UNIT # 02 (PART – I)

NEWTON LAWS OF MOTION & FRICTION

EXERCISE –I

1. Force on m_1 = Force on $m_2 \Rightarrow a_1 = \dfrac{m_2 a_2}{m_1}$

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

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

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

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

4. Impulse = Change in momentum

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

5. Impulse = $\int F dt$

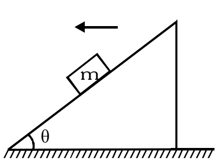
I $\rightarrow$ Impulse = 0.25 1 = 0.25

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

III $\rightarrow$ Impulse = $\dfrac{1}{2}$ 1 1 = 0.50

IV $\rightarrow$ Impulse = $\dfrac{1}{2}$ 1 1 = 0.50

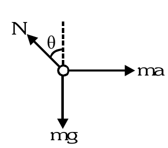
6. $\sin\theta = \dfrac{1}{x}$



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

For body $N\cos\theta = mg$

$N\sin\theta = ma$



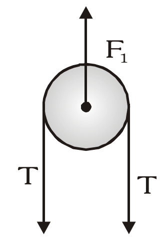
$\Rightarrow a = g\tan\theta = \dfrac{g}{\sqrt{x^2-1}}$

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

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

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

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



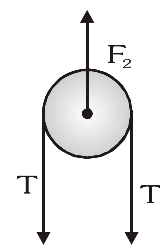
$a_1 = \dfrac{4mg - 2mg}{6m} = \dfrac{2mg}{6m} = \dfrac{g}{3}$

$\therefore T_1 - 2mg = 2m \dfrac{g}{3}$

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

Case (ii) :

$F_2 = 2T_2$



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

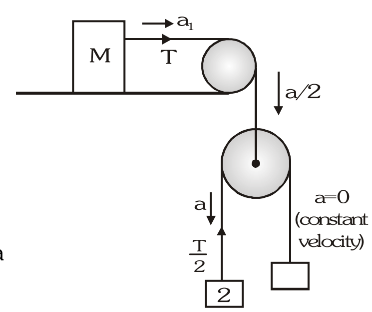
$\therefore 4mg - T_2 = 4m \dfrac{g}{3}$

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

11. $a_1 = \dfrac{2mg - mg}{m} = g$; $a_2 = \dfrac{2mg - mg}{3m} = \dfrac{g}{3}$

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

12. $T = M \times \dfrac{a}{2}$ ...(i)



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

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

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

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

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

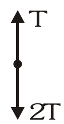
M = 8 kg

13. Acceleration

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

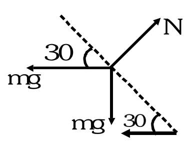
$$= \frac{750-260}{100} = 4.9 \text{ ms}^{-2}$$

14. (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

15. For pulley C,  $\Rightarrow T = 0$

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

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

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

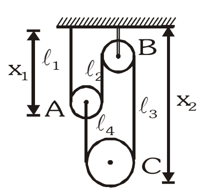
Acceleration of block w.r.t wedge

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

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

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

17. $\ell_1 + \ell_2 + \ell_3 + \ell_4 = \text{constant}$



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

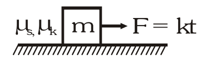
$x_1 + x_1 + x_2 + x_2 - x_1 = 0 \Rightarrow 2x_2 + x_1 = 0$

But acceleration of C = g downward

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

$\Rightarrow$ Acceleration of A = 2g upwards

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

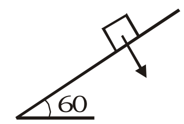


so for $t \le t_0$, $a = 0$

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

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

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



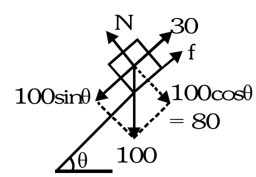
$a_1 = \dfrac{10\times\frac{\sqrt{3}}{2} - 0.5\times 10\times\frac{1}{2}}{1}$

$= 5\sqrt{3} - 2.5$; $a_1 < a_2$

OR

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

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

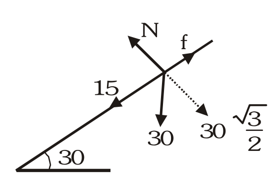


Total force exerted by plane

$= \sqrt{f^2 + N^2}$

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

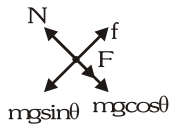
21. $N = 15\sqrt{3}$; $f = 15$ $\therefore$ Total Force



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

22. N = F + mgcosθ, f = mgsinθ but f ≤ μN

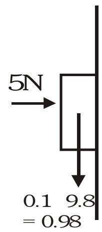
so mgsinθ ≤ μ (F + mgcosθ)



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

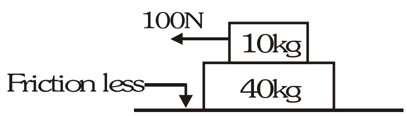
$\Rightarrow F_{min} = 2 \quad 10\left[\frac{1/2}{0.5} - \frac{\sqrt{3}}{2}\right]$

= 20(1 – 0.866) = 2.68N



23. ∵ Block is stationary so f = 0.98 N

24.

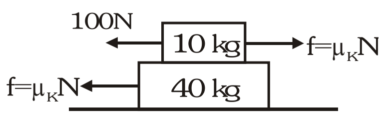


Limiting friction

F_S = μmg = 0.6 10 9.8 = 58.8 N

100 N > 58.8 N

i.e. slab will accelerate with different acceleration.



f =40a

0.4 10 9.8 = 40a ⇒ a = 0.98 m/s^2

25. Acceleration of box w.r.t truck

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

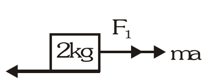
The box will fall off at time t then from

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

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

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

For upper block w.r.t lower block



f = F_1 + ma = 2 + 2(3) = 8N

27. Here μ = tanϕ

Retardation of block = gsinϕ

from v^2 = u^2 + 2as

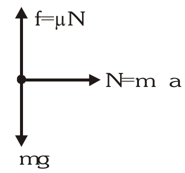
$v_0^{\,2}$ = 2(2gsinϕ)s ⇒ s = $\frac{v_0^2}{4g\sin\phi}$

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

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

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

FBD of A



μN = mg

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

⇒ Mμ–M = 3m ⇒ M = $\frac{3m}{\mu - 1}$

29. Acceleration of car along slope

= g sinθ – μgcosθ

= 10 $\frac{1}{2}$ – (0.5)(10)$\left(\frac{\sqrt{3}}{2}\right)$ = 5 – 4.33

= 0.67 ms^{-2}

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

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

= $\sqrt{36 + 20.1}$ = $\sqrt{56.1}$

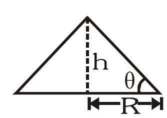
= 7.49ms^{-1}

30. Here 'M' is in equilibrium.

So net force on 'M' must be zero.

∴ f = Mg (upwards)

31. tanθ = $\frac{h}{R} = \mu$ ⇒ h = μR



32. 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

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

33. For (A) :

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

For (B) :

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

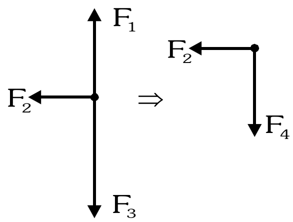
For (C) :

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

For (D) :

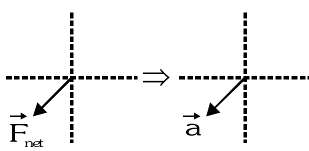
$$\vec{F}_{net} = (F\tilde{i} + F\tilde{j}) + (-2F\tilde{i}) = -F\tilde{i} + F\tilde{j}$$

34.



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

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



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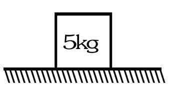
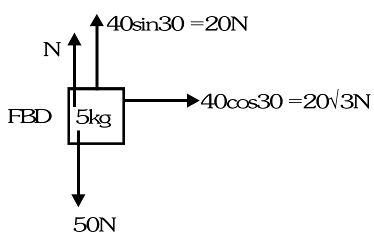


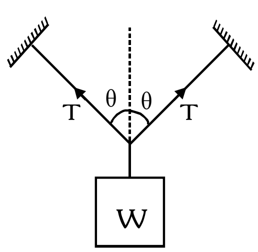


Net vertical force acting on the body is equal to zero.

36. $2T\cos\theta = W$

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

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



37. $T = \frac{2m_1m_2}{m_1 + m}g$

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

EXERCISE –II

1. Maximum tension in string T_{max}sin 30 = 40

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

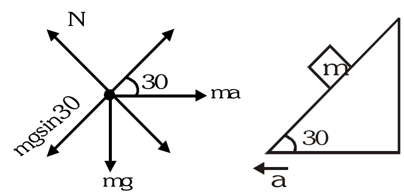
For monkey $T_{max} - mg = ma \Rightarrow a = \frac{80}{5} - 10$

$= 6 \text{ ms}^{-2}$

2. Acceleration along the groove = (g sin 30) (sin 30)

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

3. FBD of block :



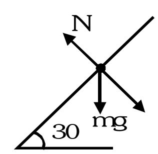
$\therefore$mgsin 30 = macos 30

$$a = g\tan 30 = \frac{g}{\sqrt{3}}$$

N = mg cos30 + ma cos 60

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

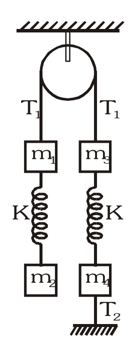
$$F_1 = \frac{3mg + mg}{2\sqrt{3}} = \frac{2mg}{\sqrt{3}}$$



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

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

4.



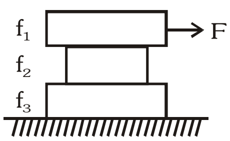
$T_1 = (m_1 + m_2)\,g$

$T_1 - T_2 = (m_3 + m_4)\,g \Rightarrow T_2 = (m_1+m_2-m_3-m_4)g$

Net force acting immediately after cutting x = T_2

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

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



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

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

To prevent downward slipping

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

7. Velocity of Block 'A' at any time

$\therefore v_1 = v_0 - \mu gt$

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

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

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

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

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

9. Acceleration of system

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

Relative acceleration of blocks = 12 ms^{-2}

Now 2 + 4 = 1/2 (12) $t^2 \Rightarrow t = 1$ sec

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

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

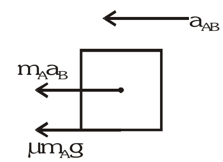
11. In (A) $T = kx_1 = 2g$

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

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

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

12. Acceleration of B,

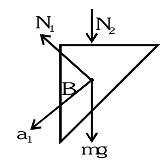


$a_B = \dfrac{\mu m_A g}{m_B} = \dfrac{\left(\frac{1}{2}\right)(m)g}{2m} = \dfrac{g}{4}$

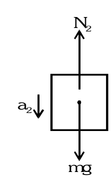
P & D of block A w.r.t. B

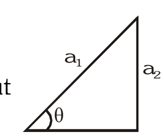
$a_{AB} = \dfrac{\mu m_A g + m_A a_B}{m_A} = \mu g + a_B = \dfrac{g}{2}+\dfrac{g}{4} = \dfrac{3g}{4}$

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



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



but 

$a_1\sin\theta = a_2$

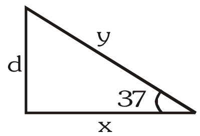
$\Rightarrow \dfrac{(mg+N_2)\sin^2\theta}{m} = \dfrac{mg-N_2}{m} \Rightarrow N_2 = \dfrac{mg\cos^2\theta}{(a+\sin^2\theta)}$

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

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

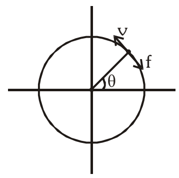
14. $x^2 + d^2 = y^2 \Rightarrow x\dfrac{dx}{dt} = y\dfrac{dy}{dt}$

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

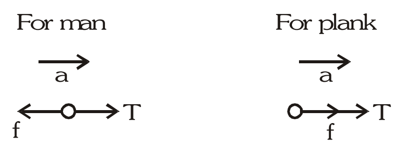


15. $\tilde{f} = \cos(\theta + 270°)\tilde{i} + \sin(\theta + 270°)$

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



16.



$T - f = 50a$ $\qquad$ $T + f = 100\ a$

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

$\because\ T - f = 50\ a\ \ \therefore\ 100 - f = 50\ \dfrac{4}{3}$

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

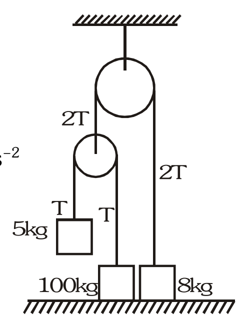
17. $5g - T = 5a_A$

$2T - 8g = 8\ a_C$

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

and $a_A = 2a_C$

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



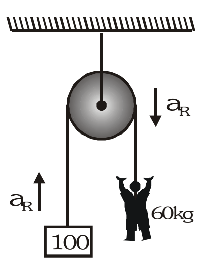
18. $a_{mR} = \dfrac{5g}{4} \uparrow = a_m - (-a_R)$

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

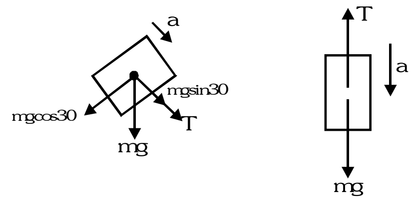
$\therefore\ T - 600 = 60\ \left(\dfrac{5g}{4} - a_R\right)$

& $T - 1000 = 100\ a_R$

By solving we get tension = 1218 N



19. Let acceleration of blocks be 'a' then



$T + mg\sin 30 = ma$, $mg - T = ma$

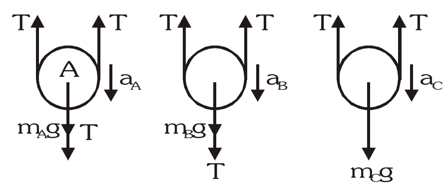
$\Rightarrow a = \dfrac{3}{4}g, \qquad T = \dfrac{mg}{4}$

20. 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.

21. Let tension in string be T



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

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

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

22. Acceleration of block w.r.t ground

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

Acceleration of block w.r.t. plank

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

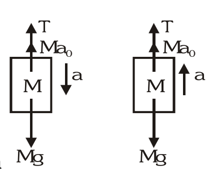
Now $s = ut + \dfrac{1}{2}at^2$ gives $s = \dfrac{1}{2}(2)(1)^2 = 1m$(w.r.t. ground & w.r.t. plank)

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

$Mg - T - Ma_0 = Ma$

$T + ma_0 - mg = ma$

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



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

But $a_0 > g$ so $a < 0$ and $T < 0$

$\Rightarrow$ Tension in string will be zero

24. Let $a \leq \mu g$ (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.

EXERCISE –III

TRUE/FALSE

1. In case (a), tension is less than 2mg.

2. Buoyant force pushes the balloon to the left.

3. Tension is greater than mgcos20 to provide necessary centripetal acceleration.

4. Friction is responsible for forward movement.

5. Friction is zero if there is no tendency of relative motion.

6. Friction force always opposes the tendency of relative motion.

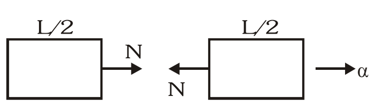
7. The tangential velocity about the centre of earth is different in both cases and hence normal reactions are different.

FILL IN THE BLANKS

1. $f_{max} = \mu\ mg = 0.6 \quad 1 \quad 10 = 6N$

$f_{Pseudo} = ma = 1 \quad 5 = 5N \therefore f = 5\ N$

2.



for the left part, $N = ma = \dfrac{\rho L \alpha}{2}$

MATCH THE COLUMN

1.(A) For the entire system

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

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

(B) Net force on 3 kg block =ma = 3 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

$= 2g\sin 30 + 2a + 25 = 39N$

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

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)

ASSERTION & REASON

1. For a non–inertial observer, pseudo force acts even on a stationary object.

2. Impulse applied by cement floor and sand floor are same.

3. A sharp impulse breaks a brick.

4. At low altitudes, density of air is high.

5. Static friction is generally greater than kinetic friction.

6. Rotation of the wheels stop but translation is present.

7. In pulling case, normal reaction is smaller than the normal reaction in the pushing case.

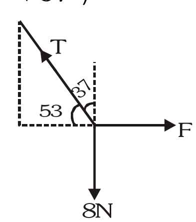
8. On the block only two forces act. One force is gravity and the other is exerted by the incline.

9. Same tension propagates to either team but the external force coming from ground help to decide the winner.

Comprehension#1

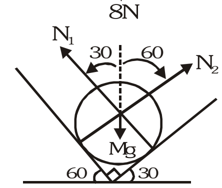
1. $\dfrac{F}{\sin(90° + 53°)} = \dfrac{T}{\sin 90°} = \dfrac{8}{\sin(90° + 37°)}$

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



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

2. $N_1 \sin 30 = N_2 \sin 60$



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

$N_1 \cos 30 + N_2 \cos 60 = Mg$

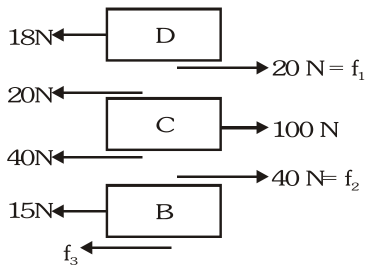
$\Rightarrow N_1 = 50\sqrt{3}$ N and

$N_2 = 50$ N

Comprehension # 2

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

f_{3max} = 90 N, 60N



$\therefore\ a_B = 0$

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

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

Comprehension#3

1. Static friction = 400 N (say)

Kinetic friction = F

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

From table

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

$\Rightarrow$ f = 200 N; M = 100 kg

$\therefore\ \mu_S = \dfrac{400}{1000} = 0.4$

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

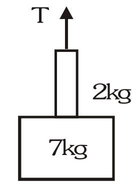
3. If F = 700N, $a = \dfrac{700-f}{M} = \dfrac{700-200}{100} = 5\ m/s^2$

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

Comprehension #4

1. Acceleration of the systme

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



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

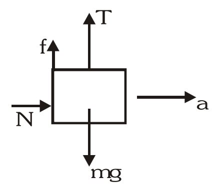
$\therefore$ a = 3g (max. acc.) & g (max. retardation)

Comprehension#5

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

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

FBD of m :



N = ma ...(1)

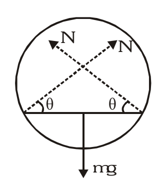
mg = T ± f ...(2)

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

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 #6



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

If 'θ' decreases sinθ decreases and N increases.

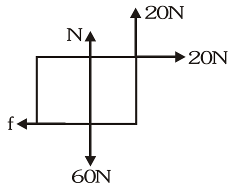
2. When ℓ = R,   2 R cos θ = ℓ

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

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 –IV (A)

1. Total force exerted by the sphere

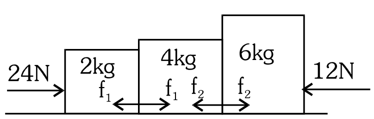
$\vec{F} = m\dfrac{d\vec{v}}{dt} + \vec{N} = m\dfrac{d\vec{v}}{dt} - m\vec{g}$

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

Total force exerted by the sphere

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

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



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

For 6 kg block f_2 – 12 = 6   1 ⇒ f_2 = 18N

For 4kg block f_1 – f_2 = 4   1 ⇒ f_1 = f_2 + 4

= f_1 = 18 + 4 [∵ f_2 = 18N] ⇒ f_1 = 22N

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

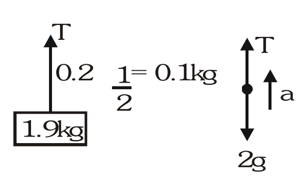
4. (i) T – 40g = 240 ⇒ T = 632 N

(ii) 392 – T = 160 ⇒ T = 232 N

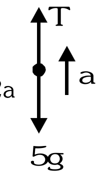
(iii) T = 392 N

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

5. (i)



T – 2g = 2a

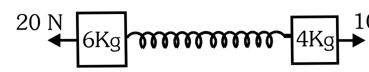


⇒ T = 2 (g +a) = 2 (9.8 + 0.2) =20 N

(ii) For midpoint of upper wire

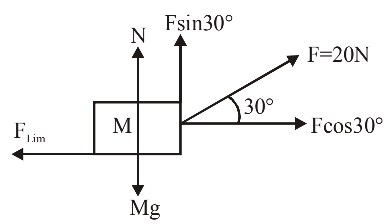
T = 5(g +a) = 5 (9.8 + 0.2) = 50 N

6. acceleration of the system a = $\dfrac{20-10}{6+4}$ =1 m/s²



If tension in the spring is T then for 6 kg block 20–T=6   1 ⇒ T=14 N so reading will be 14 N

7.



F_{lim} = μN = μ(Mg – Fsin30)= 0.5(5   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 $F_{applied} < F_{lim}$

∴ Force of friction = $F_{applied}$ = 17.3 N

8. **For block B**

T = f = μm_2 g & For block A T = m_1g

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

9. $M_1g = \mu\, M_2g\cos\theta + \mu\, M_3g + M_2g\sin\theta$

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

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

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

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

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

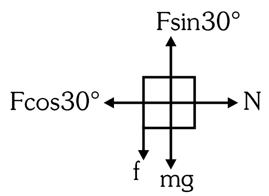
$F_{min} \Rightarrow -\sin\theta + \mu\cos\theta = 0$

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

11. According to FBD – for vertical equilibrium

$f_{net} = F\sin 30 - mg = 50 - 30 = 20$ N

in upward direction.



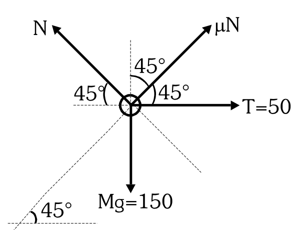
As block has tendency to slip up the wall, hence friction on it will act downwards.

$N = F\cos 30 = 50\sqrt{3}$ N

But the limiting friction is,

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

12. 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 $\mu = 1/2$

13. 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.

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

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

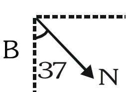
14. For the motion of pully

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

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 $T - m_1g = m_1a_1 \Rightarrow a_1 = 2\ 5\ ms^{-2}$

15. For mass B  $N\sin 37 = m_Ba$

$\Rightarrow N = \dfrac{m_Ba}{\sin 37°} = \dfrac{1\times 3}{(3/5)} = 5N$

16. Downward acceleration of bead

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

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

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

$\Rightarrow t = 1/2s$

EXERCISE –IV (B)

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

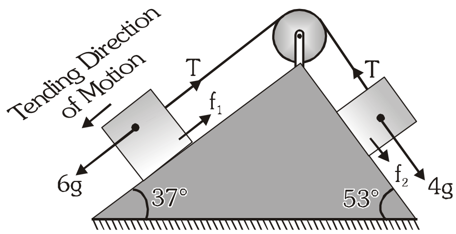
$f_{L_1} = 24$ N

(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 $f_2 < 3$N

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

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

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

So, f_2 should lie between 0 to 3N

f_1 should lie between 20 to 17N

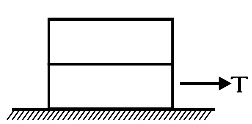
T should lie between 40 to 43 N

2. Here Acceleration of A = acceleration of C

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

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

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



For upper block $\mu_s g = a$

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

4. (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.

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

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

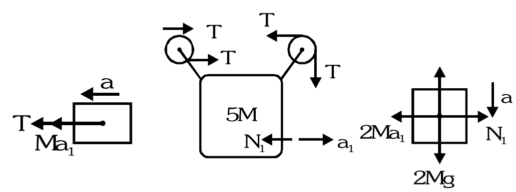
$\therefore a_A = \frac{2mg}{m} = 2g(\uparrow)$

$a_B = \frac{2mg}{m} = 2g(\downarrow)$; $a_C = 0$

(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.

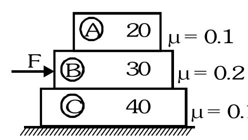
$\therefore a_A = a_B = \frac{mg}{2m} = \frac{g}{2}(\uparrow)$; $a_C = \frac{mg}{m} = g(\downarrow)$

5.



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

6.



(i) Maximum friction on ground

$(20 + 30 + 40)g(0.1) = 90N = f_0$

Maximum friction on between 30 & 40 kg blocks

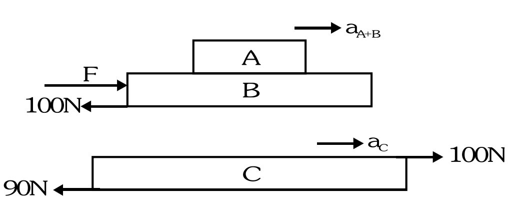
$= (50)(0.2)(10) = 100\text{ N} = f_B$

Maximum friction on between 20 & 30 kg blocks

$= (20)(0.1)(10) = 20N = f_A$

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

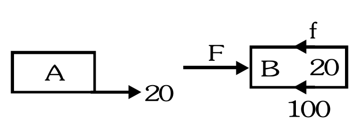
(ii)



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

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

(iii)

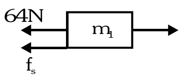


$\frac{F-120}{30} = \frac{20}{20} \Rightarrow F - 120 = 30 \Rightarrow F = 150$ N

7.(i) (a) F = 160 N

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

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

for m_1  (f$_s$ < 100 N)

$\Rightarrow \quad a_{m_1} = 3.2 \text{ ms}^{-2}$

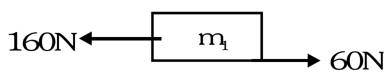
(b) F = 175 N

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

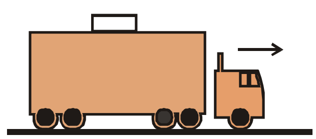
$$a_{m_1} = \frac{F - \mu_k m_1 g}{m_1} = \frac{175-60}{20} = 5.75 \text{ ms}^{-2}$$

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

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



8. 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 $v_0 = 2(1)^2 = 2\text{ms}^{-1}$

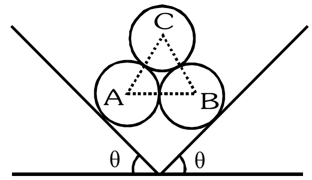
Velocity of block at t = 3 sec is $v_1 = v_0 + \mu_k g t$

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

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

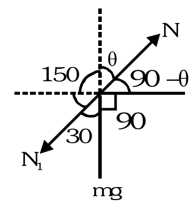
$6 = \mu_k(20) \Rightarrow \mu_k = 0.3$.

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



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

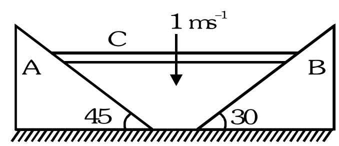
then $2N\cos\theta = 3mg \Rightarrow N = \frac{3mg}{2\cos\theta}$

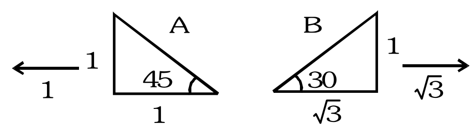


For cylinder A

$$\frac{N}{\sin 30°} = \frac{mg}{\sin(150+\theta)} \Rightarrow \tan\theta = \frac{1}{3\sqrt{3}}.$$

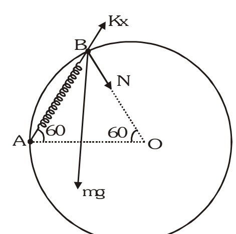
10.





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

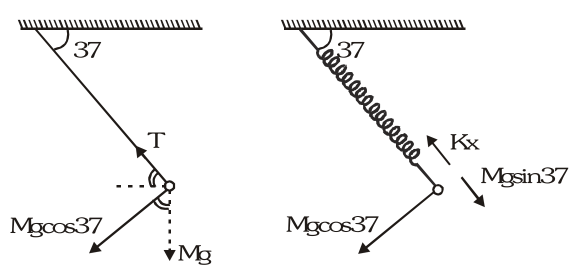
11. $\frac{Kx}{2} = N + mg\cdot\frac{\sqrt{3}}{2}$



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

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

12. 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 2kxcos 53 = Mg

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

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

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

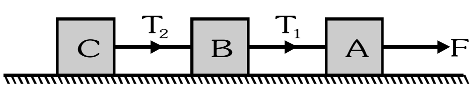
EXERCISE –V(A)

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.

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

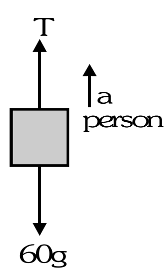
Since, in second case F_1 is removed (in terms of magnitude we are taking now), the forces acting are F_2 and F_3 the resultant of which has the magnitude as F_1, so acceleration of particle is $\frac{F_1}{m}$ in the direction opposite to that of $\vec{F}_1$.

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



T_2 = ma = 2 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,

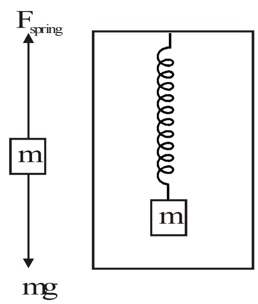
$$T - 60\,g = 60\,a \Rightarrow a_{max} = \frac{T_{max} - 60g}{60}$$

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

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 9.8 $\Rightarrow$ m = $\frac{490}{98}$ =5 kg

When lift is accelerating downwards

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

6. Initial thrust

= m(a+g)

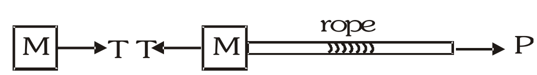
= 3.5 10^4 [10 + 10]

= 7 10^5N

7. In this question

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

8.

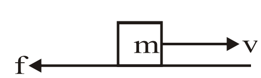


P = (M+m)a ; $T = Ma = \frac{MP}{M+m}$

9. Weight of the block is balanced by frictional force

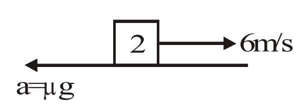
$\Rightarrow$ Weight = μN = 0.2 10 = 2N

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



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

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



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

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

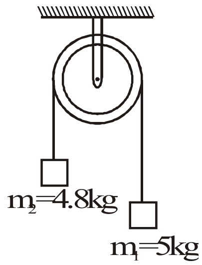
$$\Rightarrow \mu = \frac{6}{10t} = \frac{6}{100} = 0.06s$$

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

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

$\Rightarrow$ N = 3

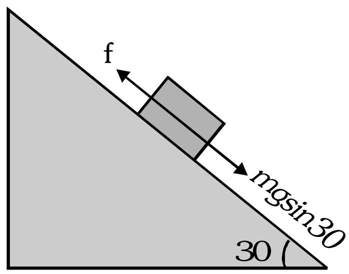
12. g= 9.8 m/s^2



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

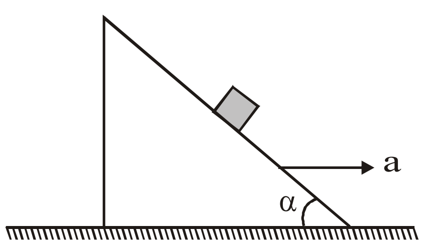
$a = \left(\frac{5-4.8}{9.8}\right)$ 9.8 = 0.2 m/s^2

13.

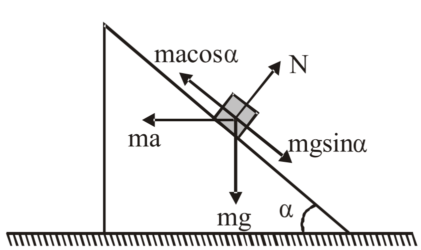


f = mg sin30 ; $m = \frac{10}{g\sin 30°}$ = 2kg

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

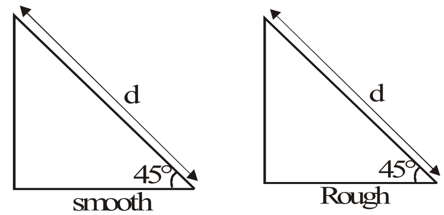


For the block not to slip on wedge



mgsinα= macosα i.e., a = g tanα

15. $d = \frac{1}{2}a_1t_1^2$; $d = \frac{1}{2}a_2t_2^2$



a_1=gsin45 ; a_2 = g(sin45 – μcos45)

$d = \frac{1}{2}a_1t_1^2 = \frac{1}{2}a_2t_2^2$; $t_2 = nt_1$ (Given)

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

16. According to work-energy theorem,W=ΔK = 0

$\Rightarrow$Work done by friction

+ work done by gravity = 0

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

or $\frac{\mu}{2}\cos\phi = \sin\phi$

or $\mu = 2\tan\phi$

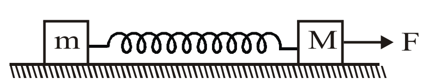
17. Stopping distance $= \frac{(\text{Speed})^2}{2\times\ \text{Retardation}}$

Retardation = μg

Stopping distance $= \frac{100\times100}{2\times0.5\times10}$ =1000 m

18. $F = \frac{\Delta p}{\Delta t} = \frac{(150\times10^{-3})(20)}{0.1} = 30$ N

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



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

20. Relative vertical acceleration of A with respect to B = g ($\sin^2 60$ – $\sin^2 30$)

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

21. Minimum force required to push up a body.

F_1 = mg sin θ + μ mg cos θ

Min. force required to prevent from sliding

F_2 = mg sin θ – μ mg cos θ

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

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

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

$m\dfrac{dv}{dt} = F_0 e^{-bt}$

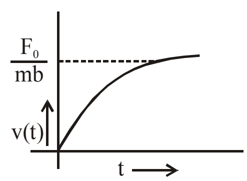
$\int m\,dv = \int F_0 e^{-bt} dt$

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

at t = 0, v = 0

$\therefore\ v = -\dfrac{F_0}{mb}e^{-bt} + \dfrac{F_0}{mb}$

$v = \dfrac{F_0}{mb}(1 - e^{-bt})$



EXERCISE –V-B

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

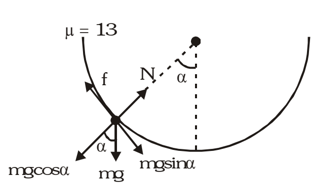
$$\Rightarrow \mu L\alpha = \omega_f^2 L \Rightarrow \omega_f = \sqrt{\mu\alpha}$$

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

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

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

mg cosα balances N



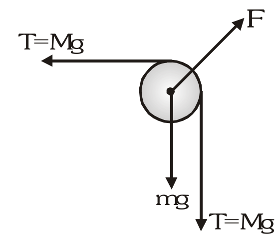
mg sinα is balanced by the frictional force.

∴ N = mg cosα

f = mg sinα But f=μN=μ mg cosα

∴ μg cos α = gsinα ⇒ cotα= $\dfrac{1}{\mu}$ ⇒ cotα =3

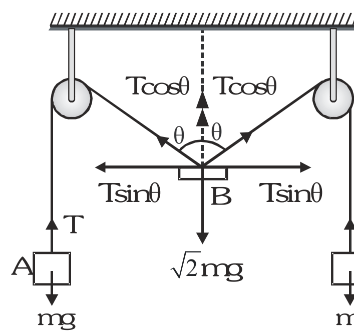
3. Forces on the pulley are



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

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

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



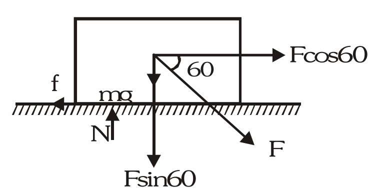
$\sqrt{2}$ mg = 2T cosθ

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

∵ T = mg (at equilibrium)

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

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 = μN...(i)

(Horizontal Direction)

and F sin 60 + mg = N ...(ii)

From (i) and(iii)

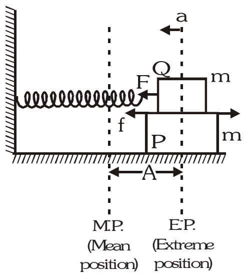
F cos 60 = μ [F sin 60 + mg]

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

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

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)

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

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

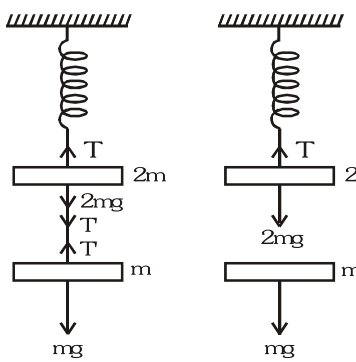
We get $f = m\frac{kA}{2m} = \frac{kA}{2}$

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 :

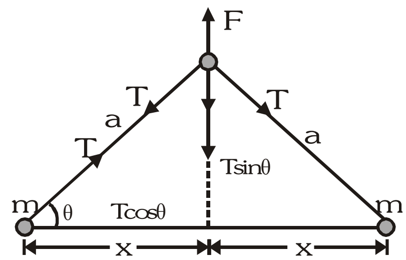
$F_{net} = ma_m \Rightarrow mg = ma_m \Rightarrow a_m = g$

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 θ



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

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

From (i) and (ii)

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

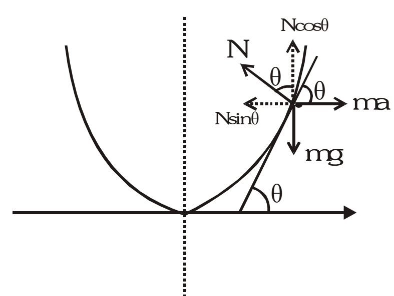
$= \frac{F}{2m\tan\theta} = \frac{F}{2m}\frac{x}{\sqrt{a^2 - x^2}}$

9. $y = kx^2$

$\tan\theta = \frac{dy}{dx} = 2kx$ ... (i)

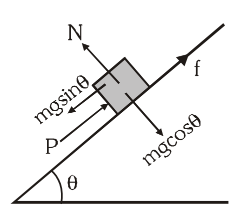
$N\cos\theta = mg$ and $N\sin\theta = ma$

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



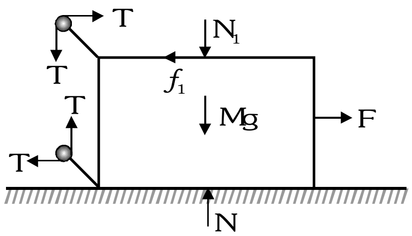
from (i) & (ii) $2kx = a/g$; $x = \frac{a}{2gk}$

10. f varies from μmg cosθ to – μmg cosθ.



13. 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



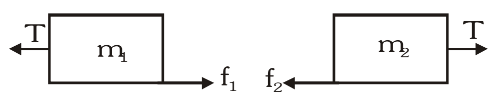
(B) The maximum value of f_1 is

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

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

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

and $\quad T \le (f_2)_{max}$ or $T \le 15N$

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

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

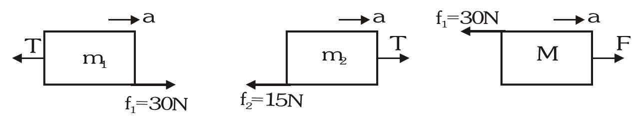
$$f_2 = (f_2)_{max} = 15\ N$$

Therefore $\quad f_1 = 2f_2 = 30N$

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)

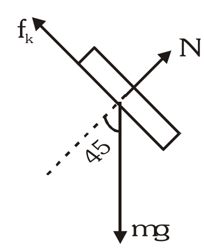
For m_2 : $T - 15 = 5a$...(ii)

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

Solving these three equations, we get,

$$F = 60N,\ T=18N \text{ and } a = \frac{3}{5}\ m/s^2$$

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



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

and

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

Putting values we get

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

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

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.

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

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

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

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

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

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

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