Motion

Introduction

There are many objects around us. Some are stationary like trees which are fixed at a place , house, a school, a factory all are stationary objects. On the other hand, a man, animals, birds, cars, buses, train, aero planes … etc do not remain stationary all time. They can move from one place to another. These are called moving objects and the movement of the body is called motion.

Scalar quantities:

A physical quantity described by its magnitude or size only. For example- Speed, time, distance, Area, Temperature etc.

Vector quantities:

A physical quantity has magnitude and direction both. For example- Weight, force, Displacement, Velocity etc.

Scalar quantities are written only by the sign of the quantity. Example: Distance (s)

Vector quantities are written by sign for the quantity with an arrow at the top for example: Velocity (v)

Distance

The distance travelled by a body is the actual length of the path covered by a moving body irrespective of the direction in which the body travels.
For example- if a man walks 4 km in east and 3km in north then actual length covered by the man is 4+ 3= 7 km. so the distance travelled by the man is 7 km.

Displacement

When the body moves from one position to another, the shortest distance b/w initial position and the final position of the body along with direction is called displacement.

Note:- distance is a scalar quantity having magnitude only but displacement is vector quantity having magnitude and direction both.

Example - In the same case the displacement is 5 km.

Note – the distance traveled by a moving body can't be zero but final displacement of the moving body can be zero.

Uniform motion:

A body has uniform motion if it travels equal distance in equal interval of time, no matter how small these time intervals may be.

And the distance time graph for uniform motion is a straight line.

Example:- if a car running at a constant speed of 10 m per second will cover equal distance of 10 m in every second. So its motion will be uniform.

Non- uniform motion

A body has non uniform motion if it travels unequal distances in equal interval of time.
For example- if we drop a ball from the roof of a tall building. We find that it covers unequal distances in equal interval of time.

Note: - the distance time graph for a body having non uniform motion is a curved line.

Speed

Speed of a body is the distance travelled by it per unit time.

$$\text{Speed} = \frac{\text{Distance traveled}}{\text{Time taken}}$$

$$S = \frac{D}{t}$$

Where S = speed, D = distance traveled, t = time taken
The SI unit of speed is m/s. it is a scalar quantity.

Average speed:

The average speed of a body is the total distance traveled divided by the total time.

Average speed = total distance traveled / total time taken

Uniform speed

A body has uniform speed if it travels equal distance in equal interval of time. No matter how small these time intervals may be.

Velocity

Velocity of a body is the distance traveled by it per unit time in a given direction.

$$\text{Velocity} = \frac{\text{Distance traveled by a given direction or displacement}}{\text{Time taken}}$$

$$v = \frac{s}{t}$$

Where v = velocity
S = distance traveled in a given direction
T= time taken (for displacement)

The SI unit of velocity is m/s. it is vector quantity

Note:- the direction of the velocity is the same as the direction of displacement of the body.

Uniform velocity

A body has a uniform velocity if it travels in a specific direction in a straight line and moves over equal distance in equal interval of time, no matter how small these time intervals may be

The velocity can be changed in two ways

1. **By changing the speed of the body**
2. **By keeping the speed constant but changing the direction.**

Acceleration

Acceleration of a body is defined as the rate of change of velocity.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken for change}}$$

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

Where a = acceleration, v = final velocity, u = initial velocity, t = time taken
SI unit of acceleration is m/sec^2. it is a vector quantity.

Note – when a body is moving with constant velocity then the acceleration is zero.

Uniform acceleration

If the velocity changes at uniform rate the acceleration will uniform.

Example: – the motion of freely falling body, the motion of bicycle going down the slop of the road and the motion of a ball rolling down an inclined plan.

Non-uniform acceleration

A body has non-uniform acceleration if its velocity increases by unequal amounts in equal interval of time.

Note- The velocity time graph for a body having non-uniform acceleration is a curved line .

Retardation

If the velocity of a body decreases the acceleration will be negative and called retardation.

Average velocity

The average velocity is given by arithmetic mean of initial velocity and final velocity.

Average velocity = (initial velocity + final velocity) / 2

$$= \frac{v + u}{2}$$

Equation of uniformly accelerated motion

There are three equation of motion of those bodies which travel with a uniform acceleration.

1. **First equation of motion:** Consider a body having initial velocity 'u'. suppose it is subjected to a uniform acceleration 'a' so that after time 't' its final velocity becomes 'v'.
   We know that

   Acceleration = change in velocity/ time = (final velocity – initial velocity)/ time taken

   $a = (v - u)/t$
   $at = v - u$
   $\mathbf{v = u + at}$

where v = final velocity
u = initial velocity
a = acceleration
t = time

2. **Second equation of motion:-** suppose a body has an initial velocity 'u' and uniform acceleration 'a' for time 't'. let the distance traveled by the body in this time be 's'. then

Average velocity = (initial velocity+ final velocity)/2

$$= \frac{v + u}{2}$$

We know that

Distance = speed x time

$$s = \{\frac{v + u}{2}\} \times t$$

$$s = \frac{\{u + u + at\}}{2} \times t$$

$$s = \frac{\{2u + at\}}{2} \times t$$

$$\mathbf{s = ut + \tfrac{1}{2} at^2}$$

Where s = distance traveled

u = initial velocity
v = final velocity
a = acceleration

Third equation motion

The third equation of motion can be obtain by elimination t b/w the first two equations of motion.

From the 2nd equation of motion we have

$$s = ut + \tfrac{1}{2} at^2 \text{ ----------(1)}$$

And the first equation of motion

$$v = u + at$$

This can be rearrange and written as

at = v - u

t= (v- u) /a

Putting this value of t in equation

$$s = \frac{u(v-u)}{a} + a\frac{(v-u)^2}{2a^2}$$

$$s = \frac{uv-u^2}{a} + \frac{v^2+u^2-2uv}{2a}$$

$$s = \frac{v^2-u^2}{2a}$$

$$v^2 = u^2 + 2as$$

where v = final velocity

u = initial velocity

a = acceleration

s = distance

Note:- we should remember that

1. if the body starts from the rest, its initial velocity, u = 0
2. if a body comes to rest (it stop) its final velocity, v = 0
3. if a body moves with uniform velocity its acceleration, a = 0

Uniform circular motion

When a body moves on a circular path this motion is called circular motion.

In other words

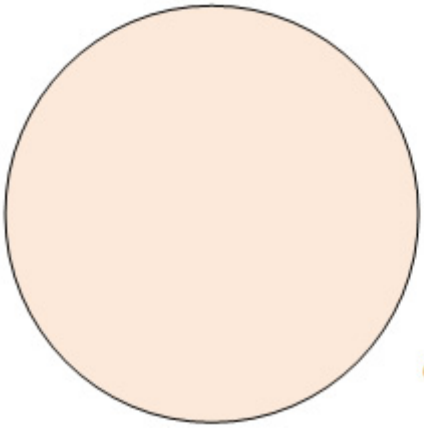
When a body in circular path with uniform speed its motion is called uniform circular motion.

Examples

- Artificial satellite moves under uniform circular motion around the earth.
- The moon moves in uniform circular motion around the earth.
- The earth moves around the earth in uniform circular motion.

- The tip of second hand of a watch exhibits uniform circular motion on the circular dial of the watch.
- An athlete moving on a circular track with constant speed exhibits circular motion.

To calculate the speed of a body in uniform circular motion:-



When a body one round of a circular path then it covers a distance equal to its circumference which is equal to 2 πr, where 'r' is the radius of the circular path

Then

Speed = 2πr / t

where

v= speed, r = radius of the circular path and t = time taken