Chapter 1.
Motion

Mr. N.D.Barne

Department of Physics

Hutatma Rajguru Mahavidyalaya

Content

- Introduction to motion,
- Types of motion, Displacement, Velocity, Acceleration, Inertia,
- Newton’s laws of motion with their explanations,
- Various types of forces in nature,
- Frames of reference (Inertial and Non inertial),
- Laws of motion and it’s real life applications,
- Problems

Introduction to motion

- The general study of the relationships between motion, forces, and energy is called mechanics.
- Motion is the action of changing location or position.
- The study of motion without regard to the forces or energies that may be involved is called kinematics. It is the simplest branch of mechanics. The branch of mechanics that deals with both motion and forces together is called dynamics and the study of forces in the absence of changes in motion or energy is called statics.

Introduction of motion

- We use the word ‘rest’ very often. For example, when someone is doing no work or lying on the bed, we often say that the person is resting. This means that the person is not moving.
- Scientifically as well, the word ‘rest’ has a similar meaning.
- Scientifically, we say an object is at rest when the position of the object does not change with time, with respect to its surroundings.
- Similarly, motion is defined as the change of position of an object with time, with respect to its surroundings.

Types of Motion

- Motion can be broadly classified into three main categories:
- Translator motion
- Rotational motion
- Periodic motion

Translational & Rotational motion

- Translational motion is the motion of a particle in a straight line. Translator motion E.g. A bus travelling on a straight road and an apple falling from a tree are examples of this kind of motion.
- Rotational motion refers to the motion of a body around a fixed axis. Rotational motion e.g. A spinning top, a bead moving on a circular track Earth's rotation are examples of this kind of motion.

Periodic & Linear Motion

- Periodic motion refers to the motion that is repeated in a regular interval of time.

Examples: Periodic motion, Oscillation of the simple pendulum , An oscillating spring and , the motion of a planet around the sun illustrate this type of motion.

- Linear Motion

The word ‘linear’ means ‘straight’ and the word ‘motion’ means ‘change in position with respect to a frame of reference’. So, a body moving in a straight line with respect to a frame of reference is said to be in linear motion. An example of this is the motion of an ant on a straight wire.

Linear Motion Points to remember regarding linear motion: *In linear motion, the object must move in a straight line. *The motion of the object along the straight line may not be uniform.

Uniform & Non-uniform Motion

- Uniform Motion:

If a body covers equal distances along a straight line in regular intervals of time, then the motion is said to be uniform.

Examples: A ball pushed in free space will continue to move uniformly, covering equal distances in equal intervals of time along a straight path. If an ant covers equal distances in equal intervals of time along a straight wire, its motion is uniform.

- Non-uniform motion

If a body covers unequal distances in regular intervals of time, then the motion is said to be non-uniform.

Examples:- The ball takes a curved path when thrown. Its direction of motion changes with time. Also, it covers unequal distances in regular intervals of time. So, its motion is non-uniform.

Displacement

- Displacement is a vector quantity.
- When an object moves in which the position of an object changes with time. Suppose at certain instant 't' the position of an object is x1 along the x axis and some other instant 'T' the position is x1 then the displacement Δx is defined as,

$$\Delta x = x2 - x$$

Distance and Displacement

- Distance-

  Distance is the length of the path or the path length travelled by a body while moving from an initial position to a final position.

- It is a scalar quantity. Its SI unit is metre (m). Therefore, only magnitude is important, not the direction of movement. (Implies that path length can never be negative)
- Displacement-

  Displacement is the shortest distance between the initial and final positions of the body. It is a vector quantity. Its SI unit is also meter (m).

- In displacement, the direction of motion is always directed from the initial position toward the final position.

Speed

- Speed is defined as the rate of distance covered by a body.
- speed is given as: It is a scalar quantity; that means no direction is required. (Implies that speed cannot be negative)

  Speed = Distance travelled / Time taken
- Average Speed

  A body travelling from one location to another might stop, slow down, speed up or move at a constant speed.

  The average speed of a body is defined as the total distance travelled divided by the total time taken. The average speed is given as:-

  Average Speed = Total Distance travelled / Time taken

Velocity

- The direction of motion with speed, we called velocity. Thus, velocity is speed with direction. Velocity is defined as the rate of change of displacement. It is a vector quantity.

  Velocity= Displacement / Time interval

- Average Velocity:

A body moving from one point to another may change its velocity a number of times, but it will have an average velocity of its journey. Average velocity of a body is defined as the net displacement divided by the total time of travel. It is a vector quantity. Its SI unit is m/s and it can be positive, negative or zero.

Average Velocity= Total displacement/ Time interval

Acceleration

- Acceleration is defined as the rate of change of velocity. It is a vector quantity and its direction is given by the direction of the force causing the acceleration. Mathematically, acceleration is given

Acceleration= Change in Velocity / Time interval

Inertia of a body

- When a body moves in uniform motion, then a body remains in motion and a body is at rest position, then it remain in rest unless it is acted by any unbalanced force. The tendency of a body to opposes the change of its state of rest or uniform motion is called as inertia.
- e.g. A coin is placed on small cardboard sheet, this cardboard sheet is put on the glass. Hence applying the force to cardboard gently, then the coin gets fall in the glass due to inertia.

Newton's First Law of Motion

- Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it.
- The first law is an experimental statement about the motions of bodies. When a body moves with constant velocity, there are either no forces present or there are forces acting in opposite directions that cancel out. If the body changes its velocity, then there must be an acceleration, and hence a total non-zero force must be present.
- The velocity can change in two ways. The first way is to change the magnitude of the velocity; the second way is to change its direction.

$$\sum F = 0$$

e.g. Mass is the measure of the inertia of the body so heavier objects have more inertia then lighter objects. For example a ball of 2Kg has more inertia then a football and it takes more effort to kick a 2Kg ball then it takes to kick a foot ball.

- 1. When a block placed on the stool, then the stool exerts the force on the block in upward direction and gravity exerts the force on the bloc in the downward direction. The both forces acting on the in upward and downward is balances. Therefore the net force acting on the bloc is zero. The stool exerts the force in upward direction on the bock..
- 2. When any unbalanced force acting on the block placed on the stool, then the stool exerts the force on the block in upward direction and gravity exerts the force on the bloc in the downward direction. The both forces acting on the in upward and downward is balances. Therefore the net force acting on the bloc is zero.
- exampleS of newton’S firSt law If a table cloth under a dish, is suddenly withdrawn, it does not disturb. It is because even if the table cloth is withdrawn , the dish tends to remain at rest to inertia. The weighing of an object.

Newton's Second Law of Motion

- The rate of change of momentum is directly proportional to the impressed force and takes place in the direction in which the force acts.

Force:- Force is defined as that physical quantity which changes or tends to change the state of rest or of uniform motion of a body in a straight line.

force = mass * acceleration

F = m a

Unit of force: - In S.I. system,

unit force = unit mass * unit acceleration

1 newton = 1 kg *1m/s2 Thus 1 newton force is that force which produces an acceleration of 1 m/s2 in a mass of 1 kg.

In C.G.S. system

1 dyne = 1 gram *1cm/s2

Thus 1 dyne force is that force which produces an acceleration of 1 cm/s2 in a mass of 1 gram.

The relation between newton and dyne is given by

1 newton = 10^5 dyne.

Force is a vector quantity;

Dimensions force are [M1 L1 T-2].

Newton's Third Law of Motion

- To every action there is always an equal and opposite reaction. Important points:- i) forces always exist in pair. A single isolated force can never exist. ii) Action and reaction do not act on the same body and hence they do not cancel each other.

Example: - 1) When a bullet is fired from the gun, a force (action) is exerted by the gun on the bullet and therefore the bullet is ejected with a high velocity. At the same time, the bullet also exerts an equal and opposite force (reaction) on the gun and therefore the gun is pushed in the opposite direction with a small velocity (called recoil velocity).

2) The reaction of a rocket is an application of the third law of motion. Various fuels are burned in the engine, producing hot gases. The hot gases push against the inside tube of the rocket and escape out the bottom of the tube. As the gases move downwards, the rocket moves in the opposite direction.

FUNDAMENTAL FORCES IN NATURE

- Following are the four fundamental forces in nature.

1) Gravitational force 2) Electromagnetic force 3) Strong nuclear force 4) Weak nuclear force.

- Gravitational force:

The force of attraction between any two bodies in the universe is called gravitational force. The force between any two particles is given by Newton's law of gravitation.

Newton's law of gravitation:- Every particle of matter attracts every other particle of matter with a force, which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

- 2) The Electromagnetic force
- This force include electric and magnetic forces. The electric force of interaction is between two charged bodies while magnetic force of interaction is between two magnets. Contact forces including the normal force, friction, viscous force, fluid resistance are all electromagnetic forces.
- This is because all atoms contain positive and negative charge so the atoms and molecules exerts electric forces on each other.
- Magnetic forces occur in interaction between magnets, but this force is of electromagnetic category because magnetic interactions result due to motion of electric charges.
- Properties of electromagnetic force :

  i) It may be attractive or repulsive

  ii)It is inversely proportional to the square of distance between two massive bodies

  iii) It is central force i. e. the electromagnetic force is directed along the line joining the centres of the two bodies.

  iv) It is long range force.

  v) It is about 1039 times stronger than the gravitational force

- The strong interaction

This interaction exists inside the nucleus so it is called nuclear force also. This interaction is responsible for holding the nucleus of an atom together. Hus is strong attractive force between proton-proton, proton-neutron, or neutron-neutron. This interaction is strong enough to counterbalance the electrostatic repulsion between the protons. This force is short range and exists over very short distance of the order of 10 - 1 ^5m.

- The weak interaction

This interaction plays no direct role in the behavior of ordinary matter. The weak interaction appears only in certain nuclear processes such as beta decay of nucleus. The weak nuclear force is much stronger the gravitational force.

- Inertial frame of reference: -

A frame of reference which is fixed or which is moving with a uniform velocity with respect to a fixed frame is called an inertial frame of reference. Newton's laws of motion are obeyed in an inertial frame of reference. Not only Newton's laws motion but also all the basic laws of physics are obeyed in this frame of reference.

- Non inertial frame of reference:-

i. A frame of reference which is moving with an acceleration relative to a fixed(inertial) frame is called a non-inertial frame of reference.

ii. Newton's laws of motion are not obeyed in a non-inertial frame of reference.

iii. In order to make Newton's laws applicable to the motion of an object in a non inertial frame, we have to assume the existence of a pseudo force.

- Pseudo force: -

It is a fictitious (imaginary) force because it cannot be produced by any of the known interactions like electrical, gravitational etc. This force can be experienced by a body in an accelerated motion. The pseudo force acts in a direction opposite to that of the acceleration of the non inertial frame.

Examples of Pseudo force

centrifugal force acting on a body in uniform circular motion. Passengers are seated in a moving car, when the speed of the is increased the passengers inside the car feel themselves to stuck to their back.. Also when breaks are suddenly applied the passengers are pushed forward. No such feeling is observed when the speed of car is constant. The force observed by the passengers during the acceleration and deceleration of car is called factious or pseudo force. The observer standing on the ground i. e. in inertial frame does not observe this force.

Applications of Newton's First Law:

- When peddling a bicycle, if stop peddling the bike continues going until friction or gravity slows it down.
- When pulling a band-aid off, it is better pull it fast, sin will at rest due to inertia and if the force pulls the band aid off.
- Objects that establish orbit around the earth lie satellite, continues on their trajectory due to inertia.
- Hockey puck on ice; eventually it will stop, because of friction on the ice. It will also stop if it hits something lie a players stick of a goal post.
- If kicked a ball in space it would be keep going forever, because here is no gravity, friction or air resistance going against it. It will only stop going in one direction if it hits something lie a meteorite of reaches the gravity field of another planet.

Applications Of Newton's Second Law:

- The second la states that acceleration is produced when an unbalanced force acts on object (mass) , then the object moves.
- If the same force to push a truck and a car, car will have more acceleration then truck (car has less mass)
- People constantly try to reduce the mass of an object to increase speed and acceleration.
- Small child cannot be able to throw a football the same distance as professional , because child would be unable to exert the same amount of force that the football player world.
- Newton's second law is used to designing the racer bikes or car to increase their speed by reducing mass.

- Applications of Newton's Third Law:
- Our hands feels he pain when we hit the table because table gives force as reaction to our hand.
- When you jump, your legs apply a force o ground, the ground applies equal to our hand.
- A car equipped with wheels that spin, as wheels spin they grip the road and push the road backward. The road also pushes the wheels forward causing it to move it motion.
- When fuel in air filled balloon burns, hot gases escape out from its tails with very high speed. The reaction of these gases on the balloon causes it to move upwards.

THANK YOU