Chapter: 02

Kinematics

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Exercise MCQs

1. A body has translatory motion if it moves along a:
(A) straight line (B) circle (C) line without rotation (D) curved path

2. The motion of a body about an axis is called:
(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 (C) Displacement (D) Power

4. If an object is moving with constant speed then its distance time graph will be a straight line:
(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 (B) at rest
(C) moving with variable speed (D) in motion

6. By dividing displacement of a moving body with time, we obtain:
(A) Speed (B) Acceleration (C) Velocity (D) Deceleration

7. A ball is thrown vertically upward. Its velocity at the highest point is:
(A) $-10\ ms^{-1}$ (B) zero (C) $10\ ms^{-2}$ (D) none of these

8. A change in position is called:
(A) speed (B) velocity (C) displacement (D) distance

9. A train is moving at a speed of $36kmh^{-1}$. Its speed expressed to ms^{-1} is:
(A) $10ms^{-1}$ (B) $20ms^{-1}$ (C) $25ms^{-1}$ (D) $30ms^{-1}$

10. **A car starts from rest. It acquires a speed of 25ms⁻¹ after 20s. The distance moved by the car during this time is:**

(A) 31.25m (B) 250m (C) 500m (D) 5000m

Answer Key:

1	A	6	C
2	B	7	B
3	C	8	D
4	C	9	A
5	A	10	C

Short Questions

Q1: Explain translatory motion and give examples of various types of translatory motion.

Ans: Translatory motion:

The motion, in which a body moves along a line (straight or curved) without any rotation, is called translator motion.

Example:

Motion of Ferris wheel

Types of translatory motion:

(a) Circular motion (b) Linear motion (c) Random motion

(a) Circular motion:

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

Example:

A car is moving along a circular track.

(b) Linear motion:

The straight line motion of a body is known as its linear motion.

Example:

Rocket flying straight in the air is linear motion.

(c) **Random motion:**

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

Example:

The motion of insects and birds is random motion.

Q2: Define the terms speed, velocity, and acceleration.

Ans: Speed (V):

The rate of change of position with time is called speed. Its unit is ms^{-1}.

Velocity ($\vec{V}$):

The rate of change of displacement is called velocity and its unit is ms^{-1}.

Acceleration ($\vec{a}$):

The rate of change of velocity is called acceleration and its unit is ms^{-2}.

Q3: Differentiate between the following:

(a) Rest and motion.

(b) Circular motion and rotatory motion.

(c) Distance and displacement.

(d) Speed and velocity.

(e) Linear and random motion.

(f) Scalars and vectors.

Ans: Difference between Rest and Motion is:

Rest	Motion
"A condition in which a body does not change its position with respect to its surroundings". **Example:** ➢ A book lying on the table. ➢ A bench fixed in a park.	"A condition in which a body changes its position with respect to its surroundings". **Example:** ➢ A flying bird. ➢ A boy playing football.

Difference Circular Motion and Rotatory Motion is:

Circular Motion	Rotatory Motion
➢ The motion of an object or body in a circular path is called circular motion. ➢ In circular motions, the point about which a body goes around is	➢ The motion of a body around an axis passing through it is called rotatory motion. ➢ In rotatory motion, the line around which a body moves about

outside the body. **Examples:** ➢ The moon circling the earth. ➢ A satellite circling round the earth.	is passing through the body itself. **Examples:** ➢ A rotating fan. ➢ A spinning top.

Difference Distance and Displacement:

Distance	Displacement
➢ Total length of a path between two points is called distance. ➢ Distance is a scalar quantity.	➢ The shortest distance between two points is called displacement. ➢ Displacement is a vector quantity.

Difference Speed and Velocity:

Speed	Velocity
➢ Distance covered by a body in unit time is called speed. ➢ Distance is a scalar quantity. **Formula:** $V = \frac{s}{t}$	➢ The shortest distance between two points is called displacement. ➢ Displacement is a vector quantity. **Formula:** $V = \frac{d}{t}$

Difference Linear and Random Motion:

Linear Motion	Random Motion
The motion of a body along a straight line is called linear motion. **Example:** Freely falling object.	The irregular or zigzag motion of a body is called random motion. **Example:** Random motion of gas molecules.

Difference Scalars and vectors:

Scalars	Vectors
A scalar quantity is a quantity which can be completely specified by a magnitude only. **Example:** Work, power, speed and distance, etc.	Vectors are quantities, which are completely specified by both magnitude and direction. **Example:** Velocity, force, torque and displacement

	etc.

Q4: Can a body moving at a constant speed have acceleration?

Ans: **Yes,** a body moving at constant speed has acceleration if it changes its direction or moves in a circular path.

Q5: How do riders in a Ferries wheel possess translatory motion but not rotatory motion?

Ans: In rotatory motion, the line, about which a body moves, it's passing through the body itself. Here, riders in the Ferris wheel have circular motion (a type of translatory motion) because the line about which wheel riders go around lies outside the body.

Q6: What would be the shape of a speed-time graph of a body moving with variable speed?

Ans: The shape of the velocity-time graph is zigzag i.e. not a straight line, when the body is moving at variable speed.

Q7: 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 shape of the graph is as shown in Fig.

$$\text{The slope of this graph gives} = \frac{\Delta S}{t}$$

$$\text{The slope of this graph gives} = \frac{\text{change in distance}}{\text{time}}$$

$$\text{The slope of this graph gives} = \frac{d}{t}$$

i.e. slope of this graph = speed

Q8: Which of the following can be obtained from speed-time graph of a body?

(a) Initial speed **(b) Final speed**

(c) Distance covered in time t **(d) Acceleration of motion**

Ans: All the above quantities can be obtained from the speed-time graph of a moving body.

Q9: How can vector quantities be represented graphically?

Ans: Vectors are graphically represented by a straight line with an arrowhead. The length of a line shows the magnitude and arrowhead tells about direction.

Q10: How are vector quantities important to us in our daily life?

Ans: Vectors quantities are important to us in our daily life because they provide complete information about quantity i.e. magnitude and direction.

Q11: Why vector quantities cannot be added and subtracted like scalar quantities?

Ans: Scalar quantities are the quantities which can be described completely by magnitude while vector quantities need direction and magnitude for their complete description. The quantities having direction cannot be added and subtracted like scalar quantities.

Q12: Derive equations of motion for uniformly accelerated rectilinear motion?

Ans: Equations of motion for uniformly accelerated rectilinear motion is:

(a) $\mathbf{v_f = v_i + at}$

$$\text{Slope of AB} = a, = \frac{BC}{AC} = \frac{BC - CD}{OD}$$

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

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

$$v_f = v_i + at$$

(b) $\mathbf{S = v_i t + \frac{1}{2} a t^2}$

From figure,

$$\text{Area of OACD} = OA \times OD$$

$$\text{Area of OACD} = v_i \times t$$

$$\text{Area of triangle ABC} = \frac{1}{2} \times \text{height} \times \text{base}$$

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

$$\text{Area of triangle ABC} = \frac{1}{2} at^2$$

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

$$\text{Total area} = v_i t + \frac{1}{2}at^2$$

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

(c) $\mathbf{2aS = v_f^2 - v_i^2}$

$$\text{Total area of OABD} = \left(\frac{OA + BD}{2}\right) \times OD$$

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

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

Multiplying by $\left(\frac{BC}{OD}\right)$ on both sides

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

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

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

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

Important Formulas

- $v_f = v_i + at$
- $2aS = v_f^2 - v_i^2$
- $S = v_i t + \frac{1}{2}at^2$
- $S = v_{av} \times t$

Important Values

- $1km = 1000m$
- $1hour = 3600second$
- $1kmh^{-1} = \frac{1000m}{3600second}$

  $1kmh^{-1} = \frac{10}{36} ms^{-1}$
- $1kmh^{-1} = 0.277\ ms^{-1}$
- $1m = \frac{11}{1000} km = \frac{1}{10^3} km$
- $1m = 10^{-3}km = 0.001km$
- $1m = \frac{1}{3600} h$
- $\frac{1m}{second} = \frac{0.001km}{\frac{1}{3600}h}$
- $1ms^{-1} = 0.001 \times 3600\ kmh^{-1}$
- $1ms^{-1} = 3.6\ kmh^{-1}$

Units: (S.I)

- Distance = S = metre (m)
- Displacement = d = metre (m)
- Speed = v = ms^{-1}
- Velocity = v = ms^{-1}
- Acceleration = a = ms^{-2}
- Time = t

Numerical

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

Ans: Given data:

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

$$V = \frac{36000}{3600}$$

$$V = 10 ms^{-1}$$

$$t = 10s$$

To Find:

$$S = ?$$

Solution:

$$S = v_i \times t$$

$$S = 10 \times 10$$

$$\mathbf{S = 100m}$$

2. A train starts from rest. It moves through 1km in 100s with uniform acceleration. What will be its speed at the end of the100s?

Ans: Given data:

$$V_i = 0 ms^{-1}$$

$$S = 1km = 1000m$$

$$t = 100s$$

To Find:

$$V_f = ?$$

Solution:

By using 2nd equation of motion.

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

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

$$1000 = \frac{1}{2}(a)(10000)$$

$$2000 = (a)(10000)$$

$$\frac{2000}{10000} = a$$

$$0.2\ ms^{-2} = a$$

Now, we can find the final velocity:

$$v_f = v_i + at$$

Using the values:

$$v_f = 0 + (0.2)(100)$$

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

The speed of the train is $20ms^{-1}$.

3. A car has a velocity of $10ms^{-1}$. It accelerates at $0.2ms^{-2}$ for half a minute. Find the distance travelled during this time and the final velocity of the car.

Ans: Given data:

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

$$a = 0.2\ ms^{-2}$$

$$t = \frac{1}{2}\text{minute} = 30sec$$

To Find:

$$S = ?$$

$$V_f = ?$$

Solution:

(i) By using 2nd equation of motion.

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

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

$$S = 300 + \frac{1}{2}(0.2)(900)$$

$$S = 300 + (0.1)(900)$$

$$S = 300 + 90$$

$$\mathbf{S = 390m}$$

(ii) Using 1st equation of motion.

$$v_f = v_i + at$$

Using the values

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

$$v_f = 10 + 6$$

$$\mathbf{v_f = 16ms^{-1}}$$

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

Ans: Given data:

$v_i = 30ms^{-1}$

$v_f = 0ms^{-1}$

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

$t = 3sec$

To Find:

$S = h = ?$

Solution:

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

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

$$h = 30 \times 3 + (-5)(9)$$

$$h = 90 - 45$$

$$h = 45$$

The time taken by the ball to come to the ground:

Data can be written in this case as,

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

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

Time $= t = ?$

Distance = height $= h = 45m$

As we know from second equation of motion.

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

By putting values, we get

$$45m = (0)(t) + \frac{1}{2}(10)(t)^2$$

$$45m = (5)t^2$$

$$\frac{45}{5} = t^2$$

$$9 = t^2$$

Or $t^2 = 9$

By taking under root on both sides:

$\sqrt{t^2} = (3)^2$

$t = 3s$

Total time taken by the ball is

$3 + 3 = 6s$

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

Ans: Given data:

Part (I)

$\text{Time} = t = 10\text{sec}$

$\text{Initial velocity} = v_i = 40ms^{-1}$

$\text{Final velocity} = v_f = 0ms^{-1}$

To Find:

$\text{Deceleration} = a = ?$

$\text{Total distance covered} = S = ?$

Solution:

$v_f = v_i + at$

$0 = 40 + a(10)$

$-40 = 10a$

$A = -4ms^{-2}$

Part (II)

To find the total distance (s)

$S = v \times t$

Using the values, we have

$S = 40 \times 10$

$\mathbf{S = 400m}$

The total distance covered by a car is 400m.

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

Ans: Given data:

$v_i = 0ms^{-1}$

$a = 0.5ms^{-2}$

$S = 100m$

To Find:

$v_f = ?$

Solution:

Using 3rd equation of motion

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

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

$$v_f^2 = 100$$

By taking square root on both sides

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

Conversion of ms^{-1} into Kmh^{-1}

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

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

7. A train starting from rest accelerates uniformly and attains a velocity of 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 traveled by the train.

Ans: Given data:

$V_i = 0ms^{-1}$

$V_f = 48kmh^{-1} = \frac{48 \times 100}{36000} ms^{-1}$

$V_f = 13.3ms^{-1}$

$t_1 = 2min = 2 \times 60 = 120sec$

Required:

Total distance = S = ?

Solution:

$$v_f = v_i + at$$

$$13.3 = 0 + a\,(120)$$

$$a = 0.1ms^{-2}$$

(i) Distance = S_1 = ?

$$S_1 = v_i t + \frac{1}{2} at^2$$

By putting values, we get

$$S_1 = 0 \times 120 + \frac{1}{2}(0.1)(120)^2$$

$$S_1 = 0 + \frac{1}{2}(0.1)(14400)$$

$$\mathbf{S_1 = 720m}$$

(ii) Motion with constant velocity

$$v = 13.33ms^{-1}$$

$$t_2 = 5min = 5 \times 60 = 300sec$$

$$S_2 = v \times t_2$$

$$S_2 = 13.33 \times 300$$

$$\mathbf{S_2 = 3999m}$$

(iii) Motion with negative acceleration

$$V_i = 13.33ms^{-1}$$

$$V_f = 0ms^{-1}$$

$$t_3 = 3min = 3 \times 60 = 180sec$$

$$S_3 = v_{av} \times t_3$$

$$S_3 = \frac{v_i - v_f}{2} \times t_3$$

$$S_3 = \frac{13.33 - 0}{2} \times 180$$

$$\mathbf{S_3 = 1199.7m}$$

Total distance = 720m + 3999m + 1199.7m

Total distance = 5918.7m

8. A cricket ball is hit vertically upwards and returns to the ground in 6s later. Calculate

(i) The maximum height reached by the ball

(ii) The initial velocity of the ball.

Ans: Given data:

Time taken by the ball to return to ground = 6s

Time to reach maximum height $= t = \frac{6}{2}$

$t = 3s$

$v_f = 0ms^{-1}$

To find:

i. $v_i = ?$

ii. $S = h = ?$

Solution:

i. By using the 1st equation of motion.

$$v_f = v_i + at$$
$$v_i = v_f - at$$
$$v_i = v_f - gt$$
$$v_i = 0 - (-10)(3)$$
$$\mathbf{v_i = 30ms^{-1}}$$

ii. By using the 3rd equation of motion.

$$2aS = v_f^2 - v_i^2$$
$$2(-10)h = (0)^2 - (300)^2$$
$$-20h = -900$$
$$H = \frac{-900}{-20}$$
$$\mathbf{h = 45m}$$

9. **When brakes are applied, the speed of a train decreases from 96 kmh⁻¹ to 48 kmh⁻¹ in 800m. How much further will the train move before coming to rest?**

Ans: **Given data:**

$$V_i = 96kmh^{-1} = \frac{96 \times 1000}{3600} ms^{-1} = 26.67ms^{-1}$$
$$V_f = 48kmh^{-1} = \frac{48 \times 1000}{3600} ms^{-1} = 13.33ms^{-1}$$
$$S_1 = 800m$$

To find:

$$S_2 = ?$$

Using 3rd equation of motion

Solution:

The motion of train consists of two steps:

$$2aS_1 = v_f^2 - v_i^2$$

$$a = \frac{v_f^2 - v_i^2}{2S_1}$$

$$a = \frac{(13.33)^2 - (26.67)^2}{2\ (800)}$$

$$a = -0.33ms^{-2}$$

Distance covered = ?

Using 3rd equation of motion

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

$$S_2 = \frac{v_f^2 - v_i^2}{2a}$$

$$S_2 = \frac{(13.33)^2 - (26.67)^2}{2\ (-0.33)}$$

$$\mathbf{S_2 = 266.6m}$$

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

Ans: Given data:

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

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

$a = -0.33ms^{-2}$

To find:

$t = ?$

Using 1st equation of motion,

Solution:

$$v_f = v_i + at$$

$$at = v_i - v_f$$

$$t = \frac{vi - vf}{\mathbf{a}}$$

$$t = \frac{0 - 26.67}{-0.33}$$

$$\mathbf{t = 80.1S}$$