Laws of Motion and Friction

SOLUTIONS

Exercise-I (Conceptual Questions)

1. Newton's I law.

2. $F_{net} = 0$, $a = 0$

3. $F_{net} = ma$, $F_{net} = \text{const}$, $a = \text{const}$.

4. $V = u + at$

$30 = a(2)$

$a = 15\ m/s^2$

$\therefore \quad F = ma = 10\ (15)$

$F = 150\ N$

5. $F = 0$ (as acceleration = 0)

6. $v = u + at$

$0 = 8 + a \times 3$

$a = -\frac{8}{3} m/s^2$

$F = 6 \times \frac{8}{3} = 16N$

7. $a = \frac{-4-8}{6} = -2\ m/s^2$

8. $a = \frac{F}{m}$

$v^2 - 0 = 2\frac{F}{m} \times d \qquad \therefore \qquad v \propto \frac{1}{\sqrt{m}}$

9. $a = \frac{F}{m}$

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

$v^2 = 2\frac{F}{m} \times d$

$v^2 = 2\left(\frac{25 \times 10^4}{5 \times 10^7}\right) \times 100$

$v^2 = 1$

$v = 1\ m/s$

10. $F = mg = 40\ (980)$

$F = 39200$ dyne

11. $\vec{F}_{net} = 0 \Rightarrow \vec{a} = 0$

$\therefore \quad \vec{v}$ remains unchanged

12. $\vec{a} = \frac{\vec{F}}{m} = -\frac{3}{5}\hat{i} + \frac{4}{5}\hat{j}$

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

$\vec{v} = 6\hat{i} - 12\hat{j} + \left(-\frac{3}{5}\hat{i} + \frac{4}{5}\hat{j}\right)t$

$\vec{v} = \left(6 - \frac{3t}{5}\right)\hat{i} + \left(\frac{4t}{5} - 12\right)\hat{j}$

To have a velocity along y-axis,
its x-component must be zero.

$6 - \frac{3t}{5} = 0$

$t = 10$ sec

13. Since, $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = \vec{0}$

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

$\vec{a} = \frac{\vec{F}_2 + \vec{F}_3}{m} = -\frac{\vec{F}_1}{m}$

$a = \frac{F_1}{m}$

14. $F_{net} = ma$

$F_{net} = 1\ N$

15. Force from road causes acceleration of car.

16. $F = \frac{dp}{dt}$

17. Inertia of stone causes reaction to get hurt.

18. $a = \frac{F}{m} = 2\ m/s^2$

$v = u + at$

$v - u = 2(20)$

$v - u = 40$

$\Delta P = m(v-u) = 10(40)$

$\Delta P = 400$ kg-m/s

or

$\because \quad F = \frac{\Delta P}{\Delta t} \quad \therefore \quad \Delta P = F\Delta t = 20 \times 20$

$\therefore \quad \Delta P = 400$ kg-m/s

19. $F_{avg} = \frac{\Delta p}{\Delta t} = \frac{100 \times 10^{-3} \times 5}{0.25}$

$F_{avg} = 2N$

20. $F_{avg} = \frac{\Delta p}{\Delta t} = \frac{0.5(15-(-10))}{0.02}$

$F_{avg} = 625N$

21. Force F = Rate of change in the momentum

$= \frac{m[v_2 - v_1]}{t}$

$= \frac{(0.1)[40-(-20)]}{(5\times10^{-3})} = 1200N$

22. $F_{avg} = \frac{2\times\frac{50}{1000}\times25}{0.05} = 50N$

23. $a = \frac{v-u}{t}$

$a = \frac{\sqrt{2gh_2} - \left(-\sqrt{2gh_1}\right)}{t}$

$a = \frac{\sqrt{2\times10\times5} + \sqrt{2\times10\times10}}{0.01}$

$a = \frac{10+14}{0.01} = 2400\ m/s^2$

24. $F_{avg} = \frac{2mv}{t}$

$\frac{2\times150\times10^{-3}\times40}{1.20\times10^{-3}} = 10000N$

25. $F = \frac{\Delta p}{\Delta t} = 2mnv$

26. $Mg = n \times 2mv$

$2 \times 9.8 = 5 \times 2 \times 0.1 \times v$

$v = \frac{9.8\times2}{1} = 19.6\ m/s$

27. $F = m \times a = 25 \times \frac{dv}{dt} = 25 \times 2 = 50$ N

28. Δp = Area under F-t graph

$m(v-u) = \frac{1}{2} \times 8 \times 4 - \frac{1}{2} \times 1 \times 2 - 1 \times 2$

$2(v-0) = 16 - 1 - 2$

$v = \frac{13}{2} = 6.5$ m/s

29. $\Delta p = \int F dt = 0$ (area of F-t graph is zero)

30. Δp = Area under F-t graph

$m(v-u) = 4 + 8 + 1.625 + 5$

$2(v-5) = 18.625$

$v - 5 = 9.31$

$v = 14.3$ m/s

32. $I = \int_0^t F dt = 50t - \frac{20t^2}{2} = 50t - 10t^2$

33. $\vec{I} = \Delta\vec{p} = \vec{p}_f - \vec{p}_i$

$= 0 - 0.2 = -0.2$ kg ms^{-1}

34. $F = \frac{dm}{dt} \times v = 1.5 \times 3 = 4.5N$

35. $F = \frac{dm}{dt} \times V = 3 \times 10 = 30$

F = 30 N

$\therefore$ 1.5 × a = 30

$a = \frac{30}{1.5} = 20\ m/s^2$

36. $F = \frac{vdm}{dt} = 5 \times 1 = 5N$

$a = \frac{5}{2} = 2.5\ m/s^2$

37. $\frac{dm}{dt} = \frac{300}{400} = 0.75$ kg/s

38. $F = -\frac{vdm}{dt} = -\alpha v^3 \ \therefore \qquad a = \frac{-\alpha v^3}{M}$

39. F = 2 × 300 = 600

$\therefore \qquad a = \frac{600}{60} = 10\ m/s^2$

40. $800 \times 9.8 + 800 \times 4.2 = \frac{dm}{dt} \times 1600$

$\frac{dm}{dt} = \frac{14}{2} = 7$ kg/s

41. $\frac{dm}{dt} = \frac{210}{300} = 0.7$ kg/s

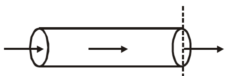
42. Minimum rate of burning fuel is $\frac{dm}{dt}$

$\therefore\ mg = u\frac{dm}{dt}$

or, $\frac{dm}{dt} = \frac{mg}{u} = \frac{800\times10}{40} = 200$ kg/s.

44. $\Delta p = 2\ mv \sin\theta$

$F = \frac{dp}{dt} = (2v\sin\theta)\frac{dm}{dt}$



The mass crossing an area a in time t would be

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

For small element

$\therefore \qquad \frac{dm}{dt} = vad \quad \therefore \qquad F = 2av^2d \sin\theta$

46. Action $\rightleftharpoons$ Reaction

47. Forces from ground causes horse motion.

48. Action $\rightleftharpoons$ Reaction

49. $m_A a_A = m_B a_B$

$m a_A = 2m \times a$

$a_A = 2a$

51. $m_1 a_1 = m_2 a_2$

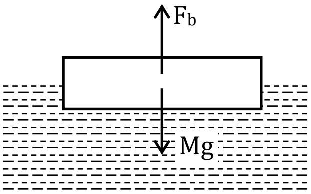
$$a_2 = \frac{m_1 a_1}{m_2} = \frac{5\times2}{8}$$

$a_2 = 1.25\ m/s^2$

52. None of the above

53. Weight is gravitational force of earth on the body.

56. Free body diagram



Net force = $Mg - F_b = 0$

(F_b = Buoyant force)

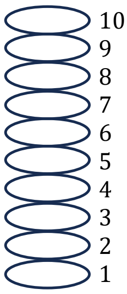
57. (1) is wrong 3rd coin has seven coins on its top which exert a force 7 mg on it.

(2) is correct. 6th coin has four coins, placed over it. Thus 7th coin exerts a force 4mg on 6th coin (downwards)

(3) is wrong,

As what is explained in (2), the reaction of 6th coin on the 7th coin is 4 mg (upwards)

(4) is wrong. 10th coin, which is the topmost coin, experiences a reaction force of mg (upwards) from all the coins below it.



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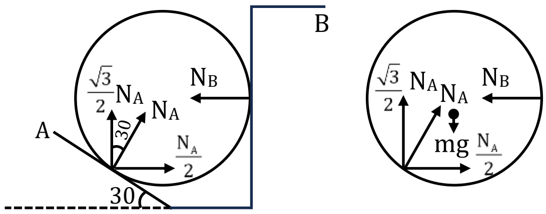


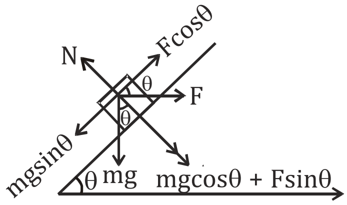
$$\because \frac{\sqrt{3}}{2}N_A = mg$$

$$\therefore N_A = \frac{2}{\sqrt{3}}\times50\times10$$

$$\therefore N_A = \frac{1000}{\sqrt{3}}N$$

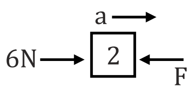
$$\therefore N_B = \frac{N_A}{2} = \frac{500}{\sqrt{3}}N$$

60.



From the figure, the normal reaction on the block is N = $mg\cos\theta + F\sin\theta$.

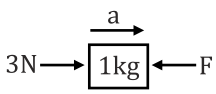
61. $a = \dfrac{6-3}{2+1} = 1\ m/s^2$



$6 - F = 2 \times 1$

F = 4 N

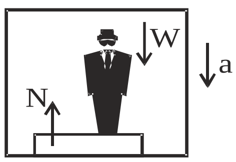
62. $a = \dfrac{3}{2+1} = 1\ m/s^2$



$3 - F = 1 \times 1$

F = 2N

64. W–N = ma



$\therefore$ N = W – ma

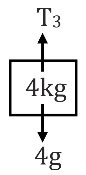
$\therefore$ Reading = 80 × 10 – 80 × 5 = 400N

65. $\dfrac{W_{app_1}}{W_{app_2}} = \dfrac{m(g+a)}{m(g-a)} = \dfrac{12}{8} = \dfrac{3}{2}$

66. Horizontal force can not balance vertical forces.

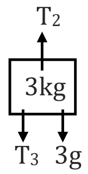
67. Arms should be vertical for least tension.

68. $T_3 = 4g$



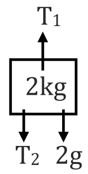
$T_2 = T_3 + 3g$

$T_2 = 7g$



$T_1 = T_2 + 2g$

$T_1 = 9g$



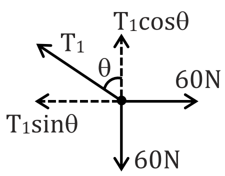
$\therefore \quad \dfrac{T_1}{T_3} = \dfrac{9g}{4g} = \dfrac{9}{4}$

69. $T_1 \cos\theta = 60$

$T_1 \sin\theta = 60$

$\therefore \ \tan\theta = \dfrac{6}{6} = 1$

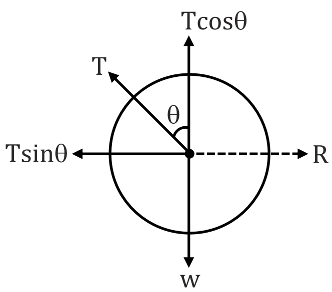
$\therefore \ \theta = 45°$



70. $T = mg, \qquad 2T\cos\theta = mg$

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

71.



$T\cos\theta = w$

$T = \dfrac{w}{\cos\theta} = \dfrac{w}{\frac{4}{5}}$

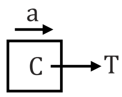
$T = \dfrac{5w}{4}$

72. $T\cos\theta = W$; $T\sin\theta = R$; $\tan\theta = \dfrac{R}{W}$

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

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

73. $a = \dfrac{10.2}{2+2+2} = 1.7 \ m/s^2$



$T = 2a = 2 \times 1.7$

$T = 3.4$ N

74. $a = \dfrac{F}{(M_1 + M_2 + M_3)}$ ...(iv)

$T = (M_1 + M_2)a$

$= (M_1 + M_2)\ F/M_1 + M_2 + M_3 = \dfrac{3MF}{6M}$

$T = \dfrac{F}{2}$

75. $a = \dfrac{36}{36} = 1 \ m/s^2$

$\therefore \ T' = (M_2 + M_3)a$

$\therefore \ T' = 35 \times 1 = 35$ N

76. The common acceleration of the blocks is

$a = \dfrac{40-10}{10+6+4} = \dfrac{30}{20} = 1.5 \ m/s^2$

$\therefore \ 40 - T_2 = m_1 a$

$\therefore \ T_2 = 40 - 10 \times 1.5$

$T_2 = 25N$

77. For figure 1 :-

$a = \dfrac{500}{25} = 20 \ m/s^2$

$T = 15 \times 20 = 300$ N

For figure 2 :-

$a = \dfrac{750}{25} = 30 \ m/s^2$

$T' = 10 \times 30 = 300$ N

Hence $T = T^1 = 300$ N

78. $T_1 = (12 + 3)a$

$30 = 15a$ ...(i)

$a = 2 \ m/s^2$

$F\cos 60° = 30 + (15 \times 2)$

$F = 120$ N

79. $a=\dfrac{25}{10}=2.5\ m/s^2$

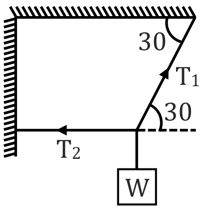
$T_A = 5 \times 2.5 = 12.5N$

$T_B = 4 \times 2.5 = 10N$

$T_C = 3 \times 2.5 = 7.5N$

80. $a = \dfrac{210-150}{15}=4\ m/s^2$

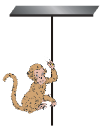
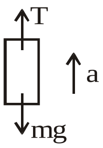
81.



$T_1 \sin30° = W$

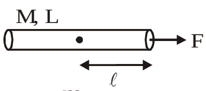
$T_1 \times \dfrac{1}{2} = 40$

$T_1 = 80N$

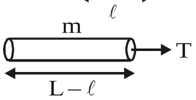
82.  FBD of monkey 

$\therefore\ T - mg = ma \qquad \because\ T_{max} = 300$

$\therefore\ 300 - 150 = ma \therefore\ a=\dfrac{150}{15} = 10\ m/s^2$

83. 

$a=\dfrac{F}{M}$



$\because\ T = m \times a$

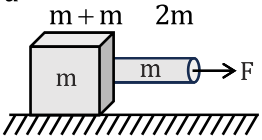
$\therefore\quad T=\dfrac{M}{L}(L-\ell)\times\dfrac{F}{M}$

$\therefore\quad T=F\left(1-\dfrac{\ell}{L}\right)$

84. $T=\dfrac{M}{L}\times x\times\dfrac{F}{M}$

$T = \dfrac{Fx}{L}$

85. $a=\dfrac{F}{m+m}=\dfrac{F}{2m}$



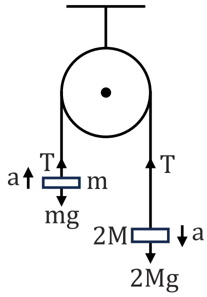
Tension at mid point = $\left(m+\dfrac{m}{2}\right)\times\dfrac{F}{2m}=\dfrac{3F}{4}$

86. For the particle of mass m,

$T - mg = ma \qquad ...(i)$

For the particle of mass 2M,

$2Mg - T = 2Ma \qquad ...(ii)$



Add (i) and (ii) to eliminate T.

$2Mg - mg = 2Ma + ma$

$g(2M - m) = a(2M + m)$

or $a = \left(\dfrac{2M-m}{2M+m}\right)g \qquad ...(iii)$

Now $T - mg = m \times \left(\dfrac{2M-m}{2M+m}\right)g$

$T = mg + mg\left(\dfrac{2M-m}{2M+m}\right)$

$T = \dfrac{2mgM+m^2g+2mgM-m^2g}{(2M+m)}$

$T = \dfrac{4mM}{(2M+m)}g \qquad ...(iv)$

87. $a=\dfrac{(10+5)g-5g}{20}$

$a=\dfrac{10g}{20}=\dfrac{g}{2}$

88. $a=\dfrac{10g-5g}{15}=\dfrac{g}{3}$

For block A :-

$T-5g=\dfrac{5g}{3}$

$T=\dfrac{20g}{3} = 66.67\ N$

89. $T=\dfrac{2m_1m_2}{m_1+m_2}g$

$\therefore\quad T=\dfrac{2\times m\times 2m}{m+2m}g$

$\therefore\quad T=\dfrac{4mg}{3}$

$\therefore\quad F = 2T + 3mg$

$\therefore\quad F = \dfrac{17}{3}mg = 5.67\ mg$

90. In case 'a' :- $a_a = \frac{2mg - mg}{3m} = \frac{g}{3}$

In case 'b' :- $a_b = \frac{2mg - mg}{2m} = \frac{g}{2}$

hence, $a_a < a_b$

91. $mg - T = ma$ ...(i)

$T = m'a$ ...(ii)

$\therefore \quad a = \frac{mg}{(m+m')}$

92. For case A

$15g - T = 15a$ ...(i)

$T = 5a$ ...(ii)

$\therefore \quad a = \frac{3g}{4}$

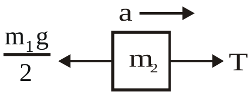
For case B

$15g - T = 15a$ ...(iii)

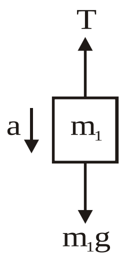
$T - 5g = 5a$ ...(iv)

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

93.



$T - \frac{m_1 g}{2} = m_2 a$ ...(1)

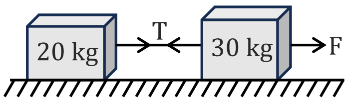


$m_1 g - T = m_1 a$ ...(2)

equation (1) + equation (2)

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

94.



$T = 20 \times 3 = 60N$

95. $a = \frac{1g}{1+1} = 5 \text{ m/s}^2$

$T = 1a = 1 \times 5$

$T = 5N$

96. $3g - T_2 = 3a$ ...(i)

$T_2 - T_1 = 6a$ ...(ii)

$T_1 - g = a$ ...(iii)

$\therefore$ By solving eq (i), (ii) and (iii)

$2g = 10a$

$a = 2 \text{ m/s}^2$

So, $T_1 = 10 + 2$

$T_1 = 12$ N

and $T_2 = 3 \times 10 - 3 \times 2$

$T_2 = 24$ N

have $\frac{T_1}{T_2} = \frac{12}{24} = \frac{1}{2}$

97. Force on block A in downward direction :-

$F_A = 3 \text{ Mg} \sin 53° = \frac{12Mg}{5}$

Force on block B in downward direction :-

$F_B = 4 \text{ Mg} \sin 37° = \frac{12Mg}{5}$

$\because \quad F_A = F_B$

hence, both the blocks remains in rest.

98. $2Mg \sin\theta - T = 2Ma$

$T = Ma$

$\therefore \quad a = \frac{2g\sin\theta}{3}$

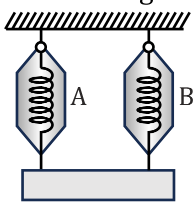
99. $Mg \times \frac{1}{2} = mg$

$\frac{M}{2} = m$

$M = 2m$

$M = 2 \times 10 = 20$ kg

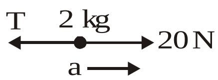
100. Both A and B reads 2 kg



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

102.

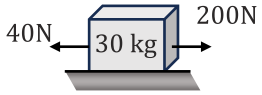
$T = 1 \times 10 = 10$ N



$20 - T = 2 \times a$

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

103. F = 20 × 2 = 40N



$a = \frac{160}{30} = 5.3\ m/s^2$

104. T = 5gsin30°

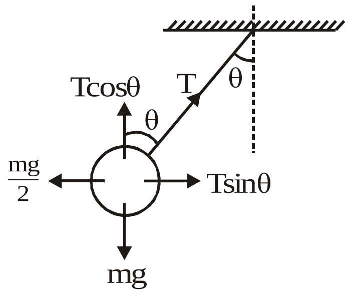
T = 25 N

108. $T\cos\theta = mg$ ...(1)

$T\sin\theta = \frac{mg}{2}$ ...(2)

eqn. $(1)^2 + (2)^2$

$T^2 = (mg)^2 + \frac{(mg)^2}{4}$



$\therefore \quad T = \frac{\sqrt{5}}{2} mg$

109. Because of train's acceleration, pseudo forces acts in opposite to the direction of motion of train.

110. Force exerted by a person on the floor is less than his weight when lift has an downward acceleration and upward retardation ($g_{eff.} = g - a$).

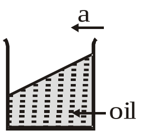
112. $\frac{m(g+a)}{m(g-a)} = \frac{3}{1}$

$(g + a) = 3(g - a) \quad \Rightarrow a = \frac{g}{2}$

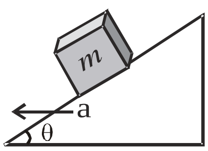
113. Zero (weightlessness)

114. N = m(g + a) = 0.5(10 + 2) = 6N

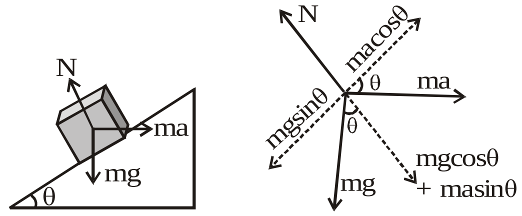
115.



116.



FBD of m w.r.t. incline plane.



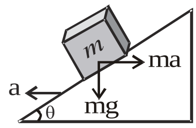
$\therefore$ mg sinθ = ma cosθ ...(i)

N = mg cosθ + ma sinθ ...(ii)

$\therefore N = mg\cos\theta + m\sin\theta \times g \times \frac{\sin\theta}{\cos\theta}$

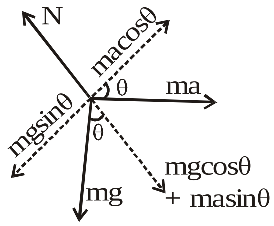
$N = \frac{mg}{\cos\theta}$

117.



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

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



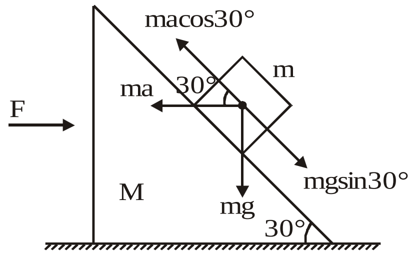
To keep the block stationary relative to the inclined plane

mgsinθ = macosθ

a = gtanθ

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

119.



$\because$ macos30° = mgsin30°

$\therefore$ a = g tan30°

$\because$ F = (M + m)a

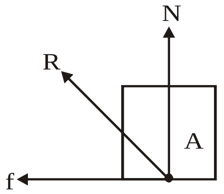
$\therefore$ F = (M + m)g tan30°

120. $M.A. = \frac{Load}{Effort} = \frac{W}{F} = 1$

121. $M.A. = \frac{Load}{Effort}$

$M.A. = \frac{400}{80} = 5$

124.



125. Static friction is self adjusting force

so, $f = F_{ext} = F$

126. $f_{max} = 40 \times 0.4 = 16N$

$\therefore$ f = 8N (Applied force)

127. $f_L = \mu_s mg$

$f_L = 0.4 \times 3 \times 10 = 12$ N

F = 8.7 N

$F < f_L$

f = F = 8.7 N

128. mg – f = ma

f = m(g–a)

= 0.5 × (10–9)

= 0.5N

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

$0^2 = 100^2 - 2 \times 0.5 \times 10 \times S$ $(\because a = \mu g)$

S = 1000 m

130. Pseudo force = 10 × 0.5 = 5 N

$f_{max} = 10 \times 10 \times 0.2 = 20N$

$\therefore$ f = 5 N

131. $F = f_L$

$75 = \mu_s \times 20 \times 10$

$\mu_s = 0.375$

132. $f_L = \mu_s\, mg$

$f_L = 0.6 \times 1 \times 10 = 6$ N

F = 1 × 5 = 5N

$\because$ $f_L > F$

hence f = F = 5N

133. F – f = 10 × 5 ...(1)

2F – f = 10 × 18 ...(2)

from equation (1) & equation (2)

f = 80 N

$$\mu = \frac{f}{mg} = \frac{80}{10 \times 10} = 0.8$$

134. $f_L = 0.15 \times 20 = 3N$

for block to be stationary

f_L = weight of block

$\therefore$ weight of block = 3N

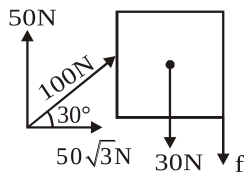
135. $f_{max} = 0.5 \times 25 = 12.5$ N

F = mg = 1 × 9.8 = 9.8 N

$F < f_{max}$

So, f = F = 9.8 N

137.



$$f_L = \mu N = \frac{1}{\sqrt{3}} \times 50\sqrt{3}$$

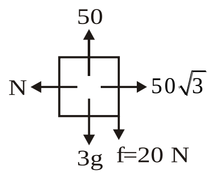
$f_L = 50$ N

$F_{ext} = 20$ N

$F_{ext} < f_L$

hence $f = F_{ext} = 20$ N

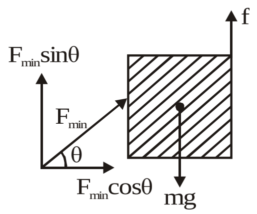
138.



$F_{net} = 0$

So, a = 0

139.



$F_{min}\sin\theta + f = mg$

$F_{min}\sin\theta + \mu F_{min}\cos\theta = mg$

$F_{min}(\sin\theta + \mu\cos\theta) = mg$

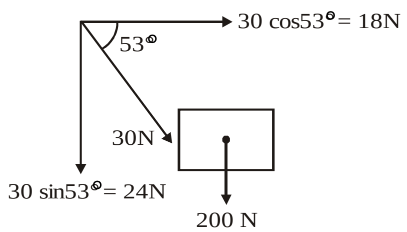
$$F_{min} = \frac{mg}{\sin\theta + \mu\cos\theta}$$

140. For, f = 0

$F\sin\theta = mg$

$$F = \frac{mg}{\sin\theta}$$

141.



$f_L = \mu_s N = 0.2 \times 224$

$f_L = 44.8$ N

$\because \ f_L > F$

hence f = F = 18 N

142. $N = mg - F\sin 45°$

$= 50 - 28.2 \times \dfrac{1}{\sqrt{2}}$

$N = 50 - 20 = 30N$

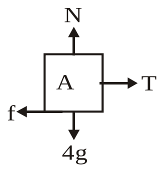
$f_s = \mu N$

$f_s = 0.8 \times 30 = 24$ N

$f_s > F_{ext} \quad \{\because F_{ext} = 28.2\cos 45° = 20N\}$

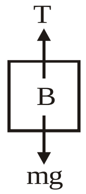
So, f = 20N

143.



N = 40

f = 0.3 × 40 = 12 N = T



mg = T

$m = \dfrac{12}{10} = 1.2$ kg

144. $\mu \times \dfrac{4m}{5} g = \dfrac{m}{5} g \Rightarrow \quad \mu = \dfrac{1}{4}$

145. $f_L = \mu_s mg$

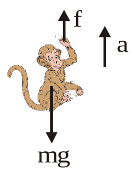
$f_L = 0.2 \times 2 \times 10 = 4N$

$F = 2 \times 1 = 2N$

$\because \ F < f_L$

hence f = F = 2N

146.



f – mg = ma

f = m (g + a)

147. For constant speed, acceleration is zero

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

$\mu = \tan\theta$

148. $0^2 - (2v_0)^2 = 2(-\mu g) \times s \Rightarrow s = \dfrac{2v_0^2}{\mu g}$

149. $f_{max} = \mu mg\cos\theta = 0.8 \times 2 \times 10 \times = 13.6N$

$F = mg\sin\theta = 2 \times 10 \times \dfrac{\sqrt{3}}{2} = 10$ N

$\because \quad F < f_{max}$, So f = F = 10 N

150. $F_1 = mg\sin\theta + \mu\, mg\cos\theta$

$F_2 = mg\sin\theta - \mu\, mg\cos\theta$

$F_1 = 3F_2$

$\therefore \quad \tan\theta + \mu = 3(\tan\theta - \mu)$

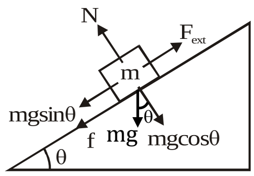
$2\mu = \tan\theta \ \Rightarrow \theta = \tan^{-1}(2\mu)$

151. $a = g\sin\theta - \mu g\cos\theta$

$g\left(\dfrac{1}{\sqrt{2}} - 0.25 \times \dfrac{1}{\sqrt{2}}\right) = \dfrac{10 \times 0.75}{\sqrt{2}} = \dfrac{7.5}{\sqrt{2}}$

$= 5.35 \text{ m/s}^2$

152.



$f = \mu N$

$f = \mu mg\cos\theta$

$F_{ext} = mg\sin\theta + f$

$F_{ext} = mg\sin\theta + \mu mg\cos\theta$

153. $mg\sin\theta = \mu\, mg\cos\theta$

$\sin\theta = \mu\cos\theta \qquad$ ...(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

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

$\therefore \quad s = \dfrac{v_0^2}{2(2g\sin\theta)} = \dfrac{v_0^2}{4g\sin\theta}$

154. Let the length of incline is d

Case I : for rough incline plane

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

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

Case II : For smooth incline plane

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

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

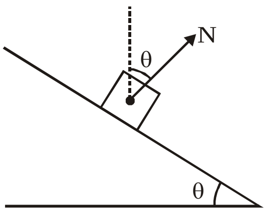
According to question

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

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

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

155.



as angle made by normal reaction with vertical = angle of inclined plane = θ
and block has to be pushed down,
So, θ < angle of repose.

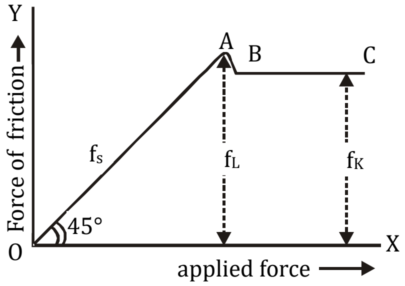
156. Angle of repose is independent of mass.

157. $\tan\theta = \mu_s$

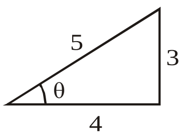
$\tan\theta = \sqrt{3}$

$\theta = 60°$

158.



159.



$\therefore \quad \tan\theta = \mu_s$

$3/4 = \mu_s$

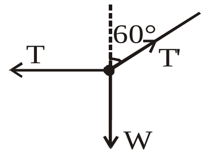
$\mu_s = 0.75$

160. $mg - Q\cos\theta = N$

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

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

161.



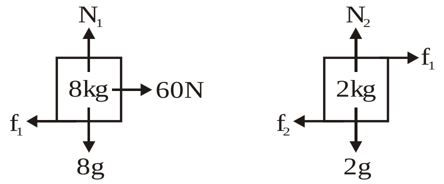
$T'\cos 60° = W$

$T'\sin 60° = T$

$\therefore \quad \tan 60° = \frac{T}{W} \Rightarrow W = \frac{T}{\sqrt{3}}$

$W = \frac{346}{1.7} = 200N$

162.



$f_{1max} = 0.5 \times 80 = 40$ N

$f_{2max} = 0.2 \times 100 = 20$ N

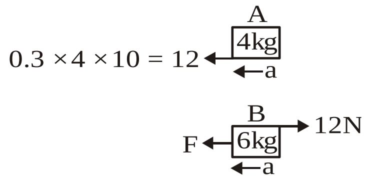
$\therefore$ combined acceleration (a) = $\frac{60-20}{10}$ = 4 m/s²

from FBD of 8 kg :-

Friction between A & B

$f_1 = 60 - 8 \times 4 = 28$ N

163.



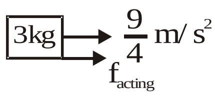
$a = \frac{12}{4}$ = 3 m/s²

$F - 12 = 6 \times a$

$F = 12 + 6 \times 3 = 30$ N

164. Acceleration of system = $\frac{27}{9+3} = \frac{9}{4}$ m/s²

For upper block w.r.t lower block



$f_{max} = \frac{1}{3} \times 30 = 10N$

$f_{acting} = 3 \times \frac{9}{4} = 6.75N$

$f_{acting} < f_{max}$

So, $f = f_{acting} = 6.75$ N

Exercise-II (Previous Year Questions)

1. Acceleration

$$= \frac{\text{Net force in the direction of motion}}{\text{Total mass of system}}$$

$$= \frac{m_1 g - \mu(m_2 + m_3)g}{m_1 + m_2 + m_3}$$

$$= \frac{g}{3}(1 - 2\mu)$$

2. Change in momentum,

$\Delta p = \int F dt$

= Area of F-t graph

$= (\frac{1}{2} \times 2 \times 6) - (3 \times 2) + (4 \times 3)$

= 12 N-s

3. Let upthrust of air be F_a then

for downward motion

$mg - F_a = ma$ ...(1)

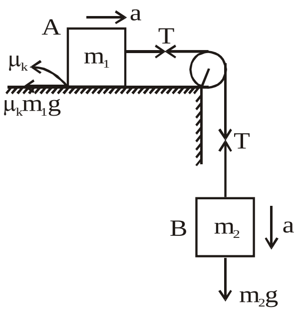
for upward motion (when Δm is removed)

$F_a - (m - \Delta m)g = (m - \Delta m)a$ ...(2)

After solving equation (1) & (2)

Therefore $\Delta m = \frac{2ma}{g + a}$

4.



For the motion of both blocks

$m_2 g - T = m_2 a$

$T - \mu_k m_1 g = m_1 a$

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

For the block of mass 'm_2'

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

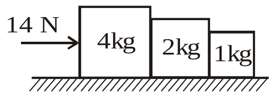
$$T = m_2 g - \left[\frac{m_2 - \mu_k m_1}{m_1 + m_2}\right] m_2 g$$

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

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

5. Acceleration of system $= \frac{F_{net}}{M_{total}}$

$$= \frac{14}{4 + 2 + 1} = 2 \text{ m/s}^2$$



The contact force between 4 kg & 2 kg block will move 2 kg & 1 kg block with the same acceleration

so $F_{contact} = (2 + 1)a = 3(2) = 6N$.

6. Coefficient of static friction,

$$\mu_s = \tan 30° = \frac{1}{\sqrt{3}} = 0.6$$

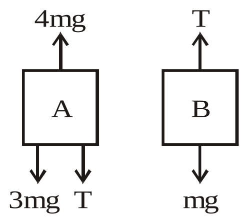
$a = g\sin 30° - \mu_K g \cos 30°$

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

$$4 = \frac{1}{2}\left[\frac{g}{2} - \frac{\mu_k g\sqrt{3}}{2}\right] \times 16 \Rightarrow \mu_k = 0.5$$

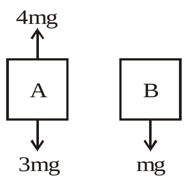
7. $\text{Impulse} = |\overrightarrow{\Delta p}| = m|\overrightarrow{\Delta V}| = m(2V\cos 60°) = mV$

8. Before cutting the string :-



$\therefore$ T = mg

After cutting the string :-

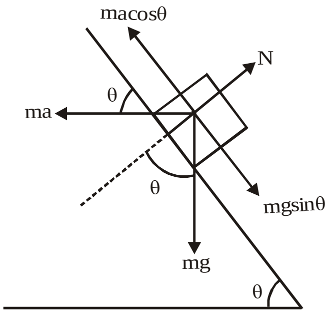


$$a_A = \frac{4mg - 3mg}{3m} = \frac{g}{3}$$

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

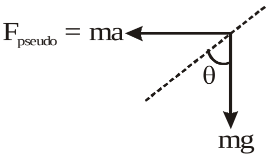
9. Coefficient of sliding friction has no dimension

10. FBD w.r.t. wedge



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

11.



$$\tan\theta = \frac{F_{pseudo}}{mg} = \frac{a}{g} \text{ towards left}$$

12. N = mg, F = f

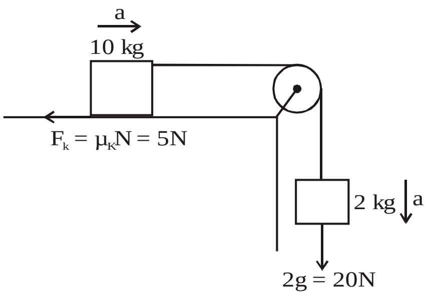
Resultant $= \sqrt{N^2+f^2} = \sqrt{(mg)^2+f^2}$

$\leq mg\sqrt{1+\mu^2}$

13. Acceleration of system

$$a = \frac{(m_2-m_1)g}{m_1+m_2} = \frac{(6-4)g}{6+4} = \frac{2g}{10} = \frac{g}{5}$$

14.

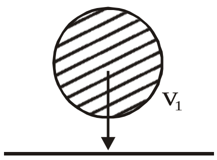


$$a = \frac{\text{net force}}{\text{total mass}} = \frac{20-5}{12} = 1.25\,m/s^2$$

15. Velocity just before striking the ground

$v_1 = \sqrt{2gh}$

$v_1 = \sqrt{2(10)(10)} = 10\sqrt{2}\,m/s$

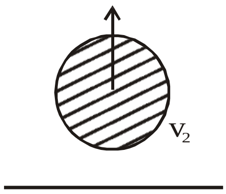


$\vec{v}_1 = -10\sqrt{2}\,\hat{j}$

If it reaches the same height, speed remains same after collision only the direction changes.

$v_2 = 10\sqrt{2}\,m/s$

$\vec{v}_2 = 10\sqrt{2}\,\hat{j}$



$|\text{Impulse}| = m|\Delta\vec{v}|$

$= m|10\sqrt{2}\,j - (-10\sqrt{2}\,j)|$

$= 0.15\left[2(10\sqrt{2})\right]$

$= 3\sqrt{2}$ kg m/s

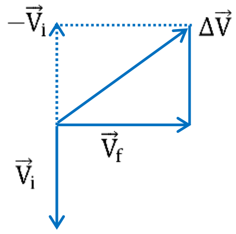
$= 4.2$ kg m/s

19. $\vec{V}_i = (V)$ southward

$\vec{V}_F = (V)$ Eastward

$\vec{\Delta V} = \vec{V}_F - \vec{V}_i$

= Along North – East



20. $F_S = ma$

$f_L = ma_{max}$

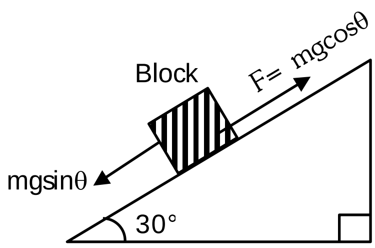
$\mu\, mg = ma_{max}$

$a_{max} = \mu g$

$= 0.15(10)$

$= 1.5\ m/s^2$

21.



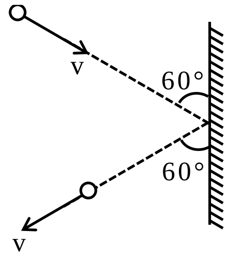
$\mu = \frac{1}{\sqrt{3}}$

$\tan 30^\circ = \frac{1}{\sqrt{3}}$

as $\mu = \tan\theta$

the block is at rest and net force on it must be zero

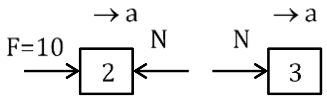
22.



$$F = \left|\frac{\Delta \vec{p}}{\Delta t}\right| = \frac{2mv\sin\theta}{t} = \frac{2(1)(1)\sin 60^\circ}{0.1} = 10\sqrt{3}\,N$$

23. From Newton's IInd law.

$F_{net} = ma$



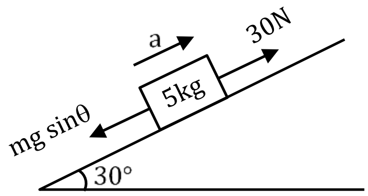
Block A : $F - N = 2a$ or $10 - N = 2a$ ......(i)

Block B : $N = 3a$ .....(ii)

On solving (i) & (ii)

$a = 2\ m/s^2$ and $N = 6\ N$

24.



$30 - Mg\sin\theta = ma$

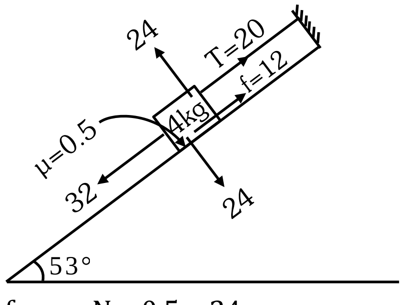
$30 - 5(10)\sin 30^\circ = 5a$

$5 = 5a$

$a = 1\ ms^{-2}$

Exercise-III (Analytical Questions)

1.



$f = f_{max} = \mu N = 0.5 \times 24$

$\Rightarrow \boxed{f = 12N}$

& $T + f = 32$

$\Rightarrow \boxed{T = 20N}$

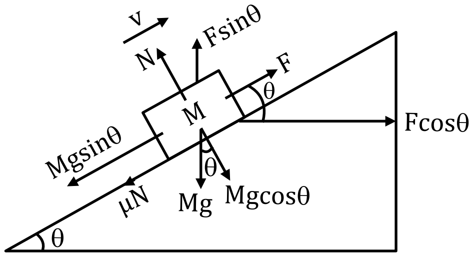
Contact force $= \sqrt{f^2 + N^2} = \sqrt{12^2 + 24^2}$

$= 12\sqrt{5}$

$\simeq 26.83\ N$

$\simeq 27\ N$

2. $F = Mg\sin\theta + \mu N = Mg\sin\theta + \mu Mg\cos\theta$



Net force in horizontal direction = $F\cos\theta$

$= (Mg\sin\theta + \mu Mg\cos\theta)\cos\theta$

$= Mg\sin\theta\cos\theta + \mu Mg\cos^2\theta$

Net force in vertical direction = $F\sin\theta$

$= (Mg\sin\theta + \mu Mg\cos\theta)\sin\theta$

$= Mg\sin^2\theta + \mu Mg\cos\theta\sin\theta$

Net force along the plane

$= F = Mg\sin\theta + \mu Mg\cos\theta$

Net force perpendicular to plane = 0

3. $\vec{F}_{net\ ext} = \frac{d\vec{P}}{dt}$ (Newton's second law)

4. Pseudo force does not actually act on a body. It is only drawn in an F.B.D. when the frame of reference is non-inertial.

5. By definition of 'equilibrium' & 'rest'

6. Acceleration of blocks is $2\ m/s^2$.

Displacement $= \frac{1}{2} \times 2 \times 1^2 = 1$ m.

One moves 1 m upwards and the other 1 m downwards. Separation = 2 m

8. When a body is placed on a rough inclined plane, it is acted upon by a reactional force due to plane [electromagnetic in nature], a frictional force due to roughness of plane [electromagnetic in nature] and a gravitational force (due to its weight).

9. Statement (I) follows Newton's first law, i.e. law of inertia.

Statement (II) follows Newton's third law, i.e. action-reaction pair.