# Motion in a Straight Line

## Case Study Based Questions

**Read the following passages and answer the questions that follow:**

**1.** For over speeding, police use speed traps to avoid accidents yet some people find a way to avoid speed traps. Many do so by slowing down before approaching the camera. Over speeding is a major issue on the long and wide highways but the authority still finds a way to fine the over speeders. The toll booth on highways knows the total distance of the highway and when a car approaches the booth, they check the time when the car got on the highway and when they are getting off the highway. By this method they deduce the speed with which the car travelled and fine the over speeders.


(A) A bike rider is travelling from Gurgaon to Noida. In between his entire travelling he crossed a circular path whose radius is r and reminds his old days that during his childhood how he enjoyed all this and noticed that he took around 40 s in covering one revolution. After reaching home he narrated the entire thing to her daughter to which she asked if he revolved around that circular path for around 2 min 20 s then how much distance he has covered and what is his displacement?
(B) The distance travelled by a body is found to be directly proportional to the square of time. Is the body moving with uniform velocity or with uniform acceleration if the distance travelled is directly proportional to time?
(C) The displacement of a body is given to be proportional to the cube of time elapsed. What is the nature of acceleration of the body?

**Ans.** (A) If
i.e., t = 2 min 20 s
1 min = 60 s

2 min = 60 x 2 = 120 s

So, total time, t = 120 s +20s = 140 s

Number of rotations, $\frac{140}{40} = 3 + \frac{1}{2}$

Displacement in $\frac{1}{2}$ rotation = 2r

Distance in $3 + \frac{1}{2}$ rotation

$= 3 \times 2\pi r + \pi r$

$= 7\pi r$

**(B)** The body is moving with uniform acceleration if the distance travelled is directly proportional to the square of time, and if it is proportional only to time, it is moving with uniform velocity.

As $s \propto t^3$ or $s = kt^3$

Velocity, $v = \frac{ds}{dt} = 3kt^2$

Acceleration, $a = \frac{dv}{dt} = 6kt$

*i.e.*, acceleration $\propto$ time

Clearly, the acceleration increases uniformly with time.

**2.** An object released near the surface of the Earth is accelerated downward under the influence of the force of gravity. The magnitude of acceleration due to gravity is represented by g. If air resistance is neglected, the object is said to be in free fall. If the height through which the object falls is small compared to the earth's radius, g can be taken to be constant, equal to 9.8 $m/s^2$. Free fall is thus a case of motion with uniform acceleration. We assume that the motion is in y-direction, more correctly in -y-direction because we choose upward direction as positive. Since the acceleration due to gravity is always downward, it is in the negative direction and we have a = - g = 9.8 $ms^2$. The object is released from rest at y = 0. Therefore, vo = 0 and the equations of motion become

$v = 0 - gt = -9.8\,t\,ms^{-1}$

$y = 0 - \frac{1}{2}gt^2 = -4.9\,t^2\,m$

$v^2 = 0 - 2\,gy = -19.6\,y\,m^2s^{-2}$

These equations give the velocity and the distance travelled as a function of time and also the variation of velocity with distance.

**(A) Suppose you hold a book in one hand and a flat sheet of paper in another hand. You drop them both, and they fall to the ground. The falling book is a good example of free fall, but the paper is not because:**
(a) The book is significantly affected by the air.
(b) The paper is relatively more affected by gravity.
(c) Free fall is the motion of an object when gravity is the only significant force on it. The paper is significantly affected by the air, but the book is not.
(d) None of the above.
**(B) Suppose you throw a ball straight up into the air. The correct option is:**
(a) Velocity is reduced at a constant rate as the ball travels upward.
(b) At its highest point, velocity is zero.
(c) As the ball begins to drop, the velocity begins to increase in the negative direction.
(d) All of the above
**(C) A stone that starts at rest is in free fall for 8.0 s. The stone's velocity after 8.0 s will be:**
(a) 78.4 m/s downward
(b) 108 m/s downward
(c) 118 m/s downward
(d) 97 m/s downward
**(D) A stone that starts at rest is in free fall for 8.0 s. The stone's displacement during this time will be:**
(a) 510 m downward
(b) 800 m downward
(c) 100 m downward
(d) 310 m downward
**(E) Assertion (A):** At any instant, the acceleration of a body can change its direction without any change in direction of velocity.
**Reason (R):** At any instant, the direction of acceleration is the same as that of the direction of change in velocity vector at that instant.
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

**Ans. (A)** (c) Free fall is the motion of an object when gravity is the only significant force on it. The paper is significantly affected by the air, but the book is not.

**Explanation:** The motion of an item when gravity is the only substantial force acting on it is referred to as free fall. The air has a considerable impact on the paper, but not on the book.

**(B)** (d) All of the above

**Explanation:** As the ball moves higher, its velocity decreases at a steady pace. Velocity is 0 at its maximum point. As the ball begins to fall, the velocity increases in the opposite direction.

**(C)** (a) 78.4 m/s downward

**Explanation:** Given: Initial velocity,

u = 0 m/s (since, the stone starts at rest)

Time, t = 8 seconds

Acceleration due to gravity,

a = 9.8 $m/s^2$. Mathematically, the first equation of motion is given by the formula;

v = u + at

v = 0 + 9.8 x 8

Velocity, v 78.4 m/s

**(D)** (d) 310 m downward

**Explanation:** Given:

Initial velocity, 0 m/s

(since, the stone starts at rest)

Time, t = 8 seconds

Acceleration due to gravity, a = 9.8 meter per seconds square of motion;

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

$$S = 0(8) + \frac{1}{2}(9.8)(8)^2$$

$$S = 0 + \frac{1}{2}(9.8)(64)$$

$$S = 4.9 \times 64$$

Displacement, S = 313.6 meters

**(E)** (b) Both A and R are true and R is not the correct explanation of A.

**Explanation:** Acceleration depends upon the applied force.

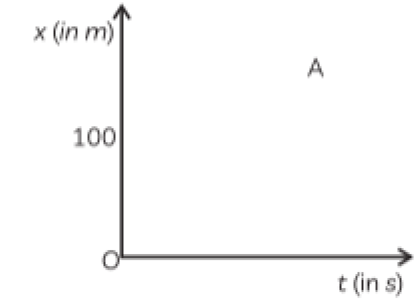
As, we know that, F = ma

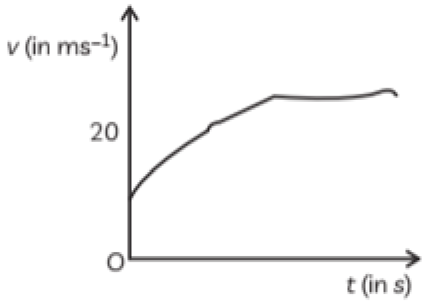
So, $a = \frac{F}{m}$

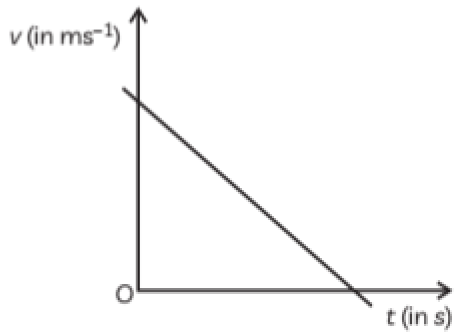
**3.** A driver is driving a car on a straight road. The car is moving with a velocity of 20 ms-1 at t = 0 along the x axis. At t = 0, the car passes a milestone at x = 100 m. The acceleration of the car varies with time as a

= (60.2t) ms $^{-2}$. The x-t, vt, and a - t

graphs of the motion of the car are shown in figure:




**(A) The velocity of the car after 5 seconds is:**

(a) 35.0 ms$^{-1}$

(b) 35.5 ms$^{-1}$

(c) 37.5 ms$^{-1}$

(d) 47.5 ms$^{-1}$

**(B) The distance travelled by car after 5 seconds is:**

(a) 295.0 m

(b) 295.5 m
(c) 270.8 m
(d) 276.5 m

**(C) The time after which the car attains maximum velocity is:**

(a) 10 s
(b) 20 s
(c) 25 s
(d) 30 s

**(D) The maximum velocity attained by the car is:**

(a) 120 $ms^{-1}$
(b) 140 $ms^{-1}$
(c) 150 $ms^{-1}$
(d) 110 $ms^{-1}$

**(E)** A displacement time graph of two particles A and B are straight lines making angles of 30° and 60° respectively with the time axis. If the velocities of these particles are va and v, respectively,

then the value of $\frac{v_a}{v_b}$ is:

(a) $\sqrt{3}$ (b) $\frac{1}{\sqrt{3}}$
(c) $\frac{1}{3}$ (d) 3

**Ans.** (A) (d) 47.5 ms-$^{1}$

**Explanation:**

$$v = 20 + \int_0^t a\,dt$$

$$= 20 + \int_0^5 (6 - 0.2t)\,dt$$

$$= 20 + \left[6t - 0.1t^2\right]_0^5$$

$$= 20 + 30 - 2.5 = 47.5\ ms^{-1}$$

**(B)** (c) 270.8 m

**Explanation:**

$$s = x + \int_0^t v t dt$$

$$= 100 + \int_0^5 (20 + 6t - 0.1t^2) dt$$

$$= 100 + \left[20t + 3t^2 - \frac{0.1t^3}{3}\right]_0^5$$

$= 100 + 100 + 75 - 4.17$

$= 270.8$ m

**(C)** (d) 30 s

**Explanation:**

Since, $a = (6 - 0.2t)$

or $\frac{dv}{dt} = 6 - 0.2t$

$6 - 0.2t = 0$

As $v$ is constant.

So, $\frac{dv}{dt} = 0$

Then, $t = 30$ s

**(D)** (d) 110 ms-1

**Explanation:**

Vmax=20+6t-0.1 x $t^2$

= 20 +6 x 30-0.1 + 900

= 110 ms-1

**(E)**

(c) $\frac{1}{3}$

**Explanation:** Velocity of a particle = slope of the displacement-time graph

$= \tan\theta$

$v_a = \tan\theta = \tan 30°$

And $v_b = \tan\theta = \tan 60°$

$$\frac{v_a}{v_b} = \frac{\tan 30°}{\tan 60°} = \frac{1}{\sqrt{3} \times \sqrt{3}} = \frac{1}{3}$$