SCIENCE & TECHNOLOGY (Class-09)

Chapter – Motion and Rest

In the physical world, one of the most common phenomena is motion. The branch of Physics, which deals with the behavior of moving objects, is known as mechanics.

Mechanics is further divided into two sections namely Kinematics and Dynamics.

Kinematics deals with the study of motion without taking into account the cause of motion.

Dynamics is concerned with the cause of motion, namely force.

☼ An object is said to be in motion if it changes its position with respect to its surroundings in a given time

An object is said to be at rest if it does not change its position with respect to its surroundings.

☼ We have observed that the position of stars and planets change while you remain stationary. In reality the earth is moving too. Thus, an object which appears to be at rest, may actually be in motion. Therefore, motion and rest are relative terms .

There are three types of motion:☼ Translatory motion ☼ Rotatory motion ☼ Vibratory motion

Translatory Motion : - In translatory motion the particle moves from one point in space to another. This motion may be along a straight line or along a curved path.

Rectilinear motion : Motion along a straight line is called rectilinear motion. Example: A car moving on a straight road

Curvilinear motion : Motion along a curved path is called curvilinear motion.

Example: A car negotiating a curve

Rotatory Motion : In rotatory motion, the particles of the body describe concentric circles about the axis of motion.

Vibratory Motion : In vibratory motion the particles move to and fro about a fixed point. Example Simple Pendulum

Distance : The distance covered by a moving object is the actual length of the path followed by the object. Distance is a scalar quantity. SI unit of distance is Metre .

Displacement is the shortest distance covered by a moving object from the point of reference (initial position of the body), in a specified direction.

Note: But the displacement when the bus moves from A ← B and then from B → A is zero. SI unit of displacement is metre. Displacement is a vector, i.e., the displacement is given by a number with proper units and direction.

☼ When a body covers equal distances in equal intervals of time then the body is said to describe *uniform motion*.

☼ When a body moves unequal distances in equal intervals of time or vice-versa, then the body is said to describe *non-uniform motion*.

☼ Speed can be defined as the distance covered by a moving object in unit time

Speed = distance / time = s/t where S is the distance covered and t is the time taken. SI unit of speed is m/s or m s^{-1}. Speed is a scalar quantity.

Uniform Speed : An object is said to be moving with uniform speed if it covers equal distances in equal intervals of time.

Non-uniform : An object is said to be moving with variable speed or non-uniform speed if it covers equal distances in unequal intervals of time or vice-versa.

Average speed : When we travel in a vehicle the speed of the vehicle changes from time to time depending upon the conditions existing on the road. In such a situation, the speed is calculated by taking the ratio of the total distance travelled by the vehicle to the total time taken for the journey. This is called the average speed.

Instantaneous speed : When we say that the car travels at an average speed of 60 km/h it does not mean that the car would be moving with the speed of 60 km/h throughout the journey. The actual speed of the car may be less than or greater than the average speed at a particular instant of time.

The speed of a moving body at any particular instant of time, is called instantaneous speed.

Velocity is defined as the distance travelled in a specified direction in unit time. The distance travelled in a specified direction is displacement.

Therefore, velocity can be defined as the rate of change of displacement .

Velocity is defined as the distance covered by a moving object in a particular direction in unit time or speed in a particular direction.

$$\text{Velocity} = \frac{\text{distance travelled in a specified direction}}{\text{time taken}}$$

$$v = \frac{S}{t}$$ [where 'S' is the distance covered and 't' is the time taken]

☼ SI unit of velocity is m/s (metre/second). [∵ SI unit of distance is metre and that of time is second] ☼ Velocity is a vector quantity.

Acceleration : When the train starts from rest its speed increases from zero and we say that the train is accelerating. After sometime the speed becomes uniform and we say that it is moving with uniform speed that means the train is not accelerating. But as the train is nearing Mysore it slows down, which means the train is accelerating in negative direction. Again the train stops accelerating when it comes to a halt at Mysore .

Acceleration is defined as the rate of change of velocity of a moving body with time

☼ Acceleration = Rate of change of velocity with time

$$= \frac{\text{change in velocity}}{\text{time}}$$

$$a = \frac{v - u}{t}$$

☼ The SI unit of velocity is m/s and time is s

$\therefore$ SI unit of acceleration is $\frac{m/s}{s} = m/s^2$

☼ Acceleration is a vector quantity

Positive Acceleration If the velocity of an object increases then the object is said to be moving with positive acceleration. Example: A ball rolling down on an inclined plane.

Negative Acceleration : If the velocity of an object decreases then the object is said to be moving with negative acceleration. Negative acceleration is also known as retardation or deceleration. Example: (1) A ball moving up an inclined plane. 2) A ball thrown vertically upwards is moving with a negative acceleration as the velocity decreases with time

Zero Acceleration : If the change in velocity is zero, i.e., either the object is at rest or moving with uniform velocity, then the object is said to have zero acceleration. Example: a parked car, a train moving with a constant speed of 90 km/hr

Uniform Acceleration : If the change in velocity in equal intervals of time is always the same, then the object is said to be moving with uniform acceleration. Example: a body falling from a height towards the surface of the earth.

Non-uniform or Variable Acceleration : If the change in velocity in equal intervals of time is not the same, then the object is said to be moving with variable acceleration.

Uniform velocity : A body is said to be moving with uniform velocity if it covers equal distances in equal intervals of time in a specified direction.

Variable velocity A body is said to be moving with variable velocity if it covers unequal distances in equal intervals of time and vice-versa in a specified direction or if it changes the direction of motion.

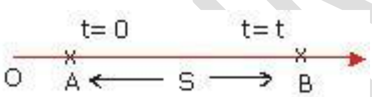
Circular motion : Motion along circular track is called circular motion .

An object moving along a circular track with uniform speed is an example for a non - uniform motion because the direction of motion of the object goes on changing at every instant of time. Example - A car negotiating a curve with uniform speed

A circle can be considered as a polygon with infinite sides and hence motion along a circular path is classified as non-uniform motion.

Derivation of the First Equation of Motion

Consider a particle moving along a straight line with uniform acceleration 'a'. At t = 0, let the particle be at A and u be its initial velocity and when t = t, v be its final velocity.



$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time}} = \frac{v-u}{t} \qquad a = \frac{v-u}{t}$$

$$v - u = at$$

$v = u + at$ I equation of motion

Second Equation of Motion

$$\text{Average velocity} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

$$\text{Average velocity} = \frac{S}{t} \quad .... (1)$$

$$\text{Average velocity can also be written as } \frac{u + v}{2}$$

From equations (1) and (2)

$$\frac{S}{t} = \frac{u + v}{2} \quad .... (3)$$

The first equation of motion is v = u + at. Substituting the value of v in equation (3), we get

$$\frac{S}{t} = \frac{u + u + at}{2} = \frac{(u + u + at)t}{2}$$

$$S = ut + \frac{1}{2}at^2 \qquad \textbf{II equation of motion.}$$

Third Equation of Motion

The first equation of motion is v = u + at. v - u = at ... (1)

$$\text{Average velocity} = \frac{S}{t} \quad ... (2) \quad \text{Average velocity} = \frac{u + v}{2} \quad .... (3)$$

From equation (2) and equation (3) we get,

$$\frac{u + v}{2} = \frac{S}{t} \quad .... (4)$$

Multiplying equation (1) and equation (4) we get,

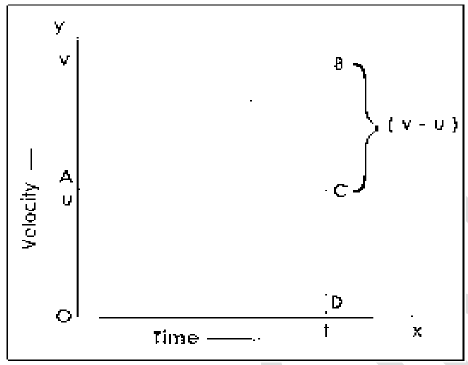
$$(v - u)(v + u) = at \times \frac{2S}{t}$$

(v - u) (v + u) = 2aS [We make use of the identity $a^2 - b^2 = (a + b)(a - b)$]

$v^2 - u^2 = 2aS$ III equation of motion

Derivations of Equations of Motion (Graphically)

First Equation of Motion



Consider an object moving with a uniform velocity u in a straight line. Let it be given a uniform acceleration a at time t = 0 when its initial velocity is u. As a result of the acceleration, its velocity increases to v (final velocity) in time t and S is the distance covered by the object in time t. The figure shows the velocity-time graph of the motion of the object.

Slope of the v - t graph gives the acceleration of the moving object.

Thus, acceleration = slope = AB

$$= \frac{BC}{AC} = \frac{v-u}{t-0}$$

$$a = \frac{v-u}{t}$$ v - u = at v = u + at I equation of motion

Second Equation of Motion

Let u be the initial velocity of an object and 'a' the acceleration produced in the body. The distance travelled S in time t is given by the area enclosed by the velocity-time graph for the time interval 0 to t.

Distance travelled S = area of the trapezium ABDO

= area of rectangle ACDO + area of ΔABC

$$= OD \times OA + \frac{1}{2} BC \times AC = t \times u + \frac{1}{2}(v-u) \times t = ut + \frac{1}{2}(v-u) \times t$$

$$= t \times u + \frac{1}{2}(v-u) \times t = ut + \frac{1}{2}(v-u) \times t$$

(v = u + at I eqn. of motion; v - u = at)

$$S = ut + \frac{1}{2} at \times t$$

$$S = ut + \frac{1}{2} at^2$$ **II equation of motion**

Third Equation of Motion

Let 'u' be the initial velocity of an object and a be the acceleration produced in the body. The distance travelled 'S' in time 't' is given by the area enclosed by the v - t graph.

S = area of the trapezium OABD.

$$= \frac{1}{2}(b_1 + b_2)h$$

$$= \frac{1}{2}(OA + BD)AC$$

$$= \frac{1}{2}(u + v)t \quad .... (1)$$

But we know that $a = \frac{v - u}{t}$ Or $t = \frac{v - u}{a}$

Substituting the value of t in equation (1) we get,

$$S = \frac{1}{2}\frac{(u+v)(v-u)}{a} = \frac{1}{2}\frac{(v+u)(v-u)}{a}$$

2aS = (v + u) (v - u)   (v + u)(v - u) = 2aS

[using the identity $a^2 - b^2 = (a+b)(a-b)$]

$v^2 - u^2 = 2aS$

III Equation of Motion