This question paper contains 7 printed pages]

Roll No. | | | | | | | | | | | |

S. No. of Question Paper : **936**

Unique Paper Code : **222202** **E**

Name of the Paper : **Oscillations and Waves (PHHT-204)**

Name of the Course : **B.Sc. (Hons.) Physics**

Semester : **II**

Duration : **3 Hours** Maximum Marks : **75**

(Write your Roll No. on the top immediately on receipt of this question paper.)

Attempt *five* questions in all including Q. No. **1** which is compulsory.

1. Attempt any *five* of the following : 5×3=15

(*a*) A wire of length 100 cm and of mass 1.25 g is stretched with a tension of 100 N. If the wire is set into vibration and touched lightly with a feather at a point one-third of its length from one end, calculate the frequency of the note emitted.

(*b*) What are beats ? What is the necessary condition to obtain them ?

(*c*) What are stationary waves ? Why are they called so ?

(*d*) A particle executes SHM with amplitude A. If its starting point is :

(*i*) $\psi = +A$

(*ii*) $\psi = -A$

(*iii*) $\psi = +A/2$.

find the different values of phase constant φ for the solution :

$$\psi(t) = A\cos(\omega t + \varphi).$$

(*e*) A solid cube of side a is made to under small oscillations about one of its sides as the asix of oscillation. Show that the frequency of oscillations is :

$$f = \frac{1}{2\pi}\sqrt{\frac{3g}{2\sqrt{2}a}}$$

Given $I = 2ma^2/3$.

(*f*) What are longitudinal and transverse waves ?

(*g*) Explain the difference between particle and wave velocity and give mathematical expression for each.

(*h*) The refractive index η of a gas is given by

$$\eta = \frac{c^2}{v^2} = \alpha + \beta k^2 - \frac{\gamma}{k^2}$$

where α, β and γ are constants, k is the wave number, v is the phase velocity and c is the speed of light in vacuum. Show that the group velocity is :

$$v_g = \frac{v}{\eta^2}\left(\alpha - \frac{2\gamma}{k^2}\right).$$

2. (*a*) Obtain the time period of oscillation of a compound pendulum and show that centres of suspension and oscillation are interchangeable. Obtain the value of the length for which the time period of the pendulum is a minimum. 10

(*b*) A smooth tunnel is bored through the earth along one of its diameters and a ball is dropped into it. Show that the ball will execute SHM with time period :

$$T = 2\pi\sqrt{\frac{R}{g}}$$

where R is the radius of earth and g is the acceleration due to gravity at the surface of earth. 5

3. (*a*) Two vibrations at right angles to each other are described by the equations :

$$x(t) = 3\sin(5\pi t) \text{ and } y(t) = 2\sin\left(5\pi t + \frac{\pi}{3}\right)$$

where x and y are expressed in centimeters and t in seconds. Construct the Lissajous curve for the combined motion using graphical method. 10

(*b*) Two pendulums are suspended one below another to form a double pendulum as shown Fig. (*i*). Show that the frequencies of two normal modes for small oscillations are given by :

$$\omega^2 = \left(2 \pm \sqrt{2}\right)\frac{g}{l}.$$ 5

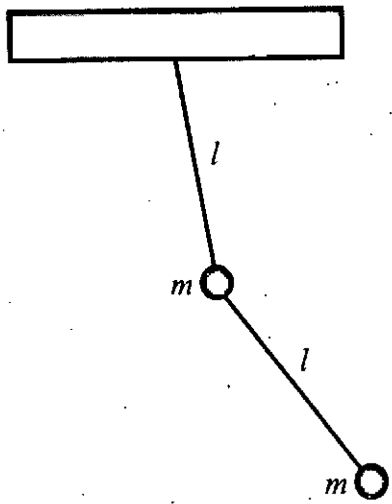

Fig. (*i*)

4. (*a*) A Helmholtz resonator consisting of a container of volume V_0 with a neck having a tube of radius *a* and length *l*. Neglecting any end corrections, show that the frequency of the resonator is :

$$f = \frac{av}{2\pi}\sqrt{\frac{\pi}{lV_0}}.$$ 10

(*b*) Two tuning forks A and B of nearly equal frequencies are employed to produce Lissajous figure. On slightly loading fork A, it is observed that cycle of change of figure slows down from 10 to 20 seconds. If the frequency of fork B is 256 Hz, determine the frequency of fork A before and after loading. 5

5. (*a*) Establish the equation of motion of a damped harmonic oscillator subjected to a resistive force that is proportional to the first power of its velocity. If the damping is less than critical, show that the motion of the system is oscillatory with its amplitude decaying exponentially with time. 10

(*b*) A massless spring suspended from a rigid support carries a flat disc of mass 100 g at its lower end. It is observed that the system oscillates with a frequency of 10 Hz and the amplitude of the damped oscillator reduces to half its undamped amplitude value in 1 min. Calculate :

(*i*) the resistive force constant

(*ii*) the relaxation time of the system and

(*iii*) its quality factor. 5

6. (*a*) Derive the differential equation of motion for the transverse vibrations of a uniform flexible stretched string. Hence find the expression for the velocity of the subsequent wave motion. 10

(*b*) Prove that the expression for magnitude of the velocity of the waves formed on the surface of liquid (density ρ) under the combined action of gravity g and surface tension T is given by :

$$v = \sqrt{\frac{\lambda g}{2\pi} + \frac{2\pi T}{\rho\lambda}}$$

where λ is the wavelength of the wave. 5

7. (*a*) A uniform flexible string of length L and linear mass density μ is stretched between its two fixed ends ($x = 0$) and ($x = L$) with tension T. The string is plucked at $x = L/4$ with amplitude h and released. Starting from :

$$y(x, t) = \sum_{n=1}^{\infty} \sin\left(\frac{n\pi x}{L}\right)\left[A_n \cos\left(\frac{n\pi vt}{L}\right) + B_n \sin\left(\frac{n\pi vt}{L}\right)\right]$$

obtain and discuss the equation for subsequent motion of the string. 10

(*b*) Also obtain the expression for its total energy given that the general expression of total energy of a vibrating string is :

$$E_{total} = \frac{\mu\pi^2 v^2}{4L} \sum_{n=1}^{\infty} n^2\left[A_n^2 + B_n^2\right].$$

8. (*a*) N identical particles of mass m are connected together by N + 1 identical massless springs constant k. The free ends of the extreme springs are rigidly fixed. Show that the frequency of normal modes of longitudinal oscillations are given by :

$$\omega_n = 2\sqrt{\frac{k}{m}} \sin\left[\frac{n\pi}{2(N+1)}\right].$$

10

(*b*) The string of length $4a$ and under tension T has three equal masses placed at a, $2a$ and $3a$.

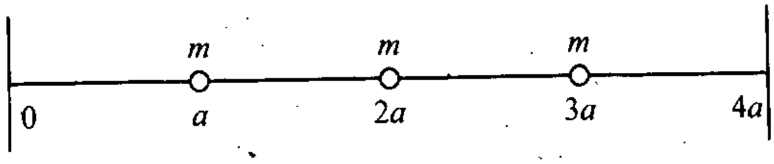

Fig. (*ii*)

Write the general expressions for the normal frequency and the corresponding amplitudes of the normal mode displacements. Draw the normal modes of transverse vibrations. 5