MOTION

Anybody is said to be in motion if its position changes w.r.t. time.

Scalar Quantity: The quantities which are defined by their magnitude only, are called scalar quantities.

Vector Quantity: The quantities which are defined by their magnitude as well as direction are called vector quantities.

Distance: It is the actual path covered by a body. Its S.I unit is 'm' (meter). It is a scalar quantity.

Displacement: It is the shortest distance between initial and final position of the body. Its unit is 'm'. It is a vector quantity.

Speed: The distance traveled by the body per unit time is called speed. Its S.I unit is m/s. It is a scalar quantity.

Velocity: The distance traveled by the body per unit time in a particular direction is called velocity. Its S.I unit is m/s. It is a vector quantity.

Uniform Velocity: If a body travels equal distances in equal intervals of time, velocity is called uniform.

Non-uniform Velocity: If a body travels unequal distances in equal intervals of time, velocity is called non- uniform.

Acceleration: Rate of change in velocity per unit time is called acceleration. Its unit is m/s^2. It is a vector quantity. It is denoted by 'a'.

Negative value of acceleration is called **retardation**.

Retardation occurs when velocity of body is reduced i.e. initial velocity (u) > final velocity (v).

Uniform Acceleration: If the speed of body changes equally in equal intervals of time, the acceleration is said to be uniform.

Non-uniform Acceleration: If the speed of body changes unequally in equal intervals of time, the acceleration is said to be non-uniform.

Three equations of motion:

(i) $v = u + at$ (ii) $s = ut + \frac{1}{2}at^2$ (iii) $v^2 - u^2 = 2as$

where, $v \rightarrow$ final velocity (in m/s)

$u \rightarrow$ initial velocity (in m/s)

$a \rightarrow$ acceleration (in m/s^2)

$t \rightarrow$ time (in s)

$s \rightarrow$ distance (in m)

DERIVATIONS OF EQUATIONS:

I – equation: $v = u + at$

We know that acceleration is the rate of change in velocity

i.e. $a = \frac{v-u}{t}$

$\Rightarrow$ $at = v - u$

$\Rightarrow$ $v = u + at$

II equation: $s = ut + \frac{1}{2}at^2$

Let the speed of moving body changes from 'u' to 'v' in time 't' after traveling a distance of 's' meters.

s = average velocity x time

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

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

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

$\Rightarrow$ $s = \frac{2ut+at^2}{2}$

$\Rightarrow$ $s = ut + \frac{1}{2}at^2$

III equation: $v^2 - u^2 = 2as$

Let the speed of moving body changes from 'u' to 'v' after traveling a distance of 's' meters. If 'a' is the acceleration, then

s = average velocity x time

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

$$\Rightarrow \quad s = \frac{v+u}{2} \times \frac{v-u}{a}$$

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

$$\Rightarrow \quad 2as = v^2 - u^2$$

alternate method:

$$v = u + at$$ (by first equation of motion)

squaring both the sides we get;

$$\Rightarrow \quad v^2 = (u + at)^2$$

$$\Rightarrow \quad v^2 = u^2 + 2uat + a^2t^2$$

$$\Rightarrow \quad v^2 = u^2 + 2a\left(ut + \frac{1}{2}at^2\right)$$

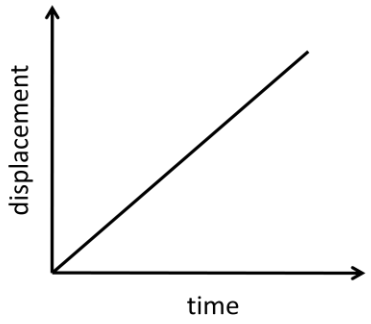
$$\Rightarrow \quad v^2 = u^2 + 2as \qquad \left\{\because\ s = ut + \frac{1}{2}at^2\right\}$$

$$\Rightarrow \quad v^2 - u^2 = 2as$$

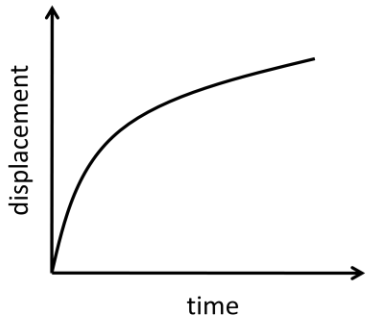
Note:

- when a body starts from rest, take u = 0.
- when a moving body stops, take v = 0.
- for uniform velocity i.e. when body is moving with constant velocity, take a = 0.

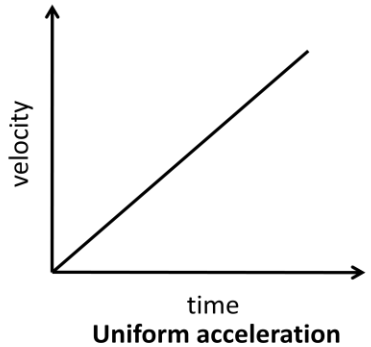
Few graphical representations:



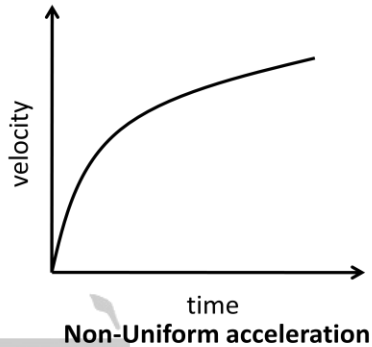
Uniform velocity



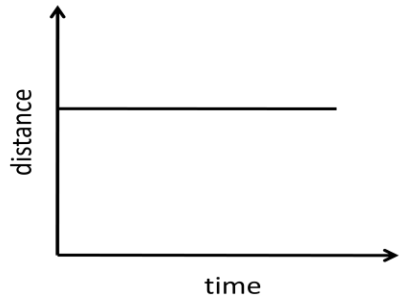
Non-Uniform velocity



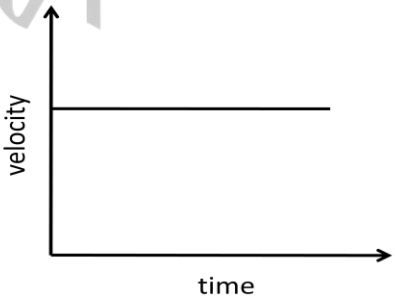
Uniform acceleration



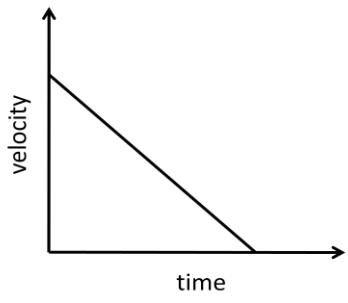
Non-Uniform acceleration



Body at rest



Uniform velocity
Or
Zero acceleration



Uniform retardation

Graphical proof of three equations of motion:

Let a body starts with a velocity 'u' (given by OA) and the velocity increases to 'v' (given by BC) after time 't' (given by OC).

I equation:

$$\text{slope of AB} = \frac{BD}{AD}$$

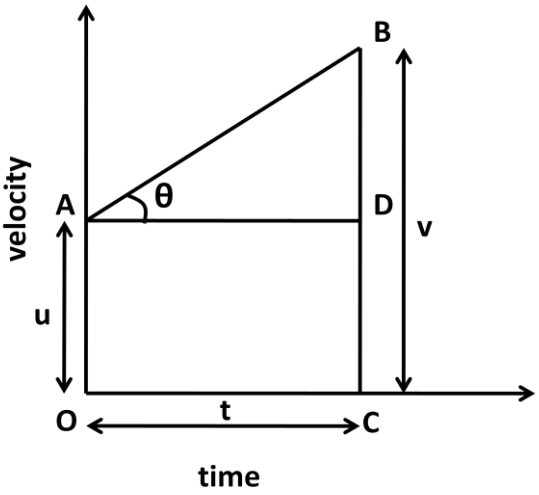
$$a = \frac{BD}{AD}$$

$$a = \frac{BC - CD}{OC} \qquad (\because AD = OC)$$

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

$$at = v - u$$

$$\Rightarrow \quad v = u + at$$



II equation:

$$\text{distance covered} = ar(ABCO)$$

$$s = ar(ABD) + ar(OADC)$$

$$s = \frac{1}{2} \times BD \times AD + OC \times CD$$

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

$$s = \frac{1}{2}at^2 + ut \qquad \left\{ a = \frac{v-u}{t} \Rightarrow at = v - u \right\}$$

$$\Rightarrow \quad s = \frac{1}{2}at^2 + ut$$

alternate method:

distance covered = $ar(ABCO)$

$s = \frac{1}{2} \times OC \times (BC + AO)$

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

$s = \frac{1}{2} \times t \times (u + at + u)$

$s = \frac{1}{2} \times t \times (2u + at)$

$s = ut + \frac{1}{2}at^2 \qquad \left\{ a = \frac{v-u}{t} \Rightarrow at = v - u \right\}$

$\Rightarrow \quad s = ut + \frac{1}{2}at^2$

III equation:

distance covered = area of trapezium OABC

$s = \frac{1}{2}(BC + AO) \times OC$

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

$= \frac{1}{2}(v + u) \times \frac{(v-u)}{a} \qquad \left\{ a = \frac{v-u}{t} \Rightarrow t = \frac{v-u}{a} \right\}$

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

$\Rightarrow \quad v^2 - u^2 = 2as$

Circular motion: If a body is moving along circular path and the speed remains constant, it is called uniform circular motion.

Since the direction is changing at every moment, the circular motion is always accelerated.

assignment

1) A body travels some distance at 50 km/h and returns at 60 km/h. Find average speed of the whole journey.

2) A body travels 50 km at an average speed of 60 km/h and returns at an average speed of 80 km/h. Find average speed of whole journey.

3) A body travels 50 km at 40 km/h, 60 km at 50 km/h and last 50 km at 60 km/h. Find average speed.

4) A body travels 500 m in 20 minutes, next 200 m in 10 minutes, 2 km in 10minutes and last 20km in 2 hrs. Find average speed of whole journey.

5) A car takes 2 hrs to cover a distance of 100 km, travels next 50 km at 50 km/h and travels at 40 km/h for 10 minutes. Find average speed.

6) A body covers first 100 km at 50 km/h. How fast must it travel next 100 km to make an average of 60 km/h?

7) A body covers 100 km at 60 km/h and next 'x' km at 50 km/h. Find x if average velocity of whole journey is 55km/h.

8) Convert 100 cm/s into (i) km/h (ii) m/s (iii) km/s.

9) The speed of the body decreases from 72 km/h to 54 km/h at retardation of 0.2 m/s^2. Find distance traveled during this time.

10) Speed of the body increases from 18 km/h to 36 km/h in 10 sec. Find acceleration and the distance covered.

11) The speed of body decreases from 72 km/h to 36 km/h in 10 sec. Find distance traveled during this time.

12) A car starts from rest and acquires a velocity of 72 km/h in one and half a minute. Find acceleration and distance covered.

13) A ball weighing 300 gm moving at 15 m/s is stopped after covering a distance of 200 m. Find retardation.

14) In fig.1

(i) What type of motion is represented by OA, AB and BC?

(ii) Find speed of a body when it moves from O to A and A to B.

15) In fig.2

(i) Find acceleration during AB, BC and CD.

(ii) Find distance covered in first two seconds.

(iii) Find distance covered from C to F.

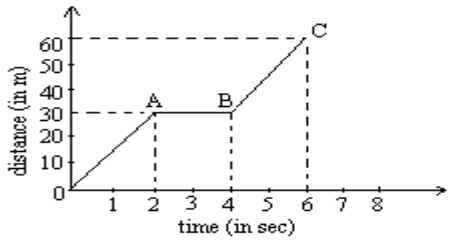


fig 1

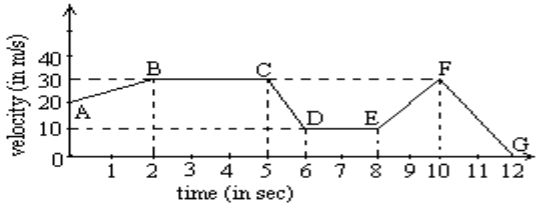


fig 2

16) An object has moved through a certain distance. Can it have zero displacement? Give example.

17) A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be magnitude of displacement of the farmer at the end of

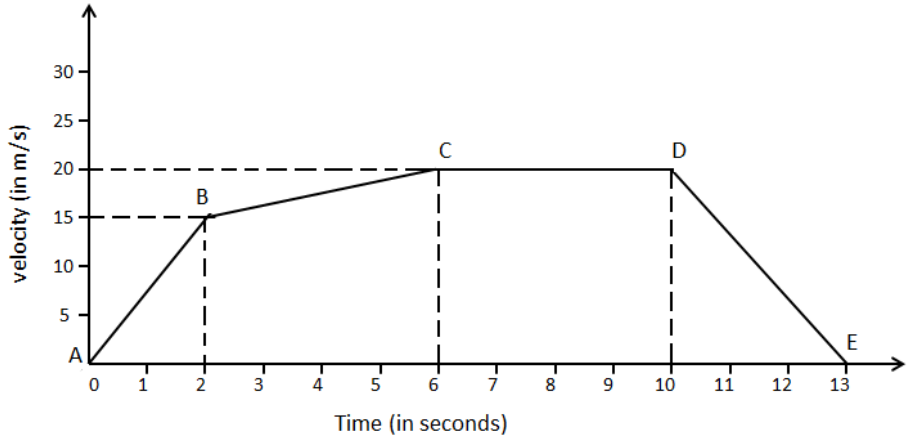
(a) 2 minutes 20 seconds (b) 3 minutes?

18) A body completes 7 rounds of a circular park of radius 14 m. Find the distance and displacement.

19) A body completes 7 and a half rounds of a circular park of radius 14 m. Find the distance and displacement.

20) A body completes one fourth part of a circular park of radius 'r'. Find distance travelled by it and its displacement.

21) Study the following graph and answer the following questions:



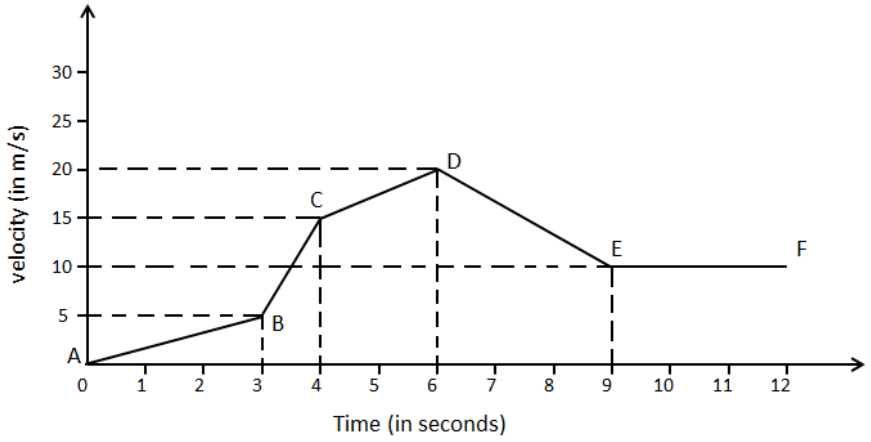
(i) Find acceleration during AB.

(ii) When was acceleration of the body zero?

(iii) When was acceleration of the body negative?

(iv) Find the total distance travelled by a body.

22) Study the following graph and answer the following questions:



(i) Find acceleration during AB, BC, CD, DE.

(ii) Find distance travelled by a body in first 6 seconds.

(iii) Find distance travelled by a body in last 6 seconds.

23) A bus decreases its speed from 80 kmph to 60 kmph in 5 seconds. Find retardation.

24) A train starting from a station and moving with uniform acceleration attains a speed of 40 kmph in 10 minutes. Find its acceleration.

25) Find the distance travelled by a light in 5 minutes.

26) Usha swims in a 90 m long pool. She covers 180 m in one minute by swimming from one end to another and back along the same straight path. Find the average speed and the average velocity of Usha.

27) A bus starting from rest moves with a uniform acceleration of 1 m/s^2 for 0.5 minutes. Find the speed acquired and the distance travelled during this time.

28) A stone is thrown vertically upward direction with a velocity of 5 m/s. If the acceleration of the stone during its motion is 10 m/s^2 in the downward direction, what will be the height attained by the stone and how much time will it take to reach there?

29) A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 m/s^2, with what velocity will it strike the ground?

30) An artificially satellite is moving in a circular orbit of radius 42250 km. Calculate its speed if it takes 24 hours to revolve around the earth.

31) In figure 1, the graph shows the distance time graph of three objects A, B, C. study the graph and answer the following questions.

(a) Which of the three is travelling the fastest?

(b) Are all three ever at the same point on the road?

(c) How far has C travelled when B passes A?

(d) How far has B travelled by the time it passes C?

32) The speed time graph for a car is given in figure 2:

(a) Find how far does the car travel in the first 4 seconds. Shade the area that represents the distance travelled by the car during the period.

(b) Which part of the graph represents the uniform motion of the car?

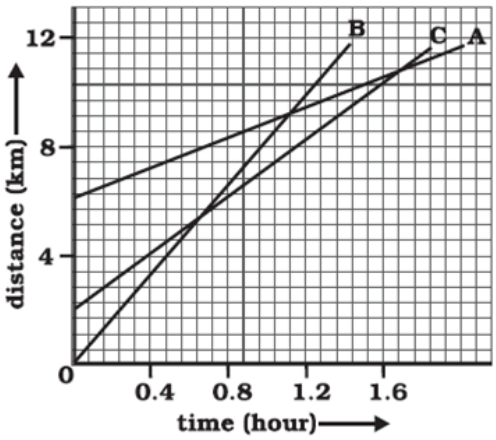


figure 1

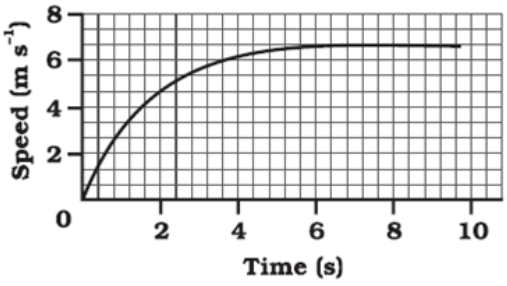


figure 2

33) An electron moving with a velocity of 5×10^4 m/s enters into a uniform electric field and acquires a uniform acceleration of 10^4 m/s^2 in the direction of its initial motion.

(a) Calculate the time in which the electron would acquire a velocity double of its initial velocity.

(b) How much distance the electron would cover in this time?

34) The driver of a train A travelling at a speed of 54 kmph applies brakes and retards the train uniformly. The train stops in 5 seconds. Another train B is travelling on the parallel track with a speed of 36 kmph. Its driver applies the brakes and the train retards uniformly. Train B stops in 10 seconds. Plot the speed time graph for both the train on the same axis. Also find graphically, which of the trains travelled farther after the brakes were applied?

35) Two stones are thrown vertically upwards simultaneously with their initial velocities u_1 and u_2 respectively. Prove that the heights reached by them would be in the ratio $u_1^2 : u_2^2$. Assume upward acceleration is g and downward acceleration to be g.

36) Which of the following is (are) possible?

(a) distance = displacement (b) distance > displacement

(c) distance < displacement (d) speed = velocity

37) Write difference between

(a) distance and displacement (b) speed and velocity

38) When will you say a body is in

(a) uniform acceleration (b) non-uniform acceleration?

39) Draw a rough graph for the following cases:

(i) Distance-time graph for stationary body.

(ii) Distance-time graph for uniform motion.

(iii) Distance-time graph for zero acceleration.

(iv) Velocity-time graph for uniform motion.

(v) Velocity-time graph for uniform acceleration.

(vi) Distance- time graph representing when a body comes at rest after covering a distance of 10km.

(vii) Displacement-time graph showing zero acceleration.

(viii) Velocity-time graph for a body thrown upward.

(ix) Velocity-time graph for a body dropped from some height.

(x) Velocity-time graph for a body whose speed increases from 20 m/s to 30 m/s in 2 sec and then decreases to 10 m/s in 1 sec.

answers

1) 54.5 km/h

2) 68.5 km/h

3) 48.7 km/h

4) 2.36 m/s

5) 49.5 km/h

6) 75 km/h

7) 83.3 km

8) 3.6 km/h, 1 m/s, 0.001 km/s9) 437.5 m

10) 0.5 m/s^2 , 75m

11) 150 m

12) 0.22 m/s^2 , 900 m

13) 0.56 m/s^2

14) (i) uniform, body at rest, uniform

(ii) 15 m/s, 0

15) (i) 5 m/s^2 , 0, – 20 m/s^2

(ii) 50 m

(iii) 80 m

17) (a) $10\sqrt{2}$ m

(b) $10\sqrt{2}$ m

19) 660 m, 28 m

20) $\frac{\pi r}{2}$, $\sqrt{2}r$

21) (i) 7.5 m/s^2

(ii) during CD

(iii) during DE

(iv) 195 m

22) (i) 1.67 m/s^2, 10 m/s^2, 2.5 m/s^2, –3.3 m/s^2, 0 m/s^2

(ii) 52.5 m

(iii) 75 m

23) 1.1 m/s^2

24) 1/54 m/s^2

25) 9×10^{10} m/s

26) 3 m/s, 0 m/s

27) 30 m/s, 450 m

28) 1.25 m, 0.5 s

29) 20 m/s

30) 11065.5 kmph

31) (a) B

(b) no

(c) 9 km (approx)

(d) 6 km (approx)

32) (a) 12.5 m

33) (a) 5s

(b) 3.75×10^5 m

sOmEthIng UsELEss cUm InTErEstIng

odometer

speedometer + odometer ***tachometer*** **Radar gun** (**speed gun**)

Metre	:	SI unit of distance
Actinometer	:	An instrument used to measure intensity of radiation
Ammeter	:	device to measure electrical current.
Anemometer	:	An instrument used to speed of wind or flowing fluid
Barometer	:	An instrument used to measure atmospheric pressure
Calorimeter	:	a vessel used to carry out thermal measurements quantitatively
Dilatometer	:	any apparatus used for studying thermal expansion
Electrometer	:	a device used to measure potential difference between two points
Fluxmeter	:	An instrument used to measure magnetic flux
Frequency meter	:	An instrument used to measure frequency of alternating current
Galvanometer	:	device used to measure very small currents.
Hydrometer	:	an instrument used to measure density of a fluid
Hygrometer	:	An instrument used to measure relative density of the atmosphere
Hypsometer	:	an apparatus used for measuring the boiling point of the liquid
Manometer	:	an instrument used for measurement of pressure
Mass spectrometer	:	device used to measure the mass of atoms or molecules.
Milli-ammeter	:	instrument used to measure very small electric currents
Multimeter	:	an instrument used to measure electrical quantities like resistance, voltage, currents etc.
Odometer	:	an instrument used to measure distance travelled by a body
Potentiometer	:	electrical device with variable resistance; rheostat.
Pyrometer	:	an instrument used for measuring very high temperatures
Radiometer	:	an instrument used to detect and measure infra red radiations.
Refractometer	:	an instrument used to measure refractive index
Sonometer	:	an instrument used to study the vibration of a fixed wire or string
Speedometer	:	an instrument used to speed of a body
Spherometer	:	an instrument used to measure small thickness or the curvature of a spherical surface
Tachometer	:	an instrument used to measure angular speeds
Thermometer	:	a device used to measure temperature of a body
Viscometer	:	an instrument used to measure viscosity of liquid
Voltmeter	:	an instrument used to measure potential difference
Voltameter	:	a container in which electrolysis is done
Watt meter	:	a device used to measure power consumed in an electrical circuit
Wavemeter	:	a device used to measure radio frequencies