Ref. No.: Ex/ME(M2)/BS/B/Ph/T/112/2024(S)
B.E. MECHANICAL ENGINEERING
1ST YEAR 1ST SEMESTER 2024
Subject: PHYSICS

Time: 3 Hours **Full Marks: 100**

Answer any ten questions. Symbols used have their usual meanings.

1. (a) Write down the features of damped vibration and forced vibration.
   (b) How is the differential equation of a simple harmonic oscillator modified to incorporate the effect of damping? $(3+3)+4$

2. (a) Give two examples of forced vibration and resonance.
   (b) Starting from the differential equation of forced vibration, establish the condition for velocity resonance. $3+7$

3. (a) Establish the differential equation of a progressive wave propagating along x-axis. In case of sound wave, is the velocity of the sound wave equal to the average velocity of a particle of the medium? Why?
   (b) Given, the frequency of a progressive wave $= 500\ Hz$ and velocity of the wave $= 360\ ms^{-1}$. Find out the distance between two points having a phase difference of $60°$. Also find out the difference between the phases of a particular point after a time interval of $10^{-3}\ s$. $(4+2)+(2+2)$

4. (a) What is the difference between steady flow and turbulence?
   (b) Write down the basic assumptions that are required to establish Poiseuille's equation for streamline flow through a tube.
   (c) A liquid is flowing in streamline through a narrow tube of length L and radius r. The pressure difference between the ends of the tube is P. Show that the velocity of the liquid at a point in the tube is given by $v_l = \frac{P}{4L\eta}(r^2 - x^2)$ where x is the distance of the point from the axis of the tube. $2+3+5$

5. (a) What is the coefficient of viscosity? Write down Stoke's law and establish the dimension of the coefficient of viscosity from Stoke's law.
   (b) In a streamline flow, the cross-section of one end of the tube is twice of the other end. If the liquid is incompressible, find out the ratio of velocities at both ends of the tube. Mention the law you use here.
   (c) Give one example of the application of Bernoulli's theorem in fluid dynamics. $(1+2+2)+(2+1)+2$

6. (a) Write down Gauss's law in free space to determine the electric field. How is it modified inside a dielectric? Define polarization vector and electric displacement vector.
   (b) Determine the electric field due to an infinitely extended charged plane. $(2+2+2)+4$

7. (a) A charge Q is placed at the body-centre of a cube of side a. Find out the electric flux passing out through each plane of the cube.
   (b) Give the statements along with the mathematical expressions of Biot-Savart's Law and Ampere's circultal law.

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(c) A wire of length L is given a circular shape and a current I passes through it. Find out the magnetic moment of the circular loop. $3+4+3$

8. (a) Determine the expression of the magnetic field at a point on the axis of a current carrying circular loop. Show in a schematic diagram the variation of the magnetic field as a function of the distance between the centre of the circle and the point on the axis.

(b) An electron ($1.6 \times 10^{-19}\ C$) rotates around the nucleus in a hydrogen atom with frequency 6.8×10^{15} revolutions per second. The radius of the circular orbit is $5.1 \times 10^{-11}\ m$. Find out (i) The magnetic field ($\vec{B}$) at the centre of the circle and (ii) the magnetic moment of the orbit. $(5+1)+(2+2)$

9. (a) What is magnetic flux density? How is it related to the induced e.m.f? Explain the importance of Lenz's law for conservation of energy.

(b) Explain the phenomenon of charging of a capacitor in a dc C-R circuit. $(2+2+2)+4$

10. (a) Write down the Maxwell equations for electromagnetic fields and give explanation of each equation.

(b) What is Poynting theorem?

(c) Establish from the Maxwell equations the wave equation satisfied by the electric field $\vec{E}(\vec{r},t)$ in free space. $4+2+4$

11. (a) What are coherent sources? Write down the conditions for observing sustained interference pattern.

(b) In case of a Young's double slit experiment, establish the condition for constructive interference.

(c) What are the differences between diffraction and interference? $(2+2)+4+2$

12. (a) For single slit diffraction, establish the expression for intensity as a function of angle of incidence.

(b) In a single slit diffraction experiment, the first minima is formed at a distance of 5 mm from the central maxima. If the distance between the lens and the screen is 2 m, find out the wavelength of the incident light.

(c) Define Brewter's angle with a schematic diagram. $5+3+2$

13. (a) Show that the state of polarization of an EM wave may be explained by considering two mutually perpendicular oscillations superposed on each other.

(b) Give brief explanation of temporal coherence and spatial coherence. $4+(3+3)$

14. (a) What is a matter wave? Write down the de Broglie hypothesis. What is the momentum associated with an X-ray photon of wavelength 5 nm? Given, $h = 6.63 \times 10^{-34}\ Js$.

(b) Given, mass of electron $= 9.1 \times 10^{-31}$ kg and charge of electron $= 1.6 \times 10^{-19}\ C$. Find out the de Broglie wavelength of the electron. $(2+2+3)+3$

15. A particle of mass m and energy E is restricted to move along x-axis from $x = 0$ to $x = a$.

(a) Give a schematic plot of the potential that can confine the particle in such a manner.

(b) Write down the boundary conditions to be satisfied by the wavefunction $\Psi(x)$ and its derivative $\frac{d\Psi}{dx}$.

(c) The general solution of an eigenstate of the Schrödinger equation for the particle is written as $\Psi_n(x) = A\sin kx + B\cos kx$ where $k = \sqrt{\frac{2mE}{\hbar^2}}$. Using the boundary conditions, normalize the function $\Psi_n(x)$ and find out the energy of the particle. $1+4+5$