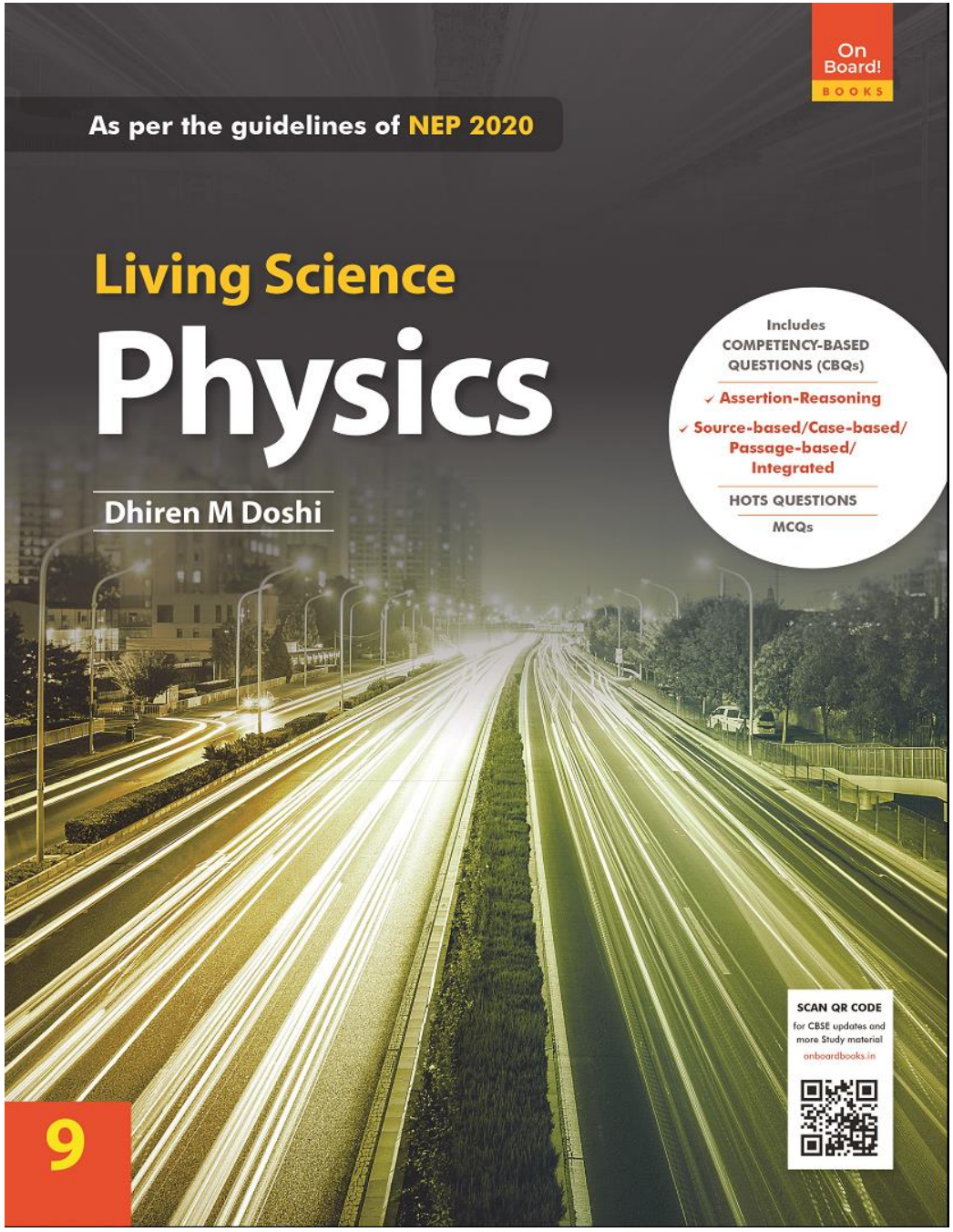


CBSE
Living Science
Physics

Class 9

Chapter-1 Motion

LEARNING OBJECTIVES

Concept of Rest and Motion

- **Rest and motion are relative terms**
- **Types of motion**

Scalar and Vector Quantities

- **Scalar quantity**
- **Vector quantity**

Concept of Distance and Displacement

Uniform and Non-Uniform Motion

Speed and Velocity

- **Speed and average speed**
- **Velocity, uniform velocity, variable velocity, and average velocity**

Acceleration

- **Positive and Negative Acceleration,**
- **Uniform acceleration and Non-uniform acceleration**

Graphical Representation of Motion

Uniform Circular Motion

What is the Concept of Rest and Motion?

A body is said to be at rest if it does not change its position with respect to a fixed point, taken as a reference point in its surroundings, with the passage of time.

A body is said to be in motion if it changes its position continuously with respect to a fixed point, taken as a reference point in its surroundings, with the passage of time.

Rest and Motion are Relative Terms

An object can be in motion in relation to one object while it can be at rest in relation to another object at the same instant of time.

Types of motion

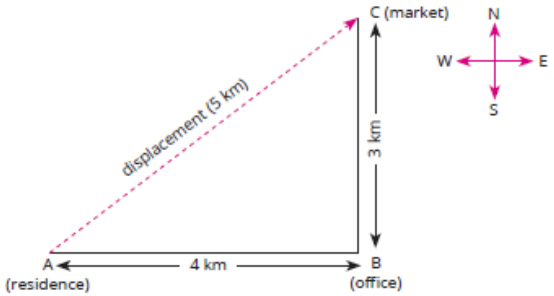
A car moving on a straight road is said to have **rectilinear motion.** A javelin or shot-put thrown by an athlete moves along a curved path and is said to have **curvilinear motion.** The blades of a fan rotate around a fixed point and therefore have **rotatory motion.** The pendulum of a clock moves to and fro about its mean position and is said to have **oscillatory motion.** The motion of a sitar string when plucked exhibits **vibratory motion.** Sometimes an object possesses two or more types of motions at the same time. Such motion is called **multiple motion.** For example, when a car moves on a straight road its wheels exhibit two types of motion, i.e. rotatory motion as well as rectilinear motion.

Scalar and Vector Quantities

A physical quantity which is described completely by its magnitude (or size) is called a scalar quantity. A physical quantity which is described completely by its magnitude (or size) as well as its direction is called a vector quantity.

Concept of Distance and Displacement

The actual length of the path travelled by a moving body in a given interval of time is called the **distance** travelled by that body. It is a scalar quantity and its value can never be zero or negative during the motion of the body. In the SI system, the unit of distance is metre (m).



Representation of displacement

When a body moves from one position to another, the shortest distance (straight distance) measured between the initial and the final positions of the body in a particular direction is called its **displacement.**

The actual length of the path travelled by the person to reach C, starting from A is AB + BC = 4 km + 3 km = 7 km, irrespective of the direction in which he travels. So, 7 km is the distance travelled by him.

The displacement of the person is AC which can be calculated by Pythagoras' theorem, i.e.

$$AC = AB^2 + BC^2 = \sqrt{4^2 + 3^2}$$

$$= \sqrt{16 + 9} = \sqrt{25} = 5 \text{ km}$$

Note: **Refer to Table 1.1 for Differences between distance and displacement**

Uniform and Non-Uniform Motion

A body is said to be in **uniform motion** if it covers equal distances in equal intervals of time, no matter how small these time intervals may be.

Examples of uniform motion

1. The movement of hands of watches.
2. The movement of the earth about its axis
3. The movement of the earth around the sun
4. A gas molecule is in uniform motion between collisions.

The distance–time graph for a body having uniform motion is a straight line.

A body is said to be in **non-uniform motion** if it covers unequal distances in equal intervals of time, however small these time intervals may be.

Examples of non-uniform motion

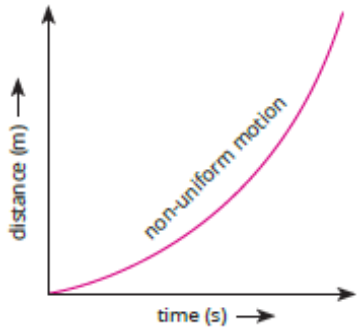
1. A train leaving a railway station covers larger distances in equal intervals of time, conversely when it approaches a station, it covers smaller distances in equal intervals of time.

2. A free-falling stone under the action of gravity.
3. When brakes are applied to a speeding car.

Average Speed

The average speed of a body is the total distance travelled by the body divided by the total time taken to cover this distance, i.e.

Average speed = Total distance travelled / Total time taken



The distance–time graph of a body having non-uniform motion is a curved line.

Speed and Velocity

Speed

The **speed** of a body is the distance travelled by it per unit time. The speed of a body can be calculated by dividing the distance travelled by the body by the time taken by it to cover that distance. So,

Speed = Distance travelled/Time taken

or $v = s / t$

The SI unit of speed is metre per second written as m s^{-1} or m/s.

The speed of fast moving bodies like cars, trains and planes is expressed in **kilometre per hour** written as km h–1 or km/h.

Velocity

The velocity of a body is the distance travelled by it per unit time in a definite direction.

Velocity = Distance travelled in a definite direction / Time taken

Since the distance in a particular direction is called displacement, the velocity of a body can also be defined as the displacement per unit time. Velocity has both magnitude and direction, so velocity is a **vector quantity.**

The units of velocity are the same as those of speed.

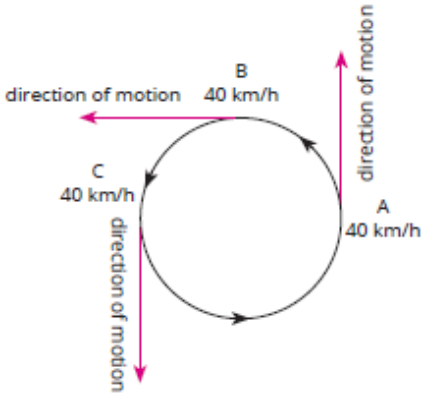
Thus, SI unit of velocity is **m s^{-1}** or **m/s.**

Uniform and Variable velocity

A body is said to have **uniform velocity** if it covers equal distances in equal intervals of time in a particular direction, however small these time intervals may be. A body is said to have **variable velocity** if it covers unequal distances in equal intervals of time in a particular direction, however small these intervals may be or if it covers equal distances in equal intervals of time but its direction keeps on changing.

Examples of objects showing variable velocity

1. A car moving on a crowded road
2. A man running on a circular track with constant speed
3. The rotating blades of a ceiling fan
4. The motion of the earth around the sun
5. The motion of the moon around the earth



Average velocity

When velocity of a moving body changes continuously at a uniform rate, then the average velocity is given by the arithmetic mean of initial and final velocities for a given period of time, i.e.

Average velocity = (Initial velocity + Final velocity) / 2

Mathematically, $v_{av} = (u + v) / 2$

where v_{av} = average velocity

Note: Refer to Table 1.3 for Comparison between speed and velocity

Acceleration

Acceleration = Change in velocity / Time taken to change

The rate of change of velocity of a body with respect to time is called its acceleration. $a = (v - u) / t$ Therefore, in the SI system, the unit of acceleration is (m/s)/ s or m/s^2.

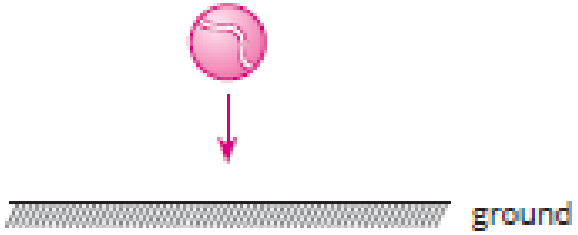
Positive acceleration and negative acceleration or retardation

When the velocity of a body increases with time, its acceleration is positive.
When the velocity of a body decreases with time its acceleration is negative.
Negative acceleration is also called **retardation** or deceleration.

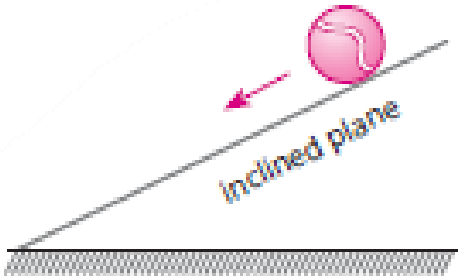
Uniform acceleration

When a body travels in a straight line and its velocity changes by equal amounts in equal intervals of time, it is said to have uniform acceleration.
The motion of a body with uniform acceleration is called uniformly accelerated motion.

Examples of uniform acceleration



a. a body falling freely from a certain height



b. a body moving down on an inclined plane

Note: Refer to Table 1.5 for Differences between velocity and acceleration

Non -uniform acceleration

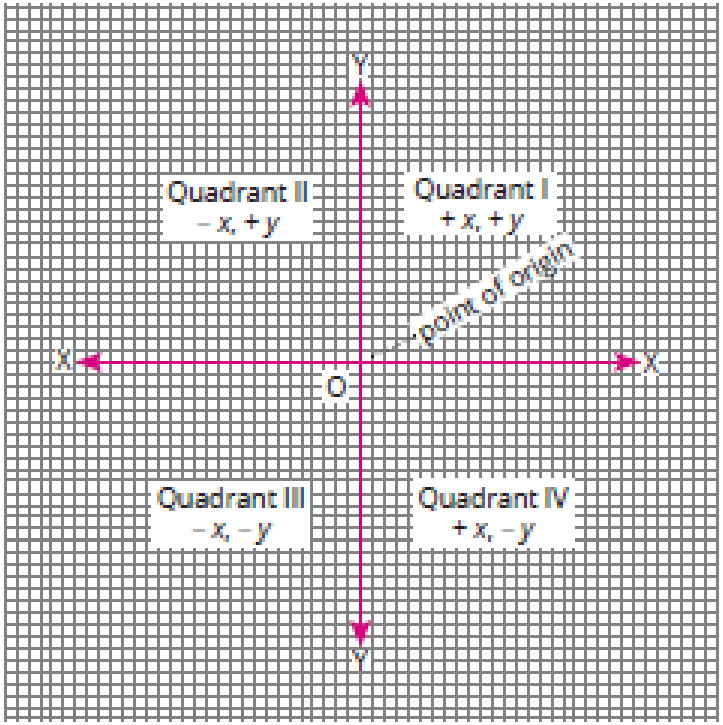
When the velocity of a body changes by unequal amounts in equal intervals of time, it is said to have non-uniform acceleration.

In other words, a body is said to have non-uniform acceleration if the rate of change of its velocity is different at different points of time during its motion. For example, an auto-rickshaw or a car being driven on a crowded city road with frequent application of brakes will have non-uniform acceleration.

Graphical Representation of Motion

When a set of data of measurements is presented on a graph paper, it is called a graph.

1. Graphs are very attractive and effective means of presenting data (of measurements).
2. Even the most complex information can be made simple and understandable with the help of graphs.
3. Graphs facilitate a comparative glance at the data.
4. We can analyse data from graphs.



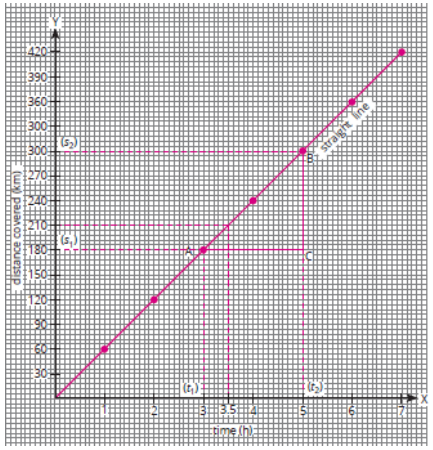
Distance–time graph

A graph showing the change in the position of an object (distance covered) with time is called its distance–time graph. It is for study the nature of motion of a body and also to calculate its speed.

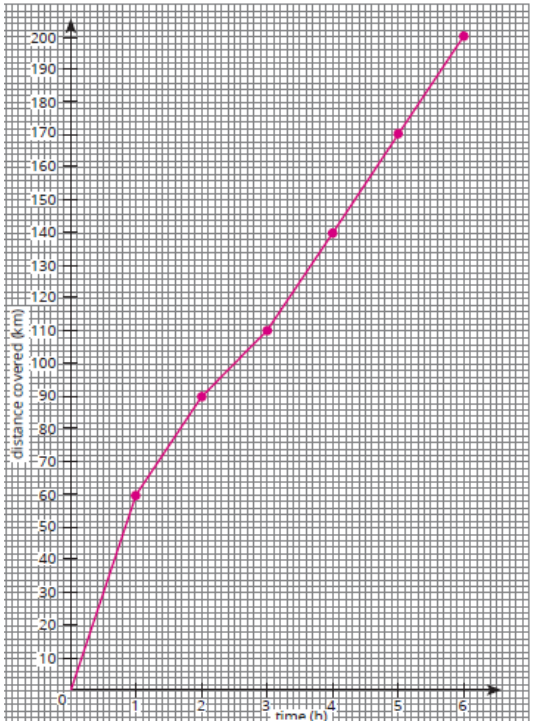
Body moving with a uniform speed

We observe that the distance–time graph of a body moving with uniform speed is a straight line. Conversely, we can say if the distance–time graph of a body is a straight line, the body is moving with uniform speed.

The slope of distance–time graph is equal to the magnitude of the speed of the moving body.



Distance–time graph for a body moving with a uniform speed



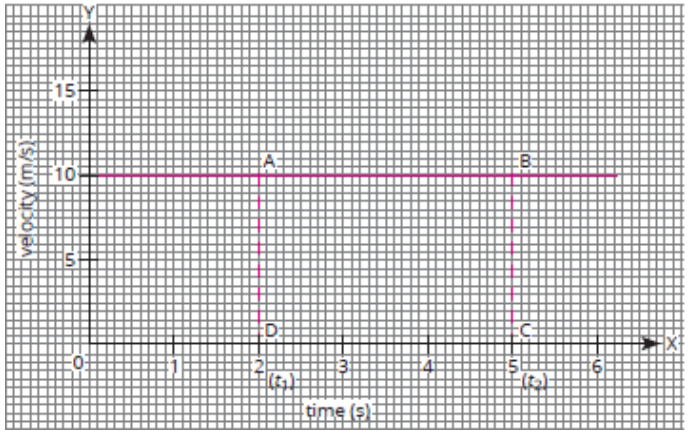
Body moving with a non-uniform speed

The distance–time graph of a body moving at non-uniform speed is not a straight line but a curved line. Conversely, we can say if the distance– time graph of a body is curved line, the body is moving with non-uniform speed.

Distance–time graph for a body moving with non-uniform speed

Velocity–time graph

The velocity–time graph of a body moving with constant velocity is a straight line parallel to the *x*-axis. Conversely, we can say if the velocity–time graph of a body is a straight line parallel to the *x*-axis, then the body is moving with constant velocity. Acceleration of a body moving with constant velocity is zero.

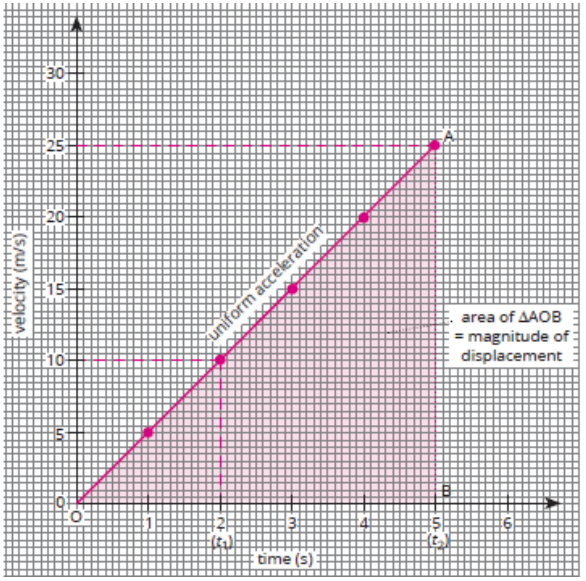


Velocity–time graph for a body moving with constant velocity

Velocity–time graph for uniformly accelerated motion (i.e. when velocity increases uniformly with time)

Condition A: When the body is initially at rest

The velocity–time graph of a body starting from rest and moving with uniform acceleration (i.e. velocity increasing uniformly with time) is a straight line.

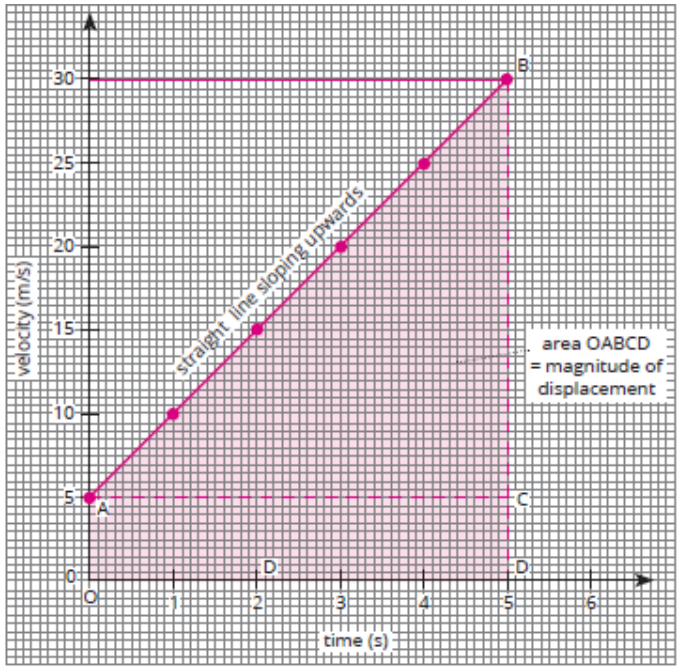


Velocity–time graph for a body initially at rest and then moving with uniform acceleration

Conversely, we can say if the velocity–time graph of a body is a straight line starting from origin, the body is moving with uniformly accelerated motion and is initially at rest.
The area enclosed by velocity–time graph and the time axis is equal to the magnitude of displacement.

Condition A: When the body is not at rest initially

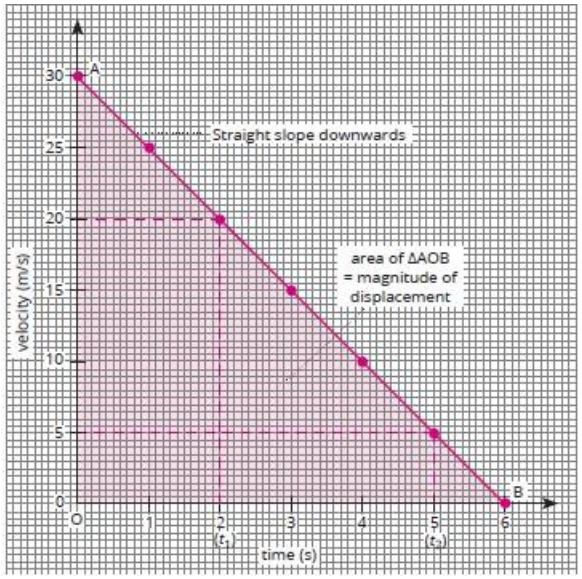
The velocity–time graph of a body initially not at rest and moving with uniform acceleration is a straight line but it does not originate from origin O. It originates from a point say A on the *y*-axis



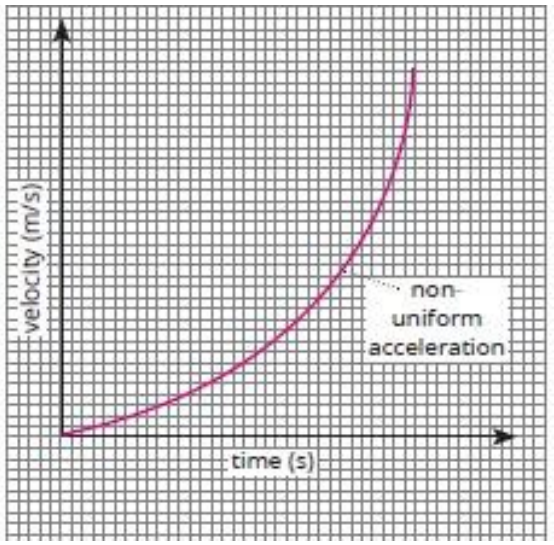
Velocity–time graph for a body initially not at rest and moving with uniform acceleration

Velocity–time graph for uniform retardation

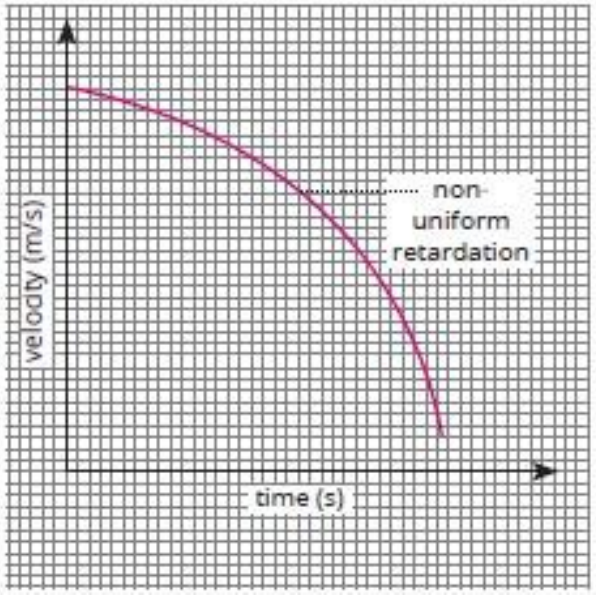
The velocity–time graph of a body moving with uniform retardation is a straight line sloping downwards



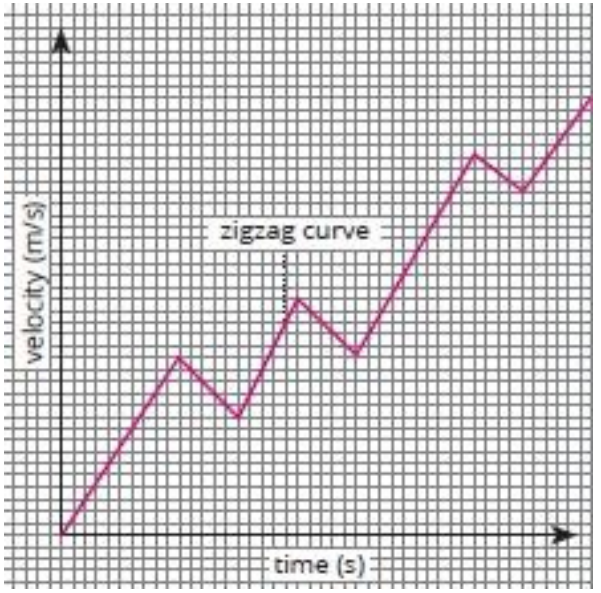
Velocity–time graph for a body moving with uniform retardation



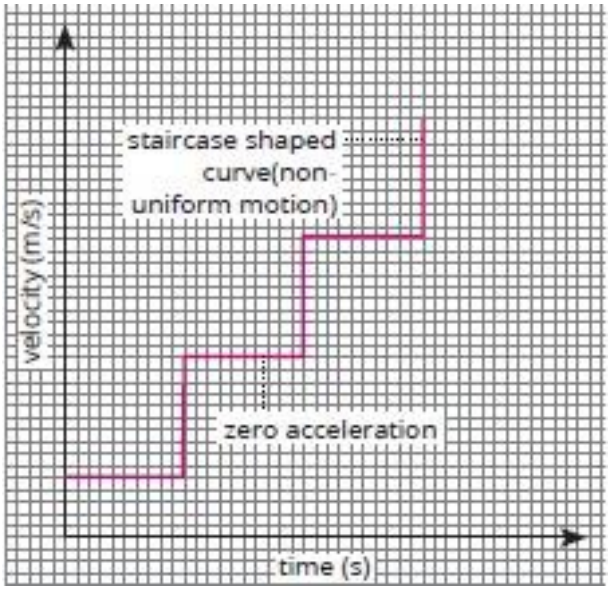
Velocity–time graph for a body when its velocity increases non-uniformly



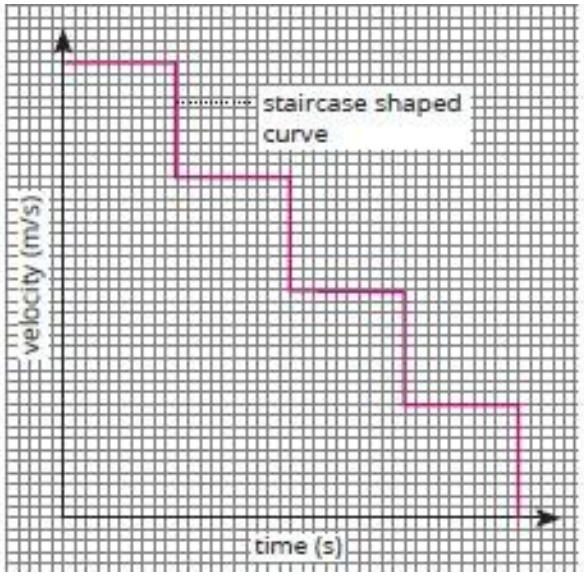
Velocity–time graph for a body when its velocity decreases non-uniformly



Velocity–time graph for a body when its velocity increases and decreases non-uniformly



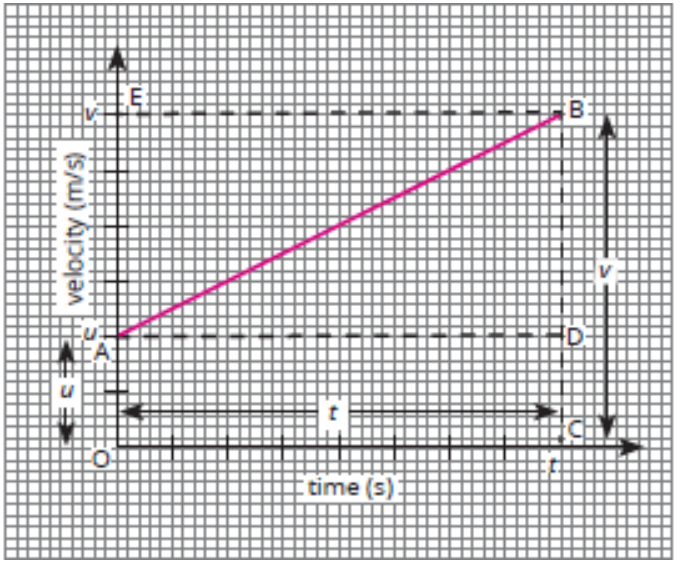
Velocity–time graph for a body when its velocity increases in a step-wise manner



Velocity–time graph for a body when its velocity decreases in a step-wise manner

Equations of Motion by Graphical Method

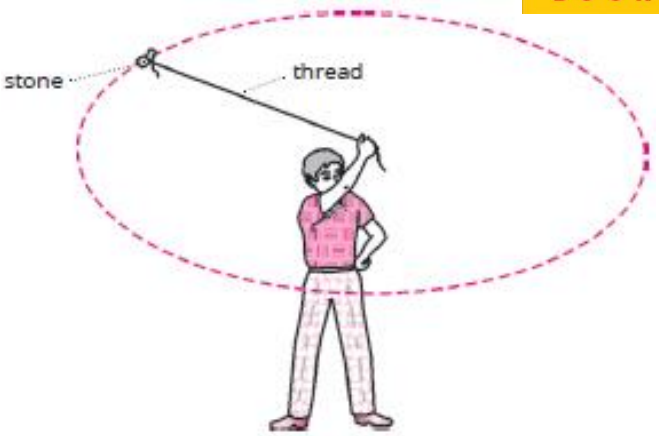
There are three equations for the motion of a body moving with a uniform acceleration. These three equations, i.e. $v = u + at$, $s = ut + 1/2at^2$ and $v^2 = u^2 + 2as$ can be derived from the velocity–time graph



Velocity–time graph

Note: For derivations of equations, refer to p 41-43 of the book.

Uniform Circular Motion



When a point object (small body or particle) is moving on a circular path with a constant speed, the motion of the object is said to be uniform circular motion**.** So, a stone tied to a thread and whirled in a circular path is an example of uniform circular motion.

Some more examples of uniform circular motions are given below:

1. The moon revolving around the earth in a circular path with constant speed.

2. An artificial satellite revolving around the earth in a circular path with constant speed.

3. The earth and other planets revolving around the sun in circular paths at constant speeds.

4. A wheel rotating about its axle.

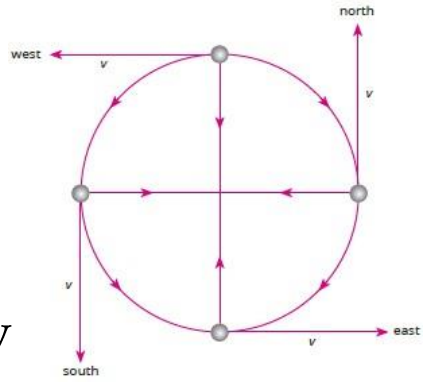
Direction of motion of an object moving along a circular path

For a body moving with constant speed along a circular path

a. the direction of the velocity constantly changes.

b. the direction of the velocity is along the tangent to the circle at any point in its motion.

For a body moving with a constant speed along a circular path, the direction of the velocity is along the tangent to the circle at any point in its motion.



For a body moving with constant speed along a circular path
a. the direction of the velocity constantly changes.
b. the direction of the velocity is along the tangent to the circle at any point in its motion.

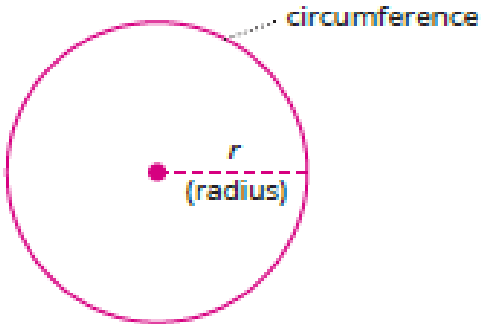
Speed of a body in uniform circular motion

Consider a body moving in a circular path. The distance travelled by the body in one round of the circular path will be $2\pi r$, where r is the radius of the circular path. The speed of the body moving in a circular path is given by

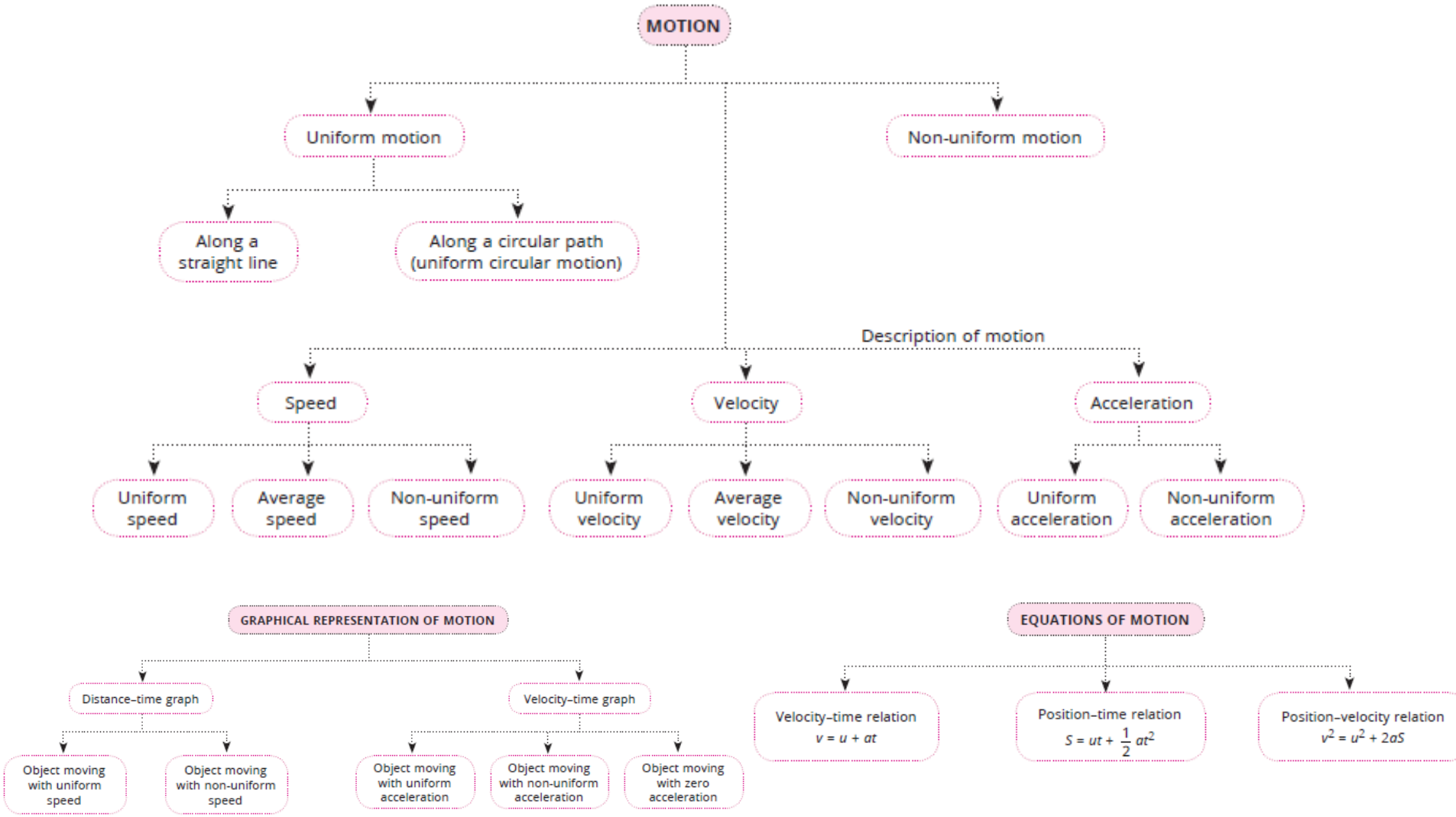
$v = 2\pi r / t$

where r = radius of the circular path

t = time taken to complete one round of the circular path.



Types of Motion



SUMMARY

1. State of rest: A body is said to be at rest if it does not change its position with respect to a fixed point taken as a reference point in its surroundings with the passage of time.

2. State of motion: A body is said to be in motion if it changes its position with respect to a fixed point taken as a reference point in its surroundings with the passage of time.

3. Types of motion: The various types of motion are rectilinear motion, curvilinear motion, oscillatory motion, vibratory motion.

4. Mechanics: The branch of physics which deals with the study of motion of objects and their response to force is called mechanics.

5. Scalar quantity: A physical quantity which is described completely by its magnitude (or size) only is called a scalar quantity.

6. Vector quantity: A physical quantity which is described completely by its magnitude (or size) and direction is called a vector quantity.

7. Distance travelled: The actual length of path travelled by a body during its motion in a given interval of time irrespective of the direction in which it travels.

8. Displacement: When a body moves from one position to another, the shortest distance (straight distance) measured between the initial position and the final position of the body in a particular direction is called its displacement.

9. Uniform motion: A body has uniform motion if it covers equal distances in equal intervals of time, no matter how small these time-intervals may be.

10. Non-uniform motion: A body has non-uniform motion if it covers unequal distances in equal intervals of time, however small these time-intervals may be.

11. Speed: The speed of a body is the distance travelled by it per unit time.

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

13. Velocity: The velocity of a body is the distance travelled by it per unit time in a definite direction.

14. Uniform velocity: A body is said to have uniform velocity if it covers equal distances in equal intervals of time in a particular direction, however small these time-intervals may be.

15. Variable velocity: A body is said to have variable velocity if it covers unequal distances in equal intervals of time in a particular direction, however small these time-intervals may be.

16. Acceleration: The rate of change of velocity of a body with respect to time i

17. Positive acceleration: When the velocity of a body increases with time, its acceleration is positive.

18. Negative acceleration: When the velocity of a body decreases with time, its acceleration is negative or it is called retardation.

19. Distance–time graph: A graph showing the change in the position of an object (distance covered) with time is called its distance–time graph. Distance–time graph

a. for a body moving with uniform speed is a straight line,

b. for a body moving with non-uniform speed is a curved line and

c. for a body at rest is a straight line parallel to the time-axis.

20. Velocity–time graph: A graph showing the variation of velocity with time is called velocity–time graph.

a. The shape of the velocity–time graph depends upon the nature of motion of the body.

b. The slope of the velocity–time graph gives the acceleration of the body.

c. The area under the velocity–time graph gives the distance travelled by the body in that interval of time.

21. Uniform circular motion: When an object is moving on a circular path with a constant speed, the motion of the object is said to be uniform circular motion. Uniform circular motion is an accelerated motion.