# SOLUTIONS
## NLM AND FRICTION

**1.** Forces from ground causes horse motion.

**2.** Weight = mg

$\therefore$ as g = 0, w = 0

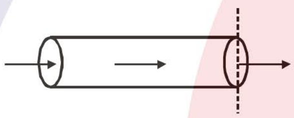
**3.** $a = \dfrac{F}{m}$

$v^2 - 0 = 2\dfrac{F}{m} \times d$

$\therefore \quad v \propto \dfrac{1}{\sqrt{m}}$

**4.** $\Delta p = 2\ mv\cos\theta$

$F = \dfrac{dp}{dt} = (2v\cos\theta)\dfrac{dm}{dt}$



The mass crossing an area in t would be

$v \times t \times a \times d = m$ ...(1)

For small element

$\therefore \quad \dfrac{dm}{dt} = vad \quad \therefore \quad F = 2av^2d\cos\theta$

**5.** For constant velocity, $\vec{a} = 0$, or $\vec{F} = 0$

Thus $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$

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

$\vec{F}_3 = -\left[\left(3\hat{i} + 2\hat{j} - 4\hat{k}\right) + \left(-5\hat{i} + 8\hat{j} - 3\hat{k}\right)\right]$

$= -\left(-2\hat{i} + 10\hat{j} - 7\hat{k}\right) = \left(2\hat{i} - 10\hat{j} + 7\hat{k}\right)N$.

**6.** $\vec{a} = -12\sin 30°\hat{i} - 12\cos 30°\hat{j} = -6\hat{i} - 6\sqrt{3}\hat{j}$.

By Newton's law, we have

$20i + \vec{F} = 2 \times \left(-6\hat{i} - 6\sqrt{3}\hat{j}\right)$

$\therefore \quad \vec{F} = -32\hat{i} - 21\hat{j}\ N$.

**7.** $J = M(v_f - v_i)$

or $50 \times 5 + 75 \times 5 = 16(v_f - 0)$

$\therefore \quad v_f = 39$ m/s.

**8.** $F = \dfrac{0.2 \times 20}{0.5} = 8N$

**9.** $F = v\dfrac{dm}{dt}$

$F = 1 \times 5$

$ma = 5$

$a = \dfrac{5}{2}$

$a = 2.5\ m/s^2$

**10.** $Mg = n \times 2mV$

$1 \times 9.8 = 10 \times 2 \times 0.05 \times V$

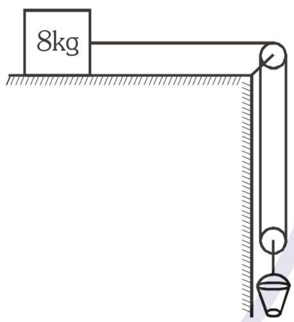
$V = \dfrac{9.8}{1} = 9.8$ m/s

**11.** $I = \int Fdt = 500t - \dfrac{100t^2}{2}$

**12.** $a = \left[\dfrac{10\cos 60°}{2+3}\right] = 1m/s^2$

and $T = ma = 2 \times 1 = 2$ N.

**13.** For 8 kg block,



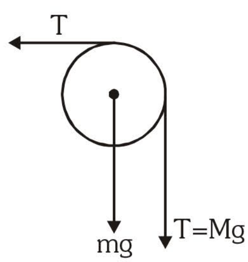

$T = 0.5 \times 8\ g$

and for bucket, $2T = mg$

$\therefore \quad m = 8$ kg

mass of sand added = 7 kg

**14.** $F = \sqrt{T^2 + (T + mg)^2}$




$= \sqrt{(Mg)^2 + (Mg + mg)^2}$

**15.** $a = \frac{(10-8)g}{10+8} = \frac{g}{9} m/s^2$

Tension in the string

$T = m(g - a) = 4(g - g/9)$

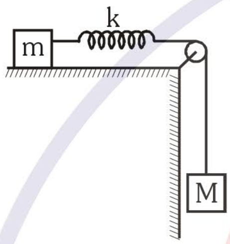
$= 4 \times \frac{8}{9} g = \frac{320}{9} N$

**16.** $a_x = \frac{F\cos 60^\circ}{M} = \frac{F}{2 \times 10} = \frac{F}{20}$

Thus $3 = (2+1) \times \frac{F}{20}$

$\therefore$ F = 20 N.

**17.** Acceleration of blocks



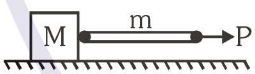

$a = \frac{Mg}{m+M}$

Tension in the string/spring

$T = ma = \frac{mMg}{m+M}$

$\therefore$ Extension in the string, $x = \frac{T}{k} = \frac{mMg}{k(m+M)}$

**18.** $a = \left(\frac{P}{M+m}\right)$




The force exerted by rope on the block

$F = Ma = \left(\frac{MP}{M+m}\right)$

**19.** $a = \frac{Mg\sin\theta}{(M+M)} = \frac{g}{2}\sin\theta$

$\therefore$ $T = Ma = \frac{Mg}{2}\sin\theta$

**20.** mg − T = ma

or $mg - \frac{3mg}{4} = ma$

$\therefore$ a = g/4 $m/s^2$

**21.** T cosθ = W ; T sinθ = R ; $\tan\theta = \frac{R}{W}$

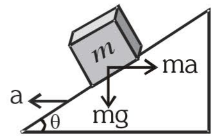
$T^2 = R^2 + W^2$

also as for equilibrium $\vec{R} + \vec{T} + \vec{W} = 0$

**22.** The system, as a whole, will fall towards ground under gravity. The spring will neither be compressed nor stretched regradless of the values of $m_1$ and $m_2$.

**23.** N = m(g − a) = 0.5(10 − 2) = 4N

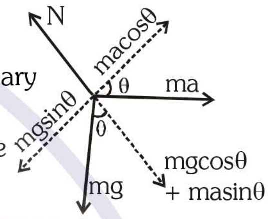
**24.**




According to question sinθ = 1/x (1 in x)

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

To keep the block stationary relative to the inclined plane




mgsinθ = macosθ

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

**25.** Increased

**26.** F = 10 × 4 = 40N


$a = \frac{160}{20} = 8 m/s^2$

**27.** In case (b) entire tension = 2mg, hence acceleration is more.

**28.** Let horizontal velocity of block is u

$u\cos\left(\frac{\pi}{2} - \theta\right) = v$

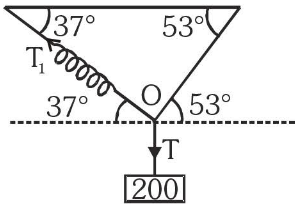
$\therefore$ $u = \frac{v}{\sin\theta}$

**29.** Let the block moves upward with velcity

u cosθ = V

$\therefore$ $u = \frac{v}{\cos\theta}$

**31.**




In equilibrium Acc to Lami's thearum

$$\frac{200}{\sin(180-90)} = \frac{T_1}{\sin(90+53)} \quad [\sin(90+\theta) = \cos\theta]$$

$$\frac{200}{1} = \frac{T_1}{\cos 53} \qquad T_1 = 120$$

$Kx = 120 \quad \Rightarrow \quad K \times 4/100 = 120$

$K = 3000 N/m$

**32.** $T_1 - mg = m \times 2 \qquad \therefore \qquad T_1 = m \times 12$

$T_2 = mg \qquad T_2 = m \times 10$

$mg - T_3 = m \times 4 \qquad T_3 = m \times 6$

$T_1 : T_2 : T_3 = 6 : 5 : 3$

**33.** $a = \dfrac{F}{m_1 + m_2 + m_3}$

For $m_2$ to be at rest wrt $m_3$

$m_2 g = m_1 a$

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

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

**34.** Tension in string

$$T = \frac{2m_1 m_2 g}{m_1 + m_2} = \frac{2 \times 2 \times 1g}{3}$$

Thrust on pulley

$$F_{Thrust} = \frac{8}{3} g$$

$\therefore$ Reading of spring balance should be less than 3kg–wt

**35.** Unchanged, both have same accleration always.

**36.** In (A) $T = kx_1 = 2g$

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

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

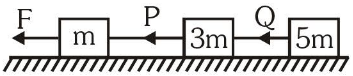
$$\frac{x_1}{2} = \frac{5x_2}{12} = \frac{3x_3}{4}$$

**37.** $T = \dfrac{2m_1 m_2 (g+g)}{m_1 + m_2} = \dfrac{4m_1 m_2 g}{m_1 + m_2}$

In terms of w

$$T = \frac{4w_1 w_2}{w_1 + w_2}$$

**38.**




Let a be the common acceleration of the system

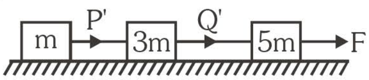
$$\therefore \ a = \frac{F}{m + 3m + 5m} = \frac{F}{9m} \qquad ....(i)$$

$\therefore$ P = (3m + 5m)a

16 = 8ma $\qquad [\because P = 16N(Given)]$

$$a = \frac{2}{m} \qquad ....(ii)$$

Substituting this value of a in eqn(i), we get F = 18 N




P' = ma = 2N $\qquad (\because a = 2/m)$

Q' = (3m + m)a = 4ma = 4 × 2 N = 8 N

* None of the given option is correct.

**39.** $F_{avg} = \dfrac{\Delta p}{t} = \dfrac{2mv \sin 30^\circ}{t} = \dfrac{2 \times 0.5 \times 48}{1/2} \times \dfrac{1}{2} = 48N$

**40.** during up the incline and down the incline constant forces respectively would be used.

**41.** Change in momentum,

$\Delta p = \int F dt$

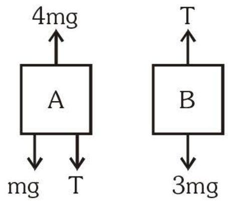
= Area of F-t graph

$= (\frac{1}{2} \times 2 \times 6) - (3 \times 2) + (2 \times 3)$

= 6 N-s

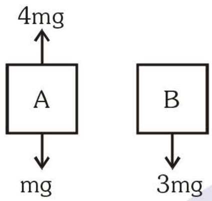
**42.** Impulse $= |\vec{\Delta p}| = m|\vec{\Delta V}| = m(V\cos 60^\circ) = \dfrac{mV}{2}$

**43.** Before cutting the string :-




$\therefore$ T = 3mg

After cutting the string :-




$$a_A = \frac{4mg - mg}{m} = 3g$$

$$a_B = \frac{3mg}{3m} = g$$

**45.** $f_L = \mu_s N$

$= 0.6 \times 20\ g = 120\ N$

Now $a = \frac{120 - 0.2 \times 20g}{20} = 4m/s^2$

**46.** $f_{lim} = \mu N = 0.4(25 - 9) = 6.4\ N$

External force is 6 N and so block will not move.

So frictional force = 6.0 N.

**47.** $10 = mg\sin 30°$

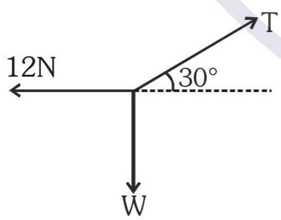
$\therefore\ m = 2\ kg$

**48.** $Q\cos\theta + mg = N$

$P + Q\sin\theta = \mu N$

$$\therefore\quad \mu = \frac{P + Q\sin\theta}{Q\cos\theta + mg}$$

**49.**




$T\cos 30° = 12$ ...(i)

$T\sin 30° = w$ ...(ii)

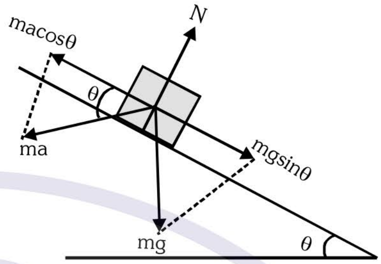
$\tan 30° = w/12$

$$w = 12 \times \frac{1}{\sqrt{3}} = 6.92\ N$$

**50.** $\mu(m\alpha) \geq mg$ $\alpha \geq \frac{g}{\mu}$

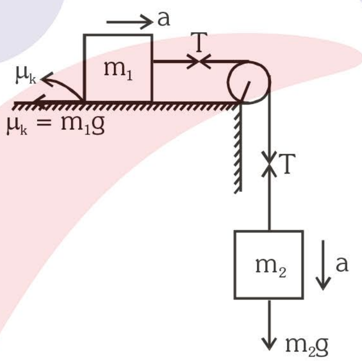
**51.** Coefficient of sliding friction has no dimension

**52.** FBD w.r.t. wedge




$ma\cos\theta = mg\sin\theta \Rightarrow a = g\tan\theta$

**53.**




For the motion of both blocks

$m_2g - T = m_2a$

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

For the block of mass '$m_2$'

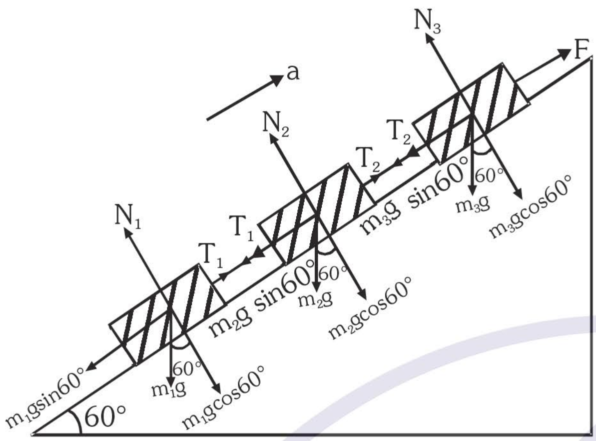
$$m_2g - T = m_2\left[\frac{m_2 - \mu_k m_1}{m_1 + m_2}\right]g$$

$$T = m_2g - \left[\frac{m_2 - \mu_k m_1}{m_1 + m_2}\right]m_2g$$

$$= m_2g\left[\frac{m_1 + \mu_k m_1}{m_1 + m_2}\right]$$

$$\Rightarrow\quad T = \frac{m_1m_2(1 + \mu_k)g}{m_1 + m_2}$$

**54.**




Here, $m_1 = 2.0$ kg, $m_2 = 4.0$ kg, $m_3 = 6.0$ kg, $F = 120$ N

Let a be common acceleration of the system.

The equation of motion of block 1 is

$T_1 - m_1 g\sin 60° = m_1 a$ ....(i)

The equation of motion of block 2 is

$T_2 - T_1 - m_2 g\sin 60° = m_2 a$ ....(ii)

The equation of motion of block 3 is

$F - T_2 - m_3 g\sin 60° = m_3 a$ ....(iii)

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

$F - (m_1 + m_2 + m_3)\, g \sin 60° = (m_1 + m_2 + m_3)a$

$$a = \frac{F - (m_1 + m_2 + m_3)g \sin 60°}{m_1 + m_2 + m_3}$$

From equation (i)

$T_1 = m_1 g\sin 60° + m_1 a$

$$= \frac{m_1[F - (m_1 + m_2 + m_3)g \sin 60°]}{m_1 + m_2 + m_3} + m_1 g \sin 60°$$

$$T_1 = \frac{m_1 F}{m_1 + m_2 + m_3} = \frac{2 \times 120}{12} = 20\text{N}$$

From equation (iii)

$T_2 = F - m_3 g\sin 60° - m_3 a$

$$T_2 = F - m_3 g\sin 60° - m_3\left(\frac{F - (m_1 + m_2 + m_3)g \sin 60°}{m_1 + m_2 + m_3}\right)$$

$$T_2 = \frac{(m_1 + m_2)F}{m_1 + m_2 + m_3} = 60 \text{ N}$$

**55.** Let the length of incline is d

**Case I :** for rough incline plane

$$a_r = g\sin 45° - \mu g\cos 45° = \frac{g - \mu g}{\sqrt{2}} = \left(\frac{1-\mu}{\sqrt{2}}\right)g$$

time taken to slide down $(t_r) = \sqrt{\dfrac{2d}{a_r}}$

**Case II :** For smooth incline plane

$$a_s = g\sin 45° = \frac{g}{\sqrt{2}}$$

$$\Rightarrow \quad t_s = \sqrt{\frac{2d}{a_s}}$$

Acc to question

$nt_s = t_r \quad \Rightarrow \quad n^2 t_s^2 = t_r^2$

$$n^2\left(\frac{2d}{g/\sqrt{2}}\right) = \frac{2d}{\left(\frac{1-\mu}{\sqrt{2}}\right)g}$$

$$n^2 = \frac{1}{1-\mu}$$

$$\Rightarrow \quad \mu = 1 - \frac{1}{n^2}$$

**56.** $mg \sin\theta = \mu\, mg\cos\theta$

$\sin\theta = \mu\cos\theta$ ...(i)

when pushed up

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

$= -(g\sin\theta + g\sin\theta) = -2g\sin\theta$

$\therefore \quad v^2 - v_0^2 = 2(a) \times s$

Final velocity $v = 0$

$-v_0^2 = 2as \Rightarrow -v_0^2 = 2(-2g\sin\theta)s$

$$\therefore \quad s = \frac{v_0^2}{2(2g\sin\theta)}$$

**57.** $a_{10} = a_4$

$$\frac{F-12}{10} = \frac{12}{4}$$

$$\frac{F-12}{10} = 3$$

$F - 12 = 30$

$F = 42$ N

**58.** $10g = \mu (10 + m)g$

$10 = \mu (10 + m)$

$10 = 0.5 (10 + m)$

$10 + m = 20$

$m = 10$ kg

**59.** Limiting friction between B and ground

$= 0.4(5 + 10)(10) = 60N$

$\Rightarrow$ acceleration of B is zero.

Therefore acceleration of block A

$$a_A = \frac{50 - 0.8(5)(10)}{5} = 2\ m/s^2$$

**60.** $a = \frac{F}{7}$ for block A

$2 \times \frac{F}{7} = 0.6 \times 2 \times 10 \Rightarrow F = 42N$

**61.** $T = M_2 g = \mu(M_1 + m)g$

$\therefore \quad M_2 = \mu(M_1 + m)$

$6 = 0.4(4 + m) = 11$ kg