FORCE AND LAWS OF MOTION

Q.1: *Define 'Balanced' and 'Unbalanced' forces. Illustrate with examples.*

Ans:

Balanced Force –

If the resultant of several forces acting on a body is zero, the forces are said to be 'Balance Forces'. Balanced forces do not change the speed. They usually change the shape of an object e.g. in a tug-of-war the rope does not move in either direction if the two teams pull the rope with equal efforts. Here the forces exerted by the two teams are equal and opposite and so, get balanced.

Unbalanced Force –

If the resultant of several forces acting on a body is not zero, the forces are said to be 'Unbalance Forces'. Unbalance Forces produce a change in the state of rest or uniform motion of a body. In other words objects continue to move, with the same velocity unless acted upon by an unbalanced force.

For example, a force larger than the force of gravity has to be applied on an object in order to raise it to a certain height from the ground. Here the two forces are unbalanced and result in the upward motion of the object.

Q.2: *What is inertia? How many types of inertia are there?*

Ans:

Inertia –

It is the inability of a body to change by itself its state of rest or uniform motion in a straight line. Generally there are three types of inertia:

Inertia of Rest - This can be defined as the tendency of a body to remain in its state of rest.

Inertia of Motion - It is the tendency of a body to remain in its state of uniform motion along a straight line.

Inertia of Direction - It is the inability of a body to change by itself its direction of motion.

Q.3: *Define: (a) Momentum, (b) Newton*

Ans:

Momentum – It is the quantity of motion possessed by a body and is equal to the product of the mass and velocity of the body. Momentum is a vector quantity and is expressed by the symbol *p.*

Momentum = Mass x Velocity

or, $p = mv$

The SI unit of momentum is $kg.m.s^{-1}$

Newton - Newton is the SI unit of force and is expressed by the symbol *N*. One Newton is that quantity of force which can produce an acceleration of $1\ ms^{-2}$ in a body of mass 1 kg.

$$1\ N = 1\ kg.m.s^{-2}$$

Q.4: State the various effects of force.

Ans: The various effects produced by a force are as follows:

1. It can change the speed of an object making it move faster or slower.
2. It can change the direction of motion of an object.
3. It can change the shape of an object.

Q.5: State Newton's first law of motion. Why the Newton's first law of motion is also called 'Law of Inertia'?

Ans: Newton's First Law of Motion –

According to this law a body at rest or in uniform motion will remain at rest or in uniform motion along a straight line unless an unbalanced force acts upon it.

According to Newton's first law of motion, a body by itself is not able to change its state of rest or of uniform motion along the same direction. This property of the body is called 'inertia' which in other words, can be defined as the tendency of undisturbed objects to stay at rest or keep moving with the same velocity. That is why the Newton's first law of motion is called 'law of inertia'.

Q.6: What is the relation between mass and inertia?

Ans: The mass of a body is measure of its inertia. The larger the mass of a body, larger is the inertia or opposition offered by a body to change its state of motion. For example if we kick a football, it flies a long way.

If we kick a stone of the same size it hardly moves. Rather we may get injured in our leg while hitting the stone. The reason is that the stone resists a change in its motion better than the football because of its greater mass. Thus the stone has more inertia than the football.

Q.7: State and explain Newton's second law of motion.

Ans: Newton's Second Law of Motion –

This law states that the rate of change of momentum of a body is directly proportional to the applied unbalanced force and the change takes place in the direction of the force. This law can be divided into two parts:

(i) *The rate of change of momentum of a body is directly proportional to the applied force.* The larger the force acting on a body, the greater is the change in its momentum. Since the change in momentum is equal to the product of mass and the change in velocity, and the mass remaining constant, the rate of change of momentum is directly proportional to the rate of change in velocity i.e. acceleration. Hence, force (F) is directly proportional to the mass (m) and acceleration (a).

$$F \alpha ma.$$

(ii) *The change of momentum occurs in the direction of the force.* If a body is at rest, a force can set it in motion. If a body is moving with a certain velocity, a force will increase or decrease this velocity accordingly as the force acts in the same or opposite direction.

Q.8: Give two examples to illustrate Newton's second law of motion.

Ans:

Examples to illustrate Newton's second law of motion -

(i) *A cricket player lowers his hands while catching a ball.* The reason is that by lowering his hands, he increases the tome of catching the ball.

As a result, the rate of change of momentum decreases and by Newton's second law, the force exerted on his hands is less. So he is less likely to get hurt.

(ii) *We are hurt less when we jump on a muddy floor than on a hard floor.* When we jump on a muddy floor, the floor is carried in the direction of the jump and the time interval for which force acts is increased. This decreases the rate of change of momentum and hence the force of reaction. Thus we get less hurt.

Q.9: Explain how Newton's second law of motion can be used to derive a quantitative definition of Force.

Ans:

Measurement of force from Newton's second law of motion –

Suppose a force *F*, acts on a body of mass *m*, and change its velocity from *u* to *v* in *t* seconds. Then,

Initial momentum of the body, $p1 = mu$

Final momentum of the body, $p2 = mv$

Change in momentum $= p2 - p1 = m(v - u)$

Time taken = t

Rate of change in momentum $= m(v - u) \div t$

Rate of change in momentum = ma,

where, *a* is the acceleration of the body. $[a = (v - u) \div t]$

According to Newton's second law of motion, the rate of change of momentum of a body is directly proportional to the applied force, so

$$F \propto ma.$$

or, $F = kma$ [k = constant]

The unit of force is so chosen that *k* is equal to one

i.e. if m = 1, a = 1 and F = 1, then k = 1

Therefore, F = ma.

So a unit of force is that force which produces unit acceleration in a body of unit mass.

The SI unit of force is Newton. From the above formula we can say that one Newton is that force which produces an acceleration of 1 m/s^2 in a body of mass 1 kg.

Thus, the Newton's second law of motion gives us a method to measure force.

Q.10:

State Law of Conservation of Momentum. Deduce this from Newton's second law of motion.

Ans: Law of conservation of momentum –

This law states that if a number of bodies are interacting with each other, their total momentum remains conserved before and after the interaction, provided there is no external force acting on them.

Derivation of Law of Conservation of Momentum from Newton's Second Law –

Suppose p_1 and p_2 represent the sum of momentum of a group of objects before and after the collision respectively. Let t is time elapsed during collision. Then according to Newton's Second Law,

External force = Rate of change of momentum
or, $F = (p_2 - p_1) \div t$
If there is no external force, F = 0 and
$(p_2 - p_1) \div t = 0$
or, $p_1 = p_2$

Therefore in the absence of an external force, the total momentum of a group of objects remains unchanged or conserved during collision. This is the law of conservation of momentum.