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FORCE AND LAWS OF MOTION

Force

- In science, a push or a pull on an object with mass that causes it to change velocity is called a force. Force has **magnitude** as well as **direction.**
- Force acting on an object may cause a change in its state of motion or a change in its shape.
- Forces applied on an object in the **same direction add to one another.**
- Forces act in the opposite directions on an object, the net force acting on it is the difference between the two forces.
- **Balanced and unbalanced forces**:
    - Balanced forces do not cause any change in motion whereas unbalanced forces does.
- Objects or things fall towards the earth because it pulls them. This force is called the force of gravity or just gravity.
- Force per unit area is called **pressure.**
- Body is said to be in equilibrium if sum of all the forces acts on the body is **zero**. In other words, if it is at rest or moving with uniform velocity.
- **Nuclear force** is the strongest force in the nature.

Inertia

The inherent property of a body to resist any change in its state of rest or the state of uniform motion, unless it is influenced upon by an external unbalanced force, is known as inertia.

Types of Inertia

Inertia of rest

- The resistance of a body to change its state of rest is called inertia of rest.
- **Example:** When you vigorously shake the branches of a tree, some of the leaves and fruits are detached and they fall down.

Inertia of direction

- The resistance of a body to change its direction of motion is called inertia of direction.
- **Example:** When you make a sharp turn while driving a car, you tend to lean sideways.

Inertia of motion

- The resistance of a body to change its state of motion is called inertia of motion.
- **Example:** An athlete runs some distance before jumping. Because, this will help him jump longer and higher.

Linear Momentum

- The product of mass and velocity of a moving body gives the magnitude of linear momentum. It acts in the direction of the velocity of the object.

  Linear Momentum = mass × velocity

  p = mv
- Linear momentum is a vector quantity.
- The linear momentum measures the impact of a force on a body.

Impulse

When a force F acts on a body for a period of time t, then the product of force and time is known as 'impulse'.

Impulse = F × t

Newton's Laws of Motion

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."
- All objects resist a change in their state of motion. In a qualitative way, the tendency of undisturbed objects to stay at rest or to keep moving with the same velocity is called inertia. This is why, the first law of motion is also known as the law of inertia.
- Inertia is the natural tendency of an object to resist a change in its state of motion or of rest. The mass of an object is a measure of its inertia. Its SI unit is kilogram.

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.
- The SI unit of force is kg m s^{-2}. This is also known as newton and represented by the symbol N. A force of one newton produces an acceleration of 1 m s^{-2} on an object of mass 1 kg.
- The second law of motion gives a method to measure the force acting on an object as a product of its mass and accelerations.

  F = ma
- The momentum, p of an object is defined as the product of its mass, m and velocity, v. That is p=mv
- Momentum has both direction and magnitude. Its direction is the same as that of velocity, v. The SI unit of momentum is kilogram-metre per second.
- Real time example is a fielder pulls his hand backward while catching a cricket ball coming with a great speed to reduce the momentum of the ball with a little delay. In doing so the fielder increases the time during which the high velocity of the moving ball decreases to zero. Thus, the acceleration of the ball is decreased and therefore the impact of catching the fast-moving ball is also reduced.
- In a high jump athletic event the athletes are made to fall either on a cushioned bed or on a

sand bed. This is to increase the time of the athlete's fall to stop after making the jump. This decreases the rate of change of momentum and hence the force. This prevents the athlete from getting hurt.

Third Law of Motion

- The third law of motion states: "To every action, there is an equal and opposite reaction and they act on two different bodies."
- If a body A applies a force F_A on a body B, then the body B reacts with force F_B on the body A, which is equal to FA in magnitude, but opposite in direction. $F_B = -F_{As}$

Examples

- Real time example is when a gun is fired it exerts a forward force on the bullet. The bullet exerts an equal and opposite force on the gun. This results in the recoil of the gun. Since the gun has a much greater mass than the bullet, the acceleration of the gun is much less than the acceleration of the bullet.
- Third law of motion is another example is when a sailor jumps out of a rowing boat. As the sailor jumps forward, the force on the boat moves it backwards.
- When birds fly, they push the air downwards with their wings (Action) and the air pushes the bird upwards (Reaction).
- Motion of rocket.

Conservation of Momentum

- Sum of momenta of the two objects before collision is equal to the sum of momenta after the collision provided there is no external unbalanced force acting on them. This is known as the law of conservation of momentum.
- In an isolated system (where there is no external force), the total momentum remains conserved.

Rocket Propulsion

- Propulsion of rockets is based on the law of conservation of linear momentum as well as Newton's third law of motion.
- Rockets are filled with a fuel (either liquid or solid) in the propellant tank. When the rocket is fired, this fuel is burnt and a hot gas is ejected with a high speed from the nozzle of the rocket, producing a huge momentum. To balance this momentum, an equal and opposite reaction force is produced in the combustion chamber, which makes the rocket project forward.

Pressure

- The effect of force can be measured using a physical quantity called pressure. It can be defined as the amount of force or thrust acting perpendicularly on a surface of area of one square meter of a body.

  Pressure = Thrust (or) Force/ Area

  The SI unit of pressure is pascal
- Pressure exerted by a force depends on the magnitude of the force and the area of contact.
- The effect of pressure can be increased by increasing the thrust or by decreasing the surface

area of the body.

Atmospheric Pressure

- The amount of force or weight of the atmospheric air that acts downward on unit surface area of the surface of the earth is known as atmospheric pressure.
- It can be measured using the device called barometer.
- The barometer was invented by Torricelli.
- Atmospheric pressure decreases with altitude from the surface of the Earth.

Friction

- Frictional force or friction arises when two or more bodies in contact move or tend to move, relative to each other. It acts always in the opposite direction of the moving body.
- This force is produced due to the geometrical dissimilarities of the surface of the bodies, which are in relative motion.
- Friction can be increased by increasing the area of the surfaces in contact.
- Friction can produce the following effects.
- Friction opposes motion.
- It causes wear and tear of the surfaces in contact.
- It produces heat.

Substances Reducing Friction

- The substances that reduce friction are known as **lubricants**. E.g. when oil, grease, or graphite is applied between the moving part of a machine, then it creates a thin layer; resultantly, moving surfaces do not directly rub against each other that ultimately reduces friction.
- When a body rolls over the surface of another body, the resistance to its motion is known as the **rolling friction**. The rolling reduces the force of friction.
- The frictional force exerted by fluids is known as **drag**.
- The frictional force, on an object in a fluid, is dependent on its speed with respect to the fluid.
- The frictional force depends on the shape of the respective object and also on the nature of the fluid.
- Fluid friction is minimized by giving suitable shapes to the bodies moving in fluids.

Advantages of Friction

- We can hold objects in our hand due to friction.
- We can walk on the road because of friction. The friction between footwear and the ground help us to walk without slipping.
- Writing on the paper with a pen is easy due to friction.
- Automobiles can move safely due to friction between the tyres and the road. Brakes can be applied due to frictional resistance on brake shoes.