HINTS & SOLUTIONS

EXERCISE - 1
Single Choice

1. $ma_{min} = mg - T_{max}$

$= mg - \frac{75}{100}mg = \frac{mg}{4} \quad \Rightarrow a_{min} = \frac{g}{4}$

2. Force on m_1 = Force on m_2 $\quad \Rightarrow a_1 = \frac{m_2 a_2}{m_1}$

3. For $BC = 0$, $a = \frac{2g}{2+5+1} = \frac{g}{4} = \frac{10}{4} = \frac{20}{8} ms^{-2}$

For $BC = 2m$, $a = \frac{(2+1)g}{2+5+1} = \frac{3g}{8} = \frac{30}{8} ms^{-2}$

4. Impulse $= \int Fdt$

I $\rightarrow$ Impulse $= 0.25 \times 1 = 0.25$

II $\rightarrow$ Impulse $= \frac{1}{2} \times 2 \times 0.3 = 0.30$

III $\rightarrow$ Impulse $= \frac{1}{2} \times 1 \times 1 = 0.50$

IV $\rightarrow$ Impulse $= \frac{1}{2} \times 1 \times 1 = 0.50$

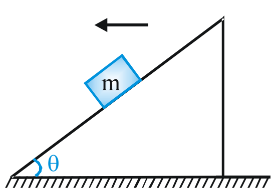
5. Impulse = Change in momentum

$= m(v_2 - v_1) = 0.1\left(0 - \frac{4}{2}\right) = -0.2 \text{ kg ms}^{-1}$

6. Acceleration of particle $= \left(\frac{m_1 - m_2}{m_1 + m_2}\right)(g+a)$

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

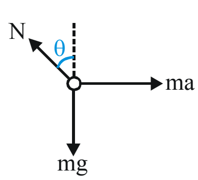
8. $\sin\theta = \frac{1}{x}$



$\tan\theta = \frac{1}{\sqrt{x^2 - 1}}$

For body $\quad N\cos\theta = mg$

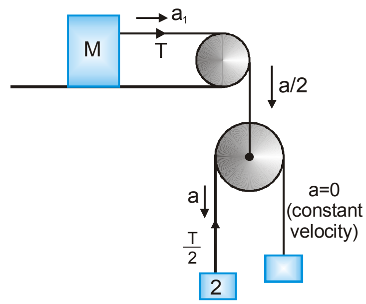
$\quad N\sin\theta = ma$



$\Rightarrow a = g\tan\theta = \frac{g}{\sqrt{x^2 - 1}}$

9. Just after release T = 0 due to non–impulsive nature of spring. So acceleration of both blocks will be g↓

10. $T = M \times \frac{a}{2}$ ...(i)



$20 - \frac{T}{2} = 2 \times a$ ...(ii)

$20 - \frac{1}{2} \times \frac{Ma}{2} = 2a$

& $\frac{T}{2} = 1 \times g \quad \Rightarrow T = 20N$

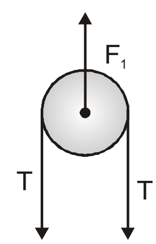
$20 - 10 = 2a \quad \Rightarrow a = 5 \text{ m/s}^2$

$20 - \frac{5M}{4} = 2 \times 5 \Rightarrow M = \frac{(20-10) \times 4}{5}$

$M = 8$ kg

11. **Case (i)** : $F_1 = 2T_1$

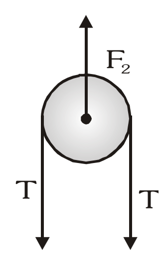
$a_1 = \frac{4mg - 2mg}{6m} = \frac{2mg}{6m} = \frac{g}{3}$



$\therefore \quad T_1 - 2mg = 2m \times \frac{g}{3}$

$\Rightarrow T_1 = \frac{8mg}{3} \quad \therefore F_1 = \frac{16mg}{3}$

Case (ii) :



$F_2 = 2T_2$

$a_2 = \frac{4mg - 2mg}{6m} = \frac{g}{3}$

$\therefore \quad 4mg - T_2 = 4m \times \frac{g}{3}$

$T_2 = \frac{8mg}{3} \quad \therefore F_2 = 2T_2 = \frac{16mg}{3}$

12. $a_1 = \frac{2mg - mg}{m} = g$; $a_2 = \frac{2mg - mg}{3m} = \frac{g}{3}$

$a_3 = \frac{mg + mg - mg}{2m} = \frac{g}{2}$; $a_1 > a_3 > a_2$

13. **(A)** – Pulling force on bricks = 2F

(B) – Pulling force on bricks = F

(C) – Pulling force on bricks = F

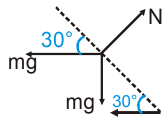
(D) – Pulling force on pulley = F/2

14. Acceleration

$$= \frac{\text{Net force}}{\text{Total mass}} = \frac{3 \times 250 - (100) g \sin\theta}{100}$$

$$= \frac{750 - 260}{100} = 4.9 \text{ ms}^{-2}$$

15. FBD of block w.r.t. wedge



Acceleration of block w.r.t wedge

$$= \frac{mg\frac{\sqrt{3}}{2} - mg\left(\frac{1}{2}\right)}{m} = \left(\frac{\sqrt{3}-1}{2}\right)g$$

Now from $S = ut + \frac{1}{2}at^2$, $1 = \frac{1}{2}\left(\frac{\sqrt{3}-1}{2}\right)gt^2$

$\Rightarrow \quad t = \sqrt{\frac{4}{(\sqrt{3}-1)g}} = 0.74$ s

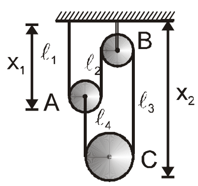
16. For pulley C,

$\Rightarrow T = 0$

Acceleration of $m_1 = \frac{m_1 g}{m_1} = g$

Acceleration of $m_2 = \frac{m_2 g}{m_2} = g$

17. $\ell_1 + \ell_2 + \ell_3 + \ell_4 =$ constant



$\ddot{\ell}_1 + \ddot{\ell}_2 + \ddot{\ell}_3 + \ddot{\ell}_4 = 0$

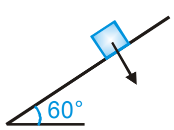
$x_1 + x_1 + x_2 + x_2 - x_1 = 0 \quad \Rightarrow \quad 2x_2 + x_1 = 0$

But acceleration of C = g downward

($\because$ Tension in string is zero as A is massless)

$\Rightarrow$ Acceleration of A = 2g upwards

18. $a_2 = \dfrac{20 \times \frac{\sqrt{3}}{2} - 0.4 \times 20 \times \frac{1}{2}}{2}$



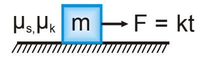
$$= \frac{10\sqrt{3} - 4}{2} = 5\sqrt{3} - 2$$

$$a_1 = \frac{10 \times \frac{\sqrt{3}}{2} - 0.5 \times 10 \times \frac{1}{2}}{1} = 5\sqrt{3} - 2.5 \text{ ; } a_1 < a_2$$

OR

As $\mu_2 < \mu_1$ so block will move separately.

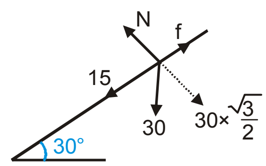
19. Block starts sliding when $kt_0 = \mu mg$



So for $t \le t_0$, $a = 0$

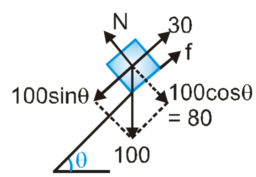
and for $t > t_0$, $a = \frac{F - \mu_k mg}{m} = \frac{kt}{m} - \mu_k$

20. $N = 15\sqrt{3}$; $f = 15 \qquad \therefore$ Total Force



$$= \sqrt{(15\sqrt{3})^2 + (15)^2} = 30\text{N}$$

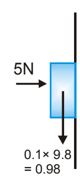
21. $f_{max} = \mu N = \left(\frac{3}{4}\right)(80) = 60$



Total force exerted by plane

$$= \sqrt{f^2 + N^2} = \sqrt{30^2 + 80^2} \text{ along OB}$$

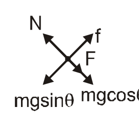
22. $\because$ Block is stationary so f = 0.98 N



23. $N = F + mg\cos\theta$, $f = mg\sin\theta$ but $f \le \mu N$

so $mg\sin\theta \le \mu (F + mg\cos\theta)$

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



$\Rightarrow \quad F_{min} = 2 \times 10\left[\frac{1/2}{0.5} - \frac{\sqrt{3}}{2}\right] = 20(1 - 0.866) = 2.68\text{N}$

24. Acceleration of box w.r.t truck

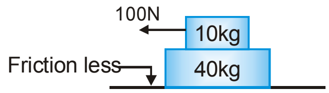
$$= \frac{ma - \mu mg}{m} = 2 - (0.15)(10) = 0.5 \text{ ms}^{-2}$$

The box will fall off at time t then from

$s = ut + \frac{1}{2}at^2$; $4 = \frac{1}{2}(0.5)t^2 \quad \Rightarrow \quad t = 4$s

Distance travelled by truck = $1/2\,(2)(4)^2 = 16$m

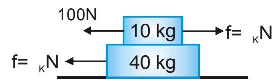
25.



Limiting friction

$F_S = \mu mg = 0.6 \times 10 \times 9.8 = 58.8\text{ N} \Rightarrow 100\text{ N} > 58.8\text{ N}$

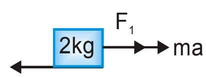
i.e. slab will accelerate with different acceleration.



$f = 40a \Rightarrow 0.4 \times 10 \times 9.8 = 40a \Rightarrow a = 0.98\text{ m/s}^2$

26. Acceleration of system $= \dfrac{20-2}{4+2} = 3\text{ms}^{-2}$

For upper block w.r.t lower block



$f = F_1 + ma = 2 + 2(3) = 8\text{N}$

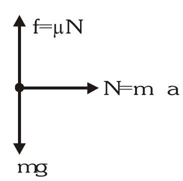
27. Let the mass of 'C' be M for 'A' remains stationary

Aceleration of system $a = \dfrac{Mg}{M + 2m + m}$

A is stationary w.r.t. to 'B'

FBD of A

$\mu N = mg$



$\therefore \mu = \dfrac{mg}{ma} = \dfrac{g(M+3m)}{Mg}$

$\Rightarrow M\mu - M = 3m \Rightarrow M = \dfrac{3m}{\mu - 1}$

28. Here $\mu = \tan\phi$

Retardation of block = $g\sin\phi$

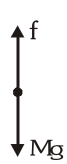
from $v^2 = u^2 + 2as$

$v_0^2 = 2(2g\sin\phi)s \Rightarrow s = \dfrac{v_0^2}{4g\sin\phi}$

29. Here 'M' is in equilibrium.

So net force on 'M' must be zero.

$\therefore$ f = Mg (upwards)



30. Acceleration of car along slope

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

$= 10 \times \dfrac{1}{2} - (0.5)(10)\left(\dfrac{\sqrt{3}}{2}\right) = 5 - 4.33 = 0.67\text{ ms}^{-2}$

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

$v = \sqrt{6^2 + 2(0.67)(15)} \Rightarrow = \sqrt{36 + 20.1}$

$= \sqrt{56.1} = 7.49\text{ms}^{-1}$

31. For (A) : $\vec{F}_{net} = (F\tilde{i} + F\tilde{j}) + (-F\tilde{i} + F\tilde{j}) = 2F\tilde{j}$

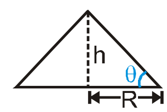
For (B) :

$\vec{F}_{net} = (F\tilde{i} + F\tilde{j}) + (-\sqrt{3}F\tilde{i} - F\tilde{j}) = -(\sqrt{3} - 1)F\tilde{i}$

For (C) : $\vec{F}_{net} = (F\tilde{i} + F\tilde{j}) + (-F\tilde{i} - F\tilde{j}) = \vec{0}$

For (D) : $\vec{F}_{net} = (F\tilde{i} + F\tilde{j}) + (-2F\tilde{i}) = -F\tilde{i} + F\tilde{j}$

32. $\tan\theta = \dfrac{h}{R} = \mu \Rightarrow h = \mu R$



33. Let forces acting on mass m in equilibrium are

$\vec{F}, \vec{F}_1, \vec{F}_2, \vec{F}_3, \vec{F}_4$

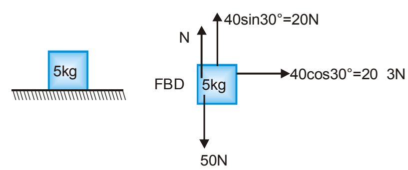
$\vec{F} + \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 = 0$ [equilibrium condition]

$\Rightarrow \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 = -\vec{F}$ .....(i)

After cutting the string with force $\vec{F}$, the net force on mass m

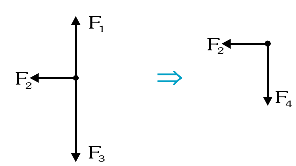
$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 \Rightarrow \vec{a} = \dfrac{\vec{F}_{net}}{m} = -\dfrac{\vec{F}}{m}$ [(from (i)]

34.



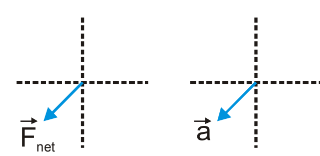
Net vertical force acting on the body is equal to zero.

35.



where $\vec{F}_4 = \vec{F}_3 + \vec{F}_1$

$\vec{F}_{net} = \vec{F}_2 + \vec{F}_4$



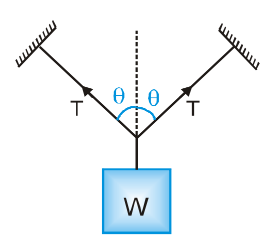
36. $T = \dfrac{2m_1m_2}{m_1 + m} g$

$\Rightarrow 10 = \dfrac{2 \times 1 \times m_2 \times 10}{1 + m_2} \Rightarrow m_2 = 1kg$

37. $2T\cos\theta = W$

$T = \dfrac{W}{2\cos\theta}$

$T\uparrow \Rightarrow \cos\theta\downarrow \Rightarrow \theta\uparrow$



EXERCISE - 2

Part # I : Multiple Choice

1. Acceleration along the groove = (g sin 30°) (sin 30°)

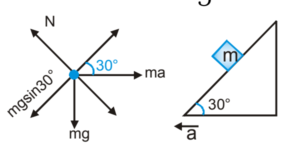
$= \frac{g}{4} = \frac{10}{4} = 2.5\ ms^{-2};\ t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 5}{2.5}} = 2s$

2. Maximum tension in string $T_{max} \sin 30° = 40$

$\Rightarrow\ T_{max} = \frac{40}{1/2} = 80\ N$

For monkey $T_{max} - mg = ma \Rightarrow a = \frac{80}{5} - 10 = 6\ ms^{-2}$

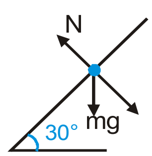
3. FBD of block :



$\therefore\ mg\sin 30° = ma\cos 30° \ \Rightarrow\ a = g\tan 30° = \frac{g}{\sqrt{3}}$

$N = mg\cos 30° + ma\cos 60°$

$= mg \times \frac{\sqrt{3}}{2} + m \times \frac{g}{\sqrt{3}} \times \frac{1}{2}$

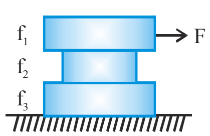


$F_1 = \frac{3mg + mg}{2\sqrt{3}} = \frac{2mg}{\sqrt{3}}$

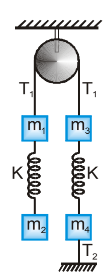
$N = F_2 = mg\cos 30° = \frac{\sqrt{3}mg}{2}$

$\therefore\ \frac{F_1}{F_2} = \frac{2mg}{\sqrt{3}} \times \frac{2}{\sqrt{3}mg} = \frac{4}{3}$

4. Maximum value of $f_1 = 0.3 \times 30 \times 10 = 90\ N$
Maximum value of $f_2 = 0.2 \times 40 \times 10 = 80\ N$
Maximum value of $f_3 = 0.1 \times 60 \times 10 = 60\ N$
$\Rightarrow$ Least horizontal force F to start motion = 60N



5.



$T_1 = (m_1 + m_2)\ g$
$T_1 - T_2 = (m_3 + m_4)\ g \Rightarrow T_2 = (m_1 + m_2 - m_3 - m_4)g$
Net force acting immediately after cutting $x = T_2$

Acceleration $= \frac{T_2}{m_4} = \left(\frac{m_1 + m_2 - m_3 - m_4}{m_4}\right) g$

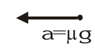
6. Block A and C both move due to friction. Hence less friction is available to A as compared to C.

Maximum acceleraton of $A = \mu g = \frac{1}{2}\ g$

But acceleration of system $a = \frac{m_D g}{3m + m_D}$

$\Rightarrow\ \frac{g}{2} = \frac{m_D g}{3m + m_D} \quad \Rightarrow\ m_D = 3m$

7. Velocity of Block 'A' at any time



$\therefore\ v_1 = v_0 - \mu g t$

and velocity of 'B' is $v_2 = \frac{\mu mg}{M} t$

here v_1–t graph is a straight line of negative slope and v_2–t graph is also a straight line of +ve slope.

8. Acceleration of system, $a = \frac{F}{2m + m + 2m} = \frac{F}{5m}$

Contact force between B and C = $(2m)a = \frac{2}{5}F$

To prevent downward slipping

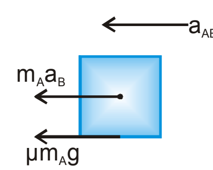
$\mu\left(\frac{2}{5}F\right) = mg \quad \Rightarrow\ F = \frac{5mg}{2\mu}$

9. Acceleration of system

$= \left(\frac{4-1}{4+1}\right) g = \frac{3}{5} \times 10 = 6\ ms^{-2}$

Relative acceleration of blocks $= 12\ ms^{-2}$
Now $2 + 4 = 1/2\ (12)\ t^2 \Rightarrow\ t = 1$ sec

10. Acceleration of B,



$a_B = \frac{\mu m_A g}{m_B} = \frac{(1/2)(m)g}{2m} = \frac{g}{4}$

P & D of block A w.r.t. B

$a_{AB} = \frac{\mu m_A g + m_A a_B}{m_A} = \mu g + a_B = \frac{g}{2} + \frac{g}{4} = \frac{3g}{4}$

11. $a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g,\ d = \frac{1}{2}\ at^2$

$\Rightarrow\ t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2(m_1 + m_2)d}{(m_1 - m_2)g}}$

12. In (A) $T = kx_1 = 2g$

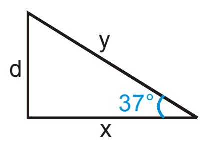
In (B) $T = kx_2 = 3g - 3 \times \frac{g}{5} = \frac{12}{5}g$

In (C) $T = kx_3 = 2g - 2 \times \frac{g}{3} = \frac{4}{3}g$

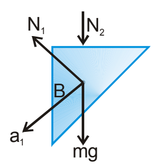
$$\frac{x_1}{2} = \frac{5x_2}{12} = \frac{3x_3}{4}$$

13. $x^2 + d^2 = y^2 \Rightarrow x\frac{dx}{dt} = y\frac{dy}{dt}$

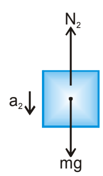
$\Rightarrow xv_A = y(20) \Rightarrow v_A = 25\ ms^{-1}$

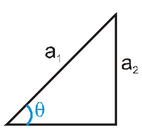


14. Acceleration of B : $a_1 = \frac{(mg + N_2)\sin\theta}{m}$



Acceleration of A, $a_2 = \frac{mg - N_2}{m}$





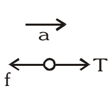
but $a_1 \sin\theta = a_2$

$$\Rightarrow \frac{(mg + N_2)\sin^2\theta}{m} = \frac{mg - N_2}{m} \Rightarrow N_2 = \frac{mg\cos^2\theta}{(a + \sin^2\theta)}$$

$$a_2 = g - \frac{g\cos^2\theta}{1 + \sin^2\theta} = \frac{2g\sin^2\theta}{(1 + \sin^2\theta)}$$

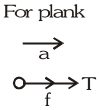
$$\text{Displacement} = \frac{1}{2}a_2t^2 = \frac{g\sin^2\theta}{(1 + \sin^2\theta)}$$

15. For man



$T - f = 50a$

For plank



$T + f = 100\,a$

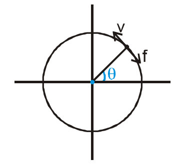
$\Rightarrow 2T = 150\,a \Rightarrow a = \frac{2 \times 100}{150} = \frac{4}{3}\ ms^{-2}$

$\because T - f = 50\,a \therefore 100 - f = 50 \times \frac{4}{3}$

$\Rightarrow f = \frac{100}{3}$ N towards left

16. $\tilde{f} = \cos(\theta + 270°)\tilde{i} + \sin(\theta + 270°)$

$\tilde{f} = \sin\theta\tilde{i} - \cos\theta\tilde{j}$



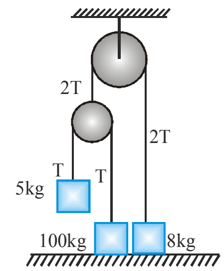
17. $5g - T = 5a_A$

$2T - 8g = 8\,a_C$

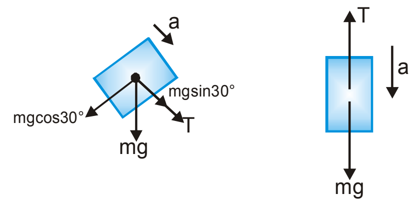
$a_A = \frac{g}{7}$; $a_C = \frac{g}{14} = \frac{5}{7}\ ms^{-2}$

and $a_A = 2a_C$

Here $a_B = 0$ as $T < 10\,g$



18. Let acceleration of blocks be 'a' then



$T + mg\sin 30° = ma$, $mg - T = ma$

$\Rightarrow a = \frac{3}{4}g,\ T = \frac{mg}{4}$

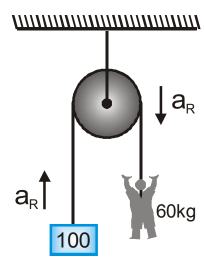
19. $a_{mR} = \frac{5g}{4} \uparrow = a_m - (-a_R)$

$\therefore a_m = \left(\frac{5g}{4} - a_R\right)\uparrow$

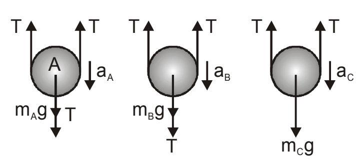
$\therefore T - 600 = 60 \times \left(\frac{5g}{4} - a_R\right)$

& $T - 1000 = 100 \times a_R$

By solving we get tension = 1218 N



20. Let tension in string be T



Here $(T)a_A + (T)a_B + (2T)a_C = 0 \Rightarrow a_A + a_B + 2a_C = 0$

$m_Ag - T = m_Aa_A,\ m_Bg - T = m_Ba_B,\ m_Cg - 2T = m_Ca_C$

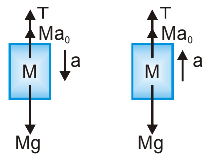
$\Rightarrow T = 6.5\text{ N},\ a_A = \frac{g}{3},\ a_B = \frac{g}{3},\ a_C = -\frac{g}{3}$

21. Acceleration of A = $g\sin\theta$ down the plane

Acceleration of B = $g\sin\theta$ down the plane

And also the contact force between two is zero.

22. Let acceleration of masses w.r.t. pulley be a



$Mg - T - Ma_0 = Ma$

$T + ma_0 - mg = ma$

$\Rightarrow (M-m)g - (M-m)a_0 = (m+M)a$

$$\Rightarrow a = \left(\frac{M-m}{M+m}\right)(g - a_0)$$

But $a_0 > g$ so $a<0$ and $T<0 \Rightarrow$ Tension in string will be zero

23. Acceleration of block w.r.t ground

$$= \frac{\mu mg}{m} = \mu g = 2ms^{-2}$$

Acceleration of block w.r.t. plank

$$= \frac{ma - \mu mg}{m} = a - \mu g = 4 - (0.2)(10) = 2ms^{-2}$$

Now $s = ut + \frac{1}{2}at^2$ gives $s = \frac{1}{2}(2)(1)^2 = 1m$ (w.r.t. ground & w.r.t. plank)

24. Let $a \le \mu g$ (i.e. friction is static)

then both the blocks are at rest w.r.t. plank.

Therefore spring will be in its natural length.

Now let $a > \mu g$ (i.e. friction is kinetic)

then both the blocks are moving with same acceleration w.r.t. plank.

In this case spring force is equal to zero.

Part # II : Assertion & Reason

1. Impulse applied by cement floor and sand floor are same.
2. For a non–inertial observer, pseudo force acts even on a stationary object.
3. A sharp impulse breaks a brick.
4. Static friction is generally greater than kinetic friction.
5. At low altitudes, density of air is high.
6. On the block only two forces act. One force is gravity and the other is exerted by the incline.
7. In pulling case, normal reaction is smaller than the normal reaction in the pushing case.
8. Rotation of the wheels stop but translation is present.
9. Same tension propagates to either team but the external force coming from ground help to decide the winner.

EXERCISE - 3

Part # I : Matrix Match Type

1. $\vec{a}_A = 2\hat{i}$; $\vec{a}_B = \vec{0}$; $\vec{a}_C = -4\hat{j}$

Pseudo force on A as observed by B = 0

Pseudo force on B as observed by C

$= (4\hat{j})\, m_B$ (+ve y–axis)

Pseudo force on A as observed by C

$= (4\hat{j})\, m_A$ (+ve y–axis)

Pseudo force on C as observed by A

$= -(2\hat{i})\, m_C$ (–ve x–axis)

2. **(A)** For the entire system

$F_1 - F_2 - (3+2+1)\, g \sin 30° = (3+2+1)\, a$

$$\Rightarrow a = \frac{60-18-30}{6} = 2m/s^2$$

(B) Net force on 3 kg block $= ma = 3 \times 2 = 6N$

(C) Normal reaction between 2kg and 1kg

$= F_2 + 1\, g \sin 30° + 1a = 18 + 5 + 2 = 25N$

(D) Normal reaction between 3kg and 2kg

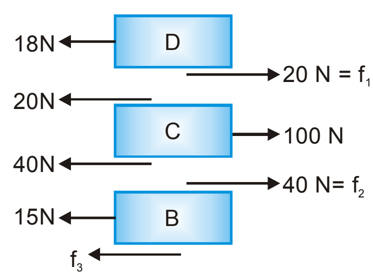
$= 2g\sin 30° + 2a + 25 = 39N$

Part # II : Comprehension

Comprehension # 1

1. $f_{1max} = 30$ N, 20N; $f_{2max} = 60$ N, 40N

$f_{3max} = 90$ N, 60N



$\therefore a_B = 0$

2. $$a_C = \frac{100-40-20}{10} = 4 \text{ m/s}^2$$

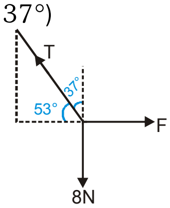
3. $$a_D = \frac{20-18}{10} = 0.2 \text{ m/s}^2$$

Comprehension # 2

1. $$\frac{F}{\sin(90° + 53°)} = \frac{T}{\sin 90°} = \frac{8}{\sin(90° + 37°)}$$

$$\Rightarrow \frac{F}{3/5} = \frac{T}{1} = \frac{8}{4/5}$$

$\Rightarrow T = 10N$ and $F = 6N$



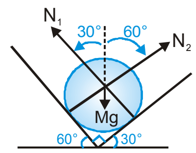
2. $N_1 \sin 30° = N_2 \sin 60°$

$N_1 = \sqrt{3}\, N_2$ ...(i)

$N_1 \cos 30° + N_2 \cos 60° = Mg$

$\Rightarrow N_1 = 50\sqrt{3}$ N and

$N_2 = 50$ N



Comprehension # 3

1. Static friction = 400 N (say)

Kinetic friction = F

Distance travelled $= \frac{1}{2} \times \frac{(F-f)}{M} \times 1^2 = \frac{F-f}{2M}$

From table :

$\frac{500-f}{2M} = 1.5\,;\ \frac{600-f}{2M} = 2\ \ \&\ \ \frac{700-f}{2M} = 2.5$

$\Rightarrow$ f = 200 N; M = 100 kg $\therefore\ \mu_S = \frac{400}{1000} = 0.4$

2. $\mu_k = \frac{200}{1000} = 0.2$

3. If F = 700N, $a = \frac{700-f}{M} = \frac{700-200}{100} = 5\ m/s^2$

$\therefore$ v = u + at = 0 + 5 × 1 = 5 m/s

Comprehension # 4

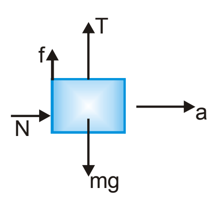
1-4 The hanging mass 'm' has the tendency to go up or to go down or to remain stationary.

Acceleration of the system $a = \frac{f}{M_0 + M + m}$

FBD of m :

N = ma ...(1)

mg = T ± f ...(2)



$\Rightarrow \quad F = \frac{mg(M_0 + M + m)}{(M \pm \mu m)}$

Hence F has a range of values for which M and m remain stationary with respect to block M_0.

If friction is absent , then there exists only one value of F for the above said setup.

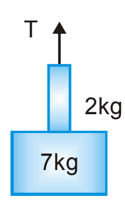
Comprehension # 5

1. Acceleration of the systme

$= \frac{200-(5+4+7)g}{5+4+7} = \frac{40}{16}\ m/s^2$

for the lower half of the system

T – 9g = 9a $\Rightarrow$ T = 112.5 N



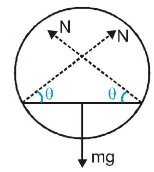
2. For maximum acceleration, T = 4mg

for maximum retardation, T = 0

Equation of motion $\Rightarrow$ T – mg = ma

$\therefore$ a = 3g (max. acc.) & g (max. retardation)

Comprehension # 6



1. For equilibrium : $2N\sin\theta = mg \Rightarrow N = \frac{mg}{2\sin\theta}$

If 'θ' decreases sinθ decreases and N increases.

2. When $\ell = R$, $2R\cos\theta = \ell$

$\Rightarrow \cos\theta = \frac{1}{2} \Rightarrow \theta = 60°\ \therefore\ N = \frac{mg}{2 \times \frac{\sqrt{3}}{2}} = \frac{mg}{\sqrt{3}}$

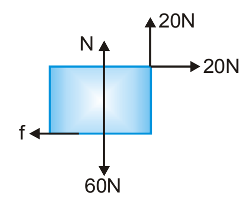
Comprehension # 7

1. N = 60 – 20 = 40

f = 0.1 × 40 = 4N

$\therefore\ F_{contact} = \sqrt{N^2 + f^2}$

$= \sqrt{1600+16} = \sqrt{1616}$ N



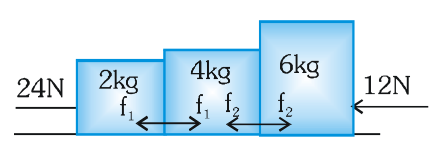
2. When F = 0, θ = 0

When F increases, friction increases gradually too limiting value and then decreases to its kinetic value. Hence θ increases to a maximum value and finally settle to a value smaller than this value.

EXERCISE - 4

Subjective Type

1. Acceleration of the blocks (2kg + 4kg + 6kg)



$a = \frac{24-12}{2+4+6} = 1\ m/s^2$

For 6 kg block $f_2 - 12 = 6 \times 1 \Rightarrow f_2 = 18N$

For 4kg block $f_1 - f_2 = 4 \times 1 \Rightarrow f_1 = f_2 + 4$

$= f_1 = 18 + 4\ [\because f_2 = 18N] \Rightarrow f_1 = 22N$

2. Total force exerted by the sphere

$$\vec{F} = m\frac{d\vec{v}}{dt} + \vec{N} = m\frac{d\vec{v}}{dt} - m\vec{g}$$

$$= 2\left(5\tilde{i} + 2\tilde{j}\right) - 2(-10\tilde{j}) = 10\tilde{i} + 24\tilde{j}$$

Total force exerted by the sphere

$$= -\vec{F} = (-10\hat{i} - 24\hat{j})N$$

3. Average force $F = \dfrac{\Delta p}{\Delta t}$

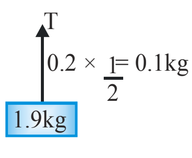
where $|\Delta\vec{p}| = |\vec{p}_2 - \vec{p}_1| = 2mv$

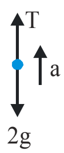
and time taken by the body in moving from

A to B is $\Delta t = \dfrac{\pi d/2}{v}$

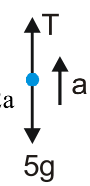
So $F = \dfrac{\Delta p}{\Delta t} = \dfrac{2mv}{\dfrac{\pi d/2}{v}} = \dfrac{4\,mv^2}{\pi d}$

4. **(i)**





$T - 2g = 2a$



$\Rightarrow$ $T = 2(g + a) = 2(9.8 + 0.2) = 20\,N$

(ii) For midpoint of upper wire

$T = 5(g + a) = 5(9.8 + 0.2) = 50\,N$

5. **(i)** $T - 40g = 240$ $\Rightarrow$ $T = 632\,N$

(ii) $392 - T = 160$ $\Rightarrow$ $T = 232\,N$

(iii) $T = 392\,N$

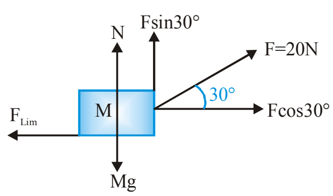
The rope will break in case (a) as $T > 600\,N$.

6. **For block B**

$T = f = \mu m_2 g$ & For block A $T = m_1 g$

By solving above equations $\mu = \dfrac{m_1}{m_2}$

7.



$F_{lim} = \mu N = \mu(Mg - F\sin 30°) = 0.5(5 \times 9.8 - 20\,\frac{1}{2})$

$= 0.5\,(49.0 - 10) = 0.5\,(39) = 19.5\,N$

$F_{applied} = F\cos 30° = \dfrac{20\sqrt{3}}{2} = 17.3\,N$

Since $F_{applied} < F_{lim}$

$\therefore$ Force of friction $= F_{applied} = 17.3\,N$

8. acceleration of the system $a = \dfrac{20 - 10}{6 + 4} = 1\ m/s^2$

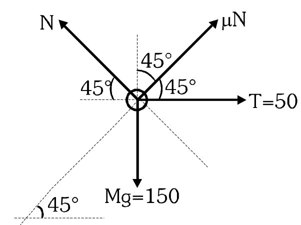
If tension in the spring is T then for 6 kg block $20 - T = 6 \times 1$ $\Rightarrow$ $T = 14\,N$ so reading will be 14 N

9. $M_1 g = \mu\,M_2 g\cos\theta + \mu\,M_3 g + M_2 g\sin\theta$

$\Rightarrow M_1 = \mu\,(M_2\cos\theta + M_3) + M_2\sin\theta$

$= 0.25\,(4 \times \frac{4}{5} + 4) + 4 \times \frac{3}{5} = \frac{21}{5} = 4.2\,kg$

10. Since the string is under tension so there is limiting friction acting between the block and the plane.



$\Sigma F_x = 0 \Rightarrow$ $50 + \mu N\cos 45° = N\cos 45°$

or $(1 - \mu)\dfrac{N}{\sqrt{2}} = 50$ .....(i)

$\Sigma F_y = 0 \Rightarrow$ $\mu N\cos 45° + N\cos 45° = 150$

or $(1 + \mu)\dfrac{N}{\sqrt{2}} = 150$ .....(ii)

Equation (ii) ÷ eq^n (i) $\Rightarrow$ $\dfrac{1 + \mu}{1 - \mu} = \dfrac{150}{50}$

or $1 + \mu = 3 - 3\mu$ $\Rightarrow$ $4\mu = 2$ or $\mu = 1/2$

11. $N = mg - F\sin\theta$; $F\cos\theta \geq \mu N$

$\Rightarrow$ $F\cos\theta \geq \mu\,(mg - F\sin\theta)$ $\Rightarrow$ $F \geq \dfrac{\mu mg}{\cos\theta + \mu\sin\theta}$

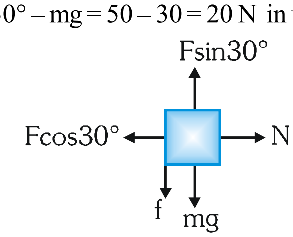
$\Rightarrow$ $\cos\theta + \mu\sin\theta$ should be maximum for

F_{min} $\Rightarrow$ $-\sin\theta + \mu\cos\theta = 0$

$\Rightarrow$ $\tan\theta = \mu$ & $F_{min} = \dfrac{\mu mg}{\sqrt{1 + \mu^2}}$

12. According to FBD – for vertical equilibrium

$f_{net} = F\sin 30° - mg = 50 - 30 = 20\,N$ in upward direction.



As block has tendency to slip up the wall, hence friction on it will act downwards.

$N = F\cos 30° = 50\sqrt{3}$ N

But the limiting friction is,

$$\mu N = \frac{1}{4}(50\sqrt{3})N = \frac{25\sqrt{3}}{2} N = 21.65\ N$$

13. For the motion of pully

$$F - 2T = 0 \Rightarrow T = \frac{F}{2} = 50\ N$$

Since the tension is less than gravitational pull on 8kg. Hence block of 8 kg will not be lifted.

Therefore $a_2 = 0$.

For 4 kg block $T - m_1 g = m_1 a_1 \Rightarrow a_1 = 2{\cdot}5\ ms^{-2}$

14. Let μ be friction coefficient between A and B. As 12 N force on A is required for slipping so max force (F_B) applied on B so that A & B move together.

$$\frac{4\mu g}{5} = \frac{12}{9} \Rightarrow \mu = \frac{1}{6}$$

$$\frac{F}{9} = \mu \Rightarrow F = \frac{1}{6} \times 10 \times 9 = 15N$$

15. Downward acceleration of bead

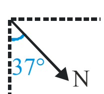
$$= \frac{mg - N}{m} = \frac{mg - \mu(ma)}{m}$$

$= g - \mu a = 10 - 1/2 \times 4 = 8\ m/s^2$

Now from $s = ut + 1/2\ at^2$, $1 = \frac{1}{2} \times 8\ t^2$

$\Rightarrow t = 1/2s$

16. For mass B



$N \sin 37° = m_B a$

$$\Rightarrow N = \frac{m_B a}{\sin 37°} = \frac{1 \times 3}{(3/5)} = 5N$$

17. Once the block comes to rest, kinetic friction disappears and static friction comes into the existence.

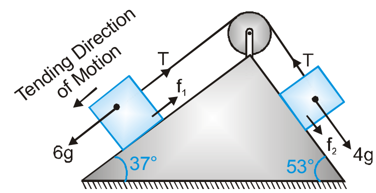
$$f_{L_1} = 24\ N$$

(Limiting friction force between 10 kg block and incline)

$$f_{L_2} = 3N$$

(Limiting friction force between 5 kg block and incline)

If we ignore the friction for the time being, then system has the tendency to move down the incline as shown in the figure.



So, we can say the friction force is acting opposite to direction of this tending motion. As system is not moving, f_1 and f_2 are static in nature.

For equilibrium of both the blocks,

$6g = T + f_1$ and $4g + f_2 = T$

other conditions are

$f_1 < 24\ N$ and $f_2 < 3N$

From hit and trial (better substitute f_2 first) we can draw some conclusions.

If $f_2 = 0$, T=40N, $f_1 = 20N$

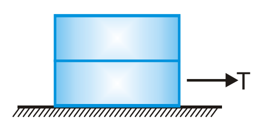
If $f_2 = 3N$, T=43 N, $f_1 = 17N$

So, f_2 should lie between 0 to 3N

f_1 should lie between 20 to 17N

T should lie between 40 to 43 N

18. $$a = \frac{T - 0.4(4)(10)}{4} = \frac{T}{4} - 4$$



For upper block $\mu_s g = a$

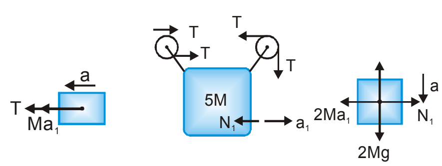
$$\Rightarrow 0.6 \times 10 = \frac{T}{4} - 4 \Rightarrow \frac{T}{4} = 10 \Rightarrow T = 40N$$

19. Here Acceleration of A = acceleration of C

$$= \frac{2\left(\frac{m}{2}g\sin\theta\right) - \left(\frac{\tan\theta}{2}\right)\left(\frac{m}{2}g\cos\theta\right)}{\frac{m}{2} + \frac{m}{2}} = \frac{\left(\frac{3}{4}\right)mg\sin\theta}{m}$$

$$\text{Acceleration of B} = \frac{mg\sin\theta}{m} = g\sin\theta$$

20.



After solving equations we get $a_1 = \frac{2g}{23}$

21. (i) When the spring between ceiling and A is cut, A and B face a downward force of 3mg and C faces no unbalancing force.

$$\therefore \quad a_A = a_B = \frac{3mg}{2m} = \frac{3}{2}g(\downarrow)\ ,\ a_C = 0$$

(ii) When the string between A and B is cut, A and B face a downwardforce of 3mg and C faces no unbalancing force.

$$\therefore \quad a_A = \frac{2mg}{m} = 2g(\uparrow) \Rightarrow a_B = \frac{2mg}{m} = 2g(\downarrow)\ ;\ a_C = 0$$

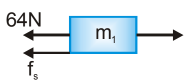
(iii) When the spring between B and C is cut, C faces a force of mg in downward direction & A and B a force of mg in upward direction.

$$\therefore \quad a_A = a_B = \frac{mg}{2m} = \frac{g}{2}(\uparrow)\ ;\ a_C = \frac{mg}{m} = g(\downarrow)$$

22. (i) (a) $F = 160\text{ N}$

$f_{s\,max} = \mu_s m_1 g = 0.5 \times 20 \times 10 = 100\text{ N}$

$$a_{m_2} = \frac{F}{m_1 + m_2} = \frac{160}{20+30} = 3.2\text{ ms}^{-2}$$

for m_1  160N ($f_s < 100$ N) $\Rightarrow a_{m_1} = 3.2\text{ ms}^{-2}$

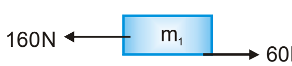
(b) $F = 175\text{ N}$

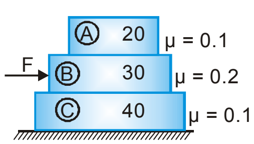
$$a_{m_2} = \frac{\mu_k m_1 g}{m_2} = \frac{(0.3)(20)(10)}{30} = 2\text{ms}^{-2}$$

$$a_{m_1} = \frac{F - \mu_k m_1 g}{m_1} = \frac{175-60}{20} = 5.75\text{ ms}^{-2}$$

(ii) For m_1 : $a_{m_1} = \frac{160-60}{20} = 5\text{ms}^{-2}$

For m_2 : $a_{m_2} = \frac{60-160}{30} = -\frac{10}{3}\text{ms}^{-2}$



23. 

(i) Maximum friction on ground

$(20+30+40)g(0.1) = 90\text{N} = f_0$

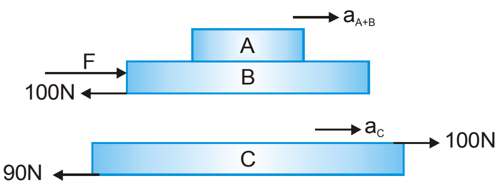
Maximum friction on between 30 & 40 kg blocks

$= (50)(0.2)(10) = 100\text{ N} = f_B$

Maximum friction on between 20 & 30 kg blocks

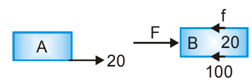
$= (20)(0.1)(10) = 20\text{N} = f_A$

Maximum value of f in which there no slipping any where $= 90$N

(ii) 

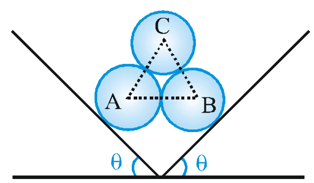
For this condition $a_{A+B} = a_C$

$$\Rightarrow \frac{100-90}{40} = \frac{F-100}{50} \Rightarrow F = 112.5\text{ N}$$

(iii) 

$$\frac{F-120}{30} = \frac{20}{20} \Rightarrow F - 120 = 30 \Rightarrow F = 150\text{ N}$$

24. Arrangement will collapse when normal reaction between A & B becomes zero.

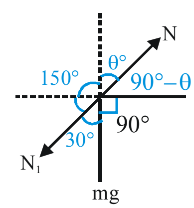


Let N = normal reaction on A & B due to surface then 2

$$N\cos\theta = 3\text{ mg} \Rightarrow N = \frac{3mg}{2\cos\theta}$$

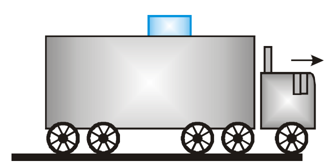
For cylinder A

$$\frac{N}{\sin 30°} = \frac{mg}{\sin(150+\theta)}$$



$$\Rightarrow \tan\theta = \frac{1}{3\sqrt{3}}.$$

25. At t = 1 sec; $\frac{dv}{dt} = 4t \Rightarrow \mu_s mg = m(4 \times 1)$



$$\Rightarrow \mu_s = \frac{4}{g} = \frac{4}{10} = 0.4$$

Velocity of car at t = 3 sec

$v = 2(2)^2 = 8\text{ ms}^{-1}$

Velocity of block at t = 1 sec is $v_0 = 2(1)^2 = 2\text{ms}^{-1}$

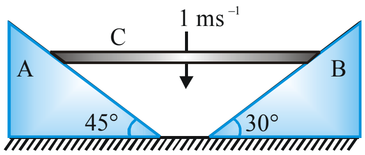
Velocity of block at t = 3 sec is $v_1 = v_0 + \mu_k gt$

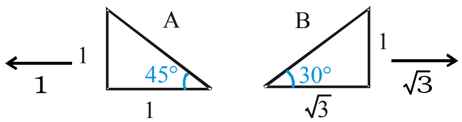
$\Rightarrow v_1 = 2 + \mu_k(10 \times 2)$

But $v_1 = 8$ so $8 = 2 + \mu_k(20)$

$6 = \mu_k(20) \Rightarrow \mu_k = 0.3.$

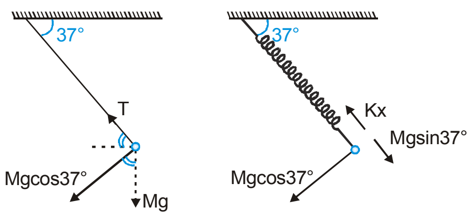
26.





velocity of A w.r.t. B = $(1+\sqrt{3})$ ms^{-1}

27. When the right string is cut, the body is constrained to move in the circular path. But when the right spring is cut, the body moves along and normal to the spring.



For string, $Mg\cos 37° = Ma_2$ ..... **(i)**

For spring, $kx - Mg\sin 37° = Ma'_1$ ..... **(ii)**

and $Mg\cos 37° = Ma''_1$ ..... **(iii)**

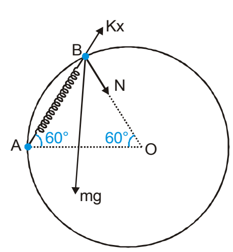
But initially $2kx\cos 53° = Mg$

$$Kx = \frac{5}{6}Mg \quad \text{..... (iv)}$$

where : $a_1 = \sqrt{a_1'^2 + a''^2_1}$

$$\therefore \frac{a_1}{a_2} = \frac{\sqrt{a_1'^2 + a_1''^2}}{a_2} = \frac{25}{24}$$

28. $\frac{Kx}{2} = N + mg \cdot \frac{\sqrt{3}}{2}$



$$\frac{(\sqrt{3}+1)mg}{R} \times \frac{(\sqrt{3}-1)}{2}R$$

$$= N + mg\frac{\sqrt{3}}{2}A \Rightarrow N = \left(1 - \frac{\sqrt{3}}{2}\right)mg$$

EXERCISE - 5

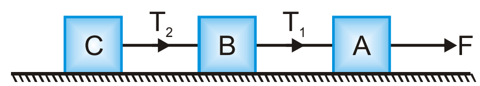
Part # I : AIEEE/JEE-MAIN

1. The particle remains stationary under the acting of three forces $\vec{F}_1$, $\vec{F}_2$ and $\vec{F}_3$, it means resultant force is zero.

$$\vec{F}_1 = -(\vec{F}_2 + \vec{F}_3)$$

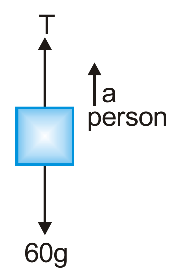
Since, in second case F_1 is removed (in terms of magnitude we are taking now), the forces acting are F_2 and F_3 the resultant of which has the magnitude as F_1, so acceleration of particle is $\frac{F_1}{m}$ in the direction opposite to that of $\vec{F}_1$.

2. The system of masses is shown in the figure.



$T_2 = ma = 2 \times 0.6 = 1.2$ N

3. The free body diagram of the person can be drawn as



Let the person move up with an acceleration a then,

$T - 60g = 60a$

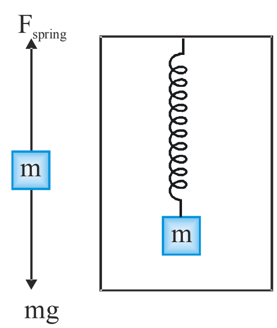
$$\Rightarrow a_{max} = \frac{T_{max} - 60g}{60}$$

$$\Rightarrow a_{max} = \frac{840 - 60g}{60} = 4 \text{ m/s}^2$$

4. Due to action reaction pair in body spring stretching force is same.

$\therefore$ Both will read M kg each.

5. When lift is stationary



$F_{spring} = mg \Rightarrow 49 = m \times 9.8 \Rightarrow m = \frac{490}{98} = 5$ kg

When lift is accelerating downwards

$mg - F'_{spring} = ma \Rightarrow F'_{spring} = 49 - 5 \times 5 = 24$ N

6. Initial thrust

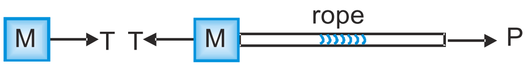
$= m(a+g)$

$= 3.5 \times 10^4 [10 + 10]$

$= 7 \times 10^5$ N

7. In this question

$\vec{F}_{system} = \vec{0}$ so $\vec{v}$ = constant

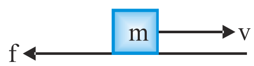
8. 

$P = (M+m)a$; $T = Ma = \dfrac{MP}{M+m}$

9. Weight of the block is balanced by frictional force

$\Rightarrow$ Weight $= \mu N = 0.2 \times 10 = 2N$

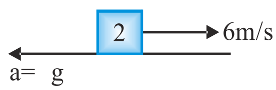
10. $f_{kinetic} = \mu N = \mu(mg)$



$f_{kinetic} = F_{net} = ma$

$\mu mg = ma \Rightarrow a = \mu g$

$\vec{v} = \vec{u} + \vec{a}t$



$\vec{0} = 6\hat{i} + 10\mu t(-\hat{i})$

$\Rightarrow \mu = \dfrac{6}{10t} = \dfrac{6}{100} = 0.06s$

11. Use $F = \dfrac{\Delta p}{\Delta t}$

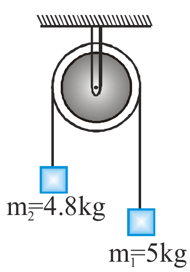
$\Rightarrow 144 = [40 \times 10^{-3} \times 1200]N$

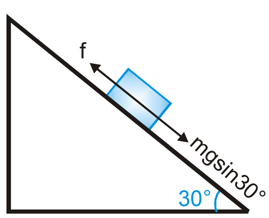
$\Rightarrow N = 3$

12. $g = 9.8$ m/s^2

$a = \left(\dfrac{m_1 - m_2}{m_1 + m_2}\right)g$

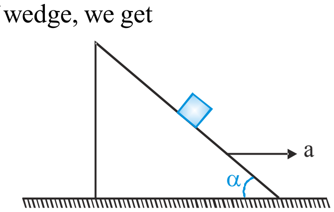
$a = \left(\dfrac{5 - 4.8}{9.8}\right) \times 9.8 = 0.2$ m/s^2



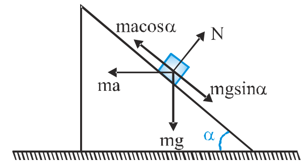
13. 

$f = mg\sin 30°$; $m = \dfrac{10}{g\sin 30°} = 2kg$

14. On drawing the free body diagram of block from the frame of wedge, we get

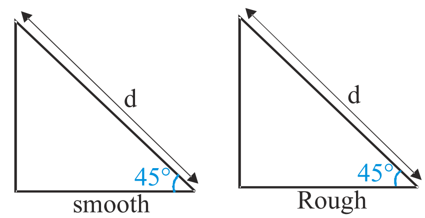


For the block not to slip on wedge



$mg\sin\alpha = ma\cos\alpha$ i.e., $a = g\tan\alpha$

15. $d = \dfrac{1}{2}a_1 t_1^2$; $d = \dfrac{1}{2}a_2 t_2^2$



$a_1 = g\sin 45°$; $a_2 = g(\sin 45° - \mu\cos 45°)$

$d = \dfrac{1}{2}a_1 t_1^2 = \dfrac{1}{2}a_2 t_2^2$; $t_2 = nt_1$ (Given)

On solving $\mu_k = 1 - \dfrac{1}{n^2}$

16. According to work-energy theorem, $W = \Delta K = 0$

$\Rightarrow$ Work done by friction + work done by gravity = 0

$\Rightarrow -(\mu mg\cos\phi)\dfrac{\ell}{2} + mg\ell\sin\phi = 0$

or $\dfrac{\mu}{2}\cos\phi = \sin\phi$ or $\mu = 2\tan\phi$

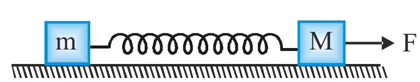
17. Stopping distance $= \dfrac{(\text{Speed})^2}{2 \times \text{Retardation}}$

Retardation $= \mu g$

Stopping distance $= \dfrac{100 \times 100}{2 \times 0.5 \times 10} = 1000$ m

18. $F = \dfrac{\Delta p}{\Delta t} = \dfrac{(150 \times 10^{-3})(20)}{0.1} = 30$ N

19. The acceleration of the system, $a = \dfrac{F}{M+m}$



force acting on m $f = ma = \left(\dfrac{m}{m+M}\right)F$

20. Relative vertical acceleration of A with respect to

$B = g(\sin^2 60° - \sin^2 30°)$

$= 9.8\left(\frac{3}{4} - \frac{1}{4}\right) = 4.9 \text{ m/s}^2$

21. Minimum force required to push up a body.

$F_1 = mg \sin\theta + \mu\, mg \cos\theta$

Min. force required to prevent from sliding

$F_2 = mg \sin\theta - \mu\, mg \cos\theta$

Given $\mu = \frac{1}{2}\tan\theta$

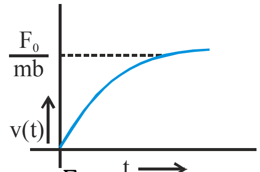
The ratio $\frac{F_1}{F_2} = \frac{mg\sin\theta + \mu\, mg\sin\theta}{mg\sin\theta - \mu\, mg\sin\theta} = \mathbf{3:1}$

22. $F(t) = F_0 e^{-bt}$

$m\frac{dv}{dt} = F_0 e^{-bt} \quad \Rightarrow \quad \int m\,dv = \int F_0 e^{-bt} dt$

$mv = -\frac{F_0}{b} e^{-bt} + C$

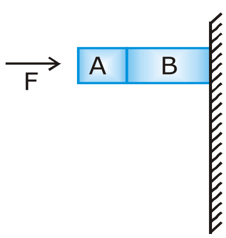
at $t = 0,\ v = 0$



$\therefore \quad v = -\frac{F_0}{mb} e^{-bt} + \frac{F_0}{mb} \Rightarrow v = \frac{F_0}{mb}(1 - e^{-bt})$

23. 4 **24.** 3

25.



Assume the system is in equilibrium. Net gravitational force must be balanced by friction force from the wall.

Force of friction = 120 N

26. $\tan 30° = \frac{h}{\ell}$

$\ell = h\sqrt{3} = 2\sqrt{3}$ m

$W_f = -\mu mg\,\ell$ or $W_f = -\mu mg\, x$

$\mu mgl = \mu mgx$; $x = \ell$

$x = 2\sqrt{3}$ m ; $W_{all} = \Delta K$

$mgh - \mu mg\,\ell - \mu mgx = 0$

$h - \mu\ell - \mu x = 0$

$2 = \mu(\ell + x) \Rightarrow \mu = \frac{2}{\ell + x} = \frac{2}{4\sqrt{3}} = \frac{1}{2\sqrt{3}}$

Part # II : IIT-JEE ADVANCED

1. $\mu N = m\omega_f^2 L$

$\Rightarrow \mu ma = m\omega_f^2 L$

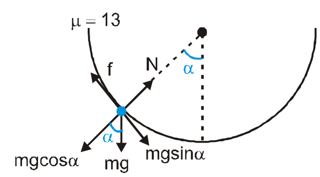
$\Rightarrow \mu L\alpha = \omega_f^2 L \quad \Rightarrow \quad \omega_f = \sqrt{\mu\alpha}$

Now from $\omega_f = \omega_0 + \alpha t$ [$\therefore \omega_0 = 0$]

$\Rightarrow t = \frac{\omega_f}{\alpha} = \frac{\sqrt{\mu\alpha}}{\alpha} = \sqrt{\frac{\mu}{\alpha}}$

2. The two forces acting at the insect are mg and N. Let us resolve mg into two components.

mg cosα balances N



mg sinα is balanced by the frictional force.

$\therefore$ N = mg cosα

f = mg sinα But f = μN = μ mg cosα

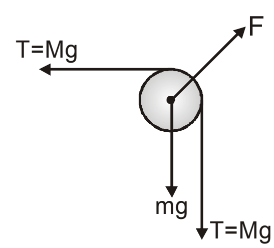
$\therefore \mu g \cos\alpha = g\sin\alpha \quad \Rightarrow \quad \cot\alpha = \frac{1}{\mu}$

$\Rightarrow \cot\alpha = 3$

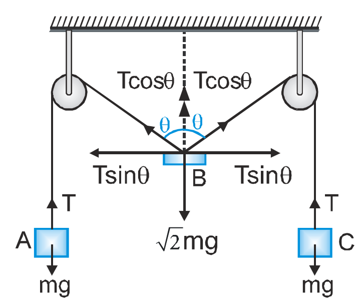
3. Forces on the pulley are

$F = \sqrt{F_1^2 + F_2^2}$

$F = \left[\sqrt{(m+M)^2 + M^2}\right]g$



4. For equilibrium in vertical direction for body B we have



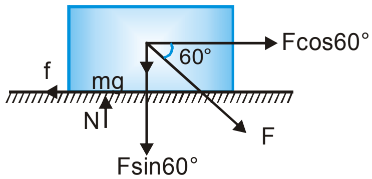
$\sqrt{2}\, mg = 2T\cos\theta$

$\therefore \sqrt{2}\, mg = 2(mg)\cos\theta$

$\because$ T = mg (at equilibrium)

$\therefore \cos\theta = \frac{1}{\sqrt{2}} \Rightarrow \theta = 45°$

5. The forces acting on the block are shown. Since the block is not moving forward for the maximum force F applied.



Therefore $F\cos 60° = f = \mu N$ ..... (i)

(Horizontal Direction)

and $F\sin 60° + mg = N$ ..... (ii)

From (i) and (iii)

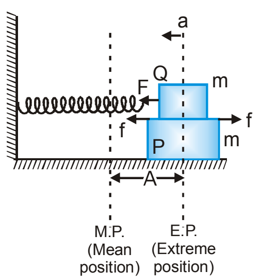
$F\cos 60° = \mu\,[F\sin 60° + mg]$

$$\Rightarrow F = \frac{\mu mg}{\cos 60° - \mu \sin 60°}$$

$$\frac{\frac{1}{2\sqrt{3}} \times \sqrt{3} \times 10}{\frac{1}{2} - \frac{1}{2\sqrt{3}} \times \frac{\sqrt{3}}{2}} = \frac{5}{\frac{1}{4}} = 20N$$

6. The forces acting on the masses are shown. Applying Newton's second law on mass Q, we get

$F - f = ma$ ..... (i)



Where a is the acceleration at the extreme position.

Now applying Newton's second law on mass P

$f = ma$ ..... (ii)

[Acceleration is same as no slipping occurs between Q and P]. From equation (i) and (ii)

$$F = 2ma \Rightarrow a = \frac{F}{2m} = \frac{kA}{2m} \quad [\because F = kA]$$

Substituting this value of a in eq. (ii),

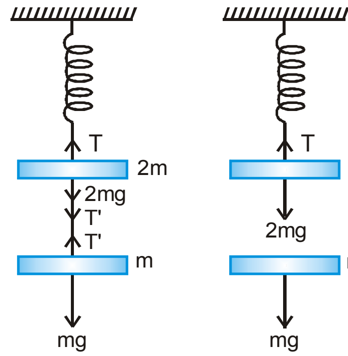
$$\text{We get } f = m \times \frac{kA}{2m} = \frac{kA}{2}$$

7. By equilibrium of mass m, $T' = mg$ ..... (i)

By equilibrium of mass 2m, $T = 2mg + T'$ ..... (ii)

From (i) and (ii), $T = 2mg + mg = 3mg$ ..... (iii)

When the string is cut :



For mass m :

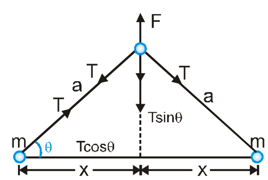
$F_{net} = ma_m \Rightarrow mg = ma_m \Rightarrow a_m = g$

For mass 2m :

$F_{net} = 2ma_{2m} \Rightarrow 2mg - T = 2ma_{2m}$

$$\Rightarrow 2mg - 3mg = 2ma_{2m} \Rightarrow a_{2m} = -\frac{g}{2}$$

8. The acceleration of mass m is due to the force $T\cos\theta$



$$\therefore T\cos\theta = ma \Rightarrow a = \frac{T\cos\theta}{m} \quad \text{..... (i)}$$

Also $F = 2T\sin\theta \Rightarrow T = \dfrac{F}{2\sin\theta}$ ..... (ii)

From (i) and (ii)

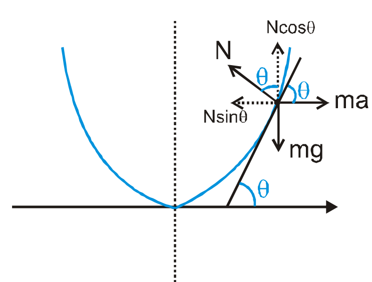
$$a = \left(\frac{F}{2\sin\theta}\right)\frac{\cos\theta}{m} \quad \left[\because \tan\theta = \frac{\sqrt{a^2 - x^2}}{x}\right]$$

$$= \frac{F}{2m\tan\theta} = \frac{F}{2m}\frac{x}{\sqrt{a^2 - x^2}}$$

9. $y = kx^2 \Rightarrow \tan\theta = \dfrac{dy}{dx} = 2kx$ ..... (i)

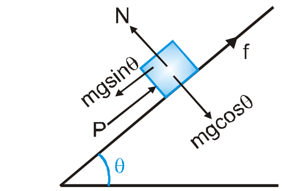
$N\cos\theta = mg$ and $N\sin\theta = ma$

$$\Rightarrow \tan\theta = \frac{a}{g} \quad \text{..... (ii)}$$



from (i) & (ii) $2kx = a/g\,;\ x = \dfrac{a}{2gk}$

10. f varies from $\mu mg\cos\theta$ to $-\mu mg\cos\theta$.



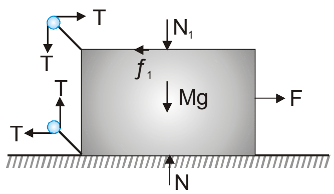
11. CD **12.** D **13.** D **14.** None **15.** A,B,D

16. B **17.** B

18. Given $m_1 = 20$ Kg, $m_2 = 5$ Kg, M=50 Kg,

$\mu = 0.3$ an $g = 10\ m/s^2$

(A) Free body diagram of mass M is



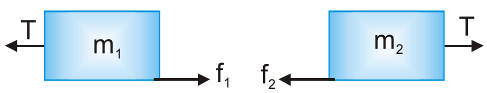
(B) The maximum value of f_1 is

$(f_1)_{max} = (0.3)(20)(10) = 60N$

The maximum value of f_2 is

$(f_2)_{max} = (0.3)(5)(10) = 15N$

Forces on m_1 and m_2 in horizontal direction are as follows



Now there are only two possibilities.

(i) either both m_1 and m_2 will remain stationary (w.r.t. ground) or

(ii) both m_1 and m_2 will move (w.r.t. ground).

First case is possible when

$$T \le (f_1)_{max} \text{ or } T \le 60N \text{ and } T \le (f_2)_{max} \text{ or } T \le 15N$$

These conditions will be satisfied when $T \le 15N$ say $T = 14$ N then $f_1 = f_2 = 14$N.

Therefore the condition f_1=2f_2 will not be satisfied. Thus m_1 and m_2 both can't remain stationary.

In the second case, when m_1 and m_2 both move

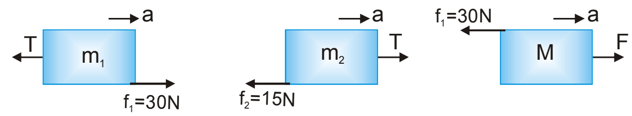
$$f_2 = (f_2)_{max} = 15\ N$$

Therefore $f_1 = 2f_2 = 30N$

Now since $f_1 < (f_1)_{max}$, there is no relative motion between m_1 and M, i.e., all the masses move with same acceleration, say 'a'.

$$f_2 = 15\ N \text{ and } f_1 = 30N$$

Free body diagrams and equations of motion are as follows



For m_1 : $30 - T = 20a$ ..... (i)

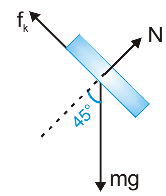
For m_2 : $T - 15 = 5a$ ..... (ii)

For M : $F - 30 = 50a$ ..... (iii)

Solving these three equations, we get,

$F = 60N$, $T=18N$ and $a = \frac{3}{5}$ m/s²

19. $a = \dfrac{mg\sin\theta - \mu_k mg\cos\theta}{m}$



$\therefore\ a_A = g\sin\theta - \mu_{kA} g\cos\theta$ ......(i)

and $\therefore\ a_B = g\sin\theta - \mu_{kB} g\cos\theta$ ......(ii)

Putting values we get

$a_A = \dfrac{0.89}{\sqrt{2}}$ and $a_B = \dfrac{0.79}{\sqrt{2}}$

a_{AB} is relative acceleration of A' w.r.t. B = $a_A - a_B$

$L = \sqrt{2}m \Rightarrow L = \frac{1}{2} a_{A/B} t^2$

[where L is the relative distance between A and B]

or $t^2 = \dfrac{2L}{a_{A/B}} = \dfrac{2L}{a_A - a_B}$

Putting values we get, t^2 =4 or t=2s

Distance moved by B during that time is given by

$$S = \frac{1}{2} a_B t^2 = \frac{1}{2} \times \frac{0.79}{\sqrt{2}} \times 4 = \frac{2 \times 0.7}{\sqrt{2}} \times 10 = 7\sqrt{2}m$$

Similarly for $A = 8\sqrt{2}$ m.

20. Applying pseudo force ma and resolving it. Applying $F_{net} = ma_x$ for x - direction.

$ma\cos\theta - (f_1 + f_2) = ma_x$

$ma\cos\theta - \mu N_1 - \mu N_2 = ma_x$

$ma\cos\theta - \mu ma\sin\theta - \mu mg = ma_x$

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

$$= \left(25 \times \frac{4}{5}\right) - \left(\frac{2}{5} \times 25 \times \frac{3}{5}\right) - \left(\frac{2}{5} \times 10\right) = 10m/s^2$$

21. Force to just prevent it from sliding

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

Force to just push up the plane

$= mg\sin\theta + \mu mg\cos\theta$

According to question

$mg\sin\theta + \mu mg\cos\theta = 3\,(mg\sin\theta - \mu mg\cos\theta)$

$$\Rightarrow \frac{1}{\sqrt{2}} + \mu\frac{1}{\sqrt{2}} = 3\left(\frac{1}{\sqrt{2}} - \frac{\mu}{\sqrt{2}}\right).$$

Therefore $\mu = \frac{1}{2} \Rightarrow N = 10\,\mu = 5$

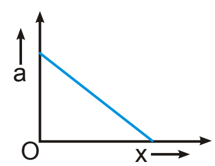
MOCK TEST : NEWTON'S LAW & MOTION

1 Let the initial compression of spring be ℓ.

Then the acceleration after the block travels a distance x is

$a = \frac{k}{m}(\ell - x)$

$\therefore$ The graph of a vs x is



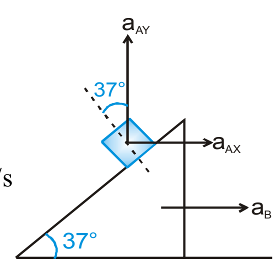
2. From wedge constraint

$(a_A)_\perp = (a_B)_\perp$

$a_{AX}\cos 53° - a_{AY}\cos 37°$

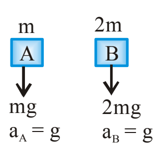
$= a_B\cos 53° \Rightarrow a_B = -5$ m/s

$\vec{a}_B = -5\hat{i}$



3. In this case spring force is zero initially

F.B.D. of A and B



4. (Force diagram in the frame of the car)

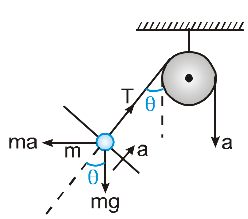
Applying Newton's law perpendicular to string

$mg\sin\theta = ma\cos\theta$

$\tan\theta = \frac{a}{g}$

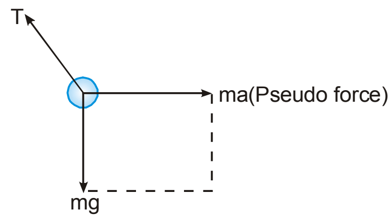
Applying Newton's law along string

$\Rightarrow T - m\sqrt{g^2 + a^2} = ma.$ **Ans.**



5. Acceleration of box = 10 m/s^2

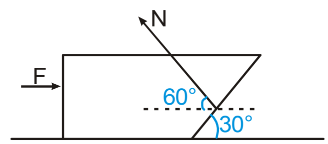
Inside the box forces acting on bob are shown in the figure



$T = \sqrt{(mg)^2 + (ma)^2} = 10\sqrt{2}$ N

6. Acceleration of two mass system is $a = \frac{F}{2m}$ leftward

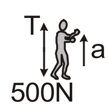
FBD of block A



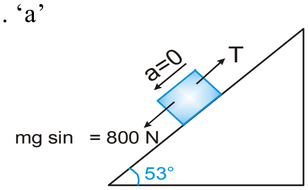
$N\cos 60° - F = ma = \frac{mF}{2m}$ solving, N = 3 F

7. For block to be stationary T = 800 N

If man moves up by acc. 'a'



$T - mg = ma$



$800 - 500 = 50\,a \quad a = 6\,\text{m/s}^2$.

8. For no relative motion between wedge and block, let the acceleration of both block and wedge be 'a' towards left.

From FBD of block

$N\cos\theta = mg$ .... (1)

and $F - N\sin\theta = ma$ .... (2)

From FBD of wedge

$N\sin\theta = Ma$ .... (3)

from equation (1), (2) and (3) solving we get

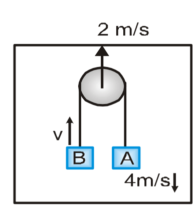
$F = \frac{m}{M}(M + m)\,g\tan\theta$

9. V = (velocity of B w.r.t ground)

$\frac{V-4}{2} = 2 \quad V = 8$ m/s

(velocity of B w.r.t ground)

V' = 6 m/s (velocity of B w.r.t lift)



10. Method - I

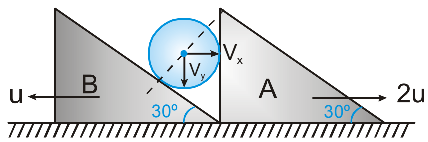
As cylinder will remain in contact with wedge A

$V_x = 2u$

As it also remain in contact with wedge B

$u \sin 30° = V_y \cos 30° - V_x \sin 30°$

$$V_y = V_x \frac{\sin 30°}{\cos 30°} + \frac{u \sin 30°}{\cos 30°}$$



$V_y = V_x \tan 30° + u \tan 30°$

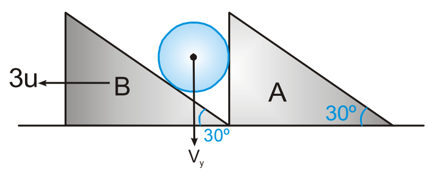
$V_y = 3u \tan 30° = \sqrt{3}\, u$

$V = \sqrt{V_x^2 + V_y^2} = \sqrt{7}\, u$ **Ans.**

Method - II

In the frame of A

$3u \sin 30° = V_y \cos 30° \Rightarrow V_y = 3u \tan 30° = \sqrt{3}\, u$



and $V_x = 2u \Rightarrow V = \sqrt{V_x^2 + V_y^2} = \sqrt{7}\, u$ **Ans.**

11. We draw axes for each block along the incline and normal to incline. The component of acceleration for each block are as shown, where a is acceleration of wedge is figure2.

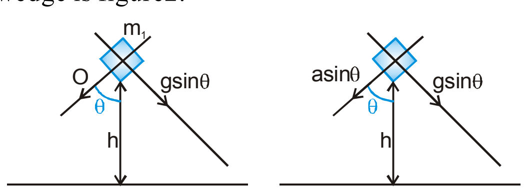
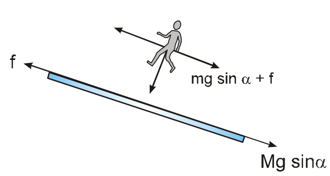


fig.-1 fig.-2

It is obvious that vertical component of acceleration is larger for block in figure 2.

$\therefore \quad T_1 > T_2$

12. F.B.D. of man and plank are



For plank to be at rest, applying Newton's second law to plank along the incline

$Mg \sin \alpha = f$ ....(1)

and applying Newton's second law to man along the incline.

$mg \sin \alpha + f = ma$ ....(2)

$$a = g \sin \alpha \left(1 + \frac{M}{m}\right) \text{ down the incline}$$

Alternate Solution (II) :

If the friction force is taken up the incline on man, then application of Newton's second law to man and plank along incline yields.

$f + Mg \sin \alpha = 0$ ....(1)

$mg \sin \alpha - f = ma$ ....(2)

Solving (1) and (2)

$$a = g \sin \alpha \left(1 + \frac{M}{m}\right) \text{ down the incline}$$

Alternate Solution (III) :

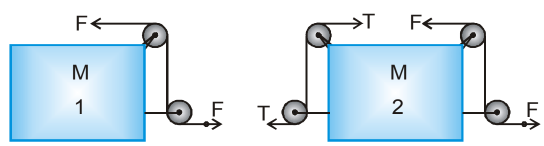
Application of Newton's seconds law to system of man + plank along the incline yields

$mg \sin \alpha + Mg \sin \alpha = ma$

$$a = g \sin \alpha \left(1 + \frac{M}{m}\right) \text{ down the incline}$$

Ans. $a = g \sin \alpha \left(1 + \frac{M}{m}\right)$**; downwards**

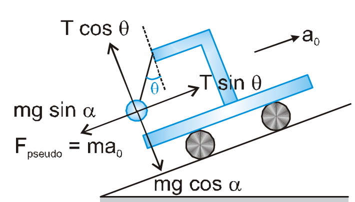
13. The free body diagram for large blocks of figure 1 and figure 2



From FBD it is obvious net force on each block is zero in horizontal direction.

$\therefore \quad a_1 = a_2 = 0$

14.

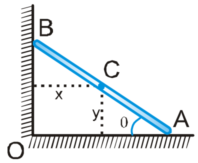


$T \sin \theta = ma_0 + mg \sin \alpha$

$T \cos \theta = mg \cos \alpha$

$$\tan \theta = \frac{a_0 + g \sin \alpha}{g \cos \alpha}$$

15. At any instant of time the rod makes an angle θ with horizontal, the x & y coordinates of centre of rod are



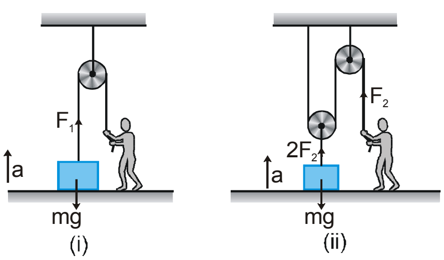
$x = \ell \cos\theta \quad y = \ell \sin\theta$

$\therefore \; x^2 + y^2 = \ell^2$

Hence the centre C moves along a circle of radius ℓ with centre at O.

$\therefore$ velocity vector of C is always directed along the tangent drawn at C to the circle of radius ℓ whose centre lies at O.

16. Since, $h = \frac{1}{2}at^2 \Rightarrow a$ should be same in both cases, because h and t are same in both cases as given.

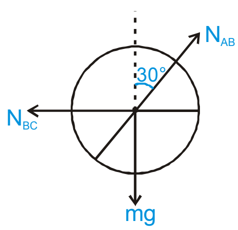


In (i) $F_1 - mg = ma. \Rightarrow F_1 = mg + ma.$

In (ii) $2F_2 - mg = ma \Rightarrow F_2$

$= \frac{mg+ma}{2} \quad \therefore \quad F_1 > F_2.$

17. The free body diagram of cylinder is as shown. Since net acceleration of cylinder is horizontal,

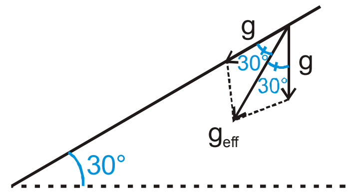


$N_{AB}\cos 30° = mg \quad \text{or } N_{AB} = \frac{2}{\sqrt{3}}mg$ .... (1)

and $N_{BC} - N_{AB}\sin 30° = ma$ or $N_{BC} = ma + N_{AB}\sin 30°$ .... (2)

Hence N_{AB} remains constant and N_{BC} increases with increase in a.

18. From frame of car, the effective acceleration (g_{eff}) due to gravity shall be measured as shown in figure. Hence g_{eff} makes an angle 30° with vertical direction (down wards). Since the string aligns with direction of g_{eff} in equilibrium, the required angle is θ = 30°.

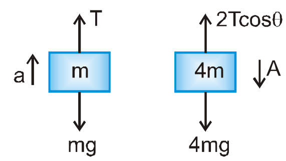


19. The FBD of blocks is as shown

From Newton's second law

$4mg - 2T\cos\theta = 4\,mA$ .... (1)

and $T - mg = ma$ .... (2)



$\cos\theta = \frac{4}{5}$ and from constraint we get $a = A\cos\theta$ ....(3)

Solving equation (1), (2) and (3)

we get acceleration of block of mass 4m, $a = \frac{5g}{11}$ downwards.

20. When all are pulling

$\vec{F}_{net} = 100 \times 3\,\hat{i}$ ....(1)

when 'A' stops

$\vec{F}_{net} - \vec{F}_A = 100 \times 1\,(-\hat{i})$ ....(2)

when 'B' stops

$\vec{F}_{net} - \vec{F}_B = 100 \times 24\,\hat{j}$ ....(3)

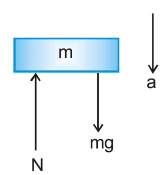
from these three get

$\vec{F}_A + \vec{F}_B$ & solve

21. $N = m(g-a)$, $N < mg$ if a (↓)

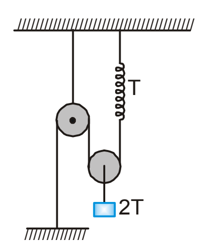
and $N > mg$ if a (↑)

Reading of spring balance is less than m if a (↓) and reading of spring balance is greater than m if a (↑)



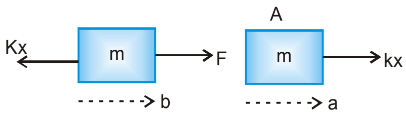
22. Initially the block is at rest under action of force 2T upward and mg downwards.

When the block is pulled downwards by x, the spring extends by 2x. Hence tension T increases by 2kx. Thus the net unbalanced force on block of mass m is 4kx.



$\therefore$ acceleration of the block is $= \frac{4kx}{m}$

23. $F - Kx = mb$ and $kx = ma$



Hence $m(b - a) = F - 2kx$

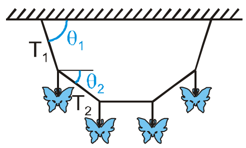
24. $T_1 \sin\theta_1 = 2\,mg$

$T_2 \sin\theta_2 = mg$

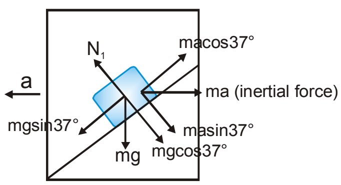
$T_1 \cos\theta_1 = T_2 \cos\theta_2$

$2mg \cot\theta_1 = mg \cot\theta_2$

$\Rightarrow \tan\theta_1 = 2 \tan\theta_2$



25. (1)



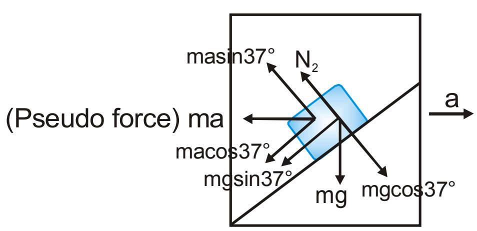
Balancing forces perpendicular to incline $N_1 = mg \cos37° + ma \sin37°$

$$N_1 = \frac{4}{5} mg + \frac{3}{5} ma$$

and along incline $mg \sin 37° - ma \cos 37° = mb_1$

$$b_1 = \frac{3}{5} g - \frac{4}{5} a$$

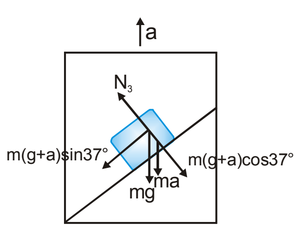
(2)



Similarly for this case get $N_2 = \frac{4}{5} mg - \frac{3}{5} ma$

and $b_2 = \frac{3}{5} g + \frac{4}{5} a \Rightarrow N_2 = \frac{4}{5} mg - \frac{3}{5} ma$

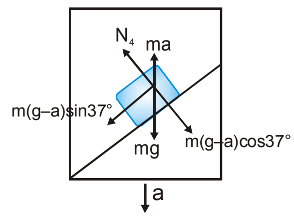
(3)



Similarly for this case get $N_3 = \frac{4}{5} mg + \frac{4}{5} ma$ and

$$b_3 = \frac{3}{5} g + \frac{3}{5} a$$

(4)

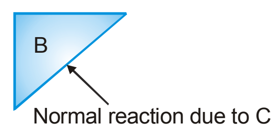


Similarly for this case get $N_4 = \frac{4}{5} mg - \frac{4}{5} ma$ and

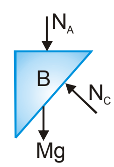
$$b_4 = \frac{3}{5} g - \frac{3}{5} a$$

26. There is no horizontal force on block A, therefore it does not move in x-direction, whereas there is net downward force (mg – N) is acting on it, making its acceleration along negative y-direction.

Block B moves downward as well as in negative x-direction. Downward acceleration of A and B will be equal due to constrain, thus w.r.t. B, A moves in positive x-direction.



Due to the component of normal exerted by C on B, it moves in negative x-direction.



The force acting vertically downward on block B are mg and N_A(normal reaction due to block A). Hence the component of net force on block B along the inclined surface of B is greater than mg sinθ. Therefore the acceleration of 'B' relative to ground directed along the inclined surface of 'C' is greater than g sin θ.

27. For painter ;

$R + T - mg = ma$

$R + T = m(g + a)$ ....(1)

For the system ;

$2T - (m + M)g = (m + M)a$

$2T = (m + M)(g + a)$ ....(2)

where ; $m = 100$ kg

$M = 50$ kg

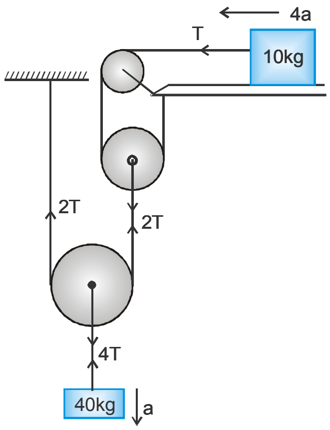
$a = 5$ m/sec^2

$$\therefore \quad T = \frac{150 \times 15}{2} = 1125\ N$$

and ; $R = 375$ N

28. Applying NLM on 40 kg block

$400 - 4T = 40\,a$



For 10 kg block $T = 10.4\,a$

Solving $a = 2 m/s^2$ $\qquad$ $T = 80\,N$

29. For equilibrium $N_A \cos 60° + N_B \cos 30° = Mg$

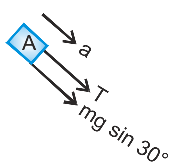
and $N_a \sin 60° = N_B \sin 30°$

On solving $N_B = \sqrt{3}\ N_A\,;\ N_A = \dfrac{Mg}{2}$

30. Let a be acceleration of system and T be tension in, the string.

F.B.D of block A

$mg \sin 30° + T = ma$



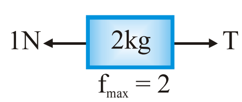
$\dfrac{mg}{2} + T = ma$ ..... (i)

F.B.D of block B

$mg - T = ma$ ..... (ii)

Adding equation (i) & (ii); we get

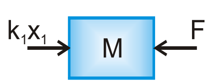
$2ma = \dfrac{3mg}{2} \Rightarrow a = \dfrac{3}{4}g$



from equation (i); $T = \dfrac{mg}{4}$

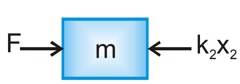
31. Let F be the force exerted by mass m on mass M.

FBD of mass M



$F = k_1x_1 = 2 \times 3 = 6\,N$

FBD of mass m

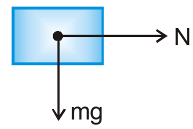


$k_2x_2 = F = 6$ N to the left

Hence the force exerted on block of mass m be the right spring (k_2x_2) is 6 N to the left. From FBD, the normal reaction (F) between blocks is 6 N.

As system is at rest, net force on block of mass m is zero.

32. The FBD of block A is



The force exerted by B on A is N (normal reaction). The forces acting on A are N (horizontal) and mg (weight downwards).

Hence statement I is false.

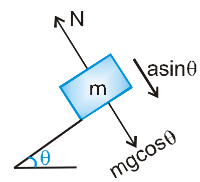
33. If the lift is retarding while it moves upward, the man shall feel lesser weight as compared to when lift was at rest. Hence statement 1 is false and statement 2 is true.

34 Newton's third law of motion is valid in all reference frames. Hence statement-1 is incorrect.

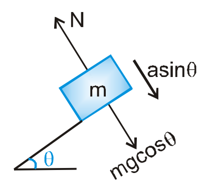
35 From wedge constraint, if acceleration of wedge is a then component of acceleration of block normal to inclined surface is a sinθ. Applying Newton's law to block in direction normal to the inclined surface.

$mg \cos\theta - N = ma \sin\theta$

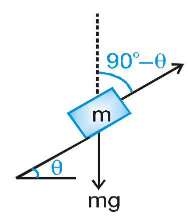
for N to be zero, $mg \cos\theta = ma \sin\theta$ or $a = g\cot\theta$



for N to be zero, $mg \cos\theta = ma \sin\theta$ or $a = g\cot\theta$



36. Since normal reaction is zero and the acceleration of block is horizontal, The net vertical force on block is zero.



Therefore

$T \sin\theta = mg$,

or $T = mg \operatorname{cosec}\theta$

37. $F_{net} = Ma = Mg \cot\theta$

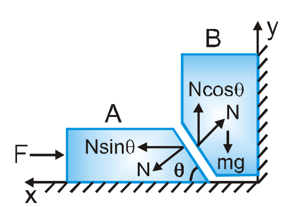
38. For equilibrium of block (A)

$F = N \sin\theta$

$N = F/\sin\theta$

To lift block B from ground

$N \cos\theta \geq mg$



$\dfrac{F}{\sin\theta} \cos\theta \geq mg$

$F \geq mg \tan\theta = mg \left(\dfrac{3}{4}\right)$

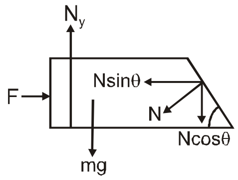
So $F_{min} = \dfrac{3}{4} mg$

39. If both the blocks are stationary,

Balancing forces along x-direction

$F = N\sin\theta \Rightarrow N = F/\sin\theta$

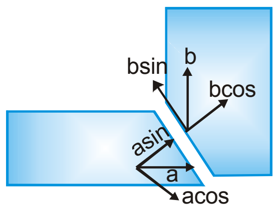
Balancing forces along y-direction



$N_y = mg + N\cos\theta$

$$= mg + \left(\frac{F}{\sin\theta}\right)\cos\theta = mg + F\cot\theta \Rightarrow N_y = mg + \frac{4F}{3}$$

40. To keep regular contact



$a\sin\theta = b\cos\theta$

$b = a\tan\theta = \frac{3}{4}a$

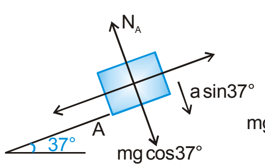
41. (A) **42. (D)** **43. (B)**

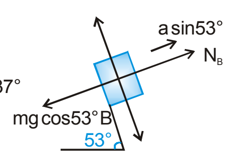
41 to 43

The FBD of A and B are

Applying Newton's second law to block A and B along normal to inclined surface

$N_B - mg\cos 53° = ma\sin 53°$





$mg\cos 37° - N_A = ma\sin 37°$

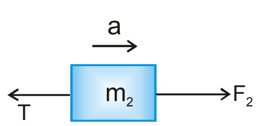
Solving $N_A = \frac{m}{5}(4g - 3a)$ and $N_B = \frac{m}{5}(3g + 4a)$

For N_A to be non zero

$4g - 3a \geq 0$ or $a \leq \frac{4g}{3}$

44. (A) Let a be acceleration of two block system towards right

$\therefore \quad a = \frac{F_2 - F_1}{m_1 + m_2}$



The F.B.D. of m_2 is

$\therefore \quad F_2 - T = m_2 a$

Solving $T = \frac{m_1 m_2}{m_1 + m_2}\left(\frac{F_2}{m_2} + \frac{F_1}{m_1}\right)$

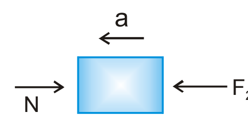
(B) Replace F_1 by $-F_1$ is result of A

$\therefore \quad T = \frac{m_1 m_2}{m_1 + m_2}\left(\frac{F_2}{m_2} - \frac{F_1}{m_1}\right)$

(C) Let a be acceleration of two block system towards left

$\therefore \quad a = \frac{F_2 - F_1}{m_1 + m_2}$

The FBD of m_2 is



$\therefore \quad F_2 - N_2 = m_2 a$

Solving $N = \frac{m_1 m_2}{m_1 + m_2}\left(\frac{F_1}{m_1} + \frac{F_2}{m_2}\right)$

(D) Replace F_1 by $-F_1$ in result of C

$N = \frac{m_1 m_2}{m_1 + m_2}\left(\frac{F_2}{m_2} - \frac{F_1}{m_1}\right)$

45. (A), (B) $\Rightarrow$ After spring 2 is cut, tension in string AB will not change.

$(T_{CD})_i = 4\,mg,\ (T_{CD})_f = m_D g + m_D \cdot \frac{m_A + m_B - m_C - m_D}{m_A + m_B + m_C + m_D}.g$

$= 2\,mg\left(1 + \frac{1}{5}\right) \quad = 2.4\,mg$

Hence T_{CD} decreases.

(C), (D) $\Rightarrow$ After string between C and pulley is cut tension in string AB will become zero.

$(T_{CD})_i = (m_D + m_E)g = 4\,mg$

Acceleration of C and D blocks is

$(m_C + m_D)\,g + m_E g = (m_C + m_D).a$

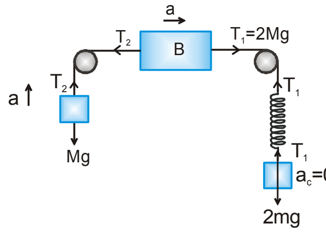
$\Rightarrow a = \frac{6mg}{4mg} = \frac{3}{2}g \quad \Rightarrow (T_{CD})_f + m_C g = m_C.a$

$(T_{CD})_f = 2\,m\,\frac{3}{2}g - 2mg = mg$

The tension decreases.

46. Before block A was released, the system was at rest, and all blocks were in equilibrium. Hence, tension in both the strings is equal to 2Mg.

When block A is released, it will have an unbalanced force on it and hence the tension in string (2) will change to say T_2. Now the arrangement will be.



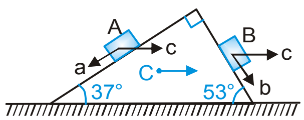
Since, tension in spring does not change instantaneously, hence, tension in string 1 will remain same i.e. 2Mg, Thus, Block C will remain at rest and $a_c = 0$.

Newton's law along the string

(2), $2Mg - Mg = Ma + Ma \Rightarrow a = \frac{g}{2}$

Hence acceleration of A $= \frac{g}{2} \uparrow$, B $= \frac{g}{2} \rightarrow$, & C = 0

47.



Let c be acceleration of wedge C.

a be acceleration of block A w.r.t. wedge C.

b be acceleration of block B w.r.t. wedge C.

Applying Newtons law in horizontal direction to system of A + B + C.

$mc + m(c - a\cos 37^o) + m(c + b\cos 53^o) = 0$ .....(1)

Applying Newton's law to block A and B along the incline gives.

In case of A : $mg\sin 37^o = m(a - c\cos 37^o)$ .....(2)

In case of B : $mg\sin 53^o = m(b + c\cos 53^o)$ .....(3)

solving (1), (2), & (3) we get c = 0 **Ans. ac = 0**

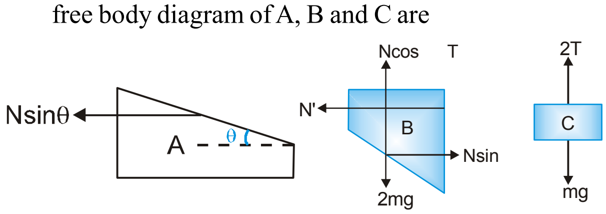
48. Let the acceleration of B downwards be $a_B = a$

From constraint ; acceleration of A and C are

$a_A = a\cot\theta = \frac{4a}{3}$ towards left

$a_C = \frac{a}{2}$ upwards

free body diagram of A, B and C are



$N\sin\theta = \frac{9m}{64}(a\cot\theta)$ ....(1)

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

$2T - mg = m\frac{a}{2}$ ....(3)

solving we get

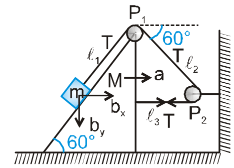
$a_c = \frac{a}{2} = 3\text{m/s}^2$

49. From length constraint

$\ell_1 + \ell_2 + \ell_3 = C$

$\ell_1'' + \ell_2'' + \ell_3'' = C$

$-b_x\cos 60^o + b_y\cos 30^o + a\cos 60^o - a\cos 60^o - a = 0$



$2a = \sqrt{3}\,b_y - b_x$ ....(i)

from wedge constraint

$a\cos 30^o = b_x\cos 30^o + b_y\cos 60^o$

$\sqrt{3}\,a = \sqrt{3}\,b_x + b_y$ ...(ii)

Applying Newton's law (wedge + block) along horizontal direction

$T + T\cos 60^o = Ma + mb_x$

$\frac{3T}{2} = 8a + 2b_x$ ...(iii)

Applying Newton's law on block along the incline plane

$T - mg\sin 60^o = m(b_x\cos 60^o - b_y\cos 30^o)$

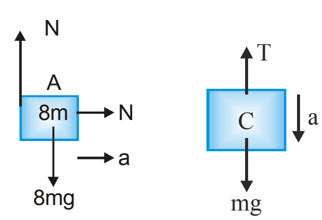
$T - \sqrt{3}\,g = b_x - \sqrt{3}\,b_y$ ....(iv)

Solving equation (i); (ii); (iii) and (iv)

we get $a = \frac{3\sqrt{3}g}{23}$ m/s^2.

MOCK TEST : FRICTION

1. FBD of A and C



If acceleration of 'C' is a

For block 'A' $N = 8ma$ .... (1)

for block A to remain stationary with respect to block B,

$8mg = \mu N$ (Limiting condition) ....(2)

$8mg = \mu\, 8ma$;

$a = g/\mu$

and acceleration a can be written by the equation of system (A + B + C)

$m_c g = (10m + m_c)a$ .... (3)

$m_c g = (10m + m_c)g/\mu$

$\Rightarrow m_c = \frac{10m}{\mu - 1}$ **Ans.**

2. Let the value of 'a' be increased from zero. As long as $a \le \mu g$, there shall be no relative motion between m_1 or m_2 and platform, that is, m_1 and m_2 shall move with acceleration a.

As $a > \mu g$ the acceleration of m_1 and m_2 shall become μg each.

Hence at all instants the velocity of m_1 and m_2 shall be same

∴ The spring shall always remain in natural length.

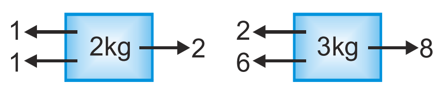
3. For the sliding not to occur when $\tan\theta \le \mu$

$$\tan\theta = \frac{dy}{dx} = \frac{2x}{a} = \frac{2\sqrt{2y}}{a} = 2\sqrt{\frac{y}{a}}$$

$$\therefore \quad 2\sqrt{\frac{y}{a}} \le \mu \quad \text{or} \quad y \le \frac{a\mu^2}{4}$$

4. FBD

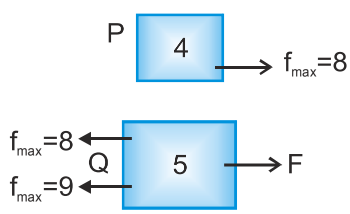
Net force without friction on system is '7N' in right side so first maximum friction will come on 3 kg block.



So $f_2 = 1$ N, $f_3 = 6$ N, T = 2N

5. So block 'Q' is moving due to force while block 'P' due to friction.

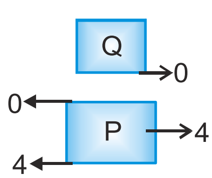
Friction direction on both P + Q blocks as shown.



First block 'Q' will move and P will move with 'Q' so by FBD taking 'P' and 'Q' as system

$$F - 9 = 0 \quad \Rightarrow \quad F = 9 \text{ N}$$

When applied force is 4 N then FBD



i.e. $a_P = a_q = 0$

4 kg block is moving due to friction and maximum friction force is 8 N.

So acceleration $= \frac{8}{4} = 2 \text{ m/s}^2 = a_{max}$.

Slipping will start at when Q has +ve acceleration equal to maximum acceleration of P i.e. 2 m/s².

$$F - 17 = 5 \times 2 \quad \Rightarrow \quad F = 27 \text{ N}.$$

6. Limiting condition for m to not slip in vertical downward direction, $mg = \mu N$

$$\Rightarrow N = \frac{mg}{\mu} = \frac{100}{.5} = 200 \text{ Newton}$$

Same normal force would accelerate M, thus

$$a_M = \frac{200}{50} = 4 \text{ m/s}^2$$

Taking m + M as system

$F = (m + M).4 = 240$ N

7. Let m_A and m_B be the mass of blocks A and B respectively. As the force F increases from 0 to $\mu_s m_A g$, the frictional force f on block A is such that f = F. When $F = \mu_s m_A g$, the frictional force f attains maximum value $f = \mu_s mg$.

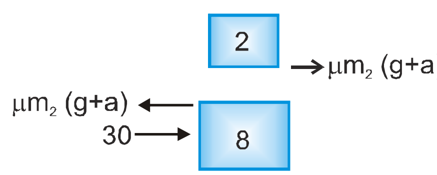
As F is further increased to $\mu_s(m_A+m_B)g$, the block A does not move. In this duration frictional force on block A remains constant at $\mu_s m_A g$.

As F further increased, system will start moving and kinetic friction ($\mu_k m_A g$) will start acting on A ($\mu_s > \mu_k$).

Hence C is correct choice.

8. FBD in reference frame of the lift

$$a_2 = \frac{1}{5}\left(g + \frac{g}{4}\right) = \frac{g}{4} = 2.5 \text{ m/s}^2$$



$$a_1 = \frac{30 - \left[\mu m_2\left(g + \frac{g}{4}\right)\right]}{8} = \frac{30 - \left[\frac{1}{5} \times 2 \times \frac{50}{4}\right]}{8} = \frac{25}{8} \text{ m/s}^2$$

9. maximum friction = μmg = 0.6 × 10 × 1 = 6N

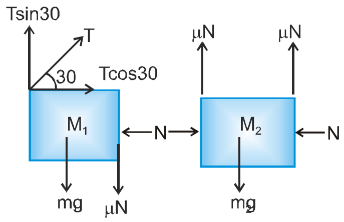
Pseudo force = ma = 5N

$$\text{Pseudo force} = \frac{1 \times 5}{1} = 5 \text{ m/s}^2$$

So required friction force is only 5N although maximum friction force available is 6 N.

10. Since block M_1 is attached to the string so it will remain stationary, M_2 has tendency to move downward. So, friction on M_2 will act in upward direction.

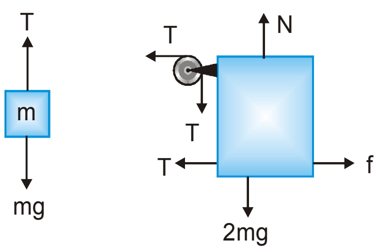
N is the force by which the both block are pressed
i.e. $N = T\cos 30°$.



for block M_1
$M_1 g + \mu(T\cos 30°) - T\sin 30° = M_1(0)$ .... (1)
($a = 0$ for M_1 since attach to string)
for block M_2
$M_2 g - (\mu N + \mu N) = M_2 a$ .... (2)

11. For chain to move with constant speed P needs to be equal to frictional force on the chain. As the length of chain on the rough surface increases. Hence the friction force $f_k = \mu_k N$ increases.

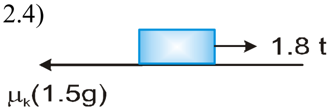
12. In equilibrium
$T = mg \Rightarrow N = 3\,mg$
& $f = 2T = 2mg$ in limiting case $f = f_{max}$.



$\Rightarrow 2mg = \mu N$
$\Rightarrow 2mg = 3\mu\, mg \Rightarrow \mu = 2/3$ Ans.

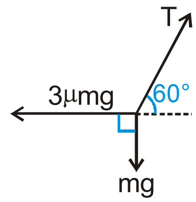
13. Limiting friction between A & B = 60 N
Limiting friction between B & C = 90 N
Limiting friction between C & ground = 50 N
Since limiting friction is least between C and ground, slipping will occure at first between C and ground. This will occure when F = 50 N.

14. $1.8\,t - \mu_k 15 = 1.5\,(1.2\,t - 2.4)$



For $t = 2.85$ sec. $\mu_k = 0.24$

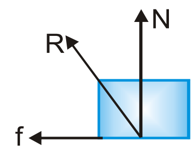
15. At the instant 3m is about to slip, tension in all the strings are as shown
$\therefore\ 3\mu mg = T\cos 60°$ .... (1)
and $mg = T\sin 60°$ .... (2)



$\therefore\ \mu = \dfrac{1}{3\sqrt{3}}$

16. Direction of friction is such that it opposes the relative velocity.

17.



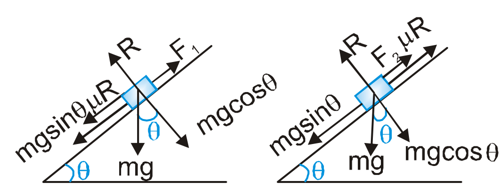
Acceleration of train will be from right to left.
$\Rightarrow$ Pseudo force will act on the box from left to right therefore friction will act from right to left.

18. For system remain in equilibrium, value of m can be decided in two limiting cases:
Case-I: m can take a maximum value such that 100kg block has tendency to move upward.
$mg = 100 \times g \times \sin 37° + \mu \times 100 \times g \times \cos 37°$

$m = 100 \times \dfrac{3}{5} + \dfrac{3}{10} \times 100 \times \dfrac{4}{5} = 60 + 24 = 84$

Case-II: m can take a minimum value such that 100kg block has tendency to move downward.
$100 \times g \times \sin 37° = mg + \mu \times 100 \times g \times \cos 37° \Rightarrow m = 36$
so we got the range of m
$36 < m < 84$
In this range 37 and 83 lie.

19.



$F_1 = mg\sin\theta + \mu\, mg\cos\theta$.
$F_2 = mg\sin\theta - \mu\, mg\cos\theta$.
But $mg = w$
$\mu = \tan\phi$

$F_1 = w\left(\sin\theta + \dfrac{\sin\phi}{\cos\phi}\cos\theta\right) \Rightarrow F_1 = w\sin(\theta + \phi)\sec\phi$

$F_2 = w\left(\sin\theta - \dfrac{\sin\phi}{\cos\phi}\cos\theta\right) \Rightarrow F_2 = w\sin(\theta - \phi)\sec\phi$

Now $F_1 = 2F_2$
$mg\sin\theta + \mu\, mg\cos\theta = 2(mg\sin\theta - \mu\, mg\cos\theta)$
$\sin\theta + \mu\cos\theta = 2\sin\theta - 2\mu\cos\theta \Rightarrow 3\mu\cos\theta = \sin\theta$
$= \tan\theta = 3\mu$
$\tan\theta = 3\tan\phi$.

20. **Case I :**

Since, no relative motion :

$$a = \frac{F_1 - F_f}{5} = \frac{F_f}{3} \Rightarrow F_{1\,(max)} = \frac{8}{3}F_f$$

Case II :

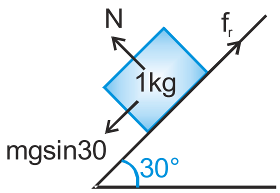
$$a = \frac{F_f}{5} = \frac{F_2 - F_f}{3} \Rightarrow F_{2\,(max)} = \frac{8}{5}F_f$$

Clearly ; $F_{1\,(max)} > F_{2\,(max)}$ and $\frac{F_{1(max)}}{F_{2(max)}} = \frac{5}{3}$

21. Block is moving upwards due to friction

$f_r - mg \sin 30 = ma$

$$\Rightarrow f_r - 1 \times 10 \times \frac{1}{2} = 1 \times 1 \Rightarrow f_r = 6\text{ N}$$



Contact force is the resultant of N and f_r

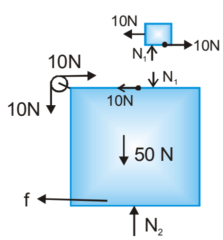
$$= \sqrt{N^2 + f_r^2} = \sqrt{(mg\cos 30)^2 + (6)^2} = 10.5\text{ N}$$

22. The frictional force on block A is

$$\Rightarrow \mu N_1 = 10 \Rightarrow N_1 = \frac{10}{0.2} = 50\text{ N}$$

The net force on block B in vertical direction is zero

$\therefore \quad N_2 = 50 + N_1 + 10 = 110\text{ N}$



$\Rightarrow$ Normal reaction exerted by ground on block B is 110N.

The net force on block B in horizontal direction is zero

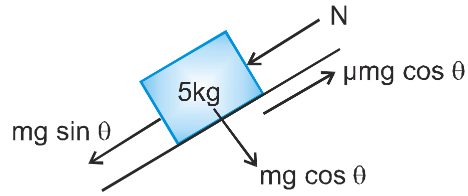
$\therefore \quad f + 10 - 10 = 0$

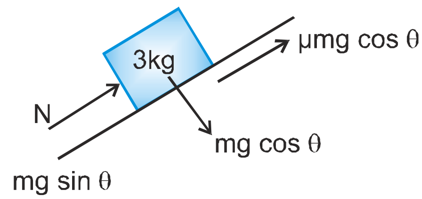
$\Rightarrow$ frictional force exerted by ground on block B is zero

23. **Case-I :** $\mu_1 = 0.5, \mu_2 = 0.3$

Along the incline, acceleration of 5 kg block will be less than acceleration of 3 kg block provided they move alone on the incline. The reason is greater friction coefficient of 5 kg block, as acceleration along the incline is $g \sin \theta - \mu g \cos \theta$

One to the contain, both blocks will move together. In this case FBDs of both are shown.





For 5 kg block

$m_1 g \sin\theta + N - \mu_1 m_1 g \cos\theta = m_1 a$

For 3 kg block

$m_2 g \sin\theta - N - \mu_2 m_2 g \cos\theta = m_2 a$

In second case, acceleration of 5 kg block is more than acceleration of 3 kg. Hence, no normal force will act between them.

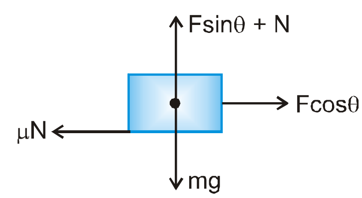
24. The FBD of block is as shown.

Minimum force at an angle θ to pull the block horizontally,

$F\cos\theta = \mu N$ ..... (1)

where $N = mg - F\sin\theta$ .... (2)

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



which can be less than μmg Putting $\mu = \frac{1}{3}, \theta = 37°$

$F_{min} = \mu mg$

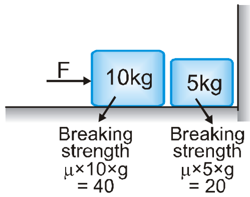
25. Due to pseudo force, the person observes the block to move back. Also the accelerating person does not observe any relative motion between body and the rough surface.

26. The block cannot move along x-axis by a force applied along x-axis.

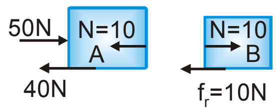
For block to move along x-axis, the component of force along y-axis should be equal to mg sinθ, So that net force along y-axis is zero.

Hence statement-1 is false.

27. If F = 20 N, 10 kg block will not move and it will not press 5 kg block So N = 0.



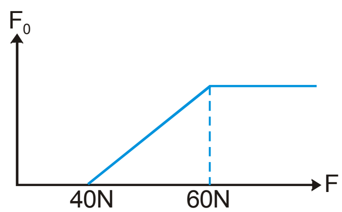
28. If F = 50 N, force on 5 kg block = 10 N



So friction force = 10 N

29. **(B)**

Until the 10 kg block is sticked with ground (... F = 40 N),



No force will be felt by 5 kg block. After F = 40 N, the friction force on 5 kg increases, till F = 60 N,and after that, the kinetic friction start acting on 5 kg block which will be constant (20N)

30. $F_{max} = kx + \mu mg$

$F_{min.} = kx - \mu mg$

$\therefore\ F_{max} - F_{min.} = 2\,\mu mg$

or $2 = 2\,\mu\, 10$

$\therefore\ \mu = 0.1$

31. $F_{max} + F_{min.} = 2\,kx$ .... (1)

from graph $F_{max} + F_{min.} = 5$

and $x = 0.1$

Putting in equation (1)

$5 = 2\,k(0.1)$

$k = 25$ N/m.

32. When $x = 0.03$

$kx = 25 \times 0.03$

$= 0.75$ N, which is less than $\mu\, mg = 0.1 \times 10 = 1$ N

$\therefore$ The block will be at rest, without applying force F.

33. **(A)** For $\mu > \tan\theta$, the magnitude of acceleration of both blocks is zero. Hence acceleration of both blocks is same.

For $\mu < \tan\theta$, the acceleration of both blocks is same and equal to $(g\sin\theta + g\cos\theta)$

Hence whatever be the value of μ, the acceleration of both blocks shall be same.

(B) For $\mu > \tan\theta$, both blocks are at rest and their binding with inclined surface is not broken.

Hence the blocks cannot exert force on each other.

Therefore normal reaction between both blocks is zero.

For $\mu < \tan\theta$, both blocks will move down the incline with same acceleration when they are not in contact.

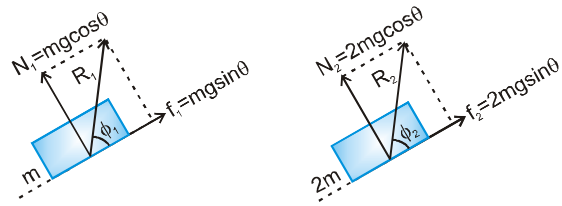
Hence they have no tendency to approach.

Hence when both blocks are in contact, they will not exert normal reaction no tendency to approach.

Hence whatever be the value of μ, normal reaction between both blocks is zero.

(C & D) For $\mu > \tan\theta$, both blocks are at rest.

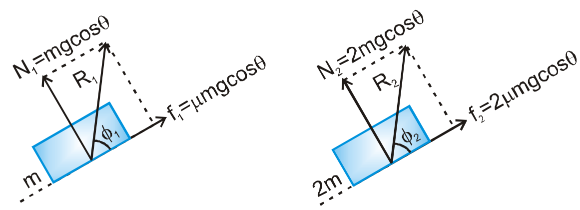
The normal reaction (N), friction (f) and net reaction on each blocks by inclined surface are as shown.



It is obvious $\phi_1 = \phi_2$ and $R_2 = 2R_1$.

For $\mu < \tan\theta$, both blocks move down the incline.

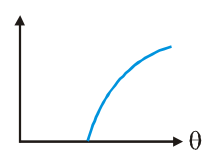
The normal reaction (N), friction (f) and net reaction on each blocks by inclined surface are as shown.



Again it can be seen that $\phi_1 = \phi_2$ and $R_2 = 2R_1$.

Hence whatever be the value of μ, $R_2 = 2R_1$ and $\phi_2 = \phi_1$.

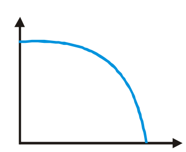
34. **(i)** Till $\theta = \tan^{-1}\mu$, T = 0



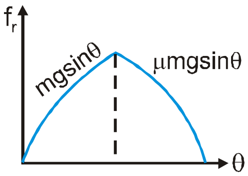
After $\theta = \tan^{-1}\mu$, $T = mg\sin\theta - \mu\, mg\cos\theta$

So curve will be

(ii) $N = mg\cos\theta$

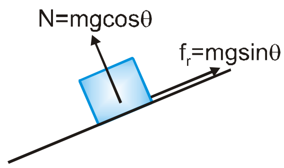


(iii) Till $\theta = \tan^{-1}\mu$



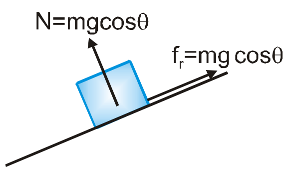
f_r will be static = mg sinθ
after $\theta = \tan^{-1}\mu$
f_r will be kinetic = μ mg cos θ

(iv) Net interaction force between the block and incline's $\Rightarrow$ for $\theta = < \tan^{-1}\mu$



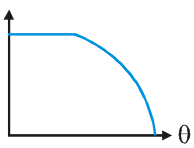
Net reaction = $\sqrt{(mg\cos\theta)^2 + (mg\sin\theta)^2} = mg$

for $\theta > \tan^{-1}\mu$



Net reaction $\sqrt{(mg\cos\theta)^2 + (\mu g\cos\theta)^2} = \sqrt{1+\mu^2}\ \cos\theta$

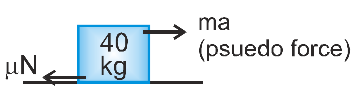
So curve will be



35. The block begins to slide if
$F\cos 37° = \mu(mg - F\sin 37°)$
$5t[\cos 37° + \mu\sin 37°] = \mu\, mg$

$$5t\left[\frac{4}{5}+\frac{3}{5}\right] = 70 \quad \text{or} \quad t = 10 \text{ second}$$

36. In the reference frame of the truck FBD of 40 kg block



Net force $\Rightarrow ma - \mu N \Rightarrow 40 \times 2 - \dfrac{15}{100} \times 40 \times 10$

$$ma_{block} \Rightarrow 80 - 60 \Rightarrow a_{block} = \frac{20}{40} = \frac{1}{2}\ \text{m/s}^2$$

This acceleration of the block in reference frame of truck so time taken by box to fall down from truck

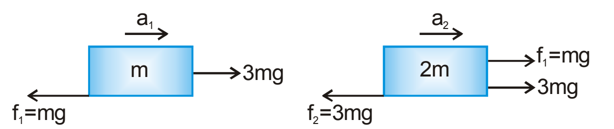
$$S_{rel} = u_{rel}t + \frac{1}{2}a_{rel}t^2 \Rightarrow 5 = 0 + \frac{1}{2} \times \frac{1}{2} \times t^2 \Rightarrow t^2 = 20$$

So distance moved by the truck

$$\Rightarrow \frac{1}{2} \times a_{truck} \times t^2 \quad \Rightarrow \frac{1}{2} \times 2 \times (20) = 20 \text{ meter}$$

37. As seen from an inside observer, the forces acting on the block are pseudoforce, frictional force and the applied force.
When the applied force is in the direction of pseudo force (in this case less force will be required to move the block)
10 + pseudoforce = μmg ....(1)
When the applied force is opposite to the pseudoforce,
20 – pseudo force = μmg ....(2)
Adding (1) & (2)
30 = 2 μmg = 2μ50 $\therefore$ μ = 0.3

38. The F.B.D of both blocks is as shown.

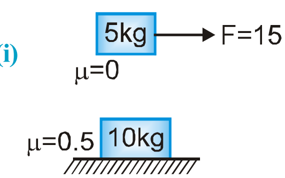


$$a_1 = \frac{3mg - mg}{m} = 20\ \text{m/s}^2 \Rightarrow a_2 = \frac{4mg - 3mg}{2m} = 5\ \text{m/s}^2$$

$$\therefore a_{pulley} = \frac{a_1 + a_2}{2} = \frac{25}{2} = \frac{X}{2}.\ \text{Hence}\ X = 25$$

39. **(i)** 3 and 0
(ii) 0 and 0
(iii) $a_A = 5\ \text{m/s}^2$; $a_B = 10\ \text{m/s}^2$; $f_A = 25N$; $f_B = 75N$
(iv) $a_A = 1\text{m/s}^2$; $a_B = 1\text{m/s}^2$; $f_A = 5N$; $f_B = 75N$

(i)

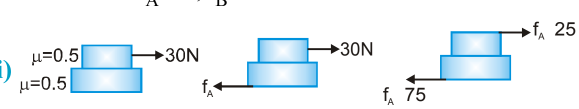


$$a_A = \frac{F}{m} = \frac{15}{5} = 3$$

$$a_B = \frac{0}{10} = 0$$

$f_A = 0, f_B = 0.$

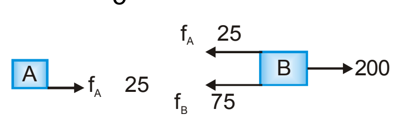
(ii)



$f_B \le 75$
Since f_A can't be greater than f_B therefore acceleration of B will be 'O'.

and $a_A = \dfrac{30-25}{5} = 1\text{m/sec}^2 \Rightarrow f_A = 25\,N, f_B = 25\,N.$

(iii)



$f_A \le 25 \quad \Rightarrow a_A \le \dfrac{25}{5}$ or $a_A \le 5$

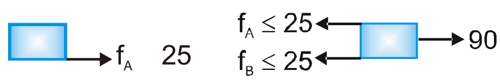
Let there is no sliding between A and B then common acceleration of A and B.

$= \dfrac{200-75}{15} = 8.33$

Since $a_A \le 5 \Rightarrow$ Hence, there will be sliding between A and B in that case.

$a_A = 5\ m/sec^2,\ a_B = \dfrac{200-100}{10} = 10\ m/sec^2$

$f_A = 25\ N,\ f_B = 75\ N.$

(iv) 

$a_A \le 5$

Let A and B move together then common acceleration.

$= \dfrac{90-75}{15} = 1 m/sec^2$

As common acceleration is less than a_A hence A and B will move together

$\therefore\quad a_A = 1 m/sec^2,\ a_B = 1 m/sec^2$

$f_A = m_A \times 1 = 5N,\quad f_B = 75\ N.$

40. The F.B.D. of A and B are

force of friction

For sliding to start between A and B, the frictional $f = \mu N$

$= \dfrac{1}{4} \times 2 \times 10 = 5\ N = f_{max}$

Applying Newton's second law to system of A + B

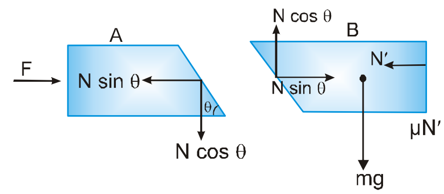
$F = (m_A + m_B)\, a = 6a$ ....(1)

Applying Newton's second law to A

$f = m_A\, a \Rightarrow a_{max} = \dfrac{f_{max}}{m_A} = \dfrac{5}{2} = 2.5\ m/s^2$ ....(2)

from (1) and (2) $F_{min} = (m_A + m_B)\, 2.5\ m/s^2 = 6 \times 2.5 = 15\ N$

41. (i) The F.B.D. of A and B are



For A to be in equilibrium $F = N \sin\theta$ ....(1)

For B to just lift off $N \cos\theta = mg + \mu_s N'$ ....(2)

For horizontal equilibrium of B $N' = N \sin\theta$ ....(3)

From (2) and (3)

$N(\cos\theta - \mu_s \sin\theta) = mg$ or $N\left(\dfrac{4}{5} - \dfrac{2}{3} \times \dfrac{3}{5}\right) = mg$ or

$N = \dfrac{5}{2}\, mg$ ....(4)

From equation (1) $F = N \times \dfrac{3}{5} \Rightarrow \therefore F = \dfrac{3}{2}\, mg$