03. LAWS OF MOTION
Questions and Answers

1. Explain the reasons for the following.
  a) When a carpet is beaten with a stick, dust comes out of it.
  b) Luggage kept on the roof of a bus is tied with a rope.
  c) A pace bowler in cricket runs in from a long distance before he bowls..

A. (**a**) When a carpet is beaten with a stick, the dust particles comes out of it due to static inertia. Actually on beating, the carpet moved and the dust particles still remains their position due to static inertia. So they comes out of it.

(b) If the luggage kept on the roof of a bus is not tied with a rope, due to dynamic inertia they can fall down from the top of the bus when the bus stopped suddenly. So they were tied with a rope.

(c) A pace bowler in cricket runs in from a long distance before he bowls, to give sufficient dynamic inertia to the ball.

2. Two objects have masses 8 kg and 25 kg. Which one has more inertia? Why?

A. The mass of an object is a measure of inertia. If mass of object increases, the inertia of that object also increases. So the object having 25 Kg. mass has more inertia than the 8 Kg. object.

3. What is the momentum of a 6.0 kg bowling ball with a velocity of 2.2 m/s?

A. Mass of the ball (m) = 6.0 Kg
Velocity of the ball (v) = 2.2 m/s
Momentum (P) = mv
= 6.0 x 2.2
= 13.2 Kg.m/s

4. Two people push a car for 3 s with a combined net force of 200 N.
  (a) Calculate the impulse provided to the car.
  (b) If the car has a mass of 1200 kg, what will be its change in velocity?

A. (a) Net force applied on car (F) = 200 N
Time (t) = 3 sec.
Impulse = F x t
= 200 x 3
= 600 N-s.

(b) Mass of the car (m) = 1200 Kg.
Net force applied (F) = 200 N
Time (t) = 3 sec
Impulse = Change in momentum
F x t = m (v-u)
200 x 3 = 1200 (v-u)
600 = 1200 (v-u)
$v-u = \frac{600}{1200} = \frac{1}{2} = 0.5$ m/s
Change in velocity = 0.5 m/s

5. What force required to produce an acceleration of 3 m/s^2 in an object of mass 0.7 Kg.?

A. Mass of the object (m) = 0.7 Kg.
Acceleration (a) = 3 m/s^2
The required force (F) = ma
= 0.7 x 3
= 2.1 N

6. A force acts for 0.2 sec on an object having mass 1.4 Kg initially at rest. The force stops to act but the object moves through 4m in the next 2 seconds find the magnitude of the force?

A.   Mass of object (m) = 1.4 Kg.
Time period of force applied (t_1) = 0.2 sec.
Initial velocity (u) = 0 m/s
After force stopped
The distance travelled by object (S) = 4 m
Time period (t_2) = 2 sec
Final velocity $V = \frac{Distance}{time}$
$= \frac{4}{2}$
= 2 m/s

Force applied (F) = ma
$= m\left(\frac{v-u}{t}\right)$
$= 1.4 \times \left(\frac{2-0}{0.2}\right)$
$= 1.4 \times \left(\frac{2}{0.2}\right)$
$= \frac{14 \times 2}{2}$
= 14 N

7. An object of mass 5 Kg is moving with a velocity of 10 ms^{-1}. A force is applied so that in 20 s, it attains a velocity of 25 ms^{-1}. What is the force applied on the object?

A. Mass of object (m) = 5 Kg.

Initial velocity (u) = 10 m/s

Time (t) = 20 s

Final velocity (v) = 25 m/s

Applied force (F) = ma

$$= m\left(\frac{v-u}{t}\right)$$
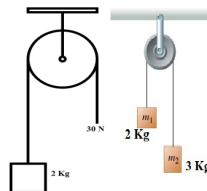
$$= 5 \times \left(\frac{25-10}{20}\right)$$

$$= 5 \times \left(\frac{15}{20}\right)$$

$$= \frac{15}{4} = 3.75 \text{ N}$$

8. Find the acceleration of body of mass 2 Kg from the figures shown.

A. (a)   T – mg = ma

30 – 2 x 10 = 2 a

10 = 2 a

2 a = 10

a = 5 m/s^2

(**b**) for 3 Kg mass 3g – T = 3a

for 2 Kg mass -2g + T = 2a

Sum   g = 5a

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

$$= \frac{10}{5}$$

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

9. Two rubber bands stretched to the standard length cause an object to accelerate at 2 m/s^2. Suppose another object with twice the mass is pulled by four rubber bands stretched to the standard length. What is the acceleration of the second object?

A.   F α x

For 2 rubber bands   For 4 rubber bands

$F_1 = F$ $F_2 = 2F$

$m_1 = m$ $m_2 = 2m$

$a_1 = 2$ m/s^2 $a_2 = ?$

$a_1 = \frac{F_1}{m_1}$ $a_2 = \frac{F_2}{m_2}$

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

                                $= \frac{F}{m}$

                                $= a_1$

No change in acceleration.

10. Illustrate an example of each of the three laws of motion.

A. Newton's first law of motion: A body continues its state of rest or uniform motion unless a net force acts on it.
Ex: When the bus which is at rest begins to move suddenly, the person standing in the bus falls backward. This happens because, the net force not acts on the person, so that he still remains his state of motion.
Newton's second law of motion: The rate of change of momentum of a body is directly proportional to the net force acting on it . And it takes place in the direction of net force.
Ex: The fielder while catching a fast moving ball, pulls back his arms to experience the smaller force on his hands. This is due to change in momentum takes a long time.
Newton's third law of motion: For every action, there should be equal and opposite reaction.
Ex: When birds fly, they push the air downwards with wings and the air pushes back the bird in upward direction with same force. This way the birds can fly.

11. A horse continues to apply a force in order to move a cart with a constant speed. Explain.

A. When horse apply force on the cart, the friction between cart and road acts in opposite direction to the applied force. So In order to move a cart with a constant speed, the horse should apply force that equals to the friction.

12. A force of 5N produces an acceleration of 8 ms^{-2} on a mass m_1 and an acceleration of 24 ms^{-2} on a mass m_2. What acceleration would the same force provide if both the masses are tied together?

A. Applied force on mass m_1 = F = 5 N

Mass of first object = m_1

Acceleration (a) = 8 m/s^2

$$m_1 = \frac{F}{a} = \frac{5}{8}$$

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Applied force on mass m_2 = F = 5 N
Mass of first object = m_2
Acceleration (a) = 24 m/s^2
$$m_2 = \frac{F}{a} = \frac{5}{24}$$
If both masses tied together, then
Total mass (m) = $m_1 + m_2$
$$= \frac{5}{8} + \frac{5}{24}$$
$$= \frac{15}{24} + \frac{5}{24}$$
$$= \frac{20}{24} = \frac{5}{6} \text{ Kg}$$
Force act on both masses F = 5 N
$$\text{Acceleration (a)} = \frac{F}{m}$$
$$= \frac{5}{5/6}$$
$$= 6 \text{ m/s}^2$$

13. A hammer of mass 400g. moving at 30 ms^{-1}, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

A. Mass of hammer (m) = 400 g = 0.4 Kg
Initial velocity (u) = 30 m/s
Final velocity (v) = 0 m/s
Time of application of force (t) = 0.01 sec
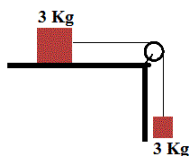Acceleration = rate of change in velocity
$$= \frac{v-u}{t}$$
$$= \frac{0-30}{0.01}$$
$$= \frac{-30}{0.01}$$
$$= -3000 \text{ m/s}^2$$
The force applied on hammer (F) = ma
$$= 0.4 \times (-3000) = -1200 \text{ N}$$
This force applied on hammer in opposite direction of applied force.

14. System is shown in figure. Assume there is no friction. Find the acceleration of the blocks and tension in the string. Take g = 10 m/s^2.

A.   In the system $m_1 = m_2$ = 3 Kg
Acceleration due to gravity (g) = 10 m/s^2
Acceleration of blocks (a) = $\frac{m_1 g}{m_1+m_2} = \frac{m_2 g}{m_1+m_2}$
$$= \frac{3 \times 10}{3+3}$$

$$= \frac{30}{6} = 5 \text{ m/s}^2$$
Tension in string (T) = $\frac{m_1 m_2 g}{m_1+m_2}$
$$= \frac{3 \times 3 \times 10}{3+3}$$
$$= \frac{90}{6} = 15 \text{ N}$$

15. Three identical blocks, each of mass 10 Kg, are pulled as shown on the horizontal frictionless surface. If the tension (F) in the rope is 30N, what is the acceleration of each block? And what are the tensions in the other ropes? (Neglect the masses of the ropes).

A.   Masses of three blocks
$$m_1 = m_2 = m_3 = 10 \text{ Kg}$$
Applied force (F) = 30 N
Acceleration in system (a) = $\frac{F}{m_1+m_2+m_3}$
$$= \frac{30}{10+10+10}$$
$$= \frac{30}{30} = 1 \text{ m/s}^2$$
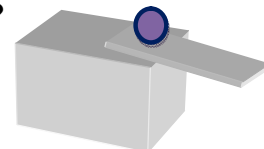Let the tensions in ropes as T_1 and T_2
In first case $T_1 = m_1.a$
$$= 10 \times 1$$
$$= 10 \text{ N}$$
In second case $T_2 = (m_1+m_2)a$
$$= (10+10)1$$
$$= 20 \text{ N}$$

16. Keep a small rectangular shaped piece of paper on the edge of a table and place an old five rupee coin on its surface vertically as shown in the figure below. Now give a quick push to the paper with your finger. How do you explain inertia with this experiment?

A. If we drag the paper quickly, the force does not apply on the coin. Due to static inertia, the coin still remains its state of rest. No change in the state of coin.

17. If a fly colloids with the wind shield of a fast moving bus,
   (a) is the impact force experienced , same for the fly and bus? Why?
   (b) Is the same acceleration experienced by the fly and the bus? Why?

A. (**a**) The impact of force experienced by the bus and fly are same. (As per Newton's third law of motion force and anti forces are equal and in opposite direction.)

(**b**) The acceleration of the bus and fly are different. It depends upon various factors. In general more mass gets less acceleration. So the acceleration of bus is less.

18. Divya observed a horse pulling a cart. She thought that cart also pulls the horse with same force in opposite direction. As per third law of motion the cart should not move forward. But her observation of moving cart raised some questions in her mind. Can you guess what questions were raised in her mind?

A. The following questions may arised to divya :
   (i) How much force applied by horse on the floor?
   (ii) There are two forces. The force by horse on cart and the force by cart on horse. Are the forces same ?
   (iii) How the cart moves?
   (iv) Why the cart apply force on the floor to pull cart?

19. Take some identical marbles. Make a path or a track keeping your note books on either side so as to make a path in which marbles can move. Now use one marble to hit the other marbles. Take two marbles, three marbles and make them to hit the other marbles. What can you explain from your observations?

A. If we keep one marble and hit it with another marble, then the first marble move

apart.
If we put two marbles and hit with one marble, then only the first marble in two marbles move apart.
If we put three marbles and hit with one marble, then only the first marble in three marbles move apart.
This is due to law of conservation of momentum.

20. How do you appreciate Galileo's thought of "any moving body continues in the state only until some external force acts on it." Which is a contradiction to the Aristotle's belief of "any moving body naturally comes to rest."

A. Aristotle believed that any moving body comes to rest naturally. It may be true.

But Galileo thought that any moving body continues its state only until some external force acts on it. Also he proved his statement with the experiments of an inclined plane. He stated that if no force acts on a body, it moves to infinite distance.

This leads to developments in various concepts in dynamics. So I appreciate Galileo's thought.

21. If a car is traveling westwards with a constant speed of 20 m/s, what is the resultant force acting on it?

A. The car is travelling with a constant speed. So no net force acts on it.

22. A man of mass 30 Kg uses a rope to climb which bears only 450N. What is the maximum acceleration with which he can climb safely?

A.   Mass of the man (m) = 30 Kg
   Tension in the rope (T) = 450 N
Maximum acceleration (a) = ?
$$T = F$$
$$T = ma$$
$$450 = 30 \times a$$
$$a = \frac{450}{30}$$
$$a = 15 \text{ m/s}^2$$

23. An vehicle has a mass of 1500 Kg. What must be the force between the vehicle and the road if the vehicle is to be stopped with a negative acceleration of 1.7 m/s^2?

A.   Mass of the vehicle (m) = 1500 Kg

Negative acceleration = 1.7 m/s^2

Acceleration (a) = -1.7 m/s^2

Applied force (F) = ma

$\qquad$ = 1500 x (-1.7)

$\qquad$ = - 2550 N

The frictional force acts in opposite direction of motion.

The frictional force between vehicle and road is 2550 N.

24. A truck is moving under a hopper with a constant speed of 20 m/s. Sand falls on the truck at a rate 20 Kg/s. What is the force acting on the truck due to falling of sand?

A. As the truck moving with constant speed, no net force acting on it.

25. Two ice skaters initially at rest, push of each other. If one skater whose mass is 60 Kg has a velocity of 2 m/s. What is the velocity of other skater whose mass is 40 Kg?

A.   **First skater** $\qquad$ **Second skater**

m_1= 60 Kg $\qquad$ m_2 = 40 Kg

u_1 = 0 m/s $\qquad$ u_2 = 0 m/s

v_1 = 2 m/s $\qquad$ v_2 = ?

Law of conservation of momentum

$m_1.u_1 + m_2.u_2 = m_1.v_1 + m_2.v_2$

60 x (0) + 40 x (0) = 60 x 2 + 40 x v_2

0 + 0 = 120 + 40 v_2

40 v_2 = - 120

$V_2 = \frac{-120}{40}$

V_2 = -3 m/s

The velocity of second skater is 3 m/s in the opposite direction to the first skater.

26. A passenger in moving train tosses a coin which falls behind him. It means that the motion of the train is ….
(a) Accelerated (b) Uniform
(c) Retarded   (d) Circular motion

A. Accelerated motion in particular conditions.

But in general the coin fall in the hand.

27. A ball of mass 'm' moves perpendicularly to a wall with speed v, strikes it and rebounds with the same speed in the opposite direction. What is the direction and magnitude of the average force acting on the ball due to the wall?

A.   The mass of the ball = m

Let Initial velocity (u) = v

$\qquad$ Final velocity = -v

The force acts on the ball by the wall

(F) = rate of change in momentum
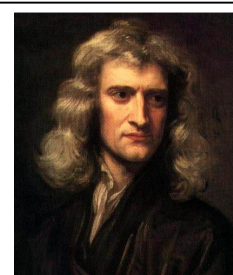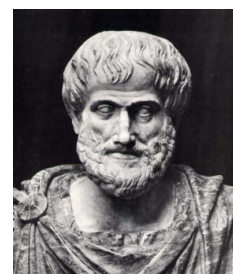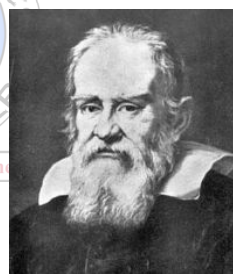
$\qquad$ = m $\left(\frac{v-u}{t}\right)$

$\qquad$ = m $\left(\frac{v-u}{t}\right)$

$\qquad$ = m $\left(\frac{-v-v}{t}\right)$

$\qquad$ = m $\left(\frac{-2v}{t}\right)$

$\qquad$ = $\frac{-2mv}{t}$

The force on ball by wall is $\frac{2mv}{t}$ and the direction is in opposite to the applied force.

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