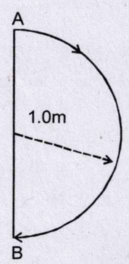
Chapter
Motion in a Straight Line

Topic-1: Distance, Displacement & Uniform Motion

1 MCQs with One Correct Answer

1. In 1.0 s, a particle goes from point A to point B, moving in a semicircle of radius 1.0 m (see Figure). The magnitude of the average velocity **[1999S - 2 Marks]**



(a) 3.14 m/s
(b) 2.0 m/s
(c) 1.0 m/s
(d) Zero

4 Fill in the Blanks

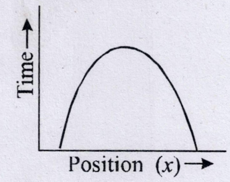
2. A particle moves in a circle of radius R. In half the period of revolution its displacement is ____________ and distance covered is _________. **[1983 - 2 Marks]**

6 MCQs with One or More than One Correct Answer

3. A particle is moving eastwards with a velocity of 5 m/s. In 10s the velocity changes to 5 m/s northwards. The average acceleration in this time is/are **[1982 - 3 Marks]**
(a) zero
(b) $1/\sqrt{2}$ m/s^2 towards north-west
(c) $1/\sqrt{2}$ m/s^2 towards north-east
(d) $\frac{1}{2} m/s^2$ towards north-west
(e) $\frac{1}{2} m/s^2$ towards north

10 Subjective Problems

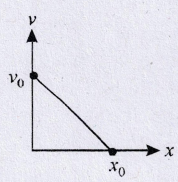
4. Answer the following giving reasons in brief:
Is the time variation of position, shown in the figure observed in nature? **[1979]**



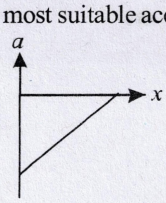
Topic-2: Non-Uniform Motion

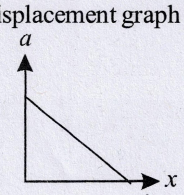
1 MCQs with One Correct Answer

1. The velocity-displacement graph of a particle moving along a straight line is shown **[2005S]**



The most suitable acceleration-displacement graph will be

(a)


(b)


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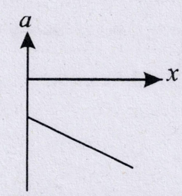
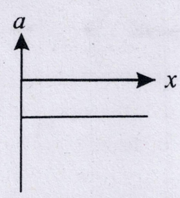
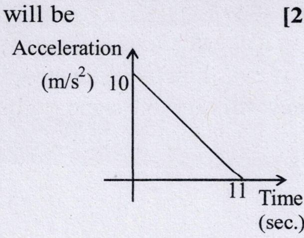


(d)


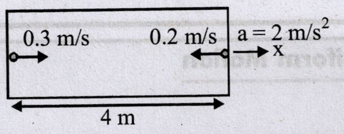
2. A body starts from rest at time $t = 0$, the acceleration time graph is shown in the figure. The maximum velocity attained by the body will be **[2004S]**

(a) 110 m/s
(b) 55 m/s
(c) 650 m/s
(d) 550 m/s



2 Integer Value Answer

3. A rocket is moving in a gravity free space with a constant acceleration of 2 m/s^2 along +x direction (see figure). The length of a chamber inside the rocket is 4 m. A ball is thrown from the left end of the chamber in $+x$ direction with a speed of 0.3 m/s relative to the rocket. At the same time, another ball is thrown in $-x$ direction with a speed of 0.2 m/s from its right end relative to the rocket. The time in seconds when the two balls hit each other is **[Adv. 2014]**



6 MCQs with One or More than One Correct Answer

4. A particle of mass m moves on the x-axis as follows : it starts from rest at $t = 0$ from the point $x = 0$, and comes to rest at $t = 1$ at the point $x = 1$. NO other information is available about its motion at intermediate times $(0 < t < 1)$. If α denotes the instantaneous acceleration of the particle, then: **[1993-2 Marks]**

(a) α cannot remain positive for all t in the interval $0 \le t \le 1$.
(b) $|\alpha|$ cannot exceed 2 at any point in its path.
(c) $|\alpha|$ must be ≥ 4 at some point or points in its path.
(d) α must change sign during the motion, but no other assertion can be made with the information given.

10 Subjective Problems

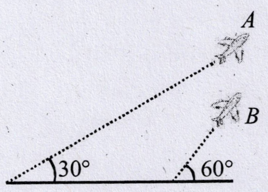
5. A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β to come to rest. If the total time lapse is t seconds, evaluate. **[1978]**

(i) maximum velocity reached, and
(ii) the total distance travelled.

Topic-3: Relative Velocity in One Dimension

2 Integer Value Answer

1. Airplanes A and B are flying with constant velocity in the same vertical plane at angles 30° and 60° with respect to the horizontal respectively as shown in figure. The speed of A is $100\sqrt{3}$ m/s. At time $t = 0$ s, an observer in A finds B at a distance of 500 m. The observer sees B moving with a constant velocity perpendicular to the line of motion of A. If at $t = t_0$, A just escapes being hit by B, t_0 in seconds is **[Adv. 2014]**



4 Fill in the Blanks

2. Four persons K, L, M, N are initially at the four corners of a square of side d. Each person now moves with a uniform speed v in such a way that K always moves directly towards L, L directly towards M, M directly towards N, and N directly towards K. The four persons will meet at a time .... **[1984- 2 Marks]**

5 True / False

3. Two identical trains are moving on rails along the equator on the earth in opposite directions with the same speed. They will exert the same pressure on the rails. **[1985 - 3 Marks]**

9 Assertion and Reason /Statement Type Questions

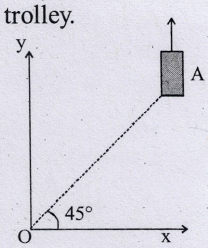
4. **STATEMENT-1 :** For an observer looking out through the window of a fast moving train, the nearby objects appear to move in the opposite direction to the train, while the distant objects appear to be stationary.
STATEMENT-2 : If the observer and the object are moving at velocities $\vec{v}_1$ and $\vec{v}_2$ respectively with reference to a laboratory frame, the velocity of the object with respect to the observer is $\vec{v}_2 - \vec{v}_1$. **[2008]**

(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1
(b) Statement1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(c) Statement -1 is True, Statement-2 is False
(d) Statement -1 is False, Statement-2 is True

10 Subjective Problems

5. On a frictionless horizontal surface, assumed to be the x-y plane, a small trolley A is moving along a straight line parallel to the y-axis (see figure) with a constant velocity of $(\sqrt{3}-1)$ m/s. At a particular instant, when the line OA makes an angle of 45° with the x-axis, a ball is thrown along the surface from the origin O. Its velocity makes an angle ϕ with the x-axis and it hits the trolley.

(a) The motion of the ball is observed from the frame of the trolley. Calculate the angle θ made by the velocity vector of the ball with the x-axis in this frame.
(b) Find the speed of the ball with respect to the surface, if $\phi = 4\theta/3$.



[2002 - 5 Marks]

Topic-4: Motion Under Gravity

5 True / False

1. Two balls of different masses are thrown vertically upwards with the same speed. They pass through the point of projection in their downward motion with the same speed (Neglect air resistance). **[1983 - 2 Marks]**

Answer Key

Topic-1 : Distance, Displacement & Uniform Motion

1. (b) 2. (2R, πR) 3. (b)

Topic-2 : Non-uniform Motion

1. (a) 2. (b) 3. (8) 4. (a, c, d)

Topic-3 : Relative Velocity in One Dimension

1. (5) 2. $\left(\frac{d}{v}\right)$ 3. (False) 4. (b) 5. (45°, 2m/s)

Topic-4 : Motion Under Gravity

1. (True)

Hints & Solutions

Topic-1: Distance, Displacement & Uniform Motion

1. **(b)** $|\text{Average velocity}| = \dfrac{|\text{displacement}|}{\text{time}}$

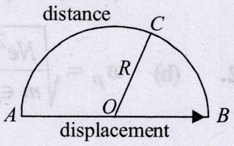
$$= \frac{2r}{t} = 2 \times \frac{1}{1} = 2\,\text{m/s.} \quad (\because\ r = 1\,\text{m}\ ;\ t = 1\,\text{s})$$

2. **(2R, πR)** Displacement = shortest distance

$= AB = AOB = 2R$

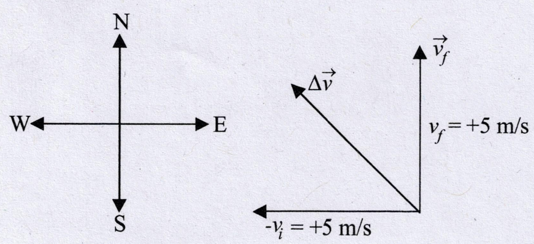
Distance = Path length

$= ACB = \dfrac{2\pi r}{2} = \pi R$



3. **(b)** Average acceleration

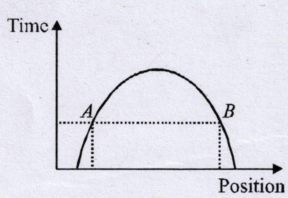
$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t} = \frac{\vec{v}_f + (-\vec{v}_i)}{t} = \frac{\Delta\vec{v}}{t}$$



$$|\Delta\vec{v}| = \sqrt{v_f^2 + v_i^2} = \sqrt{5^2 + 5^2} = 5\sqrt{2}\,\text{m/s}$$

$$|\vec{a}| = \frac{|\Delta\vec{v}|}{\Delta t} = \frac{5\sqrt{2}}{10} = \frac{1}{\sqrt{2}}\ \text{m/s}^2 \text{ in North-west direction.}$$

4. No, At a given instant of time, the body is at two different positions A and B in the given position time graph, which is not possible.



Topic-2: Non-uniform Motion

1. **(a)** The equation for the given v-x graph is

$$v = -\frac{v_0}{x_0}x + v_0 \qquad \text{...(i)}$$

$$\frac{dv}{dx} = -\frac{v_0}{x_0}$$

$$\therefore\ a = v\frac{dv}{dx} = -\frac{v}{x_0} \times v = -\frac{v_0}{x_0}\left[-\frac{v_0}{x_0}x + v_0\right] \text{ from (i)}$$

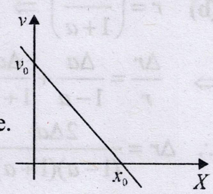
$$\Rightarrow\ a = \frac{v_0^2}{x_0^2}x - \frac{v_0^2}{x_0} \qquad \text{.... (ii)}$$

On comparing the equation (ii) with equation of a straight line

$$y = mx + c$$

we get $m = \dfrac{v_0^2}{x_0^2} = +\text{ve},$

i.e. tan θ = + ve, i.e., θ is acute.



Also $c = -\dfrac{v_0^2}{x_0^2},$

i.e., the y-intercept is negative

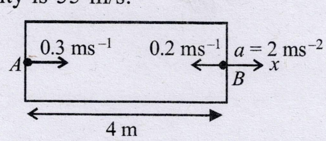
Hence graph (a) correctly depicts corresponding a-x graph.

2. **(b)** Change in velocity = area under the acceleration-time graph

$$= \frac{1}{2} \times 10 \times 11 = 55\,\text{m/s}$$

Since, initial velocity is zero, final velocity i.e., maximum velocity is 55 m/s.

3. **(8)**



For ball A

$$u_1 = 0.3\,\text{ms}^{-1},\ a_1 = -2\text{ms}^{-2},\ s_1 = x,\ t_1 = t$$

$$\therefore\ s_1 = u_1 t_1 + \frac{1}{2}a_1 t_1^2$$

$$x = 0.3t - t^2 \qquad \text{...(i)}$$

For ball B

$$u_2 = 0.2\,\text{ms}^{-1},\ a_2 = 2\text{ms}^{-2},\ s_2 = 4 - x,\ t_2 = t$$

$$\therefore\ s_2 = u_2 t_2 + \frac{1}{2}a_2 t_2^2$$

$$4 - x = 0.2\,t + t^2 \qquad \text{...(ii)}$$

Adding eq. (i) and (ii)

$$4 = 0.5t \quad \therefore\ t = \frac{4}{0.5} = 8\text{s.}$$

Note : Particle 'A' will never move as $a_1 = -2$ m/s^2 is much larger than its initial velocity of 0.2 m/s. But to match the official answer, we solved as shown above.

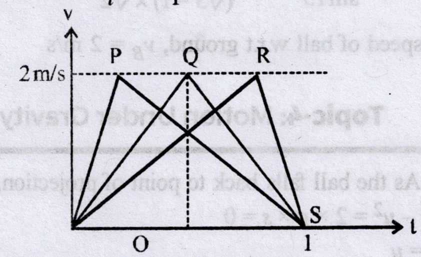
4. **(a, c, d)** At $t = 0$ and $t = 1$ body is at rest

Initially α is positive so that the body acquires some velocity. Then α should be negative so that the body comes to rest. Hence α cannot remain positive for all time in the interval $0 \le t \le 1$

The journey is depicted in the following v-t graph.
Total time of journey = 1 sec
Total displacement = 1 m = Area under (v-t) graph

$$= \frac{1}{2} \times v_{max} \times 1$$

$$v_{max} = \frac{2s}{t} = \frac{2\times 1}{1} = 2 \text{ m/s}$$



For path OQ, acceleration (α)

$$= \frac{\text{change in velocity}}{\text{time}} = \frac{2}{1/2} = 4 \text{ m/s}^2$$

For path QS is retardation = -4 m/s^2
For path OP, α (acceleration) > 4 m/s^2
For path PS (acceleration) < -4 m/s^2
For path OR, acceleration α < 4 m/s^2
For path RS, retardation α > 4 m/s^2
Hence $\alpha \geq 4$ at some point or points in its path.

5. (i) Let t_1 be the time taken by the car to attain the maximum velocity v_m while it is acceleration.
Using $v = u + at$

$$v_m = 0 + \alpha t_1 \text{ or } t_1 = \frac{v_m}{\alpha} \quad \text{.... (i)}$$

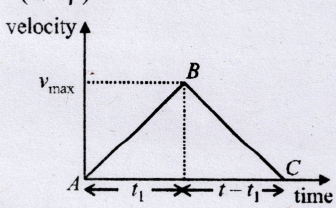
Since the total time elapsed is t, the car decelerators for time $t_2 = (t - t_1)$ to come by rest, $a = -\beta$ and $v = 0$
Usint $v = u + at_2$

$$0 = v_m - \beta(t - t_1) \text{ or } t_1 = t + \frac{v_m}{\beta} \quad \text{.... (ii)}$$

Using (i) in (ii), we get

$$\frac{v_m}{\alpha} = t - \frac{v_m}{\beta} \text{ or } t = v_m\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$$

or $$v_m = \frac{t\alpha\beta}{(\alpha+\beta)} \quad \text{.... (iii)}$$



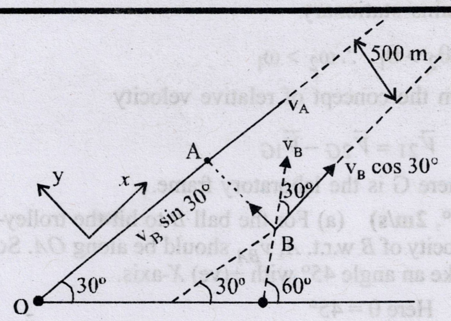
(ii) Total distance travelled = area of Δ ABC

$$= \frac{1}{2} \times \text{base} \times \text{altitude} = \frac{1}{2} \times t \times v_{max}$$

$$= \frac{1}{2} \times t \times \frac{\alpha\beta}{\alpha+\beta} t = \frac{1}{2}\left(\frac{\alpha\beta}{\alpha+\beta}\right) t^2$$

Topic-3: Relative Velocity in One Dimension

1. **(5)**



As 'A' see the motion of 'B' $\perp$ r to $\vec{V}_A$.
So, $v_A = v_B \cos 30°$ ... (i)
Now, $\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$

$$= v_B \cos 30\hat{i} + v_B \sin 30\hat{j} - v_A\hat{i}$$

$$= v_B \sin 30\hat{j} \quad \text{[From (i)]}$$

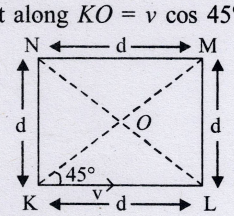
$$= \frac{v_A}{\cos 30°} \sin 30°\hat{j} \quad \text{[From (i)]}$$

$$= v_A \tan 30°\hat{j} = \frac{v_A}{\sqrt{3}} = 100 \text{ m/s}$$

so, $$t_0 = \frac{500}{|v_{BA}|} = \frac{500}{100} = 5 \text{ sec}.$$

2. $\left(\frac{\mathbf{d}}{\mathbf{v}}\right)$ Each person K, L, M, N moves with a uniform speed v such that K always move directly towards L, L dierectly towards M, M directly towards N and N directly towards K. Here on the basis of symmetry we can say that K, L, M and N will meet at the centre of the square 'O'.
At any instant velocity component along KO = v cos 45°

$$= \frac{v}{\sqrt{2}}$$



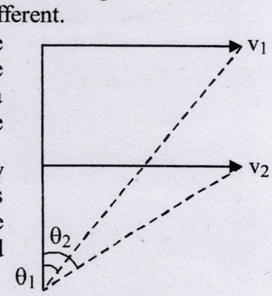
Distance $KO = d \cos 45° = \frac{d}{\sqrt{2}}$

$\therefore$ Time taken to meet at 'O' $= \frac{\text{distance}}{\text{velocity}}$

$$\text{or, } t = \frac{d/\sqrt{2}}{v/\sqrt{2}} = \frac{d}{v}$$

3. **(False)** For both trains, we have different centrifugal force. So we will have different net force acting towards centre. So, pressure exerted will be different.

4. **(b)** For a moving observer, the near by objects appear to move in the opposite direction at a large speed. This is because the angular speed of the near by object w.r.t observer is large. As the object moves away the angular velocity decreases and



therefore its speed seems to be less. The distant object almost remains stationary.

$\because \theta_2 > \theta_1 \; \therefore \omega_2 > \omega_1$

From the concept of relative velocity

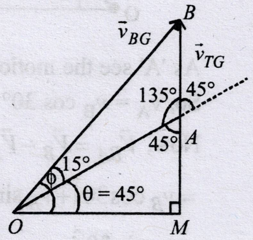
$$\vec{V}_{21} = \vec{V}_{2G} - \vec{V}_{1G}$$

Where G is the laboratory frame.

5. **(45°, 2m/s)** (a) For the ball B to hit the trolley-A retative velocity of B w.r.t. A, v_{BA} should be along OA. So, v_{BA} will make an angle 45° with +(ve) X-axis.

(b) Here $\theta = 45°$

$\therefore \quad \phi = \frac{4\theta}{3} = \frac{4 \times 45}{3} = 60°$ with +ve X-axis.



In ΔOMA,

$\theta = 45° \Rightarrow \angle OAM = 45°$

$\therefore \quad \angle OAB = 135°$

Also $\angle BOA = 60° - 45° = 15°$

Using sine law in ΔOBA

$$\frac{v_B}{\sin 135°} = \frac{v_T}{\sin 15°}$$

$$v_B = \frac{v_T \sin 135°}{\sin 15°} = \frac{(\sqrt{3}-1) \times 2\sqrt{2}}{(\sqrt{3}-1) \times \sqrt{2}} = 2 \text{ m/s}$$

Hence speed of ball w.r.t ground, $v_B = 2$ m/s

Topic-4: Motion Under Gravity

1. **(True)** As the ball falls back to point of projection, so $s = 0$

$\therefore \quad v^2 - u^2 = 2 \times g \times s = 0$

$\therefore \quad v = u$