**2023**

( CBCS )

( 1st Semester )

**PHYSICS**

FIRST PAPER

**( Properties of Matter, Oscillations and Acoustics )**

*Full Marks* : 75

*Time* : 3 hours

*The figures in the margin indicate full marks for the questions*

**( SECTION : A—OBJECTIVE )**

( *Marks* : 10 )

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. The condition for the force $\vec{F}$ to be conservative is

   (a) $\vec{\nabla} \cdot \vec{F} \neq 0$ ( )

   (b) $\vec{\nabla} \times \vec{F} \neq 0$ ( )

   (c) $\vec{\nabla} \cdot \vec{F} = 0$ ( )

   (d) $\vec{\nabla} \times \vec{F} = 0$ ( )

2. Linear momentum of a system is conserved

   (a) when angular momentum on the system is zero ( )

   (b) when external force on the system is zero ( )

   (c) when external torque on the system is zero ( )

   (d) always under any circumstances ( )

3. A meson has a lifetime of $2 \cdot 2 \times 10^{-6}$ s $(= \Delta t_0)$ in its own frame. It travels with the speed of $0 \cdot 98c$. Its lifetime measured from the earth is

(a) $5 \Delta t_0$ ( )

(b) $2 \Delta t_0$ ( )

(c) $10 \Delta t_0$ ( )

(d) $7 \Delta t_0$ ( )

4. The moment of inertia for a ring of radius $R$, mass $M$ about the axis passing through its diameter is

(a) $\frac{3}{5} MR^2$ ( )

(b) $\frac{7}{5} MR^2$ ( )

(c) $\frac{1}{2} MR^2$ ( )

(d) $\frac{4}{5} MR^2$ ( )

5. If $Y$ be the Young's modulus and $S$ be the stress, then the strain energy per unit volume is

(a) $YS$ ( )

(b) $Y^2S$ ( )

(c) $\frac{1}{2} Y^2S$ ( )

(d) $\frac{S^2}{2Y}$ ( )

6. A vertical wire is loaded (within the limit of Hooke's law) by weights which produce a total extension of 3 mm and 5 mm respectively. The ratio of the respective work done is

(a) 9 : 25 ( )

(b) 3 : 5 ( )

(c) 27 : 125 ( )

(d) 5 : 3 ( )

7. The average kinetic energy of a particle of mass $m$ executing simple harmonic motion of frequency $f$, the amplitude $a$ is

(a) $2\pi^2 ma^2 f^2$ ( )

(b) $\pi^2 ma^2 f^2$ ( )

(c) $\frac{\pi^2 ma^2 f^2}{2}$ ( )

(d) $\frac{\pi^2 ma^2 f^2}{\sqrt{2}}$ ( )

8. Let $g$ be acceleration due to gravity and $l$ be length of simple pendulum; its frequency of oscillation is

(a) $f = 2\pi \frac{l}{g}$ ( )

(b) $f = 2\pi \sqrt{\frac{l}{g}}$ ( )

(c) $f = \frac{1}{2\pi} \sqrt{\frac{l}{g}}$ ( )

(d) $f = \frac{1}{2\pi} \sqrt{\frac{g}{l}}$ ( )

9. If $b$ is the damping constant and $\omega$ is the natural frequency of the oscillating system, then the frequency of vibration is

(a) $\frac{\sqrt{\omega^2 - 2b^2}}{2\pi}$ ( )

(b) $\frac{\sqrt{\omega^2 - b^2}}{2\pi}$ ( )

(c) $\frac{\sqrt{\omega^2 + b^2}}{2\pi}$ ( )

(d) $\frac{\sqrt{\omega^2 + 2b^2}}{2\pi}$ ( )

10. When two or more notes are sounded one after another, the combined note producing a pleasing effect on the ear is called

(a) harmony ( )

(b) melody ( )

(c) noise ( )

(d) interval ( )

## ( SECTION : B—SHORT ANSWERS )

( *Marks* : 15 )

Answer the following : 3×5=

### UNIT—I

1. What do you mean by collision? Write down the differences between elastic and inelastic collisions.

**OR**

2. Show that the motion of a system of particles is simply the motion of its centre of mass.

## UNIT—II

3. State and prove perpendicular axes theorem of moment of inertia.

**OR**

4. State the two postulates of special theory of relativity. What is inertial frame?

## UNIT—III

5. Calculate the height to which a liquid will rise in a capillary tube of radius 0·2 mm, if the angle of contact is 0 °C. (Given : Surface tension of the liquid $= 26 \times 10^{-3}$ N/m and density 800 kg/m$^3$)

**OR**

. Write Bernoulli's equation and explain the significance of the different terms in it.

## UNIT—IV

Show that for a simple harmonic motion given by the equation $y = A \sin \omega t$, velocity of the particle at any instant is given by $v = \omega\sqrt{A^2 - y^2}$. What is the expression for the maximum speed? Where does it occur?

**OR**

What do you mean by simple harmonic motion (SHM)? Obtain the differential equation for SHM.

## UNIT—V

What do you mean by ultrasonic waves? Write three applications of ultrasonic waves.

**OR**

What is reverberation? Write down Sabine's law of reverberation. Define live room and dead room.

## ( SECTION : C—DESCRIPTIVE )

( *Marks* : 50 )

Answer the following : 10×5=50

### UNIT—I

**1.** *(a)* A particle is moving in *X-Y* plane. Show that if the motion is circular, velocity $\vec{v}$ of the particle is given by $\vec{v} = \omega r\hat{\theta}$, where $\hat{\theta}$ is the unit vector along transverse direction, $r$ and $\omega$ are radius of the path and angular velocity of the particle respectively. 6

*(b)* State and prove the principle of conservation of angular momentum. 4

**OR**

**2.** *(a)* A reference frame $S'$ rotates with respect to another reference frame $S$ with an angular velocity $\vec{\omega}$. If $\vec{r}$, $\vec{v}$ and $\vec{F}$ represent the position, velocity and force of a particle of mass $m$ in the frame $S$ and $\vec{F}'$ represents the force of the particle in the frame $S'$, then show that

$$\vec{F} = \vec{F}' - 2m\vec{\omega} \times \vec{v} - m\vec{\omega} \times (\vec{\omega} \times \vec{r}) - m\frac{d\vec{\omega}}{dt} \times \vec{r}$$ 6

*(b)* State and prove work-energy theorem. 4

### UNIT—II

**3.** *(a)* Obtain the expression for moment of inertia of a hollow sphere of mass $M$, radius $R$ about its diameter and about the axis passing through the edge. 6+1=7

*(b)* Show that the numerically moment of inertia of a body is twice its kinetic energy when its angular velocity is unity. 3

**OR**

**4.** *(a)* Show that the total energy $E$ of a body of mass $m$ is given by $E = mc^2$, where $c$ is the speed of light in vacuum, $m$ is moving mass of the body. 7

*(b)* Obtain the expression for length contraction when an object moves with high speed. 3

## UNIT—III

5. *(a)* Show that a shear is equivalent to a compression and an extension at right angles to each other. 4

*(b)* Find an expression of tortional rigidity of a solid cylinder. 6

**OR**

6. *(a)* A wire 300 cm long and 0·625 sq. cm. in cross-section is found to stretch by 0·3 cm under a tension of 1200 N. What is Young's modulus of the material of the wire? 3

*(b)* Using the method of dimensional analysis, derive Stokes' law and hence obtain an expression for terminal velocity for a body falling freely through a viscous medium. What do you mean by terminal velocity? 6+1=7

## UNIT—IV

7. *(a)* Let two masses $m_1$ and $m_2$ be connected by a spring of spring constant $k$. One of the masses is fixed to a rigid support and the other mass is displaced through a distance $x$ and is released. Show that the motion of the spring is simple harmonic, and hence obtain the frequency and time period of the motion. 7

*(b)* Two SHMs are given by $x_1 = 10\cos 100t$ and $x_2 = 10\sin 100t$. Calculate their resultant amplitude when they interfere. 3

**OR**

8. *(a)* Two simple harmonic motions $x = A\sin(\omega t + \phi)$ and $y = B\sin\omega t$ superposed each other at right angle. Obtain the general equation for the resultant simple harmonic motions after they superposed each other and hence discuss the case when—

*(i)* $\phi = \frac{\pi}{2}$

*(ii)* $\phi = \pi$ 5+1+1=7

*(b)* Displacement of a particle is given by $x = x_0 \sin\omega t$. Show that it performs simple harmonic motion. 3

## UNIT—V

**9.** *(a)* Show that in forced vibration, the resultant amplitude is given by

$$A = \frac{f}{\sqrt{(\omega^2 - p^2)^2 + 4b^2p^2}}$$

where $b$ is damping coefficient, $p$ is frequency of driving force. 7

*(b)* Write down the difference between free and forced vibrations. 3

**OR**

**10.** *(a)* Explain human ear and its response. What is the limit of human audibility? What do you mean by resonance? Explain sharpness of resonance. 3+1+1+2=7

*(b)* What is intensity level? Calculate the change in intensity level when the intensity of sound increases 1000 times its original intensity. 3

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