UNIT- 2

KINEMATICS

KINEMATICS

The word kinematics is derived from Greek word “Kinema” which means motion.

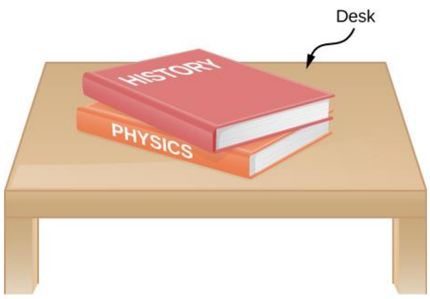
Kinematics is the branch of Mechanics, which deals with motion of objects without reference of Force which causes motion.

REST

When a body does not change it position with respect to its surroundings then it is said to be in state of rest.

EXAMPLES

A book lying on a table, A table placed in a room and a boy sitting on a chair are the examples of bodies at rest.



A book lying on the table. A person can notice that the book does not changes its position with respect to its surroundings.

A boy sitting on the chair. A person can notice that the boy does not changes its position with respect to its surroundings

MOTION

When a body changes its position with respect to its surroundings then it is said to be in state of motion.

EXAMPLES

A bus moving near a bus stop, a bird flying over a tree are the examples of a body's motion.

TYPES OF MOTION

We observe around us that all objects in universe are in motion. However the nature of their motion is different, some objects move along circular path, other move in straight line while some objects move back and forth only. There are three types of motion.

TRANSLATORY MOTION (LINEAR, CIRCULAR AND RANDOM)

When all points of a moving body move uniformly along the same straight line, such motion is called translatory motion.

(a) LINEAR MOTION

Motion of a body along a straight line is called linear motion.

FOR EXAMPLE

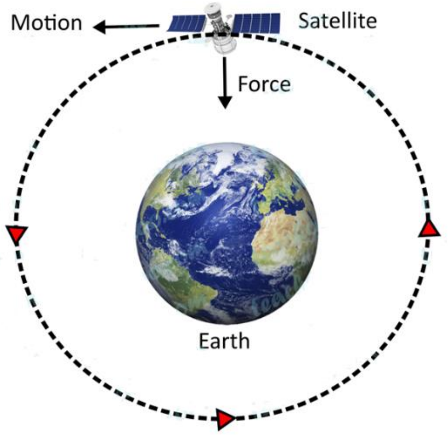
The motion of a car on a straight road is the example linear motion.

(b) **CIRCULAR MOTION:**

Motion o a body along a circular path is called circular motion.

Example

An artificial satellite moving around the Earth along circular path is an example of circular motion

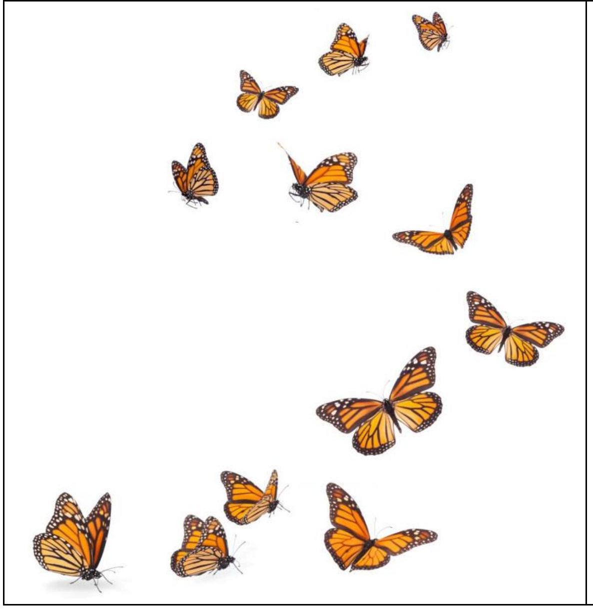


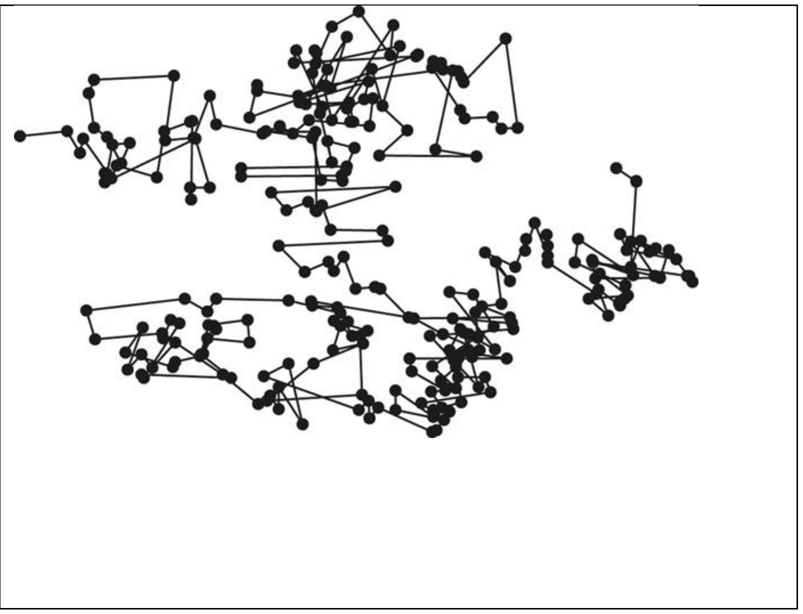
(c) RANDOM MOTION

Irregular motion of an object is called random motion.

EXAMPLE

motion of butterfly, house fly, dust and smoke particles along zigzag paths are examples of random motion.





ROTATORY MOTION

The motion of the body around a fixed axes which passes through body itself is called spin or rotatory motion.

FOR EXAMPLE

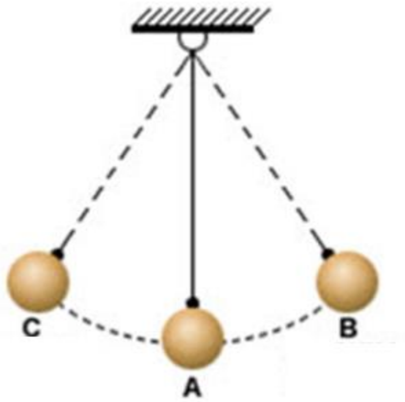
The blades of moving electric fan, the rotation of earth about its own axis. are the example so rotational motion

VIBRATORY MOTION

The change of position of a body around a mean position in one axis is called vibratory motion or oscillatory motion.

FOR EXAMPLE

The motion of wings of a bird, the motion of child in swing **and motion of simple pendulum.**



Distinguish between Translatory, Vibratory and Rotatory

TRANSLATORY MOTION	ROTATORY MOTION	VIBRATORY MOTION
A body moves along a straight line.	The spinning of a body about its axis.	The body moves back and forth about mean position.
Movement of an object from one place to another.	The motion of an object about fixed point.	The body moves up and down.
All particles of the rigid body move with the same velocity at every instant of time.	The motion of a rigid body about a fixed axis. Every particle of the body move in a circular path	An object repeat its motion itself.

DISTANCE

Distance is defined as the total path traveled by a moving object in a certain interval of time

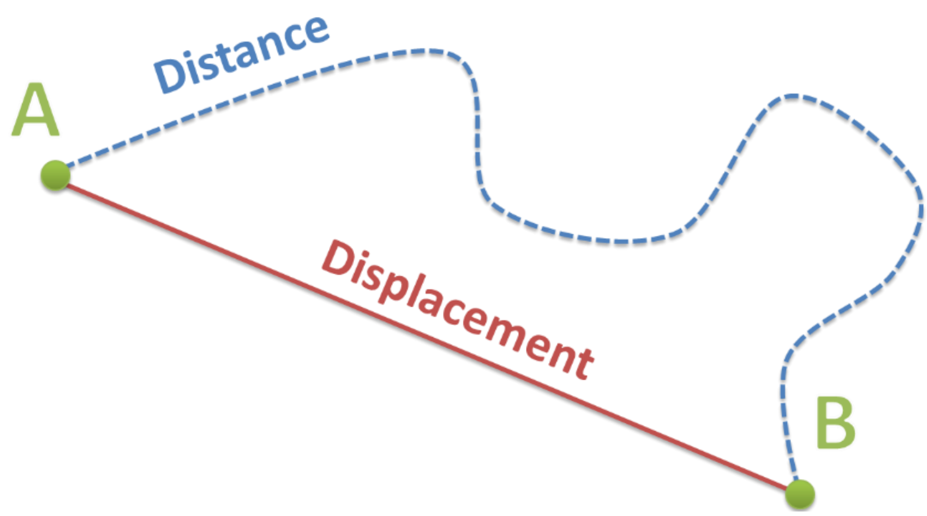
Distance is a scalar quantity.

DISPLACEMENT

Displacement is defined as the distance moved in a specified direction.
It is a vector quantity and it is also defined as the shortest distance moved in a specified direction.

FOR EXAMPLE

Let a body move from point A to another point B, but there may be various paths along which we can move the body from A to B. But the short distance from A to B is called displacement$\overrightarrow{AB}$.



DISTANCE AND DISPLACEMENT CAN BE DIFFERENTIATED AS FOLLOWS:

TRANSLATORY MOTION	ROTATORY MOTION
The total length covered by moving body without mentioning direction of motion.	The distance measured in a straight line in a particular line. .
It is a scalar quantity.	It is a vector quantity
The SI unit is metre(m)	The SI unit is metre(m)

SPEED

Speed is defined as the rate of change in distance. In other words, speed is the distance moved per unit of time. It tells us how fast or slow an object is moving.

$$speed(V) = \frac{total\ distance\ (S)\ covered}{Total\ time\ (t)}$$

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

THE AVERAGE SPEED

The total distance covered by a moving is divided by the total time taken.
It's denoted by or V_{av}

$$V_{av} = \frac{S}{t}$$

The unit of speed in SI system is m/s

UNIFORM SPEED

An object covers an equal distance in equal intervals of time its speed is known as uniform speed.

VARIABLE SPEED

An object covers an equal distance in un equal intervals of time its speed is known as variable speed.

VELOCITY

Velocity is defined as the rate of change of distance moved with time in a specified direction.
Or
The rate of change of displacement.
Or
The distance covered by a body in a particular direction per unit time.

If a body is displaced through a distance $\vec{S}$ during the time t, its average velocity is give by

$$Velocity = \frac{displacement}{time\ taken}$$

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

UNIT

In the SI system velocity is measured in "metre per second", (m/s)

AVERAGE VELOCITY

Average velocity is defined as the ratio of the total displacement to the total time taken by the object.

$$Average\ Velocity = \frac{Total\ displacement}{total\ time\ taken}$$

$$V_{av} = \frac{\Delta d}{t}$$

If a body is moving with initial velocity "Vi" and after time "t" its velocity become "Vf" is final velocity then its average velocity in that interval become,

$$V_{av} = \frac{V_f + V_i}{2}$$

UNIFORM VELOCITY

A body is said to move with uniform velocity if its rate of change of distance moved with time in a specified direction is constant.

It can also be defined as "if a body covers same distances in equal intervals of times in a specified direction is called uniform velocity."

VARIABLE VELOCITY

A body is said to move with variable velocity if its rate of change of distance moved with time in a specified direction is not constant.

It can also be defined as "if a body does not cover the same distance in equal intervals of time in a particular direction is called variable velocity".

ACCELERATION

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

If a body having an initial velocity "Vi" and final velocity in time Δt then,

$$a = \frac{Change\ in\ Velocity}{Time\ interval}$$

or

$$a = \frac{V_f - V_i}{\Delta t}$$

Acceleration is a vector quantity its SI unit is metre per second per second (m/s^2).

UNIFORM ACCELERATION

A body is said to move with uniform acceleration if its rate of change of velocity with time is constant.

It can also be defined as "if the velocity of a body is same in equal intervals of time then the body is said to have uniform acceleration".

Velocity m/s	Time sec
4 8 12 16	2 4 6 8

<u>VARIABLE ACCELERATION</u>

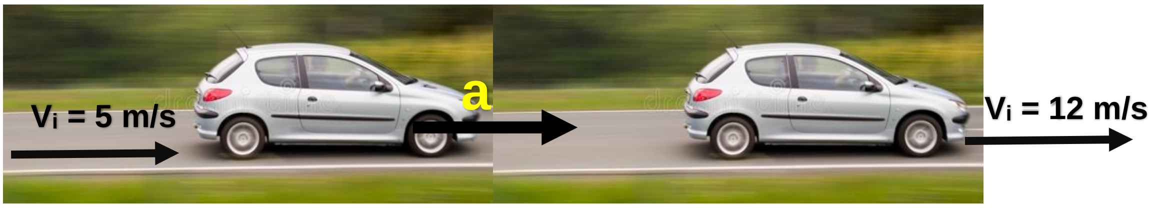
A body is said to move with variable acceleration of its rate of change of velocity with time is not constant.

It can also be defined as "if the velocity of a body is remain same in equal intervals of time then the body is said to have variable acceleration.

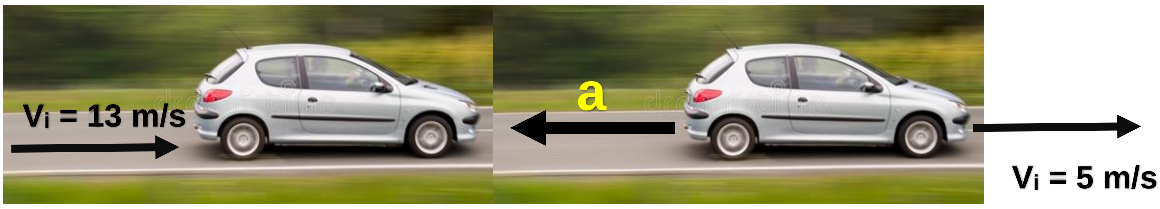
Velocity m/s	Time sec
4 8 12 16	2 4 6 8

<u>NOTE</u>

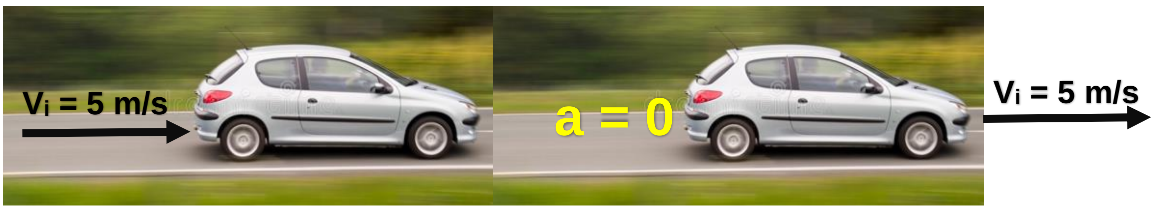
1. **If initial velocity of a body is less than its final velocity then acceleration will be taken as positive which means that is in the direction of motion.**



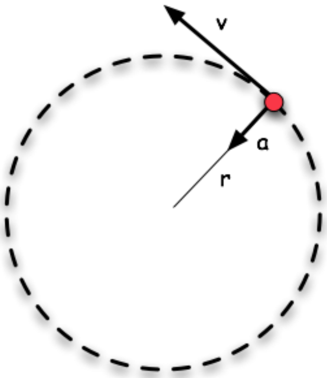
2. **If initial velocity of a body is greater than its final velocity than acceleration will be taken as negative which means that opposite in direction called retardation or deceleration.**



3. **If initial and final velocity of a body is same then no acceleration will produce.**



4 **If a body is moving in a circular path then velocity and acceleration of the body are mutually perpendicular.**



SCALARS

DEFINITION

Physical quantities that are completely specified by their magnitude (a number with suitable unit) are called scalars.

EXAMPLES

Some of the physical quantities that are scalars are:

1 Length	2. Distance.	3. Time	4. Speed	5. Volume
6. Density	7 Work	8. Mass	9. Frequency	10 Energy
11. Temperature	12. Wavelength	13 Current	14. entropy	

VECTORS

DEFINITION

Physical quantities that have both magnitude and direction and that follow the laws vector addition are called vectors.

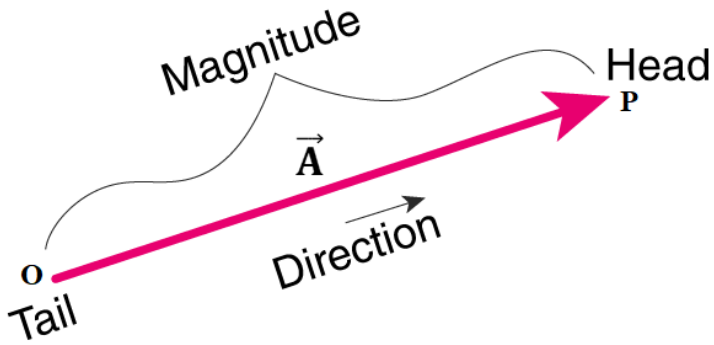
EXAMPLES

Some physical quantities that are vectors are

1. Displacement	2. Velocity	3. Acceleration	4. Momentum
5. Force	6. Angular Velocity.	7. Weight	8. Torque
9. Electric Field	10. Magnetic Field	11.Tension	

REPRESENTATION OF VECTORS

Vectors can be represented graphically as arrows. The length of the arrow indicates the magnitude of the vector. The direction of the arrow indicates the direction of the vector.



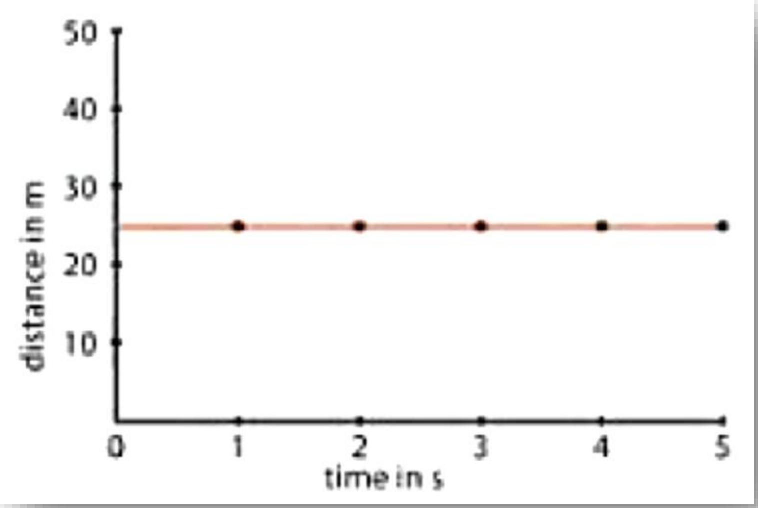
GRAPHICAL ANALYSIS OF MOTION

The graph gives complete information about the motion of the object based on the measured physical quantities such as distance, speed, time

DISTANCE TIME GRAPH

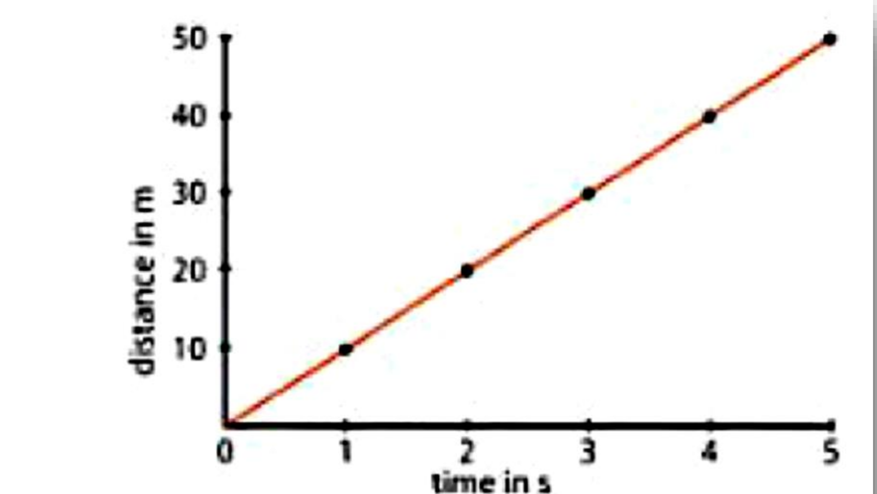
(a) CAR AT REST

Time in s	0	1	2	3	4	5
Distance in m	25	25	25	25	25	25



(b) Car moving with a uniform speed 10 m/s

Time in s	0	1	2	3	4	5
Distance in m	0	10	20	30	40	50

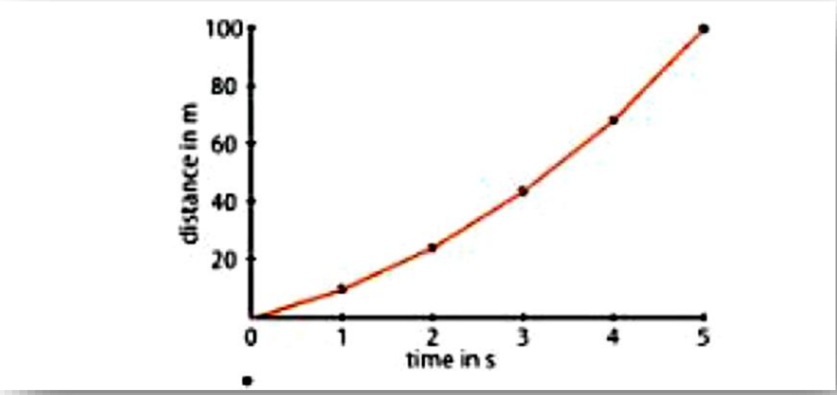


Distance increases 10 m for every 1 s.

(c) Car moving with non-uniform speed

(i) Car accelerating

Time in s	0	1	2	3	4	5
Distance in m	0	10	25	45	70	100

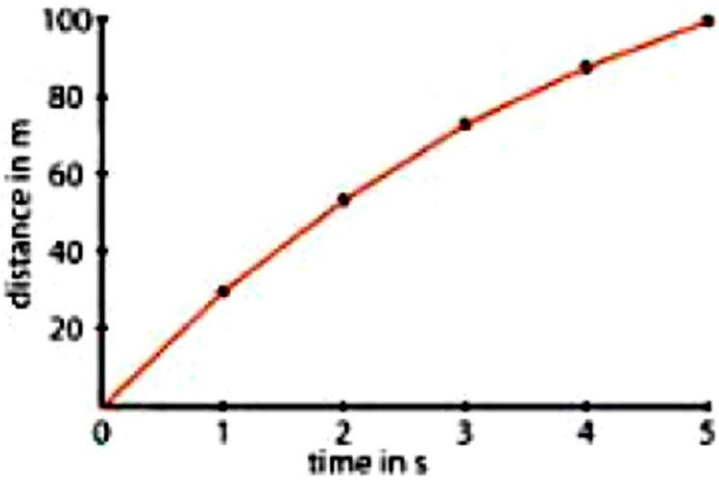


The speed increases, so the car travels a longer distance, as time increases.

The gradient on the distance time graph is numerically equal to the speed.

(ii) Car decelerating

Time in s	0	1	2	3	4	5
Distance in m	0	10	25	45	70	100



Speed decreases, so the car travels a shorter distance as time increases

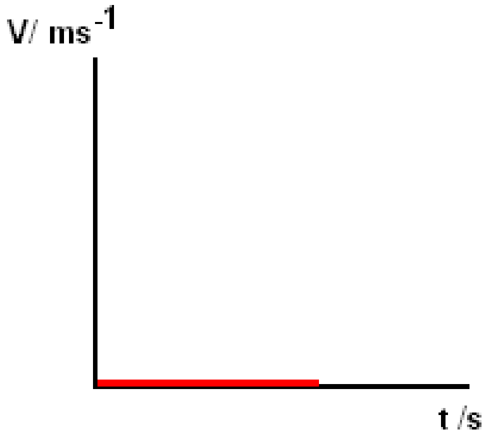
SPEED -TIME GRAPH

If the speed of the object ,v, is plotted against time, t, we can obtain

(a) the acceleration or deceleration of the object. This is found from the gradient of the graph.

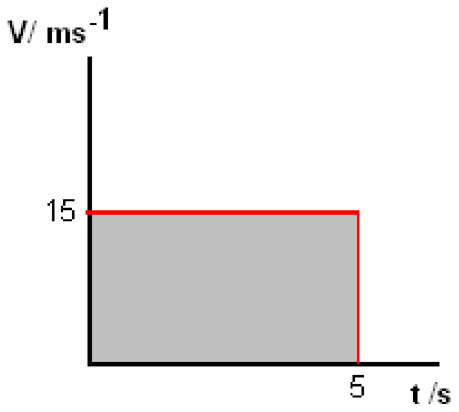
(b) The distance traveled by the object. This is found from the area under the graph. Below is the speed –time graphs from the different type of motion.

OBJECT AT REST (STATIONARY)



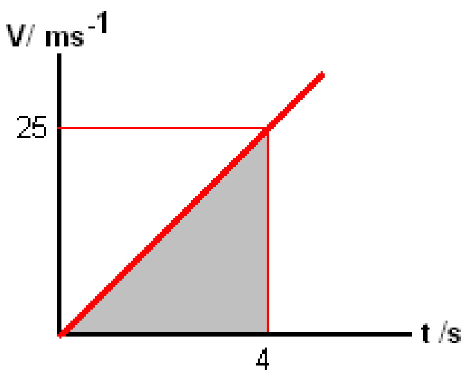
* speed is zero throughout the time
* The graph is a straight line that coincides with the time-axis
* Acceleration = gradient of graph
  = 0 ms^{-2}
* Distance = area under the graph
  = 0 m

OBJECT MOVING WITH CONSTANT SPEED



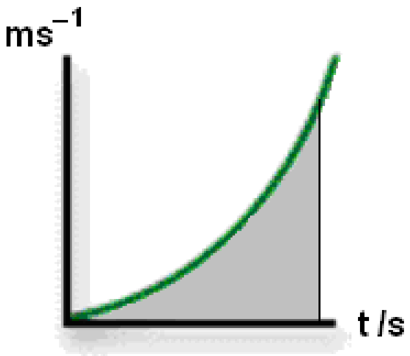
* There is no cahnge in speed over time.
* The graph is a straight line parallel to the time - axis.
* Acceleration = gradient
  = 0 ms^{-2}
* Distance = area under graph
  = 15 x 5
  = 75 m

OBJECT MOVING WITH CONSTANT ACCLELERATION

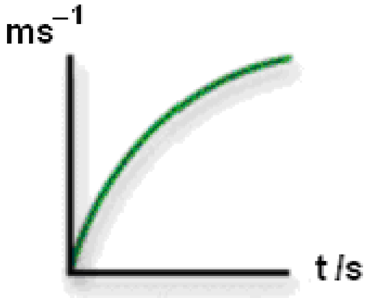


* Change in speed per unit time is constant.
* The graph is a straight line with a constant gradient.
* Acceleration = gradient of graph
  = 25/ 4 = 6.25 ms^{-2}
* Distance = area under the graph
  = 0.5 x 25 x 4
  = 50 m

OBJECT MOVING WITH INCREASING ACCELERATION



- Change in speed per unit time is increasing
- The graph is a curve with increasing gradient.
- Acceleration at a certain instant = gradient at that instant
- Distance = area under graph



- Change in speed per unit time is decreasing
- The graph is a curve with decreasing gradient.
- Acceleration at a certain instant = gradient at that instant
- Distance = area under graph

EQUATIONS OF UNIFORMLY ACCELERATED RECTILINEAR MOTION

FIRST EQUATION OF MOTION

$$V_f = V_i + at$$

DERIVATION

We know that when a body is moving with initial velocity "V_i" but after an interval of time "t" its velocity becomes "V_f" i.e. final velocity.

So, the change in velocity = $V_f - V_i$

Rate of change in velocity = $= \dfrac{V_f - V_i}{t}$

But Rate of change in velocity = a

Therefore we can write it as follows;

$$a = \frac{V_f - V_i}{t}$$

$$V_f - V_i = at$$

$$V_f = V_i + at$$

SECOND EQUATION OF MOTION

DERIVATION

We know that if a body changes its position, it covers a distance (s) in time "t" in a particular direction. If the total displacement is divided by the time we get the average velocity (V_{av}).

$$V_{av} = \frac{S}{t}$$

$$S = V_{av}\, t \ldots\ldots\ldots\ldots (i)$$

If the initial velocity of the body is "Vi" and is final velocity is "Vf" then

$$V_{av} = \frac{V_f + V_i}{2}$$

Now substituting the value of V_{av} in equation (1), we get,

$$S = \left(\frac{V_f + V_i}{2}\right) t \ldots\ldots (ii)$$

But $V_f = V_i + at$ so, equation (2), become,

$$S = \left(\frac{V_i + at + V_i}{2}\right) t$$

$$S = \left(\frac{2V_i + at}{2}\right) t$$

$$S = \left(\frac{2V_i t + at \times t}{2}\right)$$

$$S = \left(\frac{2V_i t + at^2}{2}\right)$$

$$S = \left(\frac{\cancel{2} V_i t}{\cancel{2}} + \frac{at^2}{2}\right)$$

$$S = V_i t + \frac{1}{2} at^2$$

THIRD EQUATION OF MOTION

$$2aS = V_f^2 - V_i^2$$

DERIVATION

We know that if the body changes its position it covers a distance "S" in an interval of time "t" in a particular direction. If the total distance divided by the time we get the average velocity V_{av}.

$$V_{av} = \frac{S}{t}$$

$$S = V_{av}\, t \quad \text{.............(i)}$$

If the initial velocity of the body is "V_i" and its final velocity is "V_f" then its average velocity is as follows;

$$V_{av} = \frac{V_f + V_i}{2} \quad \text{.............(ii)}$$

Acceleration is given by

$$a = \frac{V_f - V_i}{t}$$

$$t = \frac{V_f - V_i}{a} \quad \text{...........(iii)}$$

Now substituting the value of V_{av} and t is equation (1)

$$S = \left(\frac{V_f + V_i}{2}\right)\left(\frac{V_f - V_i}{a}\right)$$

$$S = \frac{(V_f + V_i)(V_f - V_i)}{2a} \qquad \left[a^2 - b^2 = (a+b)(a-b)\right]$$

$$S = \frac{V_f^2 - V_i^2}{2a}$$

$$2aS = V_f^2 - V_i^2$$

ACCELERATION DUE TO GRAVITY

The acceleration produces in a body due to the force of gravitation is called acceleration due to gravity and it is represented by "g". All bodies irrespective of their masses falls towards the earth with same acceleration due to gravity.

Since the value of "g" cannot be same everywhere because earth is not exactly round but oval in shape, while scientists get an average value of "g" i.e. 9.8 m/s^2 which is applicable throughout the world.

NOTE

The value of "g" will be taken as positive when it is moving towards the earth.

The value of "g" will be taken as negative when it is moving away from the earth.

MOTION UNDER GRAVITY

For the motion of bodies under the influence of gravity the equation of motion are slightly modified. Where distance is taken as (S=h) and acceleration is taken as g (a=g).
So, the equations of motion become,

1.	$V_f = V_i + a\,t$	**2.**	$S = V_i\,t + \frac{1}{2}\,a\,t^2$	**3.**	$2\,a\,s = V_f^2 - V_i^2$
	$V_f = V_i + g\,t$		$h = V_i\,t + \frac{1}{2}\,g\,t^2$		$2\,g\,h = V_f^2 - V_i^2$