Revision Notes

Class – 9 Science

Chapter 9 - Force and Laws of Motion

- The motion of objects is based on their displacement, velocity, and acceleration. Have you wondered why certain natural phenomena occur and why they continue to occur in the same way? For example- why do the planets move around the Sun and why does a ball thrown up come back falling down? The answer to this question is force.

- Force and Motion

  A force is applied to push the cart, a driver applies force either to stop the car or bus or in order to change the speed or direction of motion, and a football player kicks the ball in order to set it in motion.

  In all the examples given above, the force is applied on a body that brings about the following changes:

  • Change in the state of rest of a body or change in its position.

  • To changes the speed of the body.

  • To change the direction of motion of a body.

- Force is defined as any external agent that changes the state of rest or uniform motion of a body along a straight line.

- Resultant Force:

  Any object can be moved by the application of force. Several forces can act simultaneously on a single body. For instance, several people trying to move a boulder whereas a strong person can move the same boulder all by himself. In this case, the force applied by the strong man has the equal effect as that produced by the net force applied by all persons. Therefore, the force applied by the strong man is said to be the resultant force. The resultant force is “when a force acting on a body produces the same effect as that produced by a number of forces.”

Four people people can jointly move a boulder

F=F1 +F2 +F3 +F4

- Balanced and Unbalanced Forces

The above depicts a block of wood kept on the table. This block is pulled from point A, it starts to move towards the left. When a block is pulled at the point B it moves towards the right.

1. Example of Unbalanced Forces

   If the block is pulled from both sides with the same force then the block remains stationary (i.e at its position). The forces applied are unequal and opposite to each other. The resultant of the forces acting on this block is now not zero as block will shift.

2. Example of Balanced Forces

   In tug of war games when both the teams start pulling the rope with equal and opposite forces, then the rope remains in place as the forces acting on it are equal and opposite and their resultant becomes zero.

3. Example of Balanced Forces

   What do you observe when you squeeze a rubber ball between the palms of your hands. The shape of the rubber ball changes due to the forces applied on the ball are equal and opposite and the resultant of these forces does not lead to its motion instead the object gets deformed and continues to be as long as the force is applied. However, this is temporary deformation.

- Galileo's Observation and Origin of Newton Mechanics

Aristotle believed that the natural state of bodies is a state of rest. Galileo opposed this belief. Galileo observed when a ball rolls down on an inclined plane, its speed is increased. In the same way, when rolled up the inclined plane, its speed decreased. He then rolled the ball on a horizontal plane. Galileo repeated this experiment on a smooth surface. He noticed that the ball continued to move. Galileo suggested that the speed of the ball moving on a horizontal plane remains constant when no external force or force of friction

acts on it. Galileo noticed that it is the natural tendency of all bodies to oppose any change in their state of rest or motion.

Force and Laws of Motion

- Inertia

Galileo's experiments showed that all objects have a tendency to continue in their state of rest or of uniform motion unless an external force is applied to it. The examples given below will help you understand the observations of Galileo's experiment:

- Place a cardboard on an empty tumbler and keep a coin on the cardboard as given in the figure.

Cardboard and a Coin placed on Tumblr

- Now, Flick the cardboard with your finger. What do you see? The coin kept on the cardboard drops into the tumbler. On flicking the cardboard moves fast whereas the coin continues in its state of rest and hence drops into the tumbler.

- A passenger standing in a moving bus leans forward when brakes are applied suddenly. This is because the body of the person is in motion along with the bus. When the bus stops all of a sudden, the lower part of the body comes to rest with the bus but the upper part of the body remains in motion.

- From the above examples, we see that the objects continue to remain in their state of rest or of uniform motion until an external force is applied. The tendency of an object to resist any change in its state of rest or of uniform motion is known as inertia.

- Inertia is the property of the body by virtue of which it opposes any sort of change in its state of rest or uniform motion along a straight line.

  Inertia is classified into:

  1. Inertia of rest- Some examples to it: A passenger standing in a bus leans backwards when brakes are applied suddenly, fruits falling down from the tree when it is shaken, dust particles on a carpet when it is beaten with a stick.

  2. Inertia of motion- Example to this is man alighting from a moving train leans forward.

  3. Inertia of direction- For example, water particles stuck to the cycle tyre and fly off tangentially, when a drive takes a turn, the passenger feels the force away from the centre of the curve.

  The inertia of a body depends on the mass of the body. Heavy objects possess more inertia than lighter ones.

- Newton gave the three basic laws of motion

1. First law of motion: The first law of motion states that "A body continues to be either in a state of rest or of uniform motion along a straight line unless an external force is applied on it." This tells that every object has a tendency(inertia) to resist any change in its state of rest or motion This law is therefore known as law of inertia. This law explained the qualitative definition of force.

- Momentum: A cricket ball moving with a constant velocity v so is tennis ball. We apply more force in order to stop the cricket ball than to stop the tennis ball since the mass of the cricket ball is more than the tennis ball. The force required in order to stop a moving object depends on the mass of the object. The force required to stop a moving body is directly proportional to its velocity.

Momentum: It is defined as the product of the mass and velocity of the object or body. It is a vector quantity and direction of momentum will be the same as that of velocity. It is represented by p.

p = mv here, m= mass of the object, v is velocity. SI unit=kg m/s.

2. Newton's Second Law of Motion

Newton's second law of motion tells that the rate of change of momentum is directly proportional to the applied force and takes place in the same direction as the applied force.

Explanation:

Consider a body of mass m, with initial velocity u. The body is applied by force F for time t, and its final velocity is v.

Hence, Initial momentum $= mu$

and, Final momentum = mV

Therefore, Change in momentum in time $t = m(v - u)$

Change in momentum in unit time $= m(v - u)$

But since we know $v - u = a$ (acceleration) t

Now, Change in momentum in unit time $= ma$ Or

According to Newton's second law,

Rate of change of momentum F

$F = K\ ma$ (Here, $K =$ constant of proportionality)

If a body has unit mass and unit acceleration, then the force possessed by it is also one unit.

F=ma

Force =- mass × acceleration [The negative sign is an indication of the gun recoiling]

- One Newton force is equal to a force that produces an acceleration of 1 m/s2 on an object of mass 1 kg. Force is also a vector quantity. Newton's second law of motion stated the quantitative definition of force.

- Impulse:

  The mathematical representation second law of motion is F = mv−mu/t,

  Ft = mv - mu

  When forces acting on a body for a short interval of time then it is defined as an impulse.

  SI unit of impulse = kg m/s.

  When a person kicks a football, the kick lasts only for seconds. This force is an example for impulsive force.

- Newton’s Third Law of Motion

  Action and reaction forces are equal but act simultaneously on different bodies. A rubber ball rebounds when back when it is thrown on a hard floor. This is due to the action and reaction forces that are acting simultaneously. The ball applies a force (action force) on the floor whereas the floor exerts an equal and opposite force (reaction force) on the ball. The rubber ball being light rebounds. Newton's third law of motion states that “To every action, there is an equal and opposite reaction".

- Some day to day examples of newton's third law of motion:

1. While walking on the ground, our foot pushes the ground backward (action force) whereas the ground in turn exerts a force on the foot (reaction force) causing the foot move forward.

2. When a person jumps from a diving board he pushes the diving board (action force) whereas the board, in turn, pushes the man forward in the opposite direction (reaction force).

3. The birds in sky push the air with their wings (action force) whereas the air, in turn, exerts a force on the bird in the upward direction (reaction force).

4. A swimmer pushes the water in the backward direction (action force) whereas the water exerts a force on the swimmer (reaction force) which pushes him forward.

   The action and reaction forces are equal and opposite but their resultant is not zero as the action and reaction forces are acts on two different bodies. Newton's third law holds when the interacting bodies are at rest or in motion. Newton's third law gives the relationship between interacting forces between the two objects but does not give the magnitude of force.

- Law of Conservation of Momentum

  According to Newton's third law of motion, action and reaction forces result in a change in velocities of both the bodies which change the momentum of these bodies as well.

- Applications of Law of Conservation of Momentum

1. The recoil of a Gun

   When a bullet is fired from a gun, the gases produced in the barrel exert a lot more of a force on the bullet (action force). As a result, the bullet moves forward with a high velocity known as the muzzle velocity. The bullet exerts an equal and opposite force on the gun(reaction force). The gun moves backward. This backward motion of the gun is, the recoil of the gun. The velocity with which the gun moves backward is the recoil velocity of the gun.

2. The motion of a rocket

   A rocket is a projectile that carries the rocket fuel and oxidizer, which supplies oxygen required for combustion. Liquid hydrogen is generally used in rocket fuels whereas hydrogen peroxide, liquid oxygen are used as oxidizers. The fuel-oxidizer combination in a rocket is known as the propellant.

   A rocket consists of a combustion chamber in which either a solid or liquid propellant is burnt. A nozzle is present at its tail through which the gaseous products produced during combustion escape out. The rocket forces a jet of hot gases downwards by the nozzle. This acts as action. The jet of gases exerts

a force on the rocket, pushing it (reaction). This force leads to forward acceleration.

3. Rocket Propulsion

Just before the launch, the momentum of the rocket is zero. When the rocket is fired, it forces a jet of hot gases with a very high velocity down the nozzle. The jet of gases has momentum downwards. Therefore, the rocket has a momentum of equal magnitude but in opposite direction. Therefore the rocket goes upwards. In multi-stages propulsion takes place in rockets when the fuel of the first stage gets used completely, the rocket casing gets detached and is dropped off and the second stage is ignited.