

1. Four of the seven SI base units were redefined in 2019 in terms of fundamental constants. Select the correct response : 1
- (a) kg, A, S, mol (b) m, kg, K, cd
(c) kg, A, K, mol (d) mol, K, m, A
2. When a horse pulls a cart, the force that helps the horse to move forward is the force exerted by : 1
- (a) the cart on the horse (b) the ground on the horse
(c) the ground on the cart (d) the horse on the ground.
3. A car travels half the distance with constant velocity 30 km/h and another half with a constant velocity of 40 km/h along a straight line. The average velocity of car in km/h is: 1
- (a) 70 km/h (b) 35 km/h
(c) 34.3 km/h (d) $\sqrt{30 \times 40}$ km/h
4. During inelastic collision between two bodies, which of the following quantities always remain conserved? 1
- (a) Total Kinetic Energy (b) Total Mechanical Energy
(c) Total Linear momentum (d) Speed of each body
5. A vector $\vec{B}$ when added to the vector $\vec{C} = 3\hat{i} + 4\hat{j}$ yields a resultant vector that is in the positive Y-direction and has a magnitude equal to that of $\vec{C}$. The magnitude of $\vec{B}$ is : 1
- (a) -3 (b) 1
(c) $\sqrt{10}$ (d) 10
6. If the tension in the cable supporting an elevator is equal to the weight of the elevator, the elevator may be : 1
- (a) going up with uniform speed. (b) going down with decreasing speed.
(c) going up with increasing speed. (d) going down with increasing speed.

7. Measure of two quantities along with the precision of respective measuring instrument is:

$$A = 2.5 \text{ ms}^{-1} \pm 0.5 \text{ ms}^{-1}$$

$$B = 0.10 \text{ s} \pm 0.01 \text{ s}$$

The value of AB will be :

(a) $(0.25 \pm 0.8) \text{ m}$

(b) $(0.25 \pm 0.5) \text{ m}$

(c) $(0.25 \pm 0.05) \text{ m}$

(d) $(0.25 \pm 0.135) \text{ m}$

8. A stone is dropped into a lake from a tower 500 m high. The sound of splash will be heard after :

(a) 10 s

(b) 11.5 s

(c) 14 s

(d) 21 s

9. A particle is thrown vertically upwards then its velocity so that it covers same distance in 5th and 6th second would be :

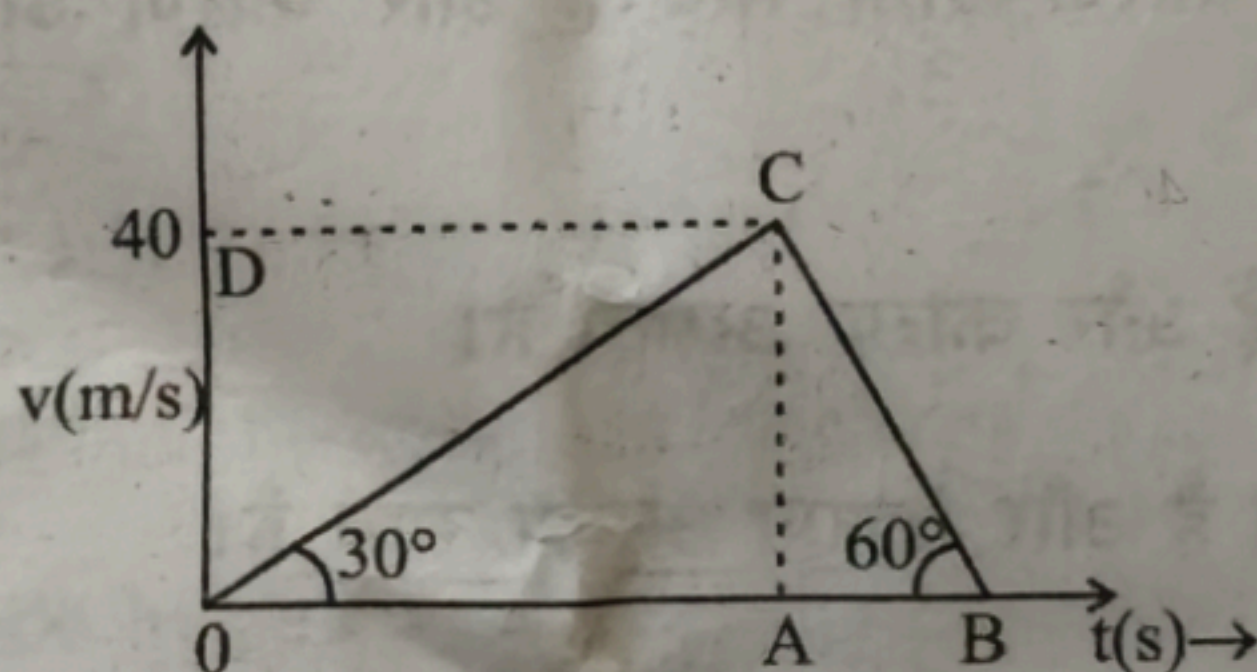
(a) 48 m/s

(b) 14 m/s

(c) 49 m/s

(d) 7 m/s

10. The velocity-time graph of a body is shown. The ratio of average acceleration during the interval OA and AB is :



(a) 1

(b) $1/2$

(c) $1/3$

(d) 3

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The displacement of a body is given to be proportional to the cube of time elapsed. The magnitude of the acceleration of the body is :

(a) increasing with time

(b) decreasing with time

(c) constant but not zero

(d) zero

11. One end of a spring of length ℓ is connected to a particle of mass m and the other to a small peg on a smooth horizontal table. If the particle moves in a circle with speed v , the net force on the particle (directed towards the centre) is (T is the tension in the string): 1

- (a) 0 (b) $T + \frac{mv^2}{\ell}$
(c) $T - \frac{mv^2}{\ell}$ (d) T

12. A uniform chain of length L and mass M is lying on a smooth table and $1/6$ of its length is hanging down over the edge of table. If 'g' is the acceleration due to gravity, the work done to pull the hanging part on the table is : 1

- (a) MgL (b) $MgL/6$
(c) $MgL/16$ (d) $MgL/72$

The following questions 13 to 16 consists of two statements each, printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses:

- (a) Both Assertion and Reason are true and Reason is correct explanation of the Assertion.
(b) Both Assertion and Reason are true and Reason is not correct explanation of the Assertion.
(c) Assertion is true and the Reason is false
(d) Assertion is false and the Reason is false/true.

13. **Assertion :** The outside horses on a merry-go-round get more acceleration than inside ones.

Reason : This is because of linear acceleration being directly proportional to the distance. 1

14. **Assertion :** Two particles moving in the same direction do not lose all their energy in a perfectly inelastic collision.

Reason : Principle of conservation of linear momentum holds true for all kinds of collisions. 1

15. **Assertion :** Use of ball bearings between two moving parts of a machine is a common practice.

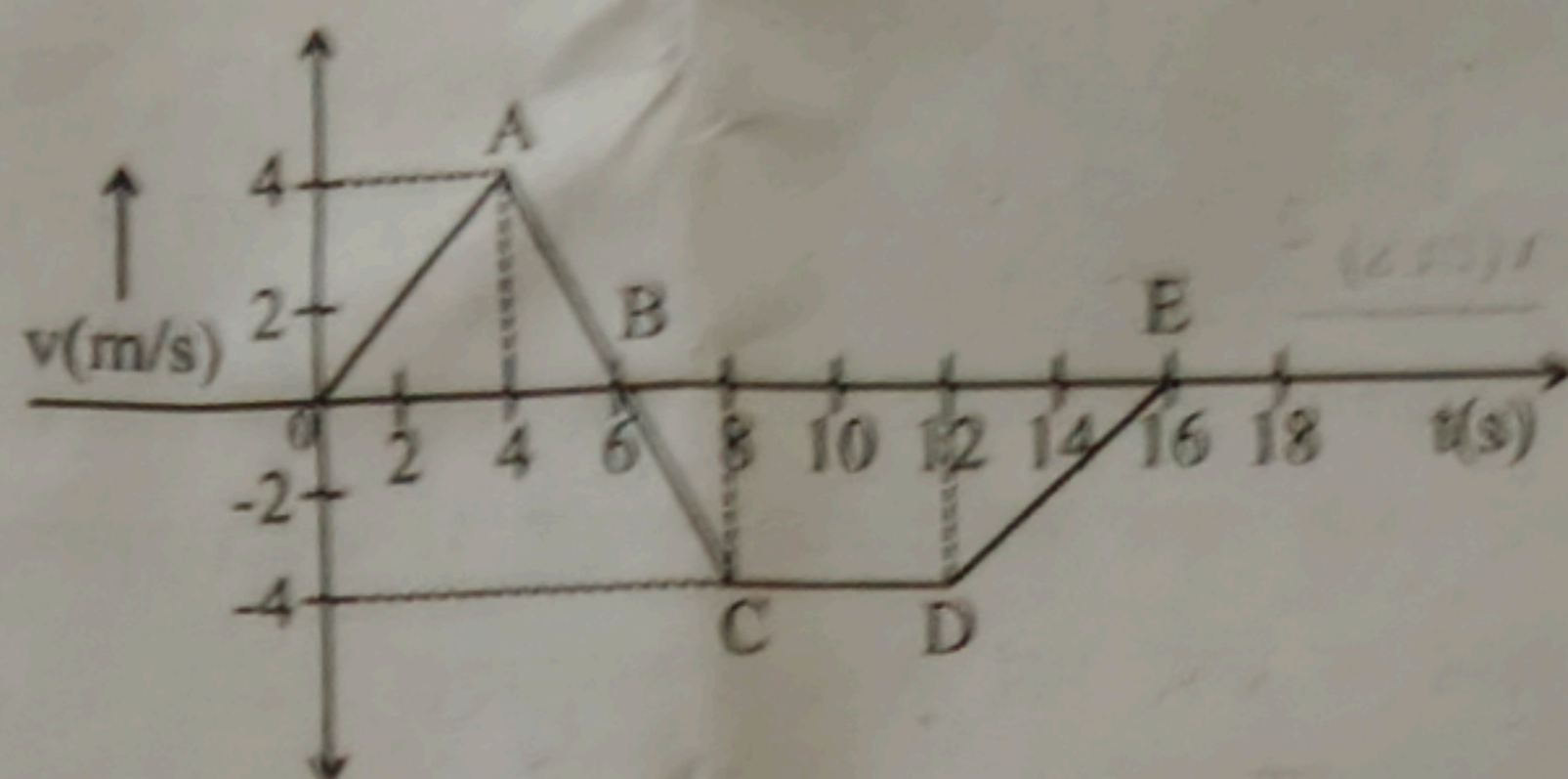
Reason : Ball bearings reduce vibrations and provide good stability.

16. **Assertion :** A stone and a feather dropped from the same height take different time to strike the ground in the presence of air resistance.

Reason : Force of friction due to the air decreases with the weight of the body.

SECTION-B

17. (A) The velocity-time graph of a particle is given by :



Draw an acceleration time graph of given v-t graph.

OR

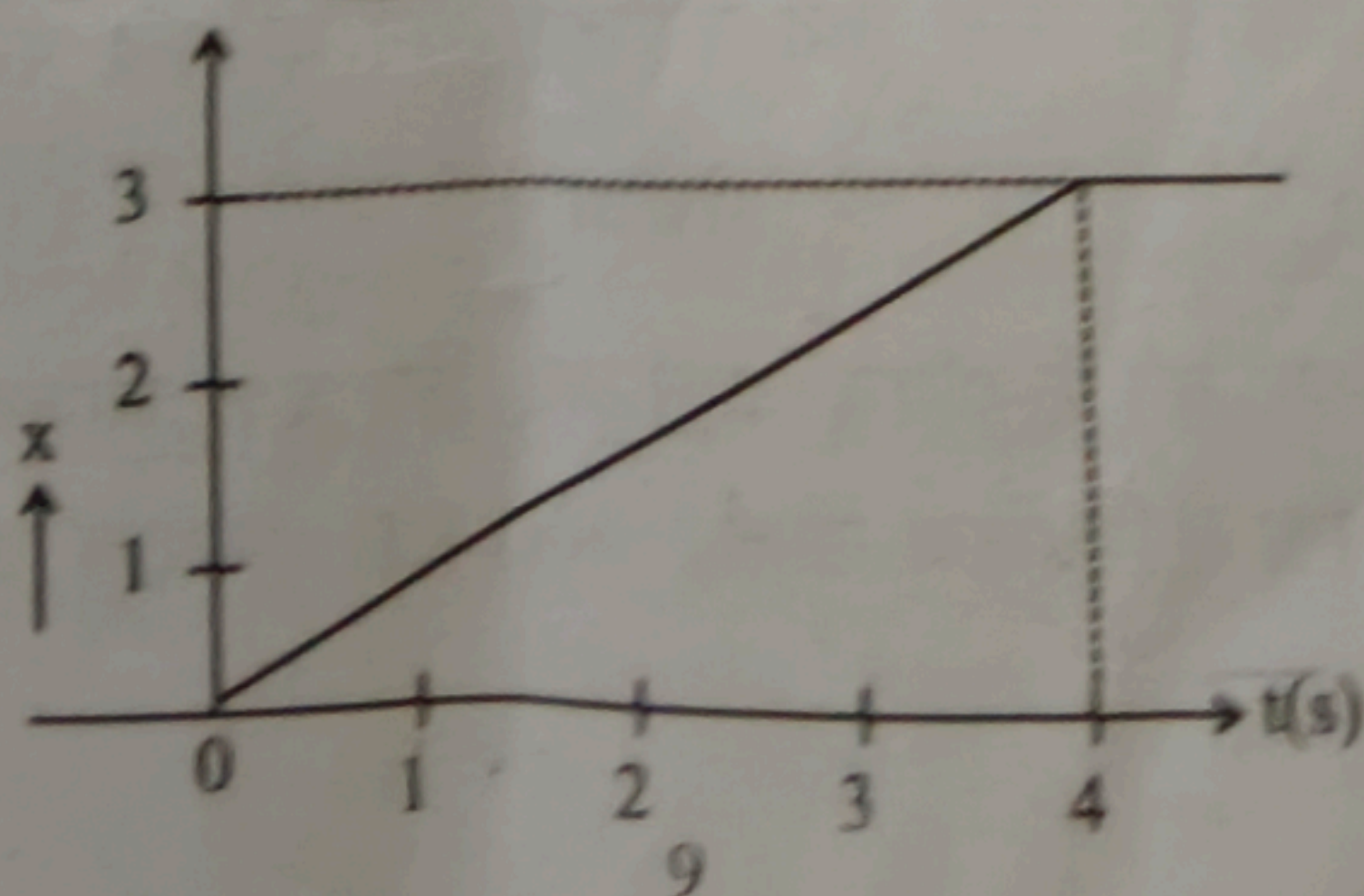
(B) A body travels with uniform acceleration a_1 for time t_1 and with uniform acceleration a_2 for time t_2 . What is the average acceleration?

18. A bob of mass m suspended by a light string of length L is whirled into a vertical circle in clockwise direction. What will be the trajectory of the particle if the string is cut at :

(i) the highest point of vertical circle

(ii) midway between highest and lowest point in a vertical circle while moving towards the lowest point

19. The position-time graph of a body of mass 2 kg is shown. What is the impulse on the body at $t = 0$ s and $t = 4$ s.



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A glass ball of mass 10 g falls vertically down from a height of 40 m and rebounds to a height of 10 m. Find the impulse and the average force between the glass ball and the floor if its time of contact is 0.1 s.

20. (A) Derive the equation of motion $v^2 = v_0^2 + 2a(x - x_0)$ for constant acceleration using calculus, where the symbols hold usual meaning. 2

OR

- (B) The distance x of a particle moving in one dimension under the action of a constant force is related to time t by the equation $t = \sqrt{x} + 2$, where x is in meter and t is in seconds. Find the displacement of the particle when its velocity is zero.
21. Block A of weight 100 N rests on a frictionless inclined plane of slope angle 30° . A flexible cord attached to A passes over a frictionless pulley and is connected to Block B of weight W . Find the weight W for which the system is in equilibrium. 2

SECTION-C

22. (A) A circular hole of radius $R/3$ is cut-out from a uniform disc of radius R . The center of the hole is at $R/3$ from the rim of the original disc.

Find the position of the center of gravity of the resulting flat body. 3

OR

- (B) A meter stick is balanced on a knife edge at its center. When two coins, each of mass 5 g are put one on top of the other at 12 cm mark, the stick is found to be balanced at 45 cm. What is the mass of the meter stick?
23. Why circular roads are banked? Derive an expression for angle of banking for safe circular turn. Consider that the coefficient of friction between the tyre and road is μ . 3
24. (A) Find the potential energy of a system of four identical particles of mass 2kg each placed at the vertices of a square of side 4 m. Also, obtain the potential at the center of the square. 3

OR

- (B) Obtain an expression for potential energy of a stretched spring and depict variation of P.E. (Potential Energy) and K.E. (Kinetic Energy) with distance from the equilibrium position.

25. A rain drop of radius 2 mm falls from a height of 500 m above the ground. It falls with decreasing acceleration (due to viscous resistance of the air) until at half its original height, it attains its maximum (terminal) speed and moves with uniform speed thereafter.

- (a) What is the work done by the gravitational force on the drop in the first and second half of its journey?
- (b) What is the work done by the resistive force in the entire journey if its speed on reaching the ground is 10 m/s. 3

26. The volume of a liquid flowing out per second of a pipe of length L and Radius r is written by a student as

$$V = \frac{\pi P r^4}{8 \eta L}$$

Where, P is the pressure difference between the two ends of the pipe and η is the coefficient of viscosity of the liquid having dimensional formula $[ML^{-1} T^{-1}]$.

Check whether the equation is dimensionally correct. 3

27. A rifle is aimed horizontally at a target 30 m away. The bullet hits the target 1.9 cm below the aiming point. What are :

- (a) the bullet's time of flight and
- (b) its speed as it emerges from the rifle 3

28. The angular speed of a motor wheel is increased from 1200 rpm to 3120 rpm in 16 seconds.

- (a) What is the angular acceleration? (assuming the acceleration to be uniform)
- (b) How many revolutions does the wheel make during this time? 3

SECTION-D

29. Read the following passage and answer the questions that follow :

(4x1=4)

An Experiment on head-on collision

In performing an on experiment on collision on a horizontal surface, we face three difficulties.

- (i) there will be friction and bodies will not travel with uniform velocities.

- (ii) if two bodies of different sizes collide on a table, it would be difficult to arrange them for a head-on collision unless their centres of mass are at the same height above the surface.
- (iii) It will be fairly difficult to measure velocities of the two bodies just before and just after collision.

By performing the experiment in a vertical direction, all the three difficulties vanish. Take two balls, one of which is heavier (basketball/football/volleyball) and the other lighter (tennis ball/rubber ball/table tennis ball). First take only the heavier ball and drop it vertically from some height, say, 1 m. Note to which it rises. This gives the velocities near the floor or ground, just before and just after the bounce (by using $v^2 = 2gh$). Hence, you will get the coefficient of restitution.

Now take the big ball and a small ball and hold them in your hands one over the other, with the heavier ball below the lighter one, as shown. Drop them together, taking care that they remain together while falling and see what happens.



You will find that the heavier ball rises less than, when it was dropped alone, while the lighter one shoots up to about 3m. With practice, you will be able to hold the ball properly so that the lighter ball rises vertically up and does not fly sideways. This is head-on collision.

- (i) If the heavier ball rises less after the collision than it did when dropped alone, what does it indicate? 1
 - (a) Energy loss
 - (b) Coefficient of restitution = 1
 - (c) Perfect elasticity
 - (d) Equal mass distribution
- (ii) Why does the heavier ball need to be placed below the lighter one before dropping? 1
 - (a) It is more stable
 - (b) It prevents rotation
 - (c) So, it hits the ground first
 - (d) So, it has greater acceleration.

(iii)A) Why must the balls be aligned properly during the fall?

- (a) To increase speed
(b) To avoid sideways motion
(c) To reduce weight
(d) To make the lighter ball heavier

OR

(B) What observation indicates that the collision is nearly elastic?

- (a) The heavier ball rises less.
(b) The lighter ball bounces vertically.
(c) The lighter ball rises significantly.
(d) Both balls move vertically.

(iv) What is the primary reason for the lighter shooting off after collision?

- (a) Air pressure
(b) loss of kinetic energy
(c) heavier ball experiencing more acceleration
(d) conservation of energy and momentum

30. Read the following passage and answer the questions that follow :

4x1=4

Kepler's laws and planetary motion

In the early 1600s, Johannes Kepler using astronomical data collected by Tycho Brahe developed three fundamental laws describing how planets move around the sun. These laws laid the ground work for Newton's law of gravitation and still used to study orbits of planets, satellites and space missions today.

Let us take an example of three planets: Earth, Mars and Jupiter and their motion around.

Planet	Average distance from the sun (in AU) (R)	Ratio T^2/R^3 ($\times 10^{-34}$ year ² /m ³)
Earth	1 AU	2.96
Mars	1.52 AU	2.98
Jupiter	5.20 AU	3.01

Where 'T' denotes the orbital period of planet around Sun (in years).

(i) Give the full form of AU.

(a) Asteroid unit

(b) Atmospheric unit

~~(c)~~ Arbitrary Unit

~~(d)~~ Astronomical Unit

(ii) If earth takes 1 year to orbit the Sun, how long does Mars take?

(a) 0.76 years

(b) 1 year

(c) 1.88 years

(d) 2.5 years

(iii) A) As per Kepler, if a planet is 4 AU from the Sun, what is its approximate orbital period?

(a) 2 years

(b) 4 years

(c) 8 years

(d) 16 years

OR

(B) If the orbital radius of a planet doubles, its orbital period.

(a) Halves

(b) Stays the same

~~(c)~~ More than doubles

(d) Decreases

(iv) When a planet is at perihelion (closest to the Sun), what happens to its speed?

~~(a)~~ Increases

(b) Decreases

(c) Becomes zero

(d) Remain constant

SECTION-E

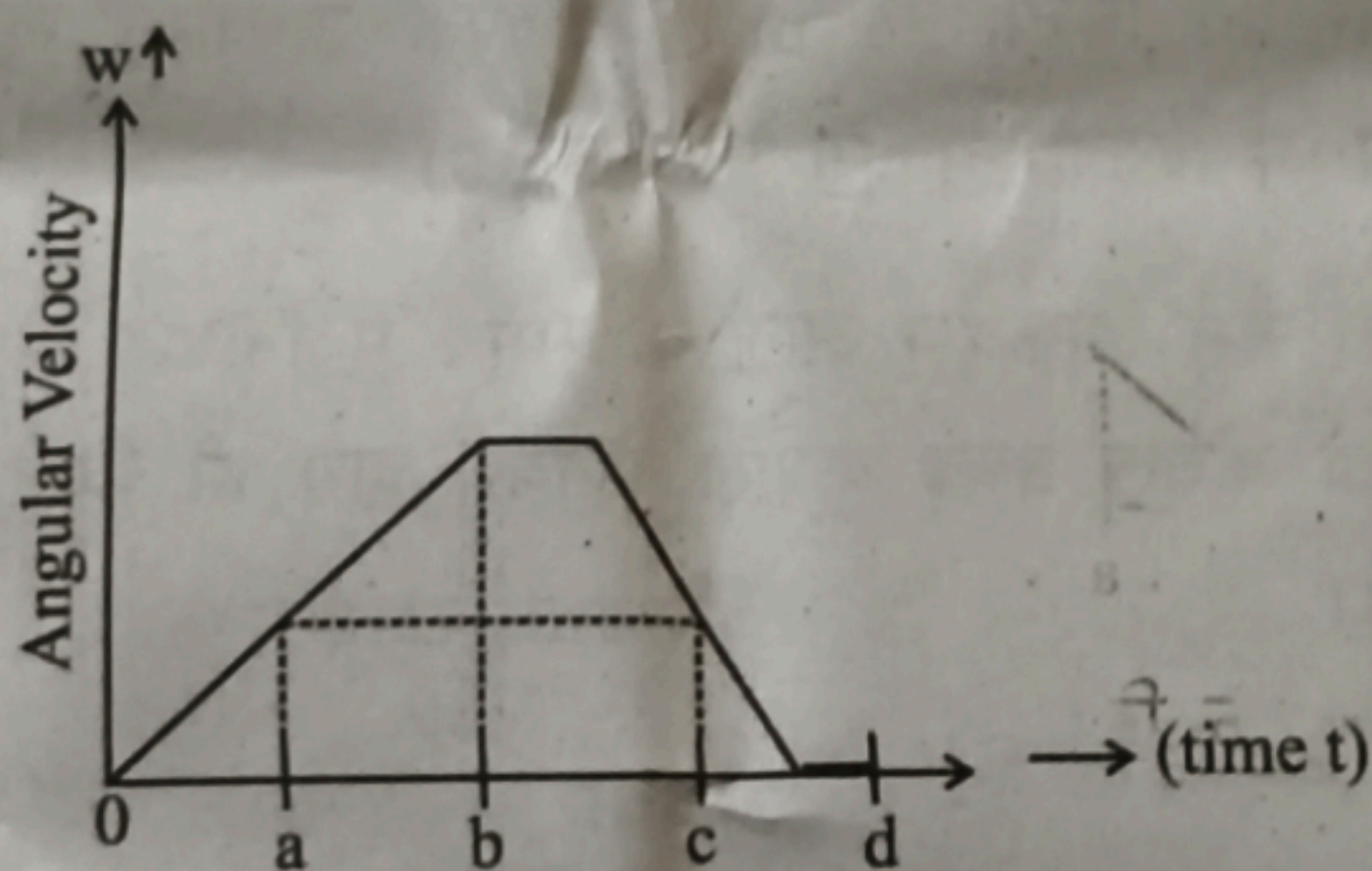
31.A) (a) Prove that the angular momentum of a particle is twice the product of its mass and areal velocity.

~~(b)~~ How does it lead to the Kepler's second law of planetary motion?

- (c) If Earth contracts to one third of its present radius, what would be the length of the day at Equator? 5

OR

- B) (a) Obtain an expression for the position vector of centre of mass of a two particle system.
- (b) Two blocks of mass 5 kg and 2 kg are placed on a frictionless surface and connected by a spring. An external kick gives a velocity of 21 m/s to the heavier block in the direction of lighter one. Calculate the velocity gained by the centre of mass.
- 32.A) (a) Derive an expression for the centripetal acceleration of a particle moving with constant speed v along a circular path of radius r .
- (b) The graph shows the angular velocity against time for a disc rotating in a horizontal plane about an axis passing through its centre and perpendicular to its plane.



For a point on the disc's rim, arrange the instant a, b, c and d in increasing order of the magnitudes of :

- (i) tangential acceleration
- (ii) radial acceleration

5

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- (b) A cyclist riding with a speed of 54 km/h approaches a circular turn on the road of radius 45 m and applies brake to reduce his speed at the constant rate of 2.5 m/s^2 . What is the magnitude and direction of the net acceleration of the cyclist on the circular turn?

32.B) (a) Show that the maximum possible speed of a car on a banked road is greater than that on a flat road.

(b) A circular race-track of radius 500 m is banked at one angle of 10° . If the coefficient of friction between the wheels of a race car and the road is 0.2. What is the :

(i) optimum speed of the ran car to avoid wear and tear on its tyres and

(ii) maximum permissible speed to avoid slipping? (given $\tan 10^\circ = 0.18$)

5

33.A) (a) Obtain an expression for minimum velocity of projection of a body at the lowest point for looping a vertical loop.

(b) In a circus, a motor cyclist driving in vertical loops inside a 'death well' (a hollow spherical chamber with holes so the spectators can watch from outside).

(i) Explain why the motorcyclist does not drop down when he is at the uppermost point, with no support from below.

(ii) What is the minimum speed required at the uppermost position to perform a vertical loop if the radius of the chamber is 25 m.

(Attractions like death well is a forbidden practice in today's times & if performed then only by highly skilled professionals as it involves risk).

OR

B) (a) Differentiate between inelastic collision and elastic collisions. Give example for each.

(b) Show that when two equal masses undergo a glancing elastic collision with one of the masses at rest then after the collision, the two masses will move at right angles to each other.