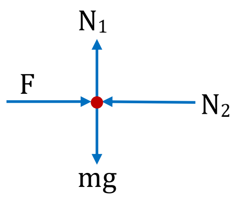
Newtons Laws of Motion and Friction

SOLUTIONS

EXERCISE - O

1. **Ans. (B)**



2. **Ans. (C)**

$F_{CB} = 25 - 20 = 5$

$F_{BH} = 25$

3. **Ans. (C)**

Force on both astronauts is equal & opposite

$$\vec{F} = m_1 \vec{a_1}$$

$$\vec{a_1} = \frac{\vec{F}}{m_1}$$

$$\vec{a_2} = \frac{\vec{F}}{m_2}$$

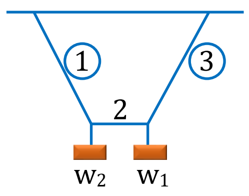
4. **Ans. (D)**

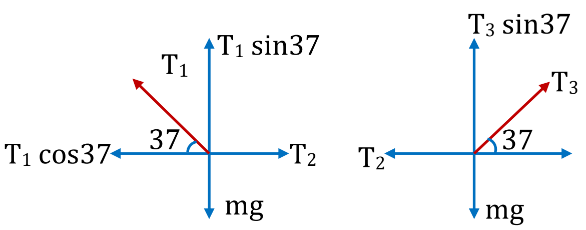
If $F_{net} = 0$ then $a = 0$. So, v = constant.

5. **Ans. (D)**

Acceleration of $3kg$ block is zero so the net force is zero.

6. **Ans. (D)**





$T_3 \sin 37 = 300$ $\qquad$ $T_2 = T_3 \cos 37$

$T_3 \times \frac{3}{5} = 300$ $\qquad$ $T_2 = 500 \times \frac{4}{5} = 400$

$T_3 = 500$

$T_1 \cos 37 = 400$

$T_1 = 500$

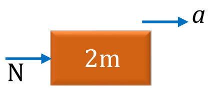
$T_1 \sin 37 = W_2$

$500 \times \frac{3}{5} = W_2$

$W_2 = 300N$

7. Ans. (D)

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

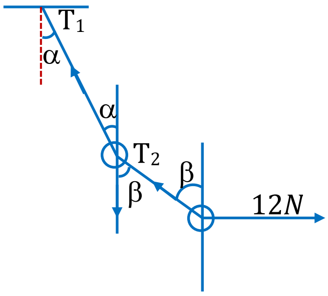


For $2m$ block

$N = 2m \times a$

$= 2m \times \dfrac{F}{3m} = \dfrac{2F}{3}$

8. Ans. (C)



$T_1 \cos \alpha = 16$

$T_2 \cos\beta = 9$

$T_2 \sin \beta = 12$

$\tan \beta = \dfrac{4}{3} = 53$

$\alpha = 37°$

$\beta = 53°$

$T_1 \cos \alpha = 16$

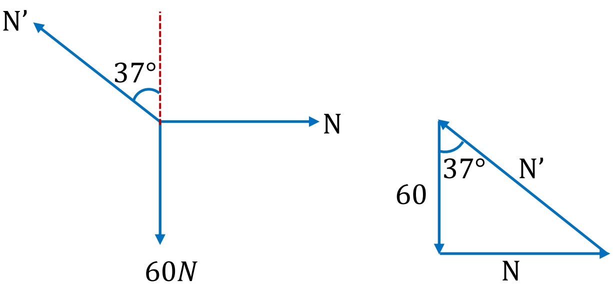
$T_1 \sin \alpha = 12$

$\tan \alpha = \dfrac{3}{4}$

9. Ans. (B)

$F_{net} = 0$

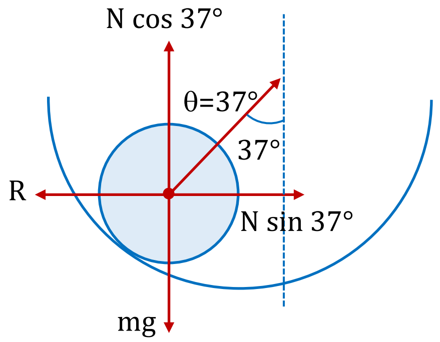
10. Ans. (D)



F.B.D. of system "sphere + block" $\dfrac{N}{60} = \dfrac{3}{4}$

$N = 45$ newton

11. Ans. (A)



$N\cos 37° = mg \Rightarrow N = \frac{5mg}{4}$ [Newton]

$R = N\sin 37° \Rightarrow \frac{3mg}{4} = \frac{75}{2}$

12. Ans. (C)

$a_{sys} = \frac{60}{20} = 3\ m/s^2$

$F = 3 \times 60 = 180\ N$

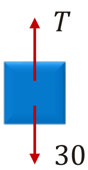
13. Ans. (B)

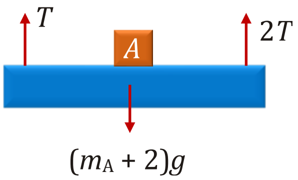
In case (ii) block & tube will move together and acceleration will be $a = \frac{F}{M+m}$

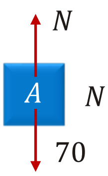
In case (i) net force on block will be zero $a_m = 0$ and acceleration of tube = $\frac{F}{M}$

14. Ans. (A)

$T = 30$





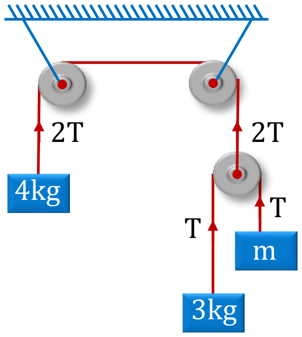


$N = 70$

$3T = (m_A + 2)g$

$m_A = 7kg$

15. **Ans. (C)**



$2T = 4g$

$$2\left[\frac{2(3\times m)}{(3+m)}\right]g = 4g$$

$m = 1.5\ kg$

16. **Ans. (C)**

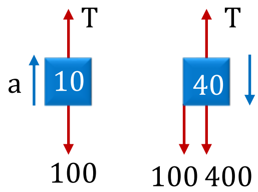
$500 - T = 40a$

$T - 100 = 10a$

$400 = 50a$

$\Rightarrow\ a = 8\ m/s^2$

and $T = 100 + 80 = 180N$



17. **Ans. (B)**

$T = m_1 g \sin 30°,\ T = m_3 g,\ 2T = m_2 g$

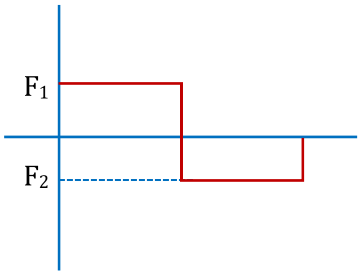
18. **Ans. (B)**

Let $F = kt^2$

where k is a constant at , $t = 5$ sec, $F = 50$

$50 = k \times 5^2 \Rightarrow k = 2,\ F = 2t^2$

$$a = \frac{F}{m} = \frac{2t^2}{10} = \frac{t^2}{5},\ \int_0^v dv = \int_0^5 \frac{t^2}{5}dt\quad v = \frac{1}{5}\times\frac{t^3}{3}\Big|_0^5 = \frac{25}{3} = 8.33\ \text{ms}^{-1}$$



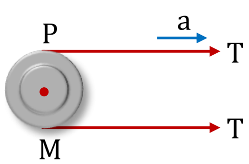
19. **Ans. (C)**

Theoretical

20. **Ans. (C)**

$N = \text{mg}\cos\phi + F\sin\theta$

21. **Ans. (D)**



$2T = Ma$

$2T = 2a \Rightarrow a = T$

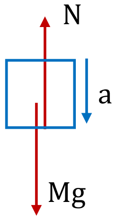
Also for pulley :

$$T = 2\times\left(\frac{m\times m'}{m+m'}\right)g_{eff} = 2\times\frac{2}{3}\times(g-a)$$

so $a = \frac{4}{3}(g-a) \Rightarrow a = \frac{4}{7}g$

22. **Ans. (C)**

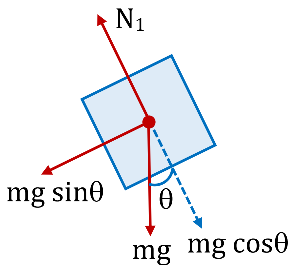
FBD of block :



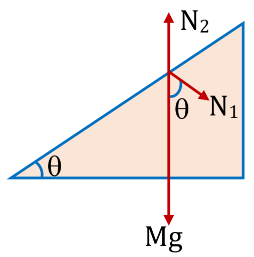
$Mg - N = Ma$

Now according to question $N = \frac{Mg}{10}$ so $a = \frac{Mg - \frac{Mg}{10}}{M} = 0.9g$

23. **Ans. (B)**



$N_1 = mg\cos\theta$



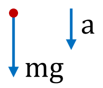
$N_2 = Mg + N_1\cos\theta = Mg + mg\cos^2\theta$

$N_2 = Mg + mg(1 - \sin^2\theta) = (M + m)g - mg\sin^2\theta$

24. **Ans. (C)**

As given springs are in natural length positions i.e. spring forces on block are zero. So only gravitational force acts downwards initially

$\therefore$



$\Rightarrow$ $a = g$ downwards

$= 10\ m/s^2$

25. **Ans. (C)**

After removing spring

$$\vec{F}_{\text{net}} = \vec{F}_{\text{onespring}}$$

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

26. **Ans. (C)**

The value of F is such that S_1 is compressed and spring force is $2N$. When F is removed the spring force of S_2 becomes zero but that of S_1 remains unchanged. So $a_A = 1\ m/s^2$ left and $a_B = 1\ m/s^2$ right.

27. **Ans. (D)**

Theoretical

28. **Ans. (B)**

At $t = 27\ s$, Acceleration of lift = $-\dfrac{9-0}{30-25} = -1.8 m/s^2$

Tension in rope $T = m\,(g-a) = 500\,(9.8 - 1.8) = 500 \times 8 = 4000\ N = 4kN$

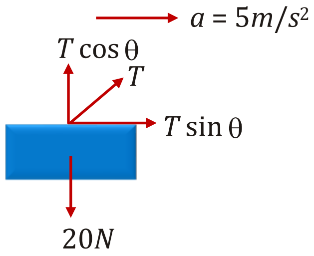
29. **Ans. (B)**

$T\sin\theta = 2 \times 5$

$T\cos\theta = 20$

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

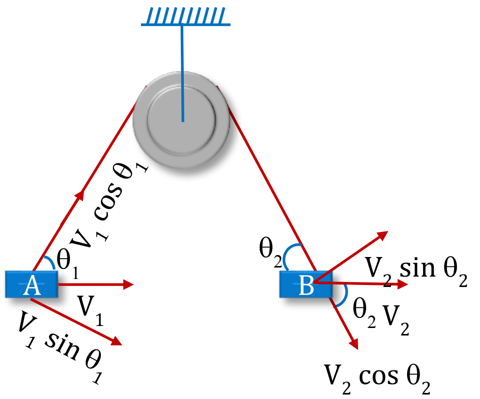
$\cot\theta = 2$



30. **Ans. (C)**

$a = g\tan 53°$

31. **Ans. (B)**



Since string is inextensible length of string can't change

∴ Rate of decreases of length of left string = Rate of increase of length of right string

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

$\Rightarrow \dfrac{V_1}{V_2} = \dfrac{\cos\theta_2}{\cos\theta_1}$

32. **Ans. (B)**

$\hat{f} = -\hat{v}_{rel} = -\hat{v}_{AP} = -\left[\dfrac{4\hat{j}-3\hat{i}}{5}\right] = \dfrac{3\hat{i}-4\hat{j}}{5}$

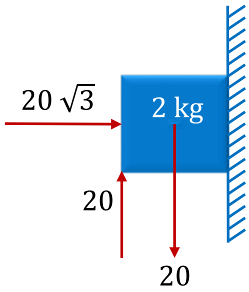
33. **Ans. (C)**

In the given situation the blocks will not be able to move, i.e. $T = 40\ N$

Thus, friction = $40\ N$

and $a = 0$

34. **Ans. (D)**



As net force along the surface is zero there is no need of friction $\therefore f_r = 0$

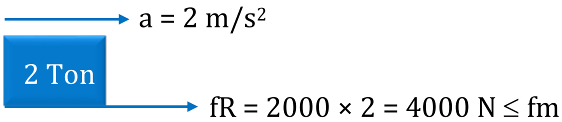
35. **Ans. (A)**

The force exerted by ground on the block.

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

$$= \sqrt{(Mg)^2 + \left[\left(\frac{4}{5}\right)(3Mg)\right]^2} = \frac{13}{5}Mg = 2.6Mg$$

36. **Ans. (B)**



37. **Ans. (C)**

Figure 'a' :- $F_{net} = F - \mu mg$

Figure 'b' :- $F_{net}' = F + P\sin\theta - \mu(mg + P\cos\theta)$

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

Given $\tan\theta = \mu \Rightarrow \sin\theta = \mu\cos\theta$

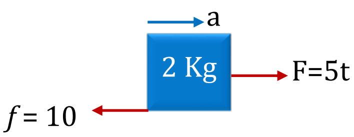
'F_{net}' $= F - \mu mg = F_{net}$

38. **Ans. (C)**

$F_{net} = 0 \Rightarrow a = 0$

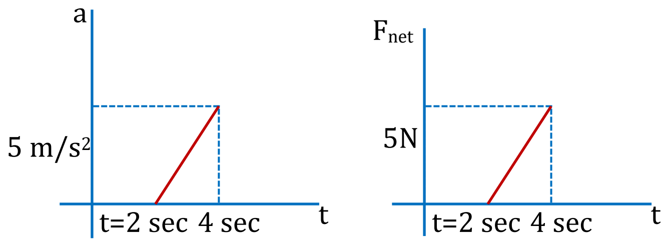
$t = 0$ to $t = 2$ sec $\Rightarrow a = 0$

after $t = 2$ sec



$5t - 10 = 2a$

at $t = 4$ sec $\Rightarrow a = 5\ m/s^2$



ΔV = area under $a - t$ curve

$v - u = \frac{1}{2} \times 2 \times 5$

$v = 5\ m/s$

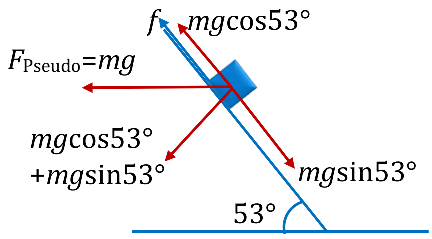
39. **Ans. (A)**

When block is about to slide down $2 + mg \sin\theta = \mu\, mg \cos\theta$ ...(1)

When block is about to slide up $mg \sin\theta + \mu\, mg\cos\theta = 10$. ...(2)

From (1) and (2) $\mu = \frac{\sqrt{3}}{2}$

40. **Ans. (C)**



$N = mg \times 3/5 + mg\, 4/5$

$N = \frac{7mg}{5}$

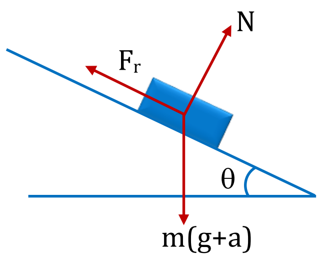
For constant velocity

$F_{net} = 0$

$mg \sin 53° = f + mg \cos 53° \Rightarrow mg \times \frac{4}{5} = \mu 7 \frac{mg}{5} + mg\frac{3}{5}$

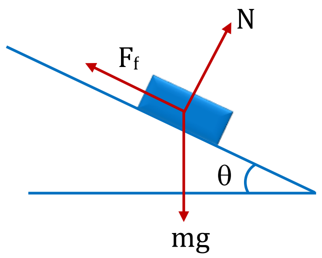
$\Rightarrow \quad \mu = \frac{1}{7}$

41. **Ans. (A)**

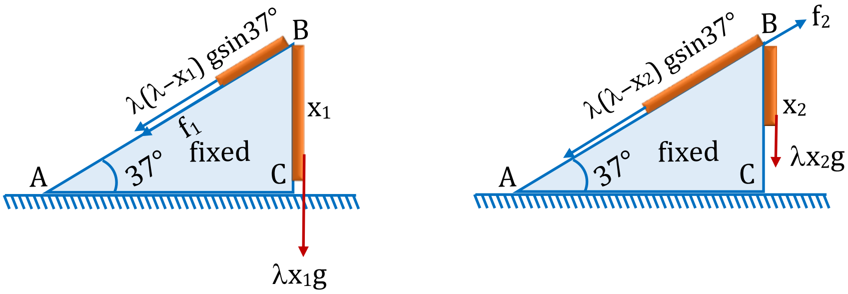


Net contact Force between block and incline is vertical.

42. **Ans. (C)**



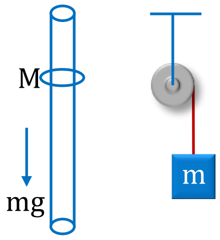
43. Ans. (A)



$f_1 = \lambda(\ell - x_1)g\cos 37°, f_2 = \lambda(\ell - x_2)g\cos 37°$

$x_1g = (\ell - x_1)\, g(\mu\cos\theta + \sin\theta), x_2g = (\ell - x_2)\,(\sin\theta - \mu\cos\theta)$

44. Ans. (A)



$f_{max} = \mu N$

$f_{max} = \mu mg$

Required = mg

45. Ans. (B)

$\mu_1 = \frac{1}{2}$; $\mu_2 = \frac{4}{10}$

$a_1 = g\sin\theta - \mu_1 g\cos\theta$

$a_2 = g\sin\theta - \mu_2 g\cos\theta$

$\mu_1 > \mu_2$

$a_2 < a_1$

46. Ans. (B)

Block moves of $2t \geq (0.4)(10)(10) \Rightarrow t \geq 20s$

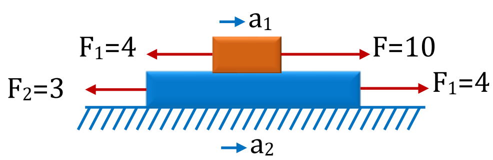
Just after start its acceleration $a = \frac{40-30}{10} = 1ms^{-2}$

After that a = $\frac{2t-30}{10} = \frac{t}{5} - 3 \Rightarrow$ Slope of a–t curve $\tan^{-1}\left(\frac{1}{5}\right) = \tan^{-1}(0.2)$

47. Ans. (C)

$a_1 = \frac{F-F_1}{m_1} = \frac{10-4}{1} = 6m/s^2$

$a_2 = \frac{F_1-F_2}{m_2} = \frac{4-3}{2} = 0.5\ m/s^2$



48. Ans. (A)

$a_{system} = \dfrac{F}{3M}$ Acceleration of $3 = \dfrac{F}{3M}$

$f = M\dfrac{F}{3M} = \dfrac{F}{3}$ $\mu Mg = \dfrac{F}{3} \Rightarrow \mu = \dfrac{F}{3Mg}$

49. Ans. (CD)

Analyse action-reaction pairs of forces of same nature. Action reaction pair do not act on same object.

50. Ans. (ABCD)

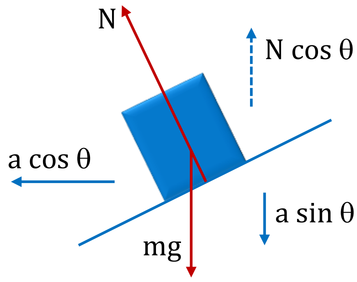
Theoretical.

51. Ans. (BD)

Resolving forces along horizontal and vertical direction,

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

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



Resolving forces along incline

$N = mg\cos\theta$

$mg\sin\theta = ma$

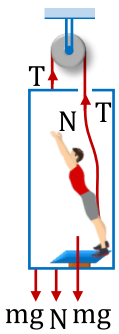
52. Ans. (AD)

Theoretical.

53. Ans. (AB)

Man $N + T = mg$

$N + T = 500$ ...(i)



Weighing machine

$T = mg + N$

$T - N = mg$

$T - N = 200$ ...(ii)

$N + T = 500$

$T - N = 200$

$2T = 700$

$T = 350$

$N + 350 = 500$

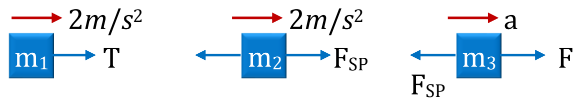
$N = 150$

Reading 15 kg

$T = 350$

54. Ans. (ABCD)

m_1 and m_2 are connected with strings so will have same acceleration.



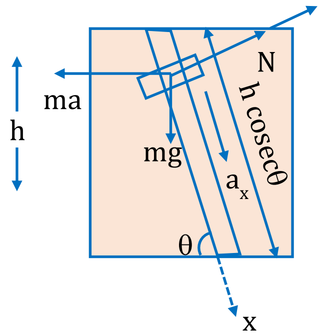
$T = m_1(2) = 2N$

$F_{SP} - T = m_2(2) \Rightarrow F_{SP} = 4 + 2 = 6N$

$F - F_{SP} = m_3 a \quad \Rightarrow a = \dfrac{18-6}{3} = 4\ m/s^2$

55. Ans. (AB)

FBD of rod wrt cart



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

$$x = h\operatorname{cosec}\theta = \frac{1}{2}a_x t^2$$

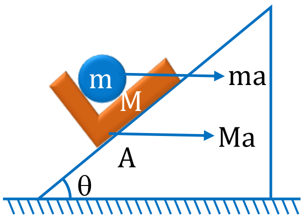
$v_{S/C} = 2a_x h\operatorname{cosec}\theta$

$$v_{S/C} = \sqrt{2h\left(g - a\cot\theta\right)}$$

56. Ans. (ABCD)

In frame of A

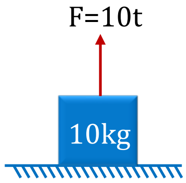
$a_{m/A} = a_{m/a} = (g\sin\theta - a\cos\theta)$



57. Ans. (ABD)

Block loose contact $\Rightarrow 10t = 100$

$t = 10$ sec.



$F_{net} = 10t - 100 = 10 \times a$

$a = t - 10$

$$\frac{dv}{dt} = t - 10$$

$$\int_0^v dv = \int_{10}^t (t-10)\,dt$$

$$v(t) = \left[\frac{t^2}{2} - 10t\right]_{10}^{t} = \frac{t^2}{2} - 10t - [50 - 100]$$

$$v(t) = \frac{t^2}{2} - 10t + 50$$

at $t = 20$ sec

$v = 200 - 200 + 50 = 50\ m/s.$

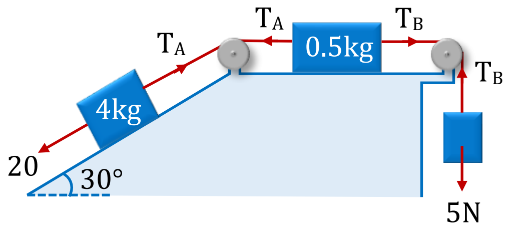
$$\frac{dx}{dt} = \frac{t^2}{2} - 10t + 50$$

$$\int dx = \int_{10}^{20}\left[\frac{t^2}{2} - 10t + 50\right]dt$$

$$x = \frac{500}{3}m$$

58. Ans. (AD)

(A) $a = \dfrac{\text{Net pulling force}}{\text{total mass}} = \dfrac{20-5}{4+0.5+0.5} = 3\ m/s^2$

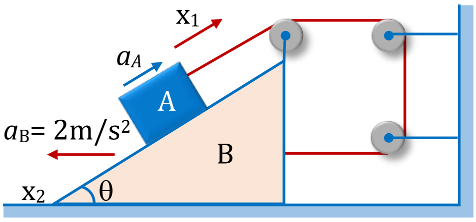


(B) Applying NLM on block of mass 4 *kg*;
$20 - T_A = 4 \times 3 \Rightarrow T_A = 8\ N$

(C) Applying NLM on block of mass 0.5 *kg* on top $T_A - T_B = 0.5 \times 3 \Rightarrow T_B = 8 - 1.5 = 6.5\ N$

(D) Difference in tensions = 1.5 *N*

59. Ans. (ACD)



$TX_1 - 2TX_2 = 0 \Rightarrow X_1 = 2X_2$

$a_1 = 2a_2$

$a_1 = 2 \times 2 = 4 m/s^2$

$4 \cos\theta - 2 = 0$

$\cos\theta = \dfrac{1}{2}$ $\qquad\qquad$ $\theta = 60°$

$a_A = 4 \sin 60°$

60. Ans. (ABCD)

(A) $\theta = \tan^{-1}\left(\dfrac{F}{mg}\right) \Rightarrow \theta < 30°$

(B) $\theta = \tan^{-1}\left[\dfrac{1mg}{\sqrt{3}mg}\right] \Rightarrow \theta = 30°$

(C) $\theta = 30°$

61. Ans. (ABC)

$F - f = ma$

$30 - 10 = m \times 10$ $\qquad\qquad$ $\mu mg = 10$

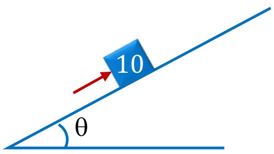
$20 = 10m$ $\qquad\qquad$ $\mu 20 = 10$

$m = 2kg$ $\qquad\qquad$ $\mu = \dfrac{1}{2}$

block start at force = 10. Limiting friction is 10.

62. Ans. (ACD)

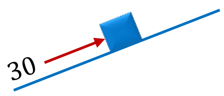
$f = \mu mg \cos\theta$



$f_{max} = \dfrac{1}{2} \times 100 \times \dfrac{4}{5} = 40$

$= mg \sin\theta$

$10 \times 10 \times \dfrac{3}{5}$ $\qquad\qquad$ $20 \times 3 = 60$



(A) Force = 30

Friction = 30

(D) $F = 120$ $\qquad\qquad$ $120 - 40 - 60 = 10a$

$20 = 10a$

$a = 2$

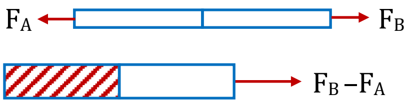
Friction = 40

63. **Ans. (D)**

$F_B - F_A = ma$

$\frac{F_B - F_A}{m} = a$

64. **Ans. (D)**

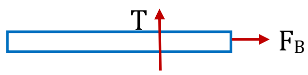


$\frac{m}{2}$

$T = \frac{m}{2}\left(\frac{F_B - F_A}{m}\right)$

$T = \frac{1}{2}(F_B - F_A)$

65. **Ans. (A)**



$F_B - T = \frac{m}{L} \times \left(\frac{F_B - F_A}{m}\right)(L - x)$

$T = F_B - \left(\frac{F_B - F_A}{L}\right)(L - x)$

$T = F_A + \left[\frac{F_B - F_A}{L}\right]x$

66. **Ans. (D)**

$F_B - T = \frac{m}{L} \times \left(\frac{F_B - F_A}{m}\right)(L - x)$

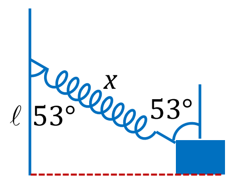
$T = F_B - \left(\frac{F_B - F_A}{\mathrm{L}}\right)(L - x)$

$T = F_A + \left[\frac{F_B - F_A}{L}\right]x$

67. **Ans. (B)**

$N = 0$, when block leaves the table.

68. **Ans. (A)**



$\frac{\ell}{x} = \frac{3}{5}$

$\frac{5}{3}\ell = x$

Extension in spring = $\frac{5}{3}\ell - \ell = \frac{2}{3}\ell$

$kx' \cos 53 = mg$

$k\frac{2}{3}\ell \times \frac{3}{5} = mg$

$k = \frac{5mg}{2\ell}$

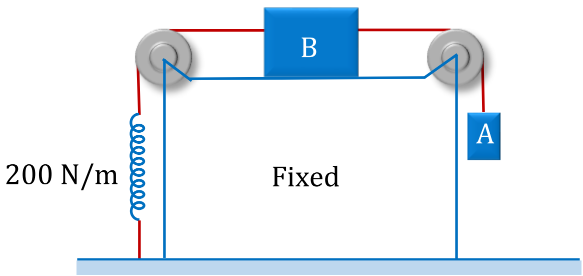
69. **Ans. (B)**

$F = kx' \sin 53$

$F = \frac{5mg}{2\ell}\frac{2}{3}\ell \times \frac{4}{5}$

$F = \frac{4mg}{3}$

70. **Ans. (B)**



$T = 20$

$kx = 20$

$200\,x = 20$

$x = \dfrac{1}{10}\,m$

$x = 10m$

71. **Ans. (C)**

$40 = 200\,x$

$\dfrac{2}{10} \times 100 = x$

$20 = x$

72. **Ans. (B)**

When force at is removed force in spring does not change suddenly.

$kx - T = 8a$

$T - 20 = 2a$

$40 - 20 = 10\,a$

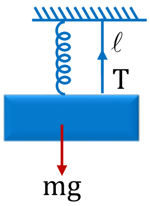
73. **Ans. (A)**

74. **Ans. (B)**

75. **Ans. (C)**

(For Ques. 73 to 75)

(i) $\Delta\ell = \dfrac{\ell}{2}$



$F_s = K\Delta\ell$

$< \dfrac{2mg}{\ell}\,\dfrac{\ell}{2}$

$F_s < mg$

$T + F_s = mg$

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

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

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

(iii) If it is So

$F_s > mg$

i.e. $\Delta\ell < \dfrac{\ell}{2}$ string unstretched and $T = 0$.

76. **Ans. (A)**

f_{max} ground = $\frac{3}{10} \times 15 \times 10 = 45$

f_{max} blocks = $\frac{1}{10} \times 10 \times 10 = 10N$

77. **Ans. (A)**

When $F = 2N$, then frictional force between 5 kg and 10 kg is 2 N.

78. **Ans. (A)**

At $F = 10N$, motion between blocks starts.

79. **Ans. (C)**

So the block will never move.

80. **Ans. (A)**

$30 - 10 = 10\, a$

$20 = 10\, a$

$a = 2$

81. **Ans. (B)**

$V_A = V_0 - \mu g t$

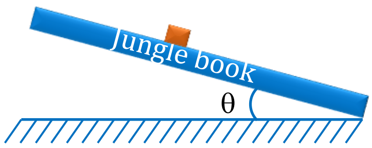
$V_B = \mu g t$

So, graph will be straight line and finally both will attain the same velocity.

82. **Ans. (B)**

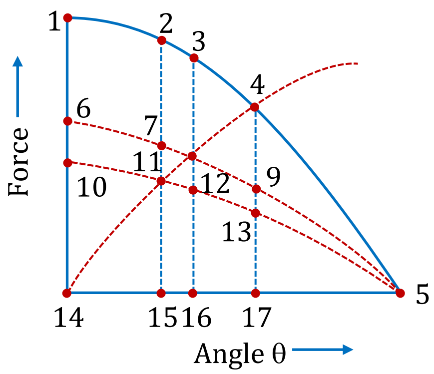
83. **Ans. (C)**

(Solution for Q. 82 and 83)



$\mu_S = 0.6$

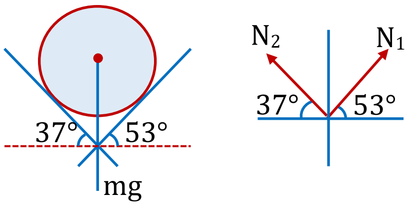
$\mu_K = 0.4$



$f_l = \mu_S\, mg \cos\theta$

$f_k = \mu_k\, mg \cos\theta$

84. **Ans. (A-R), (B-Q), (C-S), (D-P)**



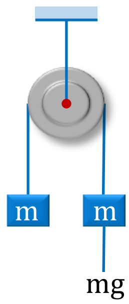
$N_2 \cos 37° = N_1 \cos 53$ $\quad N_2 \sin 37 + N_1 \cos 53 = 100$

$N_2 \times \frac{4}{5} = N_1 \times \frac{3}{5}$ $\quad N_2 \times \frac{3}{5} + N_1 \times \frac{4}{5} = 100$

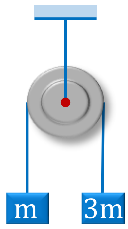
$4N_2 = 3N_1$ $\quad 3N_2 + 4N_1 = 500$

85. **Ans. (A-R), (B-T), (C-R), (D-P)**

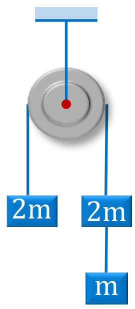
(A)



(C)



(D)



$mg + mg - T = ma$

$T - mg = ma$

$mg = 2ma$

$a = \frac{g}{2}$

$3mg - T = 3ma$

$T - mg = ma$

$2mg = 4ma$

$a = \frac{g}{2}$

$mg - T_1 = ma$

$T_1 + 2mg - T_2 = 2ma$

$T_2 - 2mg = 2ma$

$mg = 5ma$

$\frac{g}{5} = a$

86. **Ans. (A-T), (B-R), (C-R), (D-Q)**

$\vec{a}_A = 2\hat{\imath}, \vec{a}_B = 0, \vec{a}_C = -4\hat{\jmath}$ and the direction of pseudo force on particle is opposite to the acceleration of non-inertial frame.

87. **Ans. (A-S), (B-R), (C-Q)**

Taking upward direction as positive

$a_{P_2} = -a_1 = -x$

$a_{P_3} - a_{P_2} = -y$

$a_{P_3} = -x - y$

$a_4 - a_{P_3} = z$

$a_4 = a_{P_3} + z = (z - x - y) \uparrow$

$2a_{P_3} = a_3 + a_4$

$\Rightarrow \; a_3 = 2a_{P_3} - a_4 = 2(-x - y) - z + x + y \quad = -(x + y + z) = (x + y + z) \downarrow$

$\Rightarrow \; 2a_{P_2} = a_2 + a_{P_3}$

$a_2 = 2a_{P_2} - a_{P_3} = -2x - (-x - y) = -x + y = (y - x) \uparrow$

88. **Ans. (A-S), (B-S), (C-Q), (D-R)**

(A) Friction = $f_k = \frac{4}{10} \times 500 \times \frac{3}{5} = 120\,N$

(B) Friction = $f_k = \frac{4}{10} \times 500 \times \frac{3}{5} = 120\,N$

(C) Friction = $f_s = 150\ N$

(D) Friction = $50\ N$

89. **Ans. (A-R), (B-T), (C-Q), (D-T)**

For system

$F_1 - F_2 - 6g \sin 30° = 6a$

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

For 3 kg

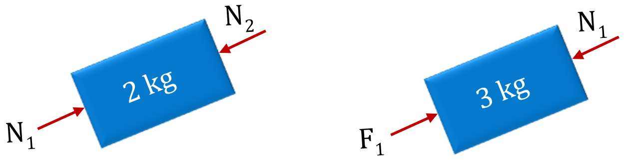
$F_1 - N_1 - 3g \sin 30° = 3a$

$\Rightarrow\ N_1 = 39\ N$

For 2 kg

$N_1 - N_2 - 2g \sin 30° = 2a$

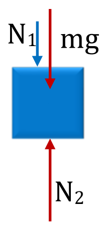
$\Rightarrow\ N_2 = 25N$



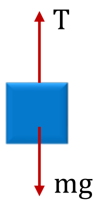
EXERCISE - S

1.

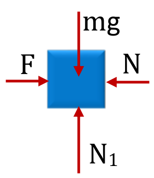
(a)



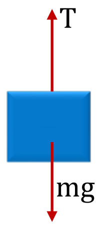
(b)



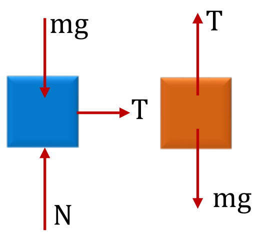
(c)



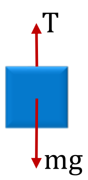
(d)



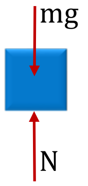
(e)



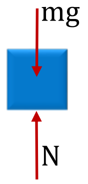
(f)



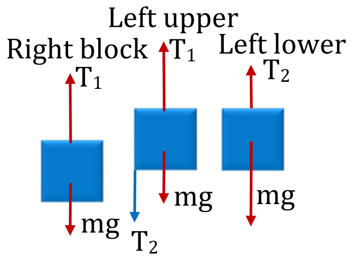
(g)



(h)



(i)



2. **Ans.** 8

$T_1 \sin 37° + T_2 \cos\theta = 10$

$T_1 \cos 37° = T_2 \sin\theta$

$\sin 37° \left(\frac{T_2 \sin\theta}{\cos 37°}\right) + T_2 \cos\theta = 10$

$T_2 = \frac{40}{3\sin\theta + 4\cos\theta}$

$T_{2\,min}$ occurs if $(3\sin\theta + 4\cos\theta)$ is maximum

$T_{2\,min} = \frac{40}{5} = 8$

3. **Ans.** 1440 N

For man B,

$T_B - 60 \times 9.8 - 540 = 0$

$T_B = 540 + 588 = 1128\ N$

For man A,

$40g + 1128 - T_A = 40 \times 2$

$T_A = 392 + 392 + 1128 - 160$

$\boxed{T_A = 1440N}$

For man C,

$T_C - 50\,g = 50 \times 1$

$T_C = 50\,g = (1+g)$

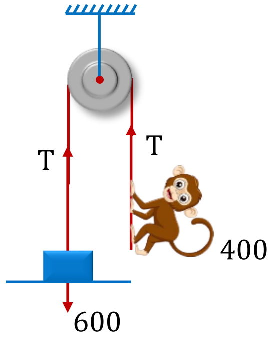
$T_C = 50\,(1+9.8)$

$T_C = 10.8 \times 50$

$T_C = 450\ N$

4. **Ans.** 0.5 g, g

$T = 600\ N$ (Block is on the verge of getting lifted)



$T - 400 = 40a$

$600 - 400 = 40a$

$a = \dfrac{200}{40} = 5\ ;\ \dfrac{g}{2} = 0.5g$

If boy move with $2g$ acceleration

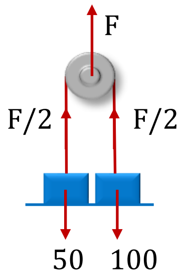
$T - 40\,g = 40 \times 2g \Rightarrow T = 120\,g$

For block $120\,g - 60\,g = 60\,a$

$a = g$

5. **Ans.** 200 N, 10 m/s^2

When 10 kg leave contact



$\dfrac{F}{2} = 100 \Rightarrow F = 200\ N$

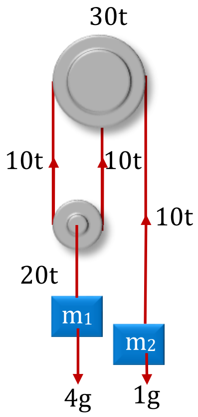
$100 - 50 = 5a$

$a = 10\ m/s^2$

6. **Ans.** 2 sec

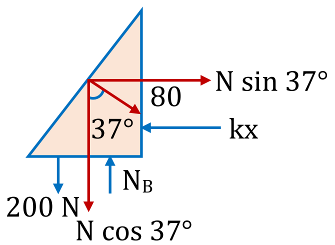
If 4 kg is leaving ground,

$20t = 40$



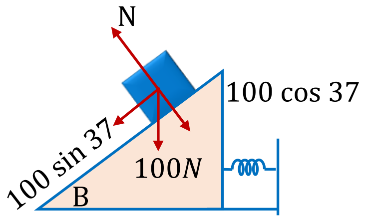
$\boxed{t = 2 sec}$

7. **Ans.** 80 N, 48 N, 264 N



$N = 100 \cos 37 = 100 \times \dfrac{4}{5}$

$= 80\ N$



$N_B = 200 + 80 \cos 37$

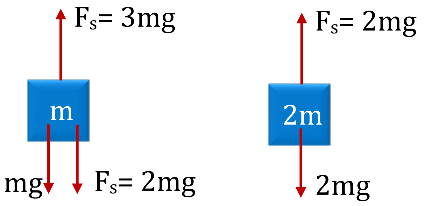
$= 200 + 80 \times \frac{4}{5}$

$= 264\ N$

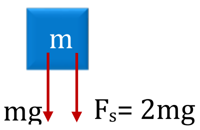
Spring force $kx = 16 \times 3 = 48\ N$.

8. **Ans.** (a) $3g\downarrow, 0$ (b) $2g\uparrow, g\downarrow$

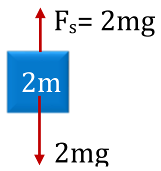
Initially



(a)

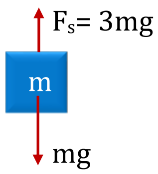


$a_m = \frac{3mg}{m} = 3g\downarrow$

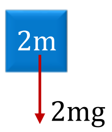


$a_{2m} = 0$

(b)



$a_m = \frac{2mg}{m} = 2g\uparrow$



$a_{2m} = \frac{2mg}{2m} = g\downarrow$

9. **Ans.** (i) $a_A = g\downarrow, a_B = \frac{2g}{3}\uparrow, a_c = \frac{2g}{3}\downarrow, a_D = \frac{2g}{3}\downarrow, a_E = 0$

(ii) $a_A = 0, a_B = \frac{g}{3}\downarrow, a_C = \frac{g}{3}\uparrow, a_D = \frac{g}{3}\uparrow, a_E = g\downarrow,$

(iii) $a_A = 0, a_B = g\downarrow, a_C = g\uparrow, a_D = 2g\downarrow, a_E = 0$

(iv) $a_A = 0, a_B = 3g\downarrow, a_C = \frac{3g}{2}\downarrow, a_D = \frac{3g}{2}\downarrow, a_E = 0$

(i) Spring 1 is cut

$\vec{a}_A = g \downarrow$

Acceleration of B, C, D are a.

$mg - T_1 = ma$

$T_1 - mg - T_2 = ma$

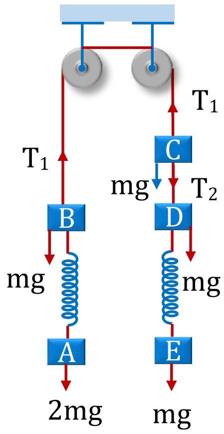
$T_2 - 2mg = ma$

$-2mg = 3ma$

$a = \frac{2g}{3}$

$a_B = \frac{2g}{3} \uparrow$ $a_C = \frac{2g}{3} \downarrow$ $a_D = \frac{2g}{3} \downarrow$

$a_E = 0$



(ii) Spring (2) is cut $a_A = 0$

Let acceleration on B, C, D be a

$3mg - T_1 = ma$ $a_B = \frac{g}{3} \downarrow$ $a_C = \frac{g}{3} \uparrow$

$T_1 - T_2 - mg = ma$ $a_D = g/3 \uparrow$

$T_2 - mg = ma$ $\vec{a}_E = g \downarrow$

$a = \frac{g}{3}$

(iii) String between C and D is cut

$a_A = 0$ $a_E = 0$ $a_D = 2g\downarrow$

Let acceleration of B and C be a

$3mg - T_1 = ma$ $a_B = g\downarrow$ $a_C = g\uparrow$

$T_1 - mg = ma$

(iv) Between B and C is cut

$a_A = 0$ $a_E = 0$

For a_B

$3mg = ma_B$

$a_B = 3g\downarrow$

Let acceleration of C and D be a

$2mg - T = ma$

$mg + T = ma$

$a = \frac{3g}{2}$ $a_c = \frac{3g}{2} \downarrow$ $a_D = \frac{3g}{2} \downarrow$

10. **Ans.** ma

Pseudo force = $m_{\text{object}} \times a_{\text{observer}}$

11. **Ans.** $a = g \cot \theta$

a_2 : Acceleration w.r.t. wedge, a_1 : Acceleration of wedge

$a_x = a_2 \cos \theta - a_1 = 0$

$a_1 = a_2 \cos \theta$

Acceleration B along y-axis

$$a_y = a_2 \sin\theta = g$$

$$a_2 = \frac{g}{\sin\theta}$$

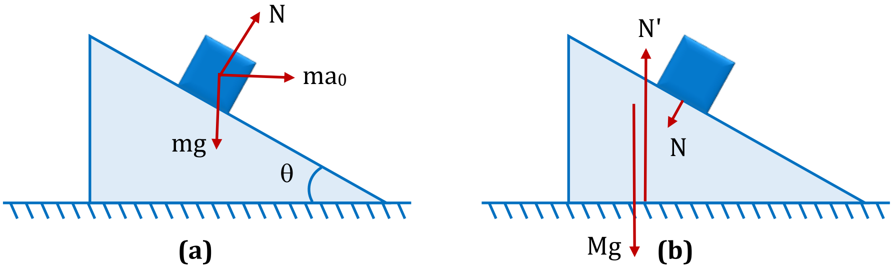
$$a_1 = \frac{g}{\sin\theta}\cos\theta = g\cot\theta$$

12. **Ans.** $\frac{(M+m)g\sin\theta}{M+m\sin^2\theta}$

Let the acceleration of the prism be a_0 in the backward direction. Consider the motion of the smaller block the frame of the prism.

The forces on the block arc (figure).

(i) N normal force (ii) mg downward (gravity) (iii) ma_0 forward (pseudo)



(a) **(b)**

The block slides down the plane. Components of the force parallel to the incline to the incline give

$$ma_0\cos\theta + mg\sin\theta = ma$$

or $a = a_0\cos\theta + g\sin\theta$

Components of the force perpendicular to the incline give

$$N + ma_0\sin\theta = mg\cos\theta$$

Now consider the motion of the prism from the lab frame. No pseudo force is needed as the frame used is inertial. The forces are (figure).

(i) Mg downward, (ii) N normal to the incline (by the block) (iii) N upward (by the horizontal surface)

Horizontal components given,

$N\sin\theta = ma_0$ or, $N = ma_0/\sin\theta$. ...(ii)

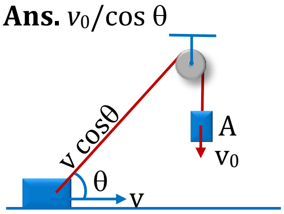
Putting in (ii)

$$\frac{Ma_0}{\sin\theta} + ma_0\sin\theta = mg\cos\theta$$

or $a_0 = \frac{mg\sin\theta\cos\theta}{M+m\sin^2\theta}$

From (i), a = $\frac{mg\sin\theta\cos^2\theta}{M+m\sin^2\theta} + g\sin\theta = \frac{(M+m)g\sin\theta}{M+m\sin^2\theta}$

13. **Ans.** $v_0/\cos\theta$

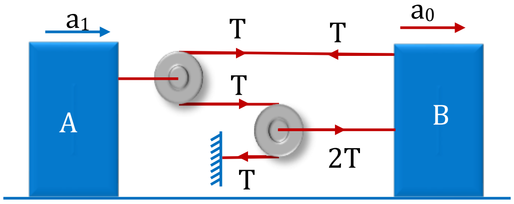


Length of string remains constant

$$v\cos\theta = v_0$$

$$v = \frac{v_0}{\cos\theta}$$

14. **Ans.** $\frac{a_0}{2}$

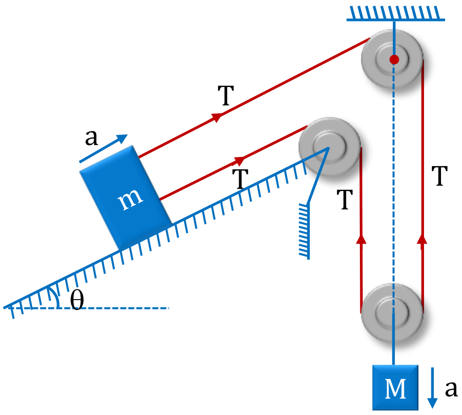


$-3T\,a_B + 2T\,a_1 = 0$

$a_1 = \frac{3a_B}{2} = \frac{3a_0}{2}$

$a_{A/B} = \frac{3a_0}{2} - a_0 = \frac{a_0}{2}$

15. **Ans.** 4



$15g - 2T = 15a$

$2T - 10g\sin30° = 10a$

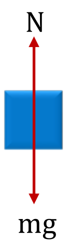
$a = 4m/s^2$

16. **Ans.** 10

$N - mg = \frac{ma}{2}$

$\frac{3mg}{2} - mg = \frac{ma}{2}$

$a = g$



17. **Ans.** 2

Block A leave contact at $t = 2$ sec and Block B leave contact at $t = 4$ sec.

$a_A = 5t - 10$

$v = \int_2^4 a_A.dt$

$\int_2^4 (5t - 10)dt$

$= 10\ m/sec \Rightarrow 10 = 5n$

$n = 2$

18. **Ans.** V_{P_1} = 5 m/s downward, V_C = 25 m/s upward

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

$V_1 = -5\ m/s$

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

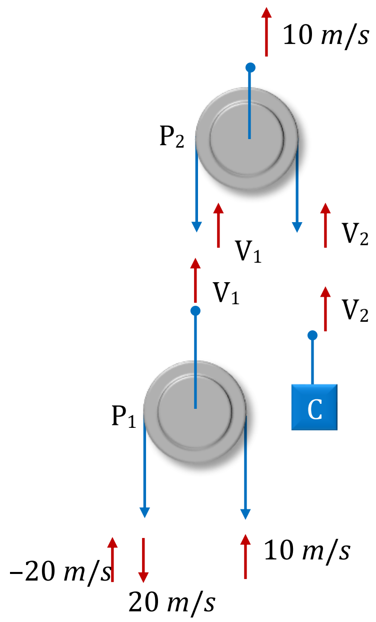
$V_2 = 25\ m/s \uparrow$

$V_C = V_2 = 25\ m/s$ upwards

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

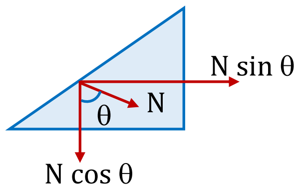
$\Rightarrow$ $V_P = 5\ m/s$ downward

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



19. **Ans.** $a_A = \dfrac{9g}{25}$, $a_B = \dfrac{12g}{25}$

$\tan 37° = \dfrac{a_A}{a_B}$ (wedge constrained relation)



$N \sin 37° = ma_B$ ...(i)

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

From equation (1) and (2) is

$a_A = \dfrac{9g}{25}$, $a_B = \dfrac{12g}{25}$

20. **Ans.** $u = v \tan\theta$ (u is velocity of rod, v is the velocity of wedge)

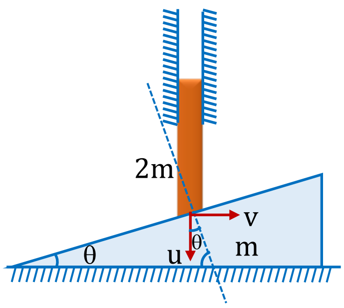
Using wedge constraint.

Component of velocity of rod along perpendicular to inclined surface is equal to velocity of wedge along that direction.

$u \cos\theta = v \sin\theta$

$\dfrac{u}{v} = \tan\theta$

$u = v \tan\theta$



Perpendicular to contact of two blocks

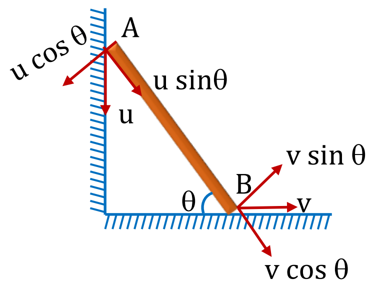
21. **Ans.** $u \tan\theta$

Since rod is rigid, its length can't increase.

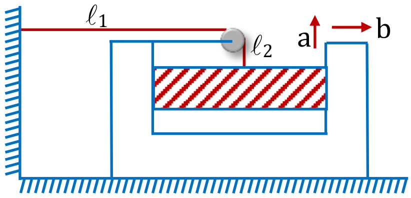
$\therefore$ Velocity of approach of A and B point of rod is zero.

$\Rightarrow$ $u \sin\theta - v\cos\theta = 0$

$\Rightarrow$ $v = u \tan\theta$



22. **Ans.** $b\hat{i} + b\hat{j}$



$\ell_1 + \ell_2 = C$

$\ell_1'' + \ell_2'' = 0$

$b - a = 0,\ a = b$

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

23. **Ans.** $5\ m/s^2$ downwards, $0\ m/s^2$, $10\ N$

$20 - T = 2a$

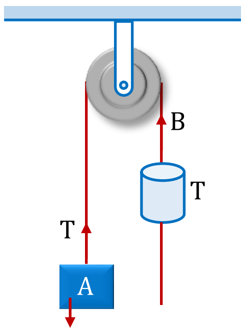
for sleeve,

$10 - f = 1a_1$

$a_1 + a = 5$

$a_1 = 5 - a$

$\boxed{a = 5m/s^2 \downarrow}$



$20 - f = 2a$

$10 - f = 5 - a$

$10 = 3a - 5$

a = 15 /3

accel,

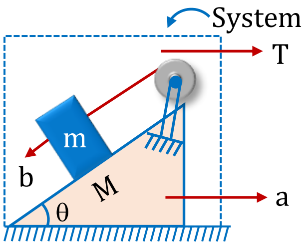
$a_1 = 5 - 5 = 0$

$20 - T = 2 \times 5$

$T = 20 - 10$

24. **Ans.** $a = \dfrac{mg\sin\theta}{M+2m(1-\cos\theta)}$

Considering block and wedge as a system and using. Newton's law for the system along x-direction

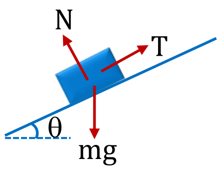


$T = Ma + m\,(a - b\cos\ \theta)$ ...(i)

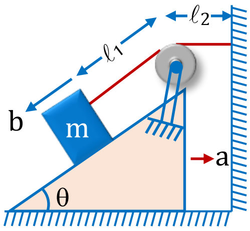
F.B.D of m

Along the inclined plane

$mg\sin\theta - T = m\,(b - a\cos\ \theta)$ ...(ii)



Using string constraint equation.



$\ell_1 + \ell_2 = \text{constant}$

$$\frac{d^2\ell_1}{dt^2} + \frac{d^2\ell_2}{dt^2} = 0$$

$b - a = 0$ ...(iii)

Solving above equations (i), (ii) and (iii), we get

$$a = \frac{mg\sin\theta}{M+2m(1-\cos\theta)}$$

25. **Ans.** $t = \sqrt{2\ell(4+\eta)/3g(2-\eta)} = 1.4s$

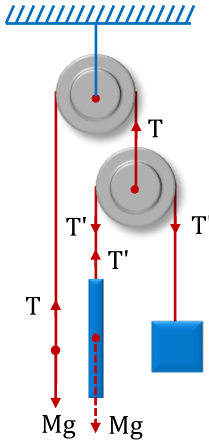
$T - mg = mw_1$ ...(ii)

and $Mg = T' = Mw_2$ ...(iii)

but $T = 2T$ ...(iv)

(Because pulley is massless)

From Eqs. (1), (2), (3) and (4)



$$w_1 = \frac{(2M-m)g}{m+4M} = \frac{(2-\eta)g}{\eta+4} \text{ (in upward direction)}$$

and $w_2 = \dfrac{2(2-\eta)g}{(\eta+4)}$ (downwards)

From kinematical equation in projection form, we get

$$l = \frac{1}{2}(w_1 + w_2)t^2$$

As w_1 and w_2 are in the opposite direction. Putting the values of w_1 and w_2, the sought time becomes.

$t = \sqrt{2l(\eta+)/3(2-\eta)g} = 1.4s$

26. **Ans.** 1 kg

Since v = constant

$T = mg$ ...(1)

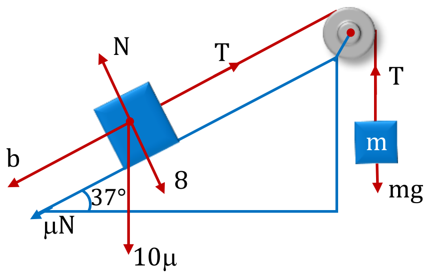
For block,

$T = 6 + N$

$T = 6 + 0.5 \times 8$

$T = 6 + 4$

$\boxed{T = 10N}$ ...(2)



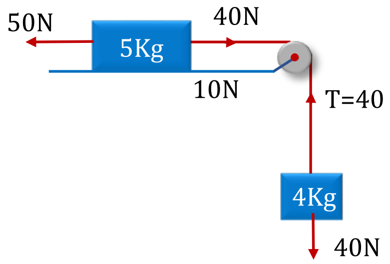
From (1) and (2)

$mg = 10$

$\boxed{m = 1kg}$

27. **Ans.** $10\hat{i}$

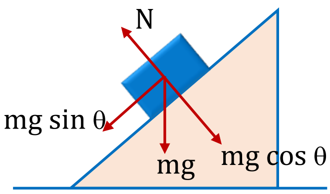
$f_{max} = \mu \times N = 0.8 \times 50 = 40N$

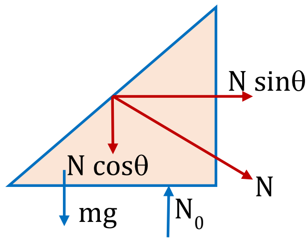


But required friction = $10N$

$f = 10\hat{i}$

28. **Ans.** $\mu_{min} = \dfrac{m\sin\theta\cos\theta}{m\cos^2\theta + M}$





$N_0 = Mg + N\cos\theta = Mg + mg\cos^2\theta$

Friction $\mu N_0 = \mu(Mg + mg\cos^2\theta) = N\sin\theta$

$$\mu_{min} = \frac{mg\sin\theta\cos\theta}{(Mg + mg\cos^2\theta)}$$

$$\mu_{min} = \frac{m\sin\theta\cos\theta}{m\cos^2\theta + M}$$

29. **Ans.** 6

$$\tan\theta = \frac{h}{r} = \mu_s \Rightarrow r = \frac{h}{\mu_s}$$

$$v = \frac{1}{3}\pi r^2 h$$

$$72 = \frac{1}{3}\times\pi\times\frac{h^2}{\mu_s^2}\times h \;= \frac{1}{3}\times\pi\times\frac{h^2}{\pi}\times h.$$

$$\Rightarrow h^3 = 216 \Rightarrow h = 6cm$$

30. **Ans.** 3

If m not sliding

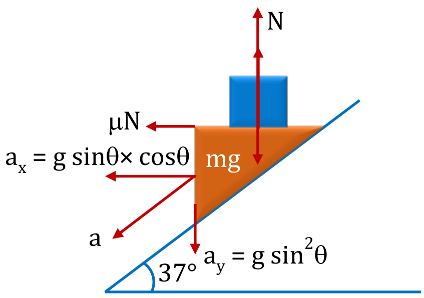
$a = g\sin\theta$

$mg - N = mg\sin^2\theta$

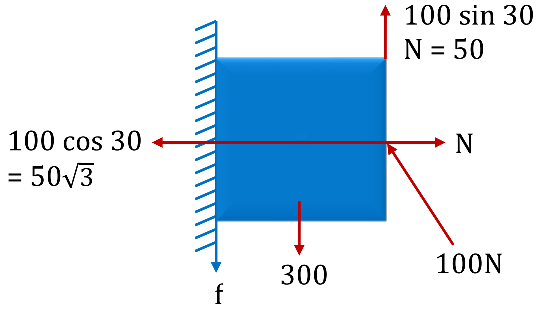
$N = mg(1 - \sin^2\theta) = mg\cos^2\theta$

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

$$\mu = \frac{\sin\theta}{\cos\theta} = \tan\theta = \frac{3}{4}$$



31. **Ans.** 20 N vertically downward



$$f_{max} = \mu N = \frac{1}{4} \times 50\sqrt{3} = 12.5\sqrt{3} = 21.25N$$

$$50 = 30 + f = f = 200 < f_{max}$$

Hence $\boxed{f = 20N}$ down words

32. **Ans.** 5

$N = mg \cos\theta$

$f_{max} = \mu mg\cos\theta$

$f_{max} = mg \sin\theta + \mu mg\cos\theta$

$f_{min} = mg \text{ in}\theta - \mu mg\cos\theta$

As given,

$f_{max} = 3 f_{min}$

$mg\sin\theta + \mu mg\cos\theta = 3mg\sin\theta - 3\mu mg\cos\theta$

$4\mu mg\cos\theta = 2mg\sin\theta$

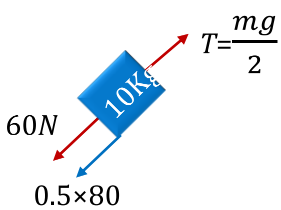
$4\mu = 2\tan\theta$

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

tan 45 = 1

$N = 10 \times \frac{1}{2}$

33. **Ans.** 20 kg



$5m = 100$

$m = 20\ kg$

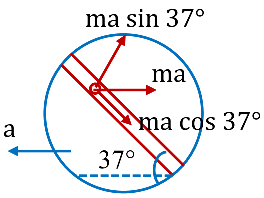
34. **Ans.** $10 m/s^2$

$ma \cos 37 - \mu\, ma \sin 37 - \mu mg = ma_0$

$$25\times\frac{4}{5}-\frac{2}{5}\times25\times\frac{3}{5}-\frac{2}{5}\times10=a_0$$

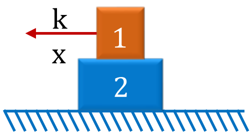
$20 - 6 - 4 = 90$

$a_0 = 10\ m/s^2$



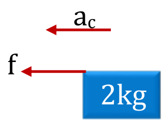
35. **Ans.** 1

When released $a_C = \dfrac{kx}{3kg}$ for no slipping $f \le \mu N$



$$f=\frac{2kx}{3}\le 0.6\times10 \Rightarrow kx\le 9 \Rightarrow x\le\frac{9}{900}$$

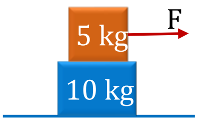
$$\Rightarrow x\le 0.01m \Rightarrow x\le 1\ cm$$



36. **Ans.** $30\ N$

$f_{max} = \mu N = 0.5 \times 50 = 25N$

$f < f_{nel}$ hence acceleration of both blocks are same



$F - f = 5a$

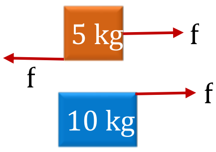
$f = 10a$

$20 = 10a$

$a = 2$

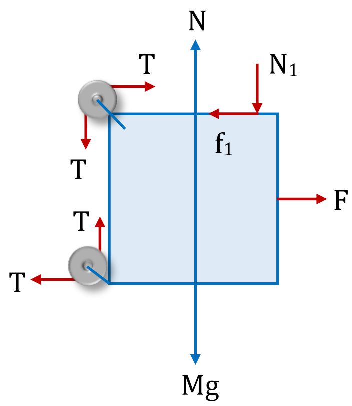
$F - 20 = 10$

$F = 30N$

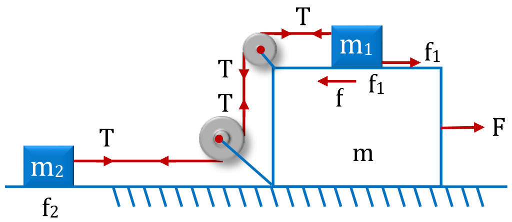


37. **Ans.**

(i)



(ii) $a = 3/5\ m/s^2$, $T = 18\ N$, $F = 60N$



$f_1 = 2f_2$

For bigger block

$f_1 - T = 20a$

$F - f_1 = 50\ a$ $\qquad$ $T - f_2 = 5a$

$F - 2f_2 = 50\ a$ $\qquad$ ...(i)

$2f_2 - T = 20a$ $\qquad$ ...(ii)

$T - f_2 = 5a$ $\qquad$ ...(iii)

$f_2 = 25\ a \Rightarrow 15 = 25\ a \Rightarrow$ a = $a = \frac{3}{5} m/s$

From equation (i)

$F_2 - 50a = 50\ a$

$F_2 = 100\ a = 60\ N$

$f_2 = \mu\ m_2 g = 0.3 \times 50$ $\qquad$ $T - 15 = 3$

$= 15\ N$ $\qquad$ $T = 18\ N$

EXERCISE - JEE (Main) PYQ

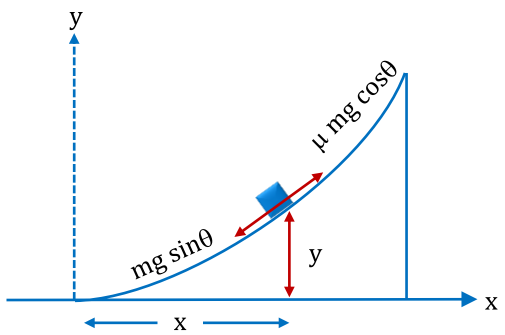
1. **Ans. (3)**

For equilibrium under limiting friction

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

$\Rightarrow \quad \tan\theta = \mu$

From the equation of surface, $y = \frac{x^3}{6}$



$$\text{slope} = \frac{dy}{dx} = \frac{3x^2}{6} = \tan\theta$$

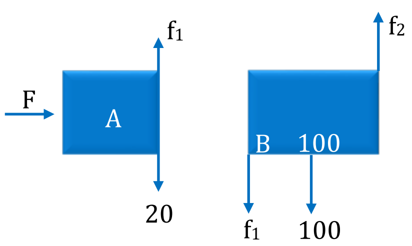
$$\Rightarrow \quad \frac{x^2}{2} = \mu = 0.5 \Rightarrow x = 1$$

So, $\quad y = \frac{1}{6}$

2. **Ans. (1)**

For equilibrium of A

$f_1 = 20$



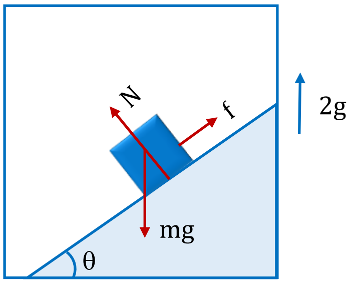
For equilibrium of B

$f_2 = f_1 + 100$

$f_2 = 120\ N$

3. **Ans. (3)**

Free body diagram is shown in the figure.



Psuedo force on the object is 2 mg in the downward direction as seen from the rocket frame of reference.

Normal force in the direction perpendicular to the inclined plane.

$N = 3\ mg\cos(\theta)$

Maximum frictional force in the direction along the plane,

$F_r = \mu_m N$

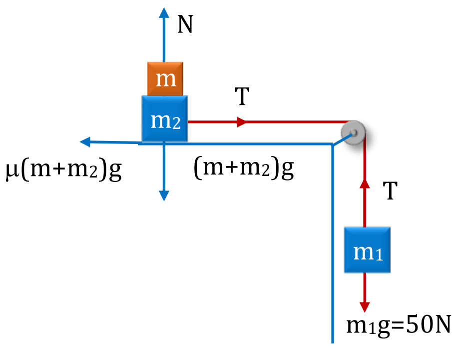
$\therefore \quad F_r = 3\ \mu_m\ mg\cos(\theta)$

This should balance the force on the block along the downward direction of plane.

$3\ mg\sin(\theta) = 3\mu_m\ mg\cos(\theta)$

$\mu_m = \tan(\theta)$

4. **Ans. (1)**



$50 - T = 5 \times a$

$T - 0.15\ (m + 10)\ g = (10 + m)a$

$a = 0$ for rest

$50 = 0.15\ (m + 10)\ 10$

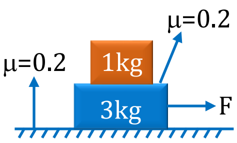
$$5 = \frac{3}{20}(m + 10)$$

$$\frac{100}{3} = m + 10$$

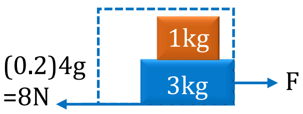
$m = 23.3\ kg$

In given options 27.3 kg is the min 'm' required.

5. **Ans. (1)**



$a_{Amax} = \mu g = 2\ m/s^2$



$F - 8 = 4 \times 2$

$F = 16N$

6. **Ans. (2)**

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

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

Integrating $0 \to t$ and $V_0 \to 0$:-

$$-gt = -\sqrt{\frac{g}{\gamma}}\tan^{-1}\left(\frac{V_0}{\sqrt{\frac{g}{\gamma}}}\right)$$

$$t = \frac{1}{\sqrt{\gamma g}}\tan^{-1}\left(\sqrt{\frac{\gamma}{g}}V_0\right)$$

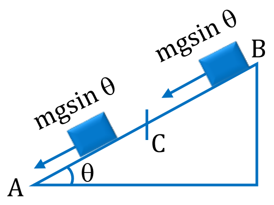
7. Ans. (3)

$$k_1 = \frac{C}{\ell_1}$$

$$k_2 = \frac{C}{\ell_2}$$

$$\frac{k_1}{k_2} = \frac{C\ell_2}{\ell_1 C}\ \ell_2 = \frac{\ell_2}{n\ell_2} = \frac{1}{n}$$

8. Ans. (3)

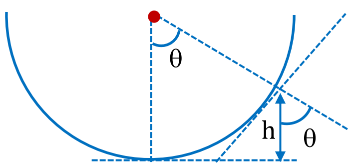


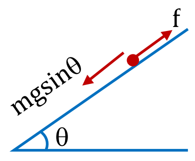
Apply work energy theorem

$mg \sin\theta\,(AC + 2AC) - \mu mg \cos\theta\, AC = 0$

$\mu = 3 \tan\theta$

9. Ans. (4)





For balancing $mg \sin\theta = f$

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

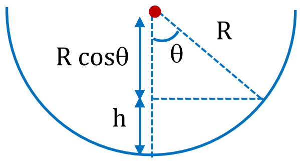
$\tan\theta = \mu$

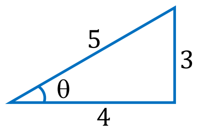
$\tan\theta = \frac{3}{4}$

$h = R - R\cos\theta$

$= R - R\left(\frac{4}{5}\right) = \frac{R}{5}$

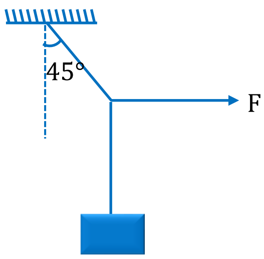
$h = \frac{R}{5} = 0.2m$

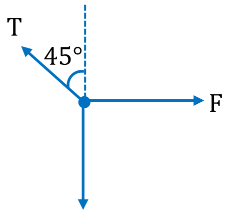




$\therefore$ Correct option is (4).

10. Ans. (1)





For equilibrium,

$T \sin 45° = F$ ...(1)

and $T \cos 45° = 10g$ ...(2)

Equation (1)/(2)

We get $F = 10g = 100\ N$

11. Ans. (3)

$t = 0, u = 0$

$$a = \frac{F_o}{M} - \frac{F_o}{MT^2}(t-T)^2 = \frac{dv}{dt}$$

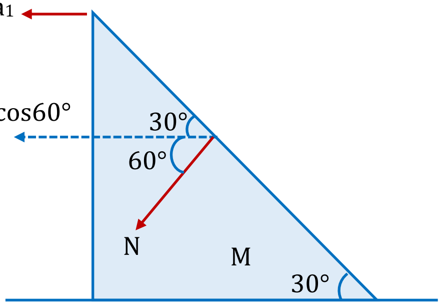
$$\int_0^v dv = \int_{t=0}^{2T}\left(\frac{F_o}{M} - \frac{F_o}{MT^2}(t-T)^2\right)dt$$

$$V = \left[\frac{F_o}{M}t\right]_o^{2T} - \frac{F_o}{MT^2}\left[\frac{t^3}{3} - t^2T + T^2t\right]_0^{2T}$$

$$V = \frac{4F_oT}{3M}$$

12. Ans. (4)

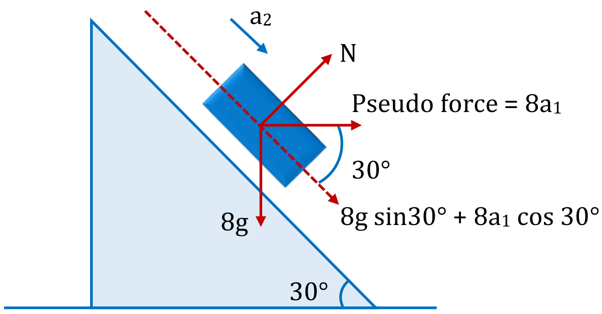
Let acceleration of wedge is a_1 and acceleration of block w.r.t. wedge is a_2



$$N\cos 60° = Ma_1 = 16a_1$$

$\Rightarrow \quad N = 32a_1$

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



$\perp$ to incline

$N = 8g\cos 30° - 8a_1 \sin 30°$

$\Rightarrow \quad 32a_1 = 4\sqrt{3}g - 4a_1$

$\Rightarrow \quad a_1 = \frac{\sqrt{3}}{9}g$

Along incline

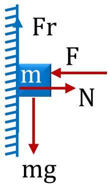
$8g\sin 30° + 8a_1\cos 30° = ma_2 = 8a_2$

$a_2 = g \times \frac{1}{2} + \frac{\sqrt{3}}{9}g.\frac{\sqrt{3}}{2} = \frac{2g}{3}$

Option (4).

13. Ans. (25)

F.B.D. of the block is shown in the diagram



Since block is at rest therefore

$fr - mg = 0$ ...(1)

$F - N = 0$ ...(2)

$fr \le \mu N$

In limiting case

$fr = \mu N = \mu F$ ...(3)

Using equation (1) and (3)

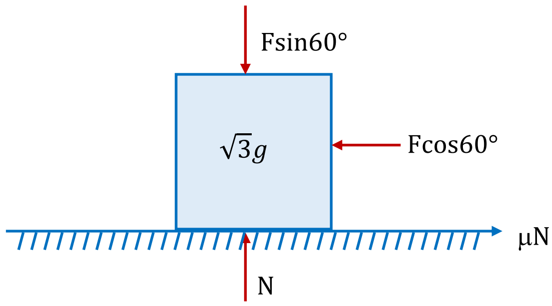
$\therefore \quad \mu F = mg$

$\Rightarrow \quad F = \frac{0.5 \times 10}{0.2} = 25\ N$

14. Ans. (3)

$F\cos 60° = \mu N$ or $\frac{F}{2}=\frac{1}{3\sqrt{3}}N$ ...(1)

and $N=\sin 60°+\sqrt{3}g$ ...(2)



From equation (1) and (2)

$$\frac{F}{2}=\frac{1}{3\sqrt{3}}\left(\frac{F\sqrt{3}}{2}+\sqrt{3}g\right)$$

$\Rightarrow$ $F = g = 10$ Newton $= 3x$

So $x=\frac{10}{3} = 3.33$

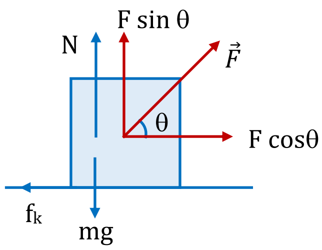
15. Ans. (2)

$N = mg - f\sin\theta$

$F\cos\theta - \mu_k N = ma$

$F\cos\theta - \mu_k (mg - F\sin\theta) = ma$

$a = \frac{F}{m}\cos\theta-\mu_K\left(g-\frac{F}{m}\sin\theta\right)$



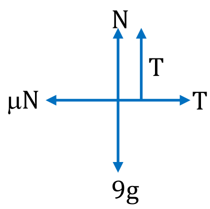
16. Ans. (30)

$N + T = 90$

$T = \mu N = 0.5\ (90-T)$

$1.5\ T = 45$

$T = 30$



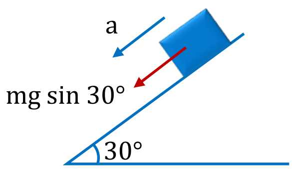
17. Ans. (3)

On smooth incline

$a = g\sin 30°$

By $S = ut + \frac{1}{2}at^2$

$S = \frac{1}{2}\frac{g}{2}T^2=\frac{g}{4}T^2$ ...(i)

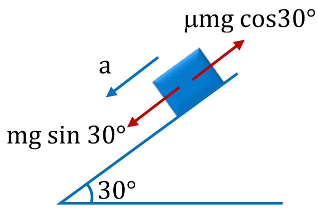


On rough incline

$a = g\sin 30° - \mu g\cos 30°$

By $S = ut + \frac{1}{2}at^2$

$S=\frac{1}{4}g\left(1-\sqrt{3}\mu\right)(\alpha T)^2$ ...(ii)



By (i) and (ii)

$$\frac{1}{4}gT^2=\frac{1}{4}g\left(1-\sqrt{3}\mu\right)\alpha^2T^2$$

$\Rightarrow \quad 1-\sqrt{3}\mu = \frac{1}{\alpha^2}$

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

$\Rightarrow \quad x = 3.00$

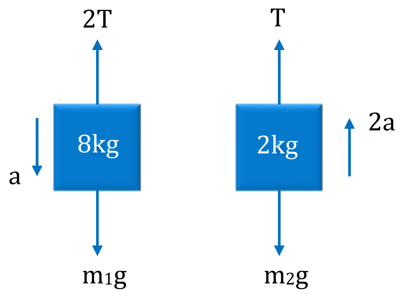
18. **Ans. (4)**

$(m_1g - 2T) = m_1a$ ...(1)

$T - m_2g = m_2(2a)$

$2T - 2m_2g = 4m_2\,a$ ...(2)

$m_1g - 2m_2g = (m_1 + 4m_2)\,a$



$a = \frac{(8-4)g}{(8+8)} = \frac{4}{16}g = \frac{g}{4}$

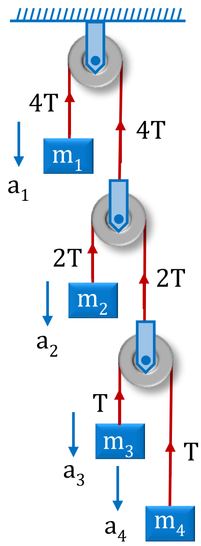
$a = \frac{10}{4}\ m/s^2$

$S = \frac{1}{2}at^2$

$\frac{0.2\times2\times4}{10} = t^2$

$t = 0.4\ sec$

19. **Ans. (1)**



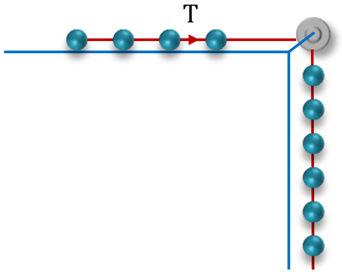
Using constraint

$$\sum \vec{T}.\vec{a} = 0$$

$-4Ta_1 - 2Ta_2 - Ta_3 - Ta_4 = 0$

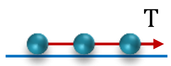
$4a_1 + 2a_2 + a_3 + a_4 = 0$

20. Ans. (36)



$$a=\frac{6mg}{10m}=\frac{6g}{10}=\frac{3g}{5}$$

Taking 8, 9, 10 together

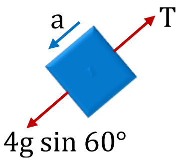


$T = 3\ ma$

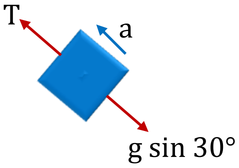
$=3m\times\frac{3g}{5}$

$= 36\ N$

21. Ans. (2)



$4g\sin 60°-T=4a$ ...(1)



$T-g\ \sin 30°=a$ ...(2)

Solving (1) and (2) we get.

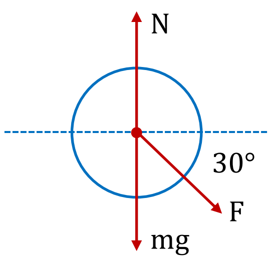
$20\sqrt{3}-T=4T-20$

$T=4\left(\sqrt{3}+1\right)N$

22. Ans. (3)

$N = mg + F\sin 30^{o}$

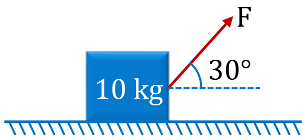
$= 700 + 200 \times \frac{1}{2}=800$ newton.



23. Ans. (2)

$N = Mg - F \sin 30°$

$$= mg - \frac{F}{2} = 100 - \frac{F}{2} = \frac{200 - F}{2}$$



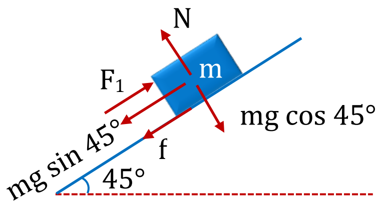
$F \cos 30° = \mu N$

$$\sqrt{3}\frac{F}{2} = 0.25 \times \left(\frac{200 - F}{2}\right)$$

$$4\sqrt{3}F = 200 - F$$

$$F = \frac{200}{4\sqrt{3} + 1} = 25.22$$

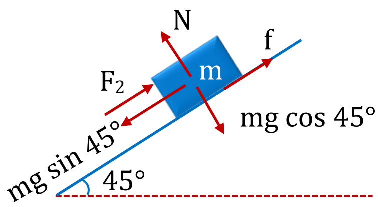
24. Ans. (1)



$F_1 = mg \sin 45° + f = mg \sin 45° + \mu N$

$$F_1 = \frac{mg}{\sqrt{2}} + \mu mg \cos 45°$$

$$F_1 = \frac{mg}{\sqrt{2}}(1 + \mu)$$



$F_2 = mg \sin 45° - f = mg \sin 45° - \mu N$

$$= \frac{mg}{\sqrt{2}}(1 - \mu)$$

$F_1 = 2F_2$

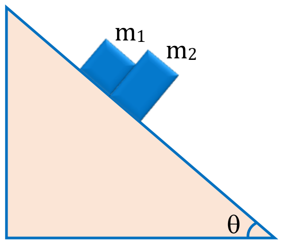
$$\frac{mg}{\sqrt{2}}(1 + \mu) = 2\frac{mg}{\sqrt{2}}(1 - \mu)$$

$1 + \mu = 2 - 2\mu$

$\mu = 1/3 = 0.33$

EXERCISE - JEE (Advanced) PYQ

1. **Ans. (D)**



The system slip down if

$(m_1 + m_2)\, g \sin\theta > \mu m_2 g \cos\theta$

$\tan\theta > \dfrac{\mu m_2}{m_1 + m_2} > \dfrac{0.3\times 2}{3}$

$\tan\theta > 0.2$

$\Rightarrow \quad \theta > 11.5°$

For P and Q system will remain stationary hence friction = $(m_1 + m_2)\, g \sin\theta$

For R and S system will move hence limiting friction acts friction = $\mu m_2 g \cos\theta$

2. **Ans. (A)**

$\vec{v} = \alpha(y\hat{x} + 2x\hat{y})$

$v_x = \alpha y \qquad\qquad v_y = 2\alpha x$

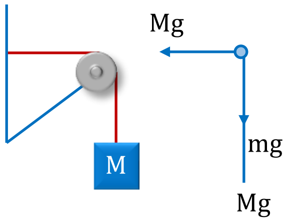
$\dfrac{dv_x}{dt} = \alpha\dfrac{dy}{dt} = 2\alpha^2 x \qquad\qquad \dfrac{dv_y}{dt} = 2\alpha v_x = 2\alpha^2 y$

$\therefore \quad \vec{F} = m\vec{a} = 2m\alpha^2(x\hat{x} + y\hat{y})$

JEE (Main) Practice Paper

SECTION–A

1. **Ans. (4)**



Force on pulley = $\sqrt{(Mg)^2 + (M+m)^2 g^2} = g\sqrt{M^2 + (M+m)^2}$

2. **Ans. (1)**

$F\sin\theta = 15 \times \frac{3}{5} = 9$

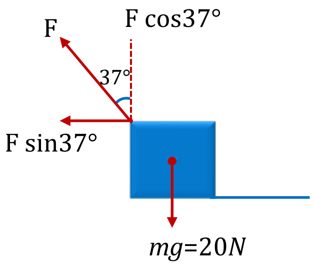
$F = ma$

$9 = 3a$

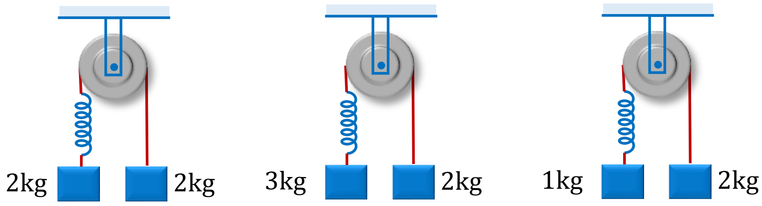
$3 = a$

The tension at mid point of rod due to

$T = \frac{1}{2}(3) = \frac{3}{2} = 1.5$



3. Ans. (2)



$T = mg$

$T = 20\ N$

$x_2 > x_1 > x_3$

$30 - T = 3a$

$a = 2$

$30 - T = 6$

$24 = T$

$20 - T = 2a$

$10 = 3a$

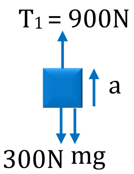
$\frac{10}{3} = a$

$20 - T = \frac{20}{3}$

4. Ans. (4)

Net force = $Ma = 8 \times 4 = 32$

5. Ans. (2)

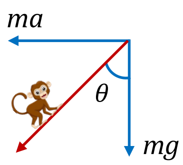


$900 - 300 - m \times 10 = ma,\ 600 = m\,(10 + a)$

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

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

6. Ans. (1)



$\tan\theta = \frac{ma}{mg} = \frac{a}{g} = \frac{7.5}{10} = \frac{3}{4} \Rightarrow \theta = 37°$

7. Ans. (3)

$F = t^2 + 6t$

The maximum value of F is

i.e. $\frac{dF}{dt} = 0$ i.e. $t = 3\ sec$

so maximum force at $t = 3\ sec$ is $F_{max} = -3^2 + 6 \times 3 = 9N$

$(F_s)_{max} = \mu mg = 0.5 \times 2 \times 10 = 10\ N$

So maximum friction acting is $9\ N$

8. Ans. (2)

Pseudo force is opposite to direction of acceleration of frame of reference. After the cable breaks, acceleration of lift is always downward pseudo force acting on an object in upward direction.

9. Ans. (1)

$20 - kx - 0.2 \times 20 = 2 \times 2$

(At $2kg$ block)

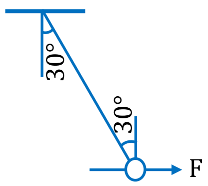
$kx = 12\ N$

$x = .012m$

$4 \times a_{4kg} = kx - 0.1 \times 40$

$a_{4kg} = 2\ m/s^2$

10. Ans. (4)



$T \cos 60 = F$

$T \sin 60 = mg$

$T > mg > F$

11. Ans. (2)

Tension = $T - mg = ma$

$T = m(g + a)$

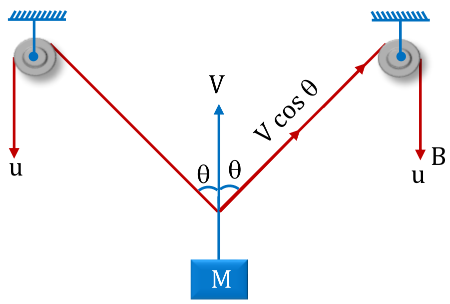
$T = 10(10 + 2)$

$T = 10 \times 12 = 120$

Upper support $120 + 80 = 200$

(80) weight of latter monkey.

12. Ans. (4)



By symmetry we can conclude that block will move only in vertical direction.

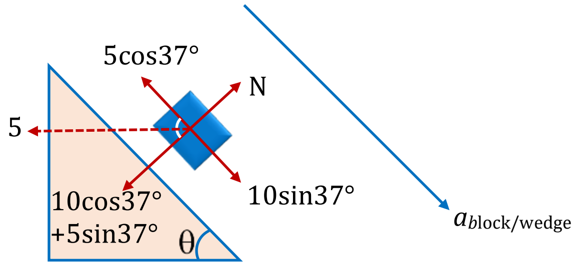
Length of string AB remains constant

$\therefore$ Velocity of point A and B along the string is same.

$V \cos \theta = u \qquad \Rightarrow \quad V = \dfrac{u}{\cos \theta}$

13. Ans. (2)

w.r.t. wedge



$$a_{\text{block/wedge}} = \frac{10\sin 37° - 5\cos 37°}{1} = 2\ m/s^2$$

$N = 10\cos 37° + 5\sin 37°$

$= 8 + 3 = 11\ N$

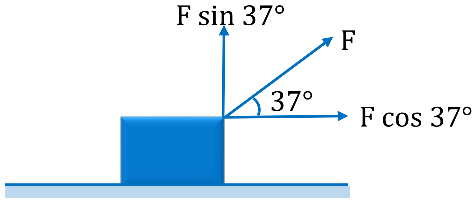
14. Ans. (2)

$f = 4N$

$f = \mu(mg - F\sin 37°)$

$= \frac{1}{2}\left(20 - \frac{3}{5}F\right) = \frac{4F}{5}$

$f = F_{\text{horizontal}}$



$$10 - \frac{3F}{10} = \frac{4F}{5}$$

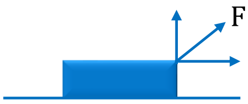
$$10 = \frac{3F}{10} + \frac{8F}{5}$$

$$\frac{100}{11} = F$$

15. Ans. (1)

$f = \mu(mg - 4)$

$= \mu\,(10 - 4)$



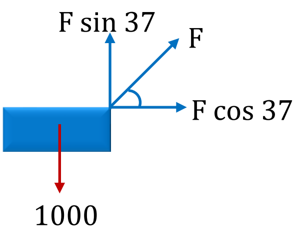
$6 \times \frac{3}{10} = \frac{18}{10} = 1.8i$

$f_{max} = -1.8i$

But required $= -1\hat{\imath}$

16. Ans. (2)

$F\cos 37° = \mu\left(1000 - \frac{3F}{5}\right)$



$$\frac{4}{5}F = \frac{1000}{3} - \frac{F}{5}$$

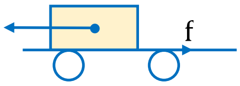
$$F = \frac{1000}{3}$$

$$\frac{1000}{3} = 25(g + a)$$

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

17. Ans. (3)

$ma = 40$



$f = \mu mg$

$f = \frac{15}{100} \times 20 \times 10 = 30$

Net force = 40 – 30 = 10

$10 = 20a$

$a = \frac{1}{2}$

$4 = \frac{1}{2} \times \frac{1}{2} t^2$

$t = 4$

Distance by truck = $s = \frac{1}{2}at^2$

$s = \frac{1}{2} \times 2 \times 16$

$s = 16\ m$

18. Ans. (1)

For upward motion

$a_1 = g(\cos\theta + \mu\cos\theta)$

Downward motion

$a_2 = g(\cos\theta - \mu\cos\theta)$

$$\frac{t_1}{t_2} = \sqrt{\frac{\sin\theta - \mu\cos\theta}{\sin\theta + \mu\cos\theta}}$$

$\sin\theta + \mu\cos\theta = 4\sin\theta - 4\mu\cos\theta$

$3\sin\theta = 5\mu\cos\theta$

$\mu = \frac{3}{5}\tan\theta = \frac{3}{5} \times \frac{3}{4} = \frac{9}{20}$

19. Ans. (2)

$F = 5ma$

$\frac{F}{5m} = a$

$f = mg$

$\mu 2ma = mg$

$\mu \times 2m \times \frac{F}{5m} = mg$

$F = \frac{5mg}{2\mu}$

20. **Ans. (3)**

$T - 24 = 4a$

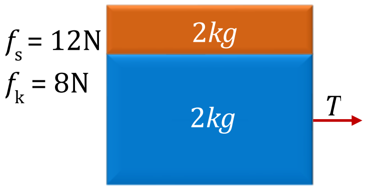
Upper block

$12 = 2a$

$a = 6$

$T - 16 = 4 \times 6$

$T = 40N$

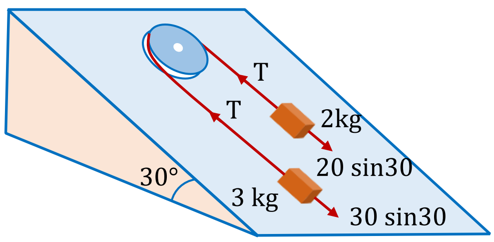


$f_s = 0.6 \times 40 = 24N$

$f_s = 0.4 \times 40 = 16$

SECTION–B

1. **Ans. (1)**



$30 \sin 30 - T = 3a$

$T - 20 \sin 30 = 2a$

$a = 1m/s^2 = \frac{g}{10} m/s^2$

$T - 10 = 2$

$T = 12N$

2. **Ans. (2)**

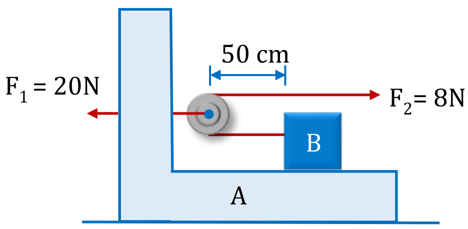
$a_A = \frac{20-16}{1} = 4m/s^2$

$a_B = \frac{8}{1} = 8m/s^2$

$a_{B/A} = 4m/s^2$

$0.5 = 1/2 \times 4t^2$

$t = \frac{1}{2}\sec = 0.5 \sec$



3. **Ans. (40)**

$4mg - T_1 = 4ma$

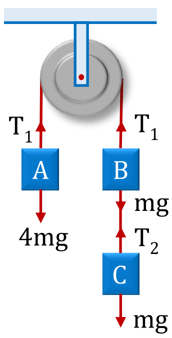
$T_1 - mg - T_2 = ma$

$T_2 - mg = ma$

$2mg = 6ma \Rightarrow a = \frac{g}{3}$

$T_2 - mg = \frac{mg}{3}$

$T_2 = \frac{4mg}{3} = \frac{4W}{3}$



4. Ans. (4)

Mass of 10 wagons = 1000 × 10 = 10000kg

So $acc. = \frac{F}{m} = \frac{10^4}{10000} = 1 m/s^2$

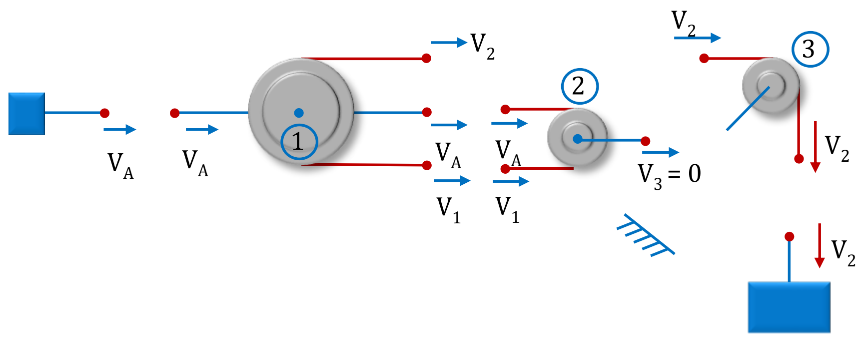
So on last 4 wagons;

T = (mass×acc.)

= (4 ×1000)(1)

T= 4000 N

5. Ans. (9)



$V_A = \frac{V_1+V_2}{2}$ [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)

$\Rightarrow$ $V_1 = -0.6$

$-0.6 + V_2 = 2V_A$

$V_2 = 2 \times 0.6 + 0.6$

$V_2 = 1.8\ m/s$

$V_B = V_2 = 1.8\ m/s$

6. Ans. (24)

$30 - T = 3a$ $a = 2m/s^2$

$T - 20 = 2a$ $T = 24\ N$

7. Ans. (1)

$N = ma$

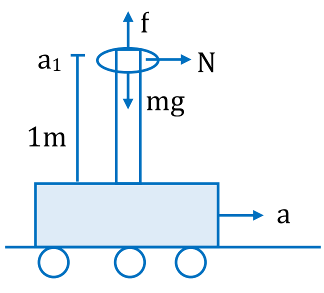
$f = \mu N = \mu ma = \frac{1}{2} m \times a = \frac{ma}{2}$

$mg - \frac{ma}{2} = ma_1$

$10 - 2 = a_1$

$a_1 = 8$

$s = \frac{1}{2} a_1 t^2$



$1=\frac{1}{2}8t^2$

$t=\frac{1}{2}$ sec

8. Ans. (67)

$f = mg \sin 30°$

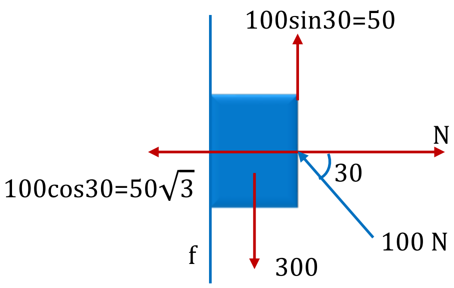
$f = \mu(mg\cos 30° + F) = mg \sin 30°$

$\frac{1}{2}\left(20\times\frac{\sqrt{3}}{2}+F\right) = 10$

$5\sqrt{3}+\frac{F}{2}=10$

$F = 2.68$

9. Ans. (20)



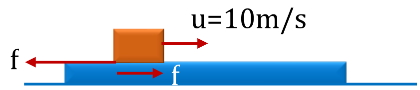
$f_{max} = \mu N$

$= \frac{1}{4}\times 50\sqrt{3} = 12.5\sqrt{3} = 21.25\ N$

$50 = 30 + f \Rightarrow f = 20\ N < f_{max}$

Hence $f = 20N$

10. Ans. (4)



$f = \mu N = 0.5 \times 10 = 5N$

Retardation of block $a_1 = -5\ m/s^2$

Acceleration of plank $a_2 = 5/2\ m/s^2$

After t sec velocity of block $10 - 5t$ velocity of plank $\frac{5}{2}t$

$10 - 5t = \frac{5t}{2}$

$10 = \frac{15t}{2}$; $t = \frac{4}{3}$ sec

JEE (Advanced) Practice Paper

1. Ans. (C)

$u = 0$

speed of block when it enter rough part.

$v=\sqrt{2(g\sin\phi)}$

for rough part

$0 = v^2 - 2as$

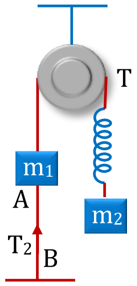
$v^2 = 2(g\cos\phi - g\sin\phi)s.$

$2g \sin\phi s = 2mg \cos\phi s - 2g \sin\phi s$

$2\sin\phi = \mu\cos\phi$

$\mu = 2\tan\phi$

2. Ans. (D)



$T = m_2g$

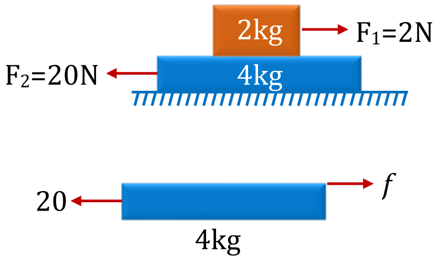
$T - m_1g - T_2 = 0$

$m_2g - m_1g = T_2$

$(m_2 - m_1)g = T_2$

3. Ans. (A)

Let both moving together



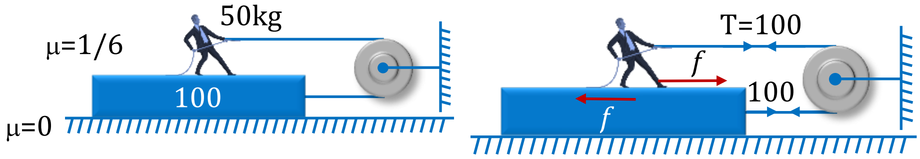
$$a = \frac{18}{6} = 3\ m/s^2$$

$$20 - f = 4 \times 3$$

$$f = 8N < f_{max}$$

Hence $f = 8N$.

4. Ans. (A)



$f_{max} = \mu mg$

$100 - f = 100\,a$

$200 = 150\,a$

$a = \frac{4}{3}$

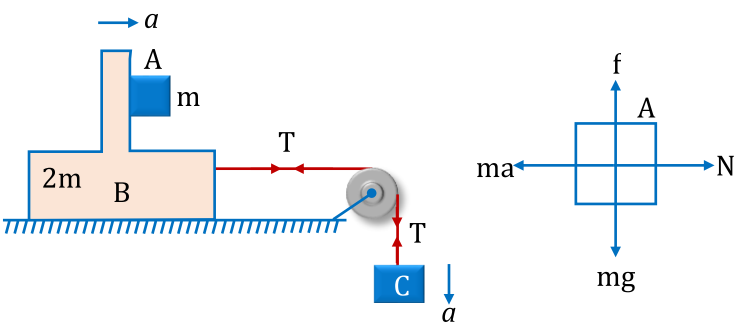
$100 - f = \frac{400}{3}$

$f = -\frac{100}{3}N$ Hence on man towards left.

$100 + f = 50\,a$

5. Ans. (C)

Block A -



$f = mg$

$\mu N = mg$

$\mu ma = mg$

$a = \frac{g}{\mu}$

Block C -

$m'g - T = m'a$

$T = 3ma$

$m'g - 3ma = \dfrac{m'g}{\mu}$

$m'g - \dfrac{m'g}{\mu} = 3ma$

$m'g\left(1 - \dfrac{1}{\mu}\right) = 3ma$

$m'g\left(\dfrac{\mu-1}{\mu}\right) = \dfrac{3mg}{\mu}$

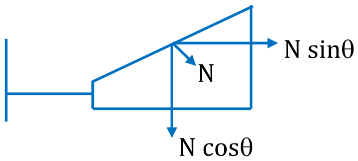
$m' = \dfrac{3m}{\mu-1}$

6. **Ans. (AD)**

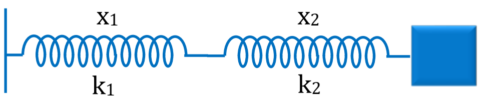
$N = mg\cos\theta$

$T = N\sin\theta = mg\sin\theta\cos\theta$

$a = g\sin\theta$



7. **Ans. (AB)**



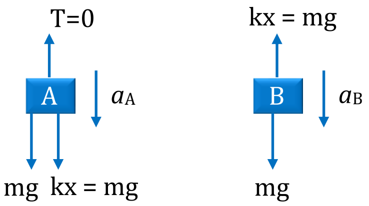
$k_1x_1 = k_2x_2$ = spring force

8. **Ans. (ABD)**

Before cutting the spring, spring force $kx = mg$

The spring force does not change instantaneously after cutting of the thread.

After cutting the spring -



$a_B = 0$

$2mg = ma_A \Rightarrow a_A = 2g$

9. **Ans. (AC)**

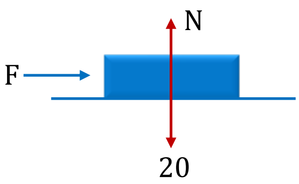
$f = \mu mg$

$\dfrac{1}{2} \times 20 = f = 10$

$14 - 10 = 2a$

$4 = 2a$

$a = 2ms^{-2}$



10. Ans. (BCD)

$f = \mu N$

$f = \mu N$

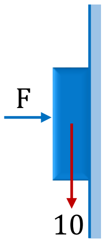
$f = \frac{1}{2} \times 40$

$f_{max} = 20$; Required 10

$F = 30\ N$; $f = 10N$

Minimum force $= 10 = \frac{1}{2} F$

$F = 20$



11. Ans. (ABD)

$F = mg \sin 37 - \mu mg \cos 37$

$ma = mg \sin 37 - \mu\ mg \cos 37$

$a = 10 \times \frac{3}{5} - \frac{1}{2} \times 10 \times \frac{4}{5}$

$a = 6 - 4 = 2$

$9 = \frac{1}{2} \times 2t^2$

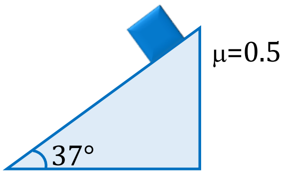
$t = 3$ sec

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

$v^2 = 2 \times 2 \times 4$

$v^2 = 16$

$v = 4\ m/s$



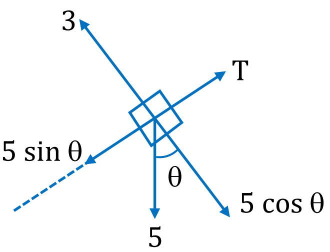
12. Ans. (AB)

$S_P = \frac{1}{2} \times 4 \times 1 = 2m$

Acceleration of block $a_B = \mu g = 2$

$S_B = \frac{1}{2} at^2 = 1m$

13. Ans. (AD)



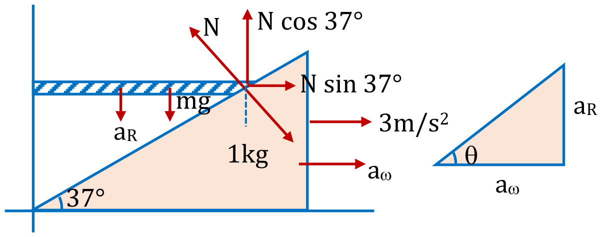
$T = 5 \sin \theta$

$3 = 5 \cos \theta$

$\therefore T^2 + 9 = 25$

$\Rightarrow T = 4N$

14. Ans. (5)



For wedge $N \sin 37 = 1 \times 3$

$$N \times \frac{3}{5} = 3$$

$N = 5N$

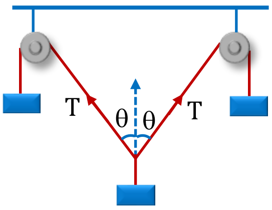
15. Ans. (45)

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

$2mg \cos \theta = \sqrt{2}\ mgs$

$$\cos \theta = \frac{\sqrt{2}}{2}$$

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



16. Ans. (4.9)

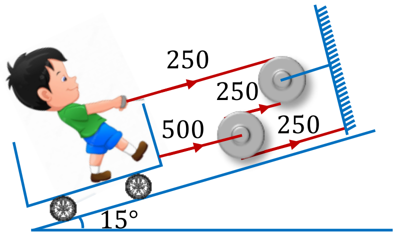
$750 - mg \sin 15 = 100\, a$

$$750 - 1000 \times \frac{26}{100}$$

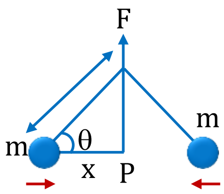
$750 - 260 = 100\, a$

$490 = 100\, a$

$a = 4.9$

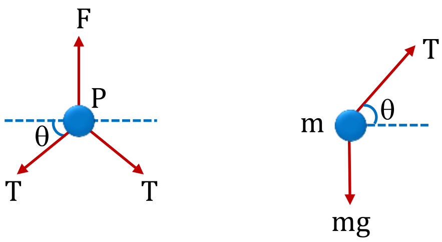


17. Ans. (3)



The arrangement is shown in the figure.

The separation between the two masses is $2x$. Each mass will move in the horizontal direction as shown in the figure.



Let the tension in the string be T. The forces acting at point P and on one of the masses are shown in the figure.

Net force a at point P must equal zero.

$2T \sin\theta = F$ ...(i)

Also, For the mass m.

$T \sin\theta - mg = 0$ ...(ii)

$T \cos\theta = ma$ ...(iii)

Equation (i) and (iii) give

$$a = \frac{F\cot\theta}{2m} = \frac{F}{2m}\left(\frac{x}{\sqrt{a^2 - x^2}}\right)$$

18. **Ans. (2)**

For motion of a body, down the inclined plane, we have

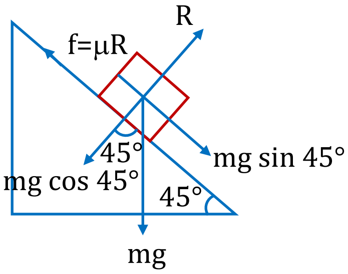
Force on body = $mg \sin 45° - \mu R$

m × acceleration = mg (sin 45° – μmg cos 45°)

$ma = mg$ (sin 45° – μ cos 45°)

$$ma = \frac{mg}{\sqrt{2}}(1-\mu)$$

$$a = \frac{g(1-\mu)}{\sqrt{2}} \quad \text{...(i)}$$



For body A,

$$a_A = \frac{g(1-\mu_A)}{\sqrt{2}}$$

$$a_A = \frac{10(1-0.2)}{\sqrt{2}} = \frac{8}{\sqrt{2}} = 4\sqrt{2} m/s^2 \quad \text{...(ii)}$$

For body B,

$$a_B = \frac{g(1-\mu_B)}{\sqrt{2}}$$

$$a_B = \frac{10(1-0.3)}{\sqrt{2}} = \frac{7}{\sqrt{2}} = 3.5\sqrt{2} m/s^2 \quad \text{...(iii)}$$

A and B are released simultaneously. They travel for time t. Let A slide by a distance S_A. along plane and let B slid by a distance S_B along plane till they come on the same line on the inclined plane.

$\therefore \quad S_A = S_B + \sqrt{2}$

$\frac{1}{2}a_A t^2 = \frac{1}{2}a_B t^2 + \sqrt{2}$, Where t is time taken

$\frac{1}{2}\times\left(4\sqrt{2}\right)\times t^2 = \frac{1}{2}\left(3.5\sqrt{2}\right)\times t^2 + \sqrt{2}$,

From (2) and (3)

$2t^2 = \frac{3.5}{2}t^2 + 1 \Rightarrow 0.5t^2 = 2 \Rightarrow t = 2\,\text{sec}$ ...(iv)

$\therefore \quad S_A = \frac{1}{2}a_A t^2 = \frac{1}{2}\times\left(4\sqrt{2}\right)(2)^2 = 8\sqrt{2}m$ ...(v)

Hence $S_A = 8\sqrt{2}m, S_B = 7\sqrt{2}m, t = 2\text{second}$