_2} = \frac{2(3)(1.5)}{4.5} \left(g + \frac{g}{10} \right)$$

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

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

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

27. (A)



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

$$\Rightarrow T_1 = mg$$

For node P , $\Sigma F_x = 0$

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

$$\Rightarrow T_3 = T_2$$

$$\Sigma F_y = 0$$

$$\Rightarrow T_2 \sin 45^\circ + T_3 \sin 45^\circ = T_1$$

$$\Rightarrow 2T_3 \sin 45^\circ = T_1$$

$$\Rightarrow T_3 \sin 45^\circ = \frac{T_1}{2} = \frac{mg}{2}$$

For node Q,

$$\Sigma F_y = 0$$

$$\Rightarrow T_4 \sin \theta = Mg + T_3 \sin 45^\circ \quad \dots(i)$$

$$\Sigma F_x = 0$$

$$\Rightarrow T_4 \cos \theta = T_3 \cos 45^\circ \quad \dots(ii)$$

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

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

28. (10)

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

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

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

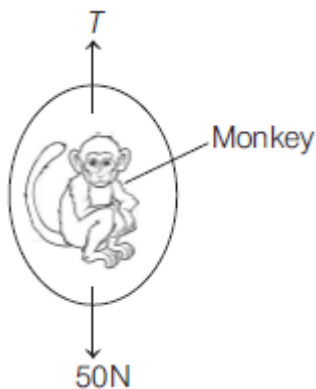
29. (2.5)

Tension the string $= m(g+a) = \text{Breaking force}$

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

30. (6)

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



For monkey, $T - 50 = 5a$

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

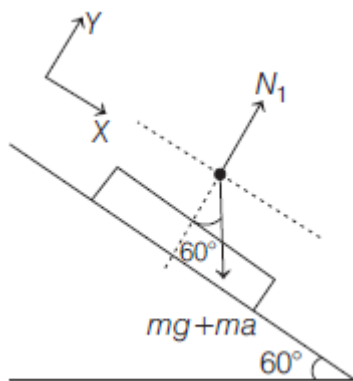
31. (322)

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

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

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

32. (40)



$$\Sigma F_y = 0$$

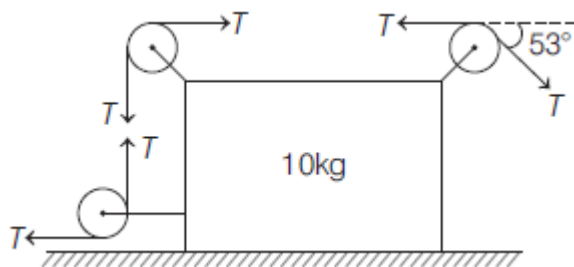
$$\Rightarrow N_1 = (mg + ma) \cos 60^\circ$$

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

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

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

33. (4)



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

$$\Sigma F_x = ma_x$$

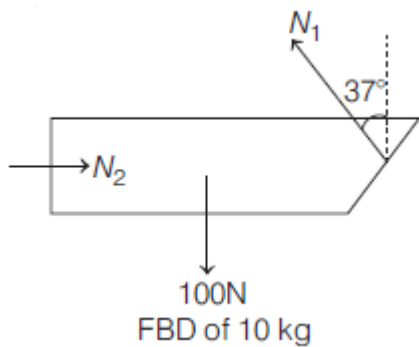
$$\Rightarrow T - T \cos 53^\circ = 10a$$

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

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

34. (75)

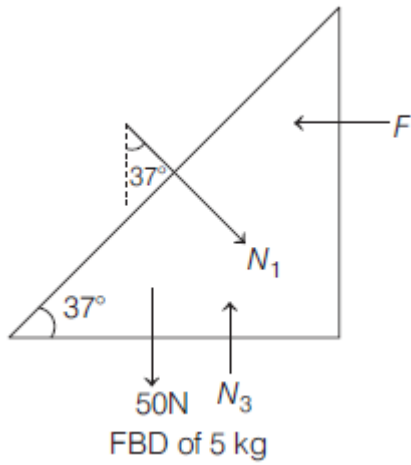
$$\Sigma F_y = 0$$



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

$$\Rightarrow N_1 = \frac{100}{\cos 37^\circ} = 125 \text{ N}$$

$$\Sigma F_x = 0$$



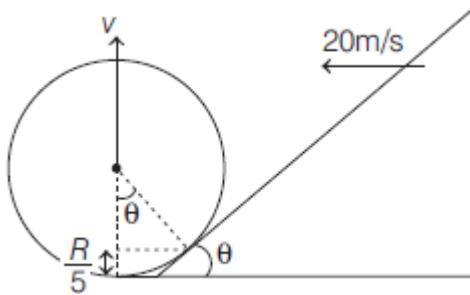
$$F = N_1 \sin 37^\circ$$

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

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

35. (15)

$$\cos \theta = \frac{4R/5}{R} = \frac{4}{5} \Rightarrow \theta = 37^\circ$$

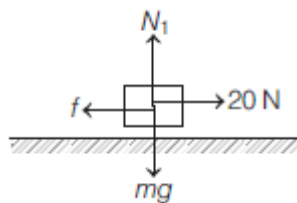


From wedge constraint, $v \cos \theta = 20 \sin \theta$

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

Friction

1. (A)



$$\Sigma F_y = 0$$

$$\Rightarrow N_1 - 40 = 0$$

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

Since, the block is not moving.

$$\Sigma F_x = 0$$

$$\Rightarrow 20 - f = 0$$

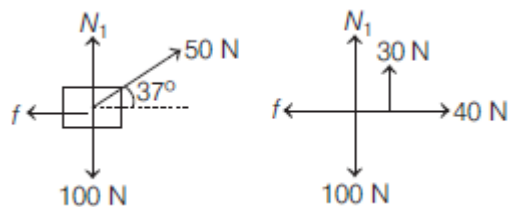
$$\Rightarrow f = 20 \text{ N (static)}$$

$$f \leq f_L$$

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

$$\Rightarrow \mu_s \geq 0.5$$

2. (A)



$$\Sigma F_y = 0$$

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

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

$$f_L = \mu_s N$$

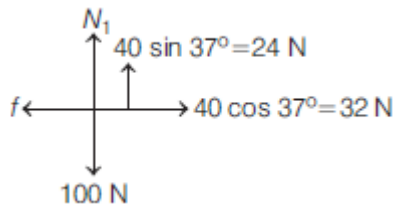
$$= 0.5(70) = 35 \text{ N}$$

$$\Sigma F_x = ma_x$$

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

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

3. (B)



$$\Sigma F_y = 0$$

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

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

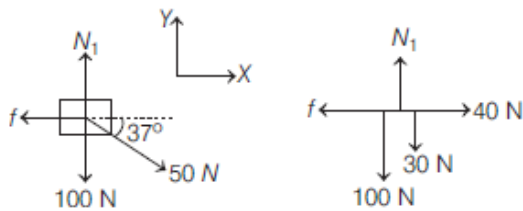
$$f_L = \mu_s N = 0.5(76) = 38 \text{ N}$$

Since, driving force is less than the limiting friction, the block will not move.

So, $a = 0$.

4. (C)

$$\Sigma F_y = 0$$



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

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

$$f_L = \mu_s N_1$$

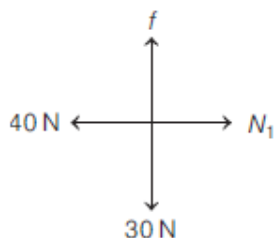
$$\Rightarrow f_L = 0.3(130) = 39 \text{ N}$$

$$\Sigma F_x = ma_x$$

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

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

5. (C)



$$\Sigma F_x = 0$$

$$\Rightarrow N_1 - 40 = 0$$

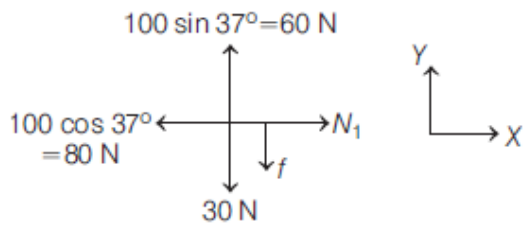
$$\Rightarrow N_1 = 40 \text{ N}$$

$$f_L = \mu_s N$$

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

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

6. (A)



$$\sum F_x = 0$$

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

$$\Rightarrow N_1 = 80 \text{ N}$$

$$f_L = \mu_s N$$

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

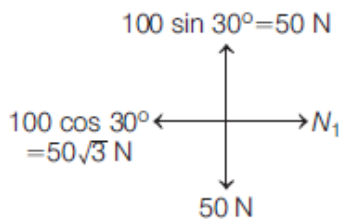
In absence of friction, driving force on the block is $60 - 30 = 30 \text{ N}$ up the wall which is more than the limiting friction. So, block will accelerate up the wall.

$$\sum F_y = ma_y$$

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

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

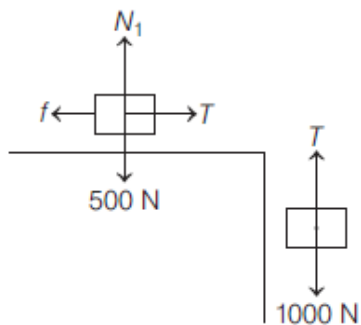
7. (A)



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

$$\Rightarrow f = 0 \text{ and } a = 0$$

8. (A)



For 100 kg block,

$$\sum F_y = 0$$

$$\Rightarrow T - 1000 = 0$$

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

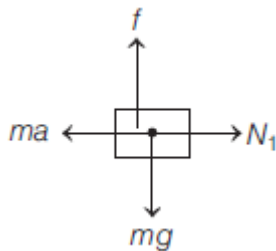
For 50 kg block,

$$\sum F_y = 0$$

$$N_1 - 500 = 0$$

$$\begin{aligned} \Rightarrow N_1 &= 500\text{N} \\ \Sigma F_x &= 0 \\ \Rightarrow T - f &= 0 \\ \Rightarrow f &= T = 1000\text{N} \\ f_L &= \mu N_1 = \mu(500) \\ f &\leq f_L \\ 1000 &\leq 500(\mu) \\ \Rightarrow \mu &\geq 2 \end{aligned}$$

9. (B)
Let's take acceleration of cart as a

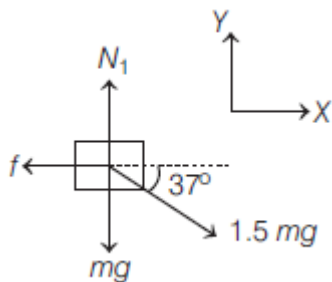


$$\begin{aligned} \Sigma F_x = 0 &\Rightarrow N_1 = ma \\ \Sigma F_y = 0 &\Rightarrow f = mg \end{aligned}$$

and $f \leq f_L$

$$\begin{aligned} \Rightarrow mg &\leq \mu N_1 \Rightarrow a \geq \frac{g}{\mu} \\ \Rightarrow a_{\min} &= \frac{g}{\mu} \end{aligned}$$

10. (A)



$$\begin{aligned} \Sigma F_y &= 0 \\ \Rightarrow +N_1 - mg - 1.5mg \sin 37^\circ &= 0 \\ \Rightarrow N_1 &= 1.9mg \\ \Sigma F_x &= ma_x \\ \Rightarrow 1.5mg \cos 37^\circ - \mu N_1 &= m(0) \\ \Rightarrow \mu &= \frac{1.5mg \cos 37^\circ}{1.9mg} \\ \Rightarrow \mu &= \frac{12}{19} \end{aligned}$$

11. (A)

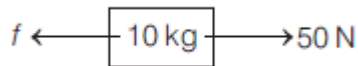
Taking both the block as a system,



$$\Sigma F = ma$$

$$\Rightarrow 50 = 20a$$

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



For upper 10 kg block,

$$50 - f = 10(2.5)$$

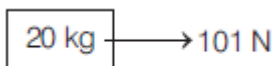
$$\Rightarrow f = 25 \text{ N}$$

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

Since, $f < f_L$

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

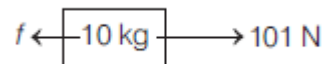
12. (B)



$$\Sigma F = ma$$

$$\Rightarrow 101 = 20a$$

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



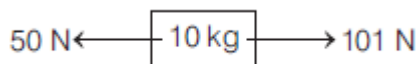
$$\Sigma F = ma$$

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

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

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

Friction between the blocks will be kinetic.



$$\Sigma F = ma$$

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

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



$$\Sigma F = ma$$

$$\Rightarrow 50 = 10a$$

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

13. (A)

For system,

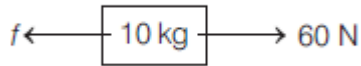


$$\Sigma F = ma$$

$$\Rightarrow 90 = 30a$$

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

For 10 kg block,



$$\Sigma F = ma$$

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

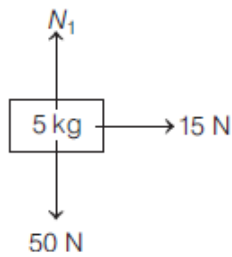
$$f = 30 \text{ N}$$

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

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

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

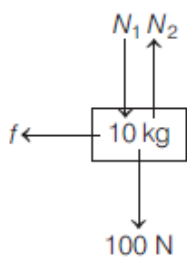
14. (B)



$$\Sigma F = ma$$

$$\Rightarrow 15 = 5a$$

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

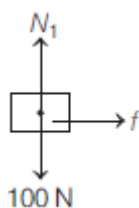


$$a = 0$$

$$f = 0$$

15. (C)

FBD of 10 kg block,



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

$$\Sigma F_x = ma$$

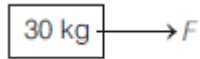
$$\Rightarrow f = 10a$$

For maximum acceleration,

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

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

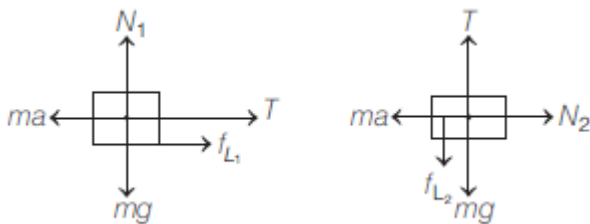
For (20 kg + 10 kg) system,



$$\Sigma F_x = ma$$

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

16. (C)



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

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

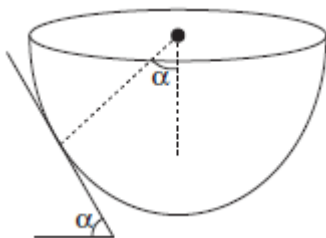
$$\Rightarrow ma = mg + \mu N_2 + \mu N_1$$

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

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

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

17. (A)



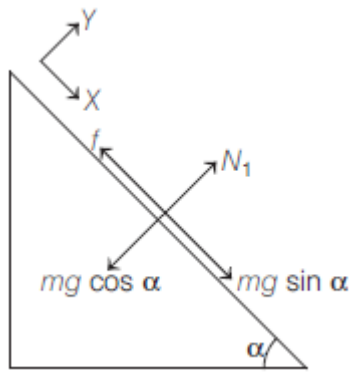
$$\Sigma F_y = 0$$

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

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

$$\Sigma F_x = 0$$

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



$$\& \quad f \leq f_L$$

$$\Rightarrow mg \sin \alpha \leq \mu mg \cos \alpha$$

$$\Rightarrow \tan \alpha \leq \frac{1}{3}$$

$$\Rightarrow \tan \alpha_{\max} = \frac{1}{3}$$

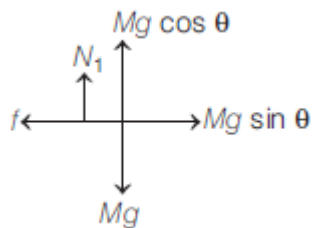
$$\Rightarrow \cot \alpha_{\max} = 3$$

18. (C)

$$\Sigma F_y = 0$$

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

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



For pulling the block,

$$Mg \sin \theta \geq f_L$$

$$\Rightarrow Mg \sin \theta \geq \mu N_1$$

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

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

$$\Rightarrow \cot\left(\frac{\theta}{2}\right) \geq \mu$$

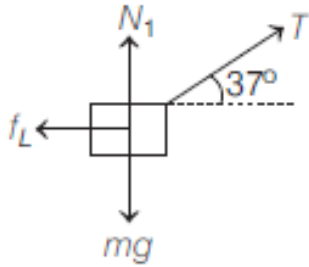
19. (B)

For block B,

$$\Sigma F_y = 0$$

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

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



$$\Sigma F_x = 0$$

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

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

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

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

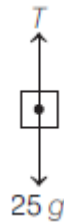
For A,

$$\Sigma F = ma$$

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

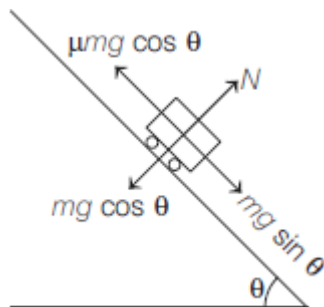
$$\Rightarrow \frac{100g}{3} - 25g = 25a$$

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



20. (C)

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



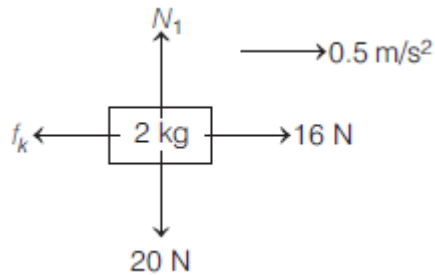
$$v^2 = u^2 + 2as$$

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

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

21. (A)

For 2 kg block,



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

$$f_k = \mu N_1 = 20\mu_1$$

$$\sum F = ma$$

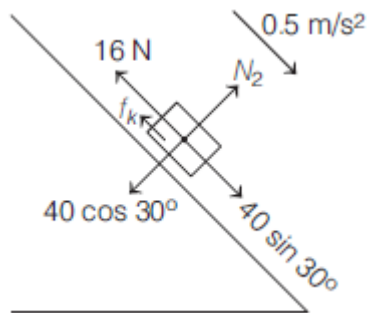
$$\Rightarrow 16 - 20\mu_1 = 2(0.5)$$

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

For 4 kg block,

$$\sum F = ma$$

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



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

$$f_k = \mu_k N$$

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

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

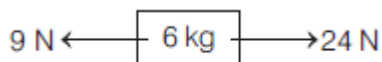
22. (B)

For 6 kg block,

$$\sum F = ma$$

$$\Rightarrow 24 - 9 = 6a$$

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

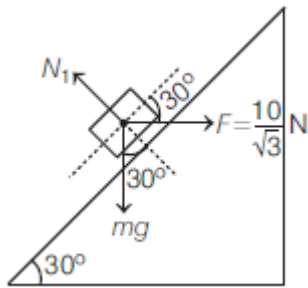


For 3 kg block,

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

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

23. (A)

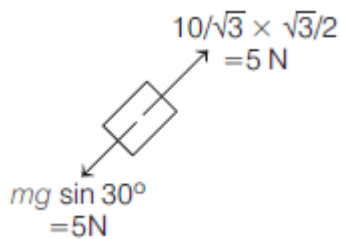


$$\Rightarrow +N_1 - mg \cos 30^\circ - F \sin 30^\circ = 0$$

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

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

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



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

So, $f = 0$

24. (0.75)

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

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

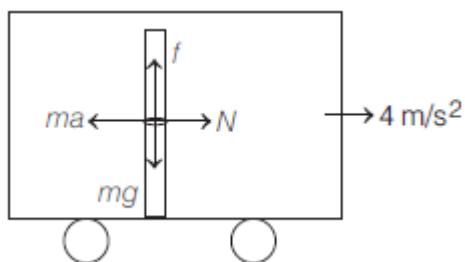
$$\Rightarrow 16\mu^2 = 9$$

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

25. (0.5)

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

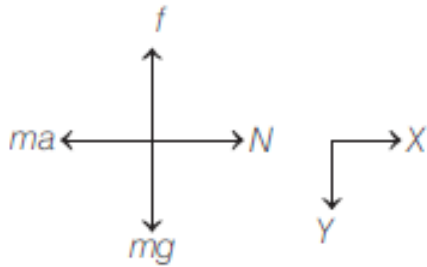
$$N = ma$$



$$\sum F_y = ma_y$$

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

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



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

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

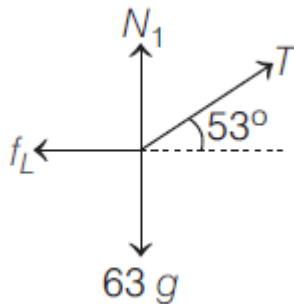
$$s_y = u_y t + \frac{1}{2} a_y t^2$$

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

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

26. (35)

For man,



$$\Sigma F_y = 0$$

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

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

$$\Sigma F_x = 0$$

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

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

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

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

$$\Rightarrow T = 35g$$

For block,

$$\Sigma F_y = Ma_y$$

$$\Rightarrow T - Mg = 0$$

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



27. (0.98)

Taking (A + B) system,

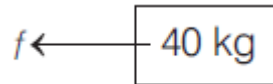


$$\Sigma F = ma$$

$$\Rightarrow 100 = 50a$$

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

For B,



$$\Sigma F = ma$$

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

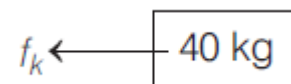
$$f_L = \mu_s N$$

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

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

Friction between the blocks will be kinetic.

For B,



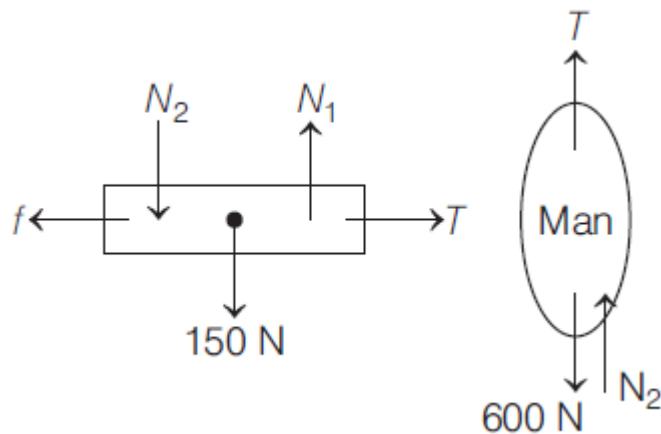
$$\Sigma F = ma$$

$$\Rightarrow f_k = 40a$$

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

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

28. (250)



For board,

$$\Sigma F_x = ma_x$$

$$\Rightarrow T - f_L = 0$$

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

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

For man,

$$\Sigma F_y = 0$$

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

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

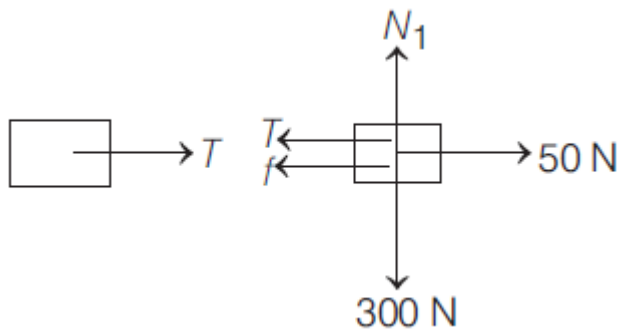
From Eqs. (i) & (ii), we get

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

$$\Rightarrow 3T = 750$$

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

29. (0)

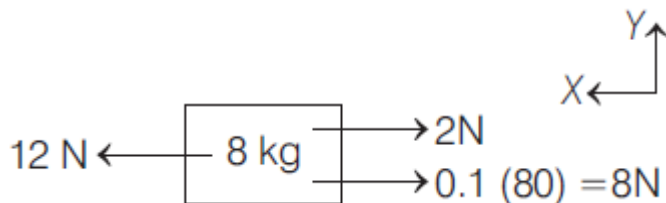


For block A,

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

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,

$$\Sigma F = ma$$

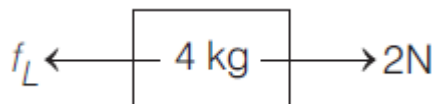
$$\Rightarrow 12 - 2 = 8 = 8a$$

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

For upper 4kg block,

$$\Sigma F = ma$$

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



$$\Rightarrow f_L = 3 \text{ N}$$

$$\text{and } f_L = 3 \text{ N} = \mu(40) \Rightarrow \mu = \frac{3}{40}$$

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

$$f_L = \mu_s N$$

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

$$f_k = \mu_k N$$

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

- (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 $f_L = 30 \text{ N}$.
(d) Since, $F > f_L$, the block will be set into motion and nature of friction will be kinetic.

$$F - f_k = ma$$

$$\Rightarrow 31 - 25 = 5a$$

$$\Rightarrow a = 1.2 \text{ m/s}^2$$

1. (b)

Impulse, $I = \text{change in momentum, } \Delta P$

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

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)

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

3. (b)

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

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

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

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

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)

$$a = \frac{v dv}{dx}; \quad a dx = v dx; \quad \int_{0.5}^{1.5} -\frac{kx}{m} dx = \int_4^v v dv$$

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

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

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

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,

$$F = ma$$

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

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

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

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

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

8. (b)

From the Newton's second law,

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

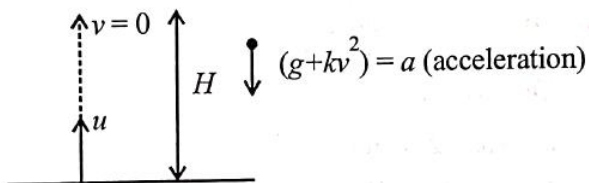
$$\text{We have given, } \frac{dM(t)}{dt} = bv^2(t) \quad \dots \text{(ii) and } F_{\text{ext}} = 0$$

Thrust on the satellite,

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

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

9. (d)



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

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

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

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

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

10. (a)
Net acceleration

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

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

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

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

11. (d)

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

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

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

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,

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

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

13. (a)

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

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

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

14. (a)
From question, mass of body, $m = 5 \text{ kg}$

Velocity at $t = 0$,

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

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

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

Force, $F = ?$

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

Force, $F = ma$

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

15. (c)
For equilibrium condition, $m_2 g = m_1 g \sin \theta$

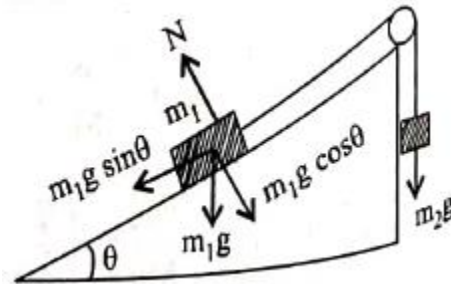
$$\sin \theta = \frac{m_2}{m_1} = \frac{3}{5}$$

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

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

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

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,
 $a = g \sin \theta$

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

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

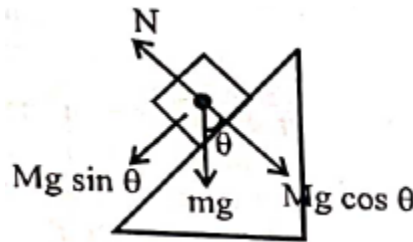
When the incline is changed to 45°

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

As distance travelled is same

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

$$\Rightarrow t = 2\sqrt{2} \approx 1.68$$

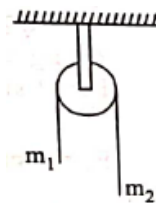


17. (d)
Acceleration in such system is given as

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

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

So, $x = 4$



18. (c)
Given that mass of monkey, $m = 50 \text{ kg}$
Acceleration due to gravity, $g = 10 \text{ m/s}^2$
Tension (T) = 350 N

Given monkey climbs downward, acceleration of monkey,
 $a = 4 \text{ m/s}^2$

When monkey climbs upward, acceleration of monkey,
 $a = 5 \text{ m/s}^2$

(For upward)

$$T = mg + ma$$

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

Rope will break while climbing upward

(For downward)

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

Rope will not break while climbing downward

19. (a)
Let a_1 be the acceleration of 100 kg block

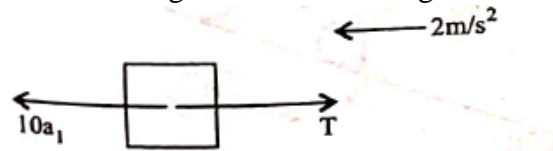
FBD of 100 kg block w.r.t. ground
 $F - T - N_1 = 100a_1$... (i)

FBD of 20 kg block w.r.t. 100 kg
 $T - 20g = 20(2) \Rightarrow T = 40 + 200$

$$\Rightarrow T = 240 \text{ ... (ii)}$$

$$N_1 = 20a_1 \text{ ... (iii)}$$

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

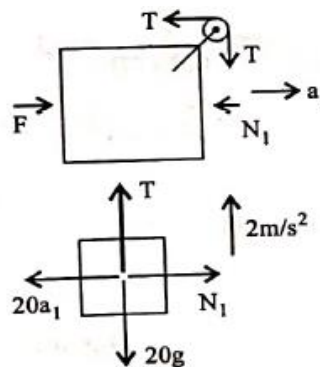


$$10a_1 - 240 = 10(2)$$

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

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

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



20. (a)
Let addition force required be $= \vec{F}$ -

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

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

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

$$\text{So, } \theta = \tan^{-1}(1) = 45^\circ.$$

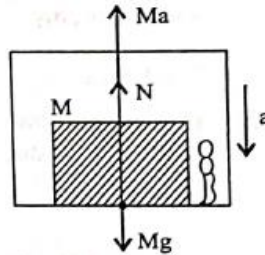
21. (c)
For observer in box

$$N + Ma = Mg$$

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

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

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

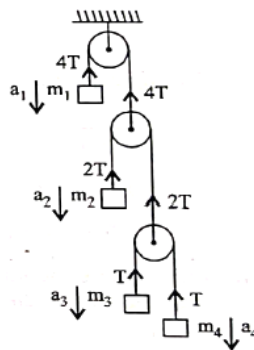


22. (b)
When elevator does downward, then a pseudo force acts on object in upward direction, due to which effective weight of object decreases.

23. (a)
 $\sum \vec{T} \cdot \vec{a} = 0$

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

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



24. (d)
From free body diagram,

$$80 - 2T = 8a \quad \dots(i)$$

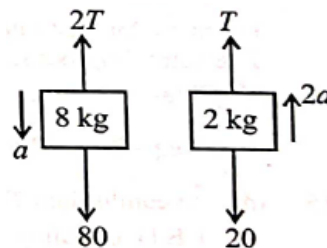
$$T - 20 = 4a \quad \dots(ii)$$

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

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

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

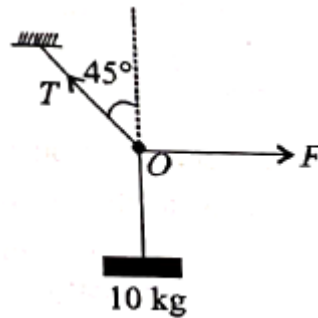
$$\Rightarrow \frac{0.2 \times 2 \times 4}{10} = t^2 \Rightarrow t = 0.4 \text{ sec}$$



25. (a)
The free body diagram is by Lami's theorem

$$\Rightarrow \frac{mg}{135^\circ} = \frac{F}{135}$$

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



26. (b)
Retardation due to friction = $\frac{\mu Mg}{M} = \mu g$

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

27. (a)
From the free diagram shown

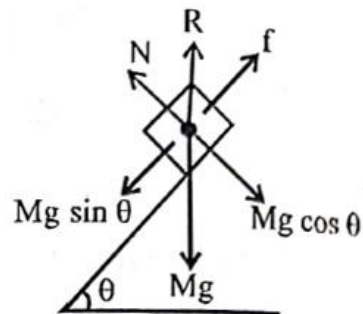
$$N = Mg \cos \theta$$

$$f = Mg \sin \theta$$

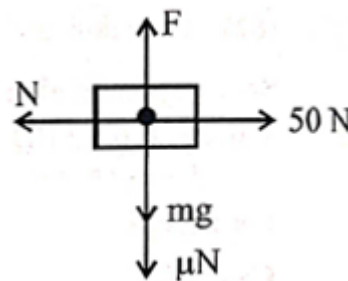
$$\text{Contact force, } R = \sqrt{N^2 + f^2}$$

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

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



28. (d)
By FBD of block, we have
 $N = 50 \text{ N}$ and $F \leq mg + \mu N$
i.e. $F \leq 2g + 0.5 \times 50 \leq 20 + 25 \leq 45 \text{ N}$
So, Maximum force that can be applied is 45 N.



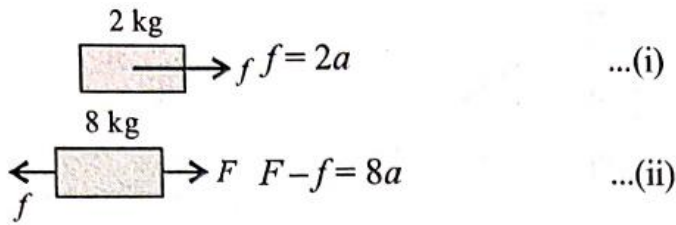
29. (d)
For 4 kg block
 $4g - T = 4a \quad \dots(i)$
For 40 kg block
 $T - 40g + 0.02 = 40a \quad [\because f_k = \mu mg]$
 $T - 8 = 40a \quad \dots(ii)$

Adding (i) & (ii), we get

$$40 - 8 = 44a$$

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

30. (c)



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

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

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

31. (b)

For beaker to move with disc

$f_s = m\omega^2 R$

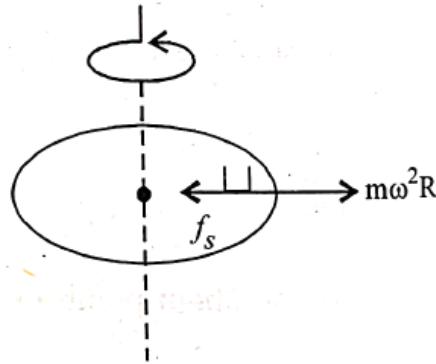
So, R will be maximum, when $f_s = f_{\text{lim}}$

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

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

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

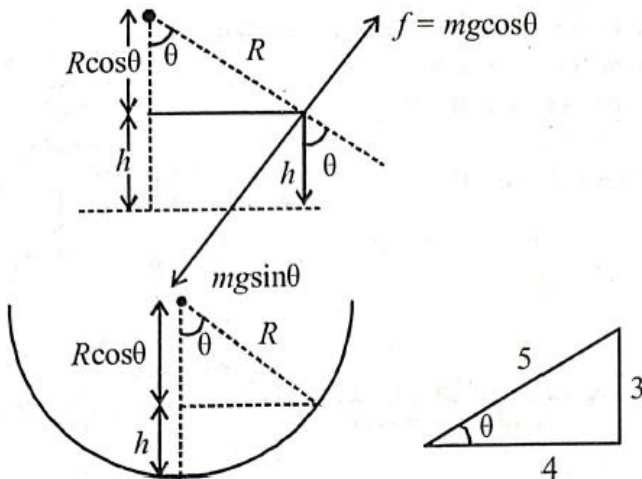
So, $R \leq \frac{\mu g}{\omega^2}$



32. (a)

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

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



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

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

33. (c)

$$A : N = 5g + 20\sin 30^\circ$$

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

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

$$= \frac{20\cos 30^\circ - \mu N}{5}$$

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

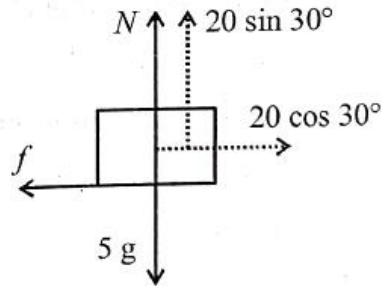
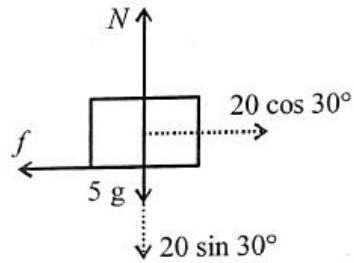
$$= 1.06 \text{ m/s}^2$$

$$B : N = 5g - 20\sin 30^\circ$$

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

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

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



34. (b)

Taking $(A + B)$ as system

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

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

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

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

35. (a)

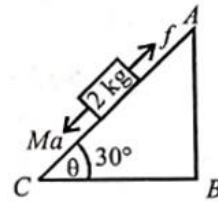
From figure, $2 + mg \sin 30^\circ = \mu mg \cos 30^\circ$ and $10 = mg \sin 30^\circ + \mu mg \cos 30^\circ = 2\mu mg \cos 30^\circ - 2$

$$\Rightarrow 6 = \mu mg \cos 30^\circ \text{ and } 4 = mg \sin 30^\circ$$

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

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

36. (d)
Equation of motion when the mass slides down
 $Mg \sin \theta - f = Ma$
 $\Rightarrow 10 - f = 6$ ($M = 2 \text{ kg}$, $a = 3 \text{ m/s}^2$, $\theta = 30^\circ$ given)
 $\therefore f = 4 \text{ N}$

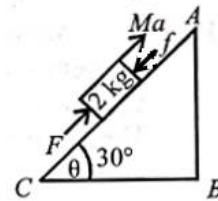


Equation of motion when the block is pushed up
Let the external force required to take the block up the plane with same acceleration be F

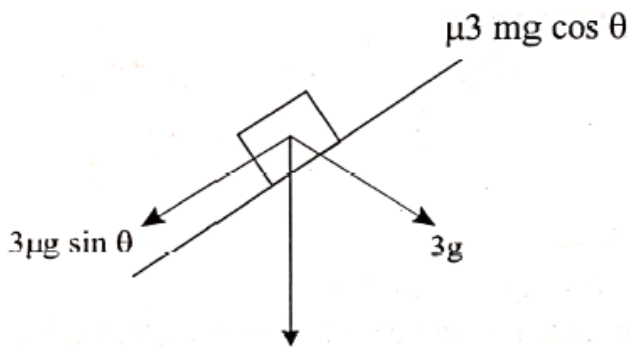
$$F - Mg \sin \theta - f = Ma$$

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

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



37. (b)
Let μ be the minimum coefficient of friction



At equilibrium, mass does not move so, $3mg \sin \theta = \mu 3mg \cos \theta$
 $\therefore \mu_{\min} = \tan \theta$

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

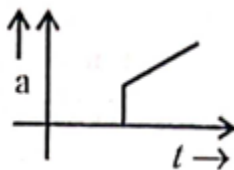
$$S = \frac{v^2}{2\mu g} = \frac{v_0^2 + 2gh}{2\mu g} = \frac{v_0^2}{2\mu g} + \frac{2gh}{2\mu g} = \frac{h}{\mu} + \frac{v_0^2}{2\mu g}$$

39. (b)
-

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

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

So, $a-t$ graph will be as shown



40. (d)

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

$$a = g \sin \theta - 0.3 x g \cos \theta$$

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

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. (6)

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

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

42. (12)

Impulse = $\Delta \vec{p}$

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

43. (500)

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

Displacement of the box along x -axis,

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

44. (3)

Along horizontal

$$F_1 + 1 \cos 45^\circ = 2 \sin 45^\circ$$

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

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, $x = 3$

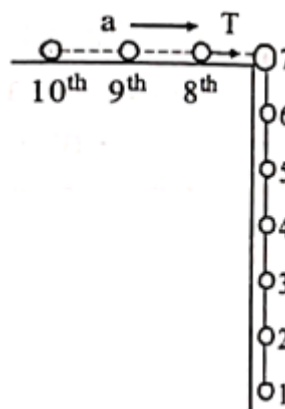
45. (36)

We have, acceleration of system as

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

taking 8, 9, 10 together

$$T = 3ma = 3m \times \frac{3g}{5} = \frac{3 \times 2 \times 3 \times 10}{5} = 36 \text{ N}$$



46. (12)

Let draw FBD of block clearly for equilibrium

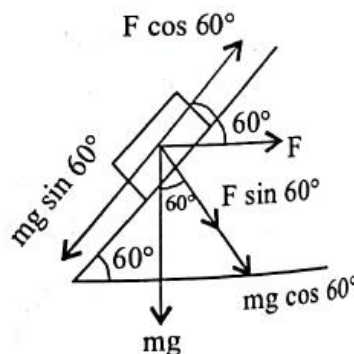
$$F \cos 60^\circ = mg \sin 60^\circ$$

$$\Rightarrow \frac{F}{mg} = \tan 60^\circ$$

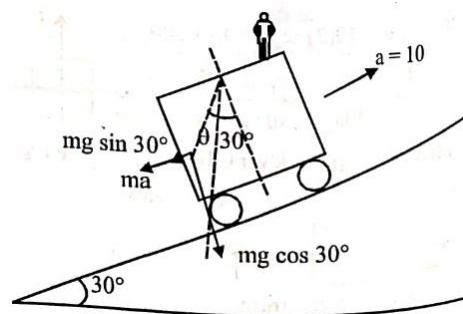
$$\Rightarrow \frac{\sqrt{x}}{0.2 \times 10} = \sqrt{3}$$

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

$$\Rightarrow x = 12$$



47. (30)



$$\text{From figure, } \tan(30^\circ + \theta) = \frac{mg \sin 30^\circ + ma}{mg \cos 30^\circ}$$

$$\Rightarrow \tan(30^\circ + \theta) = \frac{5 + 10}{5\sqrt{3}} = \frac{1 + 2}{\sqrt{3}}$$

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

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

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

$$\Rightarrow \tan \theta = \frac{1}{\sqrt{3}} \quad \therefore \theta = 30^\circ$$

48. (82)
 \vec{P} makes angle of 35° with AC
 So, component along $AC = 100 \cos 35 = 81.9 \text{ N} \approx 82 \text{ N}$

49. (3)
 Acceleration on smooth inclined plane

$$a = g \sin 30^\circ = \frac{g}{2}$$

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

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

Acceleration on rough inclined plane

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

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

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

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

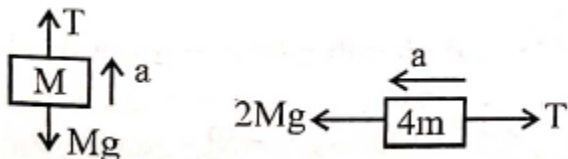
By (i) and (ii)

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

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

50. (6)
 For $4m$
 $2Mg - T = 4Ma \quad \dots (\text{i})$

For M



$$T - mg = Ma \quad \dots (\text{ii})$$

Adding (i) & (ii), we get

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

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

51. (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)

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

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

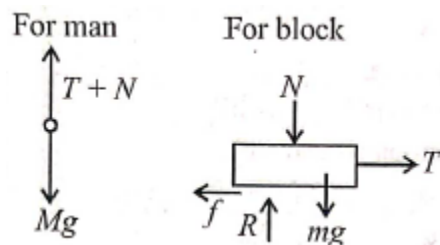
$$\Rightarrow \mu = \frac{\sqrt{3}}{5} \quad [\because \theta = 30^\circ]$$

So, $x = 3$

52. (30)

From FBD shown, $T = Mg - N$

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



For no movement of block,

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

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

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

53. (5)

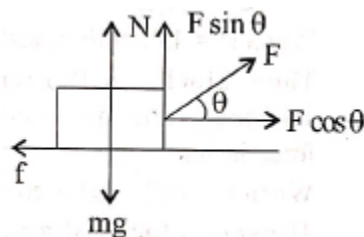
As block is at rest

$$\text{So, } F \cos \theta = f = \mu N$$

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

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

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



For F_{\min}

$(\cos \theta + \mu \sin \theta)$ should be maximum

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

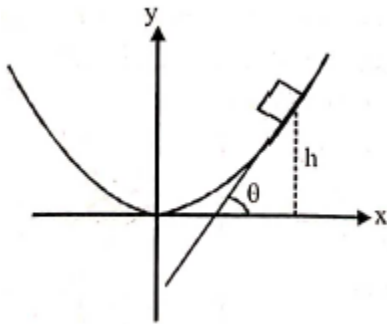
$$\text{So, } \sin \theta = \frac{\mu}{\sqrt{1+\mu^2}} \text{ and } \cos \theta = \frac{1}{\sqrt{1+\mu^2}}$$

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

Putting the value of μ , m and g

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

54. (25)



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

$$\tan \theta = \mu$$

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

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

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

55. (25)

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

Since, block is at rest,

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

$$F - N = 0 \quad \dots(ii)$$

$$f_r \leq \mu N$$

In limiting case,

$$f_r = \mu N = \mu F \quad \dots(iii)$$

Using equation (i) and (iii),

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

