General Instructions:

1. All questions are compulsory.
2. There are 30 questions in total. Questions 1 to 8 carry one mark each, questions 9 to 18 carry two marks each, questions 19 to 27 carry three marks each and questions 28 to 30 carry five marks each.
3. There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the given choices in such questions.
4. Use of calculators is not permitted.

1. The specific heats of a gas are measured as $C_p = (12.28\pm0.2)$ units and $C_v = (3.97\pm0.3)$ units. Find the value of real gas constant $R$. 1
2. The angle between vectors $\vec{A}$ and $\vec{B}$ is $60^\circ$. Calculate the ratio of $\vec{A} \cdot \vec{B}$ and $|\vec{A} \times \vec{B}|$. 1
3. A gardener pushes a lawn roller through a distance of 20m. If he applies a force of 20 kglm in a direction inclined at $60^\circ$ to the ground; find the work done by him. 1
4. What are the factors on which the radius of gyration depends? 1
5. When is a system said to be in the state of thermodynamic equilibrium? 1
6. Explain why it is impossible to design a heat engine with 100% efficiency? 1
7. The r.m.s. speed of oxygen molecules at a certain temperature $T$ is $v$. If the temperature is doubled and the oxygen gas dissociates into atomic oxygen, what is the changed r.m.s. speed? 1
8. Although the velocity of air molecules is nearly $0.5 km/s$, yet the smell of scent spreads at a much slower rate. Why? 1
9. Assuming that the mass $M$ of the largest stone that can be moved by a flowing river depends upon $'v'$ the velocity, $'p'$ the density of water and on $'g'$ the acceleration due to gravity, show that $M$ varies with the sixth power of the velocity of flow. 2

P.T.O.
10. The relation between time \( t \) and distance \( x \) is \( t = ax^2 + bx \), where \( a \) and \( b \) are constants. Express the instantaneous acceleration in terms of instantaneous velocity.

11. The ceiling of a long hall is 25m high. What is the maximum horizontal distance that a ball thrown with a speed of 40m/s can go without hitting the ceiling of the wall.

12. Points P, Q and R are in a vertical line such that PQ = QR, where point P is at the top, Q in the middle and R is at bottom. A ball at P is allowed to fall freely. What is the ratio of the times of descent through PQ and QR?

OR

If \( \mathbf{i} \) and \( \mathbf{j} \) are unit vectors along X and Y axis respectively, then find the component of \( \mathbf{a} = 2\mathbf{i} + 3\mathbf{j} \) along the direction of vectors \( \mathbf{i} + \mathbf{j} \) and \( \mathbf{i} - \mathbf{j} \).

13. Explain:
   (a) Why are ball bearings used in machinery?
   (b) What is the need for banking of roads?

14. A body of mass \( m \) moving with speed \( v \) collides elastically head-on with another body of mass \( m \) initially at rest. Show that the moving body will come to a stop as a result of this collision.

15. Show that the angular momentum of a satellite of mass \( M_s \) revolving around the \( \text{earth} \) having mass \( M_e \) in an orbit of radius \( r \) is \( L = (G M_e M_s^2 r)^{1/2} \).

16. Find the percentage decrease in weight of a body, when taken 16km below the surface of the earth. Take radius of the earth as 6400km.

17. Define the term terminal velocity, and obtain an expression for the terminal velocity of a small spherical body falling through a viscous medium.

18. The equation of a plane progressive wave is \( y = 10 \sin 2\pi (t - 0.005x) \) where \( y \) and \( x \) are in cm and \( t \) in seconds. Calculate the amplitude, frequency, wavelength and velocity of the wave.

19. Explain the working of a refrigerator as a heat pump. Derive an expression for its coefficient of performance.

20. (a) State the theorem of parallel axes.
(b) Calculate the moment of inertia of a ring about a tangent to the ring (the tangent being drawn in the plane of the ring). Given the moment of inertia of the ring about an axis passing through its centre and perpendicular to its plane is \( MR^2 \).
21. A body describes simple harmonic motion with amplitude of 5cm and a period of 0.2s.
Find the acceleration and velocity of the body when the displacement is
(a) 5cm, (b) 3cm.
22. State the law of equipartition of energy. Using this law show that the ratio of two specific
heats \( \frac{C_p}{C_v} \) of a monoatomic gas is \( \frac{5}{3} \).
23. Derive an expression for the rise of liquid in a capillary tube and explain why water rises
in a capillary tube whereas mercury falls in the same tube.
24. Define escape velocity. Obtain an expression for the escape velocity of a body from the
surface of the earth.

OR

Define intensity of gravitational field. On a planet whose size is the same and mass 4
times as that of our earth, find the amount of work done to lift 3kg mass vertically
upwards through 3m distance on the planet. The value of \( g \) on the surface of earth is
10m/s\(^2\).
25. What is the difference between a conservative and a non conservative force? An elastic
spring of spring constant ‘\( k \)’ is compressed by an amount \( x \). Show that its potential
energy is \( \frac{1}{2} Kx^2 \).
26. A block A of mass 4kg is placed on another block B of mass 5kg and the block B rests on
a smooth horizontal table. For sliding the block A on B, a horizontal force of 12N is
required to be applied on it. How much maximum horizontal force can be applied on B so
that both A & B move together? Also find out the acceleration produced by this force.
27. An insect trapped in a circular groove of radius 12cm moves along the groove steadily
and completes 7 revolutions in 100s. (i) What is the angular speed and the linear speed of
the motion? (ii) Is the acceleration vector a constant vector? What is its magnitude?
28. (i) Prove analytically that in the case of a closed organ pipe of length \( L \), the frequencies
of the vibrating air column are given by
\[ v = (2n - 1) \left( \frac{v}{4L} \right) \]
where \( n \) is an integer and symbols have their usual meaning.

(3)
(ii) Find the ratio of the length of a closed pipe to that of an open pipe in order that the second overtone of the former is in unison with the fourth overtone of the latter.

**OR**

Derive an expression for the apparent frequency of sound as heard by the stationary observer in a still medium, when the source of sound is moving towards the observer with a uniform velocity.

A rocket is moving at a speed of 200 m/s towards a stationary target. While moving, it emits a wave of frequency 1000 Hz. Some of the sound reaching the target gets reflected back to the rocket as an echo. Calculate:

1. the frequency of the sound as detected by the target and
2. the frequency of the echo as detected by the rocket.

59. State and prove Bernoulli's principle for the flow of non-viscous fluids, and also explain how Bernoulli's principle helps in explaining vascular flutter and heart attack.

**OR**

Find the expression for the excess pressure inside a soap bubble. If excess of pressure inside a soap bubble of radius 1 cm is balanced by that due to column of oil 2 mm high, find surface tension of soap bubble, given that density of oil is 0.8 x 10^3 Kg m⁻³.

Derive an expression for the maximum permissible speed with which a car can negotiate a circular track of radius 'r' banked at an angle 'θ'. The coefficient of friction between the car tyres and the road is μ.

A circular race track of radius 300 m is banked at an angle of 15°. If the coefficient of friction between the wheels of race-car and the road is 0.2. What is the

(a) Optimum speed of the race-car to avoid wear and tear on its tyres, and

(b) Maximum permissible speed to avoid slipping?

**OR**

Derive the relation between Impulse and momentum. How will you measure impulse from F-t graph?

A ball of mass 10 g hits a horizontal hard surface with speed of 5 m/s along the vertical direction and rebounds with the same speed. The ball is in contact with the surface for 1/100 s. What is the average force on the ball?