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UNIT 1ST

MOTION

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In our daily life, we see lots of things moving around for example car passing from one place to other, person riding on a bicycle and many more like this.

In scientific terms an object is said to be in motion, if it changes its position with the passage of time and if it does not change it position with the passage of time then it is said to be at rest.

Both the motion and rest are relative terms for example mobile kept on the table is resting at its position but it is moving in the sense as earth is rotating on its axis. So for a person seeing mobile from earth, it is at rest and for person on moon earth seems to change its position with time and so mobile is moving.

Simplest case of motion is rectilinear motion which is the motion of the object in a straight line

In our description of object, we will treat the object as a point object.

Object under consideration can be treated as point object if the size of the object is much smaller than the distance traveled by it in reasonable time duration for example length of a motor car traveling a distance of 500km can be neglected w.r.t. distance travelled by it.

Motion: when an object changes its position continuously with respect to the position of the other objects with the passage of time, the object is said to be in motion. In other words, we can say that motion means the change in position of an object with respect to its surrounding in a given interval of time.

Rest: - A body is said to be at rest when it does not change its position with respect to the observer.

Displacement and Distance: - Displacement is the shortest distance between the initial and final position of a moving body. Displacement is directed from the initial position to the final position. Displacement is the change in position of an object in any particular direction, while distance is the actual length of path travelled by any object to reach its final position. It has no sense of direction.

e.g. If a person moves 4 km from A to B and 3 km in north from B to C.
C

Therefore, Distance travelled from A to C = AB + BC = 4 + 3 = 7 km

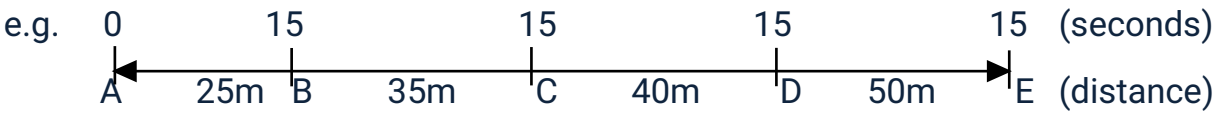
And, displacement = AC (Shortest possible distance in a particular direction)

A *B*

Uniform Motion: If a body travels equal distances in equal intervals of time, then the body is said to have uniform motion, no matter how small these intervals may be.

If a car travelling from A to F (50 km) with a distance of 10 meters each from A to B, B to C, C to D, D to E and E to F in equal intervals of time 10 seconds, then the car is said to have uniform motion.

Non – uniform Motion: A body is aid to have non uniform motion if it travels unequal distances in equal intervals of time or equal distance in unequal intervals of time whosoever small intervals may be.



A car travelling different distances from A to B, B to C, C to D and D to E in equal intervals of time of 15 seconds has a non-uniform motion.

Scalar quantities: Those quantities which are completely described by a magnitude alone are called as scalar quantities or those quantities which have only magnitude and no direction are known as scalar quantities.

e.g. mass, length, time, Temperature, Density, Volume etc. are scalar quantities.

Vector quantities: Those quantities which are completely described if direction is also given with magnitude are called as vector quantities. i.e. those quantities which possess

both magnitude as well as direction are known as vector quantities.

e.g. Displacement, weight, Velocity, Acceleration, force, momentum etc. are vector quantities.

Speed: The rate of change of motion of a body with respect to time is known as speed of a body. i.e. The distance travelled by a body in unit of time is called its speed or the ratio of distance travelled to the time taken.

Therefore, Speed = Distance travelled /Time taken

If distance travelled is S and time taken is T, then speed V will be written as

$$V = S / T$$

Average Speed: The average speed of a body is the total distance travelled divided by the total time taken to cover this distance.

Average Speed = total distance travelled / Total time taken

The S.I. unit of distance is meter (m) and time is seconds (s), so S.I. unit of average speed is meter per second i.e. m/s or ms^{-1}.

Uniform Speed: A body is said to have uniform speed if it travels equal distances in equal intervals of time. No matter how small these time intervals may be.

Non-Uniform Speed: A body is said to have non-uniform speed if it does not travels equal distances in equal intervals of time. No matter how small these time intervals may be.

Velocity: the velocity of a body is defined as the distance travelled by a body in a particular direction. i.e. the rate of change of speed in a particular direction.

i.e. velocity = Distance travelled in a given direction / Time taken

But the distance covered in a given direction is called as displacement

Therefore, Velocity = distance / Time taken

Or $V = S / T$

The unit of velocity is same as that of speed. i.e. meter per second or m/s .

Uniform Velocity: If an object moves on a straight line and covers equal distances in equal intervals of time. It is said that the object has uniform velocity.

Non-Uniform Velocity: A body is said to have non-uniform velocity if it does not travels equal displacement in equal intervals of time. No matter how small these time intervals may be.

Instantaneous velocity: The velocity of an object at any given instant of time is called as instantaneous velocity. I.e. the velocity of an object at the starting instant of time is known as the initial velocity and the velocity at the final instant of the time is known as its final velocity.

Distinguish between speed and velocity:

SPEED	VELOCITY
1. Speed is the rate of change of position of an object with respect to time. 2. It is the ratio of distance travelled by an object to the time taken. 3. It is a scalar quantity. 4. Direction is not associated with distance. 5. It is always positive. 6. It cannot have a value zero for moving body.	1. Velocity is the rate of change of position of an object with respect to time in a particular direction. 2. It is the ratio of displacement of an n object to the time taken. 3. It is a vector quantity. 4. Direction is associated with displacement. 5. It can be positive or negative. 6. I can be zero if initial and final positions is the same.

Average velocity: The average velocity of an object is defined as the arithmetic mean of the initial and final velocity for a given period of time, that is

Average Velocity = Initial velocity + Final velocity / 2

Acceleration: The acceleration of an object is defined as the rate of change of its velocity with respect to time, and is denoted by 'a'.

Therefore, Acceleration = change in velocity / Time taken

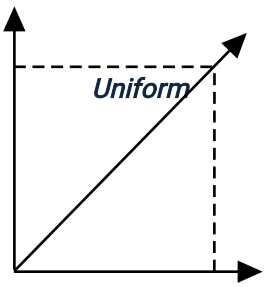
Or $a = v - u / t$

Since unit of velocity is m/s and that of time is second(s), so the S.I. unit of acceleration is m/s^2 or m/s^{-2}. The acceleration is a vector quantity.

Uniform acceleration: A body is said to have a uniform acceleration if it travels in a straight line and its velocity increases by equal amounts in equal intervals of time.

Non – uniform acceleration: A body is said to have a non uniform acceleration if its velocity increases by unequal amounts in equal intervals of time.

Distance – Time graph: A graph showing the variation of distance of a *motion*



moving object with time is called as distance – time graph. When a body moves with uniform speed, it will travel equal in equal intervals of time.

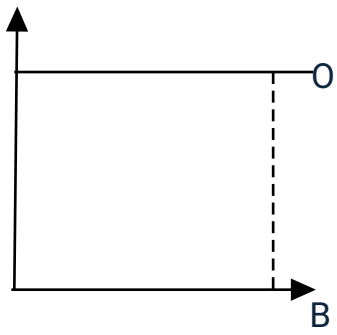
So for uniform speed a graph of distance travelled against time will be a straight line. We take any line graph and draw a perpendicular AB on the time axis (x – axis). It is clear from the graph that AB represents distance and OB represents time.

Since, speed = Distance travelled / Time taken speed = AB / OB

Now, If the speed of the body is non uniform, then the graph between distance travelled and time is curved line called as parabola. Hence from the graph it is clear that if the graph is a straight line then the speed is uniform and if the graph of a body is a curved line, then its speed is non uniform.

Speed - time graph: There are three cases of speed time graph for a moving body.

i. Speed time graph when the speed remains constant: A speed time graph for a body moving with constant speed is a straight line is parallel to the time axis. In other words if the speed - time graph of a body is a straight line parallel to the time axis, the speed of the body is constant. Since the speed of the body is constant or uniform, there is no acceleration, and hence there is no question of finding the acceleration from such a speed time graph.



We know that Speed = distance / Time

= > Distance = Speed X Time

Now, Speed at C = CB, But CB = OA

Speed at C = OA, Time at C = OC

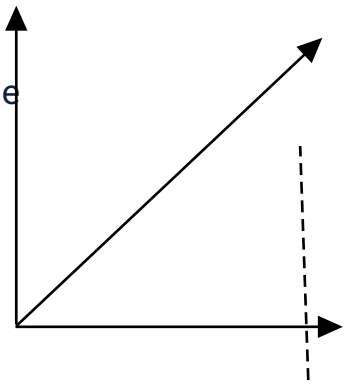
Distance = OA X OC Distance travelled = Area of rectangle OABC

ii. Speed time graph when speed changes at a uniform rate: When a body moves with uniform acceleration, its speed changes by equal intervals of time. In other words, the speed becomes directly proportional to time. Thus, the speed – time graph for a uniformly changing speed (or uniform acceleration) will be a straight line.

We know that

Acceleration = Change in Speed (velocity) / Time taken

The change in speed is represented by PQ whereas time taken is equal to OQ.

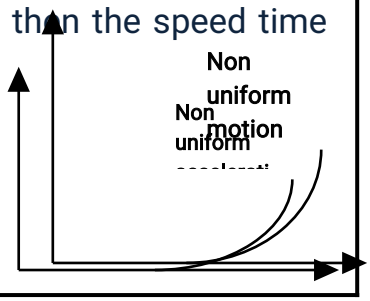


So, Acceleration = PQ / OQ,

But PQ/OQ is the slope of the speed time graph OP, Therefore the slope of a speed time graph of a moving body gives its acceleration.

iii. Speed time graph when the acceleration is non uniform:

When the speed of a body changes in an irregular manner, then the speed time graph of the body is a curved line.



Even now, the distance travelled by the body is given by

the area between the speed time curve and the time axis.

So it is clear that the velocity time graph for non uniform

acceleration is a curved line called parabola.

Equations of motion (Mathematical representation):

1. First equation: Consider a body having initial velocity 'u'. Suppose it is subjected to a uniform acceleration 'a', so that after time 't' seconds final velocity becomes 'v'.

   Therefore, rate of change of velocity = $v - u / t$

   => Acceleration = $v - u / t$

   => $a = v - u / t$

   => $at = v - u$

   or $v - u = at$ => $v = u + at$ ---------- (i)

2. Second equation: Let the initial velocity of a body is 'u' and final velocity 'v' with acceleration 'a'. we know that

   Average velocity = $u + v / 2$

   and Distance = Average velocity x time

   => $S = (u+v)\, t / 2$

   => $S = (u + u + at)t / 2$ By using equation (i)

   $S = (2u + at)t / 2$

   => $S = 2ut + at^2 / 2$

   $S = 2ut / 2 + at^2 / 2$

   => $S = ut + \frac{1}{2} at^2$ ----------(ii)

3. Third equation: We know that $S = ut + \frac{1}{2} at^2$ Second equation of motion

   And $v = u + at$ First equation of motion

   => $v - u = at$

   => $v - u / a = t$

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

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

   $S = uv - u^2 / a + v^2 + u^2 - 2uv / 2a$

   $S = (2uv - 2u^2 + v^2 + u^2 - 2uv) / 2a$

   $S = (- u^2 + v^2)/ 2a$

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

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

Circular motion: The motion described by a body in a circular path is called a circular motion. In this type of motion the direction of the body does not remain same, but remains changing at every point. Examples of circular motion are:

i. Earth moving on its axis.

ii. A bus moving at the angle of a road.

iii. Motion of electric fan running at a particular speed.

iv. Movements of hands of a clock.

v. Motion of wheel of a running vehicle.

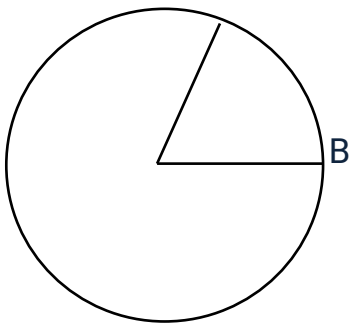
Average velocity: The angular velocity of a body is defined as the angular displacement per unit time i.e. the ratio of the angular displacement of a body to the time taken by it. Angular velocity is represented by omega 'ω'

Or $\omega = \theta$ radians / t Seconds. => $\omega = \theta / t$ radians per second.

The S.I. unit of angular velocity is radians per second.

Relation between linear velocity and angular velocity: Suppose a body is moving with a uniform linear speed v in a circular path of radius 'r', when the body moves from point A to B with uniform linear speed v covers distance 'S' in time 't' seconds it subtends an angle 'ɵ' at the center of the circular path.

A



So, Angle in radians = Length of arc / Radius of circle.

Therefore, $\theta = s / r$ ---------(i)

Now linear speed = Distance travelled / time taken

$v = s / t$ => $v \times t = s$ ---------(ii)

Substituting Equation (i) in equation (ii) we get

$\theta = v \times t / r$ => $\theta / t = v / r$

But Angular velocity = Angular displacement / Time taken

i.e. $\omega = \theta / t$

Therefore $\omega = v / r$ => $\omega r = v$ or $v = \omega r$

Graphical representation of equations of motion: Let a body moves with an initial velocity 'u' final velocity 'v' and acceleration 'a' during time 't'. Suppose its motion is represented by velocity time graph. It is clear from the graph that the body has an initial velocity 'u' at A and changes at a uniform rate from A to B in time t seconds. The final velocity of the body becomes v and it is equal to BD in the graph.

Now Initial velocity (u) = OA = CD

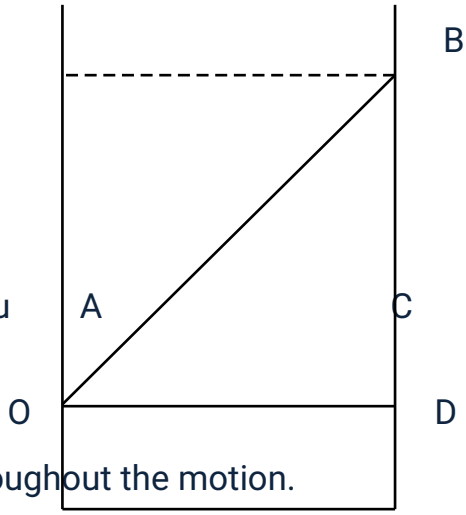
Final velocity (v) = BD

Time (t) = AC = OD

Change in velocity = v – u = BD – CD = BC

Since Acceleration a = v – u/ t => at = v – u

=> v = u + at



When the velocity of the body remains constant say ‘u’ throughout the motion.

Then distance covered = Area of rectangle OACD

=> s = OA x AC => S = u x t

But if velocity goes on increasing constantly with time, the distance covered = area of trapezium OABD

=> s = OA x AC + ½ AC x BC => s = ut + ½ t x at

=> s = ut + ½ at^2

Now, distance travelled by body = area of trapezium OABD

=> s = ½ (OA + DB) x OD
=> s = ½ (u + v) x t
=> s = ½ (u + v) x (v – u / a)

(Because v – u = at => v – u = at
=> v – u / a = t)

=> s = (v + u) (v – u) / 2a
=> 2as = $v^2 – u^2$
Or $v^2 – u^2$ = 2as