1. Details of Module and its structure

Module Detail	
Subject Name	Physics
Course Name	Physics 01 (Physics – Part 1, Class XI)
Module Name/Title	Unit 2, Module 2, **Distance and Displacement** Chapter 3, Motion in a Straight Line
Module Id	Keph_10302_eContent
Pre-requisites	Rest and motion, basic mathematics, co-ordinate system, frame of reference, kinematics
Objectives	**After going through this module, the learners will be able to:** • Understand motion as change of position with time • Distinguish between distance travelled, path length and displacement • Know that displacement can be negative, zero or positive • Describe motion by position time and displacement time graphs
Keywords	Distance, displacement, position time and displacement time graphs

2. Development Team

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TABLE OF CONTENTS:

1. UNIT SYLLABUS

This unit will be covered in two parts:

Chapter 3: Motion in a straight line

Frame of reference, motion, position –time graph Speed and velocity
Elementary concepts of differentiation and integration for describing motion, uniform and non-uniform motion, average speed and instantaneous velocity, uniformly accelerated motion, velocity –time and position time graphs relations for uniformly accelerated motion - equations of motion (graphical method).

Chapter 4: Motion in a plane

Scalar and vector quantities, position and displacement vectors, general vectors and their notations, multiplication of vectors by a real number , addition and subtraction of vectors, relative velocity, unit vector, resolution of a vector in a plane , rectangular components ,scalar and vector product of vectors.
Motion in a plane, cases of uniform velocity and uniform acceleration projectile motion uniform circular motion.

2. MODULE-WISE DISTRIBUTION OF UNIT SYLLABUS 10 Modules

The above unit is divided into 10 modules for better understanding.

Module 1	• Introduction to moving objects • Frame of reference, • limitations of our study • treating bodies as point objects
Module 2	• Motion as change of position with time • Distance travelled unit of measurement • Displacement negative, zero and positive • Difference between distance travelled and displacement • Describing motion by position time and displacement time graphs
Module 3	• Rate of change of position • Speed • Velocity • Zero , negative and positive velocity • Unit of velocity • Uniform and non-uniform motion • Average speed • Instantaneous velocity • Velocity time graphs • Relating position time and velocity time graphs
Module 4	• Accelerated motion • Rate of change of speed, velocity • Derivation of Equations of motion
Module 5	• Application of equations of motion • Graphical representation of motion • Numerical

Module 6	• Vectors • Vectors and physical quantities • Vector algebra • Relative velocity • Problems
Module 7	• Motion in a plane • Using vectors to understand motion in 2 dimensions' projectiles • Projectiles as special case of 2 D motion • Constant acceleration due to gravity in the vertical direction zero acceleration in the horizontal direction • Derivation of equations relating horizontal range vertical range velocity of projection angle of projection
Module 8	• Circular motion • Uniform circular motion • Constant speed yet accelerating • Derivation of $a = \frac{v^2}{r} or\ \omega^2 r$ • direction of acceleration • If the speed is not constant? • Net acceleration
Module 9	• Numerical problems on motion in two dimensions • Projectile problems
Module 10	• Differentiation and integration • Using logarithm tables

MODULE 2

3. WORDS YOU MUST KNOW

Let us remember the words we have been using in our study of this physics course

- Rigid body: an object for which individual particles continue to be at the same separation over a period of time
- Point object: if the position of an object changes by distances much larger than the dimensions of the body the body may be treated as a point object
- Frame of reference: any reference frame the coordinates(x, y, z), which indicate the change in position of object with time
- Inertial frame: is a stationary frame of reference or one moving with constant speed in a particular direction
- Observer: someone who is observing objects
- Rest: a body is said to be at rest if it does not change its position with respect to its surroundings with time
- Motion: a body is said to be in motion if it changes its position with respect to its surroundings with time
- Time elapsed: time interval between any two observations of an object
- Motion in one dimension: when the position of an object can be shown by change in any one coordinate out of the three (x, y, z), also called motion in a straight line
- Motion in two dimension: when the position of an object can be shown by changes any two coordinate out of the three (x, y, z), also called motion in a plane
- Motion in three dimension : when the position of an object can be shown by changes in all three coordinate out of the three (x, y, z)

4. INTRODUCTION

Earlier you learnt that motion is change in position of an object with time. In order to specify position, we need to use a reference point and a set of axes. It is convenient to choose a rectangular coordinate system consisting of three mutually perpendicular axes, labeled x-x’, y-y’, and z-z’axes.

The point of intersection of these three axes is called origin (0, 0, 0) and serves as the **reference point**.

The coordinates (x, y, z) of an object describe the position of the object with respect to this coordinate system. **To measure time, we use a clock in the frame of reference.**

If one or more coordinates of an object change with time, we say that the object is in motion. Otherwise, the object is said to be at rest with respect to this frame of reference.

The choice of a set of axes in a frame of reference depends upon the situation. For example, for describing motion in one dimension, we need only one axis. To describe motion in two/three dimensions, we need a set of two/three axes.

We have said earlier, description of an event depends on the frame of reference chosen for the description. For example, when you say that a car is moving on a road, you are describing the car with respect to a frame of reference attached to you or to the ground; but with respect to a frame of reference attached with a person sitting in the car, the car is at rest.

In this module, we are only considering rectilinear motion or motion in a straight line or motion in one dimension.

5. MOTION AS CHANGE OF POSITION WITH TIME

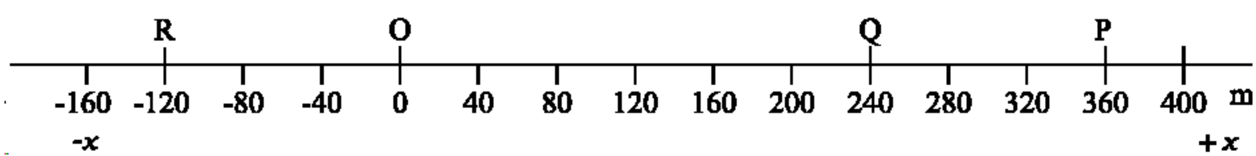
To describe motion along a straight line, we can choose an axis, say X-axis, so that it coincides with the path of the object.

We then measure the position of the object with reference to a conveniently chosen origin, say O, as shown in Fig. Positions to the right of O are taken as positive and to the left of O, as negative.

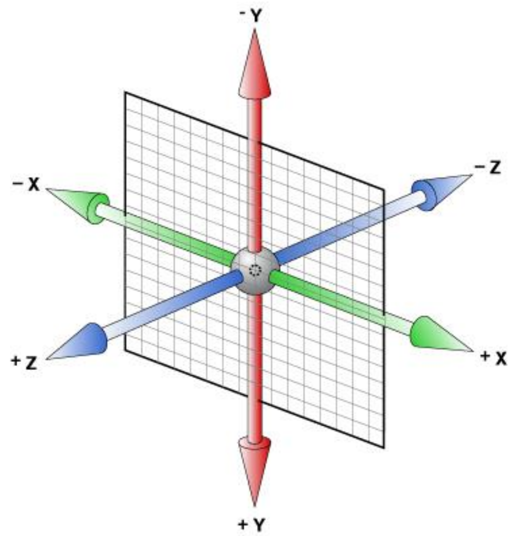
Example of using a number line

Following this convention, the position coordinates of point P and Q in Fig. are + 360 m and +240 m.

Similarly, the position coordinate of point R is –120 m.



Of course, our number line can rotate in any direction, so long as the x-x' rotate with it is of little consequence.



However for simplicity number lines are usually drawn horizontal in books and by teachers. The figure will help you imagine this.

Limiting ourselves now, we consider motion in a straight as observed by a stationary observer.

We begin our study of motion in the simplest terms possible - motion that takes place along a straight line. And our observer is in a fixed frame and stationary. A car traveling on a straight roads observed by a man standing on the roadside is an example of this kind of motion. The tip of a pencil when you draw a straight line is this kind of motion.

We define the position of the car at a point and treat it as though it was moving on a number line

To make the consideration simple we make the following assumptions

- **the earth is at rest**
- **the body is rigid and is a point object**
- **all other influences are neglected**

So we are working in **isolation with just our object**, **which is rigid and moves along a straight line in 1dimension**

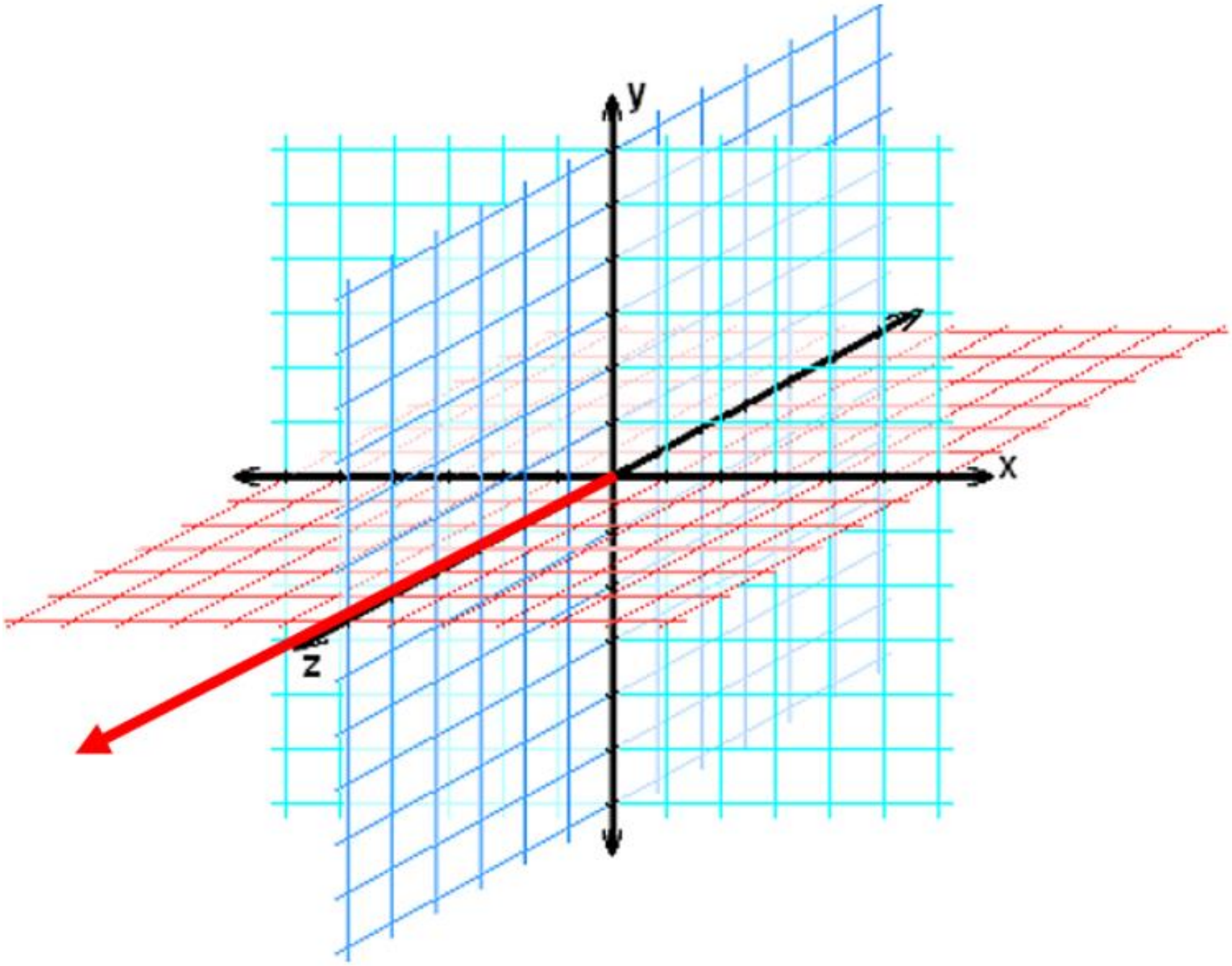
Do you think?

Even slant line tracks or paths may be considered as motion in one dimension?

The answer is yes,

We just have to imagine the coordinate axis attached to be along the line.

Different straight line paths are drawn along with the coordinate axis attached to them


y
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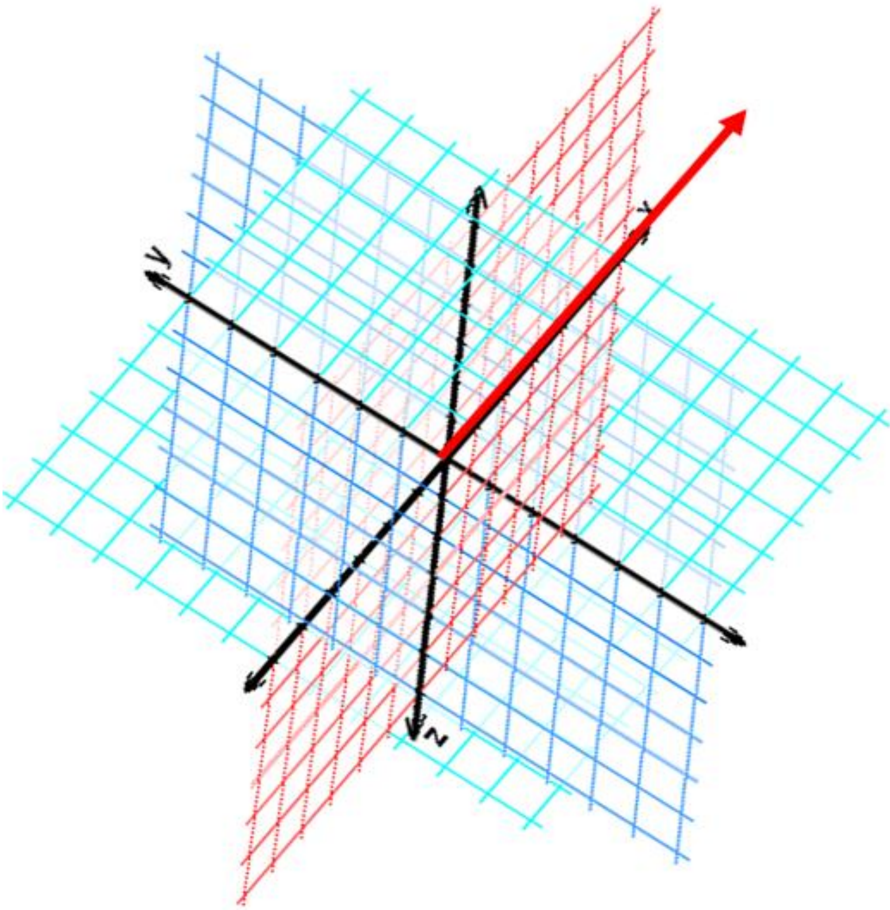
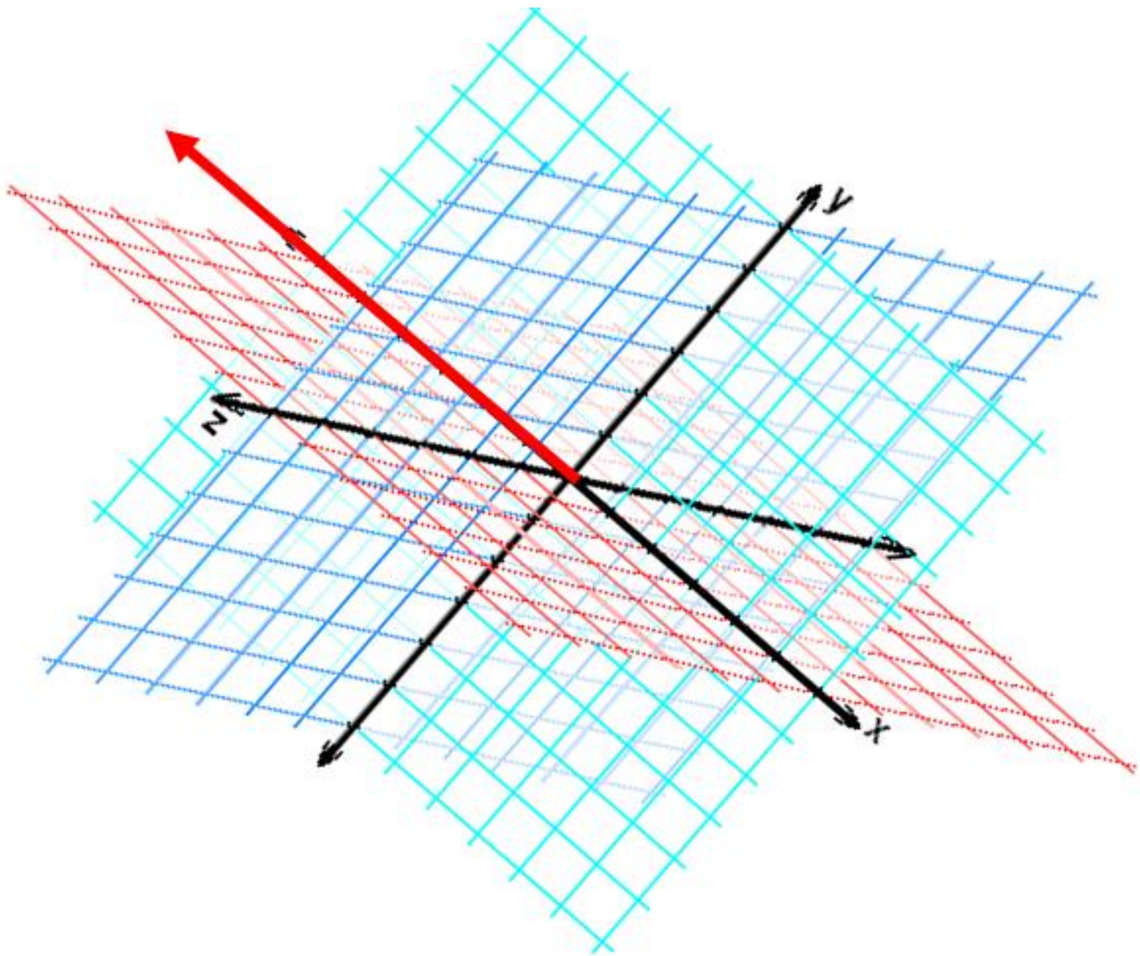




Check your understanding

Identify motion in one dimension in a game of Cricket

1. An ant moving on a rope tied along the diagonal of an enclosure for spectators
2. Spinning cricket ball that turns sharply on hitting the bat
3. An ant moving on a stationary cricket ball.
4. Stumps flying off after being hit by the ball.
5. Motion of the ball as observed by a bird sitting on the field camera capturing the game
6. Motion of a cricket ball rolling on the ground towards the boundary by an observer dancing with joy

7. Motion of a cricket ball, after delivery by the bowler as observed by the stump camera.
8. Motion of a running fielder
9. Motion of a running bowler
10. Motion of a camera stand.

6. DISTANCE TRAVELLED- CHANGE IN POSITION

When an object moves, its position coordinates change. In one dimensional motion, only one position coordinate changes along any of x, y or z axis.

Its position may be described in many ways:

1. If x_1 is the initial position of an object at time t_1, and x_2 is the final position at time t_2

Or

2. x(0) is the position at instant zero which is when we start considering the motion, and x(t) the position at instant t,

So

3. x(t) which means position at instant t

x (-t) would be a position before we start considering the motion.

We can say distance travelled is $x(t_2) – x(t_1)$ in time interval (t_2-t_1) or

x(t) - x(0) in time interval (t-0)

The actual distance covered is called **Path length** and is a scalar quantity.

Its S.I. unit is meter (m).

7. CHANGE IN POSITION IN A PARTICULAR DIRECTION - DISPLACEMENT

If same distance is covered in many directions, they are significant because in each case direction is different.

The distance covered in a particular direction is called displacement, its unit is m but direction must be specified.

Displacement suggests the final position of the object at the end of a certain time interval, with respect to the initial position

Physical quantities are classified as scalar and vector

- Scalar**:** quantities that indicate only to magnitude.
- Vector**:** quantities for which the description is incomplete without referring to direction along with magnitude

Therefore, displacement is a vector quantity

Check your understanding

EXAMPLE

1. **Which statement best describes a vector quantity?**

a. A bus covering a distance of 50 km on a highway

b. A bus covering a distance of 50km

c. A bus heading towards the east covering a distance of 50 km

SOLUTION

(c), since both magnitude and direction are given. Distance is considered the scalar component of displacement.

EXAMPLE

Is time a scalar or a vector quantity?

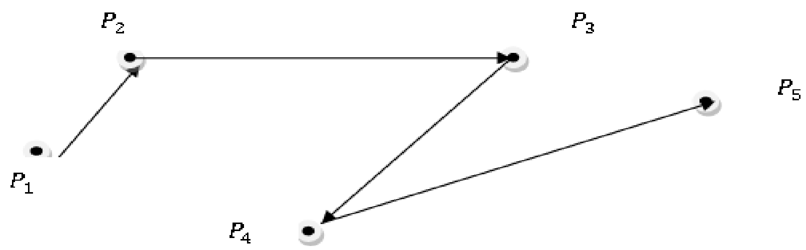
SOLUTION

Scalar We do not associate any direction with time. This is not to say that t = -3.0 s has no meaning. It simply refers to a situation that occurred three seconds before our observation began.

It does not imply that we can move backward in time. So the notion of past present and future are not directions.

8. DISPLACEMENT NEGATIVE, ZERO AND POSITIVE

Distance is a scalar quantity giving the positive length between two points. The total length for a series of distances can be computed by adding the absolute values of each length segment.



$$X = |P_1 - P_2| + |P_2 - P_3| + \ldots$$

Displacement is the final position – initial position = $X_f - X_i$

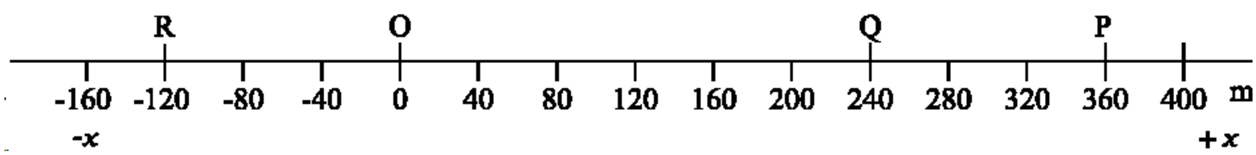
X_f is the final position

X_i is the initial position of the object.

Distance is always positive, but displacement can be positive, negative or zero.

Think about it the use of negative signs in physics typically indicates direction, rather than quantity. A position of -3 units is not a larger position than -5 units, even though mathematically, negative three is larger than negative five.

From our number line distance OP



The displacement has a magnitude of 360 m and is directed in the positive x direction as indicated by the + sign.

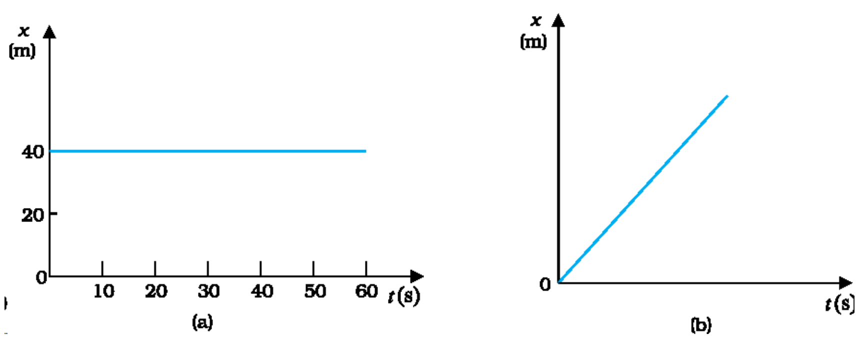
Similarly, the displacement of the car from P to Q

Displacement is the final position – initial position = $X_f - X_i$

= 240 m – 360 m = – 120 m. The negative sign indicates the direction of displacement. **Thus, it is not necessary to use vector notation for discussing motion of objects in one-dimension.**

9. DESCRIBING MOTION BY POSITION TIME AND DISPLACEMENT TIME GRAPHS

Motion of an object can be represented by a position-time graph as you have already learnt about it. Such a graph is a powerful tool to represent and analyze different aspects of motion of an object. For motion along a straight line, say X-axis, only x-coordinate varies with time and we have an x - t graph. Let us first consider the simple case in which an object is stationary, e.g. a car standing still at x = 40 m. The position-time graph is a straight line parallel to the time axis, as shown in Fig. (a).

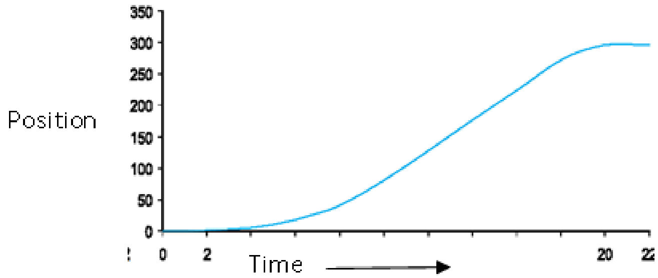


If an object moving along the straight line covers equal distances in equal intervals of time, it is said to be in **uniform motion** along a straight line. Fig.(b) shows the position-time graph of such a motion.

EXAMPLE

Let us consider the motion of a car that starts from rest at time t = 0 s from the origin O and picks up speed till t = 10 s and thereafter moves with uniform speed till t = 18 s. Then the brakes are applied and the car stops at t = 20 s and x = 296 m.

SOLUTION



EXAMPLE

Savita lives on the same road as her school. She cycles two km in 10 minutes to reach the school. She spends 5 mins in school and realizes that she has forgotten her physics copy at home, she returns home again covering 2 km in 10 mins.

How should the data be graphed to show Savita's motion?

Which of the two graphs below are correct and why?

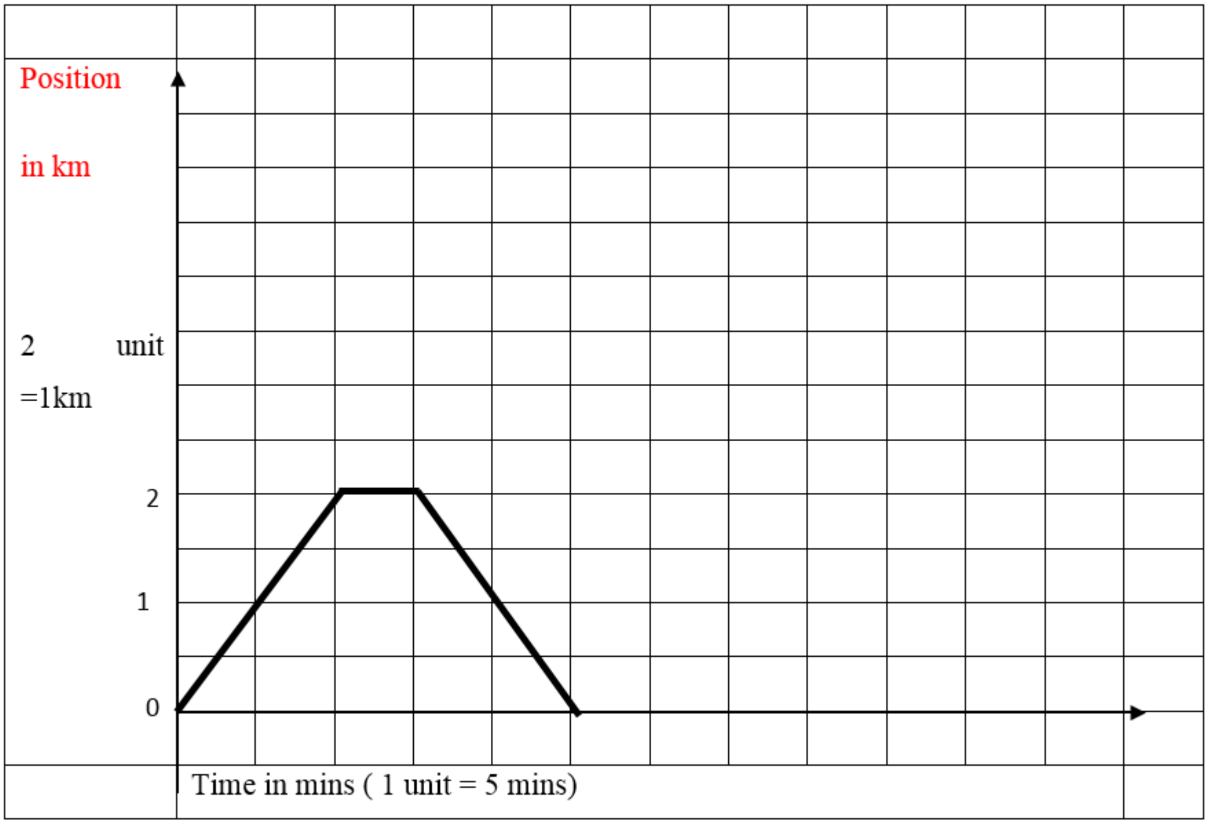
SOLUTION

Graph 1

Notice In a distance time graph

we will have distance on the y axis and time on the x axis , even when we say we are moving in a straight line along the x direction

Graph 2



Graph 1: **This graph shows how Sativa travelled, her minute to minute distance from the start of motion, what it does not display is the position of Savita at the end of 25minutes**

Graph 2: This graph shows Savita's position. You can tell from the graph that she has returned home. However, determining the distance she travelled from this graph is not that obvious.

Both of these graphs are correct, but they provide different information.

Graph 1 displays the distance travelled by Savita as a function of time,

Graph 2 displays the position of Savita as a function of time.

Using Graph 2, the total distance Savita travelled can be found by adding up the segments of her motion, while her final position can immediately read from the graph. Though the total distance travelled by Savita can immediately be read from the graph 1, but there is no way to determine her final position. For this Graph 2 the position versus time graph, is more useful.

EXAMPLE

Under what condition will the numerical values of distance and displacement be equal?

SOLUTION

As long as all of the motion takes place in only one direction.

10. USING GEO GEBRA FOR PLOTING GRAPHS

Geo gebra is a mathematical app which allows us to do several mathematical operations

Graphing is one of them

EXAMPLE

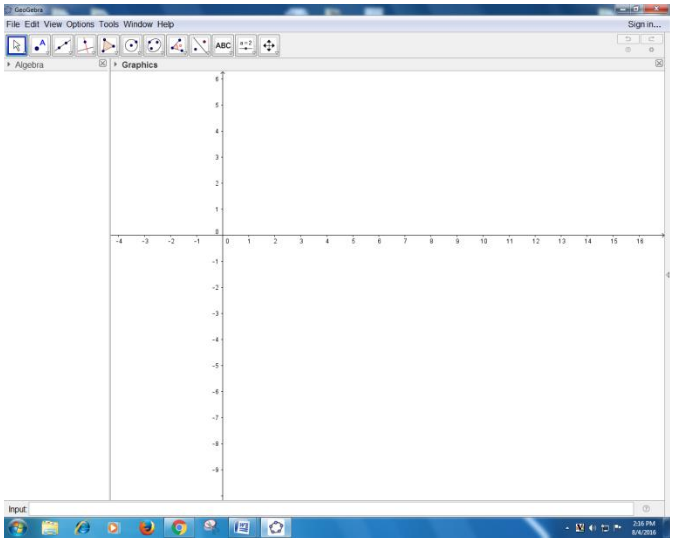
A drunkard walking in a narrow lane takes 5 steps forward and 3 steps backward, followed again by 5 steps forward and 3 steps backward, and so on. Each step is 1m long and requires 1 s. Plot the *x-t* graph of his motion. Determine graphically and otherwise how long the drunkard takes to fall in a pit 13 m away from the start

SOLUTION

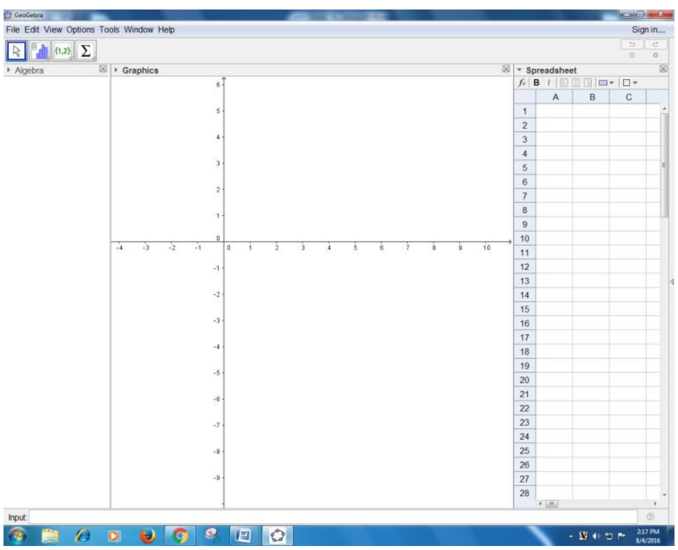
Use Geo Gebra app to view the graph

Search for Geo gebra app

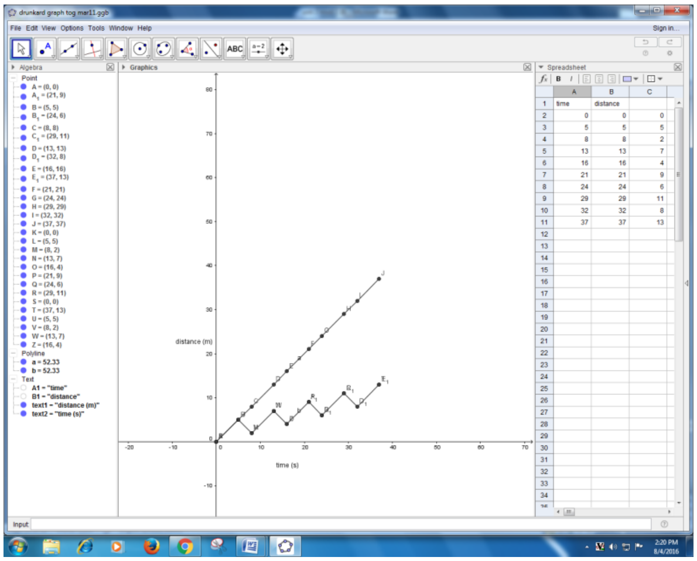
You need to download it, it's free



Go to view, click, choose spread sheet

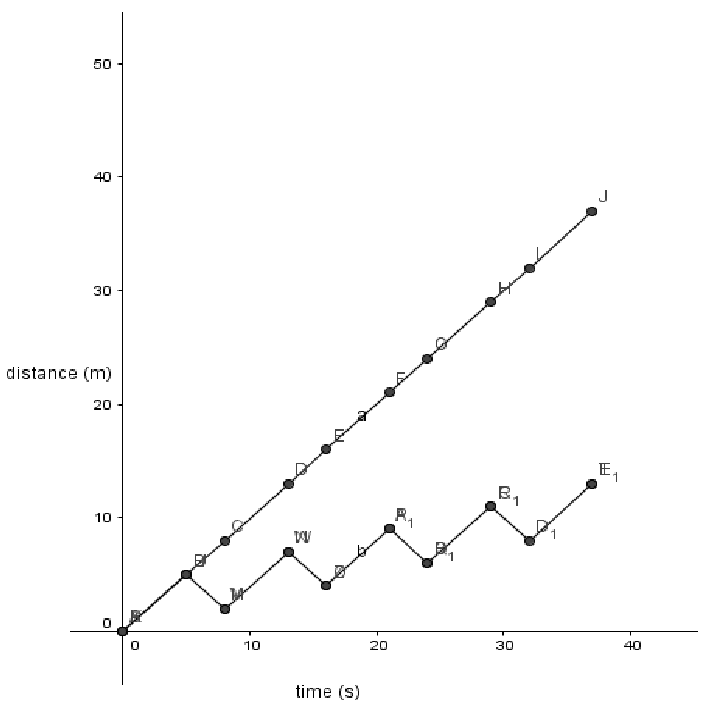


Fill the data keeping in mind the position of the man at the end of the time interval example at the end of 5s +3 s the man is at a displacement of 5m - 3m = 2m from the start point



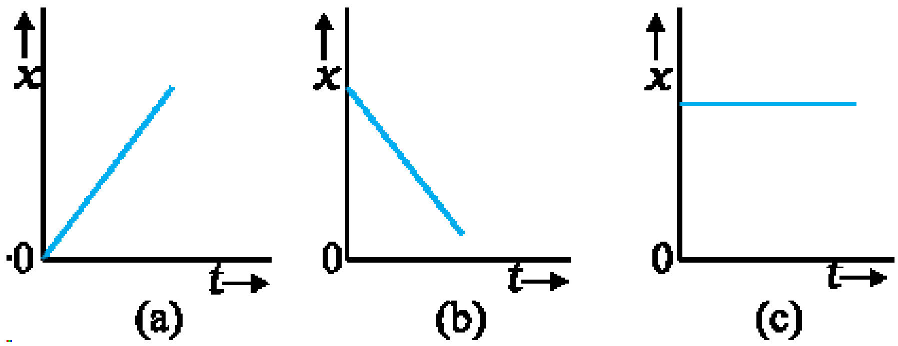
Select data right click choose create, polyline

The graph generated may be zoomed in or out for better visibility



EXAMPLE

Consider the graphs given below and answer the questions that follow giving reasons



i) **Which graph shows a body at rest?**

ii) **What is the difference between graph (a) and graph (b)?**

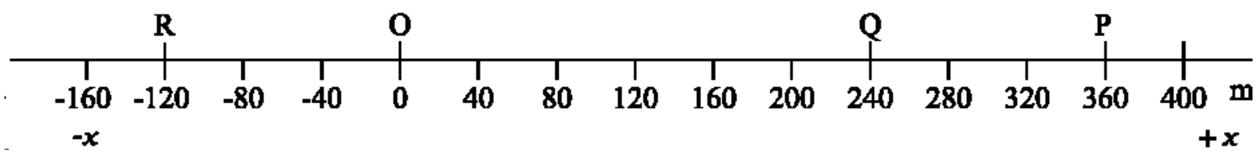
iii) **Can these graphs be used to show motion along y and z directions as well? Explain.**

SOLUTION

i) Graph (c) shows that the body is located at one location even when time is changing so it must be a body that does not change its position with respect to its surroundings with passage of time.

ii) Graph (a) shows the distance from 0 increasing with time or we can say the object is moving in a chosen positive direction with respect to a fixed reference point 0

Graph (b) on the other hand is showing the distance decreasing or the object moving towards the reference fixed point 0



Probably our object is moving from O to Q in the first graph and from Q to O in the second

iv) Yes the graph can be used to show motion in one dimension.

TRY YOURSELF:

1. **What is meant by position?**
2. **Can two objects be at the same distance from a single point but be in different positions? Why or why not?**
3. **What is the difference between distance and displacement?**
4. **Does distance have direction? Does displacement have direction?**
5. **A squirrel is 2m away from a fruit tree, a fruit falls to the ground it rushes 3 m away from the tree then 4m towards the tree and finally 5m away for another fallen fruit. What is its total distance travelled, what is its displacement from the original position? Assume all movement along a straight line. Will your answers change if the squirrel moves at different speeds between intermediate positions?**

11. SUMMARY

In this module we have learnt

- The path length traveled by an object moving in any direction or even changing direction is called distance.
- Distance travelled, which is the path length is always positive; it could be the sum of small path lengths covered by an object over a period of time.
- The location of an object in a frame of reference is called position.
- For straight line motion, positions can be shown using a number line.
- The separation between original and final position is called displacement.
- A distance time graph and a position time graphs show motion at a glance.
- These graphs can be made on graph paper or by using Geo Gebra app.