Force and Laws of Motion

(Part II)

Applications of Newton's Third Law of Motion:

- Recoil of gun: When bullet is fired from a gun, it moves ahead. By the Newton's 3rd law of motion, the bullet apply same force on gun in backward direction. Due to this force, gun moves back giving a jerk to the shoulder of the gunman. This is called recoil of gun. Here, gun moves back only by small amount due to its heavy mass.
- Walking of a person: A person is able to walk due to the Newton's Third Law of Motion. During walking, a person pushes the ground in backward direction and in the reaction the ground also pushes the person with equal magnitude of force but in opposite direction. This enables him to move in forward direction against the push.
- Swimming in water: Man pushes water back by applying force. By Newton's 3 Law, water applies equal and opposite force on swimmer. Due to this force man moves ahead.
- Propulsion of a boat in forward direction – Sailor pushes water with oar in backward direction; resulting water pushing the oar in forward direction. Consequently, the boat is pushed in forward direction.

Impulse:

Impulse is a force applied to an object for a certain short interval of time which will cause the objects momentum to change.

$$\text{Impulse} = F \cdot t$$

Impulse = Change in momentum

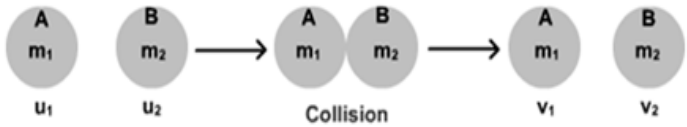
Conservation of Momentum:

When no external force is applied on a body, then momentum remains constant. This is known as conservation of Momentum.

If two or more objects apply force on each other with no extemnal force, their final momentum remains same as initial momentum.
Total momentum before collision = Total momentum after collision

Mathematical Formulation of Conservation of Momentum:

Suppose, two objects A and B each of mass m_1 and mass m_2 are moving initially with velocities u_1 and u_2, strike each other after time t and start moving with velocities v_1 and v_2 respectively.



We know that, Momentum = Mass x Velocity

Therefore,

Initial momentum of object A = m_1u_1
Initial momentum of object B = m_2u_2
Final momentum of object A = m_1v_1
Final momentum of object B = m_2v_2
Now, Rate of change of momentum = Change in momentum/ time taken

Therefore,

$$F_{AB} = \frac{(m_1v_1 - m_1u_1)}{t} = \frac{m_1(v_1 - u_1)}{t} \quad ....(i)$$

Also,Rate of change of momentum in B during collision,

$$F_{BA} = \frac{(m_2v_2 - m_2u_2)}{t} = \frac{m_2(v_2 - u_2)}{t} \quad ....(ii)$$

But from Newton's third law of motion, we have:

$$F_{AB} = -F_{BA}$$

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

$$\Rightarrow \quad m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$$

$$\Rightarrow \quad m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$$

Thus, Total initial momentum = Total final momentum

Try the following questions:

Q1. If action is always equal to the reaction, then how a horse is able to pull a cart.

Q2. Explain, why is it difficult for a fireman to hold a hose, which ejects large amounts of water at a high velocity.

Q3. If the mass of a moving object is 50 kg, what force will be required to speed up the object at a rate of $2ms^{-2}$?

Q4. An object of 50 kg gets the speed of 10m/s in 5 second from zero velocity. Calculate the required force applied by engine of the car.

Q5. A bullet of 5 gm is fired from a pistol of 1.5 kg. If the recoil velocity of pistol is 1.5 m/s, find the velocity of bullet.