Unit 2: Kinematics

Textbook Exercise Questions

2.1 Encircle the correct answer from the given choices.

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

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

ii. The motion of a body around an axis is called ___________ motion. (LHR 2015)

(a) Circular
(b) Rotatory ✓
(c) Vibratory
(d) Random

iii. Which of the following is a vector quantity?

(a) Speed
(b) distance
(c) Displacement ✓
(d) power

iv. If an object is moving with constant speed then its distance-time graph will be a straight line.

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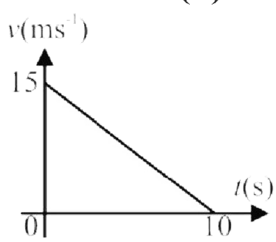
(a) Along time-axis
(b) Along distance-axis
(c) Parallel to time-axis
(d) Inclined to time-axis ✓

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

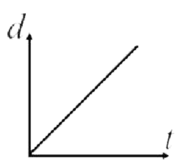
(a) Moving with constant speed
(b) At rest ✓
(c) Moving with variable speed
(d) In motion

vi. The speed-time graph of a car is shown in the figure, which of the following statement is true?

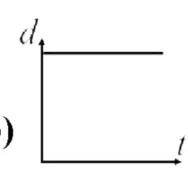
(a) Car has an acceleration of 1.5 ms^{-2}
(b) Car has constant speed of 7.5ms^{-1}
(c) Distance travelled by the car is 75 m ✓
(d) Average speed of the car is 15 ms^{-1}

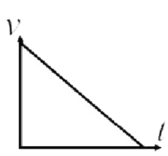


vii. Which of the following graphs is representing uniform acceleration? (LHR 2015)

(a) 

✓

(b) 

(c) 

(d) 

viii. **By dividing displacement of a moving body with time, we obtain:**

(a) Speed | (b) Acceleration
(c) Velocity ✓ | (d) Deceleration

ix. **A ball is thrown vertically upward. It velocity at the highest point is:**

(a) $-10\ ms^{-2}$ | **(b) Zero✓**
(c) $10\ ms^{-2}$ | (d) None of these

x. **A change in position is called:** **(GRW 2015)**

(a) Speed | (b) Velocity
(c) Displacement✓ | (d) Distance

xi. **A train is moving at a speed of $36kmh^{-1}$. Its speed expressed in ms^{-1} is: (GRW 2015)**

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

xii. **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:**

(a) 31. 25 m | **(b) 250 m✓**
(c) 500 m | (d) 5000 m

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

Ans: Such type of motion in which a body moves along a line without any rotation. The line may be straight or curved.

(i) Linear motion
- The motion of freely falling bodies
- A car moving along the straight line

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(ii) Circular motion
- A stone attached with thread, when whirled, it will move along a circular path.
- A toy train moving on a circular track.

(iii) Random motion
- The flight of an insect and birds
- Motion of dust or smoke particles in air

2.3 Differentiate between the following:

(i) Rest and motion
(ii) Circular motion and rotatory motion
(iii) Distance and displacement **(GRW 2014)**
(iv) Speed and velocity **(LHR 2013, 2015)**
(v) Scalars and vectors **(GRW 2013, LHR 2014, 2015)**

(i) Difference between Rest and Motion

REST	MOTION
If a body does not change its position with respect to surroundings then it is said to be in a state of rest.	If a body continuously changes its position with respect to surroundings then it is said to be in a state of motion.

(ii) Circular motion and rotatory motion.

CIRCULAR MOTION	ROTATORY MOTION
The motion of an object in a circular path is known as circular motion. **Examples:** • The motion of earth around the sun. • The motion of electron around nucleus.	The spinning motion of a body about its axis is called rotatory motion. **Examples:** • The motion of wheel about its axis. • Motion of ceiling fan.

(iii) Difference between Distance and Displacement.

DISTANCE	DISPLACEMENT
• Actual (total) length between two points is known as distance. • It is a scalar quantity. • It is represented by "S".	• The shortest distance between two points is known as displacement. • It is a vector quantity. • It is represented by "$\vec{d}$".

(iv) Difference between Speed and Velocity

SPEED	VELOCITY
• The distance covered in unit time is known as speed. • Mathematically speed is given by Speed = distance/time $v = \frac{S}{t}$ • It is a scalar quantity.	• The rate of displacement of a body is called velocity. • Mathematically velocity is given by Velocity = displacement/time $\vec{v} = \frac{\vec{d}}{t}$ • It is a vector quantity.

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(v) Difference between scalar and vector.

SCALAR	VECTOR
Physical quantities which are completely described by their magnitude only are known as scalars. **Example** Speed, distance, time etc.	Physical quantities which are completely described by their magnitude and direction as well are known as vectors. **Example** Force, displacement, velocity etc.

2.4 Define the terms speed, velocity, and acceleration. **(GRW 2013, LHR 2015)**

Ans: <u>**Speed**</u>

The distance covered by an object in unit time is called its speed.

Mathematical Formula

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

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

Distance = speed x time

Or $S = v \times t$

Velocity

The rate of displacement of a body is called velocity.

Mathematical form

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

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

Here $\vec{d}$ is the displacement of the body moving with velocity $\vec{v}$ in time t.

Acceleration

The rate of change of velocity of a body is known as acceleration.

Mathematical form

If a body is moving with initial velocity 'v_i' and after some time 't' its velocity becomes 'v_f' then change in velocity will occur in time t.

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

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

So $$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

2.5 Can a body moving at a constant speed have acceleration? (LHR 2014)

Ans: A body moving with constant speed can have acceleration if its direction of motion changes continuously. For example a body moving with constant speed in a circular path has an acceleration.

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

Ans: Riders in a Ferris wheel move in a circle without rotation therefore motion of rider in Ferris wheel is translatory not rotatory.

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?

Ans: The distance-time graph is shown below

The slope of the graph gives speed with the help of the formula

Speed (v) of the object = slope of line AB

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

$$= \frac{20\text{m}}{10\text{s}}$$

$$= 2\ \text{ms}^{-1}$$

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

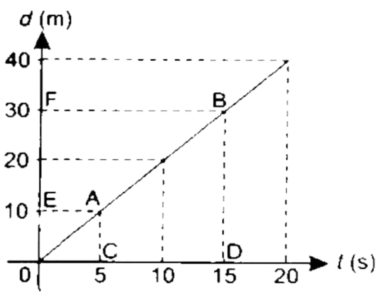

Figure 2.19: Distance-time graph showing constant speed.

2.8 What would be the shape of speed – time graph of a body moving with variable speed? (LHR 2013, 2014, 2015)

Ans: Lines OA and OB shows that body is moving with variable speed. Line OA shows that speed of body changes equally in equal intervals of time. Line OB shows that speed of body changes unequally in a equal intervals of time.

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

Ans: All the given quantities can be obtained form speed-time graph.

2.10 How can vector quantities be represented graphically? (LHR 2014, GRW 2014)

Ans: To represent a vector quantity graphically we draw a line known as represented line. The length of the line drawn is according to some selected scale give the magnitude of vector and an arrow on one end of this line shows the direction of vector.

2.11 Why vector quantities cannot be added and subtracted like scalar quantities?

Ans: Scalar quantities can be described completely by magnitude only and can be added or subtracted by simple arithmetic rules. Vector quantities in addition to magnitude also need direction for their description. So vectors cannot be added or subtracted by arithmetic rules due to direction.

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

Ans: In order to locate a place from a reference point, we will have to describe the distance and direction of that place from reference point. Description of distance along with direction will make up a vector quantity. Hence by using vector quantities we can describe the position (or location) of bodies.

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2.13 Derive equations of motion for uniformly accelerated rectilinear motion.

Ans: See Q.no.4 Long Question

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.

Ans: Total distance travelled

= area under the graph (trapezium OABC)

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

$$= \frac{1}{2}(18\text{s} + 30\text{ s}) \times (16\text{ ms}^{-1})$$

$$= 384\text{ m}$$

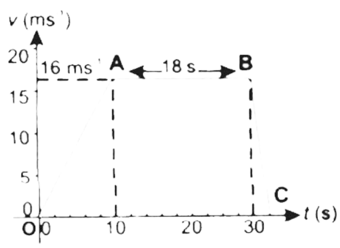

Figure 2.25: Speed-time graph of a car during 30 seconds.

Unit 2: Kinematics

Long Questions

Q.1 Define Translatory motion and its types. (LHR 2011, 2012, 2013 GRW 2013, 2015)

Ans: Such type of motion in which a body moves along a line without any rotation. The line may be straight or curved.

Examples

- Motion of a car in straight line
- Motion of electron around the nucleus
- Motion of gas molecules
- Aeroplane moving straight is in translational motion

Types of Translatory Motion

There are three types of translatory motion.

(i) Linear motion **(LHR 2014)**

(ii) Circular motion

(iii)Random motion **(LHR 2013, 2014)**

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(i) Linear motion

If the motion of a body is in straight line, it is known as linear motion.

Examples

- The motion of freely falling bodies
- A car moving along the straight line

(ii) Circular motion

If a body moves in a circle then its motion is known as circular motion.

Examples

- A stone attached with thread, when whirled, it will move along a circular path.
- A toy train moving on a circular track.
- A bicycle or car moving along a circular track
- Earth moving around the sun in solar system

(iii) Random motion

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

Examples

- The flight of an insect and birds
- Brownian motion of gas or liquid molecules
- Motion of dust or smoke particles in air

Q.2 Explain Distance – time Graph.

Ans: The term distance and displacement are used interchangeably when the motion is in straight line. Similarly, if the motion is in a straight line then speed and velocity are also used interchangeably.

In distance – time graph, time is taken along horizontal axis while the vertical axis shows the distance covered by the object.

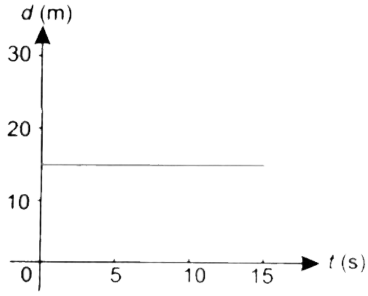

Figure 2.18: Distance-time graph when the object is at rest.

Object at Rest

In the graph shown in figure, 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.

Object moving with Constant Speed

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.

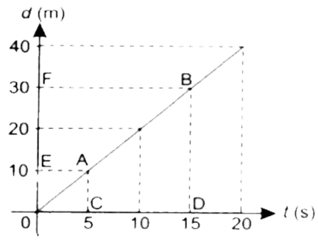

Figure 2.19: Distance-time graph showing constant speed.

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Object moving with variable speed

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 in figure. The slope of the curve at any point can be found from the slope of the tangent at that point.

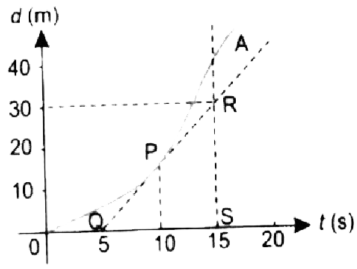

Figure 2.20: Distance-time graph showing variable speed.

Q.3 Explain Speed – Time Graph.

Ans: In a speed – time graph, time is taken along x – axis and speed is taken along y–axis.

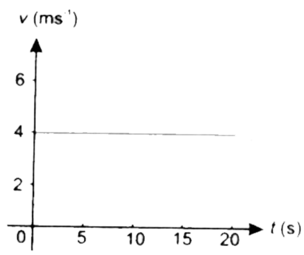

Figure 2.22: Speed-time graph showing constant speed.

Object moving with constant speed

When speed of an object is constant with time, then the speed – time graph will be a horizontal line parallel to time – axis as shown in figure. In other words, a straight line parallel to time axis represents constant speed of the object.

Object moving with uniformly changing speed (uniform acceleration)

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 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.

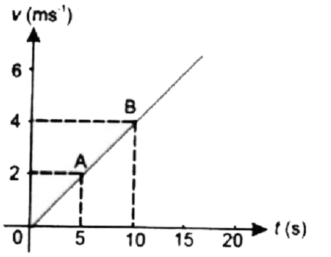

Figure 2.23: Graph of an object moving with uniform acceleration.

Distance travelled by a moving object

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.4 Derive first equation of motion using speed time graph. (GRW 2013)

- **Ans: Proof:**

Suppose a body is 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 the body is described by speed – time graph as shown in figure.

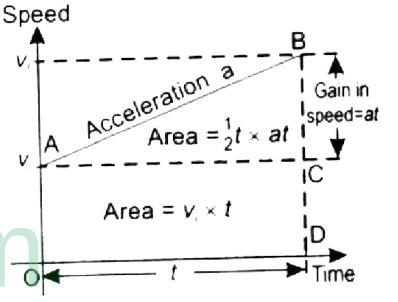

Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

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Slope of line AB $= \dfrac{BC}{AC}$

We know that slope of line in speed-time graph gives the magnitude of acceleration.

$$\therefore \quad \text{Acceleration} = \frac{BC}{AC}$$

$$a = \frac{BC}{AC}$$

As AC = OD and BC = BD – CD

So, $a = \dfrac{BD - CD}{OD}$

As $BD = v_f$, $CD = v_i$ and $OD = t$

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

Or $v_f - v_i = at$

Therefore, $v_f = v_i + at$

Which is required first equation of motion.

Q.5 Derive second equation of motion using speed-time graph. **(LHR 2012, 2013)**

Ans: Proof:

Suppose a body is 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 the body is described by speed – time graph as shown in figure.

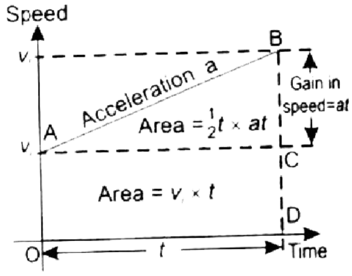

Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

In speed – time graph the total distance s travelled by the body is equal to the total area of trapezium OABD under the graph. i.e.

Area of the rectangle OACD $= OA \times OD$

$$= v_i \times t$$

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

$$= \frac{1}{2}(OD \times BC)$$

$$= \frac{1}{2} t \times at$$

$$= \frac{1}{2} a t^2$$

Area of trapezium OABD = area of rectangle OACD + area of triangle ABC

Putting the values in the above equation, we get

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

which is required second equation of motion.

Q.6 Derive third equation of motion using speed-time graph. **(GRW 2015)**

Ans: Proof:

Suppose a body is 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 the body is described by speed – time graph as shown in figure.

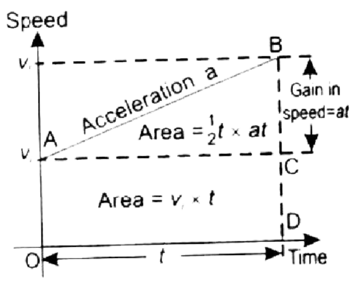

Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

In speed – time graph the total distance s travelled by the body is equal to the total area of trapezium OABD under the graph.

$$\text{Area of trapezium OABD} = \frac{1}{2}[\text{sum of parallel sides}][\text{Perpendicular distance between parallel sides}]$$

$$s = \frac{1}{2}(BD + OA)(OD)$$

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

Multiply both sides by $\frac{BC}{OD}$, we get (as $\frac{BC}{OD} = a$)

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

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

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

As $OA = CD = Vi$

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

and $BD = v_f$

Putting the values in the in the above equation, we have

$$2\ aS = (v_f + v_i)(v_f - v_i)$$

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

Which is required third equation of motion.

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Unit 2: Kinematics

Multiple Choice Questions

1. **Study of motion of the bodies is known as:**
   (a) Heat **(b)** Light
   (c) Atomic physics **(d)** Mechanics
2. **Study of motion without discussing the cause of motion is called:**
   (a) Kinematics **(b)** Dynamics
   (c) Heat **(d)** Motion
3. **If a body does not change its position with respect to some observer then it will be in a state of:**
   (a) Rest **(b)** Motion
   (c) Uniform motion **(d)** Relative motion
4. **If a body changes its position with respect to some observer then it will be in state of:**
   (a) Rest **(b)** Motion
   (c) Uniform motion **(d)** Relative motion
5. **Rest and motion are -------------- states:**
   (a) Absolute **(b)** Constant
   (c) Variable **(d)** Relative
6. **Which one of the following is a vector quantity?**
   (a) Displacement **(b)** Speed
   (c) Volume **(d)** Work
7. **The spinning motion of a body about its axis is known as.** **(LHR 2015)**
   (a) Translatory motion **(b)** Vibratory motion
   (c) Rotatory motion **(d)** none of these
8. **When a body moves to and fro about a point and repeats its motion again and again about the same point then this motion is known as:** **(GRW 2014, 2015)**
   (a) Translatory **(b)** Vibratory
   (c) Rotatory **(d)** none of these
9. **The motion of the string of a violin is:**
   (a) Translatory **(b)** Vibratory
   (c) Rotatory **(d)** none of these
10. **Total length of a path between two points is known as:**
    (a) Velocity **(b)** Acceleration
    (c) Speed **(d)** Distance
11. **The shortest distance between two points is known as:**
    (a) Velocity **(b)** Displacement
    (c) Speed **(d)** Distance
12. **The area uner a speed time graph respresents**
    (a) Speed **(b)** Volume
    (c) Acceleration **(d)** Distance
13. **SI unit of speed is:**
    (a) ms^{-1} **(b)** mh^{-1}
    (c) kms^{-1} **(d)** All of these

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14. **Speed is a ------------- quantity:**
(a) Vector (b) Scalar
(c) Both (d) none of these

15. **If a body covers equal distance in equal intervals of time, however small the intervals may be, then the speed of the body is known as:**
(a) Uniform (b) Variable
(c) Non uniform (d) All of these

16. **The rate of displacement with respect to time is known as:**
(a) Distance (b) Speed
(c) Velocity (d) Acceleration

17. **If the speed and direction of the moving body does not change with time then its velocity is said to be:**
(a) Uniform (b) Variable
(c) Constant (d) All of these

18. **If the speed or direction of the moving body changes with time then its velocity is said to be:**
(a) Uniform (b) Variable
(c) Constant (d) All of these

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

20. **If the velocity of the body is increasing then its acceleration will be:**
(a) Positive (b) Negative
(c) Uniform (d) Variable

21. **If the velocity of the body is decreasing then its acceleration will be:**
(a) Positive (b) Negative
(c) Uniform (d) Variable

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22. **If the velocity of a body is uniform then its acceleration will be:**
(a) Positive (b) Negative
(c) Zero (d) Doubled

23. **SI unit of acceleration is:**
(a) ms^{-1} (b) kmh^{-1}
(c) kms^{-2} (d) ms^{-2}

24. **If velocity of a body changes equally in equal intervals of time then its acceleration will be:**
(a) Uniform (b) Variable
(c) Constant (d) Relative

25. **The velocity and acceleration of a body moving with uniform speed in a circular path will be:**
(a) In the same direction (b) In the opposite direction
(c) Mutually perpendicular (d) Equal

26. **The direction of motion of body and acceleration is in same direction then acceleration will be:**
(a) Uniform (b) Positive
(c) Negative (d) Zero

27. **The direction of motion of body and acceleration is in opposite direction then acceleration will be:**
(a) Uniform (b) Positive
(c) Negative (d) Zero

28. **The quantity which can be described by a number, with suitable unit only is called:**
(a) Vector (b) Scalar
(c) Speed (d) Acceleration

29. **The quantity which are described by magnitude as well as direction is called:**
(a) Vector (b) Scalar
(c) Speed (d) Acceleration

30. **In equations of motion, motion will always be taken along ---------- line:**
(a) Circular (b) Straight
(c) Elliptical (d) None of above

31. **In equations of motion, Acceleration will always be:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

32. **In equations of motion, initial velocity will be taken as:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

33. **In equations of motion, quantities in the direction of initial velocity are taken as:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

34. **In equations of motion, quantities opposite to the direction of initial velocity are taken as:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

35. **The slope of straight line in speed time graph gives the magnitude of**
(a) Force (b) Displacement
(c) Torque (d) Acceleration

36. **Series of experiments on free fall of heavy bodies was performed by:**
(a) Newton (b) Einstein
(c) Galileo (d) Al-Kundi

37. **When a body is falling freely under the gravity then in equations of motion 'a' is replaced by:**
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(a) m (b) d
(c) S (d) g

38. **If a body is falling under the gravity then its initial velocity will be:**
(a) Positive (b) Negative
(c) uniform (d) Zero

39. **If a body is falling under the gravity then its gravitational acceleration will be:**
(a) Positive (b) Negative
(c) Increasing (d) Zero

40. **If a body is thrown vertically upward then its final velocity will be:**
(a) Positive (b) Negative
(c) uniform (d) Zero

41. **If a body is thrown upward, then its gravitational acceleration will be:**
(a) Positive (b) Negative
(c) Increasing (d) Zero

42. **A ball is dropped from the top of the tower. The distance covered by it in the first second is:**
(a) 100m (b) 10m
(c) 50m (d) 5m

43. **If a car is moving with uniform speed in a circle then its velocity will be:**
(a) Uniform (b) Variable
(c) Zero (d) None of the above

44. **There are -------------- equations of motion which are used to solve the problems about the motion of bodies:**
(a) 1 (b) 2
(c) 3 (d) 4

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	d	11	b	21	b	31	a	41	b
2	a	12	d	22	c	32	c	42	d
3	a	13	a	23	d	33	c	43	b
4	b	14	b	24	a	34	d	44	c
5	d	15	a	25	c	35	d		
6	a	16	c	26	b	36	c		
7	c	17	a	27	c	37	d		
8	b	18	b	28	b	38	d		
9	b	19	d	29	a	39	a		
10	d	20	a	30	b	40	d		

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Unit 2: Kinematics

Problems

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

Given Data

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

Time taken = t = 10 s

Required

Distance travelled by train = S = ?

Solution

As we know that

$S = V \times t$

By putting the values, we have

$S = 10 \times 10$

$S = 100$ m

Result

Distance travelled by train = S = 100 m

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

Given Data

Initial velocity of train = v_i = 0 ms^{-1}

Distance covered by train = S = 1 km = 1000 m

Time taken by train = t = 100 s

Required

Speed of train after 100 s = v_f = ?

Solution

First we have to find the acceleration, as we know that

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

By putting the values, we have

$1000 = 0 \times 100 + \frac{1}{2} \times a \times (100)^2$

$1000 = \frac{1}{2} \times a \times 10000$

$1000 = a \times 5000$

$a = \frac{1000}{5000}$

So, $a = 0.2$ ms^{-2}

Now from first equation of motion, we have

$v_f = v_i + at$

by putting the values, we have

$v_f = 0 + 0.2 \times 100$

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

Result

Speed of train after 100 s = v_f = 20 ms^{-1}

2.3 A car has a velocity of 10 ms^{-1}. It accelerates at 0.2 ms^{-2} for half minute. Find the distance traveled during this and the find velocity of the car.

Given Data

Velocity of the car = vi = 10 ms^{-1}

Acceleration of the car = a = 0.2 ms^{-2}

Time taken by car = t = 0.5 min. = 0.5 x 60 = 30 s

Required

Distance traveled by car = S = ?

Solution

As we know that

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

By putting the values, we have

$S = 10 \times 30 + \frac{1}{2} \times 0.2 \times (30)^2$

$S = 300 + 0.1 \times 900$

$S = 300 + 90$

$S = 390\ m$

Result

Distance traveled by car = S = 390 m

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

Given Data

Initial velocity of the tennis ball = vi = 30 ms^{-1}

Time to reach the maximum height = t = 3 s

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

Final velocity of the ball = v_f = 0ms^{-1}

Required

Maximum height reached by the ball = h = ?

Solution

From second equation of motion in vertical motion, we have

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

by putting the values, we have

$h = 30 \times 3 + \frac{1}{2} \times (-10)(3)^2$

$h = 90 - 5 \times 9$

$h = 90 - 45$

$h = 45\ m$

As the ball moves with uniform acceleration in vertical motion, so time taken by the ball in both directions will be same.

Total time taken to return the ground = Time taken upwards + Time taken downwards
Total time taken to return the ground = 3 s + 3s
Total time taken to return the ground = 6 s

Result

Maximum height reached by the ball = h = 45 m
Total time taken to return the ground = 6 s

2.5 A car moves with uniform velocity 40 ms^{-1} for 5 s. it comes to rest in the next 10 s with uniform declaration. Find
i) declaration
ii) total distance traveled by the car

Required

(i) Deceleration = $\vec{a}$ = ?
(ii) Distance traveled by the car = S = ?

Solution

(i) Slope of line BC = $\dfrac{y_2 - y_1}{x_2 - x_1}$

$$\vec{a} = \frac{0-40}{15-5} = \frac{-40}{10} = -4ms^{-2}$$

(ii) Area of trapezium OABC = $\frac{1}{2}$(sum of parallel sides)(perpendicular distance between parallel sides)

$$S = \frac{1}{2}(AB + OC)(OA)$$

$$S = \frac{1}{2}(5+15)(40)$$

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$$= \frac{1}{2}(20)(40)$$

$$S = \frac{800}{2}$$

$$S = 400\,m$$

Result

Total distance moved by car = S = 400 m

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

Given Data

Acceleration of the train = a = 0.5 ms^{-2}
Initial velocity of the train = v_i = 0 ms^{-1}
Distance moved by train = S = 100 m

Required

Final speed in kmh^{-1} = v_f = ?

Solution

From third equation of motion, we have

$$2aS = vf^2 - vi^2$$

by putting the values, we have

$$2 \times 0.5 \times 100 = vf^2 - (0)^2$$

$100 = vf^2$

by taking square root on both sides, we have

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

So $v_f = 10\ ms^{-1}$

In kmh-1

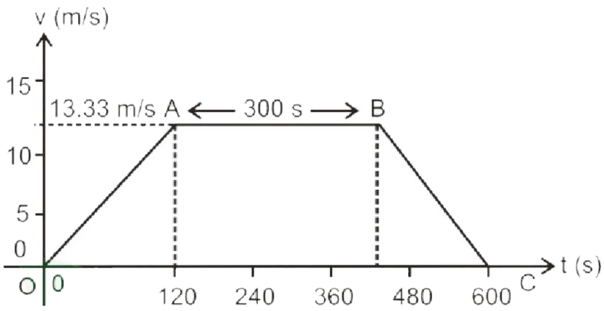
$$v_f = \frac{10 \times 3600}{1000}$$

$$v_f = 36\ kmh^{-1}$$

Result

Final speed in $kmh^{-1} = v_f = 36\ kmh^{-1}$

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



Solution

Total distance covered=?

By using the given values we plot a graph shown in figure.

Velocity = 48 kmh^{-1}

$$= \frac{48 \times 1000}{3600}$$

$$= \frac{40}{3} ms^{-1}$$

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time = 2 minutes

= 2(60)

= 120 S

Again time = 5 minutes

= 5(60)

= 300 S

Again time = 3 minutes

= 3(60)

= 180 S

We know that area under speed-time graph represents the distance covered by the object.

$\therefore$ Total distance covered = Area of trapezium OABC

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

$$= \frac{1}{2}(600 + 300)\left(\frac{40}{3}\right)$$

$$= \frac{1}{2}(900)\left(\frac{40}{3}\right)$$

Total distance covered = 6000 m

Result

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.

Given Data

Final velocity of the ball = $v_f = 0\ ms^{-1}$
Gravitational acceleration = $g = -10\ ms^{-2}$
Time in which ball return to ground = $t = 6$ s

Required

Maximum height reached by ball = $h = ?$
Initial velocity of the ball = $v_i = ?$

Solution

We know that for ball thorwn vertically upward in air
Time taken by ball to reach maximum height = Time taken by ball to reach ground from maximum height
$\therefore$ time taken by ball to reach maximum height = $t = 3$ s
From first equation of motion, we have

$$v_f = v_i + gt$$

By putting the values, we have

$$0 = v_i + (-10) \times 3$$
$$0 = v_i - 30$$

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

Now from second equation of motion, we have

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

By putting the values, we have

$$S = 30 \times 3 + \tfrac{1}{2} \times (-10) \times (3)^2$$
$$S = 90 - 5 \times 9$$
$$S = 45\ m$$

Result

Maximum height reached by ball = $h = 45$ m
Initial velocity of the ball = $v_i = 30\ ms^{-1}$

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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)

Given Data

Initial velocity of train = $v_i = 96\ kmh^{-1}$ $= \frac{96 \times 1000}{3600} = \frac{80}{3} ms^{-1}$

Final velocity of train = $v_f = 48\ kmh^{-1}$ $= \frac{48 \times 1000}{3600} = \frac{40}{3} ms^{-1}$

Distance covered by train = 800 m

Required

Retardation of the train = $a = ?$

Solution

From third equation of motion, we have

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

By putting the values, we have

$$2a\,(800) = \left(\frac{40}{3}\right)^2 - \left(\frac{80}{3}\right)^2$$

$$1600\,a = \frac{1600}{9} - \frac{6400}{9}$$

$$1600a = \frac{1600 - 6400}{9}$$

$$1600a = -\frac{4800}{9}$$

$$a = -\frac{4800}{9 \times 1600}$$

$$a = -\frac{1}{3}\text{ms}^{-2}$$

Again

Initial velocity of train = v_i = 48 $\text{kmh}^{-1} = \frac{40}{3}\text{ms}^{-1}$

Final velocity of train = v_f = 0 ms^{-1}

retardation of train = a = $-\frac{1}{3}\text{ms}^{-2}$

Required

Distance covered by train = S = ?

Solution

From third equation of motion, we have

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

By putting the values, we have

$$2\left(-\frac{1}{3}\right)S = (0)^2 - \left(\frac{40}{3}\right)^2$$

$$-\frac{2}{3}S = -\frac{1600}{9}$$

$$S = \frac{1600}{9} \times \frac{3}{2}$$

$$S = 266.66\text{ m}$$

Result

The train will move by 266.66 m before coming to rest

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2.10 In the above problem, find the time taken by the train to stop after the application of the brakes.

Given Data

Initial velocity of train = v_i = 96 kmh^{-1} $= \frac{96 \times 1000}{3600} = \frac{80}{3}\text{ms}^{-1}$

Final velocity of train = v_f = 0 ms^{-1}

retardation of train = a = $-\frac{1}{3}\text{ms}^{-2}$

Required

Time taken by the train = t = ?

Solution

From first equation of motion, we have

$$v_f = v_i + at$$

By putting the values, we have

$$0 = \frac{80}{3} + \left(-\frac{1}{3}\right)t$$

$$0 = \frac{80}{3} - \frac{t}{3}$$

$$\frac{t}{3} = \frac{80}{3}$$

$$t = \frac{80}{3} \times 3$$

$$t = 80\text{s}$$

Result

Required time is 80 s.

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