FORCE

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The external agent which tends to set a body in motion or which changes the speed and direction of motion of a body or which can change the shape of a body is called force.

- To push or to pull is also called as force.
- It is a vector quantity

◈ Types of forces :

(A) Contact forces :

The forces that act on bodies when they are in actual contact are known as contact forces. eg. Frictional force, normal reaction force, tension in string, force exerted during collision, force applied as a push or a pull etc.

(B) Non-contact forces :

The forces that act on bodies without being touched are called non-contact forces. eg. gravitational force, electrostatic force, magnetic force etc.

Newton's Laws of Motion

(A) Newton´s I law :

- A body can not change its state of motion by itself. If the object is at rest it will remain at rest and if it is in uniform motion, it continues to be in motion unless some external force is applied on it.

◈ Inertia :

- There is an inherent property of an object by virtue of which it cannot change its state of motion or rest by if self. This property is called 'inertia'.
- Inertia is of two types– inertia of rest and inertia of motion.

(A) Inertial of rest:

If the body is at rest, it will continue to be at rest unless some external force is applied on it. Examples are following.

- When a train at rest starts moving suddenly, a passenger standing inside the compartment tends to fall backward.
- When a carpet is beaten up with a stick, the dust particles are detached.
- When a bullet is fired into a glass pane, it pierces a hole only at the pt where the bullet hits the glass without breaking the entire glass pane into pieces.

(B) Inertia of motion :

When a body is in uniform motion, it will continue to remain in its uniform motion, i.e. it resists any change in its state of motion due to inertia of motion.

- when a person jumps out of a moving bus, he should run in the direction in which bus is moving otherwise he will fall down.
- A train moving with a uniform speed and if a ball is thrown upwards inside the train by a passenger, then the ball comes back to his hand.

◈ **Mass and Inertia :**

- ◆ Larger the mass of the body, larger is the inertia.
- ◆ eg. it is more difficult to stop a cricket ball than a tennis ball.

(B) Newton's second law of motion

- ◆ **Momentum** → The product of mass and velocity is called 'momentum'. i.e. $p = mv$

(a) Unit : SI unit of momentum is kg-m/s.

(b) It is a vector quantity.

- ◆ Newton's second law states that "the rate of change of momentum of a body is directly proportional to force and takes place in the direction of force."

(a) i.e. $F \propto \frac{p_2 - p_1}{t}$ or $F = km\left(\frac{v-u}{t}\right)$

wherek = proportionality constant

p_1 = initial momentum = mu

p_2 = final momentum = mv

(b) $\therefore \quad F = kma$

If we consider proportionality constant k = 1,

$\Rightarrow \quad F = ma$

(c) Unit of force in SI system is newton.

(d) 1 newton = $1kg\text{-}m/s^2$

(e) 1 N is equivalent to that force which can produce an acceleration of $1m/s^2$ in a body of mass 1 kg.

(f) Unit of force in CGS system is dyne.

(g) 1 dyne = 1 gm - cm/s^2

(h) 1 N = 10^5 dynes

- ◆ Newton's second law can be written as $\vec{F} = m\vec{a}$

Ex. Calculate the force required to produce an acceleration of 5 m/s^2 in a body of mass 2.4 kg.

Sol. We know that force = mass × acceleration

$= 2.4 \text{ kg} \times 5 \text{ m/s}^2 = 12.0\text{N}$

Ex. A body of mass 2.5 kg is moving with a velocity of 20 m/s. Calculate its momentum.

Sol. Momentum, p = mass × velocity

Here, mass $m = 2.5$ kg

Velocity, $v = 20$ m/s

$\therefore$ Momentum, $p = mv = 2.5 \times 20$ kg-m/s $= 50$ kg-m/s

◈ Impulse

- If a force F is applied on a body of mass m for a time interval Δt and if the change in velocity is Δv then, $m \Delta v = F \Delta t$
- $\therefore$ Impulse = $F\,dt = m \Delta v$

  Impulse = change in momentum
- Unit of impulse is newton × second, i.e. NS

◈ Examples of impulse

- A bullet fired from a gun with a large velocity resulting in a large momentum when strikes a body, its velocity becomes zero in a short interval of time.
- The rate of change of momentum is very large and it exerts a large force and so that it can easily pierce the body.
- while catching a cricket ball a player moves his hands backwards. Cricket ball coming towards fielder has a large momentum. By doing so he increases the time interval to reduce the momentum of the ball. Rate of change of momentum becomes slow.
- The ball exerts lesser force.
- He does not get hurt.

Ex. A force acts for 0.2 s on a body of mass 2.5 kg initially at rest. The force then ceases to act and the body moves through 4m in the next one second. Calculate the magnitude of force.

Sol. When the force ceases to act, the body will move with a constant velocity. Since it moves a distance of 4 m in 1 s, therefore, its uniform velocity = 4m/s.

Now, initial velocity, $u = 0$

Final velocity, $v = 4$ m/s

Time interval $\Delta t = 0.2$ s

$\therefore$ Acceleration, $a = \frac{v-u}{\Delta t} = \frac{4-0}{0.2} = 20 m/s^2$ From the relation, $F = ma$, we get

Force, $F = 2.5 \times 20 = 50$ N

Ex. A ball of mass 20 gm is initially moving with a velocity of 100 m/s. On applying a constant force on the ball for 0.5s, it acquires a velocity of 150 m/s. Calculate the following :

(i) Initial momentum of the ball

(ii) Final momentum of the ball

(iii) Rate of change of momentum

(iv) Acceleration of the ball

(v) Magnitude of the force applied

Sol. Given , $m = 20$ gm $= \frac{20}{1000}$ kg $= 0.02$ kg

Initial velocity, $u = 100$ m/s

Time interval, $t = 0.5$ s

Final velocity, $v = 150$ m/s

(i) Initial momentum of the ball = mass × initial velocity

or $P_1 = mu = 0.02\ kg \times 100\ m/s = 2\ kg\text{-}ms^{-1}$

(ii) Final momentum of the ball = mass × final velocity

or $P_2 = mv = 0.02\ kg \times 150\ m/s = 3\ kg\text{-}ms^{-1}$

(iii) Rate of change of momentum = $\frac{\text{Final momentum} - \text{Initial momentum}}{\text{Time}}$

or $\frac{\Delta P}{\Delta t} = \frac{3-2}{0.5} = \frac{1}{0.5} = 2.0\ kg\text{-}ms^{-1} = 2.0N$

(iv) Acceleration, $a = \frac{v-u}{t} = \frac{150-100}{0.5} = 100ms^{-2}$

(v) Force, $F = \text{mass} \times \text{acceleration}$

$= 0.02 \times 100 = 2.0\ N$

Ex. A cricket ball of mass 200 gm moving with a speed of 40 m/s is brought to rest by a player in 0.04s. Calculate the following :

(i) change in momentum of the ball,

(ii) average force applied by the player.

Sol. Mass, $m = 200\ gm = \frac{200}{1000} kg = 0.2\ kg$

Initial velocity, $u = 40\ m/s$

Final velocity, $v = 0$

Time, $t = 0.04s$

(i) Initial momentum, $p_1 = mu$

$= 0.2\ kg \times 40\ m/s = 8.0\ kg\text{-}ms^{-1}$

Final momentum, $p_2 = m \times v$

$= 0.2 \times 0 = 0\ kg\text{-}ms^{-1}$

Change in momentum, $\Delta p = p_2 - p_1$

$= 0 - 8.0\ kg\ ms^{-1} - 8.0\ kg\text{-}ms^{-1}$

(ii) Average force = $\frac{\text{Change in momentum}}{\text{Time}} = \frac{-8.0-0}{0.04} = -200\ N$

(The negative sign shows that the force is applied in a direction opposite to the direction of motion of the ball).

Ex. 6 A motorcycle is moving with a velocity of 108 km/hr and it takes 5 s to stop it after the brakes are applied. Calculate the force exerted by the brakes on the motorcycle if its mass along with the rider is 250 kg.

Sol. Given that initial velocity of the motorcycle = 108 km/hr = 30 m/s

Final velocity = 0 m/s

Time taken to stop = 5s, the mass of the motorcycle with rider = 250 kg.

The change in the velocity of the motorcycle in 5s = 0 – 30 = –30 m/s

Therefore, the acceleration of the motorcycle, $a = \frac{-30}{5} = -6\ m/s^2$

The magnitude of the force applied by the brakes is given by the equation,

F = mass × acceleration

= 250 kg × (6)m/s^2 = 1500 N

(C) Newton's third law of motion

- Newton's first law of motion gives a qualitative idea of force, while the second law provides us an idea to measure the force.
- Newton's third law of motion states that " if a body A exerts a force on the body B, the body B will also exert an equal and opposite force on A."
- The force exerted by A on B is called action while the force exerted by B on A is called the reaction.
- Newton's third law is also stated as "to every action there is an equal and opposite reaction."
- Action and reaction always act on different bodies.
- eg. by hitting a table with palm we apply a force. The table also exerts a force on palm on hitting it.
- Forces always occur in pairs.

◈ **Applications of Newtons III law :**

- Recoil of a gun – where the bullet is fired from a gun, an equal and opposite force is applied on the gun, due to which the gun recoils in backward direction.
- Application in walking : while moving in forward direction we push the ground backwards that is the action. An equal and opposite force is applied by the ground on the man, thus the reaction due to which man moves forward.
- Rowing a boat in river : when we push the water backward with the help of oars (applying a force backward), an equal and opposite force acts on the boat. This is the reaction which moves the boat forward.
- Launching Rocket : In rocket, gases are produced in large amount. Due to internal combustion they come out and move backwards with an equal and opposite force which in turn acts on the rocket and moves it forward.

Ex. Due to internal combustion inside a rocket, gases are ejected at the rate of 2.4 kg/minute. The velocity of the gases with respect to the rocket is 400 m/s. Calculate force exerted on the rocket

Sol. Since gases are ejected at the rate of 2.4 kg/minute, i.e. $\frac{\Delta m}{\Delta t} = \frac{2.4}{60}$ kg/s

Change in momentum per second = $v \times \frac{\Delta m}{\Delta t} = 400 \times \frac{2.4}{60}$

Now since force, F = Rate of change of momentum = $400 \times \frac{2.4}{60} = 16$ N

Ex. A rifle man, who together with his rifle has a mass of 100 kg, stands on a smooth surface fires 10 shots horizontally. Each bullet has a mass 10 gm a muzzle velocity of 800 m/s.What velocity does rifle man acquire at the end of 10 shots?

Sol Let m_1 and m_2 be the masses of bullet and the rifleman and v_1 and v_2 their respective velocities after the first shot. Initially the rifleman and bullet are at rest, therefore initial momentum of system = 0.

As external force is zero, momentum of system is constant

i.e. initial momentum = final momentum

$$= m_1v_1 + m_2v_2$$

or $$v_2 = \frac{m_1v_1}{m_2} = -\frac{(10\text{x}10^{-3}\text{kg})(800\text{m/s})}{100\text{kg}} = -0.08 \text{ m/s}$$

Velocity acquired after 10 shots = $10\ v_2 = 10 \text{ x } (-0.08)$

$$= -0.8 \text{ m/s.}$$

i.e, the velocity of rifle man is 0.8 m/s in a direction opposite to that of bullet.

EXERCISE - 1

VERY SHORT ANSWER TYPE QUESTION

Q.1 Define force.

Q.2 An inflated balloon was pressed against a wall after it has been rubbed with a piece of synthetic cloth. It was found that the balloon sticks to the wall. What force might be responsible for the attraction between the balloon and the wall ?

Q.3 How many objects should be present for a force to come into play ?

Q.4 Two friends A and B are applying a force of 2 newton and 4 newton on a box in the same direction. What will be the total force applied by them ?

Q.5 In a tug of war, side A applies 10 newton force and side B applies 8 newton force. Which side will the rope move ?

Q.6 What happens to the speed of a body when a force is applied ?

Q.7 Can we change the direction of the moving object by applying a force ?

Q.8 Is it possible that a force changes the direction of motion but not the speed of an object ?

Q.9 Give an example to show that force can change the shape of an object.

Q.10 What is meant by contact force ?

Short Answer Type Question

Q.11 Give two examples each of situations in which you push or pull to change the state of motion of objects.

Q.12 Give two examples each of situations in which applied force causes a change in the shape of an object.

Q.13 If the force is applied opposite to the motion, what will happen to the speed of the object?

Q.14 State the two factors which describe the state of motion of an object.

Q.15 How do the mud particles fly off the wheel of a vehicle moving on the wet road ?

Long Answer Type Question

Q.16 Name the forces acting on a plastic bucket containing water held above ground level in your hand. Discuss why the forces acting on the bucket do not bring a change in its state of motion.

Q.17 (a) What is weight ?

(b) What is the unit of weight ?

(c) Name the device used for measuring the weight of an object.

(d) Can weight be taken as a measure of force ?

Q.18 Name the type of force in the following cases.

(a) Raindrops falling on the earth.

(b) Holding a book on your hand.

(c) Running a comb through your dry hair.

(d) A bar magnet suspended freely.

(e) Bullocks ploughing the field.

EXERCISE- 2

Single Correct Answer type Questions

Q.1 Which of the following is the action-at-distance force ?
(A) muscular force (B) frictional force
(C) magnetic force (D) mechanical force

Q.2 The force exerted by one object on another by virtue of their masses is
(A) magnetic force (B) electrostatic force
(C) gravitational force (D) frictional force

Q.3 The standard unit of force is
(A) metre/second (B) newton
(C) metre/second^2 (D) gram-weight

Q.4 A spring balance is used for measuring
(A) weight (B) speed
(C) acceleration (D) mass

Q.5 A force applied on a moving body may
(A) bring it to rest
(B) increase its speed
(C) decrease the speed
(D) all of the above

Q.6 Earth always pulls everything towards it due to
(A) muscular force
(B) mechanical force
(C) gravitational force
(D) electrostatic force

Q.7 A cart being carried by a horse is an example of
(A) muscular force
(B) mechanical force
(C) gravitational force
(D) electrostatic force

Q.8 If you press an inflated balloon, it deforms due to a type of
(A) contact force
(B) non-contact force
(C) gravitational force
(D) none of these

Q.9 Force exerted by the muscless is known as
(A) mechanical force
(B) gravitational force
(C) electrostatic force
(D) muscular force

Q.10 A hockey player uses his hockey stick –
(A) To push the ball
(B) To pull the ball
(C) To change its direction
(D) All of these

Q.11 A force when applied brings change in –
(A) Direction of motion of the body
(B) Speed of moving body
(C) Shape of the body
(D) Any of these

Q.12 The force responsible for the wearing out of the car tyres is –
(A) Frictional force (B)Gravitational force
(C) Magnetic force (D) Muscular force

Q.13 The force you will use to collect the iron nails scattered on a sandy ground is –
(A) Frictional force (B)Gravitational force
(C) Magnetic force (D) None of these

Q.14 The force you use to stretch a rubber band is –
(A) Frictional force (B)Gravitational force
(C) Magnetic force (D) Muscular force

Q.15 The SI unit of force is
(A) metre (B) newton
(C) pascal (D) second

Q.16 A contact force cannot act through
(A) empty space
(B) touching
(C) touching with a metal rod
(D) touching with a wooden rod

Q.17 A force that opposes the motion of one surface sliding over another is called
(A) friction (B) newton
(C) lubrication (D) ball bearing

ANSWER KEY

EXERCISE-1

VERY SHORT ANSWER TYPE QUESTION

Sol.1 Force is a push or pull on an object.

Sol.2 Electrostatic force.

Sol.3 There should be atleast two objects for a force to come into play.

Sol.4 The total force will be 6 newton, i.e., the sum of their individual forces.

Sol.5 The rope will move towards side A as more force is applied by side A.

Sol.6 The speed of a body can be increased or decreased by applying force.

Sol.7 Yes, we can change the direction of the moving object by applying a force.

Sol.8 Yes, it is possible when a body is moving on a circular path.

Sol.9 Pressure a rubber ball with the hand.

Sol.10 A force which is applied only when it is in contact with an object is called a contact force.

Short Answer Type Question

Sol.11 Push – moving a loaded cart, batsman hitting a ball.

Pull – opening a drawer, drawing a bucket of water from a well.

Sol.12 (a) Pressing a lump of dough with hand.

(b) Pressing an inflated balloon.

Sol.13 When the force is applied opposite to the motion of the object, then either the speed decreases or the direction changes.

Sol.14 The state of motion is described by its speed and direction of motion.

Sol.15 The direction of the mud particles change at every point as the wheel of the vehicle moves.

Sol.16 The forces acting on the bucket is its own weight acting downwards and the muscular force of the hand acting upwards. Since both the forces are equal and acting in opposite directions, they balance each other. So, they donot bring any change in the state of motion of bucket. The hand feels tired due to the weight of bucket.

Sol.17 (a) Weight of an object is the force of gravity acting on the object.

(b) Unit of weight is newton or kilogram weight.

(c) Spring balance is used for measuring the weight of an object.

(d) Yes, the weight can be taken as a measure of force.

Sol.18 (a) Force of gravity.

(b) Force of gravitation (weight)

(c) Electrostatic force.

(d) Magnetic force.

(e) Muscular force.