CHAPTER - 8

FORCE & LAWS OF MOTION

Force

A force is an influence which tends to set a stationary body in motion or stop a moving body; or which tends to change the speed and direction of a moving body; or which tends to change the shape (and size) of a body.

Effects of Force

A force cannot be seen. A force can be judged only by the effects which it can produce in various bodies (or objects) around us. A force can produce the following effects:

1. A force can move a stationary body.

2. A force can stop a moving body.

3. A force can change the speed of a moving body.

4. A force can change the direction of a moving body.

5. A force can change the shape (and size) of a body.

Balanced and Unbalanced Forces

Balanced Forces

Balanced Forces

If the resultant of all the forces acting on a body is zero forces are called balanced forces. A body under the action of balanced forces does not change its position of rest (or of uniform motion) and it appears as if no force is acting on it.

Suppose a heavy box is lying on the ground . Let us push this box with our hands. We find that the box does not move (and remains in its state of rest) though as many as four forces are acting on it.

The four forces acting on the box are

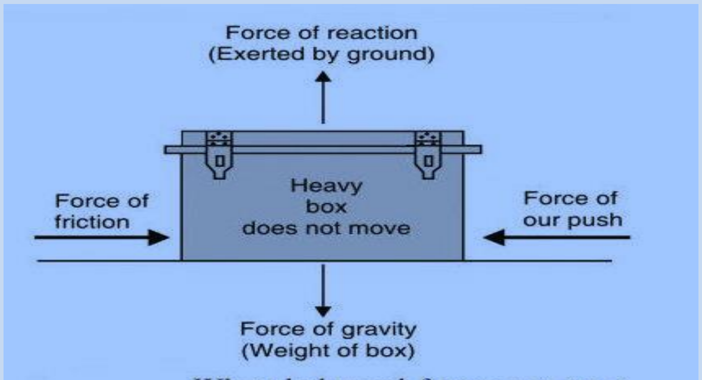
(i) Force of our push

(ii) Force of friction (which opposes the push and does not allow the box to move) .

(iii) Force of gravity (which pulls the box downwards)

(iv) Force of reaction (exerted by the ground on the box upwards which

balance force of gravity



When balanced forces act on a body (here a heavy box), they do not produce any motion in it.

Unbalanced Forces

Unbalanced Forces

If the resultant of all the forces acting on a body is not zero, the forces are called unbalanced forces. When unbalanced forces act on a body, they produce a change in its state of rest or of uniform motion. That is, unbalanced forces can move a stationary body or they can stop a moving body.

In other words, unbalanced forces acting on a body can change its speed or direction of motion.

Suppose a toy car is lying on the ground . Let us push this car with our hand. We find that the toy car starts moving. Now, in this case also four forces are acting on the toy car. These are:

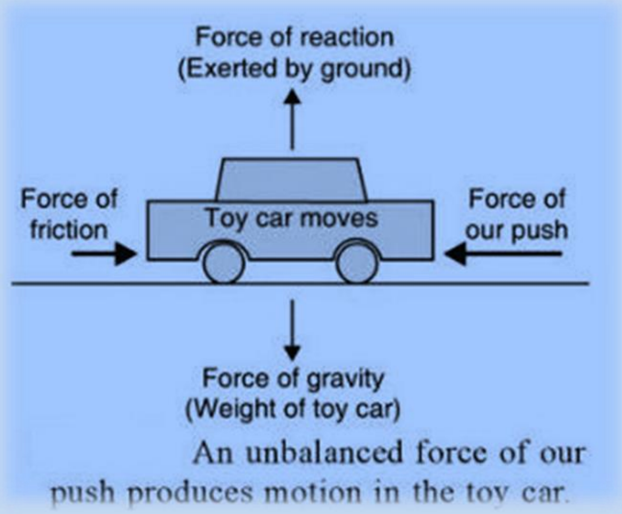
(i) Force of our push

(ii) Force of friction

(iii) Force of gravity

(iv) Force of reaction of ground

In this case also, the force of gravity on the car acting downwards and the force of reaction of ground acting upwards are equal and opposite, so they balance each other. Now, due to the wheels of the toy car, the opposing 'force of friction' is much less here. The force of our push is, therefore, greater than the force of friction in this case, so they cannot balance each other.



NEWTON'S LAWS OF MOTION

NEWTON'S FIRST LAW OF MOTION

The first law of motion is stated as: An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state by an applied force. In other words, all objects resist a change in their state of motion.

Let us take some examples to make the first law of motion more clear. Suppose a book is lying on the table. It is at rest. The book will not move by itself, that is, it cannot change its position of rest by itself. It can change its state of rest only when compelled by the force of our hands, that is, when we lift the book from the table. Thus, the position of rest of the book has been changed by the external force of our hands.

And this observation supports the first part of the first law of motion.

Inertia

The tendency of a body to remain at rest (stationary) or, if moving, to continue moving in a straight line, is called inertia.

Newton's first law recognizes that every body has some inertia.

Inertia is that property of a body due to which it resists a change in its state of rest or of uniform motion. Greater the inertia of a body, greater will be the force required to bring a change in its state of rest or of uniform motion. In fact, mass is a measure of the inertia of a body. If a body has more mass, it has more inertia. That is, heavier objects have more inertia than lighter objects. For example, a stone has greater inertia than a football. If we kick a stone, it will not move because of its high inertia but if we kick a football, it will move a long.

Second Law of Motion

The second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.

Newton's Second Law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of the force. Where

F is the force applied, m is the mass of the body, and a, the acceleration produced.

Suppose an object of mass, m is moving along a straight line with an initial velocity, u. It is uniformly accelerated to velocity, v in time, t by the application of a constant force, F throughout the time, t.

The initial and final momentum of the object will be, p_1 = mu and p_2 = mv respectively.

The change in momentum ∝ p2 – p1

∝ mv – mu

∝ m × (v – u)

The rate of change of momentum $\propto \frac{m \text{ x}(\text{v}-\text{u})}{\text{t}}$

Or, the applied force $F = \frac{\text{km x }(\text{v}-\text{u})}{\text{t}}$

= kma

Here a [= (v – u)/t] is the acceleration, which is the rate of change of velocity.

The quantity, k is a constant of proportionality. The SI units of mass and acceleration are kg and ms^{-2}respectively.

one unit of force is defined as the amount that produces an acceleration of 1 ms^{-2} in an object of 1 kg mass. That is,

1 unit of force = k × (1 kg) × (1 ms^{-2}).

Thus, the value of k becomes 1.

F = ma

Third Law of Motion

The third law of motion states that if a body exerts a force on a second body, the second body exerts a force that is equal in magnitude and opposite in direction to the first force. So for every action force there is always a reaction force.

Any of these two forces can be called as action and the other as reaction. This gives us an alternative statement of the third law of motion i.e., to every action there is an equal and opposite reaction. However, it must be remembered that the action and reaction always act on two different objects, simultaneously.

Conservation of Momentum

Suppose two objects (two balls A and B, say) of masses m_A and m_B are travelling in the same direction along a straight line at different velocities u_A and u_B , respectively. And there are no other external unbalanced forces acting on them. Let $u_A > u_B$ and the two balls collide with each other .

During collision which lasts for a time t, the ball A exerts a force FAB on ball B and the ball B exerts a force FBA on ball A.

Suppose v_A **and** v_B **are the velocities of the two balls A and B after the collision, respectively.**

momentum) of ball A before and after the collision are $m_A u_A$ **and** $m_A v_A$ **, respectively. The rate of change of its momentum during the collision will be** $m_A \frac{\boldsymbol{u_{A-\mathbf{v}_\mathbf{A}}}}{t}$

Similarly, the rate of change of momentum of ball B (= F_{BA}**) during the collision will b**

$$m_B \frac{v_{B-}U_B}{t}$$

According to the third law of motion, the force FAB exerted by ball A on ball B

and the force FBA exerted by the ball B on ball A must be equal and opposite to each other.

Therefore,

FAB = – FBA

Or $m_A \frac{v_A - u_A}{t}$ **= -** $m_B \frac{v_B - u_B}{t}$

Since (mA uA + mB uB) is the total momentum of the two balls A and B before the collision and (mA vA + mB vB) is their total momentum after the collision.

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