CBSE Test Paper 03
Chapter 5 Laws of Motion

1. Inertia refers to **1**
   a. resistance to change
   b. dullness
   c. ease of motion
   d. slow motion
2. A truck starts from rest and accelerates uniformly at 2.0 m s^{-2}. At t = 10 s, a stone is dropped by a person standing on the top of the truck (6 m high from the ground). What is the magnitude of acceleration (in m s^{-2}) of the stone at t = 11s? (Neglect air resistance.) **1**
   a. 14
   b. 12
   c. 8
   d. 10
3. Impulse is a **1**
   a. vector and equals the change of mass
   b. vector and equals the change of momentum
   c. vector and equals the inertia of momentum
   d. scalar and equals the change of mass
4. A batsman deflects a ball by an angle of 45° without changing its initial speed which is equal to 54 km/h. What is the impulse imparted to the ball? (Mass of the ball is 0.15 kg.) **1**
   a. 4.4 kg m s^{-1}
   b. 4.8 kg m s^{-1}
   c. 4.6 kg m s^{-1}
   d. 4.2 kg m s^{-1}

5. A man of mass 70 kg stands on a weighing scale in a lift which is freely falling under gravity. What would be the reading on the scale? **1**

    a. 0 kg
    b. 125 kg
    c. 95 kg Hz
    d. 115 kg

6. Two blocks of masses m_1 and m_2 are connected at the two ends of a light spring kept on a smooth horizontal surface. The two masses are pulled apart by two forces F_1 and F_2 respectively and then released. Prove that the ratio of their acceleration is inversely proportional to their masses. **1**

7. A person of mass 50 kg stands on a weighing scale on a lift. If the lift is descending with a downward acceleration of 9 ms^{-2} what would be the reading of the weighing scale? (g = 10 ms^{-2}) **1**

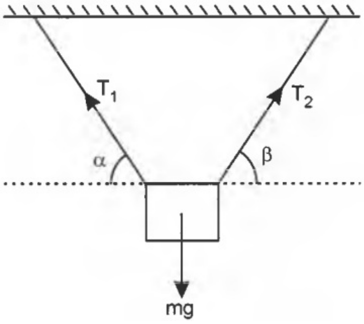
8. A thief jumps from the roof of a house with a box of weight W on his head. What will be the weight of the box as experienced by the thief during jump? **1**

9. Force of 16N and 12N are acting on a mass of 200 kg in mutually perpendicular directions. Find the magnitude of the acceleration produced? **2**

10. A shell of mass 0.020 kg is fired by a gun of mass 100 kg. If the muzzle speed of the shell is 80 ms^{-1}, what is the recoil speed of the gun? **2**

11. State Newton's first law of motion. Give an example to illustrate it. **2**

12. A body of mass m is suspended by two strings making angles α and β with the horizontal as shown in Figure. Calculate the tensions in the two strings. **3**



13. There are three forces $\vec{F}_1, \vec{F}_2$ and $\vec{F}_3$ acting on a body, all acting on a point P on the body. The body is found to move with uniform speed. **3**

    a. Show that the forces are coplanar.
    b. Show that the torque acting on the body about any point due to these three forces is zero.

14. A monkey of mass 40 kg climbs on a rope which can stand a maximum tension 600 N. In which of the following cases will the rope break? **3**
    The monkey

    a. climbs up with an acceleration of $6 m/s^2$
    b. climbs down with an acceleration of $4 m/s^2$
    c. climbs up with a uniform speed of 5m/s
    d. falls down the rope freely under gravity. Take $g = 10 m/s^2$ and ignore the mass of the rope.

15. Consider a ball falling from a height of 2 m and rebounding to a height of 0.5 m. If the mass of the ball is 60 g, find the impulse and the average force between the ball and the ground. The time for which the ball and the ground remained in contact was 0.2 s.
    5

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Answer

1. a. resistance to change

   Explanation: Inertia is the resistance of any physical object to any change in its state of motion; this includes changes to its speed, direction, or state of rest. It is the tendency of objects to keep moving in a straight line at constant velocity. Inertia is a property of matter by which it continues in its existing state of rest or uniform motion in a straight line, unless that state is changed by an external force.

2. d. 10

   Explanation: When the stone is dropped from the truck , the horizontal force acting on it become zero after stone is released. Stone continue to move under the influence of gravity only. So that acceleration of the stone is equal to the gravitational acceleration g.

   a = g = $10ms^{-2}$ acting vertically downward.

3. b. vector and equals the change of momentum

   Explanation: Since force is a vector quantity, impulse is also a vector in the same direction.

   Impulse J produced from time t_1 to t_2 is defined to be

   $J=\int_{t_1}^{t_2} F\,\mathrm{d}t$

   where F is the resultant force applied from t_1 to t_2

   force is related to momentum p by F = dp/dt

   therefore, $J=\int_{t_1}^{t_2} \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t}\,\mathrm{d}t$

   $=\int_{p_1}^{p_2} \mathrm{d}\mathbf{p}$

   $=\mathbf{p}_2-\mathbf{p}_1=\Delta\mathbf{p}$

   where Δp is the change in linear momentum from time t_1 to t_2

4. d. 4.2 kg m s^{-1}

   Explanation: Let $\overrightarrow{v_1}$ and $\overrightarrow{v_2}$ be the velocities of the ball before and after deflection, which is equal to $54 km\, h^{-1}$ = 15 $m\ s^{-1}$ as the speed of the ball does not change after deflection.

$$v = \sqrt{v_1^2 + v_2^2 + 2v_1 v_2 \cos 45^o}$$

$$= \sqrt{15^2 + 15^2 + 2 \times 15 \times 15 \times (1/\sqrt{2}}$$

$$= 27.72\, ms^{-1}$$

Impulse imparted to the ball = Mas x change in velocity of the ball

= $0.15 \times 27.72 = 4.2\, kg m\, s^{-1}$

5. a. 0 kg

Explanation: When the lift fall freely under gravity, a = g

Therefore Apparent weight, (We experience weight due to reaction)

$$R = m(g - a) = m(g - g) = 0$$

This is the condition for weightlessness.

6. The forces F_1 and F_2 due to masses m_1 and m_2 acts in opposite directions creating a vibrational to and fro motion. Now at the state of equilibrium the sum of two forces acting on the two bodies is equal to zero. If a_1 and a_2 are the accelerations produced in the two bodies, then $F_1 = m_1a_1$ and $F_2 = m_2a_2$.

   Thus $F_1 + F_2 = 0$

   $m_1a_1 + m_2a_2 = 0$

   $\times\ m_1a_1 = - m_2a_2$

   $\frac{a_1}{a_2} = -\frac{m_2}{m_1}$

   This implies that the accelerations produced in the two bodies are inversely proportional to their masses.

7. When lift is descending with acceleration a, the apparent weight decreases on weighing scale

   $\therefore W' = R = (mg - ma) = m(g - a)$

   Apparent weight due to reaction force by the lift on weighing scale.

   $\therefore W' = 50(10 - 9) = 50N$

   Reading of weighing scale= $\frac{R}{g} = \frac{50}{10} = 5\text{kg}$

8. During free fall with the box, the thief falls with the acceleration equal to the

acceleration due to gravity i.e. a = g. Weight of the box W = The apparent weight of the thief with the box W = m (g - a) = m (g - g) = 0.

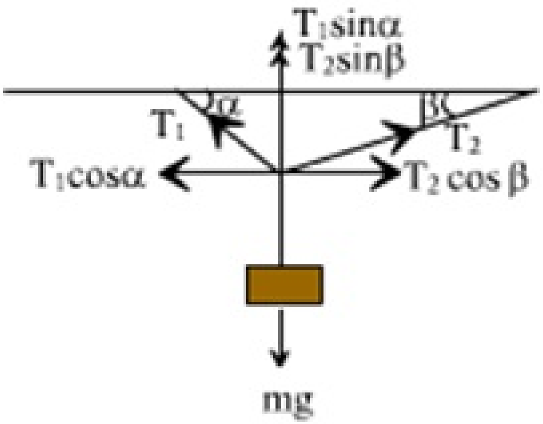
9. $F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$
$F = \sqrt{F_1^2 + F_2^2} \quad (\theta = 90^\circ)$
$F = \sqrt{(16)^2 + (12)^2}$
F = 20N
$a = \frac{F}{m} = \frac{20}{200}$
a = 0.1 m/s^2

10. Mass of the gun, M = 100 kg
Mass of the shell, m = 0.020 kg
Muzzle speed of the shell, v = 80 m/s
Recoil speed of the gun = V
Both the gun and the shell are at rest initially.
Initial momentum of the system = 0
Final momentum of the system = mv - MV
Here, the negative sign appears because the directions of the shell and the gun are opposite to each other.
According to the law of conservation of momentum:
Final momentum = Initial momentum
mv - MV = 0
$\therefore V = \frac{mv}{M}$
$= \frac{0.020 \times 80}{100 \times 1000} = 0.016 m/s$

11. According to Newton's first law of motion, each object maintains its state of rest or of uniform motion in a straight line unless it is compelled to change that state by a force impressed on it.
For example:
    - A book lying on the table remains at rest as long as no net force acts on it.
    - A moving object does not stop moving by itself.

12. Resolving the tension of two strings i.e. T_1 and T_2 into two rectangular components.

See the figure below.



Considering components of tensions T_1 and T_2 along the horizontal and vertical directions, we have

$-T_1\cos\alpha+T_2\cos\beta=0$ or $T_1\cos\alpha=T_2\cos\beta$ .... (i)

and $T_1\sin\alpha+T_2\sin\beta=mg$ .... (ii)

From (i), $T_2=\frac{T_1\cos\alpha}{\cos\beta}$

and substituting it in (ii), we obtain

$T_1\sin\alpha+\left(\frac{T_1\cos\alpha}{\cos\beta}\right)\sin\beta=mg$

or $T_1\left[\frac{\sin\alpha\cos\beta+\cos\alpha\sin\beta}{\cos\beta}\right]=mg$

or $T_1\frac{\sin(\alpha+\beta)}{\cos\beta}=mg$

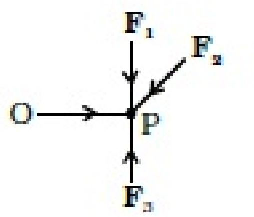
$\Rightarrow T_1=\frac{mg\cos\beta}{\sin(\alpha+\beta)}$

and hence $T_2=\frac{T_1\cos\alpha}{\cos\beta}$

$=\frac{mg\cos\beta}{\sin(\alpha+\beta)}\cdot\frac{\cos\alpha}{\cos\beta}$

$=\frac{mg\cos\alpha}{\sin(\alpha+\beta)}$

13. a. Since the body is moving with no acceleration, the sum of the forces is zero, i.e. $F_1 + F_2 + F_3 = 0$. Let F_1, F_2, F_3 be the three forces passing through a point. Let F_1 and F_2 be in the plane A. Then $F_1 + F_2$ must be in the plane A. Since $F_3 = -(F_1 + F_2)$, so F_3 is also in the plane A. Thus, the forces are coplanar.



b. Consider the torque of the forces about P. Since all the forces pass through P, the torque is zero. Now consider torque about another point O. Then torque about O is,

Torque = OP $\times$ ($F_1 + F_2 + F_3$)

Since, $F_1 + F_2 + F_3 = 0$

So, Torque = 0

Therefore, torque acting on the body about any point due to these three forces is zero.

14. mass of the monkey, m = 40kg,

Tensile strength of the rope, T = 600N (max tension rope can hold without breaking)

Here, the rope will break if reaction (R) exceeds the tension (T) applied, i.e. R > T

a. a = 6m/s^2

For upward accelerated motion the net acceleration is (g + a) instead of g, hence R = m (g + a) = 40 (10 + 6) = 640 N. Therefore the rope will break, as R > T

b. a = 4m/s^2

For downward accelerated motion the net acceleration is (g - a) instead of g, hence R = m (g – a) = 40 (10 – 6) = 240 N. Therefore the rope will not break as R < T

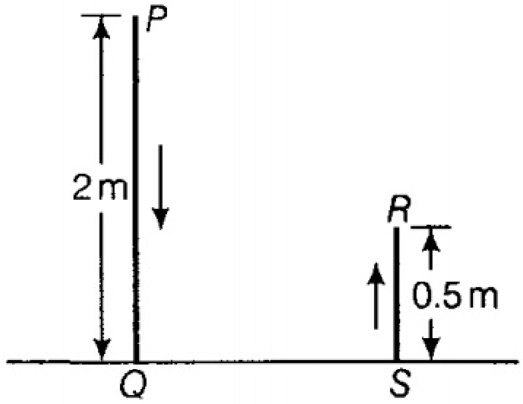
c. v= 5m/s (constant) a = 0

R = mg = 40 $\times$10 = 400 N. Therefore the rope will not break as R < T

d. For freefall, net acceleration on the body is zero, a = g; R = m (g – a) = m (g – g). Therefore R = zero (Rope will not break)

15. The initial velocity of the ball at P is zero as it is dropped. Let the final velocity of the ball at Q be v.

Given PQ = s = 2 m, then



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

$v^2 = 0 + 2 \times 9.8 \times 2 = 4 \times 9.8$

$v = \sqrt{39.2}\mathrm{m/s} = 6.26\mathrm{m/s}$ before it touched the ground.

Now, Let u' be the velocity of rebound of the ball (after it lost some kinetic energy due to collision with the ground). Given, RS = s' = 0.5 m, the final velocity at R is zero, we have

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

$0 = u'^2 + 2 \times (-9.8) \times 0.5$

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

$0 = u'^2 + 2 \times (-9.8) \times 0.5$

$u' = -\sqrt{9.8}\mathrm{m/s} = -3.13\mathrm{m/s}$ (negative sign indicates that displacement is against the direction of acceleration due to gravity i.e. upward)

We know that, Impulse = Change in momentum

= mv - (- mu’) = m(v + u')

$= \frac{60}{1000}(6.26 + 3.13)$

$= 0.06 \times 9.39 = 0.563\mathrm{Ns}$

From Newton's second law of motion,

$\because$ Average force = $\frac{\text{Impulse}}{\text{Time}} = \frac{0.563}{0.2} = 2.817\mathrm{N}$