UNIT 02 KINEMATICS

Introduction:

In this unit, we will study the types of motion, scalar and vector quantities, the relation between displacement, speed, velocity and acceleration; linear motion and equations of motion.

The first thing concerning the motion of an object is kinematics.

"Kinematics mean the study of motion of an object without describing the cause of motion".

Q.1 Differentiate between rest and motion. Also give an example that all motions are relative. 091302001

Ans. Rest: *"A body is said to be at rest, if it does not change its position with respect to its surroundings."*

Motion: *"A body is said to be in motion, if it changes its position with respect to its surroundings."*

Example: The state of rest or motion of a body are relative to each other. For example, a passenger sitting in a moving bus is at rest because he is not changing his position with respect to other passengers in the bus. But to an observer outside the bus, the passengers inside the bus are in motion which shows that motion and rest are relative to each other.

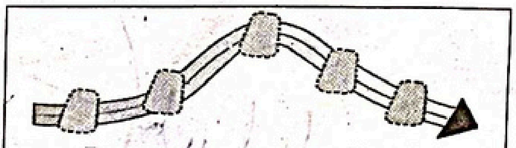
So we can say that "Rest & motion are relative states."

Q.2 What is surrounding? 091302002

Surroundings are the places in the neighbourhood where various objects are present.

Q.3 Explain different types of motion and give examples. Further explain types of translatory motion. 091302003

Ans. There are three types of motion.



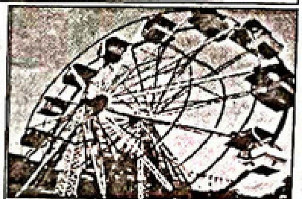
Translatory motion of an object along a curved path

(i) Translatory motion **(ii)** Rotatory motion **(ii)** Vibratory motion

1. Translatory Motion: **(F.B. 2015)**

In translational motion, a body moves along a line without any rotation. The line may be straight or curved.

For example



Translatory motion of riders in Ferris Wheel

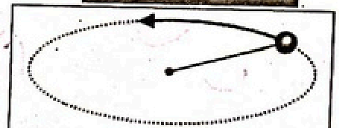
- A car is moving along a straight line and an aeroplane moving in a straight line.
- A car moves along a curved path without rotation. Riders moving in a Ferris wheel are also in translational motion.
  Their motion is in a circle without rotation.

Types of translatory motion

(a) Linear Motion :- *"If a body moves along a straight line then the motion of a body is known as linear motion".*

Example:
- Aeroplane flying straight in air.
- Objects falling vertically down are also the example of linear motion.
- A car moving on a straight and level road is in a linear motion.

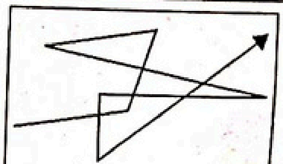
(b) Circular Motion:- *"The motion of an object in a circular path is known as circular motion".*



A stone tied at the end of a string move in a circle

For example:-

- Motion of earth around the sun.
- Motion of stone tied to string is a circular motion.
- A bicycle or a car moving along a circular track possess circular motion.
- Motion of moon around the earth is also example of circular motion.



Brownian movement of particles in liquid

(c) Random Motion:- *"The irregular or disordered motion of an object is called random motion".* **(F.B. 2016)**

Examples

- Motion of mosquitoes and insects.
- The motion of dust or smoke particles in the air.
- The Brownian motion of a gas or liquid molecules along a zig-zag path.

(ii) Rotatory Motion:- **(F.B. 2016)**

"The spinning motion of a body about its axis is called rotatory motion".

Examples:

- Motion of wheel about its axis
- Motion of earth around its own axis
- Motion of steering wheel

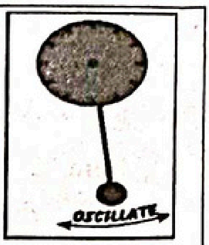
Rotatory Motion

(iii) Vibratory Motion:- **(Board 2016)**

"To and fro motion of a body about its mean position is known as vibratory motion".

Examples:-

- Motion of pendulum.
- Motion of see-saw.
- A baby in a cradle has to and fro motion about its mean position.
- To and fro motion of the hammer of a ringing electric bell.
- Motion of the strings of a sitar.



Vibratory motion of pendulum

Q.4 Differentiate between Scalar and Vector quantities. (F.B. 2016) 091302004

Ans. Scalar Quantities:- *"A physical quantity which can be completely described by its magnitude only is called a scalar quantity".* The magnitude of a quantity means its numerical value with suitable unit.

Examples: mass, length, time, speed, volume, work, energy, pressure and power etc.

Vector quantities:- *"A physical quantity which can be described completely by magnitude and direction is called a vector quantity.*

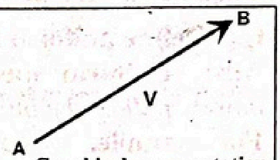
Examples: velocity, displacement, force, momentum, torque, acceleration and weight etc.

Q.5 How is a vector represented? Imp 091302005

Ans. A vector is represented by two methods symbolically and graphically.

i. Symbolically

Symbolically, we generally use bold letters to represent vector quantities, such as **F**, **a**, **d** or a bar or arrow over or below their symbols such as $\bar{F}$, $\bar{a}$, $\bar{d}$ or $\vec{F}$, $\vec{a}$ and $\vec{d}$ or $\underline{F}$, $\underline{a}$, $\underline{d}$, $\underline{F}$, $\underline{a}$, $\underline{d}$..



Graphical representation of vector

ii. Graphically

Graphically, a vector can be represented by a straight line with an arrow head at its one end. In figure, the line AB with arrow head of B represents a vector **V**. The length of the line AB gives the magnitude of the vector **V** on a selected scale. While the arrow head of the line from A to B gives the direction of the vector **V**.

Position of the school S from the home H

Q.6 What do you know about position? 091302006

Ans. Position:- *"The distance & direction of a body from a fixed point shows the position of a body".*

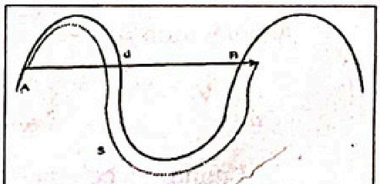
OR *"The term position describes the location of a place or a point with respect to some reference point called origin."*

Example: We want to describe the position of our school from our home. Let the school be represented by S and home by H. The position of your school from your home will be represented by a straight line HS in the direction from H to S.

Q.7 Differentiate between Distance and Displacement. or
Describe distance and displacement by diagram and explain. 091302007

Ans. Distance: *"Length of a path between two points is called the distance between those points".*

Distance is scalar quantity and is represented by S.



Distance S (dotted line) and displacement d (straight line) from A to B points

Displacement:-

"Displacement is the shortest distance between two points which has magnitude and direction".

It is a vector quantity and represented by **d**.

Example:

Consider a body that moves from point A to point B along the curved path. The length of curved path between point A and B is the distance between these points. The shortest distance which has magnitude and direction from point A to point B in particular direction is called displacement.

Q.8 Differentiate between Speed and Velocity **(F.B. 2014)** 091302008

Ans. Speed: *"The distance covered by a body in unit time is called its speed"*.

Formula: If 'S' is the distance covered by body in time 't', then.

$$\text{Speed} = \frac{\text{Distance covered}}{\text{time taken}}$$

$$\text{i.e } v = \frac{S}{t} \quad \text{or} \quad \text{Distance} = \text{Speed} \times \text{Time} \quad \text{or} \quad S = vt \;\ldots\ldots\ldots\ldots(2.1)$$

Here 'S' is the distance covered by the body, 'v' is its speed and 't' is the time taken by it. Distance is scalar; therefore, speed is also a scalar quantity.

SI unit of speed is metre per second (ms^{-1}). For large distances Kmh^{-1} is used.

Velocity: *"The rate of displacement of a body is called its velocity"*.

Formula: If **"d"** is the displacement covered by a body in time 't', then

Q: Under what circumstances average and instanteneous velocity become equal
Ans: If a body is moving with uniform velocity then its average and instantenous velocity become equal.

$$\text{Velocity} = \frac{\text{displacement}}{\text{time}} \quad \text{or} \quad \mathbf{v} = \frac{\mathbf{d}}{t} \quad \mathbf{d} = \mathbf{v}t \;\ldots\ldots\ldots(2.2)$$

Here **d** is the displacement of the body moving with velocity **v** in time t. Displacement is a vector quality, therefore velocity is also a vector quantity.

SI unit of velocity is the same as speed i.e., metre per second (ms^{-1}). Kmh^{-1} is used for large distances.

Note: Speedometer of a car tells the speed only whereas ships & aeroplanes have meters which tell speed & direction so velocity is observed through meters of ships & aeroplanes.

Q.9 Define uniform Speed and uniform velocity. 091302009

Ans: Uniform Speed: *"A body has uniform speed if it covers equal distances in equal intervals of time however short the interval may be"*.

For example, A car covers 30m distance in 20 seconds in next 20 seconds, car again covers 30m distance, then its velocity will be uniform.

If the speed of a body does not vary and has same value. Then the body possesses uniform speed.

Uniform Velocity **(F.B. 2015)**

A body has uniform velocity if it covers equal displacement in equal intervals of time however short the interval may be.

In many cases, the speed and direction of a body does not change. In such case, the body possesses uniform velocity. It means the velocity of a body during any interval of time has same magnitude and direction.

Q.10 Define Acceleration and write its formula. 091302010

Ans: Acceleration: *"Acceleration is defined as the rate of change of velocity of a body"*.

Formula: Suppose a body is moving with initial velocity 'v_i' after time 't' its velocity becomes 'v_f' then.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

$$a = \frac{V_f - V_i}{t} \;\ldots\ldots\ldots\ldots\ldots\ldots(2.3)$$

SI unit of acceleration is metre per second per second (ms^{-2}).

Q.11 Define Uniform Acceleration, and give its any example. Imp **(F.B. 2015)** 091302011

Ans: Uniform Acceleration: *A body has uniform acceleration if it has equal change in velocity in equal intervals of time, however short the interval may be.*

Example: The uniform acceleration produced by a freely falling body due to gravitational force.

Q.12 What is meant by positive and negative acceleration? 091302012

Ans: Positive acceleration: *Acceleration of a body is positive if the velocity of body increases with time. The direction of this acceleration is the same in which the body is moving without change in its direction.*

Negative acceleration: *Acceleration of a body is negative if velocity of the body decreases with time. The direction of negative acceleration is opposite to the direction in which the body is moving.* Negative acceleration is also called **deceleration** or **retardation.**

Q.13 What is meant by graph? 091302013

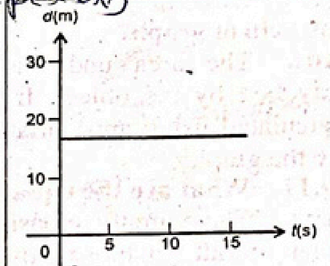
Ans. Graph:

A graph is the pictorial way of presenting information about the relationship between various quantities.

A ***graph*** *is a relation between two physical quantities which may be straight line or curved line.* The quantities between which a graph is plotted are called the **variables**. One of the quantities is called the **independent quantity** and the other quantity, is called **dependent quantity**. Graph is drawn between two mutually perpendicular lines called x–axis and y–axis. The point where these two lines meet is called **origin.** Independent quantities are taken on x–axis and dependent quantities are taken on y–axis.

Q.14 Explain the Distance-Time Graph. (slope of distance time graph gives us speed) 091302014

It is useful to represent the motion of objects by using graphs. In a distance-time graph, time is taken along horizontal axis while vertical axis shows the distance covered by the object.



Distance-time graph when the object is at rest

(i) Object is at rest 091302015

In the graph, the distance moved by the object with time is zero. That is, the object is at rest. Thus, a horizontal line parallel to time axis on a distance-time graph shows that speed of the object is zero.

(ii) Object is moving with constant speed 091302016

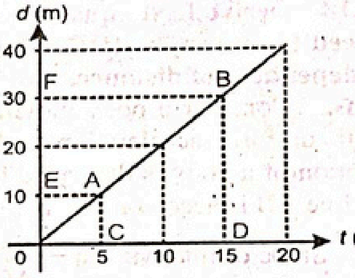
The speed of an object is said to be constant if it covers equal distances in equal intervals of time. The distance-time graph as shown in figure is a straight line. Its slope gives the speed of the object. Consider two points A and B on the graph.

Speed of the object = slope of line AB

$$\text{Speed} = \frac{\text{distance EF}}{\text{time CD}}$$

$$= \frac{20\text{m}}{10\text{s}} = 2\text{ms}^{-1}$$

The speed found from the graph is 2ms^{-1}.

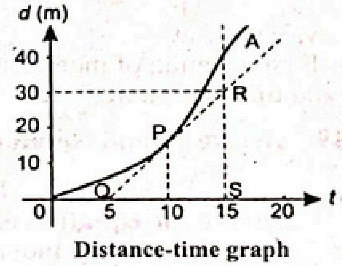


Distance-time graph showing constant speed

(iii) Object is moving with variable speed. (F.B. 2018) 091302017

When an object does not cover equal distances in equal intervals of time then its speed is not constant. In this case the distance-time graph is not a straight line as shown. The slope of the curve at any point can be found from the slope of the tangent at that point. For example,

$$\text{Slope of the tangent at P} = \frac{\text{RS}}{\text{QS}}$$



Distance-time graph showing variable speed

$$= \frac{30m}{10s} = 3ms^{-1}$$

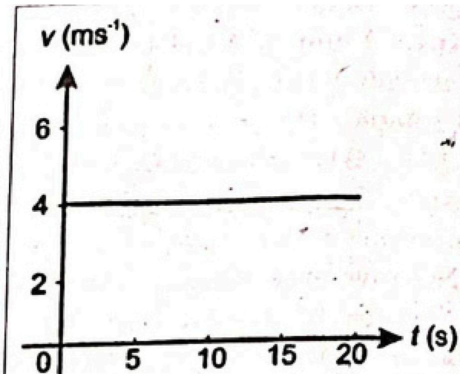
Thus, speed of the object at P is $3ms^{-1}$. "The speed is higher at instants when slope is greater; speed is zero at instants when slope is horizontal". The slope of distance – time graph shows the speed of moving object at that point. Slope of speed-time graph gives us the value of acceleration

Q.15 Explain Speed-time Graph. 091302018

In a speed time graph, time is taken along x-axis and speed is taken along y-axis.

(i) Object moving with constant speed. 091302019

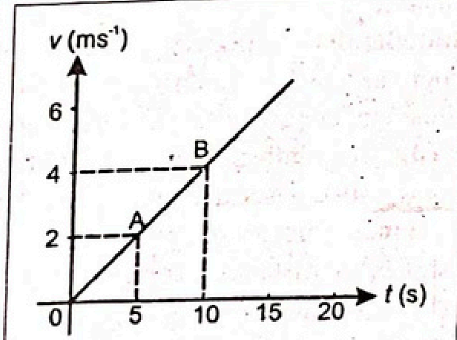
When the speed of an object is constant i.e ($4\ ms^{-1}$) with time, then the speed time graph will be a horizontal line parallel to time axis along x-axis as shown in figure. In other words, a straight line parallel to time axis represents constant speed of the object.



Speed-time graph showing constant speed.

(ii) Object moving with uniformly changing speed (uniform acceleration) or Variable Speed 091302020

Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate. Thus its speed time graph would be a straight line such as shown in figure. A straight line means that the object is moving with uniform acceleration. Slope of the line gives the magnitude of its acceleration.



Speed-time graph showing uniform acceleration

Q.16 How can you calculate distance travelled by a moving object with the help of graph? 091302021

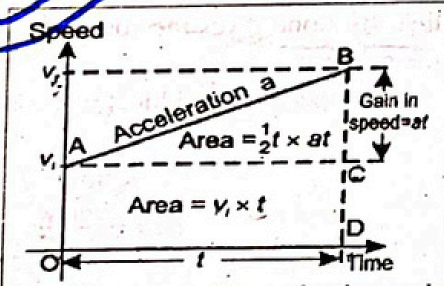
Ans. The area under a speed-time graph represents the distance travelled by the object. If the motion is uniform then the area can be calculated using appropriate formula for geometrical shapes represented by the graph.

Q.17 What are the equations of motion? 091302022

Ans. There are three basic equations of motion of bodies moving with uniform acceleration. These equations relate initial velocity v_i, final velocity v_f, acceleration **a**, time **t** and distance **S** covered by a moving body. In these equations of motion we suppose the motion of a body is along a straight line. Hence, we consider only the magnitude of displacements, velocities, and acceleration along straight line.

Q.18 Derive first equation of motion. $v_f = v_i + at$. with the help of speed-time graph. (OR) Derive the equation of motion which is independent of distance. Independent of distance **(F.B. 2010)** 091302023

Ans. Consider a body moving with initial velocity v_i in a straight line with uniform acceleration a. Its velocity becomes v_f after time t. The motion of a body is described by speed-time graph by line AB. The slope of line AB is acceleration "a".



Speed-time graph. Area under the graph gives the distance covered by the body

$$\text{Slope of line AB} = a = \frac{BC}{AC} = \frac{BD - CD}{OD} \qquad \because BC = BD - CD$$

as $\quad BD = v_f \quad CD = v_i$ and $OD = t \qquad \because AC = OD$

Hence $a = \dfrac{v_f - v_i}{t}$ or $v_f - v_i = at$

$\therefore \quad v_f = v_i + at$

First equation of motion shows the relationship between initial velocity 'v_i', final velocity 'v_f', acceleration 'a' and time duration 't'.

Q.19: Derive second equation of motion. $S = v_i t + \frac{1}{2} a t^2$ Independent of final velocity (v_f).

OR **(F.B. 2017)** 091302024

Derive the equation of motion which is independent of final velocity.

Ans. Consider a body moving with initial velocity "v_i" in a straight line with uniform acceleration a. Its velocity becomes "v_f" after time "t". The motion of body is described by speed-time graph by line AB. The slope of line AB is acceleration "**a**" the total distance covered by the body is shown by the shaded area under the line AB.

In speed-time graph shown in figure, the total distance S travelled by the body is equal to the total area OABD under the graph. That is

Total distance S = area of (rectangle OACD + triangle ABC) — (1)

Area of rectangle = Length x width

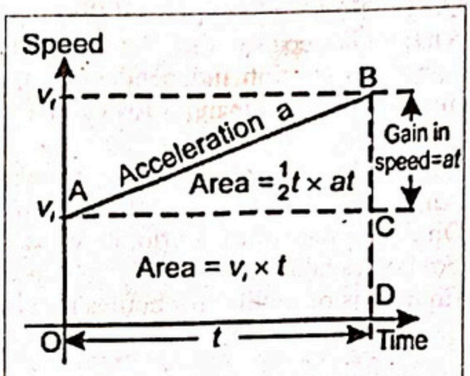
Area of Rectangle *OACD* = OA × OD $\therefore$ OA = v_i

$= \boxed{v_i \times t}$ (2) $\therefore$ OD = t

Area of triangle $= \frac{1}{2}$ base x height

Area of the triangle ABC $= \frac{1}{2}(AC \times BC)$ $\therefore AC = OD = t$

$= \boxed{\frac{1}{2} t \times at}$ (3) $\therefore BC = at$



Speed-time graph. Area under the graph gives the distance covered by the body

Since Total area OABD = area of rectangle OACD + area of triangle ABC

Putting values in the above equation, we get

$$S = v_i t + \frac{1}{2} t \times at$$

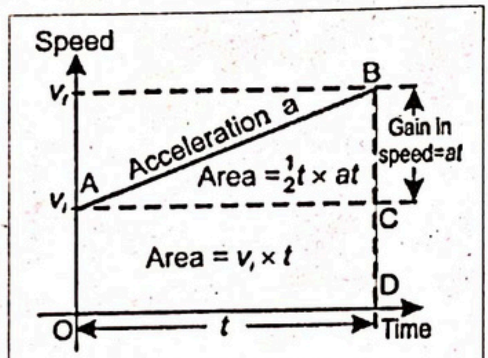
$$S = v_i t + \frac{1}{2} at^2$$

Second equation of motion shows the relationship between initial velocity 'v_i', acceleration 'a' time duration 't' and distance 's' covered by the moving body.

Q.20: Derive third Equation of motion. $2aS = v_f^2 - v_i^2$ Independent of time (t) **OR** **(F.B. 2017)** 091302025

Derive the equation of motion which is independent of time?

Consider a body moving with initial velocity "v_i" in a straight line with uniform acceleration **a**. Its velocity becomes "v_f" after time "t". The motion of a body is described by speed-time graph by line AB. The slope of line AB is acceleration "**a**". The total distance covered by the body is shown by the shaded area under the line AB. The total distance S travelled by the body is given by the total area OABD under the graph.



Speed-time graph. Area under the graph gives the distance covered by the body.

Total area of trapezium OABD = Distance

$$S = \frac{1}{2}[\text{Sum of parallel sides}] \text{ x perpendicular distance between parallel side}$$

Total area OABD = $S = \frac{OA + BD}{2} \times OD$

Or $2S = (OA + BD) \times OD$

Area under speed time graph gives us the value of distance.

Multiplying both sides by $\frac{BC}{OD}$

$$2 \times \frac{BC}{OD} \times S = (OA + BD) \times OD \times \frac{BC}{OD}$$

So $2 \times \frac{BC}{OD} \times S = (OA + BD) \times BC$ $\therefore BC = BD - CD$

$$2 \times \frac{BC}{OD} \times S = (OA + BD) \times (BD - CD)$$

Since $\frac{BC}{OD} = a$

$\therefore BD = v_f$; $CD = v_i$; $OA = v_i$

Putting the values in the above equation we get

$$2a \times S = (v_i + v_f) \times (v_f - v_i)\ ,\ 2aS = (v_f + v_i)(v_f - v_i),\ 2aS = v_f^2 - v_i^2$$

Third equation of motion shows the relationship between acceleration **'a'** initial velocity 'v_i', final velocity 'v_f' and distance covered by the moving body.

Q.21 How Galileo proved that acceleration of free falling bodies is the same? **091302026**

Ans: Galileo was the first scientist to notice that all the freely falling objects have the same acceleration independent of their masses. He dropped various objects of different masses from the leaning tower of Pisa. He found that all of them reach the ground at the same time.

Q.22 What is gravitational acceleration? Also write its value. **091302027**

Ans: *The acceleration of freely falling bodies is called gravitational acceleration.* It is denoted by 'g'. On the surface of the Earth, its value is approximately 10 ms^{-2}.

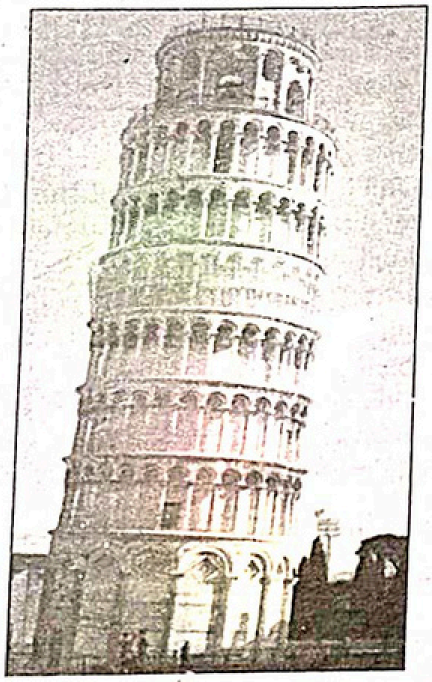
For bodies falling down freely '*g*' is positive and is negative for bodies moving up.

Equations of motion for bodies moving under the force of gravity as:

$$v_f = v_i + gt$$

$$h = v_i t + \frac{1}{2} g t^2$$

$$2gh = v_f^2 - v_i^2$$



Leaning Tower of Pisa

Multiple Choice Questions

2.1 Encircle the correct answer from the given choices:

Exercise MCQs

1. A body has translatory motion if it moves along a: 091302028

(a) Straight line (b) circle
(c) line without rotation (d) curved path

2. The motion of a body about an axis is called: 091302029

(a) Circular motion
(b) rotatory motion
(c) vibratory motion
(d) random motion

3. Which of the following is a vector quantity?

(a) speed (b) distance 091302030
(c) displacement (d) power

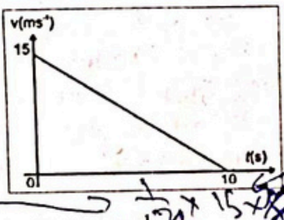
4. If an object is moving with constant speed then its distance time graph will be a straight line: 091302031

(a) along time-axis
(b) along distance –axis
(c) parallel to time–axis
(d) inclined to time–axis

5. A straight line parallel to time-axis on a distance-time graph tells that the object is:

(a) moving with constant speed 091302032
(b) at rest
(c) moving with variable speed
(d) in motion

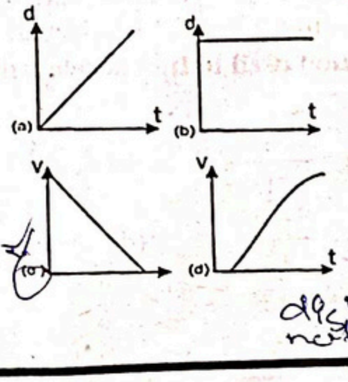
6. The speed–time graph of a car is shown in the figure, which of the following statement is true? 091302033



(a) car has an acceleration of $1.5ms^{-2}$
(b) car has constant speed of $7.5 ms^{-1}$
(c) distance travelled by the car is 75m
(d) average speed of the car is $15 ms^{-1}$

7. Which one of the following graphs is representing uniform acceleration?

(F.B. 2017) 091302034



distance time graph does not gives acceleration

8. By dividing displacement of a moving body with time, we obtain: 091302035

(a) speed (b) acceleration
(c) velocity (d) deceleration

9. A ball is thrown vertically upward. Its velocity at the highest point is: 091302036

(a) $-10 ms^{-1}$ (b) zero (F.B. 2015)
(c) $10 ms^{-2}$ (d) none of them

10. A train is moving at a speed of $36 kmh^{-1}$ Its speed expressed in ms^{-1} is: 091302037

(a) $10 ms^{-1}$ (b) $20 ms^{-1}$
(c) $25 ms^{-1}$ (d) $30 ms^{-1}$

$36kmh^{-1} = \frac{36 \times 1000}{3600} = 10 ms^{-1}$

11. A change in position from point A to B is called: (F.B. 2017) 091302038

(a) speed (b) velocity
(c) displacement (d) distance

12. A car starts from rest. It acquires a speed of $25 ms^{-1}$ after 20 s. The distance moved by the car during this time is: 091302039

(a) 31.25 m (b) 250 m
(c) 500 m (d) 5000 m

$a = \frac{v_f - v_i}{t}$, $a = \frac{25-0}{20}$, $a = 1.25$

$S = v_i t + \frac{1}{2} a t^2$

$S = (0)(20) + \frac{1}{2} \times 1.25 \times (20)^2$

$S = 0 + \frac{1}{2} \times 1.25 \times 400$

$S = 250$

Additional MCQs

13. The fastest bird falcon has speed. 091302040

(a) $100kmh^{-1}$ (b) $200 kmh^{-1}$
(c) $300 kmh^{-1}$ (d) $400 kmh^{-1}$

14. The average speed of cheetah is: 091302041

(a) $60kmh^{-1}$ (b) $75kmh^{-1}$
(c) $70kmh^{-1}$ (d) $80kmh^{-1}$

15. The unit of acceleration is: 091302042

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

16. Displacement is a quantity: 091302043

(a) Scalar (b) Vector
(c) Both a & b (d) None of these

17. When an object is moving with uniformly changing speed then the slope of the speed-time graph determines the magnitude of:

(F.B. 2018) 091302044

(a) distance (b) displacement
(c) velocity (d) acceleration

18. The value of gravitational acceleration when a body is moving in downward direction is: 091302045

(a) $10ms^{-1}$ (b) $10ms^{-2}$
(c) 10m (d) -10ms

19. **The slope of distance time graph shows:** 091302046
(a) speed (b) Displacement
(c) acceleration (d) Distance

20. **The motion of the rider in Ferris wheel is:**
(a) Translatory (b) Vibratory 091302047
(c) Rotatory (d) Linear

21. **First equation of motion is:** 091302048
(a) $v_f = v_i + at$ (b) $S = v_i t + \frac{1}{2}at^2$
(c) $2aS = v_f^2 - v_i^2$ (d) All of these

22. **If an object is moving with a uniform changing speed then speed time graph is:**
(a) Straight line 091302049
(b) Variable
(c) Parallel to time axis
(d) All of these

23. **The unit of velocity and speed is:** 091302050
(a) ms (b) ms^{-2}
(c) ms^{-3} (d) ms^{-1}

24. **Brownian motion is an example of:** 091302051
(a) Random motion
(b) Linear motion
(c) Circular motion
(d) Vibratory motion

25. **The to and fro motion of a body about its mean position is called:** 091302052
(a) Circular motion
(b) Random motion
(c) Rotatory motion
(d) Vibratory motion

26. **The motion of a body in straight line is:**
(a) Random motion 091302053
(b) Circular motion
(c) Linear motion
(d) Translatory motion

27. **If the velocity of body increases with time, the acceleration will be:** 091302054
(a) Negative (b) Uniform
(c) Positive (d) Variable

28. **If the velocity of body decreases with time then acceleration will be:** 091302055
(a) Negative (b) Positive
(c) Uniform (d) Variable

29. **The value of gravitational acceleration for bodies moving upward is:** 091302056
(a) $10ms^{-1}$ (b) $10ms^{-2}$
(c) 10m (d) $-10ms^{-2}$

30. **Rate of change of velocity is known as:** 091302057
(a) Speed (b) Acceleration
(c) Distance (d) Velocity

31. **Pressure is a quantity:** 091302058
(a) Scalar (b) Vector
(c) Base (d) Derived

32. **Motion of butterfly is an example of:** 091302059
(a) Random (b) Circular
(c) Linear (d) Vibratory

33. **Graph is plotted between ____ variables:** 091302060
(a) 2 (b) 3
(c) 4 (d) 1

34. **Independent quantities are taken on:** 091302061
(a) – x–axis (b) x–axis
(c) –y–axis (d) y–axis

35. **Dependent quantities are taken on:** 091302062
(a) x–axis (b) –ve x–axis
(c) y–axis (d) –ve –axis

36. **A car covers 100m distance in 10s. Its average speed is:** 091302063
(a) $1000 ms^{-1}$ (b) $10 ms^{-1}$
(c) $1 ms^{-1}$ (d) $20 ms^{-1}$

37. **A train start from rest. Its velocity becomes $40ms^{-1}$ in 10s. Its acceleration will be:** 091302064
(a) $4 ms^{-2}$ (b) $4 ms^{-1}$
(c) $40 ms^{-1}$ (d) $40 ms^{-2}$

38. **Paratrooper while coming down attains a velocity called:** 091302065
(a) Variable velocity
(b) Terminal velocity
(c) Uniform velocity
(d) Average velocity

39. **LIDAR gun is used to calculate the vehicle's:** 091302066
(a) Velocity (b) Acceleration
(c) Speed (d) Distance

40. **The acceleration of a body moving with uniform velocity is:** 091302067
(a) Zero (b) Variable
(c) Uniform (d) Negative

41. **Relation used to find acceleration is:** 091302068
(a) $a = \frac{v_f - v_i}{t}$ (b) $a = \frac{v_f^2 - v_i^2}{t}$
(c) $a = \frac{S - v_i}{t^2}$ (d) $a = v_f - v_i$

42. **Distance covered by freely falling downward body in first second of motion is:** 091302069
(a) 5m (b) 29.4m
(c) 10m (d) 19.6m

43. **The quantities that are completely described by only magnitude are:** 091302070
(a) Scalar (b) Vector
(c) Base (d) Derived

44. **The quantities that describe completely by magnitude and direction are:** 091302071
(a) Base (b) Derived
(c) Scalar (d) Vector

45. **The scientist who notice that all the freely falling objects have same acceleration:** 091302072
(a) Newton (b) Galileo
(c) Coulomb (d) Einstein

46. **The velocity of bodies falling down:** 091302073
(a) Decreases (b) Increases
(c) Constant (d) Zero

47. **The velocity of freely falling bodies moving upward:** 091302074
(a) Decreases (b) Increases
(c) Constant (d) Zero

48. **Speedometer measures the:** 091302075
(a) Velocity (b) Speed
(c) Acceleration (d) All of these

49. **When two bodies are in motion then the velocity of one body relative to the other is called:** 091302076
(a) Relative velocity
(b) Uniform velocity
(c) Variable velocity
(d) Average velocity

50. **Quantities between which a graph is plotted are called:** 091302077
(a) Scalars (b) Vectors
(c) Variables (d) None

51. **In graph reference point is taken as:** 091302078
(a) Origin (b) Coordinates
(c) x-axis (d) Variable

52. **A stone is dropped from a top of tower. The stone hits the ground 5s, the height of tower is:** 091302079
(a) 100 m (b) 125 m
(c) 150 m (d) 175 m

53. **Which is not a vector quantity?** 091302080
(F.B. 2016)
(a) Momentum (b) Pressure
(c) Weight (d) Torque

54. **The distance time graph for an object moving with variable speed is a:** 091302081
(a) Straight line parallel to vertical axis
(b) Straight line parallel to time axis
(c) Straight line passing through origin
(d) Carved line

55. **A body is moving with uniform velocity. What will be its acceleration?** 091302082
(a) Uniform (b) Zero
(c) $10ms^{-2}$ (d) $-10ms^{-2}$

Answers

1.	c	**2.**	b	**3.**	c	**4.**	d	**5.**	b
6.	c	**7.**	c	**8.**	c	**9.**	b	**10.**	a
11.	c	**12.**	b	**13.**	b	**14.**	c	**15.**	c
16.	b	**17.**	d	**18.**	b	**19.**	a	**20.**	a
21.	a	**22.**	a	**23.**	d	**24.**	a	**25.**	d
26.	c	**27.**	c	**28.**	a	**29.**	d	**30.**	b
31.	a	**32.**	a	**33.**	a	**34.**	b	**35.**	c
36.	b	**37.**	a	**38.**	b	**39.**	c	**40.**	a
41.	a	**42.**	a	**43.**	a	**44.**	d	**45.**	b
46.	b	**47.**	a	**48.**	b	**49.**	a	**50.**	c
51.	a	**52**	b	**53**	b	**54**	d	**55**	b

2.2 Explain translatory motion and give examples of various types of translatory motion. 091302083

Ans. See Q.No.3 on page No.

2.3 Differentiate between the following: 091302084

i. Rest and motion.
ii. Circular motion and rotatory motion.
iii. Distance and displacement
iv. Speed and velocity.
v. Linear and random motion.
vi. Scalars and vectors.

Ans.

i. Rest and motion.

Rest: A body is said to be at rest if it does not change its position with respect to its surroundings.

Motion: A body is said to be in motion if it changes its position with respect to its surroundings.

ii. Circular motion and rotatory motion.

Circular motion: The motion of an object in a circular path is known as circular motion.

Rotatory motion: The spinning motion of a body about its axis is called its rotatory motion.

iii. Distance and displacement

Distance: Length of a path between two points is called the distance between those points.

Displacement: The shortest distance between two points which has magnitude and direction is called displacement.

iv. Speed and velocity: **(F.B. 2015)**

Speed: The distance covered by a body in unit time is called its speed. It is a scalar quantity.

Velocity: Rate of change of displacement is called velocity. It is denoted by **v**. It is a scalar quantity.

v. Linear and random motion:

Linear motion: If a body moves along a straight line then the motion of a body is known as its linear motion.

Random motion: The irregular or disordered motion of an object is called random motion.

vi. Scalars and vectors:

Scalars: A physical quantity which can be completely described by its magnitude only is called a scalar quantity. For example, mass, length, time, speed, volume, pressure, etc.

Vector: A physical quantity which can be completely described by its magnitude and direction is called a vector quantity. For example, force, displacement, momentum, torque, acceleration, etc.

2.4 Define the terms speed, velocity, and acceleration. 091302085

Ans. Speed: The distance covered by a body in unit time is called its speed.

Formula:- $v = \frac{S}{t}$

Unit:- ms^{1} or kmh^{-1}

Quantity:- Scalar

Velocity: The rate of displacement of a body is called its velocity.

Formula:- $\mathbf{v} = \frac{\mathbf{d}}{\mathbf{t}}$

Unit:- ms^{-1} or kmh^{-1}

Quantity:- Vector

Acceleration: Acceleration is defined as the rate of change of velocity of a body.

Formula:- a = $\frac{v_f - v_i}{t}$

Imp for board

$a = \frac{\Delta V}{t}$

Unit:- ms^{-2} or kmh^{-2}

Quantity:- Vector

2.5 Can a body moving at a constant speed have acceleration? **(F.B. 2017)** 091302086

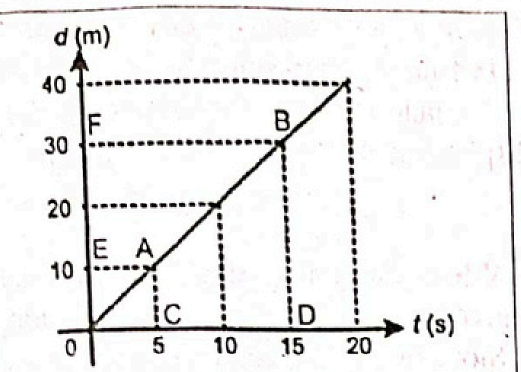
Ans. Yes! A body moving with constant speed have acceleration if the direction of moving body changes, which produce acceleration, e.g a body moving in a circle with uniform speed have acceleration because at any point its direction of motion changes.

2.6 How do riders in a Ferris wheel possess translatory motion but not rotatory motion? 091302087

Ans. Since the rider in Ferris wheel is moving without rotation in circular path so the rider in Ferris wheel possesses translatory motion.

2.7 Sketch a distance-time graph for a body starting from rest. How will you determine the speed of a body from this graph? 091302088

Ans.



Distance-time graph showing constant speed

Speed of the object = slope of line AB

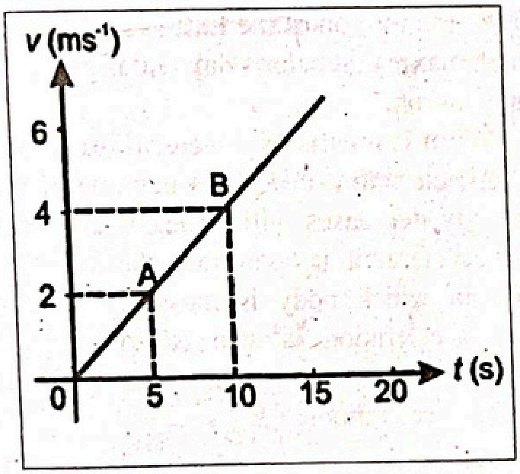
$$\text{Speed} = \frac{\text{distance EF}}{\text{time CD}}$$

$$v = \frac{20\text{m}}{10\text{s}} = 2\text{ms}^{-1}$$

The speed found from the graph is 2ms^{-1}.

2.8 What would be the shape of a speed – time graph of a body moving with variable speed? 091302089

Ans. Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate. Thus its speed time graph would be a straight line such as shown in figure. A straight line means that the object is moving with uniform acceleration. Slope of the line gives the magnitude of its acceleration.



2.9 Which of the following can be obtained from speed – time graph of a body? 091302090

(i) Initial speed.

(ii) Final speed.

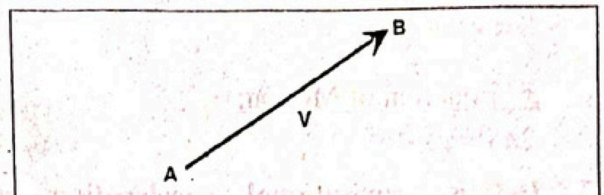
(iii) Distance covered in time *t*.

(iv) Acceleration of motion.

Ans. We can calculate all the above mentioned terms from a speed time graph.

2.10 How can vector quantities be represented graphically? 091302091

Ans. Graphically, a vector can be represented by a straight line with an arrow head at its one end. In figure, the line AB with arrow head of B represents a vector **V**. The length of the line AB gives the magnitude of the vector **V** on a selected scale. While the arrow head of the line from A to B gives the direction of the vector **V**.



Graphical representation of vector

2.11 Why vector quantities cannot be added and subtracted like scalar quantities. 091302092

Ans. Vector and scalar quantities cannot be added and subtracted by same method because vector quantity need magnitude and direction vector quantities are added by **head to tail rule** while scalars are added by **algebraic method.**

2.12 How are vector quantities important to us in our daily life? 091302093

Ans. Vectors are important tools to learn all in Physics and Engineering. Vectors are used whenever we have to calculate both size and direction of a parameter.

With the help of vector quantities we can explain the position of an object with distance and direction. Vectors are used in airplanes and in sail boat.

2.13 Derive equations of motion for uniformly accelerated rectilinear motion. 091302094

Ans. See the question no. 18, 19, 20 on Page no. 26,27

2.14 Sketch a velocity – time graph for the motion of the body. From the graph explaining each step, calculate total distance covered by the body. 091302095

Ans. See Example no. 2.9 on Page no. 37.

Additional Short Answer Questions

Q15. How can we write equations of motion under the action of gravity? 091302096

Ans. Equations of motions for freely falling bodies are:

i) $v_f = v_i + gt$ ii) $h = v_i t + \frac{1}{2}gt^2$

iii) $2gh = v_f^2 - v_i^2$

Q16. Write second and third equation of motion in mathematical form. 091302097

Ans. 2nd Equation of Motion:

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

3rd Equation of Motion:

$$2aS = v_f^2 - v_i^2$$

Q17. Define gravitational acceleration and write its value. 091302098

Ans. The acceleration of freely falling bodies is called gravitational acceleration. It is denoted by 'g'. It value is $10 ms^{-2}$ on earth.

Q18. Which is the fastest bird on the Earth? 091302099

Ans. Falcon is the fastest bird, it can fly at a speed of $200\ kmh^{-1}$.

Q19. Which is the fastest animal on the Earth? 091302100

Ans. Cheetah is the fastest animal, it can run at a speed of $70\ kmh^{-1}$.

Q20. What is LIDAR gun and for what purpose is it used? 091302101

Ans. A LIDAR gun is light detection and ranging speed gun. It uses the time taken by laser pulse to make a series of measurements of a vehicle's distance from the gun. The data is then used to calculate the vehicle's speed.

Q21. How does a paratrooper comes to ground? 091302102

Ans. A paratrooper attains a uniform velocity called terminal velocity with which it comes to ground.

Q22. What are the applications of graphs in everyday life? 091302103

Ans. A graph is used in everyday life such as to show year-wise rainfall, a patient's temperature record or runs per over scored by a team and so on.

Q23. How velocity affects the direction of acceleration? 091302104

Ans. Acceleration of a moving object will be in the direction of velocity if its velocity is increasing. Acceleration of the object is opposite to the direction of velocity if its velocity is decreasing.

Q24. Define average velocity. 091302105

Ans. Average velocity of a body is defined as the total displacement divided by the total time.

$$v_{av} = \frac{\text{total displacement}}{\text{total time}}$$

Q25. What does the slope of distance-time graph give? 091302106

Ans. Slope of the distance-time graph gives the speed of the body.

Q26. What does the slope of displacement time graph give? 091302107

Ans. Slope of the displacement time graph gives the velocity of the body.

Q27. What does the slope of velocity time graph give? 091302108

Ans. Slope of the velocity-time graph gives the acceleration of the body.

Q28. Define position. 091302109

Ans. Position means the location of a certain place or object from a reference point.

Q29. Define axis. 091302110

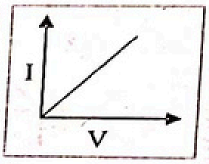
Ans. An axis is a line around which a body can rotates.

Q30. Explain the motion of the Earth about its axis and around the sun. 091302111

Ans. The motion of the Earth around the Sun is circular motion and not the spinning motion. However, the motion of the Earth about its geographic axis that causes day and night is rotatory motion.

Q31. What is meant by deceleration? 091302112

Ans. Acceleration of body is negative if velocity of the body decreases with time. The direction of negative acceleration is opposite to the direction in which body is moving. Negative acceleration is also called deceleration. It is also named as retardation acceleration.



e.g. graph between V and I is a strength line.

Q32. What is graph? 091302113

Ans. Graph is a pictorial way of presenting information about the relation between various quantities.

Q33. Name the first scientist who noticed freely falling objects? 091302114

Ans. Galileo was first scientist who noticed the freely falling object.

Q34. A cyclist completes half round of a circular track of diameter 636m in 1.5 minutes. Find his velocity. (F.B. 2018) 091302115

Ans. Given data:

Diameter = 636m

Displacement = 636m

Time taken = 1.5 minutes

= 60 s + 30 s

= 90 s

To find:

Velocity = V = ?

Solution:

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

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

$$V = \frac{636\text{m}}{90\text{s}}$$

$$V = 7.07\ \text{ms}^{-1}$$

$$V = 7.1\ \text{ms}^{-1}$$

Result:

The velocity of cyclist while moving in a half circular track is 7.1 ms^{-1}.

Mini Exercise

Q35. When a body is said to be at rest? 091302116

Ans. A body is said to be at rest if it does not change its position with respect to some observer.

Q36. Give an example of a body that is at rest and in motion at the same time. 091302117

Ans. A person driving a car is a good example of this question because when a person is driving his body is in rest but also in motion due to the motion of car.

Q37. Mention the type of motion in each of the following: 091302118

i) A ball moving vertically upward ⇒ Linear motion

ii) A child moving down a slide ⇒ Linear motion

iii) Movement of a player in a football ground ⇒ Random motion

iv) The flight of a butterfly ⇒ Random motion

v) An athlete running in a circular track ⇒ Circular motion

vi) The motion of a wheel ⇒ Rotatory motion

vii) The motion of a cradle ⇒ Vibratory motion

Conversions

Q1. How to convert ms^{-1} to kmh^{-1}? 091302119

$$1\text{ms}^{-1} = 0.001\text{km} \times 3600\text{h}^{-1} = 3.6\text{kmh}^{-1}$$

Thus multiply speed in ms^{-1} by 3.6 to get speed in kmh^{-1}.

e.g.

$$20\text{ms}^{-1} = 20 \times 3.6\text{kmh}^{-1}$$

$$= 72\text{kmh}^{-1}$$

Q2. How to convert kmh^{-1} to ms^{-1}? 091302120

$$1\text{kmh}^{-1} = \frac{1000\text{m}}{60 \times 60\text{s}} = \frac{10}{36}\text{ms}^{-1}$$

Thus multiply speed in kmh^{-1} by $\frac{10}{36}$ to get speed in ms^{-1} e.g.

$$50\text{kmh}^{-1} = 50 \times \frac{10}{36} = 13.88\text{ms}^{-1}$$

Q3. How to convert ms^{-2} to kmh^{-2}? 091302121

Multiply acceleration in ms^{-2} by

$[(3600 \times 3600)/1000] = 12960$ to get value in kmh^{-2}

Q4. How convert kmh^{-2} to ms^{-2}? 091302122

Divide acceleration in kmh^{-2} by 12960 to get value in ms^{-2}.

Solved Examples

Example 2.1: Represent a force of 80N acting toward North of East. 091302123

Solution

Step 1

Draw the directions.

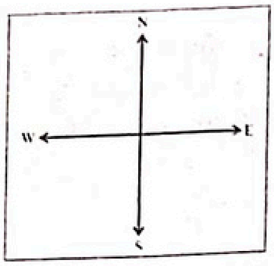
Step 2

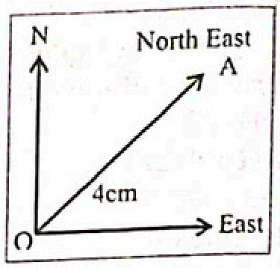
Select a suitable scale to represent the given vector.

i.e 20 N = 1cm

80 N = 4cm

Representing 80 N force acting North – East





Step 3

Draw a line according to the scale in the direction of the vector. In this case, draw a line OA of length 4cm along North-East.

Step 4

Put an arrow head at the end of the line. In this case arrow head is at point A. Thus, the line OA will represent a vector i.e., the force of 80N acting towards North-East.

Example 2.2

A sprinter completes its 100 metre race in 12s. Find its average speed. 091302124

Solution

Total distance = S = 100 m

Total time taken = t = 12 s

$$\text{Average Speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$\text{Average Speed} = \frac{100}{12} = 8.33\text{ms}^{-1}$$

Thus the speed of the sprinter is 8.33ms^{-1}.

Example 2.3

A cyclist completes half round of a circular track of radius 318m in 1.5 minutes. Find its speed and velocity. (F.B. 2017) 09130212

Given data:

Radius = r = 318 m

Time taken = t = 1.5 minutes = 1 min. 30S

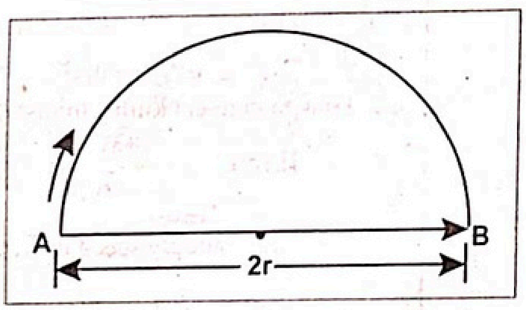
= $1.5 \times 60 = 90$ sec

Distance covered = $\pi \times$ radius

Distance covered = $3.14 \times 318\text{m} = 999\text{m}$

Displacement = 2 r

Displacement = $2 \times 318\text{m} = 636$ m



To Find:

Speed = ?

Velocity = ?

Solution: $\text{speed} = \frac{\text{distance}}{\text{time}}$

$$v = \frac{S}{t}$$

$$\text{speed} = \frac{999}{90} = 11.1\text{ms}^{-1}$$

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

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

$$\text{velocity} = \frac{636}{90} = 7.07\text{ms}^{-1}$$

Result:

Thus speed of the cyclist is 11.1ms^{-1} along the track and its velocity is about 7.1ms^{-1} along the diameter AB of the track.

Example 2.4: A car starts from rest. Its velocity becomes 20ms^{-1} in 8s. Find its acceleration.

Given Data: **(F.B. 2016)** **091302126**

Initial velocity = $v_i = 0\ \text{ms}^{-1}$

Final velocity = $v_f = 20\ \text{ms}^{-1}$

Time taken = $t = 8$ s

To Find: $a = ?$

Solution:

As $a = \dfrac{V_f - V_i}{t}$

Or $a = \dfrac{20-0}{8}$ $a = 2.5\ \text{ms}^{-2}$

Result:

The acceleration of car is 2.5ms^{-2}.

Example 2.5: Find the retardation produced when a car moving at a velocity of 30ms^{-1} slows down uniformly to 15ms^{-1} in 5s. **(F.B. 2017)** **091302127**

Given Data:

Initial velocity = $v_i = 30\text{ms}^{-1}$

Final velocity = $v_f = 15\text{ms}^{-1}$

Change in velocity = $v_f - v_i$

$= 15 - 30 = -15\ \text{ms}^{-1}$

Time taken = $t = 5$ s

To Find: $a = ?$

Solution:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

as

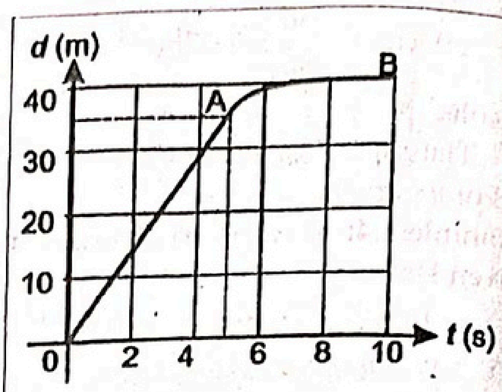
$$= \frac{v_f - v_i}{t} = \frac{15-30}{5}$$

or $a = \dfrac{-15}{5} = -3\text{ms}^{-2}$

So deceleration of the car is 3ms^{-2}.

Example 2.6: Figure shows the distance-time graph of a moving car. From the graph, find. 091302128

(a) The distance car has travelled.
(b) The speed during the first five seconds.
(c) Average speed of the car.
(d) Speed during the last 5 seconds.



Distance-time graph of a car

Solution:

a. Total distance travelled = 40 m

b. Distance travelled during first 5 s is 35 m

$$\therefore \quad \text{Speed} = \frac{35\text{m}}{5\text{s}} = 7\ \text{ms}^{-1}$$

c. $$\text{Average speed} = \frac{40\text{m}}{10\text{s}} = 4\ \text{ms}^{-1}$$

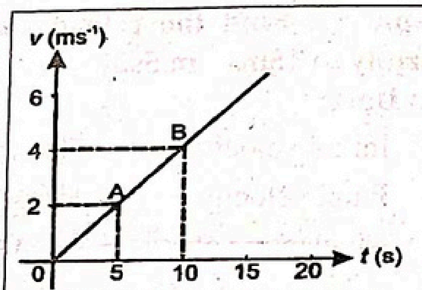
d. Distance moved during the last 5 s = 5 m

$$\therefore \quad \text{Speed} = \frac{5\ \text{m}}{5\text{s}} = 1\ \text{ms}^{-1}$$

Example 2.7: Find the acceleration from speed-time graph shown in figure (F.B. 2017) 091302129

Solution:

On the graph in figure, point A gives speed of the object as 2 ms^{-1} after 5 s and point B gives speed of the object as 4 ms^{-1} after 10 s.



Graph of an object moving with uniform deceleration

As acceleration = slope of AB

$$\text{where slope} = \frac{\text{Change in velocity}}{\text{Time interval}}$$

$$\therefore \text{acceleration} = \frac{V_f - V_i}{t_f - t_i}$$

$$\therefore \text{acceleration} = \frac{4-2}{10-5} = \frac{2}{5} = 0.4\,\text{ms}^{-2}$$

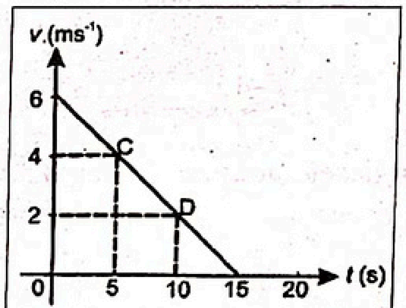
Result:

Speed-time graph in figure gives acceleration of the object as 0.4 ms^{-2}

Example 2.8: Find the acceleration from speed-time graph shown in figure 091302130

Solution:

The graph in figure shows that the speed of the object is decreasing with time. The speed after 5 s is 4 ms^{-1} and it becomes 2 ms^{-1} after 10s.



Graph of an object moving with uniform deceleration

As acceleration = slope of CD

$$\therefore \text{acceleration} = \frac{v_f - v_i}{t_f - t_i} = \frac{2-4}{10-5} = -\frac{2}{5} = -0.4\text{ms}^{-2}$$

Result:

Speed time graph in figure gives negative slope. Thus, the object has deceleration of 0.4ms^{-2}

Example 2.9

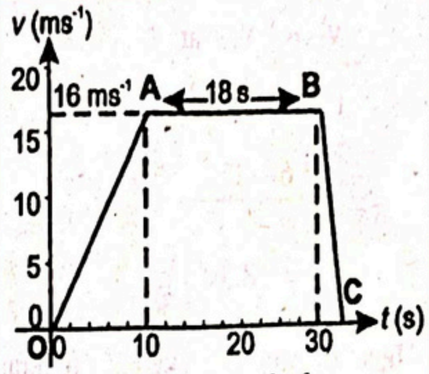
A car moves in a straight line. The speed-time graph of its motion is shown in figure. From the graph, find **091302131**

a. Its acceleration during the first 10 seconds.

b. Its deceleration during the last 2 seconds.

c. Total distance travelled.

d. Average speed of the car during its journey.



Speed-time graph of a car during 30 seconds

Solution:

a. Acceleration during the first 10 seconds

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}} = \frac{16-0}{10} = 1.6\ \text{ms}^{-2}$$

b. Acceleration during the last 2 seconds

$$\text{Acceleration} = \frac{0-16}{2} = -8\ \text{ms}^{-2}$$

c. Total distance travelled = area under the graph (trapezium OABC)

$$= \frac{1}{2}(\text{sum of parallel sides}) \times (\text{Perpendicular distance between parallel sides})$$

$$= \frac{1}{2}(18+30)\times(16) = \frac{1}{2}(48)\times(16) = 384\ \text{m}$$

d. Average speed $= V_{av} = \dfrac{\text{Total distance}}{\text{Total time}} = \dfrac{384}{30} = 12.8\ \text{ms}^{-1}$

Example 2.10:

A car travelling at 10 ms^{-1} accelerates uniformly at 2 ms^{-2}. Calculate its velocity after 5 s. **091302132**

Given data:

$V_i = 10\ \text{ms}^{-1}$

$a = 2\ \text{ms}^{-2}$

$t = 5\text{s}$

To Find:

$V_f = ?$

Using the first equation

Solution:

$V_f = v_i + at$

$V_f = 10 + 2 \times 5$

or $v_f = 20\ \text{ms}^{-1}$

Result:

The velocity of the car after 5 s is 20 ms^{-1}

Examples 2.11: A train slows down from 80 kmh^{-1} with a uniform retardation of 2 ms^{-2}. How long will it take to attain a speed of 20kmh^{-1}? **(F.B. 2017)** **091302133**

Given Data:

$v_i = 80\ \text{kmh}^{-1}$

$= \dfrac{80\times1000}{60\times60}$

$= 22.2\ \text{ms}^{-1}$

$v_f = \dfrac{20\times1000}{60\times60}$

$= 5.6\ \text{ms}^{-1}$

$a = -2\ \text{ms}^{-2}$

LMIPRJSTB

To Find:

$t = ?$

Solution:

Using first equation

$$v_f = v_i + at$$

$$t = \frac{v_f - v_i}{a}$$

$$= \frac{5.6 - 22.2}{-2}$$

$$t = 8.3s \ s$$

Result:

Thus the train will take 8.3 s to attain the required speed.

Example 2.12

A bicycle accelerates at 1 ms^{-2} from an initial velocity of 4 ms^{-1} for 10s. Find the distance moved by it during this interval of time. 091302134

Given Data:

$v_i = 4ms^{-1}$

$a = 1ms^{-2}$

$t = 10s$

To Find:

$S = ?$

Solution:

Using the second equation

$$S = v_i t + \tfrac{1}{2} at^2$$

$$S = 4 \times 10 + \tfrac{1}{2} \times 1 \times (10)^2$$

$$= 40 + \tfrac{1}{2} \times 100$$

$$= 40 + 50$$

$$= 40 + 50 = 90 \text{ m}$$

Result:

Thus, the bicycle will move 90 metres in 10 seconds.

Example 2.13

A car travels with a velocity of 5 ms^{-1}. It then accelerates uniformly and travels a distance of 50 m. If the velocity reached is 15ms^{-1}. Find the acceleration and the time to travel this distance. 091302135

Given Data:

$v_i = 5 \text{ ms}^{-1}$

$s = 50 \text{ m}$

$v_f = 15 \text{ ms}^{-1}$

To Find:

$a = ?$

$t = ?$

Solution:

Putting values in the third equation of motion, we get

$$2aS = v_f^2 - v_i^2$$

$$\therefore 2a \times 50 = (15)^2 - (5)^2$$

$$(100)a = 225 - 25$$

$$100a = 200$$

$$a = \frac{200}{100}$$

or $\quad a = 2ms^{-2}$

Using first equation of motion to find t, we get

$v_f = v_i + at$

$\therefore \quad 15 = 5 + 2 \times t$

$15 - 5 = 2 \times t$

or $\quad 2 \times t = 10$

or $\quad t = \frac{10}{2} = 5s$

Result:

Thus, the acceleration of the car is 2 ms^{-2} and it takes 5 seconds to travel 50m distance.

Example 2.14: A stone is dropped from the top of a tower. The stone hits the ground after 5 seconds. Find 091302136

a) The height of the tower.

b) The velocity with which the stone hits the ground.

Given Data:

Initial velocity = $v_i = 0$

Gravitational acceleration = g = 10 ms^{-2}

$t = 5s$

To Find:

$S = h = ?$

$v_f = ?$

Solution:

a) Applying the equation

$h = v_i t + \frac{1}{2} g t^2,$

$h = 0 \times 5 + 1/2 \times 10 \times (5)^2$

or $\quad h = 0 + 125$

$h = 125m$

b) Applying the equation

$v_f^2 - v_i^2 = 2gh$

$v_f^2 - (0)^2 = 2 \times 10 \times 125$

$v_f^2 = 2500$

$\sqrt{v_f^2} = \sqrt{2500}$

$v_f = 50ms^{-1}$

Result:

Thus the height of the tower is 125 metres and it will hit the ground with a velocity of 50 ms^{-1}.

Example 2.15

A boy throws a ball vertically up. It returns to the ground after 5 seconds. Find 091302137

a. The maximum height reached by the ball.

b. The velocity with which the ball is thrown up.

Given Data:

Gravitational acceleration = $g = -10 ms^{-2}$

Time for up and down motion $t_o = 5 s$

Velocity at maximum height $v_f = 0$

To Find:

Maximum height = $S = h = ?$

Initial velocity (upward) = $v_i = ?$

Solution:

As the acceleration due to gravity is uniform, hence the time t taken by the ball to go up will be equal to the time taken to come down = $\frac{1}{2} t_o$

or $t = 1/2 \times 5 = 2.5$ s

$v_f = v_i + gt$

$0 = v_i - 10 \times 2.5 = v_i - 25 \Rightarrow v_i = 25\ ms^{-1}$

a) Applying the equation

$h = v_i t + \frac{1}{2} gt^2$

$h = 25 \times 2.5 - \frac{1}{2} \times 10 \times (2.5)^2$ or $h = 62.5 - 31.25 = 31.25m$

Result:

Thus, the ball was thrown up with a speed of 25 ms^{-1} and the maximum height to which the ball rises is 31.25 m.

Numerical Problems

Q. 2.1 A train moves with a uniform velocity of 36 kmh^{-1} for 10s. Find the distance travelled by it. 091302138

Given Data:

$v = 36$ km/h

$= \frac{36 \times 1000}{3600} = 10 ms^{-1}$

$t = 10$ sec

To Find:

$S = ?$

Solution:

We Know

$S = v \times t$

$S = 10 \times 10 = 100$ m

Result: The distance travelled by the train is 100m.

Q. 2.2 A train starts from rest. It moves through 1 R.S km in 100 s with uniform acceleration. What will be its speed at the end of 100 s. 091302139

Given Data:

$v_i = 0$

$t = 100$ sec

$S = 1$ km $= 1000$ m

To Find:

$v_f = ?$

Solution:

We know

$S = v_{av} \times t$

$S = \left(\frac{v_i + v_f}{2}\right) t$

$1000 = \left(\frac{0 + V_f}{2}\right) 100$

$1000 \times 2 = (v_f)(100)$

$\frac{20\cancel{00}}{1\cancel{00}} = v_f$

$\boxed{v_f = 20\ ms^{-1}}$

Result: At the end of the 100s, the velocity of the train will be 20ms^{-1}.

Q.2.3 A car has a velocity of 10 ms^{-1}. It accelerates at 0.2 ms^{-2} for half minute. Find the distance travelled during this time and the final velocity of the car. (F.B. 2016) 091302140

Given Data:

$a = 0.2\ m/s^2$

$v_i = 10$ m/s

$t = 0.5$ min

$= 0.5 \times 60$ sec

$t = 30$ sec

To Find:

$S = ?$

$v_f = ?$

Solution: We know

$v_f = v_i + at$

$v_f = 10 + (0.2)(30)$

$= 10 + 6$

$v_f = 16m/s$

$S = v_{av} \times t$

$S = \frac{v_f + v_i}{2} t$

$S = \left(\frac{16 + 10}{2}\right) 30$

$S = \left(\frac{\cancel{26}^{13}}{\cancel{2}}\right) 30 \quad \boxed{S = 390\ m}$

Result: Hence, the final velocity of the car is 16ms^{-1} and car has travelled the distance 390m.

Q. 2.4 A tennis ball is hit vertically upward with a velocity of $30 ms^{-1}$. It takes 3s to reach the highest point. Calculate the maximum height reached by the ball. How long will it take to return to ground? 091302141

Given Data:

$v_i = 30\ ms^{-1}$

$t = 3$ sec

To Find:

Total time = T = ?

S = ?

$v_f = 0$

$g = -10 m/s^2$

Solution: We know

$2gh = v_f^2 - v_i^2$

$2(-10)(h) = (0)^2 - (30)^2$

$-20h = -900$

$h = \frac{-900}{-20} = \boxed{h = 45\ m}$

$$\text{Total time} = \begin{pmatrix}\text{Time to} \\ \text{reach} \\ \text{at Max} \\ \text{height}\end{pmatrix} + \begin{pmatrix}\text{Time to} \\ \text{reach} \\ \text{ground form} \\ \text{height}\end{pmatrix}$$

$= 3 + 3$

$\boxed{\text{Total time} = 6 \text{ sec}}$

Result: The tennis ball reaches the maximum height 45m and it will take 6s to return to ground.

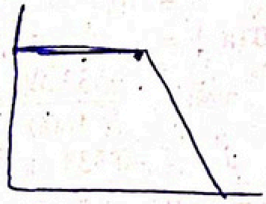
Q. 2.5 A car moves with uniform velocity of 40 ms^{-1} for 5 s. It comes to rest in the next 10 s with uniform deceleration. Find (i) deceleration (ii) Total distance travelled by the car. 091302142

Given Data:

$V_i = 40$ m/s

$V_f = 0$

t = 10 sec

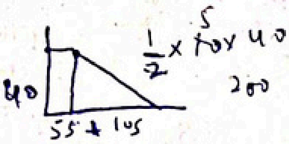


To Find:

S = ?

a = ?

Solution: We know



$V_f = V_i + at$

$0 = 40 + a(10)$

$-40 = 10(a)$

$\frac{-40}{10} = a$

$\boxed{a = -4ms^{-2}}$

Distance travelled in first five second

$S = v_i \times t$

$S = 40 \times 5$

$S = 200m$

Let

$S_1 = S$

$S_1 = 200m$

Distance covered in last 10 second

$2aS_2 = v_f^2 - v_i^2$

$2(-4) S_2 = (0)^2 - (40)^2$

$8S_2 = 1600$

$S_2 = \frac{1600}{8}$

$S_2 = 200m$

Total Distance $= S_1 + S_2$

$S = 200 + 200 = 400m$

Result: The car accelerates with $4ms^{-2}$ covers 400m distance.

Q 2.6 A train starts from rest with an acceleration of 0.5 ms^{-2}. Find its speed in kmh^{-1}, when it has moved through 100 m. 091302143

Given Data:

$v_i = 0$

$a = 0.5 m/s^2$

S = 100 m

To Find:

$v_f = ?$

Solution: We know

$2aS = v_f^2 - v_i^2$

$2(0.5)(100) = (v_f)^2 - (0)^2$

$100 = v_f^2 - 0$

$\sqrt{100} = \sqrt{v_f^2}$

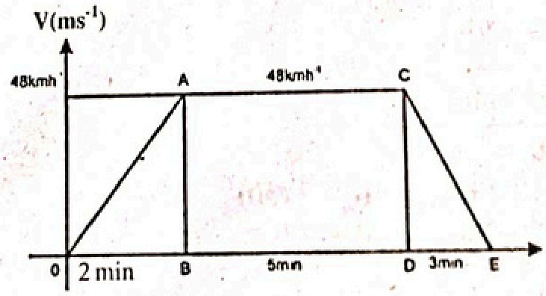
$V_f = 10\ ms^{-1}$

to convert in km / h

$V_f = \frac{10 \times 36\cancel{00}}{10\cancel{00}} = \boxed{V_f = 36\ km\ h^{-1}}$

Result: The final speed of train is $36kmh^{-1}$.

Q. 2.7 A train starting from rest, accelerates uniformly and attains a velocity 48 kmh^{-1} in 2 minutes. It travels at this speed for 5 minutes. Finally, it moves with uniform retardation and is stopped after 3 minutes. Find the total distance travelled by the train. 091302144



Given Data:

$v_i = 0$

$v_f = 48\ kmh^{-1}$

From the Speed – Time graph:

$$AB = V = \frac{48 \times 1000}{3600} = 13.33\,ms^{-1}$$

$OE = 10min = 10 \times 60 = 600\ sec$

$AC = 5min = 5 \times 60 = 300\ sec$

To Find:

Total distance = S = ?

Solution:

Total distance covered = Area of trapezium

$$S = \frac{1}{2}(\text{sum of parallel sides}) \times \text{Height}$$

distance between parallel sides.

$$S = \frac{1}{2}\ (OE + AC) \times AB$$

$$S = \frac{1}{2}\ (600s + 300s) \times 13.33ms^{-1}$$

$S = ½ (15) \times 60 \times 13.33$

$S = 5998.5\ m$

$S = 6000m$

Result: The total distance travelled by train is 6000m.

Q 2.8 A cricket ball is hit vertically upwards and returns to ground 6 s later. Calculate (i) maximum height reached by the ball. (ii) Initial velocity of the ball. 091302145

Given Data:

$v_f = 0$

$g = -10m/s^2$

Total time = 6 sec ⇒ Total time = [time to rearch at Max height] + [Time to reach ground]

= 3 +3

= 6 sec

t = 3sec (time to reach maximum height).

To Find:

S = ?

v_i = ?

Solution: We know

$v_f = v_i + gt$

$0 = v_i + (-10)(3)$

$-v_i = -30$

$$\boxed{v_i = 30ms^{-1}}$$

$2gh = v_f^2 - v_i^2$

$-2 \times 10 \times h = (0)^2 - (30)^2$

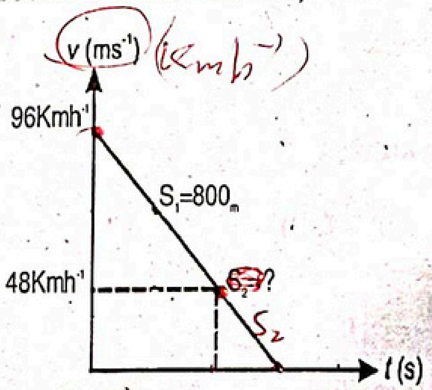
$-20h = 0 - 900$

$$h = \frac{-900}{-20}$$

$h = 45\ m$

Result: The cricket ball has initial velocity $30ms^{-1}$ and reach the maximum height of 45m.

Q 2.9 When brakes are applied, the speed of a train decreases from 96 kmh^{-1} to 48 kmh^{-1} in 800 m. How much further will the train move before coming to rest? (Assuming the retardation to be constant). 091302146



Given Data:

$S_1 = 800m$

$$v_i = 96\ kmh^{-1} = \frac{96 \times 1000}{3600} = 26.67ms^{-1}$$

$$v_f = 48\ kmh^{-1} = \frac{48 \times 1000}{3600} = 13.33ms^{-1}$$

To Find:

S_2 = ? (Before train stops)

Solution: We know

To find S_1

$2a\,S_1 = v_f^2 - v_i^2$

$2(a)(800) = (13.33)^2 - (26.67)^2$

$= 177.69 - 711.289$

$1600(a) = -533.5989$

$$a = \frac{-533.5989}{1600}$$

$a = -0.333\ ms^{-2}$

To Find 'S_2'

$2aS_2 = v_f^2 - v_i^2$

$-2(0.3335)(S_2) = (0)^2 - (13.33)^2$

$-(0.667)\,S_2 = -177.6889$

$$S_2 = \frac{\cancel{-}177.6889}{\cancel{-}0.667} = 266.40m$$

Result: Before coming to rest of the train has covered the distance 266.40m.

Q. 2.10 **In the above problem, find the time taken by the train to stop after the application c brakes.** **091302147**

Given Data:

$v_f = 0\ ms^{-1}$

$v_i = 26.67\ ms^{-1}$

$a = -0.333 ms^{-2}$

To Find:

$t = ?$

Solution: We know

$v_f = v_i + at$

$0 = 26.67+(-0.3335)$

$0 = 26.67 - 0.3335\ t$

$0.3335\ t = 26.67$

$$t = \frac{26.67}{0.333}$$

$t = 80\ sec$

Result: The time taken by the train to stop afte application of brakes is