Question 5. 21. A stone of mass 0.25 kg tied to the end of a string is whirled round in a circle of radius 1.5 m with a speed of 40 rev./min in a horizontal plane. What is the tension in the string? What is the maximum speed with which the stone can be whirled around if the string can withstand a maximum tension of 200 N?
Answer:

Here, $m = 0.25\ \text{kg}, \quad r = 1.5\ \text{m}$

$$n = 40\ \text{rpm} = \frac{40}{60}\ \text{rps} = \frac{2}{3}\ \text{rps}$$

Now $T = mr\omega^2 = mr(2\pi n)^2 = 4\pi^2 mrn^2$

$$T = 4 \times \frac{22}{7} \times \frac{22}{7} \times 0.25 \times 1.5 \times \left(\frac{2}{3}\right)^2 = 6.6\ \text{N}$$

If $T_{max} = 200$ N, then from ,

$$T_{max} = \frac{mv_{max}^2}{r} \Rightarrow v_{max}^2 = \frac{T_{max} \times r}{m}$$

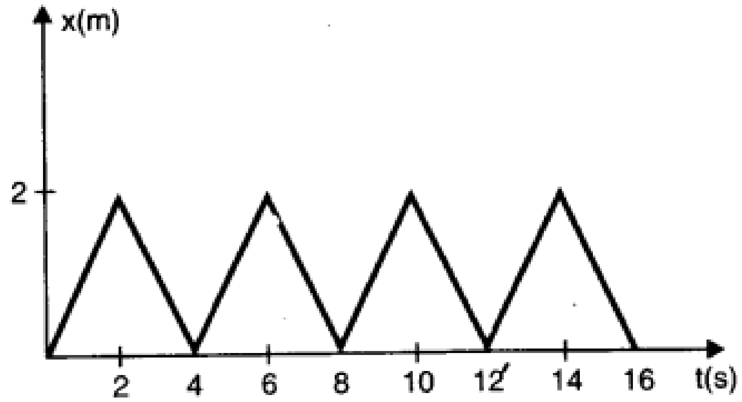
or $$v_{max}^2 = \frac{200 \times 1.5}{0.25} = 1200 \Rightarrow v_{max} = \sqrt{1200} = 34.6\ \text{ms}^{-1}.$$

Question 5. 22. If, in Exercise 5.21, the speed of the stone is increased beyond the maximum permissible value, and the string breaks suddenly, which of the following correctly describes the trajectory of the stone after the string breaks:
(a) the stone moves radially outwards,
(b) the stone flies off tangentially from the instant the string breaks,
(c) the stone flies off at an angle with the tangent whose magnitude depends on the speed of the particle?
Answer: (b) The velocity is tangential at each point of circular motion. At the time the string breaks, the particle continues to move in the tangential direction according to Newton's first law of motion.

Question 5. 23. Explain why
(a) a horse cannot pull a cart and run in empty space,
(b) passengers are thrown forward from their seats when a speeding bus stops suddenly,
(c) it is easier to pull a lawn mower than to push it,
(d) a cricketer moves his hands backwards while holding a catch.
Answer:
(a) A horse by itself cannot move in space due to law of inertia and so cannot pull a cart in space.
(b) The passengers in a speeding bus have inertia of motion. When the bus is suddenly stopped the passengers are thrown forward due to this inertia of motion.
(c) In the case of pull, the effective weight is reduced due to the vertical component of the pull. In the case of push, the vertical component increases the effective weight.
(d) The ball comes with large momentum after being hit by the batsman. When the player takes catch it causes large impulse on his palms which may hurt the cricketer. When he moves his hands backward the time of contact of ball and hand is increased so the force is reduced.

Question 5. 24. Figure shaws the position-time graph of a particle of mass 0.04 kg. Suggest a suitable physical context for this motion.

What is the time between two consecutive impulses received by the particle ? What is the magnitude of each impulse?
Answer: This graph can be of a ball rebounding between two walls situated at position 0 cm and 2 cm. The ball is rebounding from one wall to another, time and again every 2 s with uniform velocity.



Impulse. Here, Velocity $= \frac{\text{displacement}}{\text{time}} = \frac{2}{100 \times 2} = 0.01 \text{ ms}^{-1}$

Initial momentum $= mu = 0.04 \times 0.01 = 4 \times 10^{-4} \text{ kg ms}^{-1}$

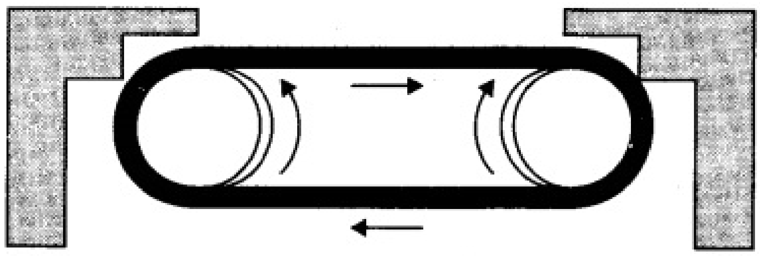
Final momentum $= mv = 0.04 \times (-0.01) = -4 \times 10^{-4} \text{ kg ms}^{-1}$

Magnitude of Impulse = Change in momentum

$= (4 \times 10^{-4}) - (-4 \times 10^{-4}) = 8 \times 10^{-4} \text{ kg ms}^{-1}$

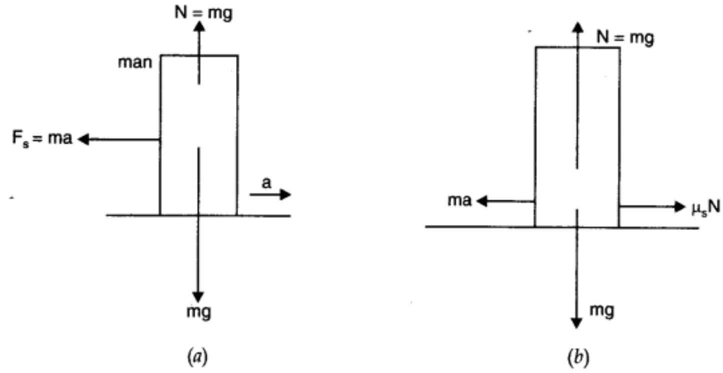
Time between two consecutive impulses is 2 s *i.e.,* the ball receives an impulse every 2 *s*.

Question 5. 25. Figure shows a man standing stationary with respect to a horizontal conveyor belt that is accelerating with 1 ms^{-2}. What is the net force on the man ? If the coefficient of static friction , between the man's shoes and the belt is 0.2, up to what acceleration of the belt can the man continue to be stationary relative to the belt? (Mass of the man = 65 kg.)



Answer: Here acceleration of conveyor belt a = 1 ms^{-2}, μ_S= 0.2 and mass of man m = 65 kg. t As the man is in an accelerating frame, he experiences a pseudo force F_S = ma as shown in fig. (a). Hence to maintain his equilibrium, he exerts a force F = - F_S = ma = 65 x 1 = 65 N in forward direction i.e., direction of motion of belt.
∴ Net force acting on man = 65 N (forward)
As shown in fig. (b), the man can continue to be stationary with respect to belt, if force of friction

$$\mu_s N = \mu_s mg = ma_{max}$$
$$a_{max} = \mu_s \cdot g = 0.2 \times 10 = 2 \text{ m s}^{-2}$$



(*a*) (*b*)

Question 5. 26. A stone of mass m tied to the end of a string is revolving in a vertical circle of radius R. The net force at the lowest and highest points of the circle directed vertically downwards are: (choose the correct alternative).

	Lowest Point	*Highest Point*
(a)	$mg - T_1$	$mg + T_2$
(b)	$mg + T_1$	$mg - T_2$
(c)	$mg + T_1 - (mv_1^2)/R$	$mg - T_2 + (mv_1^2)/R$
(d)	$mg - T_1 - (mv_1^2)/R$	$mg + T_1 + (mv_1^2)/R$

T_1 and v_1 denote the tension and speed at the lowest point. T_2 and v_2 denote corresponding values at the highest point.

Answer:
The net force at the lowest point is ($mg - T_1$) and the net force at the highest point is ($mg + T_2$). Therefore, alternative (a) is correct. Since mg and T_1 are in mutually opposite directions at lowest point and mg and T_2 are in same direction at the highest point.

Question 5. 27. A helicopter of mass 1000 kg rises with a vertical acceleration of 15 ms^{-2}. The crew and the passengers weigh 300 kg. Give the magnitude and direction of
(a) force on the floor by the crew and passengers,
(b) action of the rotor of the helicopter on surrounding air,
(c) force on the helicopter due to the surrounding air,
Answer:
Here, mass of helicopter, m_1= 1000 kg
Mass of the crew and passengers, m_2 = 300 kg upward acceleration, a = 15 ms^{-2} and g = 10 ms^{-2}
(a) Force on the floor of helicopter by the crew and passengers = apparent weight of crew and passengers
= m_2 (g + a) = 300 (10 + 15) N = 7500 N
(b) Action of rotor of helicopter on surrounding air is obviously vertically downwards, because helicopter rises on account of reaction to this force. Thus, force of action
F = (m_1+ m_2) (g + a) = (1000 + 300) (10 + 15) = 1300 x 25 = 32500 N
(c) Force on the helicopter due to surrounding air is the reaction. As action and reaction are equal and opposite, therefore, force of reaction, F = 32500 N, vertically upwards.

5.28.A stream of water flowing horizontally with a speed of 15 ms^{-1} pushes out of a tube of cross sectional area 10^{-2} m^2, and hits at a vertical wall nearby. What is the force exerted on the wall by the impact of water, assuming that it does not rebound?
Answer: In one second, the distance travelled is equal to the velocity v.
Volume of water hitting the wall per second, V = av where a is the cross-sectional area of the tube and v is the speed of water coming out of the tube.
V = 10^{-2} m^2 x 15 ms^{-1} = 15 x 10^{-2} m^3 s^{-1}
Mass of water hitting the wall per second
= 15 x 10^{-2} x 10^3 kg s^{-1} = 150 kg s^{-1} [v density of water = 1000 kg m^{-3}]
Initial momentum of water hitting the wall per second
= 150 kg s^{-1} x 15 ms^{-1} = 2250 kg ms^{-2} or 2250 N Final momentum per second = 0 Force exerted by the wall = 0 - 2250 N = - 2250 N Force exerted on the wall = - (- 2250) N = 2250 N.

Question 5. 29. Ten one rupee coins are put on top of one another on a table. Each coin has a mass m kg. Give the magnitude and direction of
(a) the force on the 7th coin (counted from the bottom) due to all coins above it.
(b) the force on the 7th coin by the eighth coin and
(c) the reaction of the sixth coin on the seventh coin.
Answer:

(a) The force on 7th coin is due to weight of the three coins lying above it. Therefore,
F = (3 m) kgf = (3 mg) N
where g is acceleration due to gravity. This force acts vertically downwards.
(b) The eighth coin is already under the weight of two coins above it and it has its own weight too. Hence force on 7th coin due to 8th coin is sum of the two forces i.e.
F = 2 m + m = (3 m) kg f = (3 mg) N The force acts vertically downwards.
(c) The sixth coin is under the weight of four coins above it.
Reaction, R = - F = - 4 m (kg) = - (4 mgf) N Minus sign indicates that the reaction acts vertically upwards, opposite to the weight.

Question 5. 30. An aircraft executes a horizontal loop at a speed of 720 km/h with its wings banked at 15°. What is the radius of the loop?
Answer:

Here $v = 720 \text{ km/h} = 720 \times \frac{5}{18} \text{ m/s} = 200 \text{ m/s}$ and angle of banking $\theta = 15°$

From the relation

$$\tan\theta = \frac{v^2}{rg} \quad \text{we have}$$

$$r = \frac{v^2}{g\tan\theta} = \frac{200 \times 200}{10 \times \tan 15°} = \frac{200 \times 200}{10 \times 0.2679}$$

$$\Rightarrow \qquad r = 14931 \text{ m} = 14.9 \text{ km.}$$

*********** END **********