Long Answer Type Questions

[5 marks]

Q. 1. Describe Newton's first law of motion in detail, giving examples.

Ans. According to Newton's first law of motion, a body at rest or in uniform motion will remain at rest or in uniform motion unless an unbalanced force acts upon it. This law consists of three parts:

(i) The first part says that a body at rest continues in its state of rest. For instance, a boy standing in a train falls backward when the train suddenly starts moving forward. This is because when the bus moves, the lower part of his body begins to move along with the train while the upper part of his body continues to remain at rest due to inertia.

(ii) The second part says that a body in uniform motion continues to move in straight line path with a uniform speed, *e.g*., when a moving train stops suddenly a person sitting in it falls forward. This is because as the train stops, the lower part of the person's body comes to rest along with the bus while upper part of his body continues to remain in motion due to inertia of motion and thus he falls forward.

(iii) Third part says that a body moving with a uniform speed in a straight line cannot change its direction of motion by itself. For example, when a bus takes a sharp turn, a person sitting in the bus gets force acting away from the centre of the curved path due to his tendency to move in the original direction.

Q. 2. Derive the mathematical relation of Newton's second law of motion.

Ans. Consider an object of mass m moving along a straight line with an initial velocity *u* (say). It is uniformly accelerated to velocity *u* in time *t* by the application of a constant force *F* in time *t*.

Then, initial momentum of the object = *mu*

$$P_1 = mu$$

Final momentum of the object = *mv*

$$P_2 = mv$$

∴ Change in momentum = $mv - mu = m(v - u)$

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

According to Newton's second law of motion, we have

$$F \propto \frac{m(v-u)}{t}$$

$$F = km\frac{(v-u)}{t}$$

$$F = k\,m\,a \qquad \ldots (1)$$

Here, a = $\frac{v-u}{t}$ = the rate of change of velocity.
= acceleration
k = a constant of proportionality

Putting m = 1 kg, a = 1 ms^{-2}
F becomes 1 N.
So, 1 N = *k* x 1 kg x 1 ms^{-2}

∴ *k* = 1

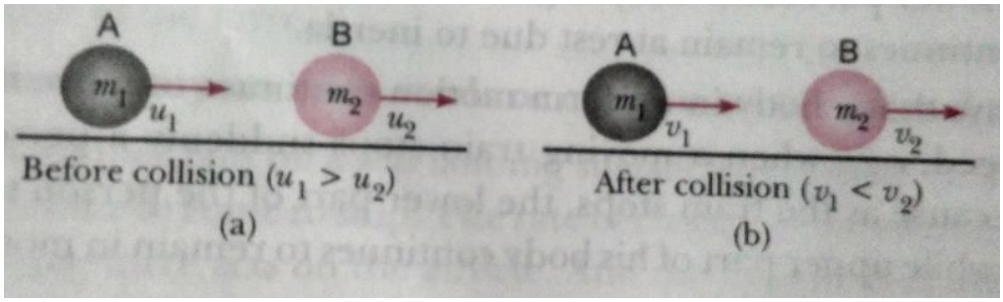
From equation (1), we have
F = *ma*

This represents the second law of motion.

Thus, the second law of motion gives a method to measure the force acting on an object as a product of its mass and acceleration.

Q. 3. Derive the mathematical formula of conservation of momentum.

Ans. To explain conservation of momentum, let us take the following example. Consider two balls A and B having masses m_1 and m_2, respectively. Let the initial velocity of ball A be u_1, and that of ball B be u_2 ($u_1 > u_2$). Their collision takes place for a very short interval of time *t* and after that A and B start moving with velocities v_1 and v_2 (now $v_1 < v_2$) respectively as shown in Figure.



The momentum of ball A before and after the collision is m_1u_1 and m_1v_1 respectively. If there are no external forces acting on the body, then the rate of change of momentum of ball A, during the collision will be
= $\frac{m_1(v_1-u_1)}{t}$

and, similarly the rate of change in momentum of ball B
= $\frac{m_2(v_2-u_2)}{t}$

Let F_{12} be the force exerted by ball A on B and F_{21} be the force exerted by ball B on A. Then,

according to Newton's second law of motion

$F_{12} = \frac{m_1(v_1 - u_1)}{t}$ and $F_{21} = \frac{m_2(v_2 - u_2)}{t}$

According to Newton's third law of motion, we have

$F_{12} = -F_{21}$

Or, $\frac{m_1(v_1 - u_1)}{t} = -\frac{m_2(v_2 - u_2)}{t}$

Or, $m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$ or $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

i.e., Total momentum before collision = Total momentum after collision
Thus, we find that in a collision between the two balls the total momentum before and after the collision remains unchanged or conserved provided no net force acts on the system. This result is law of conservation of momentum.

Q. 4. What is the relationship between mass and inertia? Explain with the help of examples.

Ans. The mass of a body is a measure of its inertia. It means larger the mass of a body, larger will be the inertia offered by the body to change its state of motion. The following examples will clarify the concept:

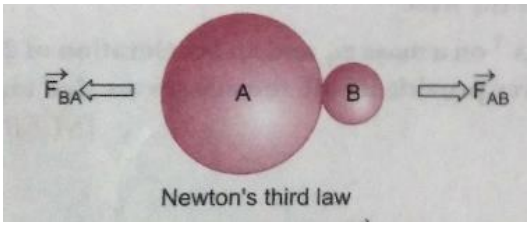
(i) When we kick a football, it flies a long way but at the same time if we kick a stone of the same size, it hardly moves, as the stone resists a change in its motion better than the football because of its more mass.

(ii) We can increase the velocity of our bicycle by pedaling harder, *i.e*., on applying more force.

But the same force will produce a negligible change in the motion of a bus, because in comparison to the bicycle, a bus has more tendency to oppose any change in its state of motion because of its larger mass i.e., the bus has more inertia than the bicycle.
The SI unit of mass and inertia is kilogram (kg).

Q. 5. Describe Newton's third law of motion.

Ans. According to this law, to every action, there is an equal and opposite reaction. When an object, say A, exert a force (action) on another object, say B, then B also exerts a force (reaction) on the A. These two forces are always equal in magnitude but opposite in direction.



Newton's third law

As shown in the above figure, if $\vec{F}_{AB}$ be the force exerted by body A on B and $\vec{F}_{BA}$ is the force exerted by B on A, then according to Newton's third law,

$\vec{F}_{BA} = -\vec{F}_{AB}$

or Force on A by B = - Force on B by A

or Reaction = - Action

This law clarifies that a single force can never exist and that the forces always exist in pairs. The two opposing forces are known as action and reaction. The forces of action and reaction always act on two different bodies.