FORCE

Force is an influence that can change the shape, direction and speed of the body. It is a push or a pull on a body.

It is denoted by 'F'. It is a vector quantity and its unit is Newton (N).

If the resultant of all the forces acting on a body is zero, it is said to be balanced force.

If the resultant of all the forces acting on a body is not zero, it is said to be unbalanced force.

Linear Momentum (or Momentum): It is the product of mass and velocity.

It is denoted by **'**M' or 'p'.

It is a vector quantity and its unit is kg m/s.

Newton's Laws of Motion:

(i) **1st law of motion:** According to this law a body will remain in rest if in rest or motion if in motion unless an unbalanced force is applied on it. This law is also called ***law of inertia***.

Inability of a body to change its state of rest or of uniform motion on its own is known as ***inertia****.*

Mass is the measure of inertia i.e. If the body has more mass, it has more inertia.

If we kick a football and a stone, the football will move a long as it has less mass and so less inertia.

applications:

- When the bus starts suddenly, the passenger falls backward. This is due to the reason that the passenger tends to remain in rest even the bus has started.
- When the bus is stopped suddenly the passenger falls forward. This is because the passenger remains in motion even after the bus has stopped.
- It is dangerous to jump out of the moving bus, as the jumping man tend to remain in motion even after falling to the ground and get hurt due to resistance offered by ground.
- The head of a hammer can be tightened onto the wooden handle by banging the bottom of the handle against a hard surface.

(ii) **2nd law of motion:** According to this law the force acting on a body is directly proportional to the product of its mass and acceleration produced in it.

$$F \propto rate\ of\ change\ in\ momentum$$

$$\Rightarrow \quad F \propto \frac{change\ in\ momentum}{time}$$

$$\Rightarrow \quad F \propto \frac{final\ momentum - initial\ momentum}{time}$$

$$\Rightarrow \quad F \propto \frac{mv - mu}{t}$$

$$\Rightarrow \quad F \propto m\left(\frac{v-u}{t}\right)$$

$$\Rightarrow \quad F \propto ma$$

$$\Rightarrow \quad F = kma$$

where k is constant and is equal to 1

$$\therefore \quad F = ma$$

If m = 1 kg and a = 1 m/s^2

Then, F = 1N

so **1 Newton** is the force which produces an acceleration of 1m/s^2 in a body of mass 1kg.

applications:

- A cricket player lowers his hands along with a ball while catching. As if he takes more time to stop the ball, the acceleration will become small. So the ball will exert less force on the hands of the player.
- The cars are provided seat belts. If a fast running car stops suddenly then the large momentum is produced in a very short time. The stretchable belts worn by the person increase the time taken by the passenger to fall forward. Due to longer time injury chances are almost reduced.
- When an athlete, after making a high jump, falls on a cushion, he takes a longer time to come to stop. Due to this he gets safe from being hurt.

(iii) **3rd law of motion:** To every action there is equal opposite reaction.

applications:

- When we walk on ground, then our foot pushes the ground backward (action) and in returns, the ground pushes our foot forward (reaction).
- When a bullet is fired from the gun, the backward force is exerted. This is why the gun recoils.
- In jet aero planes, hot gasses obtained by rapid burning of fuel rush out of the jet (action). The equal and opposite reaction pushes the aircraft forward with a great force.
- When we swim, we push the water backward and the water pushes us forward with equal force.

Law of conservation of momentum:

When two bodies act upon one another, the total momentum remains constant i.e. momentum can neither be created nor be destroyed.

Consider the bodies A and B of masses 'm_1' and 'm_2' moving with the velocities of 'u_1' and 'u_2' respectively.

Let they collide with each other and after collision their velocities become 'v_1' and 'v_2' respectively.

Now, by third law of motion

$$F_1 = -F_2$$

where F_1 is the force exerted by A on B and F_2 is the force exerted by B on A in turn (the negative sign signifies that the force F_2 is in the opposite direction)

Now $F_1 = -F_2$

$\Rightarrow$ $m_1 \times a_1 = -m_2 \times a_2$

$\Rightarrow$ $m_1 . \frac{v_1 - u_1}{t} = -m_2 . \frac{v_2 - u_2}{t}$

$\Rightarrow$ $m_1 \times (v_1 - u_1) = -m_2 \times (v_2 - u_2)$

$\Rightarrow$ $m_1 v_1 - m_1 u_1 = -m_2 v_2 + m_2 u_2$

$\Rightarrow$ $m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2$

$\Rightarrow$ $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

i.e. initial momentum in A + initial momentum in B = final momentum in A+ final momentum in B

$\therefore$ total momentum before collision = total momentum after collision

assignment

1) Define inertia.

2) Define newton.

3) What is the measure of inertia?

4) Which has more inertia: body of mass 1 kg or a body of mass 2 kg? Why?

5) Which law explains the following:

(i) A fireman turns on his hose & is knocked backwards.

(ii) It takes less force to move a DVD than a DVD player.

(iii) You have to push a heavy ball harder to get it to move as fast as a small one.

(iv) A soccer ball will not move until a player kicks it.

(v) If air is let out of a balloon quickly, air pushes down & balloon goes up.

(vi) It takes less force to push a bike than a motorcycle.

(vii) An object in motion stays in motion unless acted on by an outside force.

(viii) A bowling ball hits the pins sending the pins flying for a STRIKE!

(ix) An object at rest stays at rest unless acted on by an outside force.

(x) Feet push down on the floor & the floor pushes up at feet as you walk.

(xi) 12 lb bowling ball goes faster down the lane than a 15 lb bowling ball.

(xii) In a plane taking off you feel pushed back into your seat.

(xiii) Push a large box & a small box with the same force, the small box will go faster.

(xiv) Seatbelt stops you from hitting the windshield if you hit the brakes quickly.

(xv) A boy can throw a football farther than his friend because he uses more force.

(xvi) When you push on a door it pushes back with = and opposite force.

(xvii) Someone crashes their bike into a rock & is thrown over it to the ground.

(xviii) After covering a certain distance a rolling ball comes to rest.

6) Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor of constant velocity. What is the friction force that will be exerted on the cabinet?

7) A body of mass 2 kg is moving at 36 kmph. Find its momentum.

8) A ball of mass 200 g slows down from 10 m/s to 2 m/s. Find change in momentum.

9) How much force is needed to accelerate a trolley of mass 20 g through 1 m/s^2?

10) A force of 100 N acts on a mass of 25 kg for 5 s. What velocity does it generate?

11) A certain force is acting on a mass of 15 kg for 3 s, gives it velocity of 2 m/s. Find the magnitude of the force.

12) A cricket ball of mass 0.15 kg is moving with a velocity of 1.2 m/s. Find the force applied by the player if he is able to stop the ball in 0.18 s.

13) A hammer of mass 500 gram, moving at 50 m/s, 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?

14) A motor car of mass 2000 kg is moving with a certain velocity. It is brought to rest by applying brakes, within a distance of 20 m when the average resistance being offered to it is 5000 N. What was the velocity of the motor car?

15) A body of mass 0.5kg undergoes a change of velocity of 4cm/s in 4s. What is the force acting on it?

16) Three persons manage to push a motor car of mass 1200 kg at a uniform velocity along a level road producing an acceleration of 0.2 m/s^2. With what force does each person push the motor car? Assume that all persons push the motor car with the same muscular effort.

17) A force of 3 N acts on a mass of 0.5 kg at rest for 10 s. Find the final velocity and the momentum after 10s.

18) A force of 80 N acting on a certain mass for 3.0 s gives it a velocity of 6.0 m/s. Find the mass of the body if the body was initially at rest.

19) A truck starts from rest and rolls down a hill with constant acceleration. It travels a distance of 400 m in 20 s. find its acceleration. Find the force acting on it if mass of the truck is 7 metric tonnes.

20) A stone of 1 kg is thrown with a velocity of 20 m/s across the frozen surface of the lake and comes to rest after travelling a distance of 50 m. what is the force of friction between the stone and the ice?

21) A force of 6.0 N produces an acceleration of 2 m/s^2 when it acts on a body A, and 3 m/s^2 when it acts on another body B. If the bodies A and B are tied together and a force of 5 N is applied, what will be the acceleration?

22) A bullet of mass 15 g leaves a barrel of a gun with a velocity of 120 m/s. The gun recoils with a velocity of 1 m/s. Find the mass of the gun.

23) From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 m/s. Find the recoil velocity of the gun.

24) Two objects of masses 100 g and 200 g are moving along the same line and direction with velocities 2 m/s and 1 m/s respectively. They collide and after the collision, the first object moves with a velocity of 1.67 m/s. determine the velocity of the second object.

25) A bullet leaves a rifle with a velocity of 100m/s and the rifle (mass = 2.5kg) recoils with a velocity of 1m/s. Find the mass of the bullet.

26) A boy of mass 50 kg running at 5 m/s jumps on to a 20 kg trolley traveling in the same direction at 1.5 m/s. What is their common velocity?

27) Two objects each of mass 1.5 kg are moving in the same straight line but in opposite directions. The velocity of each object is 2.5 m/s before the collision during which they stick together. What will be the velocity of the combined object after collision?

28) An object of mass 12 kg travelling in a straight line with a velocity of 10 m/s collides with, and sticks to, a stationary wooden block of mass 5 kg. then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also calculate the velocity of the combined object.

29) A particle of mass 0.5 kg is kept at rest. A force of 2 N acts on it for 5 sec. Find the distance moved by the particle in these 5 seconds.

30) A 8000 kg engine pulls a trains of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40,000 N and the track offers a friction force of 5000 N, then calculate

(i) net accelerating force

(ii) acceleration of the train

(iii) the force of wagon 1 on wagon 2

31) A motor car of 1200 kg is moving along a straight line with a uniform velocity of 90 kmph. Its velocity is slowed down to 18 kmph in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

32) A large truck and a car, both moving with same velocity have a head-on collision and both of them come to a halt after that. If the collision lasts for 1 s,

(i) Which vehicle experiences the greater

(a) force of impact

(b) change in momentum

(c) acceleration?

(ii) Why is the car likely to suffer more damage?

answers

7) 20 kgm/s	8) 1.6 kgm/s	9) 0.02 N	10) 20 m/s
11) 10N	12) –1 N	13) 2500 N	14) 10 m/s
15) 0.005 N	16) 80 N	17) 60 m/s, 30 kgm/s	18) 40 kg
19) 2 m/s^2, 14000 N	20) –4 N	21) 1 m/s^2	22) 1.8 kg
23) 0.4375 m/s	24) 1.165 m/s	25) 0.025 kg	26) 4 m/s
27) 0 m/s	28) 120 kgm/s, 120 kgm/s, 7.06 m/s		29) 50 m
30) 35000 N, 3.5 m/s^2, 28000 N		31) 5 m/s^2, 24000 kgm/s, 6000 N	
32) (i) car	(ii) same	(iii) car	

Some of the most difficult jobs:

to listen quietly

to have patience

to forgive

to stop using the word 'I'

to be satisfied with what we have