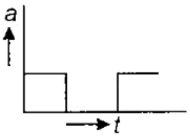
NSO NATIONAL SCIENCE OLYMPIAD

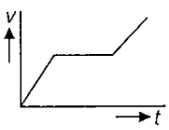
Motion

1. A boy runs for 10 minutes at a uniform speed of $9\ \text{km h}^{-1}$. At what speed should he run for the next 20 minutes so that the average speed comes to $12\ \text{km h}^{-1}$?

(a) $13.5\ \text{km h}^{-1}$ (b) $10.2\ \text{km h}^{-1}$
(c) $8.2\ \text{km h}^{-1}$ (d) $7.72\ \text{km h}^{-1}$

2. Which of the following would probably show the velocity-time graph for a body whose acceleration-time graph is shown in figure?



(a)


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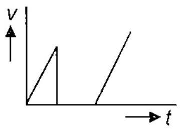

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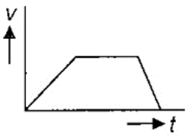
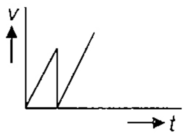


(d)


3. A particle is moving in a straight line with initial velocity u and uniform acceleration a. If the sum of the distances travelled in t^{th} and $(t+1)^{th}$ seconds is 100 cm, then its velocity after t seconds in $cm\ s^{1}$ is

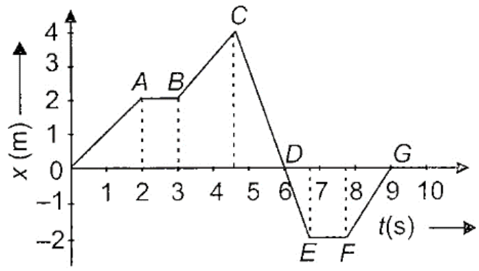
(a) 20 (b) 30
(c) 50 (d) 80

4. Two identical balls are at rest side by side at the bottom of a hill. Sometime after ball A is kicked up the hill, ball 6 is given a kick up the hill. Ball A is headed downhill when it passes ball B headed up the hill. At the instant when ball A passes ball B, it has the same.

(a) Position and velocity as ball B
(b) Position and acceleration as ball B
(c) Velocity and acceleration as ball B
(d) Displacement and velocity as ball B

Direction (Q. No. 5 and 6): Read the passage carefully and answer the following questions.

A dancer is demonstrating dance steps along a straight line. The position-time graph of the dancer is given here.



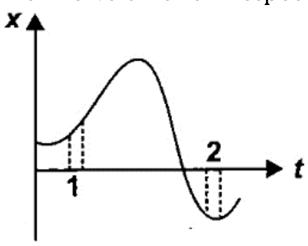
5. The average speed for the dance step depicted by CD is

(a) $1\ m\ s^{-1}$ (b) $1.33\ m\ ^{s-1}$
(c) $2.75\ \text{m s}^{-1}$ (d) $0.89\ \text{m s}^{-1}$

6. The average velocity of the dancer during time interval between t = 2 s to t = 9 s is

(a) $1\ m\ s^{-1}$ (b) $-\ 0.57\ m\ s^{-1}$
(c) $2.75\ m\ s^{-1}$ (d) $-\ 0.29\ m\ s^{-1}$

7. Figure shows the x-t plot of a particle in one-dimensional motion. Two different equal intervals of time are shown. Let v_1 and v_2 be average speeds in time intervals 1 and 2 respectively. Then



(a) $v_1 > v_2$ (b) $v_2 > v_1$
(c) $v_1 = v_2$ (d) Data is insufficient

8. Consider the given statements and select the option which correctly identifies the true (T) and false (F) statements.

(i) Distance is the magnitude of displacement in all cases.
(ii) When a body moves with uniform speed, then the average speed is same as instantaneous speed.

(iii) Average speed is greater than the average velocity if a body is moving in a straight line without reversing its direction.
(iv) When a body moves with constant velocity, the average velocity is zero.

	(i)	(ii)	(iii)	(iv)
(a)	T	F	T	F
(b)	T	T	T	T
(c)	F	F	F	F
(d)	F	T	F	F

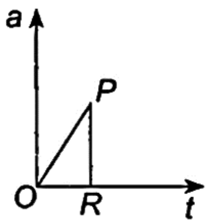
9. Match the column I with column II and mark the correct option from the codes given below.

Column I	Column II
(A) 36 km h^{-1}	(i) 20000 mm
(B) 1 m s^{-2}	(ii) 980 cm s^{-2}
(C) 9.8 ms^{-2}	(iii) 12960 km h^{-2}
(D) 0.02km	(iv) 10 ms^{-1}

(a) (A) - (iv), (B) - (iii), (C) - (ii), (D) - (i)
(b) (A) - (iii), (B) - (ii), (C) - (i), (D) - (iv)
(c) (A) - (ii), (B) - (i), (C) - (iv), (D) - (iii)
(d) (A) - (i), (B) - (ii), (C) - (iii), (D) - (iv)

10. A ball is dropped on to the floor from a height of 20 m. It rebounds to a height of 10 m. If the ball is in contact with the floor for 0.1 seconds, what is the average acceleration during contact?
(a) 142 m s^{-2} (b) 285 m s^{-2}
(c) 338 m s^{-2} (d) 564 m s^{-2}

11. A cyclist starts from centre O and reaches at R along the path OPR as shown in graph. What would you conclude from the velocity- time graph of the cyclist from the given graph?



(a) Velocity changes linearly if acceleration is changing non-linearly.
(b) Velocity becomes zero if acceleration becomes zero.
(c) Velocity changes non-linearly if acceleration is changing linearly.
(d) Velocity becomes uniform if acceleration becomes infinite.

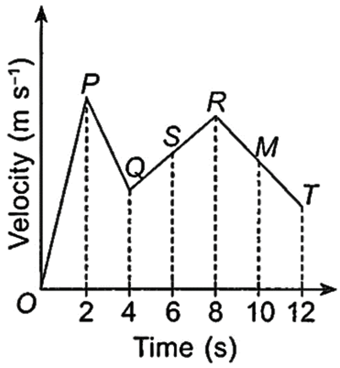
12. Read the given statements and select the correct option.
Statement 1: A body thrown vertically up with a velocity u reaches the maximum height h after T seconds. At a time 2T seconds its velocity becomes zero.
Statement 2: A particle thrown vertically up with a velocity comes back to its initial position with same magnitude of velocity but in opposite direction.

(a) Both statements 1 and 2 are true and statement 2 is the correct explanation of statement 1.
(b) Both statements 1 and 2 are true but statement 2 is not the correct explanation of statement 1.
(c) Statement 1 is true but statement 2 is false.
(d) Statement 1 is false but statement 2 is true.

13. The velocity of a particle increases from u to v in a time t during which the particle has a uniform acceleration. Which of the following equations applies to the motion?

(a) $2s = (u+v)\times t$ (b) $a = \frac{V-u}{t}$
(c) $v^2 = u^2 + 2as$ (d) $s = v \times t$

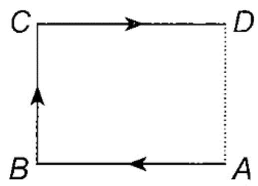
14. The velocity-time graph of an object is shown in the figure. Identify the correct statement(s) regarding this graph.



(i) This is a non uniform velocity-time graph of the object.
(ii) The velocity of the object is increasing at the same rate during OP and QR.
(iii) The velocity of the object is decreasing at same rate during PQ and RT.

(a) Only (i) is correct.
(b) Only (ii) is correct.
(c) Only (iii) is correct.
(d) All (i), (ii) and (iii) are correct.

15. A boy takes 5 seconds to reach each point from A to B, B to C and C to D as shown in the diagram. If AB = BC = CD = 20 m then which of the following information is correct when the boy reaches point D from point A?



	Velocity $(m\ s^{-1})$	Speed $(m\ s^{-1})$
(a)	4	4
(b)	1.33	1.33
(c)	4	1.33
(d)	1.33	4

Achievers Section (HOTS)

16. Two racing cars of masses m_1 and m_2 are moving in circles of radii r_1 and r_2 respectively. Their speeds are such that each makes a complete circle in the same length of time T. The ratio of angular speed of the first car to that of the second car is

(a) $m_1 : m_2$ (b) $r_1 : r_2$
(c) $1 : 1$ (d) $m_1 r_1 : m_2 r_2$.

17. The speed of a train increases at a constant rate α from zero to v, and then remains constant for an interval, and finally decreases to zero at a constant rate β. If L be the total distance travelled, then the total time taken is

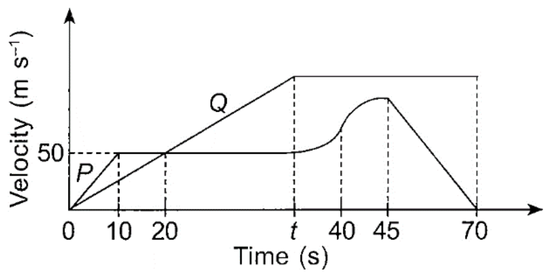
(a) $\frac{L}{v} + \frac{v}{2}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$ (b) $\frac{L}{v} + \frac{2}{v}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$

(c) $\frac{L}{v} + 2v\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$ (d) $\frac{L}{v} + \frac{1}{v}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$

18. A train starts from a station P with a uniform acceleration a_1, for some distance and then goes with uniform retardation a_2 for some more distance to come to rest at the station Q. The distance between the stations P and Q is 4 km and the train takes 4 minutes to complete this journey, then $\frac{1}{a_1} + \frac{1}{a_2} =$

(a) $2\ m^{-1}\ s^2$ (b) $4\ m^{-1}\ s^2$
(c) $7.2\ m^{-1}\ s^2$ (d) $72\ m^{-1}\ s^2$

19. The diagram shows the velocity-time graph of two moving cars P and Q. The graph indicates that



(i) The velocity of car P is increasing at a decreasing rate from 40 s to 45 s in same direction.
(ii) Car Q is moving with a constant acceleration from 0 to 20 seconds.
(iii) Acceleration of the car Q is not zero at any point during whole journey.
(iv) After 20 s, P is behind Q.

(a) Only (i) and (ii) (b) Only (ii) and (iii)
(c) Only (iii) and (iv) (d) Only (iv) and (i).

20. After jumping out from the plane, a parachutist falls 80 m without friction. When he opens up the parachute, he decelerates at $2\ m\ s^{-2}$. He reaches the ground with a speed of $4m\ s^{-1}$. How long did the parachutist spend his time in the air? (Take $g = 10\ m\ s^{-2}$)

(a) 4s (b) 16 s
(c) 18 s (d) 22 s

Answer key				
1. A	**2.** A	**3.** C	**4.** B	**5.** C
6. D	**7.** A	**8.** D	**9.** A	**10.** C
11. C	**12.** D	**13.** B	**14.** A	**15.** D
16. C	**17.** A	**18.** C	**19.** A	**20.** D

HINTS & EXPLANATIONS

1. (a) : Let, the boy runs with speed v for next 20 min.

Given that, Average speed $= 12 \text{ km h}^{-1}$

As, average speed $= \dfrac{\text{Total distance covered}}{\text{Total time taken}}$

$\therefore 12 = \dfrac{\text{Total distance covered}}{\dfrac{(10+20)}{60}h}$

$\Rightarrow$ Total distance covered

$= 12 \times \dfrac{30}{60} = 12 \times \dfrac{1}{2} = 6km$

Distance covered in 10 min $= 9 \times \dfrac{10}{60} = 1.5km$

Remaining distance $= 6 - 1.5 = 4.5km$

For next 20 min, he should run with speed

$\upsilon = \dfrac{4.5}{20/60} = 4.5 \times 3 = 13.5 \ km \ h^{-1}$

2. (a) : Graph shown in option (a) represents the velocity-time graph for the body whose acceleration-time graph is given in question. Velocity increases uniformly for some time, then it becomes constant, after that it increases further uniformly.

3. (c) : Distance travelled in t^{th} second of uniformly accelerated motion is

$s_t = u + \dfrac{a}{2}(2t-1)$ ...(i)

Distance travelled in $(t+1)^{th}$ second can be written as

$s_{t+1} = u + \dfrac{a}{2}[2(t+1)-1]$

Or $s_{t+1} = u + \dfrac{a}{2}(2t+1)$

$\because s_t + s_{t+1} = 100cm$ (given)

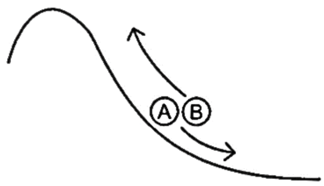
$\therefore u + \dfrac{a}{2}(2t-1) + u + \dfrac{a}{2}(2t+1) = 100$

Or $u + at - \dfrac{a}{2} + u + at + \dfrac{a}{2} = 100$

Or $2u + 2at = 100$ or $u + at = 50$

$\therefore \upsilon = 50 \ cm \ s^{-1}$

4. (b)



Position and acceleration of A is same as that of B at the instant when ball A passes ball B.

5. (c):Distance covered for dance step $CD = 4m$

Time taken for CD is greater than 1 s but less than 2s.

Since, average speed $= \dfrac{\text{total distance}}{\text{total time}}$

Therefore, average speed is less than $4 \ m \ s^{-1}$ but greater than $2ms^{-1}$.

Hence, option (c) is correct.

6. (d) : During time interval t = 2 s to t = 9 s, six dance steps namely AB, BC, CD, DE, EF and FG have been demonstrated by the dancer.

Total displacement $= (0-2) = -2 \ m$

Total time taken $= 9 - 2 = 7s$

Average velocity $= \dfrac{\text{total displacement}}{\text{total time taken}}$

Thus, average velocity $= \dfrac{-2}{7} = -0.29 \text{ m s}^{-1}$

7. (a) : We know, slope of distance-time graph gives speed.

In time interval 1, slope is more as compared to the slope in time interval 2.

$\therefore \quad \upsilon_1 > \upsilon_2$

8. (d) : (i) F; Distance is equal to the magnitude of displacement only when a body moves in a straight line without reversing its direction.

(ii) T

(iii) F; Average speed is equal to average velocity when a body moves in a straight line without reversing its direction. In all other cases, Average speed > |Average Velocity|

(iv) F

9. (a) Not Available

10. (c) : Here height from which ball is dropped h = 20 m

Using $v^2=u^2+2gh$; $v^2=2gh(\because u=0)$

or $v=\sqrt{2gh}$ (downward)

Ball rebounds to a height, h' = 10 m

So, $0^2=v'^2-2gh'$ or $v'=\sqrt{2gh'}$ (upward)

Acceleration of the ball,

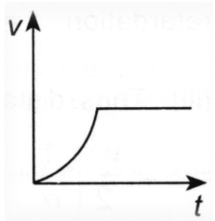
$$a=\frac{(v'-v)}{t}=\frac{[\sqrt{2gh'}-(-\sqrt{2gh})]}{t}$$

Or

$$a=\frac{[\sqrt{2\times9.8\times10}+\sqrt{2\times9.8\times20}]}{0.1}\simeq 338\text{ m s}^{-2}$$

11. (c) : As $v^2=u^2+2as$

We get, $v^2\propto a$



Thus velocity changes non-linearly if acceleration is changing linearly. As acceleration becomes zero, velocity becomes uniform.

12. (d) : During upward motion, initial velocity is $\bar{u}$ and maximum height is h after time T seconds.

$\therefore$ Velocity at maximum height = 0

During downward motion, initial velocity is zero, height covered is h after T seconds.

$\therefore$ Final velocity $=-\vec{u}$

So it can be concluded that at a time 2T seconds its velocity becomes $=-\vec{u}$.

13. (b) : For uniform acceleration and given information, $a=\frac{v-u}{t}$

14. (a) : From the graph, velocity of the object is increasing at constant rate for OP and QR and decreasing at constant rate for PQ, and RT.

But rate of increasing or decreasing the velocity is not same for all intervals.

It is a non-uniform velocity-time graph.

15. (d) : Total distance = 60 m

Displacement = 20 m

Total time = 15 s

Speed $=\frac{60}{15}=4m\ s^{-1}$;

Velocity $=\frac{20}{15}=1.33m\ s^{-1}$

16. (c) : Both the cars make a complete circle in the same length of time T, which means that angular speeds of both cars are same.

$$\because \omega=\frac{v}{r}=\frac{2\pi r}{Tr}=\frac{2\pi}{T}$$

17. (a) : (i) Velocity increases from 0 to v:

We know that v = u + at

Here, u = 0, v = v, $a=\alpha$ $\therefore t=\frac{v}{\alpha}$

and $s=ut+\frac{1}{2}at^2; s_1=\frac{v^2}{2\alpha}$

(ii) Velocity decreases from v to 0: Using $v=u+at$

Here, $u=v, v=0, a=-\beta \Rightarrow t=\frac{v}{\beta}$

And $s=ut+\frac{1}{2}at^2; s_2=\frac{v^2}{2\beta}$

So, distance travelled during acceleration and retardation, $d=s_1+s_2=\frac{v^2}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)$

(iii) Thus, distance travelled during constant velocity

$$=L-\frac{v^2}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)$$

So, time taken to travel this distance

$$T=\frac{L-\frac{v^2}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)}{v}=\frac{L}{v}-\frac{v}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)$$

Hence, total time taken to cover distance L.

$$=\left(\frac{v}{\alpha}\right)+\left[\frac{L}{v}-\frac{v}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)\right]+\left(\frac{v}{\beta}\right)$$

$$=\frac{L}{v}+\frac{v}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)$$

18. (c): For motion with uniform acceleration a_1:

From v = u + at

$v=a_1t_1(\because u=0)$

$\therefore t_1 = \dfrac{v}{a_1}$ ...(i)

And from $s = ut + \dfrac{1}{2}at^2$,

$s_1 = \dfrac{1}{2}a_1\left(\dfrac{v}{a_1}\right)^2 = \dfrac{v^2}{2a_1}$ ...(ii)

For motion with uniform retardation a_2 :

From $v = u + at$

$v = a_2 t_2 (\because v - 0, u = v, a = -a_2)$

$\therefore t_2 = \dfrac{v}{a_2}$ ...(iii)

And from $s = ut + \dfrac{1}{2}at^2$

$s_2 = v\dfrac{v}{a_2} + \dfrac{1}{2}(-a_2)\cdot\dfrac{v^2}{a_2^2}$

$s_2 = \dfrac{v^2}{a_2} - \dfrac{v^2}{2a_2} = \dfrac{v^2}{2a_2}$ ...(iv)

Given, $s_1 + s_2 = 4km$ and $t_1 + t_2 = 4\,\text{min}$

$\therefore \dfrac{v^2}{2}\left(\dfrac{1}{a_1} + \dfrac{1}{a_2}\right) = 4$ ...(v)

And $v\left(\dfrac{1}{a_1} + \dfrac{1}{a_2}\right) = 4$ ...(vi)

Dividing eqn. (v) by eqn. (vi), we get v=2

Putting this in eqn. (vi)

$\dfrac{1}{a_1} + \dfrac{1}{a_2} = 2\dfrac{\text{min}^2}{km} = \dfrac{2\times 3600}{1000}\dfrac{s^2}{m} = 7.2m^{-1}s^2$

19. (a) : (i) From 40 s to 45 s, direction of car P is same but velocity is increasing at a decreasing rate of acceleration.

(ii) Acceleration of car Q from 0 to 20 seconds is

$\dfrac{(50-0)}{(20-0)} = 2.5ms^{-2}$ i.e., constant.

(iii) Acceleration of the car Q is zero from t s to 70 s, so velocity is constant.

(iv) Distance travelled by P at the end of first 20 s

$= \dfrac{1}{2}\times 50\times(10+20) = 750m$

Distance travelled by Q at the end of first 20s

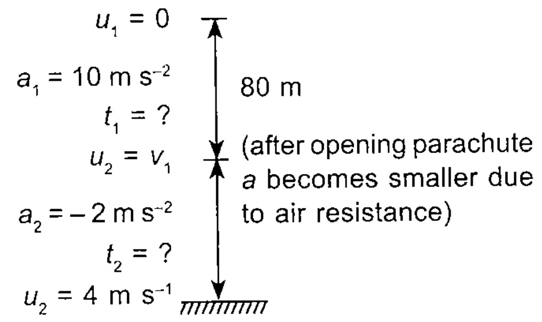
$= \dfrac{1}{2}\times 50\times 20 = 500m$

Difference in the distance travelled by P and Q = ($750 - 500$) m = 250 m

After 20 s, Q is behind P by 250 m.

20. (d) : Time taken when he falls 80 m in the air is

$\therefore d = u_1t_1 + \dfrac{1}{2}a_1t_1^2$ or $80 = 0 + \dfrac{1}{2}\times 10\times t_1^2$



Or $t_1^2 = 16; t_1 = 4s \Rightarrow v_1 = u_1 + a_1t_1$

$v_1 = 0 + 10\times 4 = 40ms^{-1}$

Since $v_1 = u_2 \therefore u_2 = 40ms^{-1}$

Time taken after he opens up his parachute and before reaching the ground, t_2,

$v_2 = 4ms^{-1}, a_2 = -2ms^{-2}$

$v_2 = u_2 + a_2t_2 \Rightarrow 4 = 40 + (-2)\times t_2$

$2t_2 = 36; t_2 = 18s$

Total time $= 4s + 18s = 22s$