2 Motion in a Straight Line

Trend Analysis with Important Topics & Sub-Topics

		2020		2019		2018		2017		2016	
Topic	Sub-Topic	Qns.	LOD	Qns.	LOD	Qns.	LOD	Qns.	LOD	Qns.	LOD
Distance, Displacement & Uniform motion	Average Speed					1	A				
	Integration & Differentiation									1	E
Non-uniform motion											
Relative Velocity	Use of eqn. of motion	1	E								
Motion Under Gravity	Velocity-time graph							1	A		
	River-Man problem			1	A						

LOD - Level of Difficulty | E - Easy | A - Average | D - Difficult | Qns - No. of Questions

Topic 1: Distance, Displacement & Uniform motion

1. A person travelling in a straight line moves with a constant velocity v_1 for certain distance 'x' and with a constant velocity v_2 for next equal distance. The average velocity v is given by the relation ***[NEET Odisha 2019]***

(a) $v = \sqrt{v_1 v_2}$ (b) $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2}$

(c) $\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$ (d) $\frac{v}{2} = \frac{v_1 + v_2}{2}$

2. Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time t_1. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time t_2. The time taken by her to walk up on the moving escalator will be: ***[2017]***

(a) $\frac{t_1 t_2}{t_2 - t_1}$ (b) $\frac{t_1 t_2}{t_2 + t_1}$

(c) $t_1 - t_2$ (d) $\frac{t_1 + t_2}{2}$

3. A particle covers half of its total distance with speed v_1 and the rest half distance with speed v_2. Its average speed during the complete journey is ***[2011M]***

(a) $\frac{v_1 v_2}{v_1 + v_2}$ (b) $\frac{2v_1 v_2}{v_1 + v_2}$

(c) $\frac{2v_1^2 v_2^2}{v_1^2 + v_2^2}$ (d) $\frac{v_1 + v_2}{2}$

4. A car moves from X to Y with a uniform speed v_u and returns to Y with a uniform speed v_d. The average speed for this round trip is ***[2007]***

(a) $\sqrt{v_u v_d}$ (b) $\frac{v_d v_u}{v_d + v_u}$

(c) $\frac{v_u + v_d}{2}$ (d) $\frac{2v_d v_u}{v_d + v_u}$

5. If a car at rest accelerates uniformly to a speed of 144 km/h in 20 s, it covers a distance of ***[1997]***

(a) 2880 m (b) 1440 m

(c) 400m (d) 20m

6. A bus travelling the first one third distance at a speed of 10 km/h, the next one third at 20 km/h and the last one-third at 60 km/h. The average speed of the bus is **[1991]**
(a) 9 km/h (b) 16 km/h
(c) 18 km/h (d) 48 km/h

7. A car moves a distance of 200 m. It covers the first half of the distance at speed 40 km/h and the second half of distance at speed v. The average speed is 48 km/h. Find the value of v
(a) 56 km/h (b) 60 km/h **[1991]**
(c) 50 km/h (d) 48 km/h

8. A car covers the first half of the distance between two places at 40 km/h and other half at 60 km/h. The average speed of the car is **[1990]**
(a) 40 km/h (b) 48 km/h
(c) 50 km/h (d) 60 km/h

Topic 2: Non-uniform motion

9. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1s and 2s is : **[2016]**
(a) $\frac{3}{2}A + 4B$ (b) $3A + 7B$
(c) $\frac{3}{2}A + \frac{7}{3}B$ (d) $\frac{A}{2} + \frac{B}{3}$

10. A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = bx^{-2n}$
where b and n are constants and x is the position of the particle. The acceleration of the particle as the function of x, is given by: **[2015]**
(a) $-2nb^2x^{-4n-1}$ (b) $-2b^2x^{-2n+1}$
(c) $-2nb^2e^{-4n+1}$ (d) $-2nb^2x^{-2n-1}$

11. The displacement 'x' (in meter) of a particle of mass 'm' (in kg) moving in one dimension under the action of a force, is related to time 't' (in sec) by $t = \sqrt{x} + 3$. The displacement of the particle when its velocity is zero, will be **[NEET Kar. 2013]**
(a) 2m (b) 4m
(c) zero (d) 6m

12. A particle has initial velocity $(2\vec{i} + 3\vec{j})$ and acceleration $(0.3\vec{i} + 0.2\vec{j})$. The magnitude of velocity after 10 seconds will be : **[2012]**
(a) $9\sqrt{2}$ units (b) $5\sqrt{2}$ units
(c) 5 units (d) 9 units

13. The motion of a particle along a straight line is described by equation :
$x = 8 + 12t - t^3$
where x is in metre and t in second. The retardation of the particle when its velocity becomes zero, is : **[2012]**
(a) 24 ms^{-2} (b) zero
(c) 6 ms^{-2} (d) 12 ms^{-2}

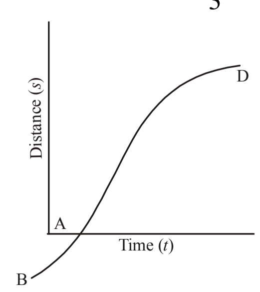
14. A body is moving with velocity 30 m/s towards east. After 10 seconds its velocity becomes 40 m/s towards north. The average acceleration of the body is **[2011]**
(a) 1 m/s^2 (b) 7 m/s^2
(c) 7 m/s^2 (d) 5 m/s^2

15. A particle has initial velocity $(3\hat{i} + 4\hat{j})$ and has acceleration $(0.4\hat{i} + 0.3\hat{j})$. It's speed after 10 s is: **[2010]**
(a) 7 units (b) $7\sqrt{2}$ units
(c) 8.5 units (d) 10 units

16. A particle moves a distance x in time t according to equation $x = (t + 5)^{-1}$. The acceleration of particle is proportional to: **[2010]**
(a) $(\text{velocity})^{3/2}$ (b) $(\text{distance})^2$
(c) $(\text{distance})^{-2}$ (d) $(\text{velocity})^{2/3}$

17. A particle starts its motion from rest under the action of a constant force. If the distance covered in first 10 seconds is S_1 and that covered in the first 20 seconds is S_2, then: **[2009]**
(a) $S_2 = 3S_1$ (b) $S_2 = 4S_1$
(c) $S_2 = S_1$ (d) $S_2 = 2S_1$

18. The distance travelled by a particle starting from rest and moving with an acceleration $\frac{4}{3}ms^{-2}$, in the third second is: **[2008]**
(a) 6m (b) 4m
(c) $\frac{10}{3}$m (d) $\frac{19}{3}$m

19.


A particle shows distance-time curve as given in this figure. The maximum instantaneous velocity of the particle is around the point: ***[2008]***

(a) B (b) C
(c) D (d) A

20. A particle moves in a straight line with a constant acceleration. It changes its velocity from 10 ms^{-1} to 20 ms^{-1} while passing through a distance 135 m in t second. The value of t is: ***[2008]***

(a) 10 (b) 1.8
(c) 12 (d) 9

21. The position x of a particle with respect to time t along x-axis is given by $x = 9t^2 - t^3$ where x is in metres and t in second. What will be the position of this particle when it achieves maximum speed along the +ve x direction? ***[2007]***

(a) 54 m (b) 81 m
(c) 24 m (d) 32 m.

22. A particle moving along x-axis has acceleration f, at time t, given by $f = f_0\left(1 - \frac{t}{T}\right)$, where f_0 and T are constants. The particle at $t = 0$ has zero velocity. In the time interval between $t = 0$ and the instant when $f = 0$, the particle's velocity (v_x) is ***[2007]***

(a) $\frac{1}{2}f_0T^2$ (b) f_0T^2
(c) $\frac{1}{2}f_0T$ (d) f_0T

23. A particle moves along a straight line OX. At a time t (in seconds) the distance x (in metres) of the particle from O is given by $x = 40 + 12t - t^3$. How long would the particle travel before coming to rest? ***[2006]***

(a) 40 m (b) 56 m
(c) 16 m (d) 24 m

24. The displacement x of a particle varies with time t as $x = ae^{-\alpha t} + be^{\beta t}$, where a, b, α and β are positive constants. The velocity of the particle will ***[2005]***

(a) be independent of α and β
(b) drop to zero when $\alpha = \beta$
(c) go on decreasing with time
(d) go on increasing with time

25. The displacement of a particle is represented by the following equation : $s = 3t^3 + 7t^2 + 5t + 8$ where s is in metre and t in second. The acceleration of the particle at $t = 1$s is ***[2000]***

(a) 14 m/s^2 (b) 18 m/s^2
(c) 32 m/s^2 (d) zero

26. A car moving with a speed of 40 km/h can be stopped by applying brakes at least after 2 m. If the same car is moving with a speed of 80 km/h, what is the minimum stopping distance? ***[1998]***

(a) 8m (b) 6m
(c) 4m (d) 2m

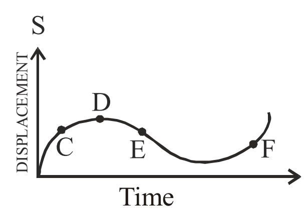
27. The displacement of a particle varies with time (t) as: $s = at^2 - bt^3$. The acceleration of the particle will be zero at time t equal to ***[1997]***

(a) $\frac{a}{b}$ (b) $\frac{a}{3b}$
(c) $\frac{3b}{a}$ (d) $\frac{2a}{3b}$

28. A car accelerates from rest at a constant rate α for some time, after which it decelerates at a constant rate β and comes to rest. If the total time elapsed is t, then the maximum velocity acquired by the car is ***[1994]***

(a) $\left(\frac{\alpha^2 + \beta^2}{\alpha\beta}\right)t$ (b) $\left(\frac{\alpha^2 - \beta^2}{\alpha\beta}\right)t$
(c) $\frac{(\alpha + \beta)t}{\alpha\beta}$ (d) $\frac{\alpha\beta t}{\alpha + \beta}$

29. The displacement time graph of a moving particle is shown below



The instantaneous velocity of the particle is negative at the point ***[1994]***

(a) D (b) F
(c) C (d) E

30. A particle moves along a straight line such that its displacement at any time t is given by
$s = (t^3 - 6t^2 + 3t + 4)$ metres
The velocity when the acceleration is zero is ***[1994]***

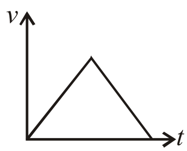
(a) 3 ms^{-1} (b) – 12 ms^{-1}
(c) 42 ms^{-2} (d) – 9 ms^{-1}

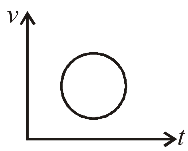
31. A body starts from rest, what is the ratio of the distance travelled by the body during the 4th and 3rd seconds? *[1993]*

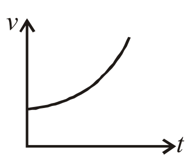
(a) $\frac{7}{5}$ (b) $\frac{5}{7}$

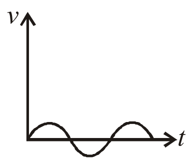
(c) $\frac{7}{3}$ (d) $\frac{3}{7}$

32. Which of the following curve does not represent motion in one dimension? *[1992]*

(a) 

(b) 

(c) 

(d) 

33. A car is moving along a straight road with a uniform acceleration. It passes through two points P and Q separated by a distance with velocity 30 km/h and 40 km/h respectively. The velocity of the car midway between P and Q is *[1988]*

(a) 33.3 km/h (b) $20\sqrt{2}$ km/h

(c) $25\sqrt{2}$ km/h (d) 35 km/h

Topic 3: Relative Velocity

34. A bus is moving with a speed of 10 ms^{-1} on a straight road. A scooterist wishes to overtake the bus in 100 s. If the bus is at a distance of 1 km from the scooterist, with what speed should the scooterist chase the bus? *[2009]*

(a) 40 ms^{-1} (b) 25 ms^{-1}

(c) 10 ms^{-1} (d) 20 ms^{-1}

35. A train of 150 metre long is going towards north direction at a speed of 10 m/s. A parrot flies at the speed of 5 m/s towards south direction parallel to the railway track. The time taken by the parrot to cross the train is *[1988]*

(a) 12 sec (b) 8 sec

(c) 15 sec (d) 10 sec

Topic 4: Motion Under Gravity

36. A ball is thrown vertically downward with a velocity of 20 m/s from the top of a tower. It hits the ground after some time with a velocity of 80 m/s. The height of the tower is : ($g = 10$ m/s^2) *[2020]*

(a) 340 m (b) 320 m

(c) 300 m (d) 360 m

37. A stone falls freely under gravity. It covers distances h_1, h_2 and h_3 in the first 5 seconds, the next 5 seconds and the next 5 seconds respectively. The relation between h_1, h_2 and h_3 is *[2013]*

(a) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$

(b) $h_2 = 3h_1$ and $h_3 = 3h_2$

(c) $h_1 = h_2 = h_3$

(d) $h_1 = 2h_2 = 3h_3$

38. A boy standing at the top of a tower of 20m height drops a stone. Assuming $g = 10$ ms^{-2}, the velocity with which it hits the ground is *[2011]*

(a) 10.0 m/s (b) 20.0 m/s

(c) 40.0 m/s (d) 5.0 m/s

39. A ball is dropped from a high rise platform at $t = 0$ starting from rest. After 6 seconds another ball is thrown downwards from the same platform with a speed v. The two balls meet at $t = 18$s. What is the value of v? *[2010]*
(take $g = 10$ m/s^2)

(a) 75 m/s (b) 55 m/s

(c) 40 m/s (d) 60 m/s

40. A man of 50 kg mass is standing in a gravity free space at a height of 10 m above the floor. He throws a stone of 0.5 kg mass downwards with a speed 2 m/s. When the stone reaches the floor, the distance of the man above the floor will be:

(a) 9.9 m (b) 10.1 m *[2010]*

(c) 10 m (d) 20 m

41. Two bodies, A (of mass 1 kg) and B (of mass 3 kg), are dropped from heights of 16m and 25m, respectively. The ratio of the time taken by them to reach the ground is *[2006]*

(a) 12/5 (b) 5/12

(c) 4/5 (d) 5/4

42. A ball is thrown vertically upward. It has a speed of 10 m/sec when it has reached one half of its maximum height. How high does the ball rise? *[2005, 2001]*
Take $g = 10$ m/s^2.

(a) 10 m (b) 5 m

(c) 15 m (d) 20 m

43. If a ball is thrown vertically upwards with speed u, the distance covered during the last t seconds of its ascent is ***[2003]***
(a) $(u+gt)\,t$ (b) ut
(c) $\frac{1}{2}gt^2$ (d) $ut-\frac{1}{2}gt^2$

44. A man throws balls with the same speed vertically upwards one after the other at an interval of 2 seconds. What should be the speed of the throw so that more than two balls are in the sky at any time? [Given g = 9.8 m/s^2] ***[2003]***
(a) Only with speed 19.6 m/s
(b) More than 19.6 m/s
(c) At least 9.8 m/s
(d) Any speed less than 19.6 m/s

45. If a ball is thrown vertically upwards with a velocity of 40 m/s, then velocity of the ball after two seconds will be (g = 10 m/s^2) ***[1996]***
(a) 15 m/s (b) 20 m/s
(c) 25 m/s (d) 28 m/s

46. A body is thrown vertically upward from the ground. It reaches a maximum height of 20 m in 5 sec. After what time, it will reach the ground from its maximum height position? ***[1995]***
(a) 2.5 sec (b) 5 sec
(c) 10 sec (d) 25 sec

47. A stone released with zero velocity from the top of a tower, reaches the ground in 4 sec. The height of the tower is $(g = 10 m/s^2)$ ***[1995]***
(a) 20 m (b) 40 m
(c) 80 m (d) 160 m

48. Three different objects of masses m_1, m_2 and m_3 are allowed to fall from rest and from the same point O along three different frictionless paths. The speeds of the three objects on reaching the ground will be in the ratio of ***[1995]***
(a) $m_1 : m_2 : m_3$ (b) $m_1 : 2m_2 : 3m_3$
(c) 1 : 1 : 1 (d) $\frac{1}{m_1}:\frac{1}{m_2}:\frac{1}{m_3}$

49. The water drops fall at regular intervals from a tap 5 m above the ground. The third drop is leaving the tap at an instant when the first drop touches the ground. How far above the ground is the second drop at that instant?
(Take g = 10 m/s^2) ***[1995]***
(a) 1.25 m (b) 2.50 m
(c) 3.75 m (d) 5.00 m

50. A body dropped from top of a tower fall through 40 m during the last two seconds of its fall. The height of tower is (g = 10 m/s^2) ***[1991]***
(a) 60 m (b) 45 m
(c) 80 m (d) 50 m

51. What will be the ratio of the distances moved by a freely falling body from rest in 4th and 5th seconds of journey? ***[1989]***
(a) 4 : 5 (b) 7 : 9
(c) 16 : 25 (d) 1 : 1

ANSWER KEY

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

Hints & Solutions

1. (c) As $t_1 \frac{x}{v_1} =$ and $t_2 = \frac{x}{v_2}$

$$\therefore \quad v = \frac{x+x}{t_1+t_2} = \frac{2x}{\frac{x}{v_1}+\frac{x}{v_2}} = \frac{2v_1v_2}{v_1+v_2}$$

$$\therefore \quad \frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$$

2. (b) Let the distance be 'd' time taken by preeti to travel up the stationary escalator = t_1 Velocity of preeti w.r.t. elevator $v_1 = \frac{d}{t_1}$

Since the distance is same let the time taken when preeti stands on the moving escalator = t_2.

Velocity of elevator w.r.t. ground $v_2 = \frac{d}{t_2}$

Then net velocity of preeti w.r.t. ground

$$v = v_1 + v_2$$

$$\frac{d}{t} = \frac{d}{t_1} + \frac{d}{t_2}$$

$$\frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2}$$

$\therefore \; t = \frac{t_1t_2}{(t_1+t_2)}$ (time taken by preeti to walk up on the moving escalator)

3. (b) Let the total distance covered by the particle be 2s. Then

$$v_{av} = \frac{2s}{\frac{s}{v_1}+\frac{s}{v_2}} = \frac{2v_1v_2}{v_1+v_2}$$

NOTES The average speed of an object is the total distance travelled by the object divides by the elapsed time to cover that distance. It's a scalar quantity which means it is defined only by magnitude. A related concept, average velocity, is a vector quantity. A vector quantity is defined by magnitude and direction both.

4. (d) Average speed

$$= \frac{\text{total distance travelled}}{\text{total time taken}}$$

Let s be the distance from X to Y.

$$\therefore \text{ Average speed } = \frac{s+s}{t_1+t_2} = \frac{2s}{\frac{s}{v_u}+\frac{s}{v_d}}$$

$$= \frac{2v_uv_d}{v_d+v_u}$$

5. (c) Initial velocity of car (u) = 0

Final velocity of car (v) = 144 km/hr = 40 m/s

Time taken = 20 s

We know that, $v = u + at$

$40 = a \times 20 \Rightarrow a = 2 \text{ m/s}^2$

Also, $v^2 - u^2 = 2as$

$$\Rightarrow s = \frac{v^2-u^2}{2a}$$

$$\Rightarrow s = \frac{(40)^2-(0)^2}{2\times 2} = \frac{1600}{4} = 400 \text{ m.}$$

6. (c) Average speed $= \dfrac{s}{\frac{s/3}{10}+\frac{s/3}{20}+\frac{s/3}{60}}$

$$= \frac{s}{s/18} = 18 \text{km/h}$$

NOTES In case speed is continuously changing with time, then, $Vav = \dfrac{\int vdt}{\int dt}$

7. (b) Given, Total distance = 200 m speed in first half distance = 40 km/hr speed in second half distance = $v$km/hr.

$$\text{So, } v_{av} = \frac{\text{Total distance covered}}{\text{Total time elapsed}}$$

$$48 = \frac{200\times 10^{-3}}{\left(\frac{100\times 10^{-3}}{40}\right)+\left(\frac{100\times 10^{-3}}{v}\right)}$$

or $\frac{1}{40}+\frac{1}{v}=\frac{2}{48}=\frac{1}{24}$

or $\frac{1}{v}=\frac{1}{24}-\frac{1}{40}=\frac{2}{120}=\frac{1}{60}$

or $v=60$ km/h

> **NOTES** $v_{av}=\frac{2v_1v_2}{v_1+v_2}\Rightarrow 48=\frac{2\times 40\times v}{40+v}$
>
> $\Rightarrow v=60$ km/h

8. (b) Total distance = s;
Total time taken

$$=\frac{s/2}{40}+\frac{s/2}{60}=\frac{5s}{240}=\frac{s}{48}$$

$$\therefore \text{Average speed}=\frac{\text{total distance}}{\text{total time}}$$

$$=\frac{s}{s/48}=48\text{km/h}$$

$$v_{av}=\frac{2v_1v_2}{v_1+v_2}=\frac{2\times 40\times 60}{40+60}=48\text{ km/h}$$

9. (c) **Given :** Velocity $v=\text{At}+\text{Bt}^2$

$$\Rightarrow \frac{dx}{dt}=\text{At}+\text{Bt}^2$$

By integrating we get distance travelled by the particle between 1s and 2s,

$$\Rightarrow \int_0^x dx=\int_1^2\left(At+Bt^2\right)dt$$

$$x=\frac{A}{2}\left(2^2-1^2\right)+\frac{B}{3}\left(2^3-1^3\right)=\frac{3A}{2}+\frac{7B}{3}$$

10. (a) Given, $v(x)=bx^{-2n}$

$$a=\frac{dv}{dt}=\frac{dv}{dx}\cdot\frac{dx}{dt}$$

$$=v\cdot\frac{dv}{dx}$$

So, $\frac{dv}{dx}=-2\,nb\,x^{-2n-1}$

Acceleration of the particle as function of x,

$$a=v\frac{dv}{dx}=bx^{-2n}\{b(-2n)x^{-2n-1}\}$$

$$=-2nb^2x^{-4n-1}$$

> **NOTES** For one dimensional motin, the angle between velocity and acceleration is either 0° or 180° and it does not change with time.

11. (c) $\because t=\sqrt{x}+3$

$\Rightarrow \sqrt{x}=t-3\Rightarrow x=(t-3)^2$ ...(i)

$v=\frac{dx}{dt}=2(t-3)=0$

$\Rightarrow t=3$

From equation (i)

$\therefore x=(3-3)^2$

$\Rightarrow x=0$

12. (b) $\vec{v}=\vec{u}+\vec{a}t$

$v=(2\hat{i}+3\hat{j})+(0.3\hat{i}+0.2\hat{j})$ ´ $10=5\hat{i}+5\hat{j}$

$|\vec{v}|=\sqrt{5^2+5^2}$

$|\vec{v}|=5\sqrt{2}$

13. (d) $x=8+12t-t^3$

The final velocity of the particle will be zero, because it retarded.

$\therefore v=0+12-3t^2=0$

$3t^2=12$

$t=2$ sec

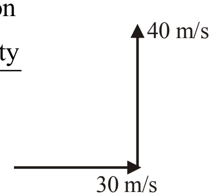
Now the retardation

$a=\frac{dv}{dt}=0-6t$

$a[t=2]=-12$ m/s^2

retardation = 12 m/s^2

14. (d) Average acceleration



$<a>=\frac{\text{Change in velocity}}{\text{Total Time}}$

$<a>=\frac{|40\hat{j}-30\hat{i}|}{10}$

$<a>=\sqrt{4^2+(-3)^2}$

$<a>=5$ m/s^2

15. (b) Given, $\vec{u}=3\hat{i}+4\hat{j}$ and $\vec{a}=0.4\hat{i}+0.3\hat{j}$

$\Rightarrow$ $u_x=3$units, $u_y=4$ units

$\Rightarrow$ $a_x=0.4$ units, $a_y=0.3$ units

Along x-axis,

$\therefore$ $v_x=u_x+a_x\times 10=3+4=7$ units

Along y-axis,

and $v_y=4+0.3\times 10=4+3=7$ units

Net final velocity

$\therefore \quad v = \sqrt{v_x^2 + v_y^2} = 7\sqrt{2}$ units

$\vec{v}_i = 3\hat{i} + 4\hat{j}$ and $\vec{a} = 0.4\hat{i} + 0.3\hat{j}$

time, $t = 10$ sec.

Final velocity $\vec{v}_f$ after time $t = 10$ sec, $\vec{v}_f = \vec{v}_i + \vec{a}t$

$\vec{v}_f = (3\hat{i} + 4\hat{j}) + (0.4\hat{i} + 0.3\hat{j})(10) = 7\hat{i} + 7\hat{j}$

> **NOTES** The particle speeds up i.e., the speed of the particle increases when the angle between $\vec{a}$ and $\vec{v}$ lies between 0° + 90°. The particle speeds down i.e., the speed of the particle decreases when the angle between $\vec{a}$ and $\vec{v}$ lies between + 90° and 180°.

16. (a) distance $x = \dfrac{1}{t+5}$

$\therefore$ velocity $v = \dfrac{dx}{dt} = \dfrac{-1}{(t+5)^2}$

$\therefore$ acceleration $a = \dfrac{d^2x}{dt^2} = \dfrac{2}{(t+5)^3} = 2x^3$

Therefore, $v^{3/2} = -(t+5)^{-3}$

So, $a \propto v^{3/2}$

17. (b) $u = 0, t_1 = 10\text{s}, t_2 = 20s$

Using the relation, $S = ut + \dfrac{1}{2}at^2$

Acceleration being the same in two cases,

$S_1 = \dfrac{1}{2}a \times t_1^2,\ S_2 = \dfrac{1}{2}a \times t_2^2$

$\therefore \quad \dfrac{S_1}{S_2} = \left(\dfrac{t_1}{t_2}\right)^2 = \left(\dfrac{10}{20}\right)^2 = \dfrac{1}{4}$

$S_2 = 4S_1$

18. (c) Distance travelled in the nth second is given by $S_n = u + \dfrac{a}{2}(2n-1)$

Given $u = 0$, $a = \dfrac{4}{3}\text{ms}^{-2}$, $n = 3$

$\therefore S_n = 0 + \dfrac{4}{3\times 2}(2\times 3 - 1) = \dfrac{4}{6}\times 5 = \dfrac{10}{3}\text{m}$

19. (b) The slope of the graph $\dfrac{ds}{dt}$ is maximum at C and hence the instantaneous velocity is maximum at C.

Instantaneous velocity,

$$\vec{v}_{\text{ins}} = \lim_{\Delta t\to 0}\frac{\Delta\vec{s}}{\Delta t} = \frac{d\vec{s}}{dt}$$

> **NOTES** The instantaneous velocity of an object at a given instant is first derivative of displacement with respect to time.
> The slope of displacement-time graph at any instant of time gives the measure of instantanesous velocity of an object at that instant.

20. (d) Initial velocity, $u = 10\text{ ms}^{-1}$

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

Distance, $s = 135$ m

Let, acceleration $= a$

Using the formula, $v^2 = u^2 + 2as$

$$a = \frac{v^2 - u^2}{2s}$$

$$= \frac{(20)^2 - (10)^2}{2\times 135} = \frac{400-100}{2\times 135}$$

or, $a = \dfrac{300}{2\times 135} = \dfrac{150}{135} = \dfrac{10}{9}\text{ms}^{-2}$

Now, using the relation, $v = u + at$

$$t = \frac{v-u}{a} = \frac{20-10}{10/9} = \frac{10}{10}\times 9\text{ sec} = 9\text{ sec.}$$

21. (a) Speed $v = \dfrac{dx}{dt} = \dfrac{d}{dt}(9t^2 - t^3) = 18t - 3t^2$

For maximum speed its acceleration should be zero,

Acceleration $\dfrac{dv}{dt} = 0 \Rightarrow 18 - 6t = 0 \Rightarrow t = 3$

At $t = 3$ its speed is max

$\Rightarrow \quad x_{\text{max}} = 81 - 27 = 54$ m

> **NOTES** Position of any point is completely expressed by two factors its distance from the observer and its direction with respect to observer.
> That is why position is characterised by a vector known as position vector.

22. (c) Here, $f = f_0\left(1 - \dfrac{t}{T}\right)$

or, $\dfrac{dv}{dt} = f_0\left(1 - \dfrac{t}{T}\right)$

If $f = 0$, then

$0 = f_0\left(1 - \dfrac{t}{T}\right) \Rightarrow t = T$

Hence, particle's velocity in the time interval $t = 0$ and $t = T$ is given by

$$v_x = \int_{v=0}^{v=V_z} dv = \int_{t=0}^{T}\left[f_0\left(1 - \frac{t}{T}\right)\right]dt$$

$$= f_0\left[\left(t - \frac{t^2}{2T}\right)\right]_0^T$$

$$= f_0\left(T - \frac{T^2}{2T}\right) = f_0\left(T - \frac{T}{2}\right) = \frac{1}{2}f_0 T.$$

23. (b) $x = 40 + 12t - t^3$

$$v = \frac{dx}{dt} = 12 - 3t^2$$

For $v = 0$; $t = \sqrt{\frac{12}{3}} = 2$ sec

So, after 2 seconds velocity becomes zero.
Value of x in 2 secs $= 40 + 12 \times 2 - 2^3$
$= 40 + 24 - 8 = 56$ m

24. (d)

25. (c) Displacement
$s = 3t^3 + 7t^2 + 5t + 8$;

$$\text{Velocity} = \frac{ds}{dt} = 9t^2 + 14t + 5$$

$$\text{Acceleration} = \frac{d^2s}{dt^2} = 18t + 14$$

Acceleration at ($t = 1$s)
$= 18 \times 1 + 14 = 18 + 14 = 32$ m/s^2

26. (a) $v^2 - u^2 = 2as$

$$\Rightarrow a = \frac{v^2 - u^2}{2s}$$

$$= -\frac{u_1^2}{2s},$$

For same retarding force $s \propto u^2$

$$\because \frac{s_2}{s_1} = \frac{u_2^2}{u_1^2} \Rightarrow \frac{s_2}{s_1} = \left(\frac{80}{40}\right)^2 = 4$$

$\therefore s_2 = 4s_1 = 8$ m

If F is retarding force and s the stopping distance, then $\frac{1}{2}mv^2 = Fs$

For same retarding force, $s \,\alpha\, v^2$

$$\therefore \frac{s_2}{s_1} = \left(\frac{v_2}{v_1}\right)^2 = \left(\frac{80\text{km/h}}{40\text{km/h}}\right)^2 = 4$$

$\therefore s_2 = 4s_1 = 4 \times 2 = 8$ m

27. (b) distance, $s = at^2 - bt^3$

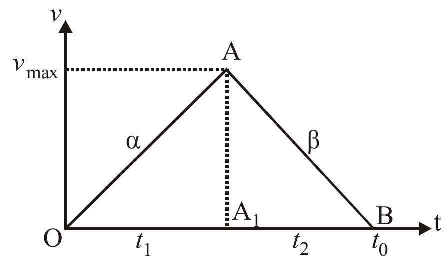
$$\text{velocity, } v = \frac{ds}{dt} = 2at - 3bt^2$$

$$\text{acceleration } a = \frac{dv}{dt} = 2a - 6bt$$

Acceleration is zero at

$$2a - 6bt = 0 \Rightarrow t = \frac{a}{3b}$$

28. (d)



In Fig.
$AA_1 = v_{max.} = \alpha t_1 = \beta t_2$

$$\text{But } t = t_1 + t_2 = \frac{v_{max}}{\alpha} + \frac{v_{max}}{\beta}$$

$$= v_{max}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) = v_{max}\left(\frac{\alpha + \beta}{\alpha\beta}\right)$$

$$\text{or, } v_{max} = t\left(\frac{\alpha\beta}{\alpha + \beta}\right)$$

NOTES If a body starting from rest accelerates at a constant rate α for certain time and then retards at constant β and comes to rest after t. second from the starting point, then

$$\text{Distance travelled by the body} = \frac{\alpha\beta t^2}{(2\alpha + 2\beta)}$$

29. (d) At E, the slope of the curve is negative.

NOTES The line bending towards time axis represents decreasing velocity or negative velocity of the particle. It means the particle possesses retardation.

30. (d) Velocity, $v = \frac{ds}{dt} = 3t^2 - 12t + 3$

Acceleration, $a = \frac{dv}{dt} = 6t - 12$; For $a = 0$, we have, $0 = 6t - 12$ or $t = 2$s. Hence, at $t = 2$ s the velocity will be
$v = 3 \times 2^2 - 12 \times 2 + 3 = -9$ ms^{-1}

31. (a) $\frac{S_4}{S_3} = \frac{0+\frac{a}{2}(2\times4-1)}{0+\frac{a}{2}(2\times3-1)} = \frac{7}{5}$

> **NOTES** Equation of the motion of uniformly accelerated motion, the distance travelled in n^{th} sec is given by,
>
> $S_n = u + \frac{a}{2}(2n-1)$

32. (b) In one dimensional motion, the body can have at a time one velocity but not two values of velocities.

33. (c) Let PQ = x, then
$u = 30$ km/h
$v = 40$ km/h

$a = \frac{40^2 - 30^2}{2x} = \frac{350}{x}$ [$\because v^2 = u^2 + 2as$]

Also, velocity at mid point is given by v_m,
$\Rightarrow v_m = u^2 + 20(7)$

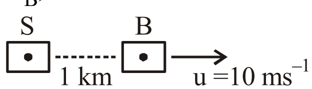
$\Rightarrow v_m^2 - 30^2 = 2 \times \frac{350}{x} \times \frac{x}{2}$

This gives $v = 25\sqrt{2}$ km/h

34. (d) Let v be the relative velocity of scooter w.r.t bus as $v = v_S - v_B$

$v = \frac{1000}{100} = 10\,\text{ms}^{-1}$ $v_B = 10\text{ms}^{-1}$

$\therefore$ $v_S = v + v_B$,



$= 10 + 10 = 20\text{ ms}^{-1}$

$\therefore$ velocity of scooter = 20 ms^{-1}

> **NOTES** When two bodies are moving in same directions, relative velocity is between difference individual velocities.

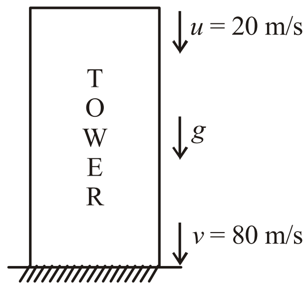
$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$

35. (d) Relative velocity of parrot w.r.t the train $= 10 - (-5) = 15\text{ ms}^{-1}$.
Time taken by parrot to cross the train

$= \frac{150}{15} = 10$ s

> **NOTES** When two bodies are moving in direction relative velocity is sum of individual velocities.
>
> $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$
>
> The distance which bird has to travel to cross the train is equal to the length of train. Now since the train and the bird are travelling in opposite direction, therefore the speed will be added up.

36. (c)



Using $v^2 = u^2 + 2gh$

Height, $h = \frac{v^2 - u^2}{2g} = \frac{(80)^2 - (20)^2}{2\times10}$

$= \frac{6400 - 400}{20} = 300$ m

37. (a) $\because$ $h = \frac{1}{2}gt^2$

$\therefore$ $h_1 = \frac{1}{2}g(5)^2 = 125$

$h_1 + h_2 = \frac{1}{2}g(10)^2 = 500$

$\Rightarrow$ $h_2 = 375$

$h_1 + h_2 + h_3 = \frac{1}{2}g(15)^2 = 1125$

$\Rightarrow$ $h_3 = 625$

$h_2 = 3h_1$, $h_3 = 5h_1$

or $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$

> **NOTES** The distance covered in time t, $2t$, $3t$, etc. will be in the ratio of $1^2 : 2^2 : 3^2$ i.e., square of integers i.e., h $\propto t^2$.

38. (b) Here, $u = 0$
We have, $v^2 = u^2 + 2gh$

$\Rightarrow v = \sqrt{2gh} = \sqrt{2\times10\times20} = 20$ m/s

39. (a) Clearly distance moved by 1st ball in 18s = distance moved by 2nd ball in 12s. ...(i)
Now, distance moved in 18 s by 1st ball $= \frac{1}{2} \times 10 \times 18^2 = 90 \times 18 = 1620$ m

Distance moved in 12 s by 2nd ball

$= ut + \frac{1}{2}gt^2 \quad \Rightarrow \quad 12v + \frac{1}{2}\times10 \times (12)^2$

$\Rightarrow \quad 12\,v + 720$

From equation (i)

$\therefore \quad 1620 = 12\,v + 5 \times 144$

$\Rightarrow \quad v = 135 - 60 = 75\ \text{ms}^{-1}$

40. (b) No external force is acting, therefore, momentum is conserved.

By momentum conservation,

$50\,u + 0.5 \times 2 = 0$

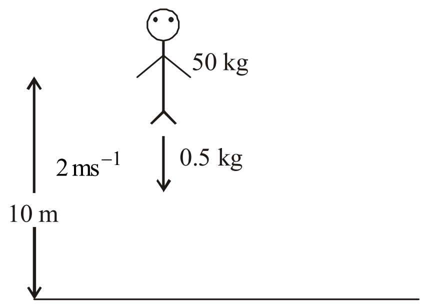
where u is the velocity of man.

$$u = -\frac{1}{50}\ \text{ms}^{-1}$$

Negative sign of u shows that man moves upward.

Time taken by the stone to reach the ground

$$= \frac{10}{2} = 5\ \text{sec}$$



Distance moved by the man $= 5 \times \dfrac{1}{50} = 0.1\,\text{m}$

$\therefore$ when the stone reaches the floor, the distance of the man above floor = 10.1 m

41. (c) Let t_1 & t_2 be the time taken by A and B respectively to reach the ground then from the formula,

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

For first body, $\quad 16 = \dfrac{1}{2} g t_1^2$

For second body, $\quad 25 = \dfrac{1}{2} g t_2^2$

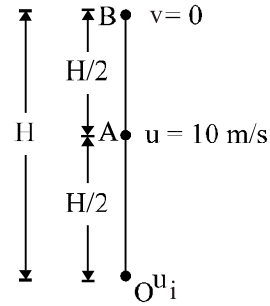
$$\therefore \frac{16}{25} = \frac{t_1^2}{t_2^2} \Rightarrow \frac{t_1}{t_2} = \frac{4}{5}.$$

NOTES If a body is a dropped from some height, the motion is independent of mass of the body. The time taken to reach the ground $t = \sqrt{2h/g}$ and final velocity $V = \sqrt{2gh}$ and initial velocity, $u = 0$.

42. (a) For part AB

From 3rd equation of motion

$v^2 = u^2 - 2gH$



$0 = u^2 - 2g(H/2) = u^2 - gH$

$$H = \frac{u^2}{g} = \frac{10^2}{10} = 10\ \text{m}$$

43. (c) Let body takes T sec to reach maximum height.

Then $v = u - gT$

$v = 0$, at highest point.

So, $\quad T = \dfrac{u}{g} \quad \ldots(1)$

Velocity attained by body in $(T - t)$ sec $\quad v = u - g(T - t)$

$v = u - gT + gt = u - g\dfrac{u}{g} + gt \quad (\because T = u/g)$

or $v = gt \quad \ldots(2)$

$\therefore$ Distance travelled in last t sec of its ascent

$$s = vt - \frac{1}{2} g t^2$$

$$s = (gt)t - \frac{1}{2} g t^2 = \frac{1}{2} g t^2$$

NOTES If a body is projected vertically upward, then, final velocity, $v = 0$; intial speed, $u = gt$ and height attained, $h = \dfrac{u^2}{2g} = \dfrac{g^2 t^2}{2g} = \dfrac{1}{2} g t^2$

44. (b) Let the required speed of throw be u ms^{-1}. Then time taken to reach maximum height,

$$t = \frac{u}{g}$$

For two balls to remain in air at any time, t must be greater than 2.

$$\therefore \quad \frac{u}{g} > 2 \Rightarrow u > 19.6\ \text{m/s}$$

45. (b) Initial velocity (u) = 40 m/s
Acceleration $a = -g$ m/s^2 = –10 m/s^2
Time = 2 seconds
By Ist equation of motion,
$v = u + at$
$v = 40 - 10(2) = 20$ m/s

46. (b) h_{max} = 20 m and t = 5 sec. Time taken by the body to reach the ground from some height is the same as taken to reach that height. Therefore, time to reach the ground from its maximum height is 5 sec.

47. (c) Initial velocity (u) = 0; Time (t) = 4 sec and gravitational acceleration (g) = 10 m/s^2.
Height of tower

$$h = ut + \frac{1}{2}gt^2 = (0 \times 4) + \frac{1}{2} \times 10 \times (4)^2. = 80\text{ m.}$$

48. (c) The speed of an object, falling freely due to gravity, depends only on its height and not on its mass $V = \sqrt{2gh}$. Since the paths are frictionless and all the objects fall through the same height, therefore, their speeds on reaching the ground will be in the ratio of 1 : 1 : 1.

49. (c) Height of tap = 5m and (g) = 10 m/sec^2.

For the first drop, S = $ut + \frac{1}{2}gt^2$

$5 = (0 \times t) + \frac{1}{2} \times 10t^2 = 5t^2$ or $t^2 = 1$ or $t = 1$ sec.

It means that the third drop leaves after one second of the first drop. Or, each drop leaves after every 0.5 sec.
Distance covered by the second drop in 0.5 sec

$$= ut + \frac{1}{2}gt^2 = (0 \times 0.5) + \frac{1}{2} \times 10 \times (0.5)^2$$
$= 1.25$ m.

Therefore, distance of the second drop above the ground = 5 – 1.25 = 3.75 m.

50. (b) Let the body fall through the height of tower in nth seconds. From,

$D_n = u + \frac{a}{2}(2n-1)$ we have, total distance travelled in last 2 seconds of fall is
$D = D_t + D_{(t-1)}$

$$= \left[0 + \frac{g}{2}(2n-1)\right] + \left[0 + \frac{g}{2}\{2(n-1)-1\}\right]$$

$$= \frac{g}{2}(2n-1) + \frac{g}{2}(2n-3) = \frac{g}{2}(4n-4)$$

$$= \frac{10}{2} \times 4(n-1)$$

or, $40 = 20(n-1)$ or $n = 2 + 1 = 3$s
Distance travelled in t seconds is
where, t = 3 sec

$$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 10 \times 3^2 = 45\text{ m}$$

51. (b) $$\frac{x(4)}{x(5)} = \frac{\frac{g}{2}(2\times4-1)}{\frac{g}{2}(2\times5-1)} = \frac{7}{9}$$

$$\left[\because S_{n^{\text{th}}} = u + \frac{a}{2}(2n-1) \text{ and } u = 0, a = g\right]$$

NOTES

In the absence of air resistance, all bodies irrespective of the size, weight or composition fall with the same acceleration near the surface of the earth. This motion of a body falling towards the earth from a small altitude (h<<R) is called free fall.

Distance travelled in nth second $h_n = \frac{g}{2}(2n-1)$