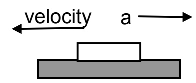
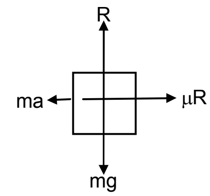
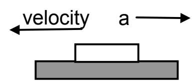
SOLUTIONS TO CONCEPTS
CHAPTER 6

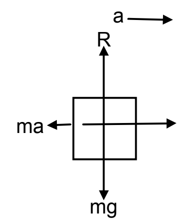
1. Let m = mass of the block
   From the freebody diagram,
   $R - mg = 0 \Rightarrow R = mg$ ...(1)
   Again $ma - \mu R = 0 \Rightarrow ma = \mu R = \mu mg$ (from (1))
   $\Rightarrow a = \mu g \Rightarrow 4 = \mu g \Rightarrow \mu = 4/g = 4/10 = 0.4$
   The co-efficient of kinetic friction between the block and the plane is 0.4



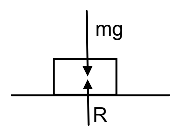


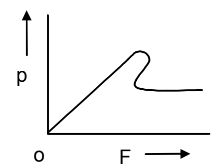
2. Due to friction the body will decelerate
   Let the deceleration be 'a'
   $R - mg = 0 \Rightarrow R = mg$ ...(1)
   $ma - \mu R = 0 \Rightarrow ma = \mu R = \mu mg$ (from (1))
   $\Rightarrow a = \mu g = 0.1 \times 10 = 1 m/s^2.$
   Initial velocity u = 10 m/s
   Final velocity v = 0 m/s
   $a = -1 m/s^2$ (deceleration)
   $$S = \frac{v^2 - u^2}{2a} = \frac{0 - 10^2}{2(-1)} = \frac{100}{2} = 50m$$
   It will travel 50m before coming to rest.



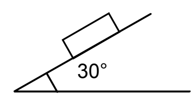


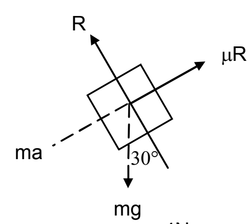
3. Body is kept on the horizontal table.
   If no force is applied, no frictional force will be there
   $f \rightarrow$ frictional force
   $F \rightarrow$ Applied force
   From grap it can be seen that when applied force is zero, frictional force is zero.



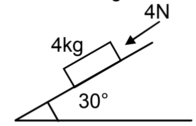


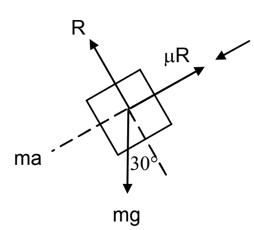
4. From the free body diagram,
   $R - mg \cos \theta = 0 \Rightarrow R = mg \cos \theta$ ..(1)
   For the block
   U = 0, s = 8m, t = 2sec.
   $\therefore s = ut + ½ at^2 \Rightarrow 8 = 0 + ½ a 2^2 \Rightarrow a = 4 m/s^2$
   Again, $\mu R + ma - mg \sin \theta = 0$
   $\Rightarrow \mu mg \cos \theta + ma - mg \sin \theta = 0$ [from (1)]
   $\Rightarrow m(\mu g \cos \theta + a - g \sin \theta) = 0$
   $\Rightarrow \mu \times 10 \times \cos 30° = g \sin 30° - a$
   $\Rightarrow \mu \times 10 \times \sqrt{(3/3)} = 10 \times (1/2) - 4$
   $\Rightarrow (5/\sqrt{3})\mu = 1 \Rightarrow \mu = 1/(5/\sqrt{3}) = 0.11$
   $\therefore$ Co-efficient of kinetic friction between the two is 0.11.



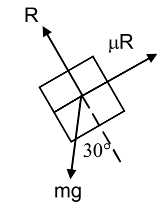


5. From the free body diagram
   $4 - 4a - \mu R + 4g \sin 30° = 0$ …(1)
   $R - 4g \cos 30° = 0$ ...(2)
   $\Rightarrow R = 4g \cos 30°$
   Putting the values of R is & in equn. (1)
   $4 - 4a - 0.11 \times 4g \cos 30° + 4g \sin 30° = 0$
   $\Rightarrow 4 - 4a - 0.11 \times 4 \times 10 \times (\sqrt{3}/2) + 4 \times 10 \times (1/2) = 0$
   $\Rightarrow 4 - 4a - 3.81 + 20 = 0 \Rightarrow a \approx 5 m/s^2$
   For the block u =0, t = 2sec, $a = 5 m/s^2$
   Distance $s = ut + ½ at^2 \Rightarrow s = 0 + (1/2) 5 \times 2^2 = 10m$
   The block will move 10m.





6. To make the block move up the incline, the force should be equal and opposite to the net force acting down the incline = μ R + 2 g sin 30°



(body moving down)

= 0.2 × (9.8) $\sqrt{3}$ + 2 I 9.8 × (1/2)   [from (1)]

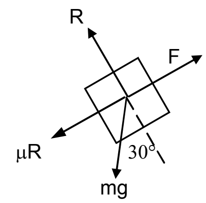
= 3.39 + 9.8 = 13N

With this minimum force the body move up the incline with a constant velocity as net force on it is zero.

b) Net force acting down the incline is given by,

F = 2 g sin 30° – μR

= 2 × 9.8 × (1/2) – 3.39 = 6.41N



(body moving us)

Due to F = 6.41N the body will move down the incline with acceleration.

No external force is required.

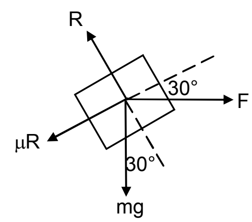
∴ Force required is zero.

7. From the free body diagram

$g = 10m/s^2$,   m = 2kg, $\theta = 30°$, $\mu = 0.2$

$R - mg\cos\theta - F\sin\theta = 0$

$\Rightarrow R = mg\cos\theta + F\sin\theta$ ...(1)



And $mg\sin\theta + \mu R - F\cos\theta = 0$

$\Rightarrow mg\sin\theta + \mu(mg\cos\theta + F\sin\theta) - F\cos\theta = 0$

$\Rightarrow mg\sin\theta + \mu\, mg\cos\theta + \mu\, F\sin\theta - F\cos\theta = 0$

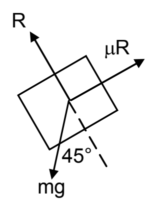
$$\Rightarrow F = \frac{(mg\sin\theta - \mu mg\cos\theta)}{(\mu\sin\theta - \cos\theta)}$$

$$\Rightarrow F = \frac{2\times 10\times(1/2) + 0.2\times 2\times 10\times(\sqrt{3}/2)}{0.2\times(1/2) - (\sqrt{3}/2)} = \frac{13.464}{0.76} = 17.7N \approx 17.5N$$

8. m → mass of child

R – mg cos 45° = 0

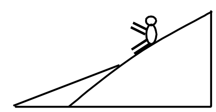
$\Rightarrow$ R = mg cos 45° = mg /$\sqrt{2}$ ...(1)



Net force acting on the boy due to which it slides down is mg sin 45° - μR

= mg sin 45° - μ mg cos 45°

= m × 10 (1/ $\sqrt{2}$) – 0.6 × m × 10 × (1/ $\sqrt{2}$)



= m [(5/ $\sqrt{2}$) – 0.6 × (5 / $\sqrt{2}$)]

= m(2 $\sqrt{2}$)

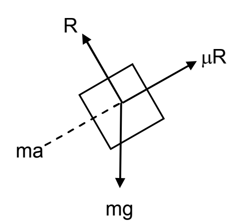
$$\text{acceleration} = \frac{\text{Force}}{\text{mass}} = \frac{m(2\sqrt{2})}{m} = 2\sqrt{2}\ m/s^2$$

9. Suppose, the body is accelerating down with acceleration 'a'.

From the free body diagram

$R - mg\cos\theta = 0$

$\Rightarrow R = mg\cos\theta$ ...(1)



$ma + mg\sin\theta - \mu R = 0$

$$\Rightarrow a = \frac{mg(\sin\theta - \mu\cos\theta)}{m} = g(\sin\theta - \mu\cos\theta)$$

For the first half mt. u = 0, s = 0.5m,   t = 0.5 sec.

So, v = u + at = 0 + (0.5)4 = 2 m/s

$S = ut + ½ at^2 \Rightarrow 0.5 = 0 + ½ a (0/5)^2 \Rightarrow a = 4m/s^2$ ...(2)

For the next half metre

u` = 2m/s, $a = 4m/s^2$,   s= 0.5.

$\Rightarrow 0.5 = 2t + (1/2)\, 4\, t^2 \Rightarrow 2\, t^2 + 2\, t - 0.5 = 0$

$\Rightarrow 4t^2 + 4t - 1 = 0$

$\therefore = \dfrac{-4 \pm \sqrt{16+16}}{2 \times 4} = \dfrac{1.656}{8} = 0.207\text{sec}$

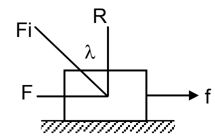
Time taken to cover next half meter is 0.21sec.

10. f $\rightarrow$ applied force

$F_i \rightarrow$ contact force

F $\rightarrow$ frictional force

R $\rightarrow$ normal reaction

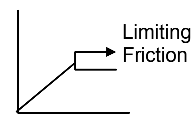


$\mu = \tan\lambda = F/R$

When F = μR, F is the limiting friction (max friction). When applied force increase, force of friction increase upto limiting friction (μR)

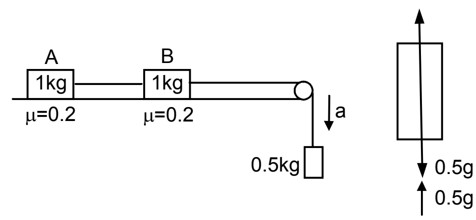
Before reaching limiting friction

F < μR



$\therefore \tan\lambda = \dfrac{F}{R} \le \dfrac{\mu R}{R} \Rightarrow \tan\lambda \le \mu \Rightarrow \lambda \le \tan^{-1}\mu$

11. From the free body diagram



$T + 0.5a - 0.5g = 0$ ...(1)

$\mu R + 1a + T_1 - T = 0$ ...(2)

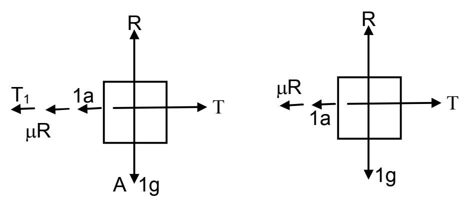
$\mu R + 1a - T_1 = 0$

$\mu R + 1a = T_1$ ...(3)

From (2) & (3) $\Rightarrow \mu R + a = T - T_1$

$\therefore T - T_1 = T_1$

$\Rightarrow T = 2T_1$



Equation (2) becomes $\mu R + a + T_1 - 2T_1 = 0$

$\Rightarrow \mu R + a - T_1 = 0$

$\Rightarrow T_1 = \mu R + a = 0.2g + a$ ...(4)

Equation (1) becomes $2T_1 + 0/5a - 0.5g = 0$

$\Rightarrow T_1 = \dfrac{0.5g - 0.5a}{2} = 0.25g - 0.25a$ ...(5)

From (4) & (5) $0.2g + a = 0.25g - 0.25a$

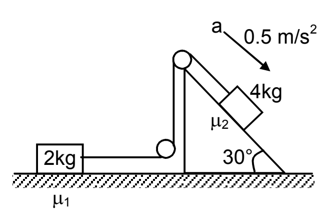
$\Rightarrow a = \dfrac{0.05}{1.25} \times 10 = 0.04 \text{ I } 10 = 0.4\text{m/s}^2$

a) Accln of 1kg blocks each is 0.4m/s^2

b) Tension $T_1 = 0.2g + a + 0.4 = 2.4\text{N}$

c) $T = 0.5g - 0.5a = 0.5 \times 10 - 0.5 \times 0.4 = 4.8\text{N}$

12. From the free body diagram



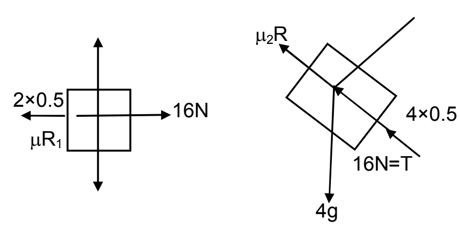
$\mu_1 R + 1 - 16 = 0$

$\Rightarrow \mu_1 (2g) + (-15) = 0$

$\Rightarrow \mu_1 = 15/20 = 0.75$

$\mu_2 R_1 + 4 \times 0.5 + 16 - 4g \sin 30° = 0$

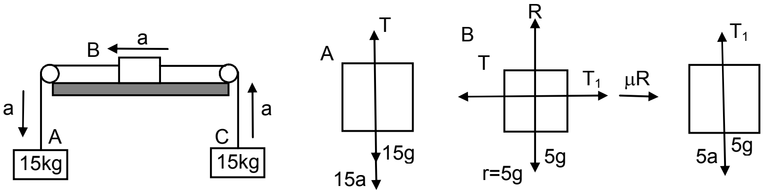
$\Rightarrow \mu_2 (20\sqrt{3}) + 2 + 16 - 20 = 0$



$\Rightarrow \mu_2 = \dfrac{2}{20\sqrt{3}} = \dfrac{1}{17.32} = 0.057 \approx 0.06$

$\therefore$Co-efficient of friction $\mu_1 = 0.75$ & $\mu_2 = 0.06$

13.



From the free body diagram

$T + 15a - 15g = 0$
$\Rightarrow T = 15g - 15a$ ...(i)

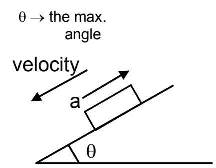
$T - (T_1 + 5a + \mu R) = 0$
$\Rightarrow T - (5g + 5a + 5a + \mu R) = 0$
$\Rightarrow T = 5g + 10a + \mu R$ …(ii)

$T_1 - 5g - 5a = 0$
$\Rightarrow T_1 = 5g + 5a$ …(iii)

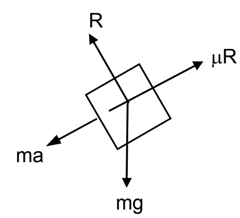
From (i) & (ii) $15g - 15a = 5g + 10a + 0.2\,(5g)$
$\Rightarrow 25a = 90 \Rightarrow a = 3.6\text{m/s}^2$
Equation (ii) $\Rightarrow T = 5 \times 10 + 10 \times 3.6 + 0.2 \times 5 \times 10$
$\Rightarrow$ 96N in the left string
Equation (iii) $T_1 = 5g + 5a = 5 \times 10 + 5 \times 3.6 = 68\text{N}$ in the right string.

14. $s = 5\text{m}$, $\mu = 4/3$, $g = 10\text{m/s}^2$
$u = 36\text{km/h} = 10\text{m/s}$, $v = 0$,

$$a = \frac{v^2 - u^2}{2s} = \frac{0 - 10^2}{2 \times 5} = -10\text{m/s}^2$$



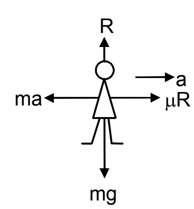
From the freebody diagrams,
$R - mg\cos\theta = 0$; $g = 10\text{m/s}^2$
$\Rightarrow R = mg\cos\theta$ ….(i) ; $\mu = 4/3$.
Again, $ma + mg\sin\theta - \mu R = 0$
$\Rightarrow ma + mg\sin\theta - \mu\, mg\cos\theta = 0$
$\Rightarrow a + g\sin\theta - mg\cos\theta = 0$
$\Rightarrow 10 + 10\sin\theta - (4/3) \times 10\cos\theta = 0$
$\Rightarrow 30 + 30\sin\theta - 40\cos\theta = 0$
$\Rightarrow 3 + 3\sin\theta - 4\cos\theta = 0$
$\Rightarrow 4\cos\theta - 3\sin\theta = 3$
$\Rightarrow 4\sqrt{1 - \sin^2\theta} = 3 + 3\sin\theta$
$\Rightarrow 16\,(1 - \sin^2\theta) = 9 + 9\sin^2\theta + 18\sin\theta$



$$\sin\theta = \frac{-18 \pm \sqrt{18^2 - 4(25)(-7)}}{2 \times 25} = \frac{-18 \pm 32}{50} = \frac{14}{50} = 0.28 \text{ [Taking +ve sign only]}$$

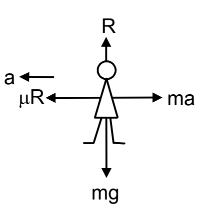
$\Rightarrow \theta = \sin^{-1}(0.28) = 16°$
Maximum incline is $\theta = 16°$

15. to reach in minimum time, he has to move with maximum possible acceleration.
Let, the maximum acceleration is 'a'
$\therefore ma - \mu R = 0 \Rightarrow ma = \mu\, mg$
$\Rightarrow a = \mu\, g = 0.9 \times 10 = 9\text{m/s}^2$



a) Initial velocity $u = 0$, $t = ?$
$a = 9\text{m/s}^2$, $s = 50\text{m}$

$$s = ut + ½\,at^2 \Rightarrow 50 = 0 + (1/2)\,9\,t^2 \Rightarrow t = \sqrt{\frac{100}{9}} = \frac{10}{3}\text{ sec.}$$



b) After overing 50m, velocity of the athelete is
$V = u + at = 0 + 9 \times (10/3) = 30\text{m/s}$
He has to stop in minimum time. So deceleration ia $-a = -9\text{m/s}^2$ (max)

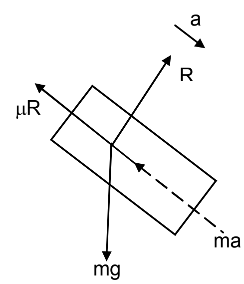
$$\begin{bmatrix} R = ma \\ ma = \mu R(\text{max frictional force}) \\ \Rightarrow a = \mu g = 9m/s^2(\text{Deceleration}) \end{bmatrix}$$

u^1 = 30m/s, v^1 = 0

$t = \dfrac{v^1 - u^1}{a} = \dfrac{0-30}{-a} = \dfrac{-30}{-a} = \dfrac{10}{3}$ sec.

16. Hardest brake means maximum force of friction is developed between car's type & road.

Max frictional force = μR



From the free body diagram

$R - mg \cos\theta = 0$

$\Rightarrow R = mg \cos\theta$ ...(i)

and $\mu R + ma - mg \sin) = 0$ …(ii)

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

$\Rightarrow \mu g \cos\theta + a - 10 \times (1/2) = 0$

$\Rightarrow a = 5 - \{1 - (2\sqrt{3})\} \times 10\ (\sqrt{3}/2) = 2.5\ m/s^2$

When, hardest brake is applied the car move with acceleration $2.5m/s^2$

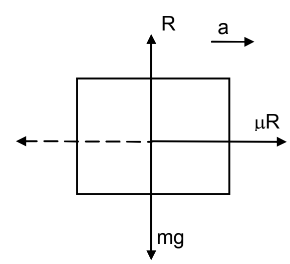
S = 12.8m, u = 6m/s

S0, velocity at the end of incline

$V = \sqrt{u^2 + 2as} = \sqrt{6^2 + 2(2.5)(12.8)} = \sqrt{36+64}$ = 10m/s = 36km/h

Hence how hard the driver applies the brakes, that car reaches the bottom with least velocity 36km/h.

17. Let, , a maximum acceleration produced in car.



$\therefore$ ma = μR [For more acceleration, the tyres will slip]

$\Rightarrow ma = \mu\ mg \Rightarrow a = \mu g = 1 \times 10 = 10m/s^2$

For crossing the bridge in minimum time, it has to travel with maximum acceleration

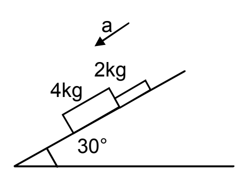
u = 0, s = 500m, a = $10m/s^2$

$s = ut + ½ at^2$

$\Rightarrow 500 = 0 + (1/2)\ 10\ t^2 \Rightarrow t = 10$ sec.

If acceleration is less than $10m/s^2$, time will be more than 10sec. So one can't drive through the bridge in less than 10sec.

18. From the free body diagram



$R = 4g \cos 30° = 4 \times 10 \times \sqrt{3}/2 = 20\sqrt{3}$ ...(i)

$\mu_2 R + 4a - P - 4g \sin 30° = 0 \Rightarrow 0.3\ (40) \cos 30° + 4a - P - 40 \sin 20° = 0$ …(ii)

$P + 2a + \mu_1 R_1 - 2g \sin 30° = 0$ …(iii)

$R_1 = 2g \cos 30° = 2 \times 10 \times \sqrt{3}/2 = 10\sqrt{3}$ ...(iv)

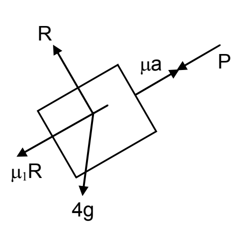
Equn. (ii) $6\sqrt{3} + 4a - P - 20 = 0$

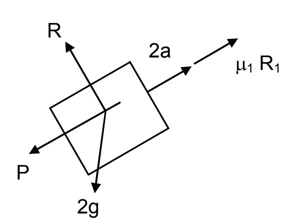
Equn (iv) $P + 2a + 2\sqrt{3} - 10 = 0$

From Equn (ii) & (iv) $6\sqrt{3} + 6a - 30 + 2\sqrt{3} = 0$

$\Rightarrow 6a = 30 - 8\sqrt{3} = 30 - 13.85 = 16.15$

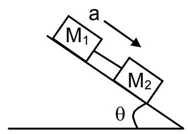
$\Rightarrow a = \dfrac{16.15}{6} = 2.69 = 2.7m/s^2$

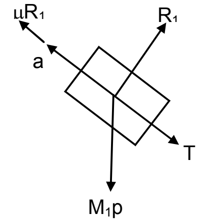


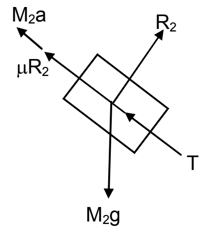


b) can be solved. In this case, the 4 kg block will travel with more acceleration because, coefficient of friction is less than that of 2kg. So, they will move separately. Drawing the free body diagram of 2kg mass only, it can be found that, $a = 2.4m/s^2$.

19. From the free body diagram







$R_1 = M_1 g \cos\theta$ ...(i)

$R_2 = M_2 g \cos\theta$ ...(ii)

$T + M_1 g \sin\theta - m_1 a - \mu R_1 = 0$ ...(iii)

$T - M_2 - M_2 a + \mu R_2 = 0$ ...(iv)

Equn (iii) $\Rightarrow$ $T + M_1 g \sin\theta - M_1 a - \mu M_1 g \cos\theta = 0$

Equn (iv) $\Rightarrow$ $T - M_2 g \sin\theta + M_2 a + \mu M_2 g \cos\theta = 0$ ...(v)

Equn (iv) & (v) $\Rightarrow$ $g \sin\theta (M_1 + M_2) - a(M_1 + M_2) - \mu g \cos\theta (M_1 + M_2) = 0$

$\Rightarrow a (M_1 + M_2) = g \sin\theta (M_1 + M_2) - \mu g \cos\theta (M_1 + M_2)$

$\Rightarrow a = g(\sin\theta - \mu\cos\theta)$

$\therefore$ The blocks (system has acceleration $g(\sin\theta - \mu\cos\theta)$

The force exerted by the rod on one of the blocks is tension.

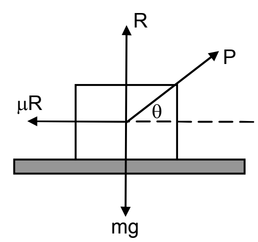
Tension $T = - M_1 g \sin\theta + M_1 a + \mu M_1 g \sin\theta$

$\Rightarrow T = - M_1 g \sin\theta + M_1(g \sin\theta - \mu g \cos\theta) + \mu M_1 g \cos\theta$

$\Rightarrow T = 0$

20. Let 'p' be the force applied to at an angle θ

From the free body diagram



$R + P \sin\theta - mg = 0$

$\Rightarrow R = - P \sin\theta + mg$ ...(i)

$\mu R - p \cos\theta$ ...(ii)

Equn. (i) is $\mu(mg - P \sin\theta) - P \cos\theta = 0$

$\Rightarrow \mu\, mg = \mu\,\rho \sin\theta - P\cos\theta \Rightarrow \rho = \dfrac{\mu mg}{\mu\sin\theta + \cos\theta}$

Applied force P should be minimum, when $\mu \sin\theta + \cos\theta$ is maximum.

Again, $\mu \sin\theta + \cos\theta$ is maximum when its derivative is zero.

$\therefore d/d\theta\, (\mu \sin\theta + \cos\theta) = 0$

$\Rightarrow \mu\cos\theta - \sin\theta = 0 \Rightarrow \theta = \tan^{-1}\mu$

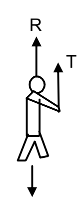
$$\text{So, } P = \frac{\mu mg}{\mu\sin\theta + \cos\theta} = \frac{\mu mg/\cos\theta}{\dfrac{\mu\sin\theta}{\cos\theta} + \dfrac{\cos\theta}{\cos\theta}} = \frac{\mu mg\sec\theta}{1 + \mu\tan\theta} = \frac{\mu mg\sec\theta}{1 + \tan^2\theta}$$

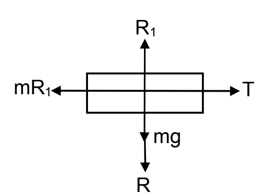
$$= \frac{\mu mg}{\sec\theta} = \frac{\mu mg}{\sqrt{(1+\tan^2\theta}} = \frac{\mu mg}{\sqrt{1+\mu^2}}$$

Minimum force is $\dfrac{\mu mg}{\sqrt{1+\mu^2}}$ at an angle $\theta = \tan^{-1}\mu$.

21. Let, the max force exerted by the man is T.

From the free body diagram





$R + T - Mg = 0$

$\Rightarrow R = Mg - T$ ...(i)

$R_1 - R - mg = 0$

$\Rightarrow R_1 = R + mg$ ...(ii)

And $T - \mu R_1 = 0$

$\Rightarrow T - \mu (R + mg) = 0$ [From equn. (ii)]

$\Rightarrow T - \mu R - \mu mg = 0$

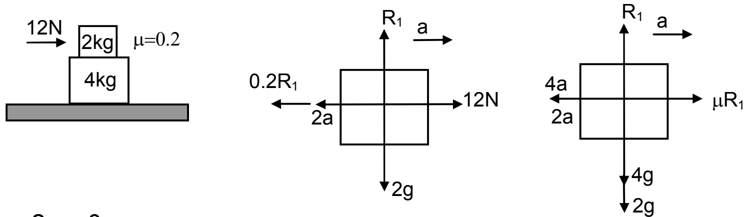
$\Rightarrow T - \mu (Mg + T) - \mu mg = 0$ [from (i)]

$\Rightarrow T (1 + \mu) = \mu Mg + \mu mg$

$\Rightarrow T = \dfrac{\mu(M+m)g}{1+\mu}$

Maximum force exerted by man is $\dfrac{\mu(M+m)g}{1+\mu}$

22.



$R_1 - 2g = 0$

$\Rightarrow R_1 = 2 \times 10 = 20$

$2a + 0.2 R_1 - 12 = 0$

$\Rightarrow 2a + 0.2(20) = 12$

$\Rightarrow 2a = 12 - 4 = 8$

$\Rightarrow a = 4m/s^2$

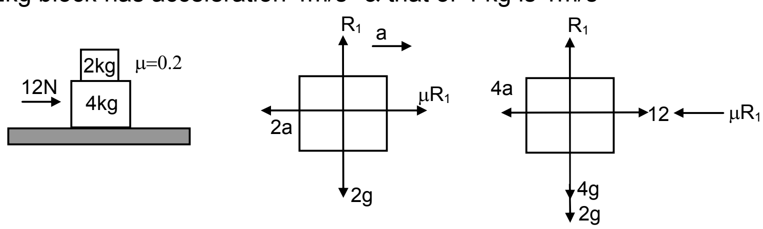
$4a_1 - \mu R_1 = 0$

$\Rightarrow 4a_1 = \mu R_1 = 0.2 (20)$

$\Rightarrow 4a_1 = 4$

$\Rightarrow a_1 = 1m/s^2$

2kg block has acceleration $4m/s^2$ & that of 4 kg is $1m/s^2$



(ii) $R_1 = 2g = 20$

$Ma - \mu R_1 = 0$

$\Rightarrow 2a = 0.2 (20) = 4$

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

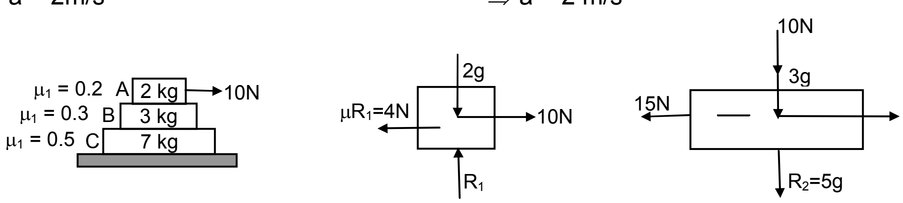
$4a + 0.2 \times 2 \times 10 - 12 = 0$

$\Rightarrow 4a + 4 = 12$

$\Rightarrow 4a = 8$

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

23.



a) When the 10N force applied on 2kg block, it experiences maximum frictional force

$\mu R_1 = \mu \times 2kg = (0.2) \times 20 = 4N$ from the 3kg block.

So, the 2kg block experiences a net force of 10 – 4 = 6N

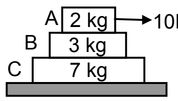
So, $a_1 = 6/2 = 3 m/s^2$

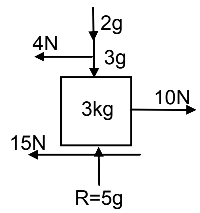
But for the 3kg block, (fig-3) the frictional force from 2kg block (4N) becomes the driving force and the maximum frictional force between 3kg and 7 kg block is

$\mu_2 R_2 = (0.3) \times 5kg = 15N$

So, the 3kg block cannot move relative to the 7kg block. The 3kg block and 7kg block both will have same acceleration ($a_2 = a_3$) which will be due to the 4N force because there is no friction from the floor.

$\therefore a_2 = a_3 = 4/10 = 0.4m/s^2$





b) When the 10N force is applied to the 3kg block, it can experience maximum frictional force of 15 + 4 = 19N from the 2kg block & 7kg block.

So, it can not move with respect to them.

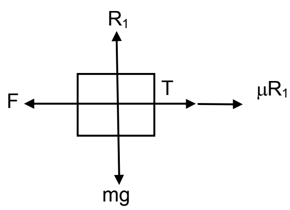
As the floor is frictionless, all the three bodies will move together

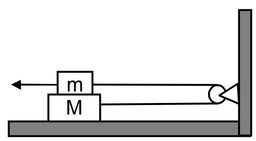
$\therefore a_1 = a_2 = a_3 = 10/12 = (5/6) m/s^2$

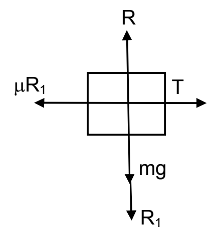
c) Similarly, it can be proved that when the 10N force is applied to the 7kg block, all the three blocks will move together.

Again $a_1 = a_2 = a_3 = (5/6) m/s^2$

24. Both upper block & lower block will have acceleration $2 m/s^2$







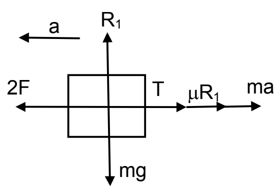
$R_1 = mg$ ...(i)

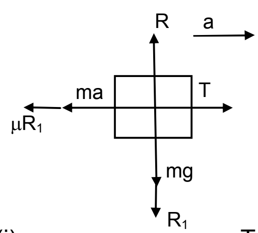
$F - \mu R_1 - T = 0 \Rightarrow F - \mu mg - T = 0$ ...(ii)

$\therefore F = \mu\, mg + \mu\, mg = 2\, \mu\, mg$ [putting $T = \mu$ mg]

$T - \mu R_1 = 0$

$\Rightarrow T = \mu mg$





b) $2F - T - \mu\, mg - ma = 0$ …(i)

$T - Ma - \mu\, mg = 0$ [$\therefore R_1 = mg$]

$\Rightarrow T = Ma + \mu\, mg$

Putting value of T in (i)

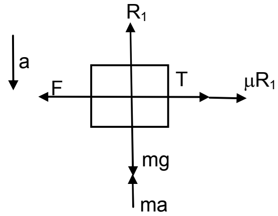
$2f - Ma - \mu mg - \mu\, mg - ma = 0$

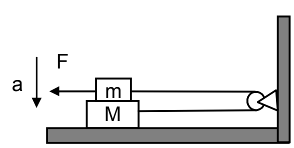
$\Rightarrow 2(2\mu mg) - 2\, \mu\, mg = a(M + m)$ [Putting $F = 2\, \mu mg$]

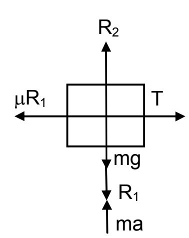
$\Rightarrow 4\mu\, mg - 2\, \mu\, mg = a\,(M + m)$ $\Rightarrow a = \dfrac{2\mu mg}{M+m}$

Both blocks move with this acceleration 'a' in opposite direction.

25.







$T = mR_1$
$= m\,(mg - ma)$

$R_1 + ma - mg = 0$

$\Rightarrow R_1 = m(g - a) = mg - ma$ ...(i)

$T - \mu\, R_1 = 0 \Rightarrow T = m\,(mg - ma)$ ...(ii)

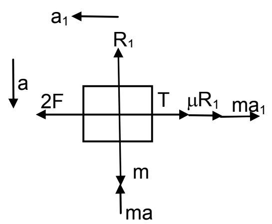
Again, $F - T - \mu\, R_1 = 0$

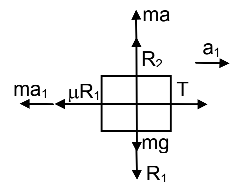
$\Rightarrow F - \{\mu(mg - ma)\} - u(mg - ma) = 0$

$\Rightarrow F - \mu\, mg + \mu\, ma - \mu\, mg + \mu\, ma = 0$

$\Rightarrow F = 2\,\mu\, mg - 2\mu\, ma \Rightarrow F = 2\mu\, m(g-a)$

b) Acceleration of the block be a_1





$R_1 = mg - ma$ ...(i)

$2F - T - \mu R_1 - ma_1 = 0$

$\Rightarrow 2F - t - \mu mg + \mu a - ma_1 = 0$ ...(ii)

$T - \mu R_1 - M\, a_1 = 0$

$\Rightarrow T = \mu R_1 + M\, a_1$

$\Rightarrow T = \mu\,(mg - ma) + Ma_1$

$\Rightarrow T = \mu\, mg - \mu\, ma + M\, a_1$

Subtracting values of F & T, we get

$2(2\mu m(g - a)) - 2(\mu mg - \mu ma + Ma_1) - \mu mg + \mu\, ma - \mu\, a_1 = 0$

$\Rightarrow 4\mu\, mg - 4\,\mu\, ma - 2\,\mu\, mg + 2\mu\, ma = ma_1 + M\, a_1$ $\Rightarrow a_1 = \dfrac{2\mu m(g-a)}{M+m}$

Both blocks move with this acceleration but in opposite directions.

26. $R_1 + QE - mg = 0$

$R_1 = mg - QE$ ...(i)

$F - T - \mu R_1 = 0$

$\Rightarrow F - T\ \ \mu(mg - QE) = 0$

$\Rightarrow F - T - \mu\, mg + \mu QE = 0$ …(2)

$T - \mu\, R_1 = 0$

$\Rightarrow T = \mu\, R_1 = \mu\,(mg - QE) = \mu\, mg - \mu QE$

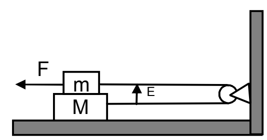
Now equation (ii) is $F - mg + \mu\, QE - \mu\, mg + \mu\, QE = 0$

$\Rightarrow F - 2\,\mu\, mg + 2\mu\, QE = 0$

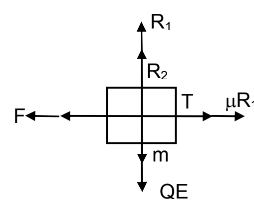
$\Rightarrow F = 2\mu mg - 2\mu\, QE$

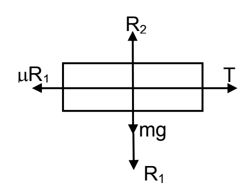
$\Rightarrow F = 2\mu(mg - QE)$

Maximum horizontal force that can be applied is $2\mu(mg - QE)$.



F=QE





27. Because the block slips on the table, maximum frictional force acts on it.

From the free body diagram

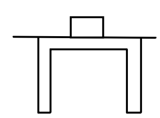
$R = mg$

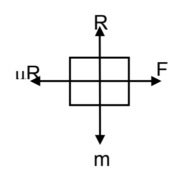
$\therefore F - \mu\, R = 0 \Rightarrow F = \mu R = \mu\, mg$

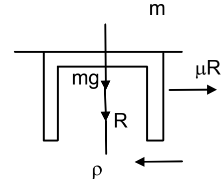
But the table is at rest. So, frictional force at the legs of the table is not $\mu\, R_1$. Let be f, so form the free body diagram.

$f_o - \mu\, R = 0 \Rightarrow f_o = \mu R = \mu\, mg$.

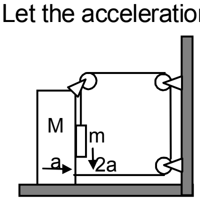
Total frictional force on table by floor is μ mg.

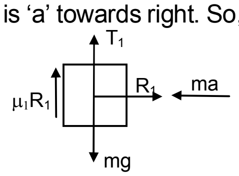




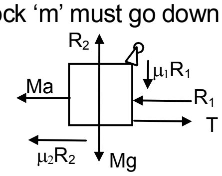


28. Let the acceleration of block M is ‘a’ towards right. So, the block ‘m’ must go down with an acceleration ‘2a’.





(FBD-1)



(FBD-2)

As the block ‘m’ is in contact with the block ‘M’, it will also have acceleration ‘a’ towards right. So, it will experience two inertia forces as shown in the free body diagram-1.

From free body diagram -1

$R_1 - ma = 0 \Rightarrow R_1 = ma$ ...(i)

Again, $2ma + T - mg + \mu_1 R_1 = 0$

$\Rightarrow T = mg - (2 - \mu_1)ma$ …(ii)

From free body diagram-2

$T + \mu_1 R_1 + mg - R_2 = 0$

$\Rightarrow R_2 = T + \mu_1\ ma + Mg$ [Putting the value of R_1 from (i)]

$= (mg - 2ma - \mu_1\ ma) + \mu_1\ ma + Mg$ [Putting the value of T from (ii)]

$\therefore R_2 = Mg + mg - 2ma$ …(iii)

Again, form the free body diagram -2

$T + T - R - Ma - \mu_2 R_2 = 0$

$\Rightarrow 2T - MA - mA - \mu_2\ (Mg + mg - 2ma) = 0$ [Putting the values of R_1 and R_2 from (i) and (iii)]

$\Rightarrow 2T = (M + m) + \mu_2(Mg + mg - 2ma)$ ...(iv)

From equation (ii) and (iv)

$2T = 2\ mg - 2(2 + \mu_1)mg = (M + m)a + \mu_2(Mg + mg - 2ma)$

$\Rightarrow 2mg - \mu_2(M + m)g = a\ (M + m - 2\mu_2 m + 4m + 2\mu_1 m)$

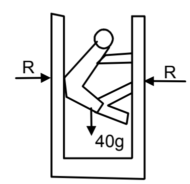
$\Rightarrow a = \dfrac{[2m - \mu_2(M+m)]g}{M + m[5 + 2(\mu_1 - \mu_2)]}$

29. Net force = *(202 + (15)2 – (0.5) × 40 = 25 – 20 = 5N

$\therefore \tan\theta = 20/15 = 4/3 \Rightarrow \mu = \tan^{-1}(4/3) = 53°$

So, the block will move at an angle 53 ° with an 15N force

30. a) Mass of man = 50kg. $g = 10\ m/s^2$



Frictional force developed between hands, legs & back side with the wall the wt of man. So he remains in equilibrium.

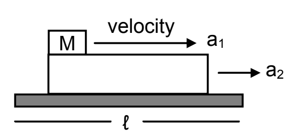
He gives equal force on both the walls so gets equal reaction R from both the walls. If he applies unequal forces R should be different he can't rest between the walls. Frictional force $2\mu R$ balance his wt.

From the free body diagram

$\mu R + \mu R = 40g \Rightarrow 2\ \mu R = 40 \times 10 \Rightarrow R = \dfrac{40 \times 10}{2 \times 0.8} = 250N$

b) The normal force is 250 N.

31. Let a_1 and a_2 be the accelerations of ma and M respectively.



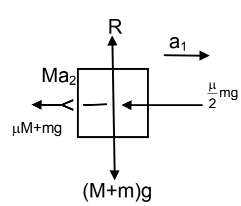
Here, $a_1 > a_2$ so that m moves on M

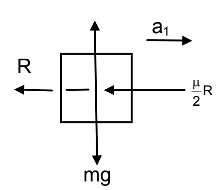
Suppose, after time 't' m separate from M.

In this time, m covers $vt + ½\ a_1 t^2$ and $S_M = vt + ½\ a_2 t^2$

For 'm' to m to 'm' separate from M. $vt + ½\ a_1 t^2 = vt + ½\ a_2 t^2 + \ell$ ...(1)

Again from free body diagram





$Ma_1 + \mu/2\ R = 0$

$\Rightarrow ma_1 = -(\mu/2)\ mg = -(\mu/2)m \times 10 \Rightarrow a_1 = -5\mu$

Again,

$Ma_2 + \mu\ (M + m)g - (\mu/2)mg = 0$

$\Rightarrow 2Ma_2 + 2\mu\ (M + m)g - \mu\ mg = 0$

$\Rightarrow 2\ M\ a_2 = \mu\ mg - 2\mu Mg - 2\ \mu mg$

$\Rightarrow a_2\ \dfrac{-\mu mg - 2\mu Mg}{2M}$

Putting values of a_1 & a_2 in equation (1) we can find that

$T = \sqrt{\left(\dfrac{4ml}{(M+m)\mu g}\right)}$

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