**Understanding Motion**

* An object is said to be in motion when its position changes with time.
* We describe the location of an object by specifying a reference point. To describe the position of an object, we need a reference point or origin. An object may seem to be moving to one observer and stationary to another. Motion is relative. The total path covered by an object is said to be the distance travelled by it.
* Example: A passenger inside a bus sees the other passengers to be at rest, whereas an observer outside the bus sees the passengers to be in motion.
* In order to make observations easy, a convention or a common reference point or frame is needed. All objects must be in the same reference frame.
* The shortest path/distance measured from the initial to the final position of an object is known as the displacement. To describe the position of an object we need a reference point or origin. An object may seem to be moving to one observer and stationary to another.
* Example: A passenger inside a bus sees the other passengers to be at rest, whereas an observer outside the bus sees the passengers to be in motion.
* In order to make observations easy, a convention or a common reference point or frame is needed. All objects must be in the same reference frame.

**Distance and Displacement**

* The magnitude of the length covered by a moving object is called distance. It has no direction.
* Displacement is the shortest distance between two points or the distance between the starting and final positions with respect to time. It has magnitude as well as direction.
* Displacement can be zero, but distance cannot.

**Magnitude**

Magnitude is the size or extent of a physical quantity. In physics, we have scalar and vector quantities.

Scalar quantities are only expressed as magnitude. E.g: time, distance, mass, temperature, area, volume

Vector quantities are expressed in magnitude as well as the direction of the object. E.g: Velocity, displacement, weight, momentum, force, acceleration, etc.

**Time, Average Speed and Velocity**

**Time and speed**

Time is the duration of an event that is expressed in seconds. Most physical phenomena occur with respect to time. It is a scalar quantity.

The distance travelled by an object in unit time is referred to as speed. Its unit is m/s.

Speed is the rate of change of distance. If a body covers a certain distance in a certain amount of time, its speed is given by

Speed =

The instantaneous speed is the speed of an object at a particular moment in time.

**Average speed**: For non-uniform motion, the average speed of an object is obtained by dividing the total distance travelled by an object by the total time taken. Average speed is stated as the distance covered by the object within a period of time.

**Average speed** =

The below table lists the difference between Average Speed and Instantaneous Speed.

|  |  |
| --- | --- |
| **Average Speed** | **Instantaneous Speed** |
| It is defined as the total distance travelled divided by the total time elapsed. | It is defined as the speed at a particular instant of time. |
| It is constant | It is not constant |
| Measured by calculating the speed for an entire journey | It is measured by a speedometer |
| Example: A car travelling with a speed of 60 kmph. Thus, the average speed of the car is 60 km an hour | Example: A car travelling at a certain speed at an instant of time can be given by a speedometer. |

**Uniform motion and Non-uniform motion**

When an object covers equal distances in equal intervals of time it is in uniform motion.

Examples of Uniform Motion

* Movement of the ceiling fan’s blades.
* Motion of earth around the sun
* Pendulum with equivalent amplitude on either side

When an object covers unequal distances in equal intervals of time it is said to be in non-uniform motion.

* Bouncing ball
* Running horse
* Moving train

**Velocity**

Velocity is the speed of an object moving indefinite direction. S.I. unit is m/s. The Rate of change of displacement is velocity. It is a vector quantity. Here the direction of motion is specified.

Velocity =

Instantaneous velocity is the rate of change of position for a time interval which is very small i.e. almost zero. In more simple words, the velocity of an object at a given instant of time is known as instantaneous velocity.

Average velocity is defined as the displacement (∆x) divided by the time intervals (∆t) in which the displacement occurs.

Average Velocity =

|  |  |
| --- | --- |
| **Average Velocity** | **Instantaneous Velocity** |
| Average velocity is defined as the displacement (∆x) divided by the time intervals (∆t) in which the displacement occurs. | Instantaneous velocity is the rate of change of position for a time interval which is very small i.e. almost zero. |
| Average velocity is calculated by dividing the rate of displacement by the time elapsed. | Instantaneous velocity is calculated by dividing displacement by time at that instant. |
| If Yashika took a total of 1 hour to travel 10 km from his house to school then his average velocity will be 10 km/hr | In Yashika’s case on his way to school, while he is sitting and waiting for the train to pass his instantaneous velocity will be zero. Though the instantaneous velocity was zero for a small part of the journey, the average velocity will not be zero. |

**Acceleration**

The rate of change of velocity is called acceleration. It is a vector quantity. Its unit is m/s2 .In non-uniform motion, velocity varies with time, i.e., change in velocity is not 0. It is denoted by “a”

Acceleration = Change in Velocity / Time

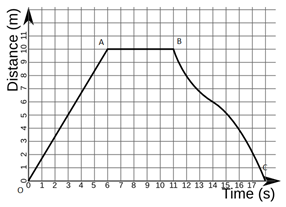
a=

Where, t (time taken), v (final velocity) and u (initial velocity)

**Motion Visualised**

Distance-Time graph

* Distance-Time graphs show the change in position of an object with respect to time.
* Linear variation = uniform motion and non-linear variations imply non- uniform motion
* The slope gives us speed

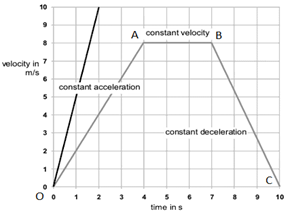


**Distance – Time Graph**

* OA implies uniform motion with constant speed as the slope is constant
* AB implies the body is at rest as the slope is zero
* B to C is non-uniform motion

**Velocity-Time Graph**

* Velocity-Time graphs show the change in velocity with respect to time.
* Slope gives acceleration
* The area under the curve gives displacement
* Line parallel to x-axis implies constant velocity-



Velocity – Time Graph

OA = constant acceleration, AB = constant velocity, BC = constant retardation

**Equations of Motion**

The motion of an object moving at uniform acceleration can be described with the help of three equations, namely

(i) v = u + at

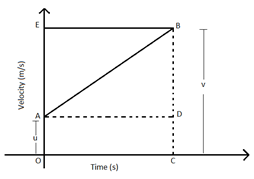
(ii) v2 – u2 = 2as

(iii) s = ut + (1/2)at2

where u is the initial velocity, v is the final velocity, t is the time, a is the acceleration and s is the displacement.

**Derivation of velocity-time relation by graphical method**

**Velocity – Time Graph**



A body starts with some initial non-zero velocity at A and goes to B with constant acceleration a.

From the graph BD = v (final velocity) – DC = u (initial velocity)…………..(eq 1).

BD = BC – DC……………..(eq 2).

**We know acceleration a = slope = BD/AD or Ad=OC = t (time taken to reach point B)**

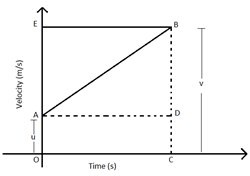
Therefore BD = at………………….(eq 3)

Substitute everything we get : at = v – u.

Rearrange to get v = u + at.

**Derivation of position-time relation by graphical method**

**Velocity – Time Graph**



A body starts with some initial non-zero velocity at A and goes to B with constant acceleration a

Area under the graph gives Displacement as follows:

A(∆ABD) A(OADC)= ½ (AD X BD) + (OA X OC) …. eq(1)

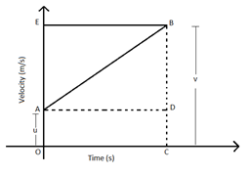
OA = u , OC = t and BD = at

Substituting in (eq 1) we get

S = ut + ½ at2

**Derivation of position-velocity relation by graphical method**

**Velocity – Time Graph**



A body starts with some initial non-zero velocity at A and goes to B with constant acceleration a

Displacement covered will be the area under the curve which is the trapezium OABC.

We know the area of trapezium is

S =

OA = u and BC = v and OC = t

Therefore, S = eq (1)

We also know that

t = eq(2)

Substitute (eq 2) in (eq 1) and arrange to get

v2−u2=2as

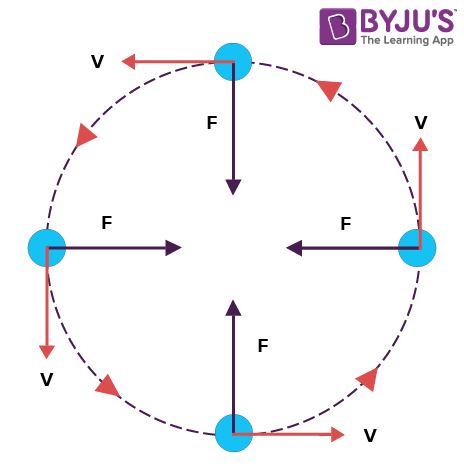
**Uniform Circular Motion**

* If an object moves in a circular path with uniform speed, its motion is called uniform circular motion.
* Velocity is changing as direction keeps changing.
* Acceleration is constant
* The uniform circular velocity is given by the following formula

V =

**Uniform Circular Motion Examples**

* Motion of artificial satellites around the earth is an example of uniform circular motion.
* The motion of electrons around its nucleus.
* The motion of blades of the windmills.
* The tip of second’s hand of a watch with circular dial shows uniform circular motion.



**Question** The phenomenon of motion was placed on a sound scientific footing by two scientists. Write their names.

**Answer**  Galileo Galilei and Isaac Newton.

**Question** Are rest and motion absolute or relative terms?

**Answer** They are relative terms.

**Question**  Suppose a ball is thrown vertically upwards from a position P above the ground. It rises to the highest point Q and returns to the same point P. What is the net displacement and distance travelled by the ball?

**Answer**  Displacement is zero. Distance is twice the distance between position P and Q.

**Question** Which speed is greater: 30 m/s or 30 km/h?

**Answer** 30 m/s

**Question** What do you mean by 2 m/s2?

**Answer** The velocity of the body increases by 2 m/s after every second.

**Question** Can uniform linear motion be accelerated?

**Answer** No

**Question** Define one radian.

**Answer** It is the angle which is subtended at the centre by an arc having a length equal to the radius of the circle.

**Question** What is the relation between linear velocity and angular velocity?

**Answer** Linear velocity = Angular velocity × Radius of circular path.

**Question** Give an example when we infer the motion indirectly.

**Answer** We infer the motion of air by observing the movement of dust particles or leaves and branches of trees, or simply by feeling the blowing air on our face.

**Question** What is essential to describe the position of an object?

**Answer** We need to specify a reference point called the origin.

**Question** What is the simplest type of motion?

**Answer** Motion in a straight line.

**Question** What indicates the motion of the earth?

**Answer** The phenomenon like day and night indicates the motion of the earth.

**Question** If the displacement of a body is zero, is it necessary that the distance coyered by it is also zero?

**Answer** No. When the body comes back to the same position after travelling a distance, its displacement is zero though it has travelled some distance.

**Question** Can the displacement be greater than the distance travelled by an object?

**Answer** No, it is always either equal to or less than the distance travelled by the object.

**Question** When do the distance and displacement of a moving object have the same magnitude?

**Answer** The magnitude of distance and displacement of a moving object are same when the object moves along the same straight line in the same fixed direction.

**Question** Does the speedometer of a car measure its average speed?

**Answer** No. It measures its instantaneous speed.

**Question** A body is moving with a velocity of 10 m/s. If the motion is uniform, what will be the velocity after 10 s?

**Answer** As the motion is uniform, the velocity remains 10 m/s after 10 s.

**Question** Can a body have constant speed but variable velocity?

**Answer** Yes, e.g. a body in uniform circular motion has constant speed but due to the change in the direction of motion, its velocity changes at every point.

**Question** When is the acceleration taken as negative?

**Answer** Acceleration is taken as negative if it is in the direction opposite to the direction of velocity.

**Question** What is uniform acceleration?

**Answer** Acceleration of an object is said to be uniform if it travels in a straight line and its velocity increases or decreases by equal amounts in equal intervals of time.For example, motion of a freely falling body.

**Question** Give an example of non-uniform acceleration.

**Answer** A car is travelling along a straight road increases its speed by unequal amounts in equal intervals of time.

**Question** How are the distances travelled by an object related to the time taken when an object travels equal distances in equal intervals of time?

**Answer** In this case, distance travelled by the object is directly proportional to the time taken.

**Question** What would be acceleration of a body if its velocity-time graph is a line parallel to the time axis?

**Answer** Zero, as the body possesses uniform velocity.

**Question** Is the motion of a body uniform or accelerated if it goes round the sun with constant speed in a circular orbit?

**Answer** It is accelerated, as its velocity changes due to change in direction.

**Question** Give an example of a body which may appear to be moving for one person and stationary for the other.

**Answer** The passengers in a moving bus observe that the trees, buildings as well as the people on the roadside appear to be moving backwards. Similarly, a person standing on the roadside observes that the bus (along with its passengers) is moving in forward direction. But, at the same time, each passenger in a moving bus or train observes, his fellow passengers sitting and not moving. Thus, we can tell that motion is relative.

**Question** How can we describe the location of an object?

**Answer** To describe the position of an object we need to specify a reference point called the origin.

For example, suppose that a library in a city is 2 km north of the railway station. We have specified the position of the library with respect to the railway station i.e., in this case, the railway station acts as the reference point.

**Question** What do you mean by average speed? What are its units?

**Answer** Average speed is defined as the average distance travelled per unit time and is obtained by dividing the total distance travelled by the total time taken. The unit of average speed is the same as that of the speed, that is, ms-1.

**Question** What is the difference between uniform velocity and non-uniform velocity?

**Answer** Uniform velocity: An object with uniform velocity covers equal distances in equal intervals of time in a specified direction, e.g., an object moving with speed of 40 kmh-1 towards west has uniform velocity.

Non-uniform velocity: When an object covers unequal distances in equal intervals of time in a specified direction, or if the direction of motion changes, it is said to be moving with a non-uniform or variable velocity, e.g., revolving fan at a constant speed has variable velocity.

**Question** What do you understand by instantaneous velocity?

**Answer** Instantaneous velocity is the velocity of a body at any particular instant during its motion. For example, the instantaneous velocity of a motorcycle at a particular instant is 40 kmh-1 if it is moving at 40 kmh-1 at that particular instant. It is measured by the speedometers on the vehicles.

**Question** What is negative acceleration?

**Answer** If the velocity of a body decreases with time, then its final velocity is less than the initial velocity and thus its acceleration is negative. Negative acceleration is called retardation or deceleration. For example, when brakes are applied to a moving truck, its velocity gradually decreases. In other words, it is under retardation.

**Question** How will the equations of motion for an object moving with a uniform velocity change? **Answer** Acceleration a = 0, v = u

So, the equations of motion will become

s = ut

v2 – u2 = 0

**Question** Express average velocity when the velocity of a body changes at a non-uniform rate and a uniform rate.

**Answer** When the velocity of a body changes at a non-uniform rate, its average velocity is found by dividing the net displacement covered by the total time taken.

i.e., Average velocity = Net displacement /Total time taken

In case the velocity of a body changes at a uniform rate, then the average velocity is given by the arithmetic mean of initial velocity and final

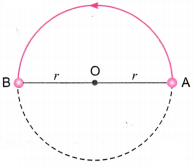
i.e., Average velocity = (Initial velocity + Final velocity)/ 2

**Question** A particle is moving in a circular path of radius r. What would be the displacement after half a circle?

**Answer** Displacement = AB

= Shortest distance between initial and final positions

= r + r = 2r



**Question** A particle is moving in a circular path of radius r. The displacement after half a circle would be:

(a) Zero

(b) π r

(c) 2 r

(d) 2π r

**Answer** (c) 2 r.

**Explanation:**

After half revolution

Distance travelled = X circumference= πr

Path length

Displacement = Final position- Initial Position

It comes out to be the diameter of the circle = 2 r.

**Question** A body is thrown vertically upward with velocity u, the greatest height h to which it will rise is,

(a) u/g

(b) u2/2g

(c) u2/g

(d) u/2g

**Answer** (b) u2/2g.

**Explanation:**

V2= u2+2 as

here v = 0

a = -g

s = H

0 = u² -2gH

H = u²/2g

Question The numerical ratio of displacement to the distance for a moving object is

(a) always less than 1

(b) always equal to 1

(c) always more than 1

(d) equal or less than 1

**Answer** (d) equal or less than 1

**Explanation:**

The shortest distance between the initial and the endpoint is called displacement. Distance is the total path length.

Displacement is vector, and it may be positive or negative, whereas Distance is scalar, and it can never be negative.

The distance can be equal to or greater than displacement, which means the ratio of displacement to distance is always equal to or less than 1.

**Question** If the displacement of an object is proportional to square of time, then the object moves with

(a) uniform velocity

(b) uniform acceleration

(c) increasing acceleration

(d) decreasing acceleration

**Answer** (b) uniform acceleration

**Explanation:**

Velocity is measured in distance/second, and acceleration is measured in distance second2. Hence uniform acceleration is the right answer.

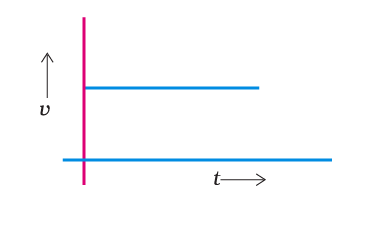
Question From the given v – t graph (Fig. 8.1), it can be inferred that the object is

(a) in uniform motion

(b) at rest

(c) in non-uniform motion

(d) moving with uniform acceleration



**Answer** (a) in uniform motion

**Explanation:**

From the above-given graph, it is clear that the velocity of the object remains constant throughout hence the object is in uniform motion.

Question Suppose a boy is enjoying a ride on a merry-go-round which is moving at a constant speed of 10 m/s. It implies that the boy is

(a) at rest

(b) moving with no acceleration

(c) in accelerated motion

(d) moving with uniform velocity

**Answer** (c) in accelerated motion

**Explanation:**

The boy is moving in a circular motion, and circular motion is an accelerated motion; hence C) is the right answer.

Question Area under a v – t graph represents a physical quantity which has the unit

(a) m2

(b) m

(c) m3

(d) m s–1

**Answer** (b) m

**Explanation:**

The area given in the graph represents Displacement, and its unit is meter. Hence, (b) m.

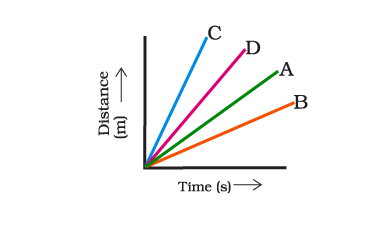
Question Four cars, A, B, C and D, are moving on a levelled road. Their distance versus time graphs are shown in Fig. 8.2. Choose the correct statement

(a) Car A is faster than car D.

(b) Car B is the slowest.

(c) Car D is faster than car C.

(d) Car C is the slowest.

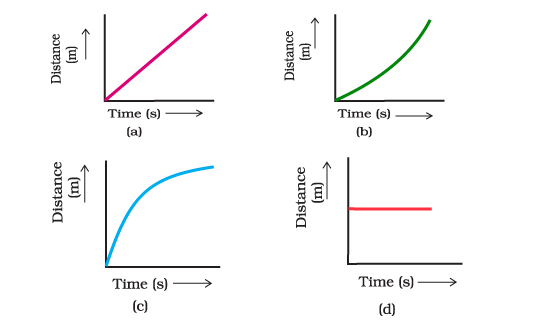
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**Answer** (b) Car B is the slowest.

**Explanation:**

The graph shows that Car B covers less distance in a given time than A, C and D cars hence it is the slowest.

**Question** Which of the following figures (Fig. 8.3) represents the uniform motion of a moving object correctly?

****

**Answer** (a)

**Explanation:**

Distance in graph a) is uniformly increasing with time hence it represents uniform motion.

Question Slope of a velocity–time graph gives

(a) the distance

(b) the displacement

(c) the acceleration

(d) the speed

**Answer** (c) the acceleration

Question In which of the following cases of motions the distance moved and the magnitude of displacement are equal?

(a) If the car is moving on a straight road

(b) If the car is moving in a circular path

(c) The pendulum is moving to and fro

(d) The earth is revolving around the Sun

**Answer** (a) If the car is moving on a straight road

**Explanation:**

In other cases given here, displacement can be less than distance; hence option (a) If the car is moving on a straight road, is the right answer.

Question The displacement of a moving object in a given interval of time is zero. Would the distance travelled by the object also be zero? Justify your answer.

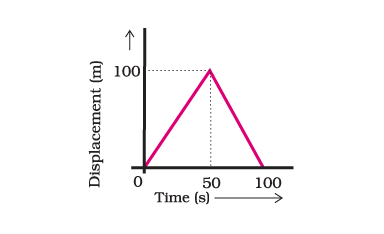
**Answer** Displacement zero does not mean zero distance. The distance can be zero when moving an object back to the place it started. Displacement is either equal to or less than distance, but the distance is always greater than one, and it cannot be a negative value.

**Question** How will the equations of motion for an object moving with a uniform velocity change?

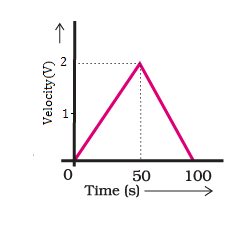
**Answer** If the object is moving with a uniform velocity, then v = µ and a = 0. In this scenario equation for distance is given below.

S= ut and V2– µ2=0

**Question** A girl walks along a straight path to drop a letter in the letterbox and comes back to her initial position. Her displacement–time graph is shown in Fig.8.4. Plot a velocity-time graph for the same.

****

**Answer**



**Question** A car starts from rest and moves along the x-axis with a constant acceleration of 5 m/s2 for 8 seconds. If it then continues with constant velocity, what distance will the car cover in 12 seconds since it started from the rest?

**Answer**

Car Starts from rest hence Initial velocity u=o acceleration a=5 m/s2 and time t=8s

v = u+at

v = 0+5×8

v = 40ms-1

From second equation

s = ut + ½ at2

s = 0x8 + ½ x5x(8)2

s = ½ x5x(8)2

s = ½ x5x64

s = 5×32 =160 is the distance covered in 8 seconds.

Therefore, the total distance covered in 12 seconds  is 160+160=320m

**Question** A motorcyclist drives from A to B with a uniform speed of 30 km/h and returns back with a speed of 20 km h–1. Find its average speed.

**Answer** Let the distance from A to B is D kms.

Distance for the entire journey is 2D kms.

The time taken to go from A to B is D/30 hr, and that of B to A is D/20 hr. So, the total time taken T is

T = (D/30) + (D/20). By solving, we will get,

T = D/12 hrs.

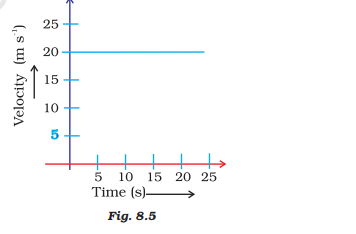
Average speed = Total distance/Total time.

Av.speed = 2D ÷ D/12

=> 2D x 12/D = 24 km/h.

Hence Average speed of the motorcycle is 24 km/h.

**Question** The velocity-time graph (Fig. 8.5) shows the motion of a cyclist. Find (i) its acceleration, (ii) its velocity, and (iii) the distance covered by the cyclist in 15 seconds



**Answer** (i) As velocity is constant, acceleration is 0 m/s2

(ii) Here, the velocity is constant, hence v=20m/s

(iii) s = v x t

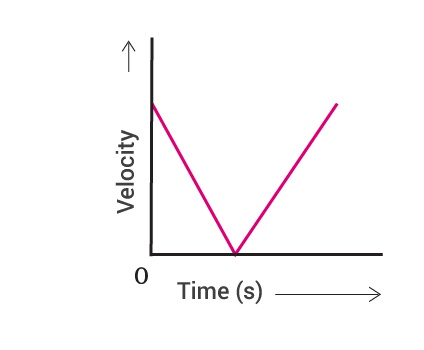
= 20 x 15

= 300 m

**Question** Draw a velocity versus time graph of a stone thrown vertically upwards and then coming downwards after attaining the maximum height.

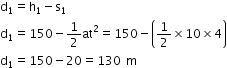
**Answer**

The velocity versus time graph of a stone thrown upwards vertically is as given below:

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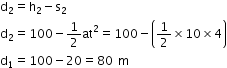
**Question** An object is dropped from rest at a height of 150 m, and simultaneously another object is dropped from rest at a height of 100 m. What is the difference in their heights after 2 s if both the objects drop with the same accelerations? How does the difference in heights vary with time?

**Answer** When two objects fall with the same acceleration simultaneously, after 2 seconds, the difference in their heights will not change, and it remains 50 m.



Therefore the height of the first object after 2 seconds is 130 m.

In the same way, the height of the second object is



Therefore, the height of the second object after 2 seconds is 80 m.

So, the difference is the same, i.e. 50 m.

This concludes that the difference in the height of the two objects does not depend on time and will always be the same.

**Question** An object starting from rest travels 20 m in first 2 s and 160 m in next 4 s. What will be the velocity after 7 s from the start?

**Answer** Here Object starts from rest hence initial velocity u=0 t =2s and s=20 m

According to the second equation of motion s= ut+at2

S = 0+ ½ ax22

20 = 2+ ½ ax22= 2a

= 20/2

a = 10m/s

According to the first equation of motion velocity after 7 s from the start

V = u+at

V = 0+10×7

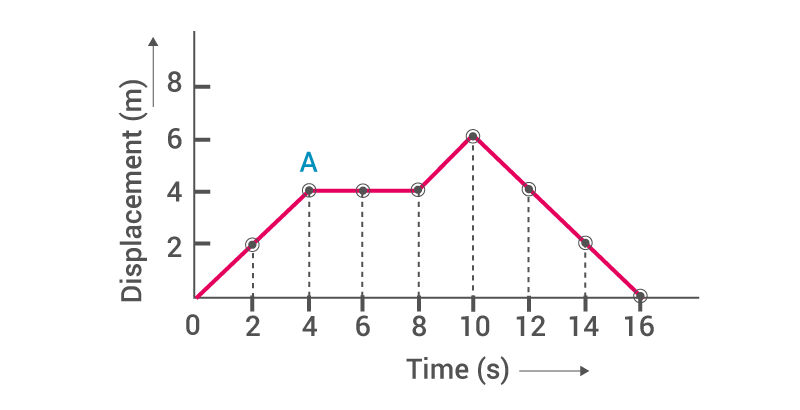
V = 70m/s

**Question** Using the following data, draw time-displacement graph for a moving object:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Time(s) | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
| Displacement(m) | 0 | 2 | 4 | 4 | 4 | 6 | 4 | 2 | 0 |

Use this graph to find the average velocity for the first 4 s, for the next 4 s and for the last 6 s.

**Answer**

****

Average velocity for the first 4s =

= (4-0)/(4-0)=4/4 = 1ms-1

Average velocity of next 4 s = V =

=0

Average velocity for last 6 s =

=

= 1 ms-1

**Question** An electron moving with a velocity of 5 × 104 m/s enters into a uniform electric field and acquires a uniform acceleration of 104 ms-2 in the direction of its initial motion.

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

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

**Answer**

Given initial velocity, u = 5 × 104 m/s  and acceleration, a = 104ms-2

(i) final velocity = v = 2 u = 2 × 5 ×104 m/s =10 × 104 m/s

To find t,      use  v  =  at  or t = u – u / a = (5 × 104)/104

=5s

(ii)   Using s = ut + ½ at2  = (5 ×104) × 5 + ½ (10 ) × (5)2

= 25 ×104 + 25 /2 ×104

= 37.5×104 m

**Question** Obtain a relation for the distance travelled by an object moving with a uniform acceleration in the interval between the 4th and 5th seconds.

**Answer**

a = dv/dt

Assume that air resistance is nil.

We can directly contain it by using Newton’s equations of motion or from the below-mentioned method:

Thus, the area under the v-t curve and the x-axis where the slope of the curve is the instantaneous acceleration.

In this case, acceleration g is constant, and due to the free-fall condition, the initial velocity is zero. Therefore the v-t curve is a straight line with a slope equal to g equal to 9.81 m/s  passing through the origin.

On dividing the total area under the curve into the interval of unit seconds, then we initially obtain a triangle followed by trapeziums of increasing height.

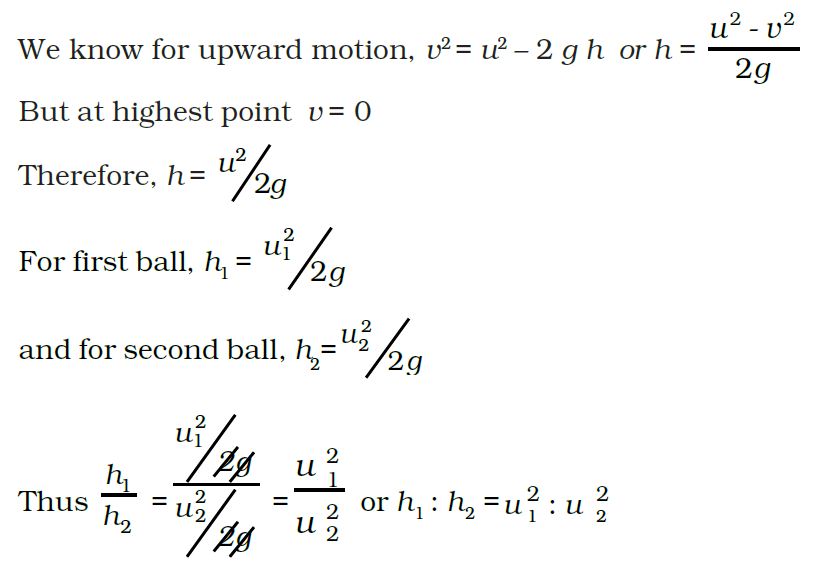
The ratio of the area of the first triangle to the second triangle to the third triangle is equal to the ratio of displacement in the first, second and third second. We get ratio equal to 1:3:5:7:9…  and so on.

For the 4th & 5th second, it is 7:9.

**Question** Two stones are thrown vertically upwards simultaneously with their initial velocities u1 and u2, respectively. Prove that the heights reached by them would be in the ratio of u1² :u2²

(Assume upward acceleration is –g and downward acceleration is +g ).

**Answer**

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