EXERCISE

1. In Fig. 13, the pulley is massless and frictionless. The relation between T_1, T_2, and T_3 will be

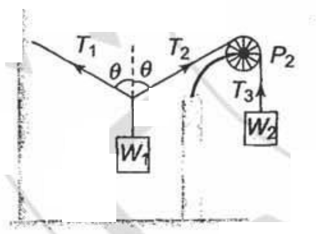

Fig. 13

(a) $T_1 = T_2 \neq T_3$ (b) $T_1 \neq T_2 = T_3$

(c) $T_1 \neq T_2 \neq T_3$ (d) $T_1 = T_2 = T_3$

2. In Q.1, the relation between W_1 and W_2 will be

(a) $W_2 = \frac{W_1}{2\cos\theta}$ (b) $2W_1 \cos\theta$

(c) $W_2 = W_1$ (d) $W_2 = \frac{2\cos\theta}{W_1}$

3. In Fig. 14 the masses of the blocks A and B are same and each is equal to m. The tensions in the strings OA and AB are T_2 and T_1, respectively. The system is in equilibrium with a constant horizontal force mg on B. The tension T_1 is

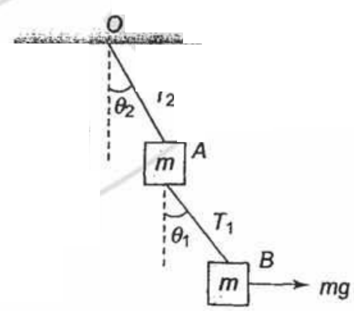

Fig. 14

(a) mg (b) $\sqrt{2}\,mg$

(c) $\sqrt{3}\,mg$ (d) $\sqrt{5}\,mg$

4. In Q.3, angle θ_1 is
(a) 30° (b) 45°
(c) 60° (d) $\tan^{-1}\left(\frac{1}{2}\right)$

5. In Q.3, tension T_2 will be
(a) mg (b) $\sqrt{2}\,mg$
(c) $\sqrt{3}\,mg$ (d) $\sqrt{5}\,mg$

6. In Q.3, angle θ_2 will be
(a) 30° (b) 45°
(c) 60° (d) $\tan^{-1}\left(\frac{1}{2}\right)$

7. A man of mass m stands on a crate of mass M (Fig. 15). He pulls on a light rope passing over a smooth light pulley. The other end of the rope is attached to the crate. For the system to be in equilibrium, the force exerted by the men on the rope will be

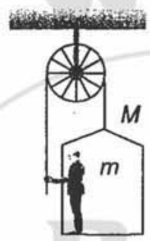

Fig. 15

(a) $(M + m)g$ (b) $\frac{1}{2}(M+m)g$
(c) Mg (d) mg

8. The force–time (F–t) curve of a particle executing linear motion is as shown in Fig. 16. The momentum acquired by the particle in time interval from 0 to 8 s will be

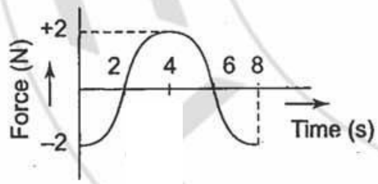

Fig. 16

(a) −2 N-s (b) +4 N-s
(c) 6 N-s (d) Zero

9. A rocket has a mass of 100 kg. 90% of this is fuel. It ejects fuel vapors at the rate of 1 kg/s with a velocity of 500 m/s relative to the rocket. It is supposed that the rocket is outside the gravitational field. The initial upthrust on the rocket when it just starts moving upwards is
(a) Zero (b) 500 N
(c) 1000 N (d) 2000 N

10. The ratio of the weight of a man in a stationary lift and when it is moving downward with uniform acceleration a is 3 : 2. The value of a is (g:acceleration due to gravity on the earth)

(a) $\frac{3}{2}g$ (b) $\frac{g}{3}$ (c) $\frac{2}{3}g$ (d) g

11. Two blocks are in contact on a frictionless table. One has a mass m and the other $2m$ as shown in Fig. 17. When force F is applied on mass $2m$, the system moves toward right. Now the same force F is applied on m. The ratio of the force of contact between the two blocks will be

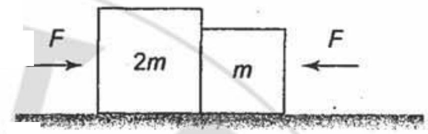

Fig. 17

(a) 1 : 1 (b) 1 : 2 (c) 1 : 3 (d) 1 : 4

12. A monkey of mass 20 kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspended from it but will break if the mass exceeds 25 kg. What is the maximum acceleration with which the monkey can climb up along the rope (g = 10 m/s^2)?
(a) 10 m/s^2 (b) 25 m/s^2
(c) 2.5 m/s^2 (d) 5 m/s^2

13. The two pulley arrangements shown in Fig. 18 are identical. The mass of the rope is negligible. In (a), the mass m is lifted up by attaching a mass $2m$ to the other end of the rope. In (b), m is lifted up by pulling the other end of the rope with a constant downward force of $2mg$. The ratio of accelerations in two cases will be

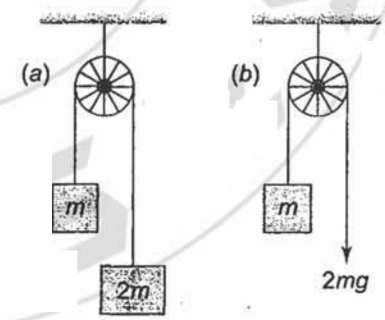

Fig. 18

(a) 1 : 1 (b) 1 : 2
(c) 1 : 3 (d) 1 : 4

For Problems 14–20.

In Fig. 19, $m_1 = 4m_2$. The pulleys are smooth and light. At time $t = 0$, the system is at rest.

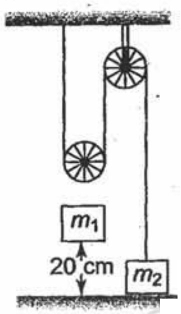

Fig. 19

14. If the system is released and if the acceleration of mass m_1 is a, then the acceleration of m_2 will be
(a) g (b) a (c) $a/2$ (d) $2a$

15. The value of a will be
(a) g (b) $g/2$ (c) $g/4$ (d) $g/8$

16. The tension T in the string will be
(a) m_2g (b) $\frac{m_2g}{2}$
(c) $\frac{2}{3}m_2g$ (d) $\frac{3}{2}m_2g$

17. The time taken by m_1 in coming to rest position will be
(a) 0.2 s (b) 0.4 s
(c) 0.6 s (d) 0.8 s

18. The distance covered by m_2 in 0.4 s will be
(a) 40 cm (b) 20 cm
(c) 10 cm (d) 80 cm

19. The velocity acquired by m_2 in 0.4 s will be
(a) 100 cm/s (b) 200 cm/s
(c) 300 cm/s (d) 400 cm/s

20. The additional distance traversed by m_2 in coming to rest position will be
(a) 20 cm (b) 40 cm
(c) 60 cm (d) 80 cm

21. A bird is sitting on stretched telephone wires. If its weight is W, then the additional tension produced by it in the wires will be
(a) $T = W$ (b) $T > W$
(c) $T < W$ (d) $T = 0$

22. One end of a massless rope, which passes over a massless and frictionless pulley P is tied to a hook C, while the other end is free (Fig. 20). Maximum tension that the rope can bear is 360 N. With what value of maximum safe acceleration (in m/s^2) can a man of 60 kg climb on the rope?

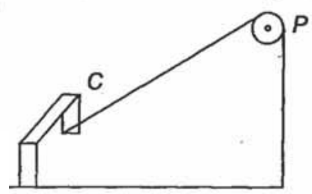

Fig. 20

(a) 16 (b) 6 (c) 4 (d) 8

23. When forces F_1, F_2, F_3 are acting on a particle of mass m such that F_2 and F_3 are mutually perpendicular, then the particle remains stationary. If the force F_1 is now removed, then the acceleration of the particle is
(a) F_1/m (b) F_2F_3/mF_1
(c) $(F_2 - F_3)/m$ (d) F_2/m

24. A lift is moving down with acceleration a. A man in the lift drops a ball inside the lift. The acceleration of the ball as observed by the man in the lift and a man standing stationary on the ground is, respectively,
(a) g, g (b) $(g - a)$, $(g - a)$
(c) $(g - a)$, g (d) a, g

25. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is $g/8$, then the ratio of the masses is:
(a) 8 : 1 (b) 9 : 7
(c) 1 : 8 (d) 7 : 9

26. A light spring balance hangs from the hook of the other light spring balance and a block of mass M kg hangs from the former one. Then the true statement about the scale reading is
(a) Both the scales read $M/2$ kg each
(b) Both the scales read M kg each
(c) The scale of the lower one reads M kg and of the upper one zero.
(d) The reading of the two scales can be anything but the sum of the reading will be M kg.

27. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force

P is applied at the free end of the rope, the force exerted by the rope on the block is

(a) $\frac{PM}{M+m}$ (b) $\frac{Pm}{M+m}$

(c) $\frac{Pm}{M-m}$ (d) P

28. A spring balance is attached to the ceiling of a lift. A man hangs his bag on the spring and the spring reads 49 N, when the lift is stationary. If the lift moves downward with an acceleration of 5 m/s^2, the reading of the spring balance will be

(a) 49 N (b) 24 N
(c) 74 N (d) 15 N

29. A rocket with a lift-off mass 3.5×10^4 kg is blasted upward with an initial acceleration of 10 m/s^2. Then the initial thrust of the blast is

(a) 1.75×10^5 N (b) 3.5×10^5 N
(c) 7.0×10^5 N (d) 1.40×10^5 N

30. A machine gun fires a bullet of mass 40 g with a velocity of 1200 m/s. The man holding it can exert a maximum force of 144 N on the gun. How many bullets can he fire per second at the most?

(a) Two (b) Four (c) One (d) Three

31. Two masses $m_1 = 5$ kg and $m_2 = 4.8$ kg tied to a string are hanging over a light frictionless pulley (Fig. 21). What is the acceleration of the masses when left free to move? ($g = 9.8$ m/s^2)

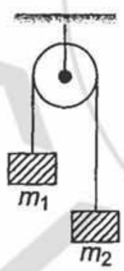

Fig. 21

(a) 5 m/s^2 (b) 9.8 m/s^2
(c) 0.2 m/s^2 (d) 4.8 m/s^2

32. A player caught a cricket ball of mass 150 g moving at a rate of 20 m/s. If the catching process is completed in 0.1 s, the force of the blow exerted by the ball on the hand of the player is equal to

(a) 30 N (b) 300 N
(c) 150 N (d) 3 N

33. A ball of mass 0.2 kg is thrown vertically upwards by applying a force by hand. If the hand moves 0.2 m while applying the force and the ball goes upto 2 m height further, find the magnitude of the force. Consider $g = 10$ ms.

(a) 20 N (b) 22 N
(c) 4 N (d) 16 N

34. a body of mass $m = 3.513$ kg is moving along the x-axis with a speed of 5.00 m/s. The magnitude of its momentum is recorded as

(a) 17.6 kg-m/s (b) 17.565 kg-m/s
(c) 17.56 kg-m/s (d) 17.57 kg-m/s

35. Figure 22 shows the position–time (x–t) graph of one-dimensional motion of a body of mass 0.4 kg. The magnitude of each impulse is

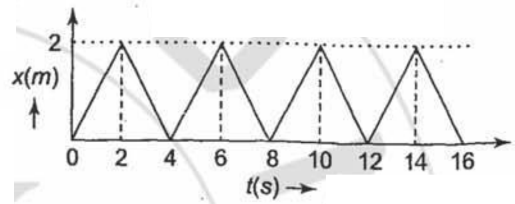

Fig. 22

(a) 0.4 N s (b) 0.8 N s
(c) 1.6 N s (d) 0.2 N s

36. Two fixed frictionless inclined planes making an angle 30° and 60° with the vertical are shown in the Fig. 23. Two blocks A and B are placed on the two planes. What is the relative vertical acceleration of A with respect to B?

Fig. 23

(a) 4.9 m/s^2 in horizontal direction
(b) 9.8 m/s^2 in vertical direction
(c) zero
(d) 4.9 m/s in vertical direction

SOLUTIONS

1.(d) Since through a single string whole system is attached, so $W_2 = T_3 = T_2 = T_1$

2.(a) For vertical equilibrium,

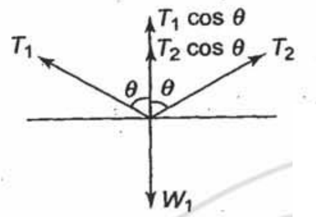

Fig. 24

$T_1 \cos \theta + T_2 \cos \theta = W_1$ [as $T_1 = T_2 = W_2$]

$2W_2 \cos \theta = W_1$

$\therefore \quad W_2 = \dfrac{W_1}{2\cos\theta}$

3.(b) From the free body diagram of block B (Fig. 25),

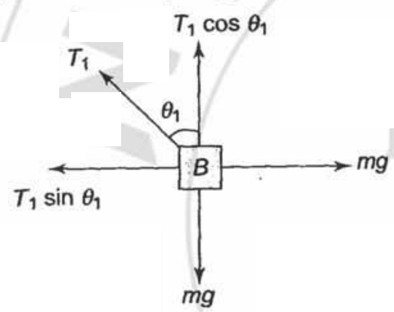

Fig. 25

$T_1 \cos \theta_1 = mg$ (i)

$T_1 \sin \theta_1 = -mg$ (ii)

By squaring and adding,

$T_1^2(\sin^2\theta_1 + \cos^2\theta_1) = 2(mg)^2$

$\therefore \quad T_1 = \sqrt{2}mg$

4.(b) From the solution of Q.3, by dividing (ii) by (i),

$\dfrac{T_1 \sin\theta_1}{T_1\cos\theta_1} = \dfrac{mg}{mg}$

$\therefore \quad \tan \theta_1 = 1$ or $\theta_1 = 45°$

5.(d) From the free body diagram of block A (Fig. 26)

For vertical equilibrium, $T_2 \cos \theta_2 = mg + T_1 \cos \theta_1$

$T_2 \cos\theta_2 = mg + \sqrt{2}mg\cos 45°$

$T_2 \cos\theta_2 = 2mg$ (i)

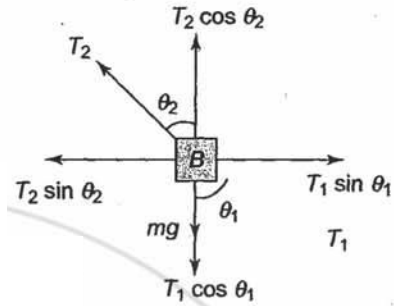

Fig. 26

For horizontal equilibrium

$T_2 \sin \theta_2 = T_1 \sin \theta_1$

$= \sqrt{2}mg \sin 45°$

$= mg$ (ii)

By squaring and adding (i) and (ii),

$T_2^2 = 5(mg)^2$ or $T_2 = \sqrt{5}mg$

6.(d) From the solution of Q.5, by dividing (ii) by (i),

$\dfrac{\sin\theta_2}{\cos\theta_2} = \dfrac{mg}{2mg} \Rightarrow \tan\theta_2 = \dfrac{1}{2}$

$\theta_2 = \tan^{-1}\left[\dfrac{1}{2}\right]$

7.(b) From the free body diagram of man and crate system (Fig. 27),

Fig. 27

For vertical equilibrium,

$2T = (M + m)g$

$\therefore \quad T = \dfrac{(M+m)g}{2}$

8.(d) Momentum acquired by the particle is numerically equal to the area enclosed between the F–t curve and time Axis. For the given diagram, area in the upper half is positive and in the lower half is negative (and equal to the upper half). So net area is zero. Hence, the momentum acquired by the particle will be zero.

9.(b) Upthrust force, $F = u\left(\frac{dm}{dt}\right) = 500 \times 1 = 500$ N

10.(b) $\frac{\text{Weight of a man in stationary lift}}{\text{Weight of a man in downward moving lift}}$

$$= \frac{mg}{m(g-a)} = \frac{3}{2}$$

$\therefore \quad \frac{g}{g-a} = \frac{3}{2} \Rightarrow 2g = 3g - 3a$ or $a = \frac{g}{3}$

11.(b) When the force is applied on mass $2m$, contact force $f_1 = \frac{m}{m+2m} g = \frac{g}{3}$

When the force is applied on mass m, contact force. $f_2 = \frac{2m}{m+2m} g = \frac{2}{3} g$

Ratio of contact forces $\Rightarrow \frac{f_1}{f_2} = \frac{1}{2}$

12.(c) Maximum tension that string can bear (T_{max}) = 25 × g N = 250 N

Tension in rope when the monkey climbes up, $T = m(g + a)$

For limiting condition,

$T = T_{max} \Rightarrow m(g + a) = 250$

$\Rightarrow \quad 20(10 + a) = 250 \Rightarrow a = 2.5$ m/s^2

13.(c) For first case,

$$a_1 = \frac{m_2 - m_1}{m_1 + m_2} g = \frac{2m - m}{m + 2m} = \frac{g}{3} \qquad \text{(i)}$$

For second case, from free body diagram of m,

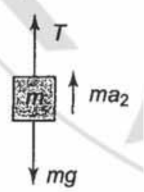

Fig. 28

$ma_2 = T - mg$

$= 2mg - mg \qquad [\text{as } T = 2mg]$

$$a_2 = g \qquad \text{(ii)}$$

From (i) and (ii), $\frac{a_1}{a_2} = \frac{g/3}{g} = 1/3$

14.(d) Since mass m_2 travels double distance in comparison to mass m_1, therefore its acceleration will be double, i.e., $2a$

15.(c) By drawing the free body diagram (Fig. 29) of m_1 and m_2

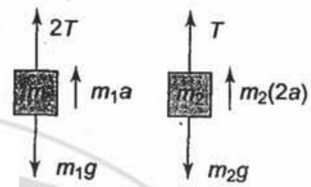

Fig. 29

$m_1 a = m_1 g - 2T \qquad$ (i)

$m_2 (2a) = T - m_2 g \qquad$ (ii)

By solving (i) and (ii), $a = g/4$

16.(d) From the solution of Q.15,

$$T = \frac{3}{2} m_2 g$$

17.(b) Time taken by mass m_2 to cover the distance 20 cm

$$t = \sqrt{\frac{2h}{a}} = \sqrt{\frac{2 \times 0.2}{g/4}} = \sqrt{\frac{2 \times 0.2}{2.5}} = 0.4 \text{ s}$$

18.(a) Since m_2 mass covers double distances therefore $S = 2 \times 20 = 40$ cm

19.(b) Velocity acquired by mass m_2 in 0.4 sec

From $v = u + at \qquad \left[\text{as } a = \frac{g}{2} = \frac{10}{2} = 5\text{m/s}^2\right]$

$= 0 + 5 \times 0.4 = 2$ m/s $= 200$ cm/s

20.(a) When m_2 mass acquired velocity of 200 cm/s, it will move upward till its velocity becomes zero.

$$H = \frac{v^2}{2g} = \frac{(200)^2}{2 \times 100} = 20 \text{ cm}$$

21.(b) For equilibrium

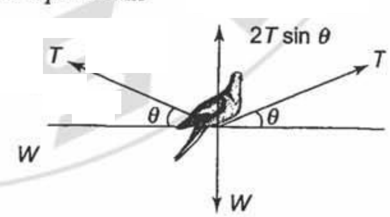

Fig. 30

$$2T \sin \theta = W$$

$$T = \frac{W}{2\sin\theta}$$

Since θ lies between 0 to 90°, i.e. $\sin < 1 \Rightarrow T > W$.

22.(c) Apparent weight: $W_1 = m(g - a)$, But $W_1 = 360$ N

$\therefore\ 360 = 60(10 - a)$

or $\quad a = 4\ \text{m/s}^2$

23.(a) For the equilibrium of the body, F_1 must act opposite to F_2 and F_3 and must be equal and opposite to the resultant of F_2 and F_3. So on removing F_1,

$$a = (\text{resultant of } F_2 \text{ and } F_3)/m = F_1/m$$

24.(c) As the lift is descending with an acceleration a, so the man also has acceleration a. Hence, the acceleration of the ball wrt the man in the lift will be $(g - a)$ and wrt the stationary man on the ground will be g.

25.(b) Here. $a = \dfrac{m_1 - m_2}{m_1 + m_2} g$, if $m_1 > m_2$. But $a = g/8$.

$$\frac{g}{8} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g \quad \text{or} \quad m_1 : m_2 = 9 : 7$$

26.(b) Reading of both the spring balances will be same as they are being pulled by the same force.

27.(a) Required force, $F = Ma = MP/(M + m)$

28.(b) Here $mg = 49$ or $m = 5$ kg.

Required reading: $R = 5(9.8 - 5) = 24$ N

29.(c) Here thrust on the rocket is

$$F = m(g + a)$$

$$= 3.5 \times 10^4 (10 + 10) = 7.0 \times 10^5\ \text{N}$$

30.(d) $F = mnu \Rightarrow 144 = \dfrac{40}{1000} \times n \times 1200 \Rightarrow n = 3$

31.(c) $a = \left(\dfrac{m_1 - m_2}{m_1 + m_2}\right) g = \left(\dfrac{5 - 4.8}{5 + 4.8}\right) 9.8 = 0.2\ \text{m/s}^2$

32.(a) $F_{av} = \dfrac{\Delta P}{\Delta t} = \dfrac{0.150 \times 20}{0.1} = 30$ N

33.(b) From B to C:

$$v^2 = u_1^2 - 2 \times 10 \times 2$$

$$\Rightarrow \quad 0 = u_1^2 - 40$$

$$\Rightarrow \quad u_1 = \sqrt{40}\ \text{m/s}$$

From A to B:

Let acceleration is a

$$u_1^2 = u^2 + 2a \times 0.2$$

$$\Rightarrow 40 = 0^2 + 0.4a$$

$$\Rightarrow \quad a = 100\ \text{m/s}^2$$

Now $F - mg = ma$

$$\Rightarrow \quad F = m(g + a)$$

$$= 0.2\ [10 + 100]$$

$$= 22\ \text{N}$$

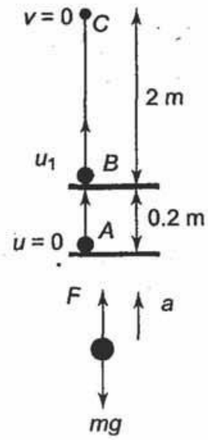

Fig. 31

34.(a) $P = mv$

$$= 3.513 \times 5.00$$

$$= 17.565 \approx 17.6\ \text{kgm/s}$$

(rounding off to three significant figures)

35.(b) From the graph, it is a straight line, so uniform motion. Because of impulse, direction of velocity changes as can be seen from the slope of the graph.

Initial velocity $= \dfrac{2}{2} = 1$ m/s

Final velocity $= -\dfrac{2}{2} = -1$ m/s

$$\vec{P}_i = 0.4\ N - s$$

$$\vec{P}_{fi} = -0.4\ N - s$$

$$\vec{J} = \vec{P}_f - \vec{P}_i = -0.4 - 0.4 = -0.8\ \text{N-s} \ (J = \text{impulse})$$

$$|\vec{J}| = 0.8\ \text{N-s}$$

36.(d) $mg \sin \theta = ma$

$\therefore \quad a = g \sin \theta$

where a is along the inclined plane.

$\therefore$ Vertical component of acceleration is $g \sin^2 \theta$.

$\therefore$ Relative vertical acceleration of A with respect to B is $g(\sin^2 60 - \sin^2 30) = \dfrac{g}{2} = 4.9\ \text{m/s}^2$ in vertical direction.