SOLUTIONS OF NEWTONS LAWS OF MOTION
EXERCISE-1
PART - I

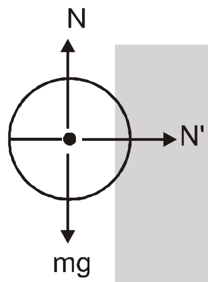
SECTION (A) :

A-1. Gravitational, Electromagnetic, Nuclear.

A-2. Newton's IIIrd Law

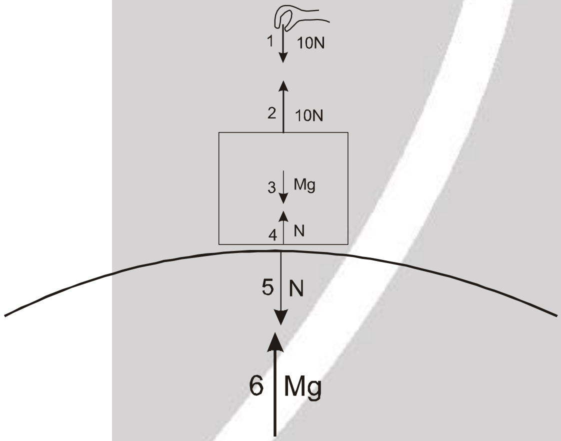
A-3. Newton's IInd Law

A-4.



Vertical wall does not exert force on sphere (N' = 0).

A-5.



For block

mg = 10 +N [Equilibrium]

$\Rightarrow$ $1\times 10 = 10 + N$

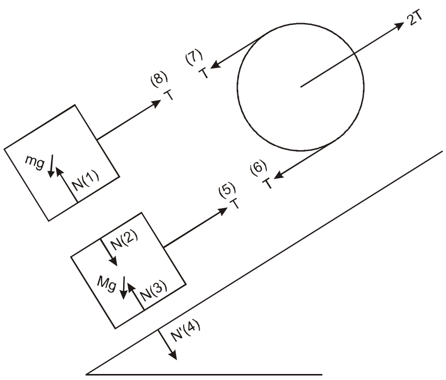
$\Rightarrow$ N = 0

(1) and (2) are action reaction pair

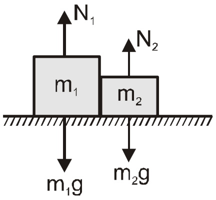
(3) and (6) are action reaction pair

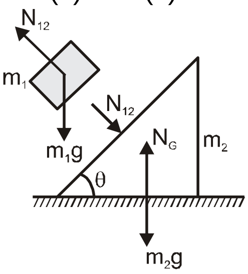
(4) and (5) are action reaction pair

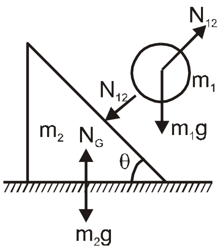
A-6.

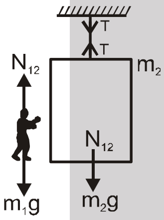


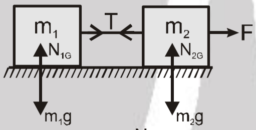
Action reaction pairs (1) and (2)
(3) and (4)
(5) and (6)
(7) and (8)

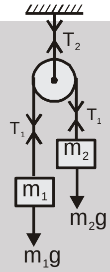
A-7. (a)


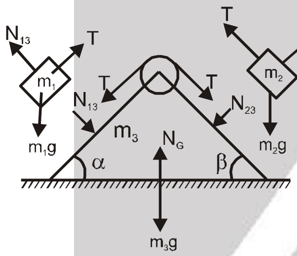
(b)


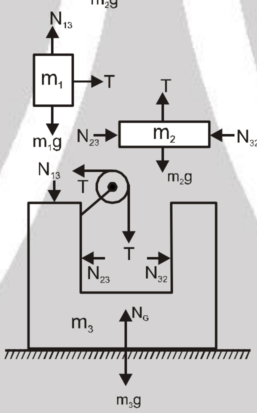
(c)


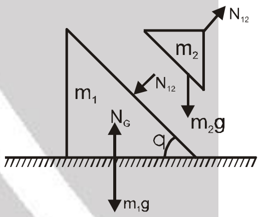
(d)


(e)


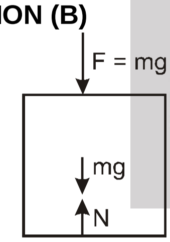
(f)


(g)


(h)


(i)


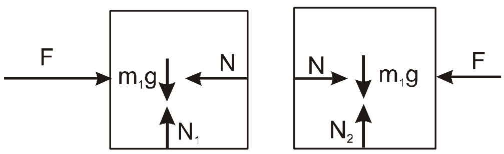
SECTION (B)

B-1.


N = F + mg [equilibrium]

$\Rightarrow$ N = mg + mg

$\Rightarrow$ N = 2mg

B-2.


It is obvious that both blocks will have same acceleration. If we take both block as one system then.

F – F = (m_1 + m_2) a $\begin{bmatrix} \text{Newton's second law} \\ \text{in horizontal direction} \end{bmatrix}$

$\Rightarrow$ a = 0

Now take m_1 as a system

$$\begin{bmatrix} \text{Newton's second law} \\ \text{in horizontal direction} \end{bmatrix}$$

$F - N = m_1 a$

$\Rightarrow \quad F - N = 0$

$\Rightarrow \quad F = N$

$m_1g - N_1 = 0$ [Equilibrium in vertical direction]

Now take m_2 as system

$$N - F = m_2 a \quad \begin{bmatrix} \text{Newton's second law} \\ \text{in horizontal direction} \end{bmatrix}$$

$\Rightarrow \quad N - F = 0$

$N = F$

$m_2g - N_2 = 0$ [Equilibrium in vertical direction]

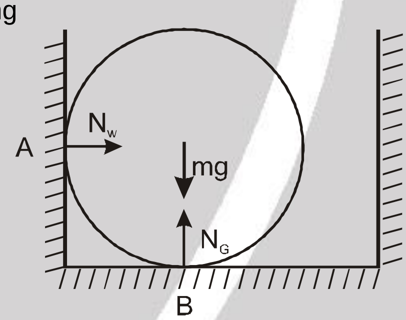
$\Rightarrow \quad N_2 = m_2g$

B-3. The sphere is in contact at two surfaces one at wall and one at ground.
So one Normal reaction can be exerted at A and another at B.

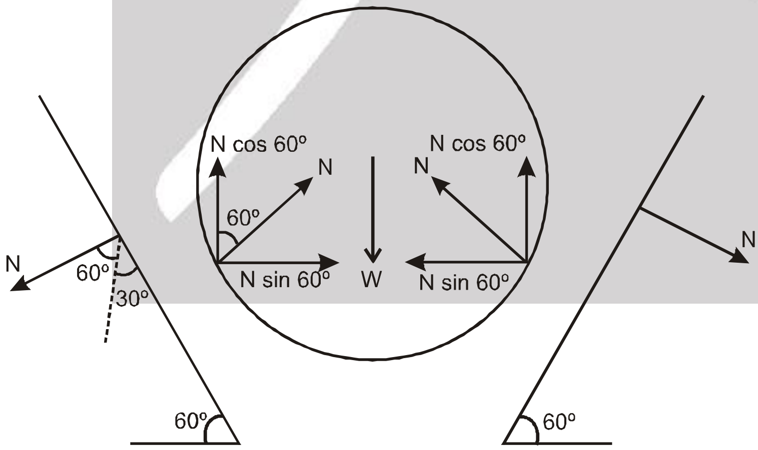
$N_w = 0$ [Equilibrium in horizontal direction]

$N_G - mg = 0$ [Equilibrium in vertical direction]

$\Rightarrow \quad N_G = mg$



B-4.



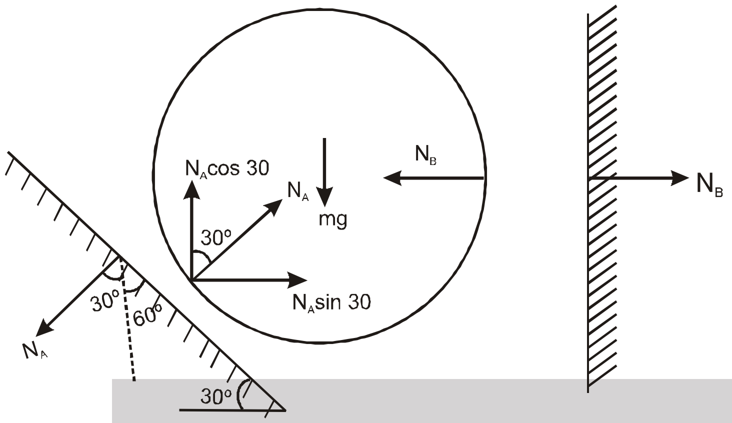
Due to symmetry normal reactions due to left and right wall are same in magnitude

$W - N \cos 60 - N \cos 60 = 0$ [Equilibrium in vertical direction]

$\Rightarrow \quad W - \frac{N}{2} - \frac{N}{2} = 0$

$\Rightarrow \quad N = W$

B-5.



$mg - N_A \cos 30 = 0$ [Equilibrium in vertical direction]

$\Rightarrow$ $N_A = \dfrac{mg}{\cos 30}$

$\Rightarrow$ $N_A = \dfrac{1000}{\sqrt{3}}$ N

$N_B - N_A \sin 30 = 0$ [Equilibrium in horizontal]

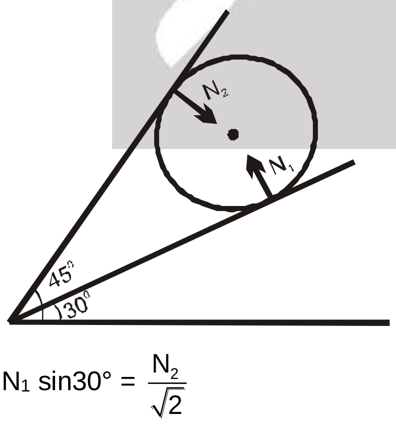
$\Rightarrow$ $N_B = N_A \sin 30$

$\Rightarrow$ $N_B = \dfrac{1000}{\sqrt{3}} \dfrac{1}{2}$

$\Rightarrow$ $N_B = \dfrac{500}{\sqrt{3}}$ N

B-6. $N_1 \cos 30° = 50 + \dfrac{N_2}{\sqrt{2}}$

$N_1 \dfrac{\sqrt{3}}{2} - \dfrac{N_2}{\sqrt{2}} = 50$ .... (1)



$N_1 \sin 30° = \dfrac{N_2}{\sqrt{2}}$

$N_1 = \sqrt{2}\, N_2$ ....(2)

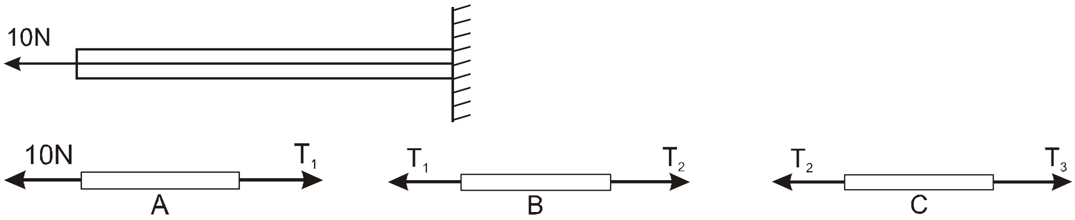
Solving equation (1) & (2)

$N_1 = 136.6$ N

$N_2 = 96.59$ N

SECTION (C) :

C-1.

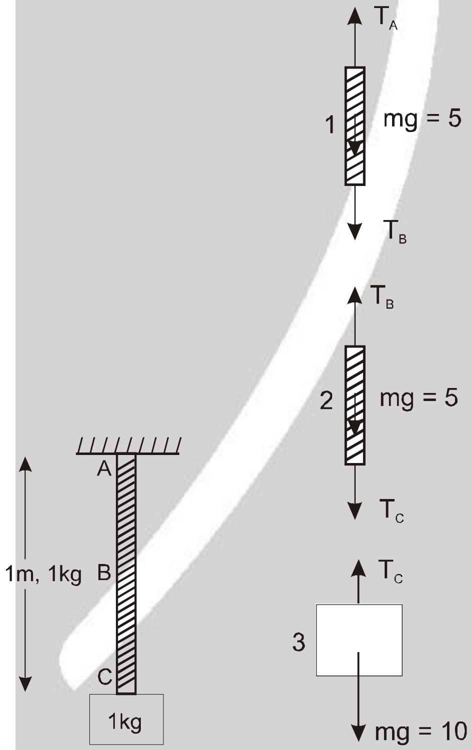


$T_1 - 10 = 0$ [Equilibrium of A]

$T_1 = 10$ N

Similarly T_2 and T_3 are also 10 N

C-2. (a) 10 N (b) 15 N (c) 20 N



$T_C - 10 = 0$ [Equilibrium of block]

$\Rightarrow$ $T_C = 10$ N

$T_B - T_C - 5 = 0$ [Equilibrium of 2]

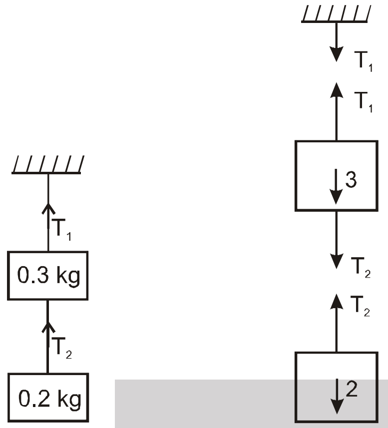
$\Rightarrow$ $T_B - 10 - 5 = 0$

$\Rightarrow$ $T_B = 15$ N

$T_A - T_B - 5 = 0$ [Equilibrium of 1]

$\Rightarrow$ $T_A = 20$ N

C-3.



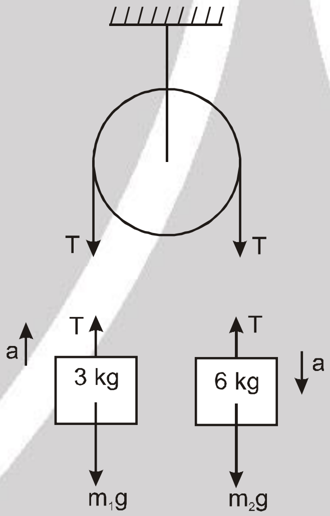
$T_2 - 2 = 0$ [Equilibrium of lower block]

$\Rightarrow$ $T_2 = 2N$

$T_1 - T_2 - 3 = 0$ [Equilibrium of upper block]

$\Rightarrow$ $T_1 = 5$ N

C-4. For finding distance travelled we need to know the acceleration and initial velocity of block.



$m_2g - T = m_2a$ [Newton's second law for m_2]

$T - m_1g = m_1a$ [Newton's second law for m_1]

$m_2g - m_1g = (m_2 + m_1)a$ [adding both the equation]

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

$a = \dfrac{6-3}{6+3} \times g$

$a = \dfrac{g}{3} = \dfrac{10}{3}$ m/s^2

$s = ut + 1/2\ at^2$

$= 0 \times 2 + 1/2 \times 10/3 \times 2^2$

$S = \dfrac{20}{3}$ m

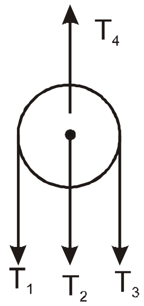
$T - m_1g = m,\ a$

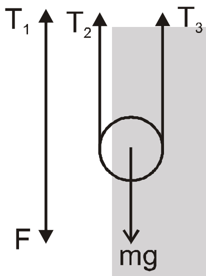
$T = m_1\left(g + \dfrac{g}{3}\right) = 3 \times 40/3$ $T = 40$ N

Force exerted by clamp on pulley is 2T

$\Rightarrow$ $2 \times 40 = 80$ N

C-5.





$T_1 = F$ [Equilibrium of string]

$T_3 = T_1$ [String is massless and pulley is friction less so tension must be same on both sides of string]

$\Rightarrow \quad T_3 = F$

Similarly $T_2 = F$

$T_5 = T_2 + T_3$ [Equilibrium of lower pulley]

$\Rightarrow T_5 = 2F$

$T_5 = mg$ [Equilibrium of block]

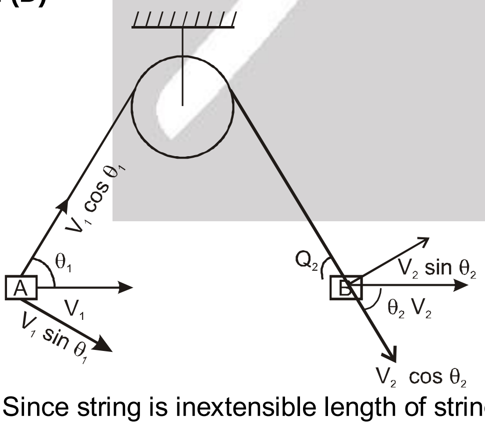
$F_1 = T_2 = T_3 = \frac{Mg}{2}$ $T_4 = T_1 + T_2 + T_3$

[Equilibrium of upper pulley]

$\Rightarrow T_4 = \frac{3 \ Mg}{2}$

Section (D)

D-1.



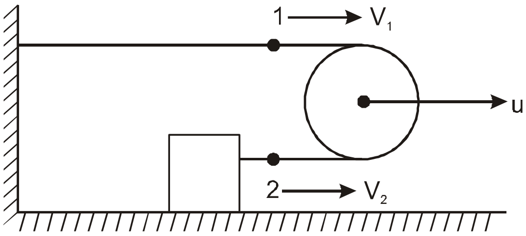
Since string is inextensible length of string can't change

$\therefore$ Rate of decreases of length of left string = rate of increase of length of right string

$\Rightarrow \quad V_1 \cos\theta_1 = V_2 \cos\theta_2$

$\Rightarrow \quad \frac{V_1}{V_2} = \frac{\cos\theta_2}{\cos\theta_1}$

D-2.



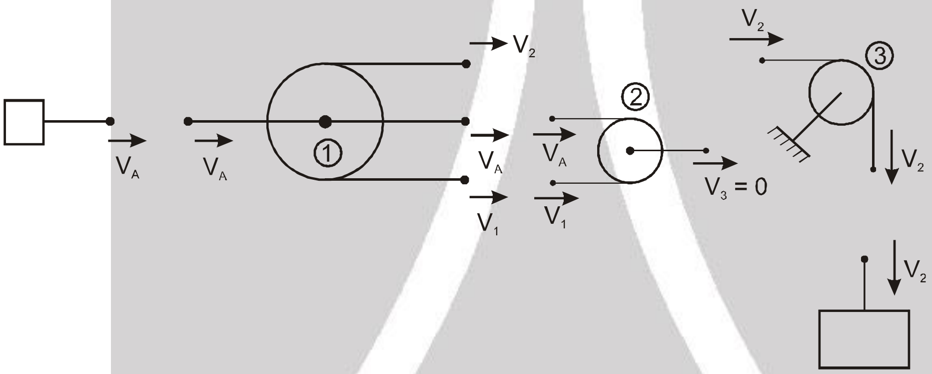
Velocity of point 1 is V_1 which is 0 because string is fixed.
Velocity of point 2 is V_2

$$\frac{V_1 + V_2}{2} = u$$

$$\frac{0 + V_2}{2} = u$$

$V_2 = 2\,u$

D-3.



$V_A = \frac{V_1 + V_2}{2}$ [Pulley 1]

$V_1 + V_2 = 2V_A$ I

$\frac{V_A + V_1}{2} = V_3$ [Pulley 2]

$V_A + V_1 = 0$ II

$\Rightarrow$ $V_1 = -\,0.6$

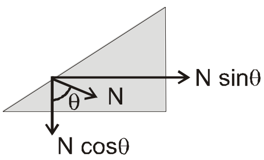
$-\,0.6 + V_2 = 2V_A$

$V_2 = 2 \times 0.6 + 0.6$

$V_2 = 1.8$ m/s

$V_B = V_2 = 1.8$ m/s

D-4. $\tan 37^o = \frac{a_A}{a_B}$ (wedge constrained relation)

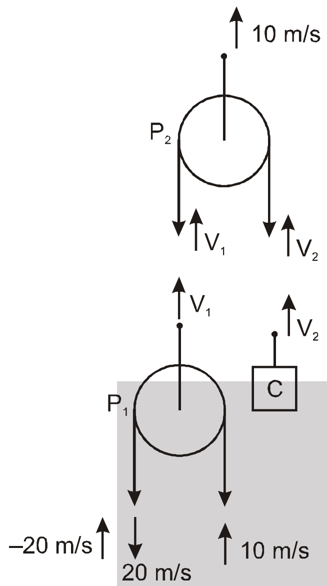


$N \sin 37° = ma_B$ ....(i)

For Rod $\rightarrow$ $mg - N \cos 37° = ma_A$ ....(ii)

From equation (1) & (2) $a_A = \frac{9g}{25}$, $a_B = \frac{12g}{25}$

D-5.



$V_1 = \dfrac{10-20}{2}$ [constrained relation of P_1]

$V_1 = -5$ m/s

$10 = \dfrac{-5+V_2}{2}$

$V_2 = 25$ m/s $\uparrow$

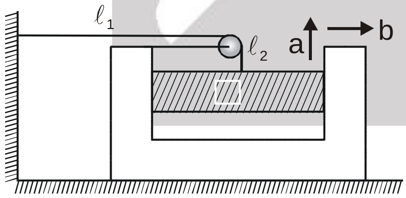
$V_C = V_2 = 25$ m/s upwards

$V_{P_1} = V_1 = -5$ m/s

$\Rightarrow V_P = 5$ m/s downward

[because we have assumed upward direction as +ve for V_1]

D-6.



$\ell_1 + \ell_2 = C$

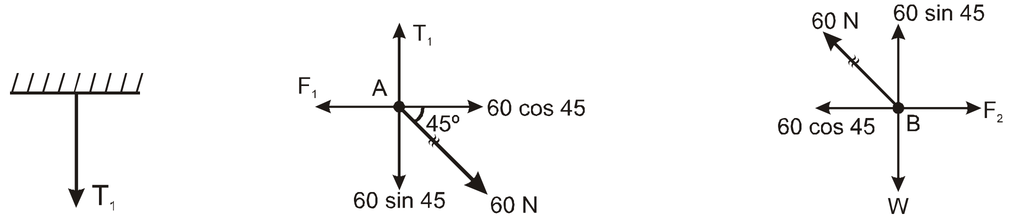
$\ell_1'' + \ell_2 = 0$

$b - a = 0 \qquad a = b$

Acceleration of A $\mathbf{b}\,\hat{i} + \mathbf{b}\,\hat{j}$

SECTION (E)

E-1.



Since point A is massless net force on it must be zero other wise it will have ∞ acceleration.

⇒ $F_1 - 60 \cos 45 = 0$

⇒ $F_1 = 30\sqrt{2}$ N

$F_2 - 60 \cos 45 = 0$

$F_2 = 30\sqrt{2}$ N

$W - 60 \sin 45 = 0$

$W = 30\sqrt{2}$ N

E-2. $\vec{F} = m\vec{a}$

$\vec{a} = a_x\hat{i} + a_y\hat{j}$

$= \frac{d^2x}{dt^2} + \frac{d^2y}{dt^2}\hat{i}$

$= (10)\hat{i} + (18\,t)\hat{j}$

at t = 2 sec t = 2 sec

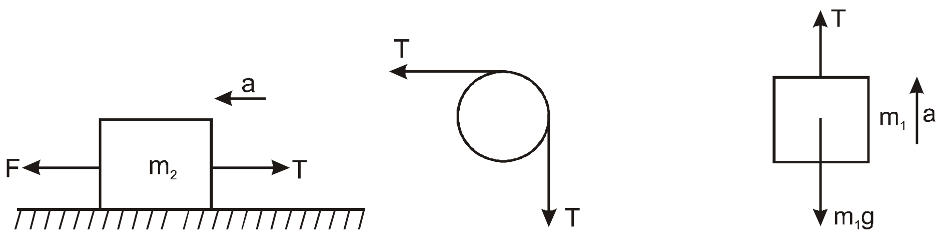
$\vec{a} = 10\hat{i} + 36\hat{j}$

$\vec{F} = 3\,(10\hat{i} + 36\hat{j})$

$= 30\hat{i} + 108\hat{j}$

$|\vec{F}| = \sqrt{30^2 + 108^2} = 112.08$ N

E-3.



It is obevious that acceleration of both the blocks is same in magnitude.

$F - T = m_2a$ [Newtons second law for m_2]

$T - m_1g = m_1a$ [Newtons second law for m_1]

After adding the above equations.

$F - m_1g = (m_2 + m_1)a$

$\frac{m_1g}{2} - m_1g = (m_2 + m_1)a$

$\Rightarrow \quad a = -\frac{m_1g}{2(m_1+m_2)}$

The value of a is –ve it means

$a = \frac{m_1g}{2(m_1+m_2)}$ in the direction opposite to assumed direction

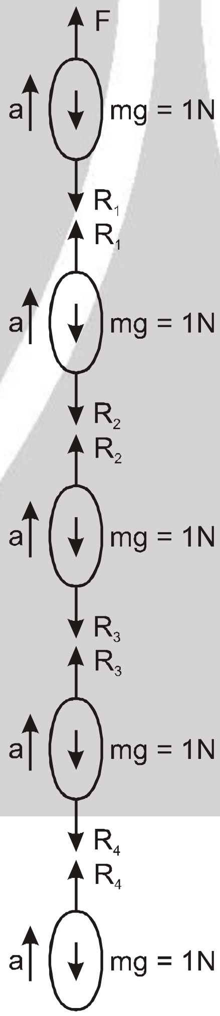
E-4. $R_4 - mg = ma$

$R_4 - 1 = 0.1 \times 2$

$R_4 = 1.2$ N

$R_3 - mg - R_4 = ma$

$R_3 - 1 - 1.2 = 0.1 \times 2$



$\Rightarrow \quad R_3 = 2.4$ N

Similarly

$R_2 = 3.6$ N

$R_1 = 4.8$ N

$F = 6$ N

$F_{net} = ma$

$= 0.1 \times 2$

$= 0.2$ N

E-5. $\int dp = p_f - p_i = \int F \ dt$ = Area under the curve.

$p_i = 0$

Net Area 16 – 2 – 1 = 13 N-s

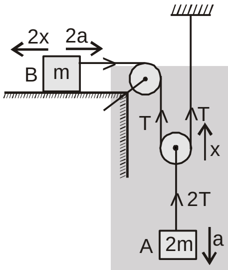
$V_f = 13/2 = 6.5 \hat{i}$ m/s

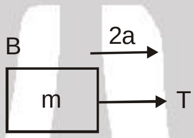
[As momentum is positive, particle is moving along positive x axis.]

E-6. (a) When the block m is pulled 2x towards left the pully rises vertically up by x amount.

$\therefore \ a_B = 2a_A$

F.B.D. of blocks

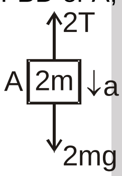




$T = m2a$ ……(1)

F.B.D.

FBD of A,



$2mg - 2T = 2ma$

$mg - T = ma$ …….(2)

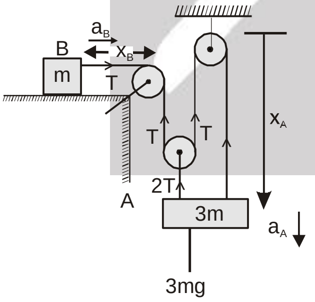
(1) + (2) $\Rightarrow$ $mg = 3ma$

$a = g/3$

$\therefore \quad a_B = 2g/3$

(b) $\ell = x_B + 3x_A$

$$\Rightarrow \quad 0 = \frac{d^2x_B}{dt^2} + 3\frac{d^2x_A}{dt^2}$$



$\Rightarrow \quad 0 = -a_B + 3a_A$

$\Rightarrow \quad a_B = 3a_A$ ……..(1)

For B,

$T = ma_B$ ……..(2)

For A,

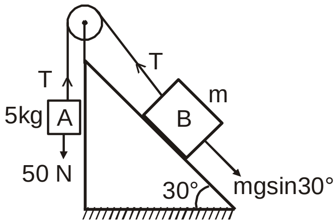
$3mg - 3T = 3ma_A$ ……..(3)

$mg - T = ma_A$

By (1), (2) & (3)

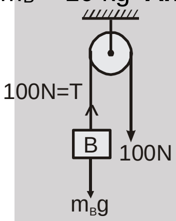
$\therefore \quad a_B = 3g/4$ **Ans.**

E-7. (a)
For Block (A)



T = 50 N ......(1)
For Block (B)
T = mgsin30° ......(2)
∴ 50 = m_B × 10 × 1/2
⇒ m_B = 10 kg **Ans.**

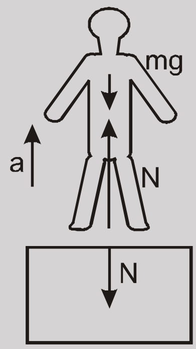
(b)



T – m_Bg = 0
⇒ 100 = m_Bg
∴ m_B = 10 kg **Ans.**

SECTION (F)

F-1. Reading of weighing machine is equal to the normal reaction Normal reaction is not affected by velocity of lift, it is only affected by acceleration of lift.
For I, II and III a = 0



N – mg = 0 [Equilibrium of man]
N = mg = 600 N
For IV, VI and VII IV, a = +2 m/s^2
N – mg = ma [Newtons II law]
N = 60 × 2 + 60 × 10 = 720 N
For V and VIII a = – 2 m/s^2
N – mg = ma [Newtons II law]
N = 60 × (–2) + 60 × 10 = 480 N

F-2. Reading of spring balance is equal to the tension in spring balance which doesn`t depend on velocity of lift but depend on acceleration.

For I, II and III a = 0 a = 0

$T - 100 = 0$ [Equilibrium]

$T = 100$ N

For IV, VI and VII

$T - 100 = ma$ [Newton's II law]

$T - 100 = 10 \times 2$

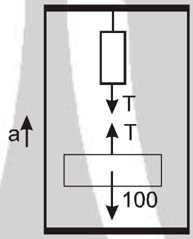
$T = 120$ N

For V and VII

$T - 100 = ma$ [Newton`s II law]

$T - 100 = 10(-2)$

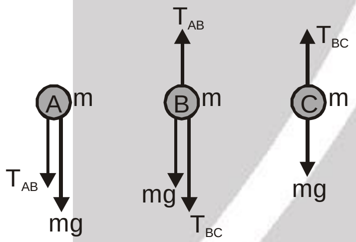
$T = 80$ N



F-3. Initially

$T_{AB} = 2mg$, $T_{BC} = mg$

(a)



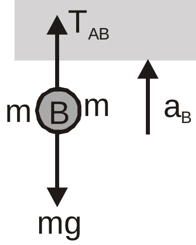
For A $2mg + mg = ma_A$ $\Rightarrow$ $a_A = 3g$

For B $T_{AB} - mg - T_{BC} = ma_B$

$\Rightarrow$ $2mg - mg - mg = ma_B$ $\Rightarrow$ $ma_B = a_B = 0$

$T_{BC} - mg = ma_c$ $\Rightarrow$ $a_c = 0$.

(b)



$T_{AB} = 2mg$

$T_{AB} - mg = ma_B$

$2mg - mg = ma_B$

$\Rightarrow$ $a_B = g\ (\uparrow)$

$a_A = 0\ \&\ a_C = g(\downarrow)$.

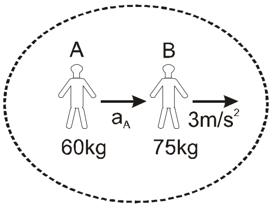
SECTION (G)

G-1. If we take both A and B as a system then there is no external force on system.

$\Rightarrow$ $m_A a_A + m_B a_B = 0$ [Newton's II law for system]

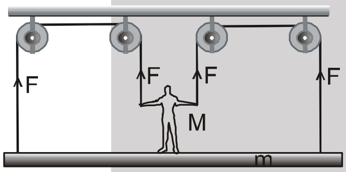
$60\, a_A + 75 \times 3 = 0$

$a_A = \frac{-15}{4}$ m/s^2



–ve sign means that acceleration is in direction opposite to the assumed direction.

G-2.



$4F - (M + m)g = (M + m)a$

$a = \frac{4F-(M+m)g}{M+m} = \frac{4F}{M+m} - g$

G-3. $T_D = W_{A_{app}} + W_{B_{app}} + W_{C_{app}}$

$T_D = W_{A_{\text{आभासी}}} + W_{B_{\text{आभासी}}} + W_{C_{\text{आभासी}}}$

$= 10(10 - 2) + (15 \times 10) + 8\,(10 + 1.5)$

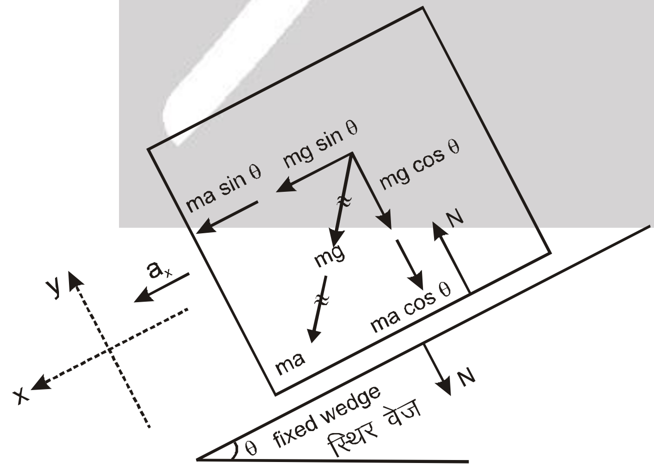
$= 322$ N **Ans.**

SECTION (H)

H-1. Pseudo force depends on mass of object and acceleration of observer (frame) which is zero in this problem.

$\Rightarrow$ Pseudo force is zero.

H-2.



F.B.D. in frame of lift

It is obevious that block can accelerate only in x direction. ma is Pseudo force.

$\Rightarrow$ $mg \sin\theta + ma \sin\theta = ma_x$ [Newton`s II law for block in x direction]

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

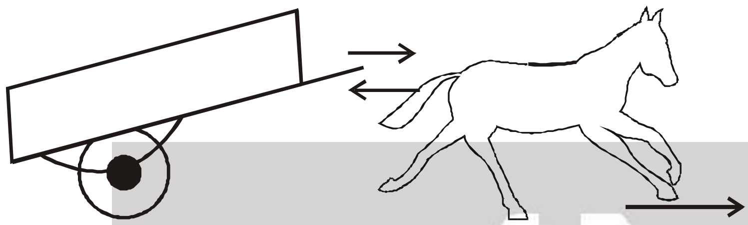
PART - II

SECTION (A)

A-1. Force exerted by string is always along the string and of pull type.

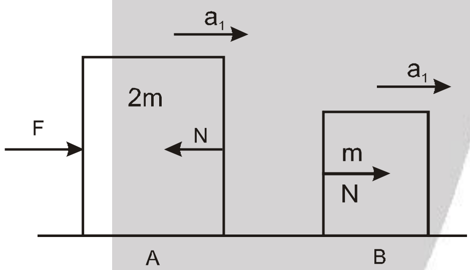
When there is a contact between a point and a surface the normal reaction is perpendicular to the surface and of push type.

A-2. The ground on the horse



SECTION (B)

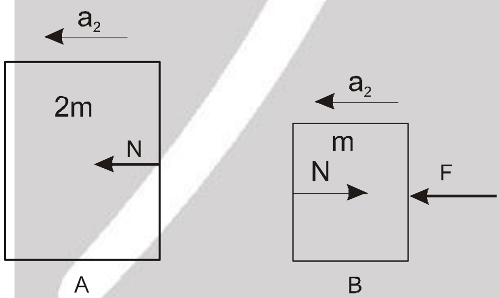
B-1.



$F - N = 2\ ma$, [Newton`s II law for block A] $N = ma_1$

[Newton`s II law for block B]

$\Rightarrow$ $N = F/3$

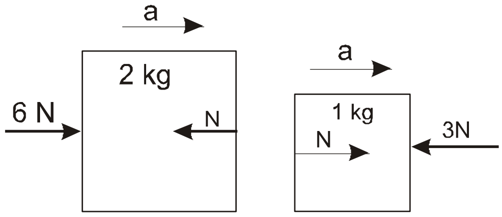


$N = 2\ ma_2$ [Newtons II law for block A]

$F - N = m_2a$ [Newtons II law for block B]

$\Rightarrow$ $N = 2F/3$ so the ratio is 1 : 2

B-2.



Both blocks are constrained to move with same acceleration.

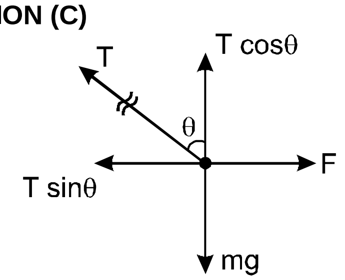
$6 - N = 2a$ [Newtons II law for 2 kg block]

$N - 3 = 1a$ [Newtons II law for 1 kg block]

$\Rightarrow$ N = 4 Newton

SECTION (C)

C-1.

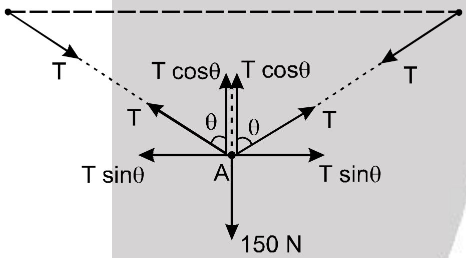


Point A is mass less so net force on it most be zero otherwise it will have ∞ acceleration.

$\Rightarrow$ $F - T\sin\theta = 0$ [Equilibrium of A in horizontal direction]

$\Rightarrow$ $T = \dfrac{F}{\sin\theta}$

C-2.



$T\cos\theta + T\cos\theta - 150 = 0$ [Equilibrium of point A]

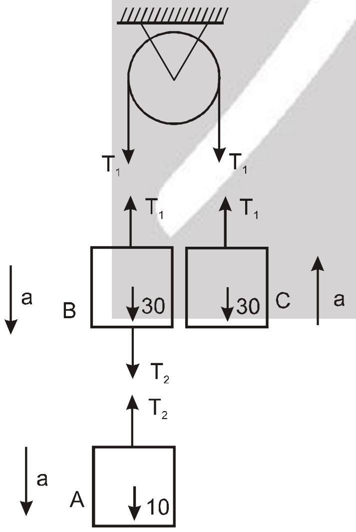
$2\,T\cos\theta = 150$

$T = \dfrac{75}{\cos\theta}$

When string become straight θ becomes 90º

$\Rightarrow$ $T = \infty$

C-3.



$10 - T_2 = 1\,a$ [Newton's II law for A]

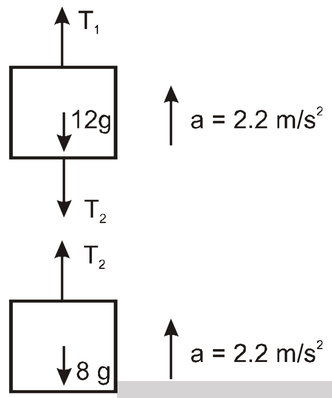
$T_2 + 30 - T_1 = 3\,a$ [Newton's II law for B]

$T_1 - 30 = 3a$ [Newton's II law for C]

$\Rightarrow$ $a = g/7$

$\Rightarrow$ $T_2 = 6g/7$

C-4.



$T_2 - 8g = 8a$ [Newton's II law for 8 kg block]

⇒ $T_2 = 8 \times 2.2 + 8 \times 9.8$

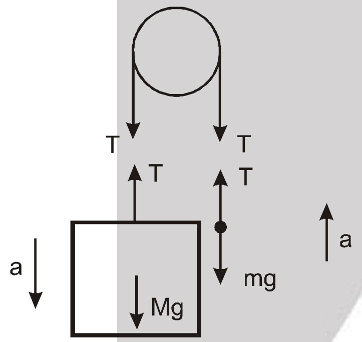
$= 96$ N

$T_1 - 12\,g - T_2 = 12\,a$ [Newton's II law for 12 kg block]

⇒ $T_1 = 12 \times 2.2 + 12 \times 9.8 + 96$

$T_1 = 240$ N

C-5.



$Mg - T = Ma$ [Newton's II law for M]

$T - mg = ma$ [Newton's II law for m]

⇒ T =

If m << M than $m + M \approx M$

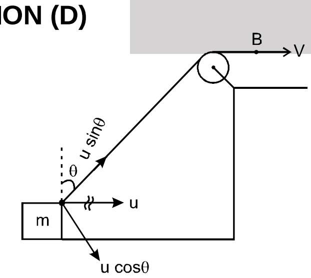
⇒ $T = \frac{2\ m\ Mg}{m + M}$

⇒ $T = 2\,mg$

Total downward force on pulley is 2T = 4 mg.

SECTION (D)

D-1.

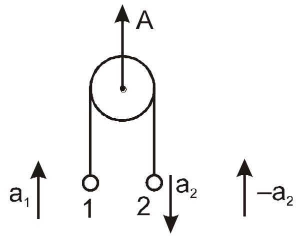


The length of string AB is constant.

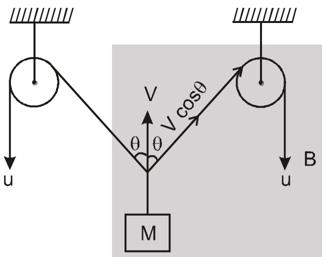
⇒ Speed A and B along the string are same $u \sin\theta = V$

$u \sin\theta = V$ $u = \frac{V}{\sin\ \theta}$

D-2. $A = \frac{a_1 - a_2}{2}$



D-3.



By symmetry we can conclude that block will move only in vertical direction.
Length of string AB remains constant
∴ Velocity of point A and B along the string is same.

$V\cos\theta = u \quad \Rightarrow \quad V = \frac{u}{\cos\theta}$

D-4. Let $AB = \ell$, $B = (x, y)$

$\vec{v}_B = v_x\hat{i} + v_y\hat{j}$

$\vec{v}_B = \sqrt{3}\,\hat{i} + v_y\hat{j} \quad \rightarrow \quad \text{(i)}$

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

$2x\,v_x + 2y\,v_y = 0 \quad \Rightarrow \quad \sqrt{3} + \frac{y}{x}v_y = 0$

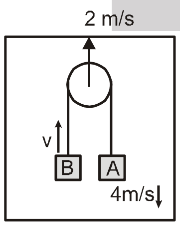
$\Rightarrow \quad \sqrt{3} + (\tan 60°)\,v_y = 0 \quad \Rightarrow \quad v_y = -1$

Hence from (i)

$\vec{v}_B = \sqrt{3}\,\hat{i} - \hat{j}$

Hence $v_B = 2$ m/s

D-5.

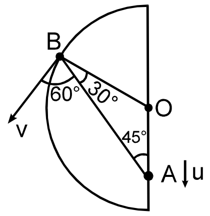


V = (velcoity of B w.r.t ground)

$\frac{V-4}{2} = 2 \qquad V = 8$ m/s (velcoity of B w.r.t ground)

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

D-6. u cos 45° = v cos 60°



or $v = \sqrt{2}\ u$

SECTION (E)

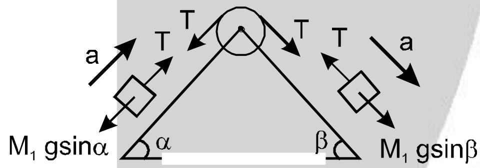
E-1. $\vec{F} = m\vec{a}$

$\vec{a} = \frac{d\vec{v}}{dt}$

E-2. $\vec{F} = m\vec{a}$

E-3. In free fall gravitation force acts.

E-4.



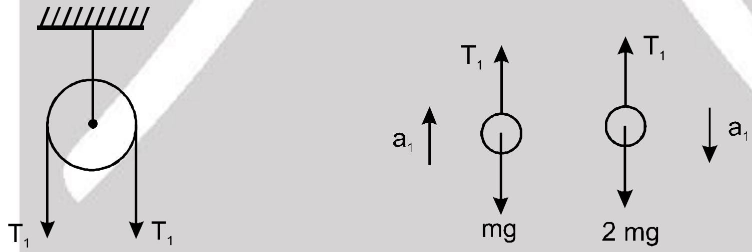
M_2 g sinα – T = M_2a [Newton's II law for M_2]

T – M_1g sinβ = M_1a [Newton's II law for M_1]

By adding both equations

$$a = \left[\frac{M_2 \sin\alpha - M_1 \sin\beta}{M_1 + M_2}\right] g$$

E-5. Case 1

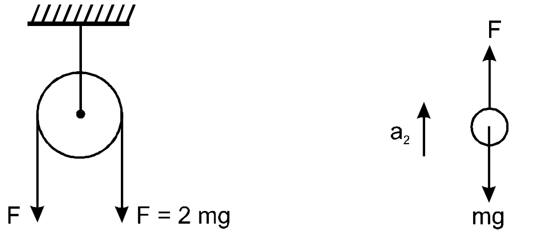


T_1 – mg = ma_1 [Newton's II law for m]

2 mg – T_1 = 2 ma_1 [Newton's II law for 2m]

⇒ a_1 = g/3

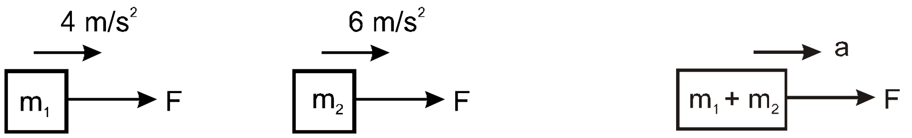
Case 2



F – mg = ma_2 [Newton's II law for m]

⇒ 2 mg – mg = ma_2 ⇒ a_2 = g ⇒ a_2 > a_1

E-6.



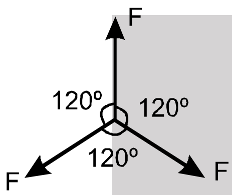
$F = m_1 4$ [Newton's II law for m_1]

$F = m_2 6$ [Newton's II law for m_2]

$F = (m_1 + m_2)a$ [Newton's II law for $(m_1 + m_2)$]

$\Rightarrow \quad F = \left[\frac{F}{4} + \frac{F}{6}\right] a \quad \Rightarrow \quad 1 = \left[\frac{1}{4} + \frac{1}{6}\right] a \quad \Rightarrow \quad a = 2.4\ m/s^2.$

E-7.



Due to symmetry we can say net force on body M is 0.

$\therefore$ Acceleration is 0

E-8. $mg - \frac{3}{4}mg = ma$ [Newton's II law for man]

$\Rightarrow \quad a = g/4$

E-9. $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$

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

$|\vec{F}| = m|\vec{a}|$

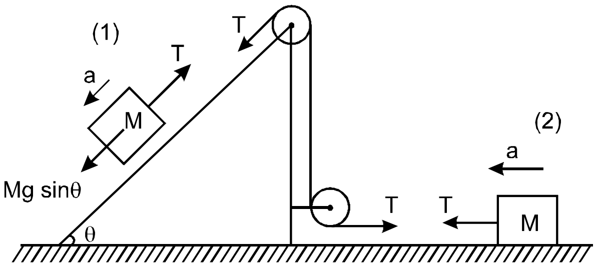
$\sqrt{6^2 + 8^2 + 10^2} = m\ 1$ $\qquad m = 10\sqrt{2}$ kg.

E-10. $\upsilon^2 = \upsilon^2 + 2as$ $\qquad 0^2 = 1^2 + 2\left(\frac{F}{m}\right)x$

$x = \frac{-m}{2F}$ $\qquad \upsilon^2 = \upsilon^2 + 2as$

$O^2 = 3^2 + \frac{2F^1}{m}x$ $\qquad 0 = 9 + \frac{2F^1}{m}\left(\frac{-m}{2F}\right) \Rightarrow F^1 = 9F$

E-11.



$Mg\sin\theta - T = Ma$ [Newton's II law for block 1]

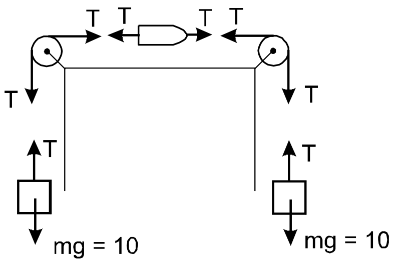
$T = Ma$ [Newton's II law for block 2]

By dividing both equations

$2T = Mg\sin\theta \qquad T = \frac{Mg\sin\theta}{2}$

SECTION (F)

F-1.



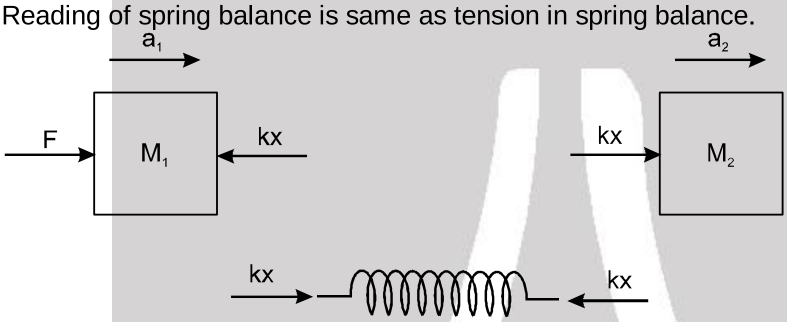
T – mg = 0 [Equilibrium of block]

T – 10 = 0

T = 10

Reading of spring balance is same as tension in spring balance.

F-2.



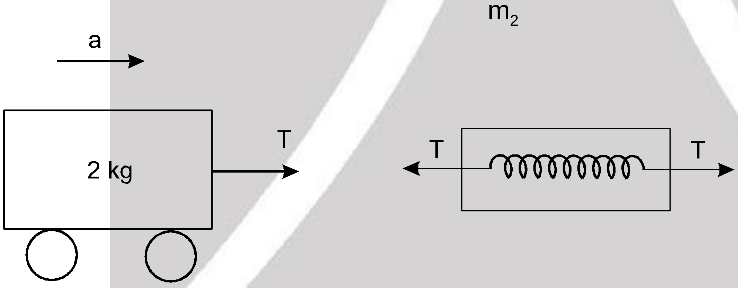
$F - kx = m_1 a_1$ [Newton's II law for M_1]

$kx = m_2 a_2$ [Newton's II law for M_2]

By adding both equations.

$F = m_1 a_1 + m_2 a_2 \Rightarrow a_2 = \dfrac{F - m_1 a_1}{m_2}$

F-3.



Reading of spring balance is same as tension in the balance.

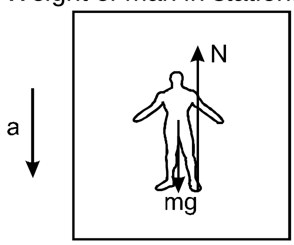
$\Rightarrow \quad T = 10\,g = 98$ N

T = 2 a

[Newton's II law for 2 kg block]

$\Rightarrow \quad a = 49$ m/s^2

F-4. Weight of man in stationary lift is mg.



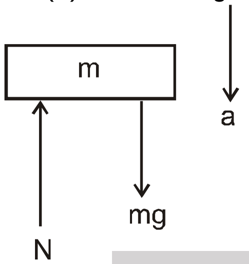
mg – n = ma [Newton's II law for man]

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

Weight of man in moving lift is equal to N.

$\Rightarrow \dfrac{m\ g}{m\ (g-a)} = \dfrac{3}{2} \Rightarrow a = \dfrac{g}{3}$

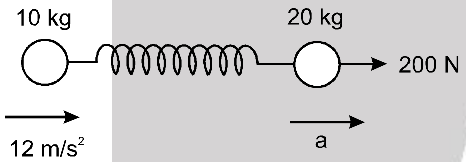
F-5. N = m (g – a), N < mg if a (↓)
N = m (g – a) N < mg
and N > mg if a (↑)
Reading of spring balance is less than m
if a (↓) and reading of spring balance is



greater than m if a (↑)

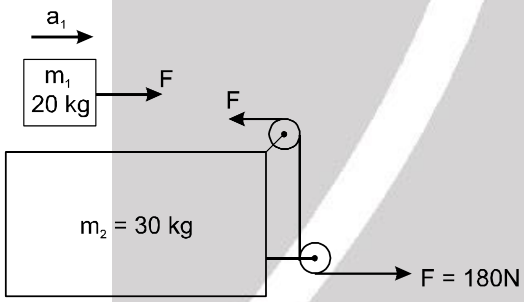
SECTION (G)

G-1.



$F = m_1a_1 + m_2a_2$ [Newton's law for system]
$200 = 10 \times 12 + 20 \times a$ $a = 4\ m/s^2$.

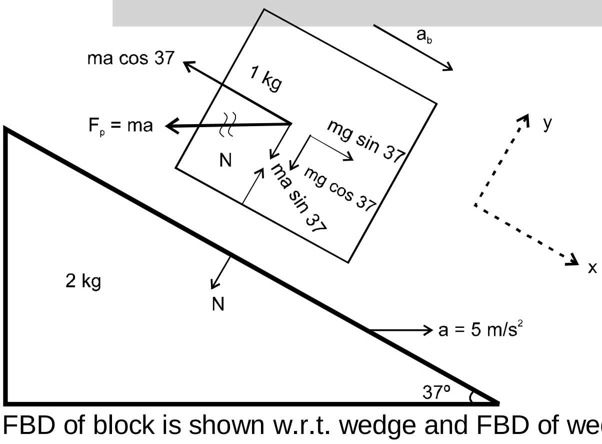
G-2.



F = m1a1 [Newton's II law for m1]
$180 = 20\ a_1$
$\Rightarrow$ $a_1 = 9\ m/s^2$
Net force on m_2 is 0 therefore acceleration of m_2 is 0.

SECTION (H)

H-1.



FBD of block is shown w.r.t. wedge and FBD of wedge is shown w.r.t. ground. F_P is pseudo force.
$mg \sin 37 - ma \cos 37 = ma_b$
$\Rightarrow$ $a_b = g \sin 37 - a \cos 37 = 10 \times 3/5 - 5 \times 4/5 = 2\ m.s^2$ w.r.t. wedge

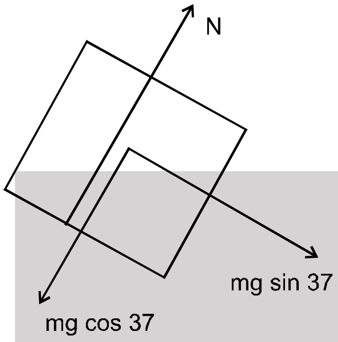
⇒ Block is not stationary w.r.t. wedge

N – ma sin 37 – mg cos 37 = 0 [Newton's II law for block]

⇒ N = 1 × 10 × 4/5 + 1 × 5 × 3/5

⇒ N = 11 N.

Net force acting on block w.r.t. ground.

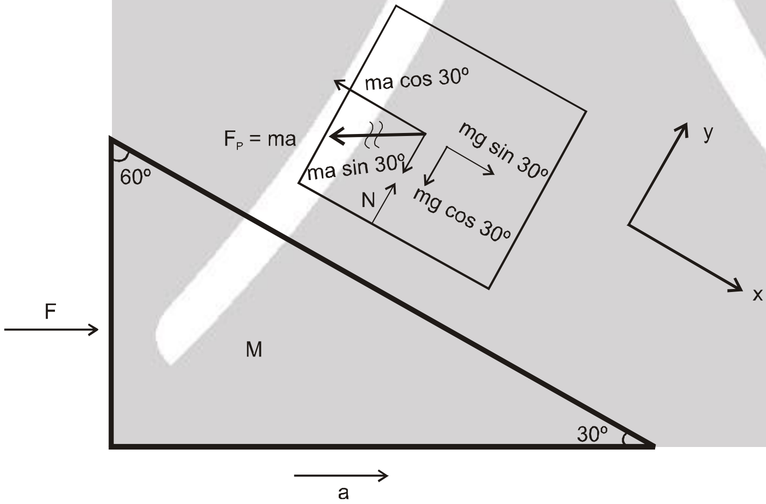


$$F = \sqrt{(mg\ \sin\ 37)^2 + (mg\ \cos\ 37 - N)^2}$$

$$= \sqrt{\left(10 \times \frac{3}{5}\right)^2 + \left(10\frac{4}{5} - 11\right)^2} = \sqrt{6^2 + 3^2}$$

$$F = 3\sqrt{5}\ N.$$

H-2.



F.B.D. of wedge is w.r.t. ground and

F.B.D. of block is w.r.t. wedge.

Let a is the acceleration of wedge due to force F.

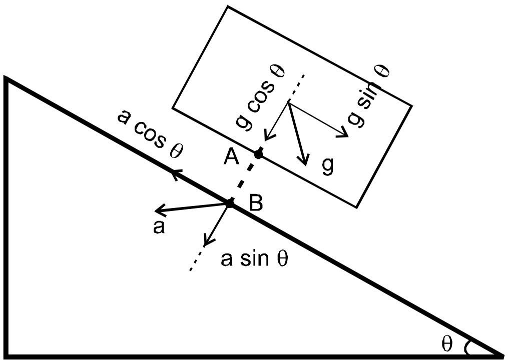
F_P is pseudo force on block

mg sin 30º – ma cos 30º = 0 [Equilibrium of block in x direction w.r.t. wedge] a = g tan 30º

F = (M + m)a [Newtons II law for the system of block and wedge in horizontal direction]

⇒ F = (M + m) g tan 30º.

H-3.



Acceleration of point A and B must be some along the line ⊥ to the surface

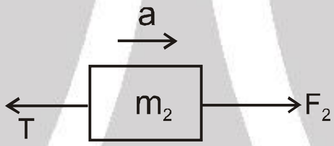
$\Rightarrow$ $a \sin\theta = g \cos\theta$

$a = g \cot\theta$

PART - III

1. Let a be acceleration of two block system towards right

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



The F.B.D. of m_2 is

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

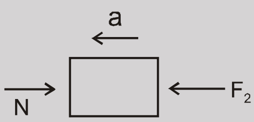
Solving $T = \frac{m_1\ m_2}{m_1 + m_2}\left(\frac{F_2}{m_2} + \frac{F_1}{m_1}\right)$

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

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

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

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



The FBD of m_2 is

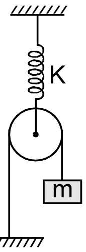
$\therefore$ $F_2 - N_2 = m_2 a$

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

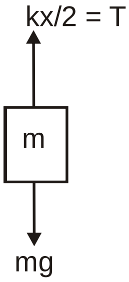
(D) Replace F_1 by $-F_1$ in result of C

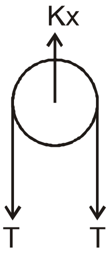
$$N = \frac{m_1\ m_2}{m_1 + m_2}\left(\frac{F_2}{m_2} - \frac{F_1}{m_1}\right)$$

2. (a)



F.B.D. of m ;

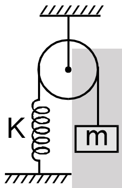




$2T = Kx$

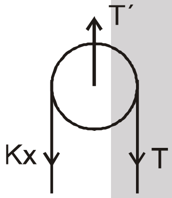
$\frac{kx}{2} = mg$ $\quad x = \frac{2mg}{k}$ $\quad T = mg$

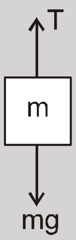
(b)



$kx - mg = 0$

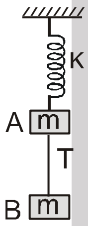
F.B.D of pulley



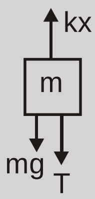


$x = \frac{mg}{k}$ $\quad T = kx$ $\quad \therefore T = mg$, $T' = kx + T = 2mg$

(c)

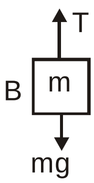


F.B.D. Block A



$kx = mg + T$ ....(1)

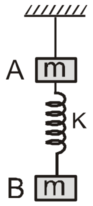
F.B.D. Block B



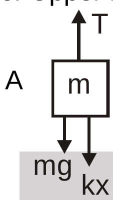
$T = mg$ ....(2)

$\therefore kx = 2mg$ $\quad x = \frac{2mg}{k}$

(d)

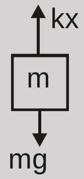


F.B.D. of Upper Block A



$T = mg + kx$ .... (1)

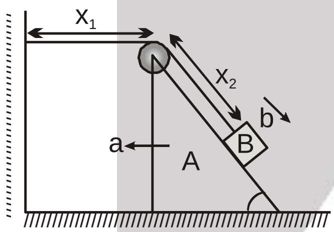
F.B.D. of Lower Block (B)

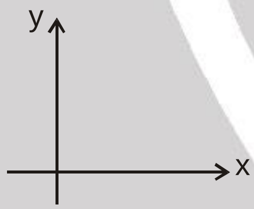


$kx = mg$ ..... (2) $\therefore\ x = \dfrac{mg}{k}$

By (1) & (2) $\quad T = 2mg$

3.





(a) Let b be acceleration of block B w.r.t. wedge

i.e. $\left|\vec{a}_{BW}\right| = b \quad \vec{a}_{BW} = b\cos\theta\,\hat{i} - b\sin\theta\,\hat{j}$

$\ell = x_1 + x_2$ ……..(1)

$\Rightarrow \quad 0 = \dfrac{dx_1}{dt} + \dfrac{dx_2}{dt} \quad \Rightarrow\ 0 = -a + b$

$\Rightarrow \quad b = a$ ……..(2)

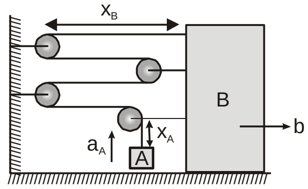
$\therefore \quad \vec{a}_{BW} = a\cos\theta\,\hat{i} - a\sin\theta\,\hat{j}$

$\vec{a}_{WG}$ = acceleration of wedge w.r.t. ground = $-a\,\hat{i}$ .... (3)

$\vec{a}_{BG} = \vec{a}_{BW} + \vec{a}_{WG}$

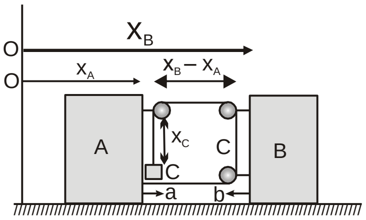
$\therefore\ \vec{a}_{BG} = (a\cos\theta - a)\,\hat{i} - a\sin\theta\,\hat{j}$ **Ans.**

(b)



$\ell = 4x_B + x_A \Rightarrow 0 = 4\dfrac{d^2x_B}{dt^2} + \dfrac{d^2x_A}{dt^2}$; $\quad \dfrac{d^2x_A}{dt^2} = -a_{AB}$; $\dfrac{d^2x_B}{dt^2} = b \Rightarrow 4b = a_{AB}$

(c)



$\vec{a}_{CA} = \frac{d^2x_c}{dt^2}$; $a = \frac{d^2x_A}{dt}$, $b = -\frac{d^2x_B}{dt^2}$

Length = $x_C + x_B - x_A + C + x_B - x_A$

$\Rightarrow \quad \ell = x_C + 2x_B - 2x_A + C$

$\Rightarrow 0 = \frac{d^2x_C}{dt^2} + 2\frac{d^2x_B}{dt^2} - 2\frac{d^2x_A}{dt^2}$

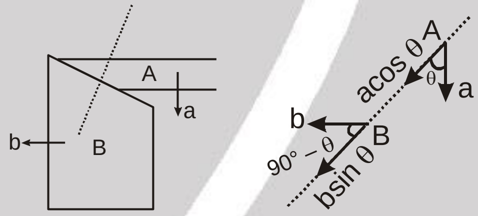
$\Rightarrow 0 = a_{CA} - 2b - 2a \qquad \therefore \vec{a}_{CA} = -(2a + 2b)$

$\vec{a}_{CG} = \vec{a}_{CA} + \vec{a}_{AG} = -(2a + 2b)\,\hat{j} + a\,\hat{i}$

$\therefore \vec{a}_{CG} = a\,\hat{i} - 2(a+b)\,\hat{j}$ **Ans.**

(d) Let a be acceleration of wedge A.

Acceleration of blocks A & B along normal to contact surface (shown by dotted line) must be equal.

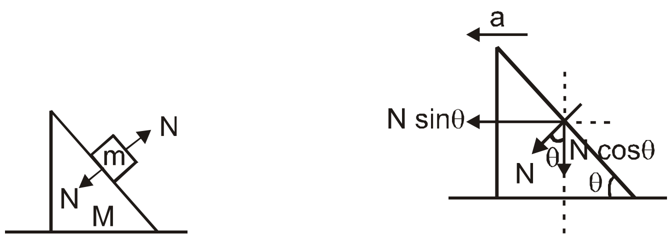


i.e. $b \sin\theta = a \cos\theta \qquad a = b \tan\theta$

$\therefore \vec{a}_A = -b \tan\theta\,\hat{j}$ **Ans.**

EXERCISE-2
PART - I

1.



$a = \frac{N\sin\theta}{M}$ along (– ve x axis)

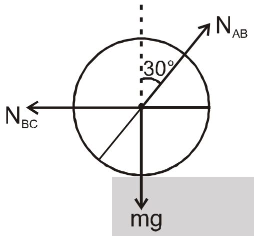
2. The free body diagram of cylinder is as shown.

Since net acceleration of cylinder is horizontal,

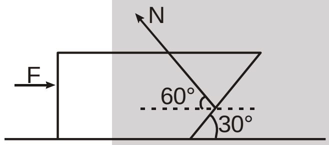
$N_{AB}\cos 30° = mg$ or $N_{AB} = mg$ .... (1)

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.



3.

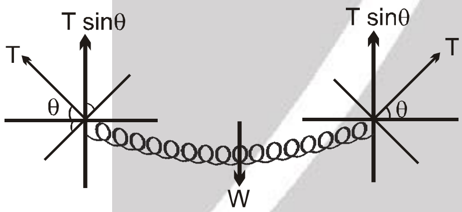


Acceleration of two mass system is $a = \frac{F}{2m}$ leftward

FBD of block A

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

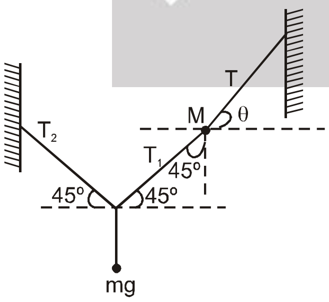
4.



$2T\sin\theta = W$

$T = W/2 \text{ cosec } \theta$

5.



$T_1\cos 45° = T_2\cos 45°$

$\Rightarrow \quad T_1 = T_2$

$(T_1 + T_2)\sin 45° = mg$

$\sqrt{2}\, T_1 = mg$

$T_1 = \frac{mg}{\sqrt{2}}$.

$$T \sin\theta = Mg + \frac{T_1}{\sqrt{2}}$$

$$T \sin\theta = Mg + \frac{mg}{2} \qquad ....(i)$$

$$T \cos\theta = \frac{T_1}{\sqrt{2}} = \frac{mg}{2} \qquad ....(ii)$$

Dividing (i) and (ii)

$$\tan\theta = \frac{M + m/2}{m/2} = 1 + \frac{2M}{m} \text{ Ans.}$$

6. $T = mg$

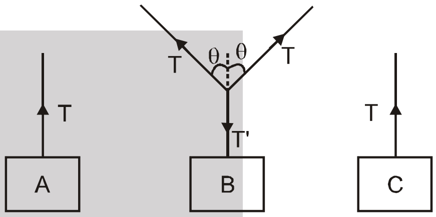
$2T\cos\theta = T'$

$T' = Mg$

$2mg \cos\theta = Mg$

$$\cos\theta = \frac{M}{2m} < 1$$

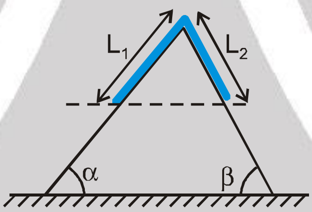
$M < 2m$



7. let L_1 and L_2 be the portions (of length) of rope on left and right surface of wedge as shown

$\therefore$ Magnitude of acceleration of rope

$$a = \frac{\frac{M}{L}[L_1 \sin\alpha - L_2 \sin\beta]\ g}{M} = 0 \qquad (\because L_1 \sin\alpha = L_2 \sin\beta)$$



8. By setting string length constant

$L = \ell_1 + 2\ell_2 + 2\ell_3$

After differentiation L' = 0 so

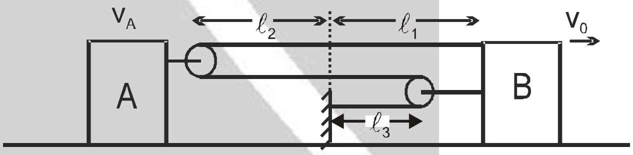
$-2v_A + v_0 + 2v_0 = 0$

$\Rightarrow \quad 3v_0 = 2v_A$

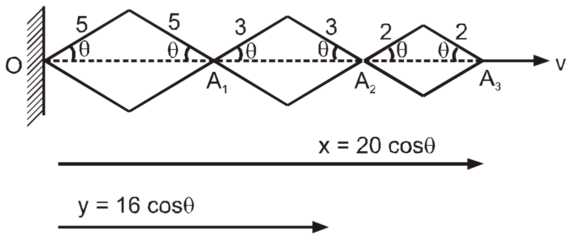
$$v_A = \frac{3}{2} v_0$$

$v_{AB} = v_A - v_B$

$$= \frac{v_0}{2} \text{ towards right.}$$

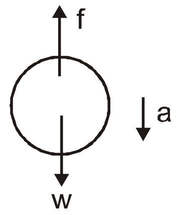


9.



$$v = \frac{dx}{dt} = -20 \sin\theta \frac{d\theta}{dt} \quad \Rightarrow \quad u = \frac{dy}{dt} = -16 \sin\theta \frac{d\theta}{dt} \quad \Rightarrow \quad u = \frac{4}{5} v = 0.8\ v$$

10.



$w - f = ma \qquad w - ma = g$

$w\left\{1 - \frac{m}{w}a\right\} = f \quad w\left\{1 - \frac{m}{mg}a\right\} = f \qquad\qquad w\left\{1 - \frac{a}{g}\right\} = f$

11. Legnth of groove = $\sqrt{3^2 + 4^2}$ = 5m

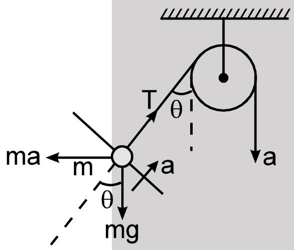
Acceleration along the incline = $g\sin\theta = g \sin 30^o = g/2$

Acceleration along the groove = $g/2 \cos(90 - \alpha) = g/2 \sin\alpha = \frac{g}{2} \times \frac{4}{5} = 4 m/s^2$

$v^2 = 2as$

$v = \sqrt{2 \times 4 \times 5} = \sqrt{40}$ m/sec.

12.



(Force diagram in the frame of the car)

Applying Newton's law perpendicular to string

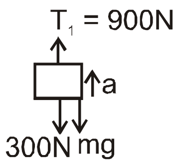
$mg \sin\theta = ma \cos\theta$

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

Applying Newton's law along string

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

13.

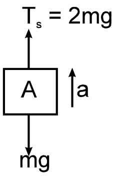


$900 - 300 - m \times 10 = ma \qquad 600 = m(10 + a)$

$\frac{600}{10 + a} = m$

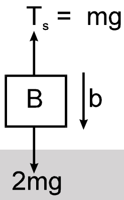
$\frac{600}{10 + 10} = m = \frac{600}{20} = 30$ kg.

14. For first case tension in spring will be



$T_s = 2mg$ just after 'A' is released.

$2mg - mg = ma \Rightarrow a = g$



In second case $T_s = mg$

$2mg - mg = 2mb$

$b = g/2$

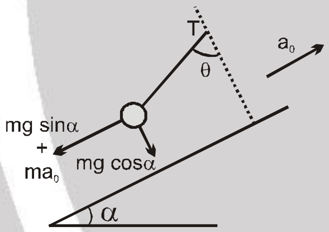
$a/b = 2$

15. $T \sin\theta = m(g \sin\alpha + a_0)$

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

$\Rightarrow \quad \tan\theta = \left(\dfrac{g\sin\alpha + a_0}{g\cos\alpha}\right)$

$\theta = \tan^{-1}\left(\dfrac{g\sin\alpha + a_0}{g\cos\alpha}\right)$



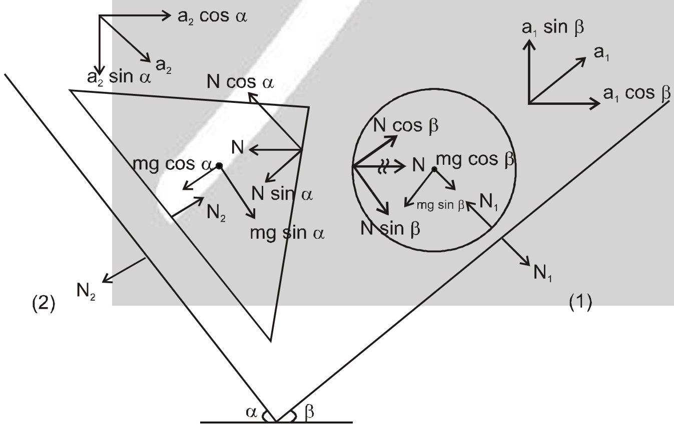
16. Slope of $v_{rel} - t$ curve is Constant.

$\Rightarrow \quad a_{rel} = \text{Const.} = a_1 - a_2 \neq 0$

Inference that at least one reference frame is accelerating both can't be non - accelerating simultaneously.

PART - II

1.



It is obvious that aceleration of cylinder is II to the wedge I and acceleration of triangular block is II to the wedge 2.

$a_2 \cos\alpha = a_1 \cos\beta$ [constrained relation between the contact surface of block and cylinder]

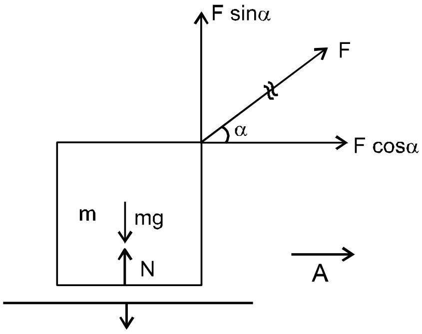
$N \cos\beta - m_1 g \sin\beta = m_1 a_1$ [Newton's II law for cylinder along the direction parallel to the wedge1]

$m_2 g \sin\alpha - N\cos\alpha = m_2 a_2$ [Newton's II law for block along the direction parallel to the wedge2]

By solving equation I, II and III we get

$$N = mg\left(\frac{\sin\alpha\cos\alpha + \sin\beta\cos\beta}{\cos^2\alpha + \cos^2\beta}\right) = 5\text{N Ans}$$

2.



$mg - N - F\sin\alpha = 0$ [Equilibrium of block in vertical direction]

at breaking off the contact N = 0 .

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

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

$\Rightarrow \quad t = \dfrac{mg}{a\ \sin\ \alpha}$

$F\cos\alpha = m A$ [Newton's second law for block in horizontal direction]

$\Rightarrow \quad at\cos\alpha = m\dfrac{d\upsilon}{dt}$

$$\int_0^{\upsilon} d\upsilon = \frac{a\ \cos\ \alpha}{m}\int_0^{t=\frac{mg}{a\sin\alpha}} t\ dt$$

$\Rightarrow \quad \upsilon = \dfrac{a\ \cos\ \alpha}{m}\dfrac{t^2}{2}$ 1

After putting time limits $\upsilon = \dfrac{mg^2\ \cos\ \alpha}{2a\ \sin^2\alpha}$

equation I can be written as $\dfrac{dx}{dt} = \dfrac{a\ \cos\alpha}{2m}\ t^2$

$$\int_0^x d\ x = \frac{a\ \cos\alpha}{2m}\int_0^t t^2\ dt = \frac{a\ \cos\alpha}{2\ m}\frac{t^3}{3}$$

After putting limits. $x = \dfrac{m^2g^3\ \cos\alpha}{6a^2\ \sin^3\alpha}$

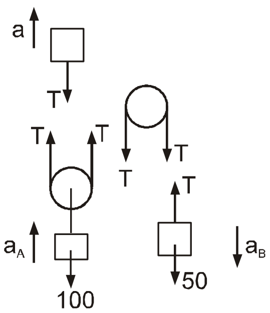
3. $v_{nm} = \dfrac{v_B + {}^{v_A}\!/_2}{2} = \dfrac{4 + {}^{4}\!/_2}{2} = \dfrac{4+2}{2} = 3$

4. $a_A = \dfrac{d^2y}{dt^2} = \dfrac{1}{2}$

$a_B = 8a_A$ by constrained relation

$a_B = 4\ m/s^2$

5.



$2a_A = a + a_B$

$2a_A = 3 + a_B$

$2T - 100 = 10a_A$

$50 - T = 5a_B$

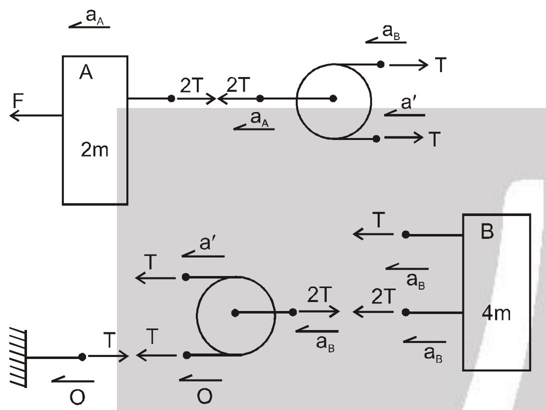
$\Rightarrow \quad a_B + a_A = 0$

$2a_A - 3 + a_A = 0$

$a_A = 1 m/s^2$

$\Rightarrow \quad a_B = -1 m/s^2$.

6.



$a_B + a' = 2a_A$ [constrained relation for pulley 1]

$O + a' = 2a_B$ [contrained relation for pulley 2]

From above two equations

$3a_B = 2a_A$

$\Rightarrow a_A = \frac{3}{2} a_B$ I

$F - 2T = 2ma_A$ [Netwon's II law for block A] II

$3T = 4\ m\ a_B$ [Netwon's II law for block B] III

From equation I, II and III

$a_B = \frac{3F}{17m}$.

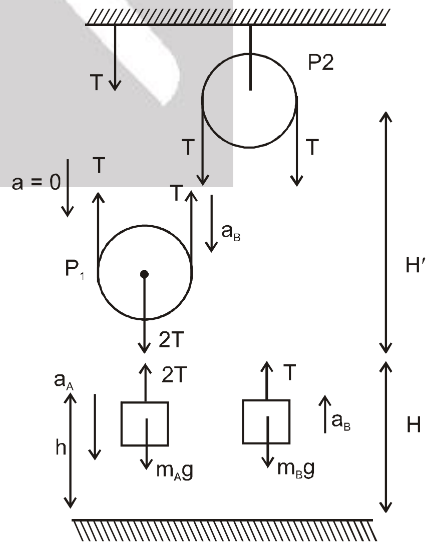
7. $m_Ag - 2T = m_Aa_A$ [Newton's II law for block A]

$T - m_Bg = m_Ba_B$ [Newton's II law for block B]

$a_B + O = 2a_A$ [constrained relation for pulley P1]

$m_A = 4m_B$ [Given in question]

From above four equations



$a_A = \frac{g}{4} = 2.5 m/s^2$

$a_B = \frac{g}{2} = 5 m/s^2$

$h = \frac{1}{2} a_At^2$ [Equation of motion for block A]

$\Rightarrow \quad t = \frac{2}{5}$ sec.

H is the distance travelled by block B in vertical direction till $\frac{2}{5}$ second

$\Rightarrow \quad H = \frac{1}{2} a_Bt^2$ [Equation of motion for block B]

⇒ $\frac{1}{2}5\left(\frac{2}{5}\right)^2$

H = 0.4 m

H´ is the distance travelled by block B due to gained velocity.

$v_1 = a_B t$

= 5 × 0.4

v_1 = 2 m/s

$v_2^2 = v_1^2 + 2a\,H´$

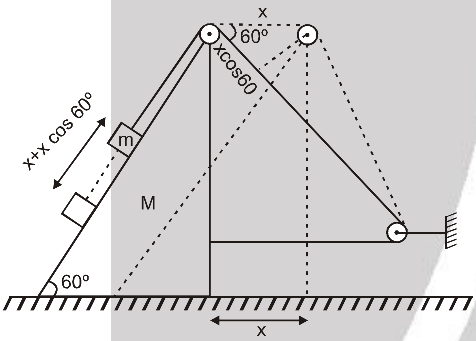
$0^2 = 2^2 + 2(-10)\,H´$

$H´ = \frac{2}{10} = 0.2$ m

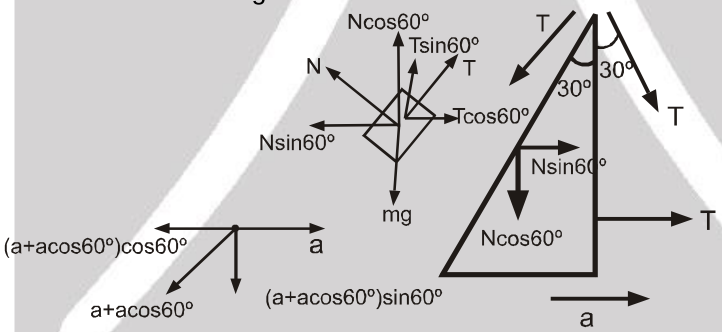
Total distance = H + H´

= 0.6 m = 60 cm.

8.



⇒ If acceleration of wedge is x then acceleration of block w.r.t. wedge is x + x cos60º.



T + N sin60º = Ma

$T + N\frac{\sqrt{3}}{2} = Ma$

T cos60º – N sin60º = m[a – a cos60º – a cos²60º]

$\frac{T}{2} - \frac{N\sqrt{3}}{2} = ma\left[1 - \frac{1}{2} - \frac{1}{4}\right]$

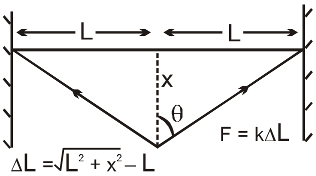
⇒ $T - N\sqrt{3} = \frac{ma}{2}$

mg – N cos60º – T sin60º = m(a sin60º + a cos60º sin60º)

$mg - \frac{N}{2} - \frac{T\sqrt{3}}{2} = ma\left[\frac{\sqrt{3}}{2} + \frac{\sqrt{3}}{4}\right]$

$2mg - N - T\sqrt{3} = \frac{3\sqrt{3}}{2}\,ma$ ⇒ $a = \frac{30\sqrt{3}}{23}$ m/s².

9.

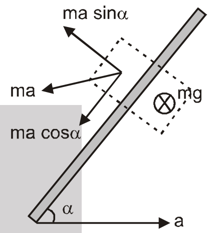


$\Delta L = \sqrt{L^2 + x^2} - L$

$F_{net_{कुल}} = mg - 2F\cos\theta$

$a_{net} = g - \dfrac{2k}{m}\left(\sqrt{L^2+x^2} - L\right)\dfrac{x}{\sqrt{L^2+x^2}}$

10. Acceleration of bead along rod is

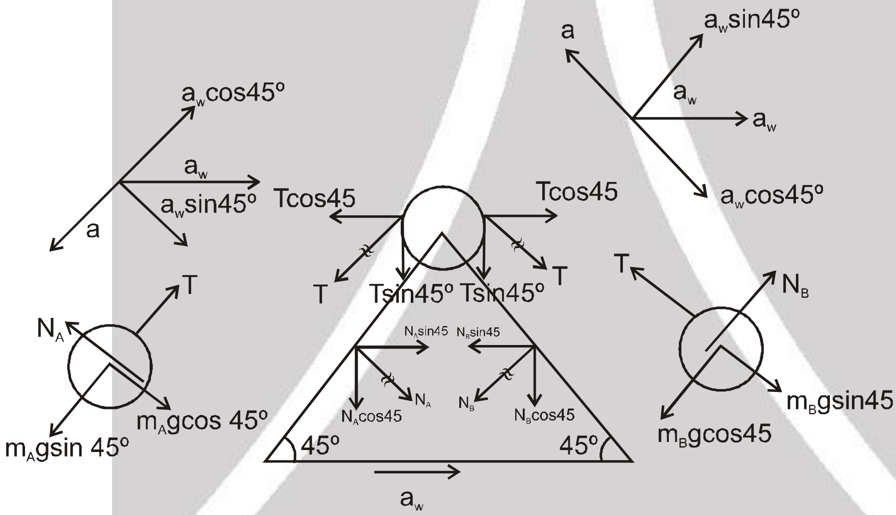


$\dfrac{ma\cos\alpha}{m}$ = a cosα

$\dfrac{1}{2}a\cos\alpha t^2 = \ell$

$t = \sqrt{\dfrac{2\ell}{a\cos\alpha}}$ = 2sec

11.



All the forces shown are in ground frame. a_w is the acceleration of wedge w.r.t ground and a is the acceleration of blocks w.r.t wedge.

$m_Ag\sin45^o - T = m_A(a - a_w\cos45^o)$ [Newton's II law for block A along the wedge in ground frame]

$m_Ag\cos\theta - N = m_A a_w\sin45^o$ [Newton's Ii law for block A in direction ⊥ to the wedge in ground frame.]

$T - m_Bg\sin45 = m_B(a - a_w\cos45)$ [Newton's II law for block B along the wedge in ground frame.]

$N_B - m_Bg\cos45^o = m_B(a_w\sin45)$ [Newton's II law for block B in direction ⊥ to the wedge in ground frame]

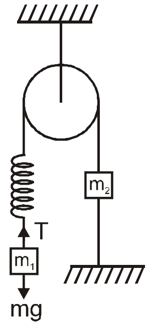
$N_A\sin45 + T\cos45 - N_B\sin45 - T\cos45 = m_wa_w$

[Newton's II law for wedge in horizontal direction in ground frame].

After solving above five equations we will get $a_w = \dfrac{2}{5}$ m/s² = 40 cm/s²

PART - III

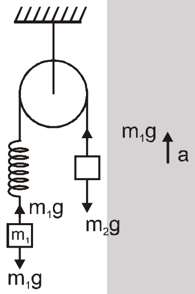
1.



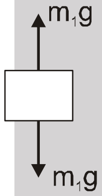
T = m_1g

when thred is burnt, tension in spring remains same = m_1g.

$m_1g - m_2g = m_2a$ $\qquad \frac{(m_1 - m_2)}{m_2} g = a$ = upwards



for m_1



a = o

2. F = αt

$a = \frac{dv}{dt} = \frac{\alpha}{m} t$ ....(i) straight line curve 1

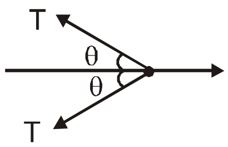
$dv = \frac{\alpha}{m}$ tdt

$v = \frac{\alpha}{m} \frac{t^2}{2}$ curve 2 ...(ii)

divide (ii) by (ii)

$v = \frac{t}{2} a = \frac{a}{2} \times \frac{am}{\alpha} = \frac{a^2 m}{2\alpha}$ $\rightarrow$ Paacebole curve 2.

3.



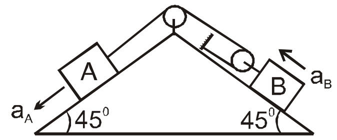
F = 2 T cos θ $\quad T = \frac{F}{2\cos\theta}$

θ↑ cos θ↓ T↑

on incrcasing θ, cosθ decreases and hence T increases.

4. By string constraint

$a_A = 2a_B$ ....(1)



Equation for block A.

$$10 \times 10 \times \frac{1}{\sqrt{2}} - T = 10\, a_A \quad \text{........(2)}$$

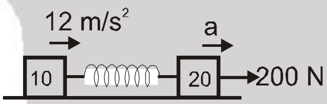
Equation for block B.

$$2T - \frac{400}{\sqrt{2}} = 40\, a_B \quad \text{........(3)}$$

Solving equation (1), (2) & (3), we get $a_A = \frac{-5}{\sqrt{2}}$ m/s^2

$$a_B = \frac{-5}{2\sqrt{2}} \text{ m/s}^2 \Rightarrow \quad T = \frac{150}{\sqrt{2}} \text{ N}$$

5. Apply NLM on the system



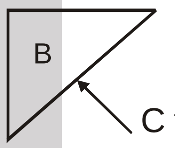
200 = 20 a + 12 × 10

$\frac{80}{20} = a$

= 4 m/s^2

Spring Force = 10 × 12 = 120 N

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

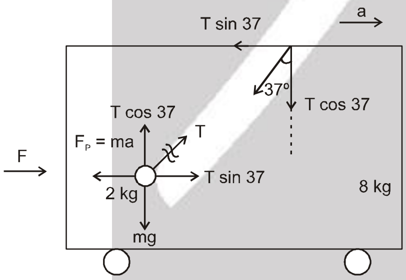


Block B moves downward as well as in negative x-direction. Downward acceleration of A and B will be equal due to constrain, thus w.r.t. B, A moves in positive x-direction.

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

7. Pseudo force depends on acceleraton of frame and mass of object

8.



F.B.D. of trolley is w.r.t. ground

F.B.D. of suspended mass is w.r.t. Trolley.

Tcos 37º – mg = 0 [Equilibrium of mass in y direction w.r.t. trolley]

$$\Rightarrow \quad T = \frac{5 \quad mg}{4} \qquad T = 25 \text{ N}$$

T sin 37º – ma = 0 [Equilibrium of mass in x direction w.r.t. trolley]

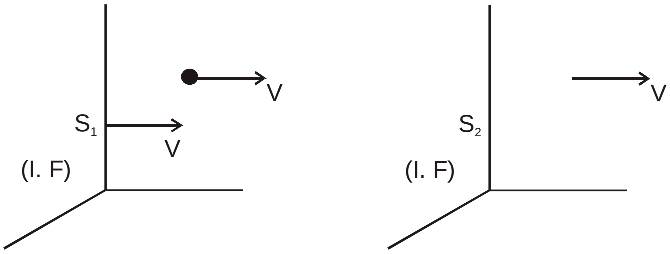
$$\Rightarrow \quad a = \frac{T \quad \sin 37}{m} = \frac{15}{2}$$

F – T sin37 = 8a [Newton's II law for trolley in x direction w.r.t. ground]

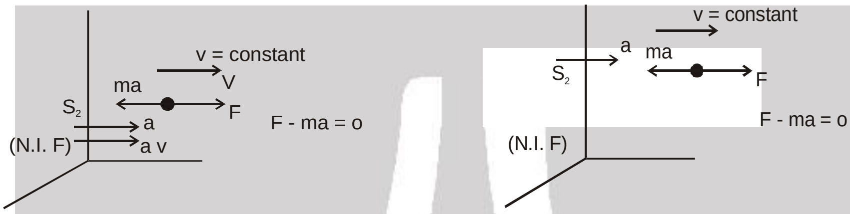
$\Rightarrow$ F = 8 ×15/2 + 25 × 3/5 F = 75 N

9. (A) True

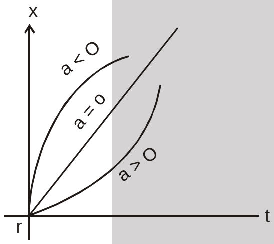
(B) True



Accelerated & moving with velocity V. Accelerated but not moving.



10.



x -t curve is

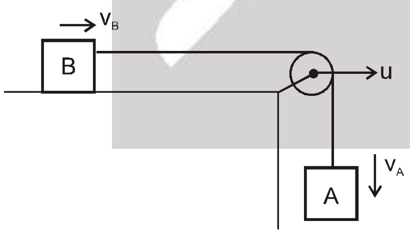
(1) straight line when a = 0

(2) concave up when uniform a > 0

(3) concave down when uniform a < 0.

In the region AB & CD acceleration = 0 = Force = 0

11.



By string constrain

$v_A + u - v_B = 0$

or $v_B = u + v_A$

Differentiating both side

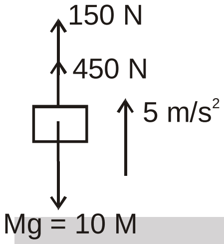
$a_B = 0 + a_A$ **Ans.**

PART - IV

1. FBD of Block in ground frame :

Applying N.L. $150 + 450 - 10\,M = 5M$

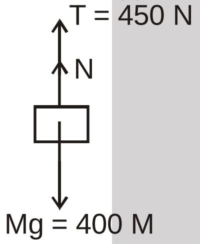
$\Rightarrow \quad 15\,M = 600 \quad \Rightarrow \quad M = \frac{600}{15}$



$\Rightarrow$ M = **40 Kg Ans.**

Normal on block is the reading of weighing machine i.e. 150 N.

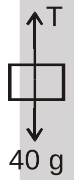
2. If lift is stopped & equilibrium is reached then



$450 + N = 400$

$\Rightarrow \quad N = -50$

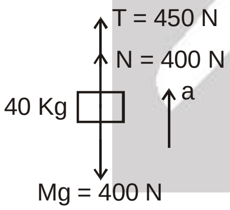
So block will lose the contact with weighing machine thus reading of weighing machine will be zero.



T = 40 g

So reading of spring balance will be 40 Kg.

3.



$a = \frac{950 - 400}{40} \quad \Rightarrow \quad a = \frac{450}{40} = \frac{45}{4}\ m/s^2$ **Ans.**

4. $a_p = \frac{10\ \ t}{10} = t$

$\therefore \quad \frac{dv}{dt} = t \quad \Rightarrow \quad \int_0^v dv = \int_0^t t\ \ dt \quad \Rightarrow \quad v = \frac{t^2}{2}$

Putting v = 2 we have t = 2 sec.

Now $\frac{dx}{dt} = \frac{t^2}{2} \quad \therefore \quad x_p = \left[\frac{t^3}{6}\right]_0^2 = \frac{4}{3}$

$x_B = 2 \times 2 = 4$ m

Hence relative displacement = 4 – 4/3 = 8/3 m

5. From above

$2t = t^3/6 \quad \Rightarrow \quad t^2 = 12 \quad \Rightarrow t = 2\sqrt{3}$ sec.

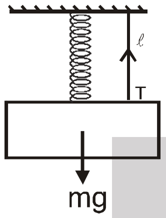
6. $a = t = 4$

$\therefore$ after 4 seconds $V_B = 2$ m/s

$V_p = 4^2/2 = 8$ m/s

$\therefore$ $V_{rel} = 8 - 2 = 6$ m/s.

9.



(i) $\Delta\ell = \ell/2$

$F_s = K\Delta\ell$

$< \frac{2mg}{\ell}\frac{\ell}{2}$

$F_s < mg$

$T + F_s = mg$

$T = mg - \frac{K\ell}{2}$

(ii) $mg - \frac{K\ell}{2} = ma$

$g - \frac{k\ell}{2m} = a$

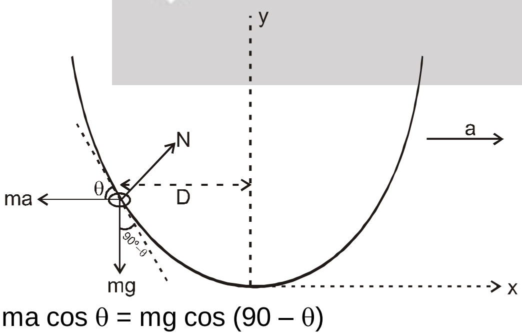
If it is so

$F_s > mg$

i.e., $\Delta\ell < \frac{\ell}{2}$ string unstretched & $T = 0$.

EXERCISE-3
PART - I

1.



$ma \cos\theta = mg \cos(90 - \theta)$

$\Rightarrow \frac{a}{g} = \tan\theta \qquad \Rightarrow \frac{a}{g} = \frac{dy}{dx}$

$\Rightarrow \frac{d}{dx}(kx^2) = \frac{a}{g} \qquad \Rightarrow x = \frac{a}{2gk} = D$

PART - II

1. Vertical component of acceleration of A

$a_1 = (g \sin\theta).\sin\theta$

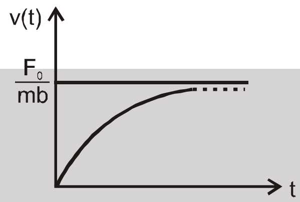
$= g \sin 60^o . \sin 60^o = g . 3/4$

That for B

$a_2 = g \sin 30^o . \sin 30^o = g \frac{1}{4}$

$\therefore \quad (a_{AB})_\perp = \frac{3g}{4} - \frac{g}{4} = \frac{g}{2} = 4.9 \text{ m/s}^2$

2. $F = ma = F_0 e^{-bt}$



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

$\int_0^v dv = \frac{F_0}{m}\int_0^t e^{-bt}dt \quad ; \quad v = \frac{F_0}{m}\left[\frac{e^{-bt}}{-b}\right]_0^t$

$v = \frac{F_0}{mb}\left(1-e^{-bt}\right)$

3. $a = -(g + \gamma v^2)$

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

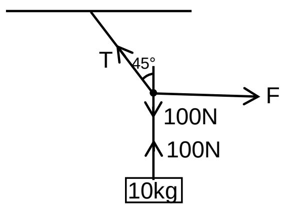
$\int_{v_0}^{0} \frac{dv}{g+\gamma v^2} = -\int_0^t dt$

$\frac{1}{\gamma}\int_{v_0}^{0} \frac{dv}{\left(\frac{g}{\gamma}+v^2\right)} = -\int_0^t dt$

$\frac{1}{\gamma}\frac{1}{\sqrt{\frac{g}{\gamma}}}\left[\tan^{-1}\left(\frac{v}{\sqrt{\frac{g}{\gamma}}}\right)\right]_{v_0}^{0} = -t$

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

4.

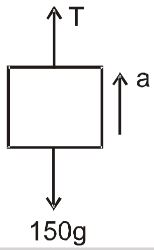


$\frac{T}{\sqrt{2}} = 100 \; ; \qquad \frac{T}{\sqrt{2}} = F \; ; \quad F = 100N.$

HIGH LEVEL PROBLEMS (HLP)

1. (a) (i) acceleration at t = 1s

$a = \frac{3.6 - 0}{2 - 0} = 1.8 \text{ m/s}^2$



T – 150 g = 150 a

T = 150 × 9.8 + 150 × 1.8

= 1740 N.

(ii) At t = 6s t = 6s, a = o

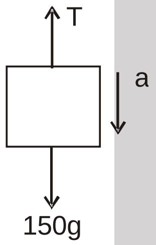
$\therefore$ T = 150 g N

= 150 × 9.8 = 1470N

(iii) At t = 118 t = 118 ; $a = -1.8 \text{ m/s}^2$

1.8 m/s^2 down

150 g – T = 150 a



T = 150 × (9.8 – 1.8) = 1200 N

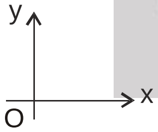
(b) Height = Area of v - t graph

= 1/2(12 + 8)3.6 = 36 m

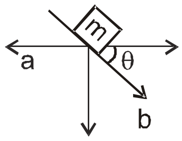
(c) Average velocity = $\frac{\text{Displacement}}{\text{time}} = \frac{36}{12} = 3 \text{ m/s}$

(d) Average acceleration = $\frac{\text{change in velocity}}{\text{time in taken}} = \frac{0-0}{12} = 0$

2.



$\vec{a}_A = -a\hat{i}$



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

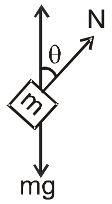
As there is no external force along x direction

$\therefore$ $2ma_{Ax} + ma_{Bx} = 0$

$\Rightarrow$ $2m(-a) + m\,(b\cos\theta - a) = 0$

$\Rightarrow$ $3a = b\cos\theta$ .... (1)

$\therefore$ $\vec{a}_B = 2a\,\hat{i} - 3a\,\hat{j}\,\tan\theta$ .... (2)



$\therefore$ along x-direction

$N \sin\theta = m \times 2a$ ....(2)

Along y-direction

$mg - N\cos\theta = m\,3a \tan\theta$ ....(3)

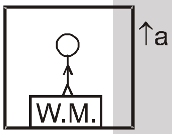
$\Rightarrow$ $mg - 2ma \cot\theta = 3ma \tan\theta$

$\Rightarrow$ $g = a\,[2\cot\theta + 3\tan\theta]$

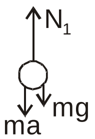
$$a = \frac{g\sin\theta\cos\theta}{2\cos^2\theta + 3\sin^2\theta}$$

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

3.

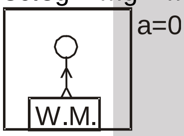


F.B.D. in NIF.

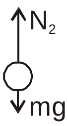


$N_1 = mg + ma$

$80.5g = mg + ma$ .... (1)

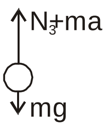


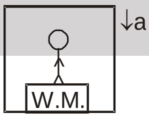
F.B.D. in



$N_2 = mg$ .... (2)

F.B.D. in N.I.F.





$N_3 + ma = mg$

$\Rightarrow N_3 = mg - ma$ $\Rightarrow 59.5\,g = mg - ma$ .... (3)

(1) + (3) $140\,g = 2mg$

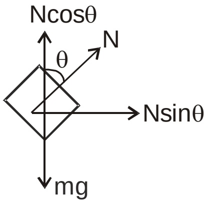
m = 70 kg Ans.

(a) $\therefore$ N_2 = true weight = **70 kg. Ans.**

(b) by (1) $80.5 \times g = mg + ma$

$\Rightarrow$ $10.5\,g = 70\,a$ $\Rightarrow$ $a = \frac{10.5 \times 10}{70} = 1.5\ m/s^2$ **Ans.**

4. Let a be acceleration of system

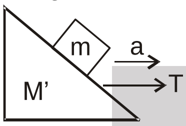


a → $N\sin\theta = ma$ ……(1)

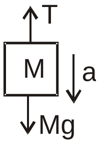
$N\cos\theta = mg$ ……(2)

Dividing (1) by (2) , we get

$a = g\tan\theta$ ……(3)



$T = (M' + m)\,a$ ……(4)

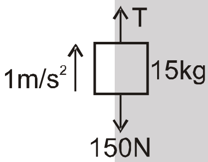


$Mg - T = Ma$ ……(5)

(4) + (5) $Mg = (M' + m + M)a$ ……(6)

by (3) & (6) $Mg = (M' + m + M)g\tan\theta$ $\Rightarrow M = \dfrac{M'+m}{\cot\theta - 1}$ **Ans.**

5.



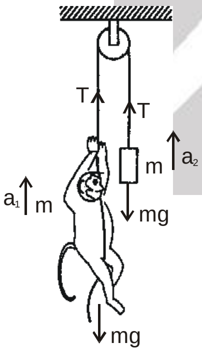
$T - 150 = 15 \times 1$

T = 165 N Ans.

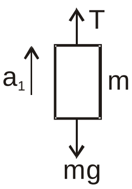
$S = \frac{1}{2}at^2$ $5 = \frac{1}{2} \times 1 \times t^2$

t = $\sqrt{10}$ s Ans.

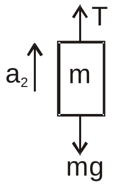
6. Let a_1 & a_2 be acceleration of monkey & Block respectively



F.B.D. Monkey



$ma_1 = T - mg$ $a_1 = \frac{T}{m} - g$ .... (1)

F.B.D. Block 

$ma_2 = T - mg \quad a_2 = \frac{T}{m} - g$ .... (2)

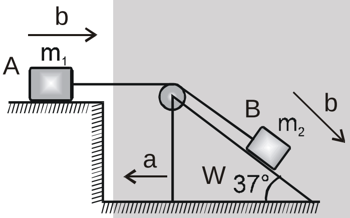
By (1) & (2)

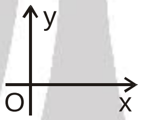
$a_1 = a_2 \qquad \therefore \qquad a_{rel} = 0$, as $u_{rel} = 0$

Relative displacement is zero.

Hence separation remains same.

7. Let b be acceleration of masses m_1 & m_2 with respect to wedge & a be acceleration of wedge w.r.t. ground.





$\vec{a}_{WG} = -a\hat{i}$ ...... (1)

$\vec{a}_{AG} = \vec{a}_{AW} + \vec{a}_{WG}$

$= b\hat{i} - a\hat{i} \Rightarrow \vec{a}_{AG} = (b - a)\ \hat{i}$ .... (2)

$\vec{a}_{BG} = \vec{a}_{BW} + \vec{a}_{WG} = b\cos 37°\ \hat{i} - b\sin 37°\ \hat{j} - a\hat{i}$

$\vec{a}_{BG} = \left(\frac{4b}{5} - a\right)\hat{i} - \frac{3b}{5}\hat{j}$ .... (3)

As $F_{external,\ x} = 0$

$\Rightarrow \quad M_A a_{AG\ ,\ x} + M_B a_{BG\ ,\ x} + m_W\ a_{WG\ ,\ x} = 0$

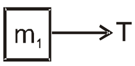
$\Rightarrow \quad 1.3\ (b - a) + 1.5\left(\frac{4b}{5} - a\right) + 3.45\ (-a) = 0$

$\Rightarrow \quad (1.3 + 1.5 + 3.45)\ a = (1.3 + 1.2)\ b$

$\Rightarrow \quad 6.25\ a = 2.5\ b$

$\Rightarrow \quad 5a = 2\ b$ ....(1)

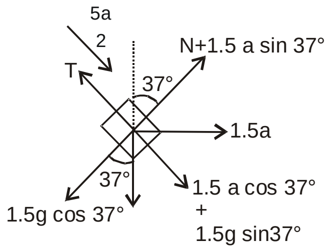
$b - a = \frac{3}{2}a$

F.B.D. System : m_1 

Frame : $T = 1.3 \times \frac{3}{2}a$ ....(2)

F.B.D. System : m_2

Frame :



Along the incline :

$$1.5a\frac{4}{5} + 1.5g\ \frac{3}{5} - T = 1.5\frac{5a}{2}$$

$\Rightarrow$ $9 - T = 2.55\ a$ ....(3)

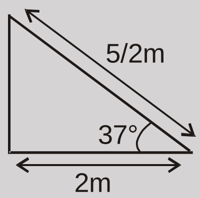
by (2) & (3) (2)

$9 = 4.5\ a$

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

$\therefore$ $b = 5 m/s^2$

$S = \frac{1}{2}bt^2 \quad \Rightarrow \quad \frac{5}{2} = \frac{1}{2} \times 5t^2 \quad t = 1\ s$



(i) $\therefore\ V_{m_3} = u + a_{m_3} = 0 + 2 \times 1$

$\therefore\ V_{m_3} = 2 m/s$ **Ans.**

(ii) $\vec{a}_{BG} = \left(\frac{4}{5} \times 5 - 2\right)\hat{i} - \frac{3}{5} \times 5\,\hat{j}$

$\vec{a}_{BG} = 2\,\hat{i} - 3\,\hat{j}$

$a_{M_2} = |\vec{a}_{BG}| = \sqrt{13}\ m/s^2$

$V_{M_2} = a_{m_2}\ t$

$V_{M_2} = \sqrt{13}\ m/s^2$ **Ans.**

by (2) $T = \frac{3.9}{2} \times 2 \quad \Rightarrow T = 3.9$ N Ans.

8. $m > m'$

Let a be acceleration of M w.r.t. ground

b_1 = acceleration of m' w.r.t. ground

b_2 = acceleration of m w.r.t. ground

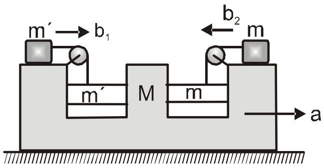
$\vec{a}_{MG} = a\,\hat{i} \qquad a_{m'G} = b_1\,\hat{i} \qquad \vec{a}_{mG} = -b_2\,\hat{i}$

As $F_{external\ x} = 0$

$\Rightarrow$ $m'a_{m'Gx} + (M + m + m')\ a_{MGx} + m\ a_{MG,\ x} = 0$

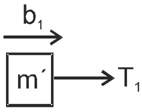
$m'b_1 + (M + m + m')a - mb_2$

$m'b_2 - m'b_1 = (M + m + m')a$ ....(1)



F.B.D. System : m'

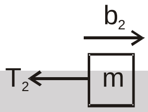
Frame : I.F.



$T_1 = m'b_1$ .... (2)

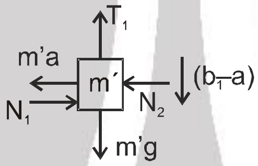
F.B.D. System : M

Frame :



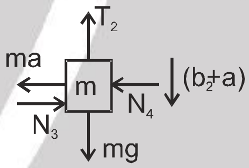
$T_2 = mb_2$ .... (3)

F.B.D.
System



Frame : N.I.F. $m'g - T_1 = m'(b_1 - a)$ .... (4)

F.B.D.
System :



Frame : N.I.F. $mg - T_2 = m(b_2 + a)$ .... (5)

(2) + (4) $\Rightarrow$ $m'g = m'(2b_1 - a)$

$g = 2b_1 - a$ .... (6)

(3) + (5) $\Rightarrow$ $mg = m(2b_2+a)$ .... (7)

$g = 2b_2 + a$

Solving (1), (6) & (7) we get

$$a = \frac{(m - m')g}{2M + 3m + 3m'} \quad \textbf{Ans.}$$

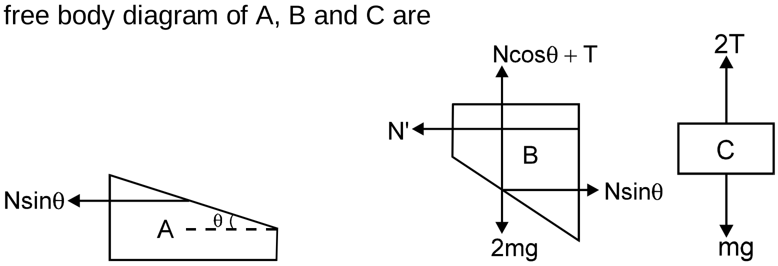
9. Let the acceleration of B downwards be $a_B = a$

From constraint ; acceleration of A and C are

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

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

free body diagram of A, B and C are



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

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

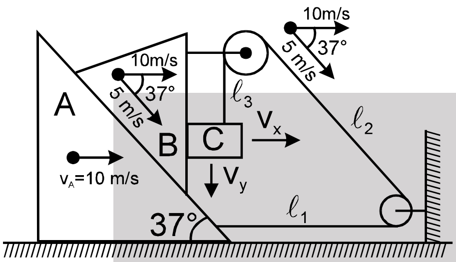
$2T - mg = m\dfrac{a}{2}$ ....(3)

solving we get

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

Ans. $3\,m/s^2$ upwards

10.



Let v_x and v_y be the horizontal and vertical component of velocity of block C.

The component of relative velocity of B and C normal to the surface of contact is zero.

$\therefore \quad 10 + 5\cos 37° - v_x = 0$ ...(1)

$v_x = 14$ m/s

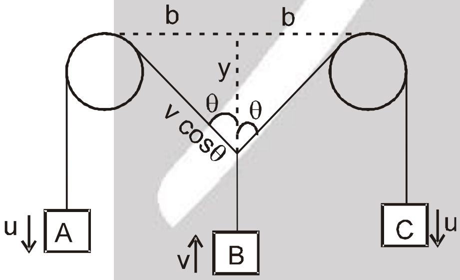
From the figure $\ell_1 + \ell_2 + \ell_3$ = constant

$$\therefore \quad \frac{d\ell_1}{dt} + \frac{d\ell_2}{dt} + \frac{d\ell_3}{dt} = 0$$

$(-10) + (-5 - 10\cos 37°) + (-5\sin 37° + v_y) = 0 \quad \therefore \quad v_y = 26$ m/s.

11. Pseudo force on a particle depends on mass of particle and negative accleration of observer.

12.



$v\cos\theta = u$

$v = u\sec\theta$

$$\frac{dv}{dt} = u\sec\theta\tan\theta\,\frac{d\theta}{dt} \text{ .... I}$$

$\tan\theta = b/y$

$$\sec^2\theta\,\frac{d\theta}{dt} = -\frac{b}{y^2}\,\frac{dy}{dt}$$

$$= +\frac{b}{y^2}\cos^2\theta\,\frac{u}{\cos\theta}$$

$$= \frac{1}{b}\,\frac{b^2}{y^2}\cos\theta\,u$$

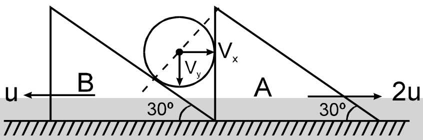
$= \frac{u\cos\theta}{b}\tan^2\theta$ II

$\Rightarrow \frac{dv}{dt} = \frac{u^2}{b}\tan^3\theta$ from I and II $\quad\quad \Rightarrow \frac{dv}{dt} = \frac{u^2}{b}\tan^3\theta$

13. **Method - I**

As cylinder will remains in contact with wedge A

$V_x = 2u$



As it also remain in contact with wedge B

$u \sin 30° = V_y \cos30° - V_x \sin30°$

$V_y = V_x \frac{\sin30°}{\cos30°} + \frac{U\sin30°}{\cos30°}$

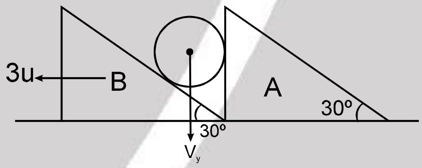
$V_y = V_x \tan30° + u \tan 30°$

$V_y = 3u \tan30° = \sqrt{3}\,u$

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

Method - II

In the frame of A

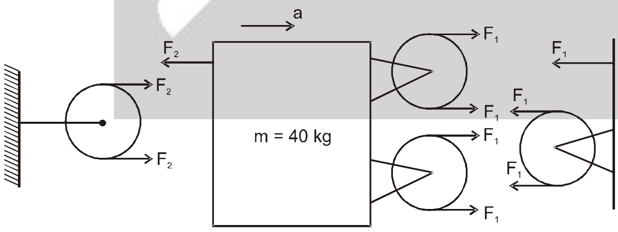


$3u \sin 30^o = V_y\cos30^o$

$\Rightarrow \quad V_y = 3u \tan 30^o = \sqrt{3}\,u$

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

14.



$4F_1 - F_2 = ma$ [Newtons II law for block]

$\Rightarrow a = \frac{4F_1 - F_2}{m}$

t = 0 to 2 sec.

$F_1 = 30N$

$F_2 = 10N$

$\Rightarrow a = \frac{4\times30-10}{40} = 2.75 \text{ m/s}^2$

t = 2 to 4 sec

$F_1 = 30N$
$F_2 = 20N$

$\Rightarrow a = \frac{4 \times 30 - 20}{40} = 2.5 \text{ m/s}^2$

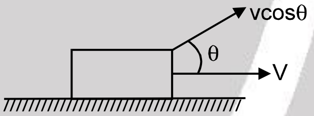
For t = 4 to 6 sec.
$F_1 = 10N$
$F_2 = 40N$

$\Rightarrow a = \frac{4 \times 10 - 40}{40} = 0 \text{ m/s}^2$

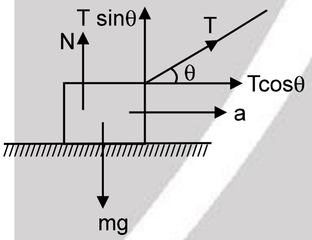
For t = 6 to 12 sec
$F_1 = 0$, $F_2 = 0$
$\Rightarrow a = 0 \text{ m/s}^2$
$V_{12} - V_0 = a_{0-2}(2 - 0) + a_{2-4}(4 - 2) + a_{4-6}(6 - 4) + a_{6-12}(12-6)$
$V_{12} - 1.5 = 2.75 \times 2 + 2.5 \times 2 + 0 \times 2 + 0 \times 6$
$V_{12} = 12$ m/s

15. By constraint velocity component of block along the string should be u

$\Rightarrow$ $v \cos\theta = u$ or $v = u \sec\theta$ ....(1)

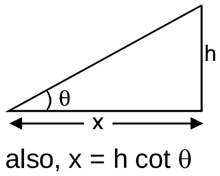


from (1) $a = \frac{dv}{dt} = u \sec\theta \tan\theta \frac{d\theta}{dt}$ ....(2)



Initially when block is at a large distance θ is a small component of T in vertical direction is very small. As block comes nearer and nearer. T sin θ increases and N decreases.
When T sinθ = mg then block just loses contact with the ground

so $T \sin\theta = mg$ ....(3)
$T \cos\theta = ma$ ....(4)
(3) & (4) $\Rightarrow$
$a \tan\theta = g$ ....(5)



also, $x = h \cot\theta$

$\frac{dx}{dt} = - h \text{ cosec}^2\theta \frac{d\theta}{dt}$

$\Rightarrow - v = - h\text{cosec}^2\theta \frac{d\theta}{dt}$ [as x is decreasing $\frac{dx}{dt} = - v$]

or $\frac{u\sec\theta}{h\,\text{cosec}^2\theta} = \frac{d\theta}{dt}$ ....(using (1)) ....(6)

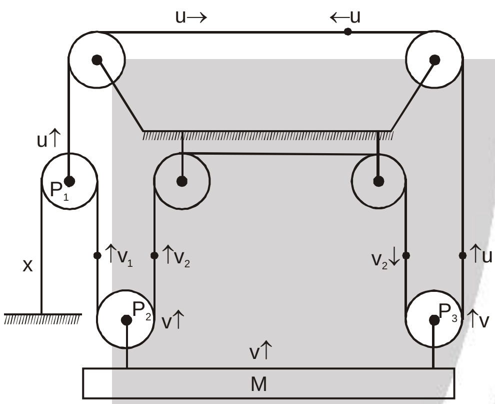
using (2) , (5) and (6) we get

$u\sec\theta\tan\theta\left(\frac{u\sec\theta}{h\,\text{cosec}^2\theta}\right)\tan\theta = g$

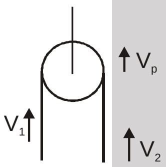
putting values of u, h & g we get.

$\tan^4\theta = 1 \Rightarrow \theta = \frac{\pi}{4}$ **Ans.** $\theta = \frac{\pi}{4}$

16.



$V_p = \frac{V_1 + V_2}{2}$



Pulley P_1

$u = \frac{0 + v_1}{2}$ .... (1)

Pulley P_2

$v = \frac{v_1 + v_2}{2} \Rightarrow 2V = V_1 + V_2$ ... (2)

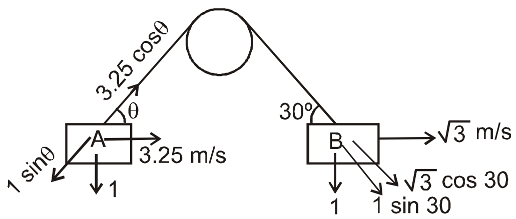
Pulley P_3 $v = \frac{-v_2 + u}{2}$ .... (3)

Eliminate V_1 & V_2 to get

$\Rightarrow$ 2u + u – 2u = 2v $\Rightarrow$ 3u = 4v

$v = \frac{3}{4}u$ **Ans.**

17. Solving problem in the frame of pulley



$3.25\cos\theta - 1\sin\theta = \sqrt{3}\cos 30 + 1\sin 30$

$3.25 \cos\theta - \sin\theta = \frac{3}{2} + \frac{1}{2}$

$3.25 \cos\theta - \sin\theta = 2$

$13 \cos \theta - 4 \sin \theta = 8$

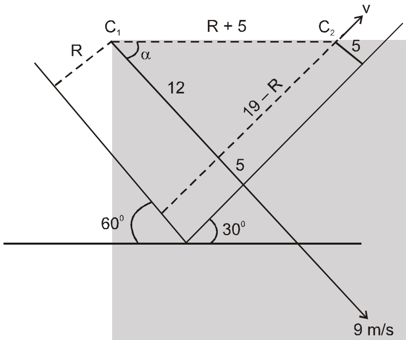
$13\sqrt{1 - \sin^2 \theta} = 8 + 4 \sin\theta$

$169 - 169 \sin^2\theta = 64 + 16 \sin^2\theta + 64 \sin\theta$

$185 \sin^2\theta + 64 \sin\theta - 105 = 0$

$\Rightarrow \sin \theta = \frac{3}{5} \qquad \Rightarrow \tan \theta = \frac{3}{4}$.

18.



$9 \cos\alpha = v \sin\alpha \qquad \rightarrow \qquad$ (i)

$\frac{19 - R}{12} = \tan\alpha \qquad \rightarrow \qquad$ (ii)

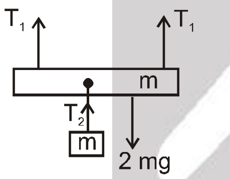
$(R + 5)^2 = (12)^2 + (19 - R)^2 \qquad$ [Pythagorean]

$\Rightarrow R = 10$

Hence from (i) and (ii)

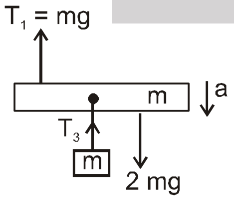
$v = 12$ m/s

19. Before cutting the spring



$T_2 = mg$

After cutting the spring



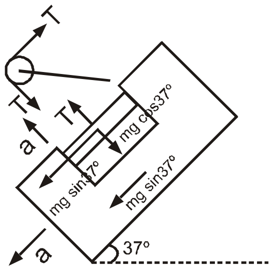
$2mg - mg = 2\,ma$

$a = g/2$

$T_3 = mg/2$

$T_2 - T_3 = mg - \frac{mg}{2} = \frac{mg}{2}$

20.



$T - mg\cos 37^\circ = ma$

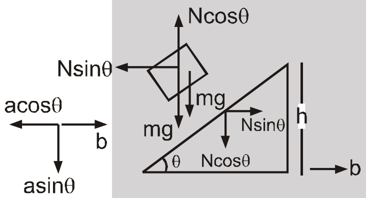
$2mg\sin 37^\circ - T = 2ma$

$\Rightarrow \quad a = \frac{4}{3}$ m/s

$\Rightarrow \quad a_B = \frac{4}{3}$ m/s

$\Rightarrow \quad a_A = \frac{4\sqrt{2}}{3}$ m/s

21.



$N\sin\theta = mb$

$N\sin\theta = m(a\cos\theta - b)$

$2mg - N\cos\theta = ma\sin\theta$

$\Rightarrow \quad a = \frac{4g\sin\theta}{1+\sin^2\theta}$

$\Rightarrow \quad h = \frac{1}{2}a\sin\theta\, t^2 \qquad \Rightarrow \qquad t = \sqrt{\frac{h(1+\sin^2\theta)}{2g\sin^2\theta}}$.