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Preeti Agarwal

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National Science Olympiad

9

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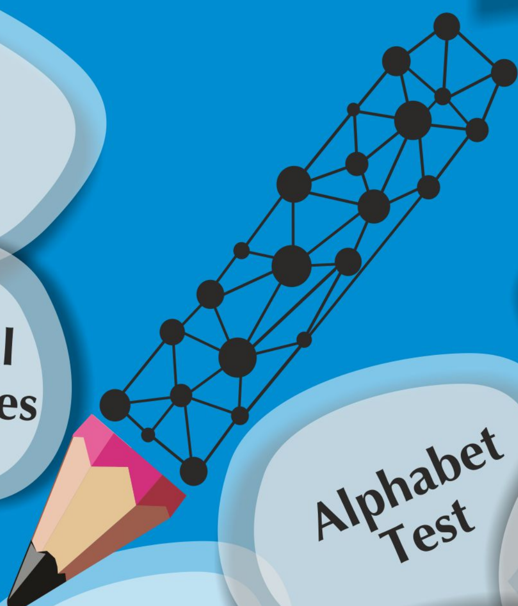

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NATIONAL SCIENCE OLYMPIAD

Exploring the World of Science

Class 9

Preeti Agarwal

V&S PUBLISHERS

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Publisher's Note

V&S Publishers, after the grand success of a number of Academic and General books, is pleased to bring out a series of *Science Olympiad books* under *The Gen X series – generating Xcellence in generation X* – which has been designed to focus on the problems faced by students. In all books the concepts have been explained clearly through various examples, illustrations and diagrams wherever required. Each book has been developed to meet specific needs of students who aspire to get distinctions in the field of science and want to become Olympiad champs at national level.

To go through Science Olympiads, students need to do thorough study of topics covered in the *Olympiad syllabus and the topics covered in the school syllabus as well*. The Olympiads not only tests subjective knowledge but Reasoning skills of students also. So the students are required to comprehend the depth of concepts and problems. The Olympiads check efficiency of candidates in problem solving. These exams are conducted in different stages at regional, and national levels. At each stage of the test, a candidate should be fully prepared to go through the exam. Therefore, this test requires careful attention towards comprehension of concepts, thorough practice, and application of concepts and rules.

While other books in market focus selectively on questions or theory; V&S Science Olympiad books are rather comprehensive. Each book has been divided into five sections namely *Science, Logical Reasoning, Achievers section, Subjective section, and Model Papers.* The theory has been explained through solved examples. To enhance problem solving skills of candidates, *Multiple Choice Questions (MCQs)* with detailed solutions are given at the end of each chapter. Two *Mock Test Papers* have been included to understand the pattern of exam. A CD containing Study Chart for systematic preparation, Tips & Tricks to crack Science Olympiad, Pattern of exam, and links of Previous Years Papers is accompanied with this book. The books are also useful for various other competitive exams such as NTSE, NSTSE, and SLSTSE as well.

We wish you all success in the examination and a very bright future in the field of science.

All the best

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Section 1

Science

1

Motion

Learning Objectives

- ❒ Concept of Motion
- ❒ Distance Travelled and Displacement
- ❒ Types of Motion
  - ♦ Linear motion
  - ♦ Circular motion
  - ♦ Rotatory motion
  - ♦ Vibratory motion
- ❒ Uniform Motion and Non–Uniform Motion
- ❒ Concept of Speed, Velocity and Average Velocity
- ❒ Acceleration and Deceleration or Retardation
- ❒ Uniform Acceleration and Non–Uniform Acceleration
- ❒ Equations of Uniformly Accelerated Motion
- ❒ Uniform Circular Motion

Motion

A body is said to be in motion when its position changes continuously with respect to a stationary object, taken as reference point. For example, when a car changes its position with respect to a stationary object like traffic signal (see figure 1.1), we say that the car is in motion. Hands of clock, pendulum of a clock, merry–go–round, moving blades of mixer are some of the examples of motion observed around us in our daily life.

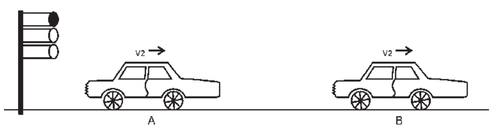


Fig: 1.1

Distance Travelled and Displacement

The concept of distance travalled and displacement of an object can be understand by an example. Suppose a man lives at a place, say A and he has to reach his office located at C, but first he has to take his medicine from the shop located at place, say B. The path travelled by him is drawn in the fig. 1.2.

Distance from A to B = 5 km

Distance from B to C = 4 km

Length of the path ABC travelled by the man = 5 + 4 = 9 km. Then the actual distance travelled by the man in reaching from A to C, is given by, distance travelled, AB + BC = 9km.

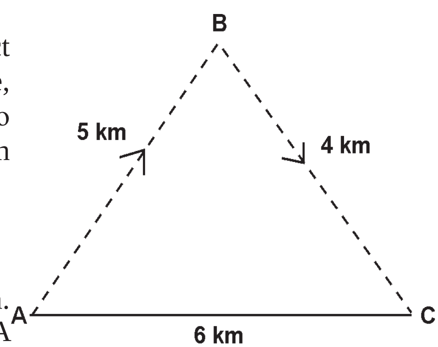


Fig: 1.2

If we want to know how far the man is from his starting point

A, then is, we have to find the shortest distance between point A and point C. To do this draw a strainght line joining A and C whose length is 6km. This distance AC is called the displacement of the man from point A to the point C.

This displacement in is the East direction

Thus,

Distance travelled – refers to the actual length of the path travelled by an object during motion.

Displacement – refers to the shortest path between the initial and the final position of an object during motion.

Key Note: Distance has only magnitude but displacement has magnitude as well as direction. Thus, Distance is a scalar quantity and displacement is a vector quantity.

Can the Displacement of a Body be Zero?

- Yes, the displacement of a body can be zero, when it traces a closed loop path and its final and initial position is at same point for example a boy takes a path along the, border of a square park whose each side is 1km long, and reaches back to its starting position A. He travelled along the path AB→BC→CD→DE, Distance travelled
  = 1+1+1+1= 4 km Displacement (from A to A) = 0

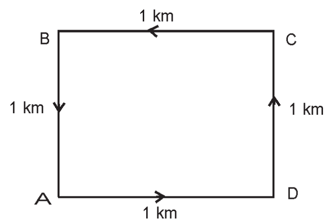


Fig: 1.3

***Example* 1:** A boy travels a distance of 1 km towards East, then 3 km towards South and finally moves 5 km towards East. Find the total distance travelled and the resultant displacement.

***Solution*:** Total distance travelled

= AB + BC + CD

= 1+ 3 + 5 = 9 km

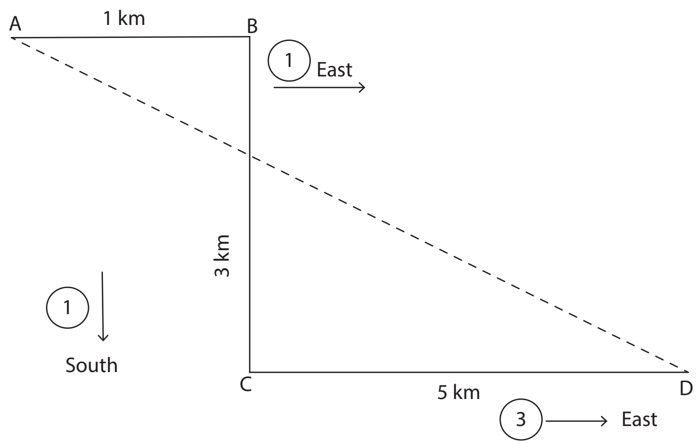


Fig: 1.4

To measure displacement, join points A and D by a straight line. Suppose 1cm represents 1km. Using this scale draw AB = 1 cm, BC = 3cm and CD = 5 cm on a page. Now measure the length AD which is 7.2 cm thus 7.2 cm = 7 km is the final displacement.

Types of Motion

- **Linear motion :** The motion of an object along a straight line is called linear or rectilinear motion. For example, a boy running on a 100 m straight track on a ground, the motion of a bus on a straight highway etc
- **Circular motion:** The motion of an object on a circular path is called circular motion. For example, an athlete running on a circular path around the field.
- **Rotatory Motion:** The motion of an object along its axis on a fixed point is called the rotatory motion. For example, motion of a top, motion of a globe, motion of a ceiling fan, etc.
- **Vibratory Motion:** The to–and–fro motion of a body about the mean position along the same path is called vibratory motion. For example, the motion of a pendulum in a clock.

Uniform Motion and Non-Uniform Motion

Uniform Motion

A body moves in a uniform motion if it travels equal distances in equal intervals of time. For example, a car running at speed of 15 meters per second will always cover 15 meters in every one second of its motion.

Timetostart	Distance(km)	TimePeriod(hr)
9:00	2km	1
10:00	2km	1
11:00	2km	1
12:00	2km	1

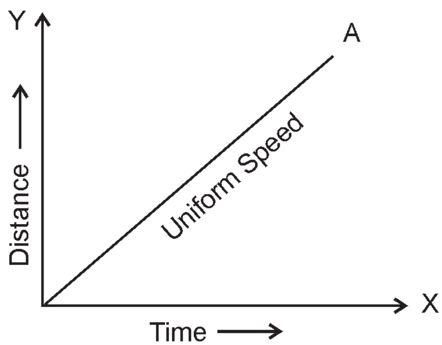


Fig: 1.5

From the above table, we observe that an athlete runs'a marathon 8 km long, starting at 9 : 00 AM. He covers 2 km in every 1 hour, thus covering the whole distance in 4 hours.

Note: The distance - time graph for uniform motion is a straight line.

Non–Uniform Motion

A body moves in a non–uniform motion if it travels unequal distances in equal intervals of time. For example, a car travels 15 km in one hour due to heavy traffic, but 25 km in the next one hour due to no traffic, and then 35 km on the road outside the city with no traffic at all. Thus, total distance covered is 75 km in 3 hours.

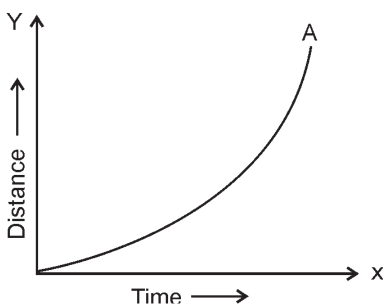


Fig: 1.6

Timetostart	Distance(km)	TimePeriod(hr)
9:00	15	1
10:00	25	1
11:00	35	1

Note: The distance time graph for a body having non-uniform motion is a curved line. The non–uniform motion is also called accelerated motion.

Speed, Velocity and Acceleration

The motion of a body can be described by three terms : speed, velocity and acceleration.

Speed

The distance travelled by an object in unit time is called speed. It can be measured by dividing the distance travelled by the time taken to travel this distance. It is a scalar quantity.

$$\text{Speed} = \frac{\text{Distance Travelled (in meters)}}{\text{Time taken (in seconds)}}$$

If a body travels a distance *d* in time *t*, then its speed v is given by:

$$\boxed{v = \frac{d}{t}}$$

The SI unit of speed is metres per second written as ms^{-1}.

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

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{speed}}$$

***Example* 2:** An athlete runs 200 m in 25 seconds and another 300 m in 35 seconds. What is average speed of the athlete?

***Solution* :** Total distance travelled by the athlete

= 200 m + 300 m = 500 m

Total time taken = 25s + 35s = 60 s

$$\text{Average speed} = \frac{500m}{60s} = 8.33 \text{ ms–1}$$

***Example* 3:** A car travels a distance of 30 km at a speed of 40 km/hr and the next 30 km at a speed of 20 km/hr. Find its average speed.

***Solution*:** First 30 km travelled at the speed of 40 km/hr. Let time taken during this journey is

$$t_1 = \frac{\text{distance travelled}}{\text{speed}} = \frac{30}{40} = \frac{3}{4} hrs$$

Next 30 km travelled at the speed of 20 km/hr

Time taken $t_2 = \frac{\text{distance}}{\text{Speed}} = \frac{30}{20} = \frac{3}{2}$ hours

Total distance travelled = (30 + 30) km = 60 km

Total time taken $= \frac{3}{4}hr + \frac{3}{2}hr = \frac{9}{4}hrs$

Average speed $= \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{60}{9/4}$

$= \frac{240}{9}$ = 26.6 km/hr

Velocity

Velocity of a moving body is the distance travelled by it per unit time in a given direction, denoted by the symbol *v*

If a body travels *a* distance *d* in time *t* in a given direction, then its velocity *v* is given by

$$V = \frac{d}{t}$$

d = distance travelled in a given direction = displacement, thus, velocity of a body is the displacement produced per unit time. The SI unit of velocity is same as that of speed, namely m/s or ms^{-1}. Velocity is a vector quantity.

Key Note: The direction of velocity is same as the direction of displacement of the body.

Can average velocity of an object be zero ?

In most cases, the bodies move in a single straight line without changing direction. The values of speed and velocity will be same in these cases. In case the body changes its direction at some point of time, then speed and velocity may be different.

Though average speed of a moving body can never be zero, but the average velocity of a moving body can be zero.

***Example* 4:** A bus travels a distance of 200 km from Delhi to Agra towards East in 3 hours in the afternoon and returns to Delhi in West covering the same distance in 3 hours again at night. Find its average speed and average velocity for the whole journey.

***Solution*:** Average speed (s) $= \frac{\text{Total distance travelled}}{\text{Total time taken}}$

$= \frac{(200+200)}{(3+3)\text{hrs}} = \frac{400}{6}$ = 66.6 (km/h)

$$\text{Average velocity } (v) = \frac{\text{Total displacement}}{\text{Total time taken}}$$

Total displacement = Distance travelled in East – distance travelled in West = 200 km – 200 km = 0

$$\therefore \text{Average velocity} = \frac{0\,\text{km}}{6\,\text{km}} = 0 \text{ km/h}$$

Thus, the average velocity of the bus for the whole journey is 0km/h. no direction can be stated in the case of zero velocity.

Average velocity: Average velocity can also be calculated by taking the average of the initial velocity, represented by u and the final velocity, represented by v.

$$\text{Average velocity, } v_{av} = \frac{u+v}{2}$$

Distance – time graph for uniform speed

The graph for an object moving at uniform speed (covering equal distances in equal time periods) is a linear graph.

Distance – time graph for a non–uniform speed

Case1: When the speed of a moving object increases with time, the graph will be curving upward.

Case2: When the speed of a moving object decreases with time, the graph will be curving downward.

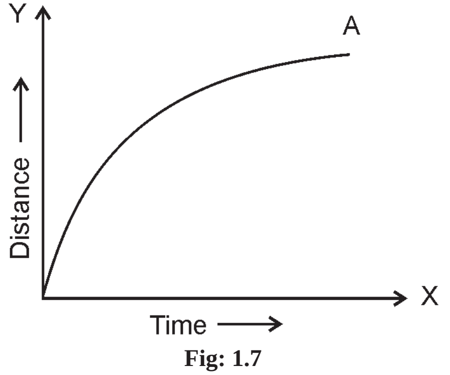


Fig: 1.7

Acceleration

When an object starts, its velocity is zero. Gradually, it increases and then decreases to get halted. The rate at which the velocity of the object changes with time is called *acceleration*, it is denoted by a.

$$Acceleration = \frac{Change\ in\ velocity}{Time\ taken}$$

Change in velocity = Final velocity – Initial Velocity = $v - u$

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

∴ t is the time taken for the change in velocity.

The SI unit of acceleration is m/s^2 or ms^{-2}

Key Note: When a body is moving with uniform velocity, its acceleration will be zero as $v = u$ *i.e*, change in velocity is zero.

Uniform acceleration

If the body travels in a straight line and its velocity increases by equal amounts in equal intervals of time, the body is said to be in *uniform acceleration* .The motion of a freely falling body or the motion of a ball rolling down on an inclined plane is an example of uniformly accelerated motion.

The velocity – time graph of a body having uniformly accelerated motion is a *straight line.*

Non–uniform acceleration

A body is said to be in non–uniform acceleration if its velocity increases by unequal amounts in equal intervals of time *i,e* its velocity changes at a non–uniform rate. The velocity–time graph for a body having non–uniform acceleration is a curved line.

Retardation or negative acceleration

Acceleration takes place when the velocity of a body changes. This change can be increasing or decreasing. Thus, acceleration can be classified into two groups.

Positive acceleration : When a car runs down on an inclined plane, the velocity of car increases and it is said to be moving with positive acceleration, which we usually called *acceleration*.

Negative acceleration : When a car runs upward on an inclined plane, the velocity of car decreases and it is said to be running with negative acceleration, which we generally called *retardation or deceleration*. A ball thrown vertically upwards is also an example of negative acceleration. Parachute is also example of deceleration.

Zero acceleration: A bus standing at the bus stop and a bus moving on a straight road with a constant speed of 40 km/hr are the examples of zero acceleration. In both cases, velocity is constant i.e; $\Delta v = 0$.

***Example* 5:** A driver decreases the speed of a car from 45 m/s to 25 m/s in 5 seconds. Find the acceleration of the car.

***Solution*:** Initial velocity, u = 45 m/s; Final velocity, v = 25 m/s; Time taken, t = 5 seconds

$$A = \frac{v-u}{t} = \frac{25-45}{5} = \frac{-20}{5} \; -4 \text{ m/s}^2$$

The negative sign of acceleration means that it is retardation; so, we can say that the car is decelerating at the rate of 4 m/s^2.

Equations of uniformly accelerated motion

There equations for the motion of those bodies which travel with a uniform acceleration these equations give relationship between initial velocity (u), final velocity (v), time taken (t), acceleration (a) and distance travelled (s) by the bodies.

1. **First equation of motion:** It gives the velocity acquired by a body in time *t* moving with acceleration *a*.

   $v \quad u$

   $v = u + at$

2. **Second equation of motion:** It gives the distance travelled (s) by a body, moving at an initial speed of *u*, in time *t*

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

3. **Third equation of motion:** It gives the velocity (*v*) acquired by a body in travelling a distance (*s*)

   $v^2 = u^2 + 2as$

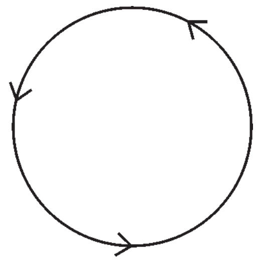


Fig: 1.8

Key Point: 1. If a body starts from rest, initial velocity, u = 0

2. If a body comes to rest, its final velocity, v = 0

3. If a body moves moves with uniform velocity, its acceleration, a = 0

***Example* 6:** A bus acquires a velocity of 36 km per hour in 10 seconds just after the start. Calculate the acceleration of the bus.

***Solution*:** 36 km/hr = $36 \times \frac{1000}{3600}$ = 10 m/s

u = o, v = 10, t = 10

$v = u + at$

$10 = 0 + a \times 10$

$10\,a = 10 \Rightarrow a = 1$ m/s^2

***Example* 7:** A motor bike has a uniform acceleration of 4m/s^2. What distance will it cover in 10 seconds after the start ?

***Solution*:** u = 0, *a* = 4, *t* = 10

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

$= 0 \times 10 \frac{1}{2} \times 4 \times 102 = 200$ m

Thus, the distance covered by the bike in 10 s is 200 m.

***Example* 8:** A scooter moving at a speed of 10 m/s is stopped by applying brakes which produce a uniform acceleration of – 0.5 m/s^2. How much distance will be covered by the scooter before it stops?

***Solution*:** u = 10 m/s, *v* = 0 (scooter stops); a = – 0.5 m/s^2 , $v^2 = u^2 + 2as$

$(0)^2 = (10)^2 + 2(-0.5) \times s$

$0 = 100 - s,$

$s = 100$ m.

Uniform Circular Motion

When a body (or any object) moves along a circular path, then its direction of motion keeps changing continuously. This we can understand with the concept of motion along an octagonal track. While running along the octagonal track, the athlete changes his direction of motion eight times at the eight corners A, B, C, D, E, F, G and H of this track if we increase these directions to a greater number, it gets converted into a circular track so, if an athlete moves with a constant speed along a circular path, then the velocity of the athlete will not be constant because velocity is the speed in a specified direction and here the direction of speed changes continuously. **Since the velocity changes (due to continuous change in direction) therefore, the motion along a circular path is said to be accelerated.**

Define Circular Motion

When a body moves in circular path with uniform speed (constant speed), its motion is called uniform circular motion.

Examples:

- Artificial satellites moving in their orbits in space
- Moon moving around the earth
- Toy train moving on a circular track
- Tip of the needle of a clock.

Speed of a body in uniform circular motion: When a body takes one round of a circular path, then it travels a distance of 2πr, where r is radius of the circular path.

$$\text{Speed } v = \frac{\text{Distance travelled (circumference)}}{\text{Time taken}}$$

$$\boxed{v = \frac{2\pi r}{t}}$$

$$\pi = \frac{22}{7} = 3.14$$

***Example* 9:** A cyclist goes around a circular track once every 2 minutes. If the radius of the circular track is 105 m, calculate his speed. (given $\pi = \frac{22}{7}$)

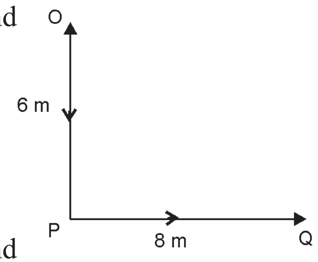
***Solution*:** $v = \frac{2\pi r}{t} = \frac{2 \times \frac{22}{7} \times 105}{2 \times 60} = 5.5$ m/s

Key Points

- ✓ Motion is the change in an object's position described in terms of the distance moved as the displacement.
- ✓ The actual length of the path travelled by an object is called distance and the shortest distance between the starting point and the destination point is called displacement.
- ✓ Speed = $\frac{\text{Distance}\, travelled}{Time\ taken} = \frac{d}{t}$
- ✓ Velocity = $\frac{Displacement}{Time\, taken} = \frac{s}{t}$
- ✓ Acceleration = $\frac{Change\, in\, velocity}{Time\ taken} = \frac{v-u}{t}$
- ✓ If an object covers equal distance in equal time interval, it is called uniform motion. The distance time graph for uniform motion is a straight line.
- ✓ The motion of an object moving at uniform acceleration can be describe with the help of three equations:
- ✓ $v = u + at$
- ✓ $s = ut + \frac{1}{2} at^2$
- ✓ $v^2 = u^2 + 2as$
- ✓ If an object moves in circular path with uniform speed, its motion is called uniform circular motion.

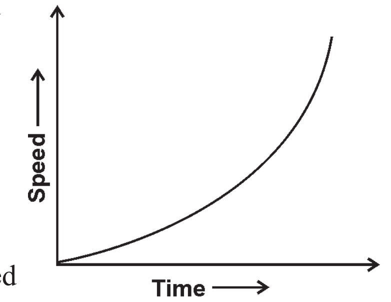
Multiple Choice Questions

1. What remains constant in uniform circular motion ?
   (a) Speed (b) Direction
   (c) Both (*a*) and (*b*) (d) None of these
2. The quantity which is measured by the area occupied under the speed-time graph is
   (a) Velocity (b) Distance travelled
   (c) Time taken (d) None of these
3. If a body moves 6 m towards South and then turns towards East and moves 8 m, then find the displacement of the body
   (a) 12 m
   (b) 8 m
   (c) 10 m
   (d) 6 m



4. A man travels a distance of 2 m towards East, 6 m towards South and finally 6m towards East. The resultant displacement is
   (a) 10 m (b) 8 m
   (c) 12 m (d) 14 m
5. The motion in which a body has a constant speed but not constant velocity is called
   (a) Uniform linear motion
   (b) Uniform circular motion
   (c) Rotatory motion
   (d) Vibratory motion
6. What does the slope of a velocity-time graph indicate ?
   (a) Speed (b) Distance travelled
   (c) Velocity (d) Acceleration
7. What can you say about the motion of body if its speed–time graph is a straight line parallel to the time axis ?
   (a) Speed of the body is zero
   (b) Speed of the body is increasing at a constant rate
   (c) Speed of the body is uniform i.e. ,constant
   (d) None of these
8. A car travels first 40 km at the speed of 55 km/h and next 20 km at the speed of 50 km/h. Find the total time taken by the car to reach its destination
   (a) 1.34 hours (b) 1.2 hours
   (c) 1.72 hours (d) 1.127 hours
9. What can you say about the motion of a body whose distance–time graph is a straight line parallel to time axis ?
   (a) Body is moving at same speed (b) Body is at rest
   (c) Both body and time are at rest (d) None of these

10. What conclusion can you draw about the acceleration of a body from the speed –time graph shown below ?



(a) Positive acceleration
(b) Deceleration
(c) Non–uniform acceleration
(d) Uniform acceleration

11. It is possible for an object to accelerate but not to change its speed if it moves

(a) In a circular track
(b) On a sloppy hill
(c) On a straight path
(d) To and fro

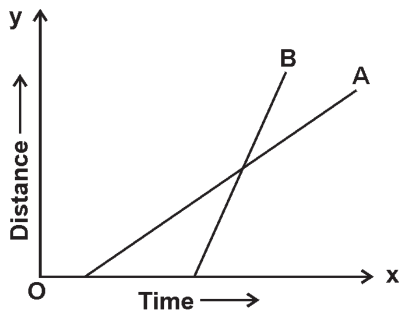
12. Find the acceleration of a cyclist whose speed changes from 30 m/s to 45 m/s in 3 seconds

(a) 3 m/s^2
(b) –3 m/s^2
(c) 5 m/s^2
(d) –5 m/s^2

13. Which of these, decides the direction of motion of the body?

(a) Speed
(b) Velocity
(c) Distance
(d) Acceleration

14. The figure shows distance–time graphs of two cars A and B running at different speeds. Which car is running with a greater speed in comparison to the other car?



(a) Car A is running faster than B
(b) Car B is running faster than A
(c) Both A and B have same speed
(d) None of these

15. A bus increases its speed from 36 km/h to 72 km/h in 10 seconds. Its acceleration is

(a) 5 m/s^2
(b) 2 m/s^2
(c) 3.6 m/s^2
(d) 1 m/s^2

16. A bus moving along a straight line at 15 m/s undergoes an acceleration 2.5 m/s^2. After 2 seconds, its speed will be

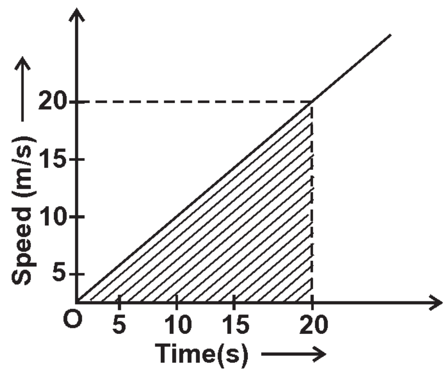
(a) 20 m/s
(b) 26 m/s
(c) 25 m/s
(d) 30 m/s

17. The area under a speed–time graph represents a physical quantity which has the unit

(a) m
(b) ms
(c) ms^{-1}
(d) ms^{-2}

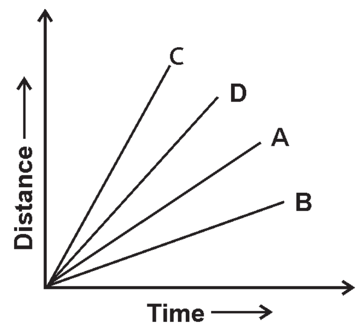
18. If the displacement of an object is proportional to the square of time, then the object is moving with
(a) Uniform velocity
(b) Uniform acceleration
(c) Increasing acceleration
(d) Decreasing acceleration

19. What is the distance covered by a particle during the time interval of 20 seconds, for which the speed–time graph is shown in the adjacent figure



(a) 400 m
(b) 100 m
(c) 200 m
(d) All of these

20. Four cyclists A, B, C, and D are cycling on a levelled straight road. Their distance–time graphs are shown in the given figure. Which of the following is correct regarding the motion of these cyclists?



(a) Cyclist A is faster than D
(b) Cyclist B is the slowest
(c) Cyclist D is faster than C
(d) Cyclist C is the slowest

21. A car of mass 1000 kg is moving with a velocity of 10 ms^{-1}. If the velocity–time graph for this car is a horizontal line parallel to the time–axis, then the velocity of car at the end of 25 s will be
(a) 10 ms^{-1} (b) 25 ms^{-1}
(c) 125 ms^{-1} (d) 40 ms^{-1}

22. An object moving with a velocity of 30 m/s decelerate at the rate of 1.5 m/s^2. Find the time taken by the object to come to rest
(a) 10 seconds (b) 20 seconds
(c) 15 seconds (d) 30 seconds

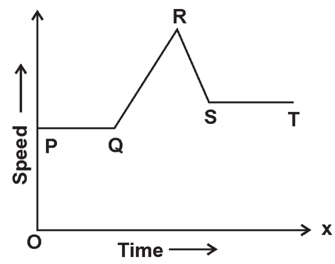
23. A car accelerates from 15 km/h to 60 km/h in 300 seconds. Find the distance travelled by the car during this time
(a) 3.35 km (b) 3.33 km
(c) 4.33 km (d) 5 km

24. A motor cycle is being driven at a speed of 20 m/s when a brakes are applied to bring it to rest in five seconds. The deceleration produced in this case will be
(a) + 4 m/s^2 (b) – 4 m/s^2
(c) + 0.25 m/s^2 (d) – 0.25 m/s^2

25. An artificial satellite is moving in a circular orbit of radius 32,000 km. If it takes 30 hours to complete one revolution around the earth, then find the velocity of the satellite
    (a) 9428 km/h (b) 9500 km/h
    (c) 6704 km/h (d) 7295 km/h

26. A cyclist takes 3 minutes to complete one round of the circular track. If the radius of the circular track is 45 metres, then the speed of the cyclist is
    (a) 1.57 m/s (b) 3.14 m/s
    (c) 4.25 m/s (d) 5.67 m/s

27. A sprinter is running along the circumference of a big stadium with a uniform speed. Which of the following is changing in this case
    (a) Magnitude of acceleration being produced
    (b) Distance covered by the sprinter per second
    (c) Direction in which the sprinter is running
    (d) Centripetal force acting on the sprinter



28. In the speed-time graph for a moving object shown here, the part which indicates uniform deceleration of the object is
    (a) ST (b) QR
    (c) RS (d) PQ

29. Which one of the following is most likely not a case of uniform circular motion?
    (a) Motion of the earth around the sun
    (b) Motion of a racing car on a circular track
    (c) Motion of a toy train on a circular track
    (d) Motion of hours' hand on the dial of a clock

30. A train starting from rest attains a velocity of 72 km/h in 5 minutes. Assuming that the acceleration is uniform, find the distance travelled by the train for attaining this velocity
    (a) 5 km (b) 7 km
    (c) 6 km (d) 3 km

Answer Key

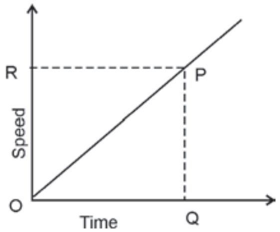
1. (a)	2. (b)	3. (c)	4. (a)	5. (b)	6. (d)	7. (c)	8. (d)	9. (b)	10. (c)
11. (a)	12. (c)	13. (b)	14. (b)	15. (d)	16. (a)	17. (a)	18. (b)	19. (c)	20. (b)
21. (a)	22. (b)	23. (d)	24. (b)	25. (c)	26. (a)	27. (c)	28. (c)	29. (b)	30. (d)

Hints and Solutions

2. (b)

Distance travelled = $\frac{1}{2}$ × Area of rectangle OQPR

$= \frac{1}{2} \times OR \times OQ$



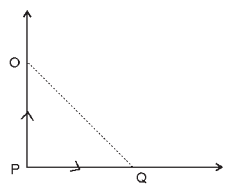
OR = speed,

OQ = time at

OP ⟶ velocity curve.

3. (c)

Applying Pythagoras theorem,



$OQ = \sqrt{OP^2 + PQ^2}$

$= \sqrt{36 + 64} = 10$

Since, OQ is the actual displacement.

4. (a)

A man starts from O and reaches Q. Shortest distance is OQ.

Apply Pythagoras theorem to ΔORQ.

(RQ = PM) and (PR = MQ)

$OQ^2 = OR^2 + RQ^2$

$= (2 + 6)^2 + (6)^2 = \sqrt{64 + 36}$

$OQ = \sqrt{100} = 10$ m

5. (b)

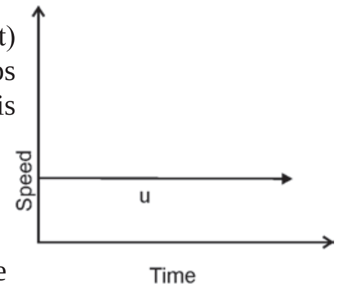
As the direction keeps on changing continuously in a circular motion, the speed remains constant but velocity keeps on changing all the time.

6. (d)

$\text{Acceleration} = \dfrac{\text{change in velocity}}{\text{Time taken}}$

7. (C)

In case of speed–time graph, having a constant line parallel to time (x) axis, we see that speed is fixed (constant) but time keeps on moving in this graph as shown, Speed = u (throughout).



8. (d)

$\text{Speed} = \dfrac{\text{Distance}}{\text{Time}}$

t_1 for first 40 km $= \dfrac{d_1}{v_1} = \dfrac{40}{55} = \dfrac{8}{11} h$

t_2 for next 20 km $= \dfrac{d_2}{v_2} = \dfrac{20}{50} = \dfrac{2}{5} h$

Total time taken $= t_1 + t_2 = \dfrac{8}{11} + \dfrac{2}{5} = \dfrac{62}{55}\ h$

= 1.127 hours.

12. (c)

$A = \dfrac{v-u}{t} = \dfrac{45-30}{3} = 5\ \text{m/s}^2.$

Here, acceleration, is positive as speed is increasing.

14. (b)

The line graph for car B makes a larger angle with time –axis. Its slope is larger than the slope of the line for car A. And the slope of distance–time graph shows speed. Thus car B has greater speed than car A.

15. (d)

$v = 72 \text{ km/h} = 72 \times \dfrac{5}{18} = 20 \text{ m/s}$

$u = 36 \text{ km/h} = 36 \times \dfrac{5}{18} = 10 \text{ m/s}$

t = 10 sec.

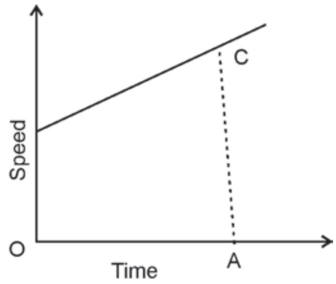
$A = \dfrac{v-u}{t} = \dfrac{20-10}{10} = 1\ \text{m/s}^2.$

16. (a)

$v = u + at$

$= 15 + 2.5 \times 2 = 20$ m/s.

17. (a)



Area of trapezium = $\frac{(OB+AC)\times OA}{2}$

= Distance travelled in A seconds, whose unit is m. Initial speed = OB, then accelerating from B to C in time A.

19. (c)

Distance = $\frac{1}{2}$ × base × height

= $\frac{1}{2}$ × 20 s × 20 m/s = 200 m.

20. (b)

Slope of the distance–time graph shows speed. The slope of line B is smallest, thus cyclist B is the slowest and cyclist C is the fastest among all four cyclists.

21. (a)

A horizontal line parallel to the time–axis shows a uniform velocity throughout the motion of the object.

22. (b)

When a body comes to rest, v = 0, here u = 30 m/s,

a = –1.5 m/s^2

$v = u + at$

$t = \frac{v-u}{a} = \frac{0-30}{-1.5} = \frac{-30}{-1.5} = 20$ seconds

23. (d)

u = 15 km/h, v = 60 km/h, t = 300 sec $= \frac{1}{12}$ h

$a = \frac{v-u}{t} = \frac{60-15}{1/12} = 540\,km/h^2$

Distance travelled by the car is given by

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

$= 15\times\frac{1}{12} + \frac{1}{2}\times 540\times\frac{1}{12}$

= 5 km

24. (b)

v = 0 u = 20 m/s, t = 5 s; a

$= \frac{v-u}{t} = \frac{0-20}{5} - 4\,m/s^2$

25. (c)

R = 32000 km, t = 30 hours

Circumference of the orbit = 2π R

= 2 × $\frac{22}{7}$ × 32000

= 201,142.86 km

velocity $= \frac{d}{t} = \frac{2\pi R}{t} = \frac{201{,}142.86}{30} \approx 6704\,km/h$

26. (a)

$$v = \frac{2\pi r}{t} = \frac{2\times\frac{22}{7}\times 45}{180} = 2\times\frac{22}{7}\times\frac{45}{180} = \frac{11}{7} = 1.57ms$$

t = 3, m = 180 Sceonds, r = 45 m

28. (c)

As we move along the graph, PQ and ST shows uniform acceleration. QR shows acceleration at an increasing rate. RS shows deceleration i.e.,speed is decreasing.

30. (d)

u = 0, v = 72 km/h = 72 × $\frac{5}{18}$ = 20 ms^{-1}, t = 5 minutes = 300 s

a = $\frac{v-u}{t} = \frac{20}{300} = \frac{1}{15}\,m/s^2$

v^2 = u^2 + 2as

s = $\frac{v^2-u^2}{2a} = \frac{(20)^2-(0)^2}{2\times\frac{1}{15}}$ = 3000 ssms

= 3 kms.

Force and Laws of Motion

2

Learning Objectives

- ❒ Concept of Force and its Effects
- ❒ Balanced and Unbalanced Forces
- ❒ Newton's Law of Motion
- ❒ Newton's First Law of Motion and Inertia
- ❒ Newton's Second Law of Motion and Momentum
- ❒ Application of Newton's Second Law
- ❒ Newton's Third Law of Motion
- ❒ Application of Third Law
- ❒ Conservation of Momentum
- ❒ Application of the Law of Momentum

Force

It is believed that rest is the natural state of an object. We put in some effort like pushing, pulling, stretching, pressing, hitting, etc. in order to move the object at rest into motion. The objects move because we apply a force on them.

For example, a force is used when we push the door to open it; we use force in pulling the drawer of a table; a force is used in lifting a heavy box; a force is used when we squeeze out water by twisting wet clothes; dry leaves from trees fly away because the force of wind pushes them.

Effects of Force

We cannot see force. A force can be judged only by the effects by it. A force can produce the following effects.

- A force can move a stationary object.
- A force can stop a moving object.
- A force can change the direction and speed of a moving body.
- A force can change the shape and size of a body.

Balanced and Unbalanced Forces

If the resultant of all the forces acting on a body is zero the forces are called ***balanced forces***. A heavy box placed on the table is pushed from the left side in order to move it. The four forces are acting on the box are as shown below.

1. Force of our push.
2. Force of friction (which opposes the push and does not allow the box to move).
3. Force of gravity or weight of box (which pulls the box downwards).
4. Force of reaction exerted by the ground on the box (upwards which balances the force of gravity).

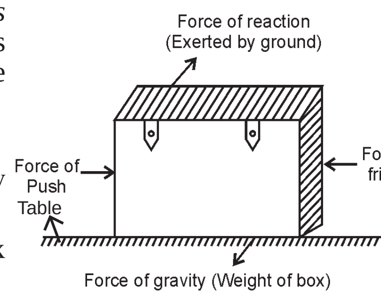


Fig: 2.1

Even after application of these four forces, the box does not move at all. Thus, we can conclude that the resultant of all the forces is zero.

In a tug of war, if the two teams have equal strength and apply equal force in opposite directions, the rope will stay and does not move in either direction.

Key Note

- If a number of balanced forces act on a stationary body, the body continues to remain in its stationary position.
- If a number of balanced forces act on a body in uniform motion, the body continues to be in its state of uniform motion.

The resultant of all the forces acting on a body is not zero, the forces are called ***unbalanced forces****:*

Unbalanced forces can move a stationary body or they can stop a moving body.

In case of a toy car, again four forces of push, friction, gravity and reaction are applied. Force of gravity on the car acting downwards and the force of reaction of ground acting upwards are equal and opposite, so they balance each other. Due to the wheels of the toy car, the opposing force of friction is much less than the force of our push. The resultant of all the forces is not zero *causing an unbalanced force acting on the toy car which makes the car move from its position of rest.*

Newton's Laws of Motion

Isaac Newton gave three laws of motion to describe the motion of bodies. These laws give a precise definition of force and establish a relationship between the force applied on a body and the state of motion acquired by it.

Newton's First Law of Motion

A body at rest will remain at rest, and a body in motion will continue in motion in straight line with a uniform speed, unless it is compelled by an external force to change its state of rest or of uniform motion.

Inertia

The tendency of a motionless body to remain at rest, or if moving, to continue moving in a straight line, is called inertia. Newton's first law recognizes that everybody has some inertia. Inertia is that property of a body due to which it resists a change in its state of rest or of uniform motion.

Key Point: Mass is measure of the inertia of a body. Heavier objects have more inertia and require more force to move as compared to the lighter objects.

Momentum

The force required to stop a moving body is directly proportional to the mass and velocity of that body. A cricket ball requires more force than a tennis ball to get stopped from moving in air. *Thus, the quantity of motion in a body depends on the mass and the velocity of the body. This quantity was introduced by Newton as momentum, denoted by P. It is the product of mass and velocity.*

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

$$\boxed{P = m \times v}$$

If a body is at rest, its velocity is zero, hence momentum is zero. The SI unit of momentum is kgm/s. Momentum is a vector quantity.

Key Note: Every moving body possesses momentum.

***Example* 1:** What is the momentum of a man of weight 70 kg when he walks with a uniform velocity of 3 m/s ?

***Solution*:** momentum, P = m × v

= 70 × 3

= 210 kg ms^{-1}

Newton's Second Law of Motion

According to Newton's second law of motion, the *rate of change of momentum of a body is directly proportional to the applied force, and takes place in the direction in which the force acts.*

The force necessary to change the momentum of an object depends on the time taken at which the momentum is changed.

$$\text{Force} \propto \frac{\text{Change in momentum}}{\text{Time taken}}$$

or $$F \propto \frac{mv - mu}{t}$$

or $$F \propto m\frac{(v-u)}{t}$$

$$\boxed{F \propto ma}$$

Thus the force acting on a body is directly proportional to the product of 'mass' of the body and the 'acceleration' produced in the body by the action of the force, and it acts in the direction of acceleration.

$$F = k \times m \times a$$

In SI units, value of constant k is 1. So the equation becomes

$$F = ma$$

Putting m = 1 kg and a = 1 m/s^2, F becomes 1 Newton.

Key Note: A Newton is that force which when acting on a body of mass 1 kg produces on acceleration of 1 m/s2 in it, represented by 1N.

Applications of Newton's second law

- A cricket fielder moves his hands backwards on catching a fast running cricket ball, in order to increase the time taken to reduce the momentum of ball to zero.
- A high jumping athlete is provided either a cushion or a heap of sand on the ground to fall upon. This cushion or sand, being soft reduces the athlete's momentum more gently.

***Example* 2:** Calculate the force required to impart to a car a velocity of 30 m/s in 10 sec, starting from rest. The mass of the car is 1500 kg.

***Solution*:** u = 0, v = 30 m/s, t = 10 s.

$$A = \frac{v-u}{t} = \frac{30}{10} = 3 \text{ m/s}^2$$

F = ma = 1500 × 3 = 4500 N

Newton's Third Law of Motion

Newton's third law of motion describes the relationship between the forces that come into play when the two bodies interact with one another. According to this law,

Whenever one body exerts a force on another body, the second body exerts an equal and opposite force on the first body. It can also be written as ' To every action, there is an equal and opposite reaction.'

Key Note: Action and reaction are just forces acting on two different bodies, and they act simultaneously.

Application of third law

- The box exerts 'action' (force of its weight) in downward direction on the ground. The ground is exerting an equal and opposite force, upward, on the box, which we called 'reaction'.
- Same way, when a gun is fired, it exerts a forward force on the bullet. The bullet exerts an equal and opposite reaction force on the gun which makes the gun recoil back.
- In another case, as the sailor jumps from the boat in forward direction towards the shore, the boat moves backward in water.

All these examples prove the Newton's third law of motion.

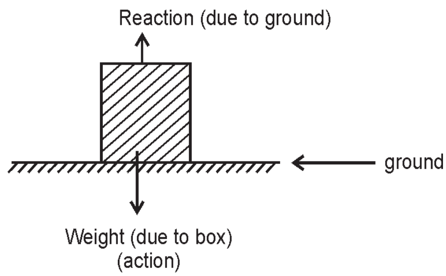


Fig: 2.2

Conservation of momentum

According to the law of conservation of momentum, '*when two (or more)bodies collide with one another, their total momentum remains constant (or conserved) provided no external forces are acting.*'

It means that whenever one body gains momentum, then the other body must lose an equal amount of momentum so that total momentum of the two bodies remains same. Thus, the law states that

'Momentum is neither created nor destroyed.' suppose two bodies, a truck (of mass m_1 and speed u_1) and a car (of mass m_2 and speed u_2) are moving in the same direction. Then,

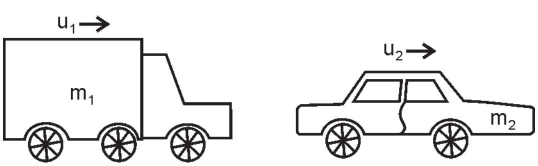


Fig: 2.3

Momentum before collision = $m_1 u_1 + m_2 u_2$

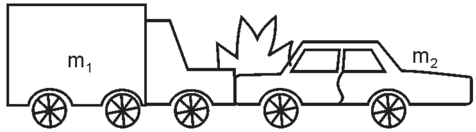


Fig: 2.4

Truck collided with the car

After collision, they again move in the same direction but with new velocities, m_1 with v_1 and m_2 with v_2 due to forces acting on each other.

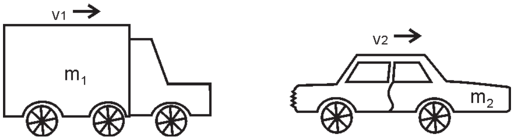


Fig: 2.5

Momentum after collision = $m_1v_1 + m_2v_2$

According to this law

Total momentum Before collision = Total momentum after collision

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Applications of the law of conservation of momentum

- The chemicals inside the rocket burn and produce high velocity blast of hot gases passing through the tail nozzle of the rocket in the downward direction. The rocket moves up to balance the momentum of gases.

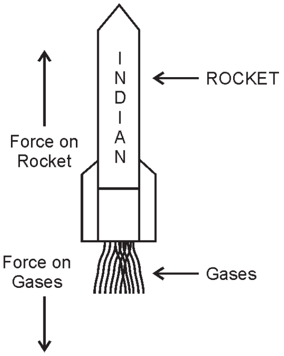


Fig. 2.6

Although the mass of gases emitted is comparatively small, but they have a very high velocity and hence a very large momentum. An equal momentum is imparted to the rocket in the opposite direction, so that, in spite of its large mass, the rocket goes up with a high velocity.

***Example* 3:** A bullet of mass 10 g is fired from a gun of mass 6 kg with a velocity of 300 m/s. calculate the recoil velocity of the gun.

***Solution*:** According to the law of conservation of momentum,

momentum of bullet = Momentum of gun

$\frac{10}{100}\,kg \times 300$ m/s = 6 kg × v (lets recoil velocity of gun be v m/s)

3 = 6v v = 0.5 m/s

***Example* 4:** The car A of mass 1500 kg, running at the speed of 25 m/s collides with another car B of mass 1000 kg travelling at the speed of 15 m/s in the same direction. After collision the velocity of car A becomes 20 m/s. calculate the velocity of car B after collision.