WEST BENGAL STATE UNIVERSITY

B.Sc. Honours PART-II Examinations, 2017

PHYSICS-HONOURS

PAPER-PHSA-III

Time Allotted: 4 Hours | Full Marks: 100

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Use Separate Answer Books For Unit-III-A and Unit-III-B

Unit-III-A

Answer Questions No. 1 and any *four* questions from the following

1. Answer any ***five*** questions from the following: 2×5 = 10

   (a) Show that $\sqrt{\frac{\mu_0}{\varepsilon_0}}$ has the dimension of resistance.

   (b) The electrostatic potential at a point (x, y) is given by $V = 2x + 4y$ volts. Find the electrostatic energy density in $\mathrm{J/m^3}$.

   (c) A sphere of homogenous linear dielectric material is placed in an uniform electric field. Write down the appropriate boundary conditions.

   (d) E.M.F. is the open circuited voltage across a battery, then how e.m.f can be measured in a closed circuit?

(e) Verify the magnetic vector potential $\vec{A}$ due to uniform magnetic field $\vec{B}$ is given by $\vec{A} = -\frac{1}{2}(\vec{\gamma} \times \vec{B})$.

(f) Magnetic field arises due to changes in motion. Can a system have magnetic moment, even though its net charge is zero? Give example.

(g) What are the characteristic of an ideal voltage source and an ideal current source?

(h) What is eddy current? What are its uses?

2. (a) Obtain the multipole expansion of the electrostatic potential due to an arbitrary localized charge distribution at a point well outside the charge distribution. 4

(b) In a certain region the electric field in spherical polar coordinates is given by $\vec{E} = (a \sin\theta\, \hat{r} + b \cos\theta\, \hat{\theta})$, where a and b are constants. Prove that the charge density responsible for the field is 3

$$\rho = \frac{(2a \sin^2\theta + b \cos 2\theta)}{r \sin\theta} .$$

(c) State and explain Earnshaw's theorem. What is its importance? 2+1

3. (a) What is an electrical image? 1+2

A point charge q is at a distance d from an infinite conducting plane. Find the work necessary to remove the charge to infinite distance from the plane.

(b) The variation of electrostatic potential is given as 2+2+1

$$V(r) = V_0 \frac{e^{-\alpha r}}{r} \quad (V_0 \text{ is constant}).$$

Obtain corresponding electric field and charge density. When this potential resembles Coulomb's potential?

(c) Show that the electrostatic energy stored in capacitance C charged to a voltage V is $\frac{1}{2}CV^2$. 2

4. (a) What is meant by dielectric polarization $\vec{P}$ and electric displacement vector $\vec{D}$. 1+1

   (b) A primitive model for an atom consist of a point nucleus ($+q$) surrounded by an uniformly charged spherical cloud ($-q$) of radius a. Calculate the atomic polarizability of such an atom. 3

   (c) Establish the relation $\vec{P} = \varepsilon_0 (K-1)\vec{E}$, where $\vec{E}$ is the electric vector and K is the dielectric constant of the material. Hence prove that polarization vanishes in vacuum. 1+1

   (d) A concentric spherical volume of inner radius 'a' and outer radius 'b' is filled with a material of finite conductivity $\sigma(r) = \frac{A}{r^2}$, where A is a positive constant of appropriate dimension. The outer surface is grounded while the inner surface is maintained a potential. Show that the resistance of the configuration is $\frac{b-a}{4\pi A}$. 3

5. (a) Starting from Biot-Savart law show that $\vec{\nabla}\cdot\vec{B} = 0$. What is its physical significance? 2+1

   (b) A current distribution gives rise to the magnetic vector potential $\vec{A}(x, y, z) = 2xy^2\hat{i} - x^2y\hat{j} - 3xyz\hat{k}$. Find the corresponding magnetic field $\vec{B}$ as $(-1, 2, 1)$. 3

   (c) A sphere made of linear magnetic material of radius a and permeability μ is placed in vacuum having an external uniform magnetic intensity H_0. Solving the Laplace's equation satisfied by the magnetic scalar potential with proper boundary condition find the magnetic field at any inside and outside points. 2+2

6. (a) Show that Kirchoff's first law is consistent with the principle of conservation of charge and the second law is consistent with the law of conservation of energy. 2+2

(b) State maximum power transfer theorem. Show that the efficiency of power transfer is 50% when the maximum power is delivered to a resistive load. 2+2

(c) Using Thevenins theorem find the balanced condition of the Wheatstone bridge. 2

7. (a) Deduce differential form of Faraday's law of induction. 2

(b) In a certain region of space electric field is given by $\vec{E} = \hat{j}E_0 \cos(\omega t - kx)$. Using differential form of Faraday's law find the corresponding magnetic field $\vec{B}$. 2

(c) Self inductances of two coils are L_1 and L_2 and their mutual inductance is M. Starting from their energy consideration show that $M^2 \leq L_1 L_2$. 3+2+1

What is co-efficient of coupling?

Unit-III-B

Answer Questions No. 8 and *four* other questions, at least, one from question numbers 9 & 10, one from 11 & 12 and one from 13 & 14.

8. Answer any ***five*** questions from the following: 2×5 = 10

(a) In an a.c. line with a source of 220 V- 50 Hz, calculate the minimum time required for attaining instantaneous voltage of 220 V.

(b) An a.c. voltage $V(t) = V_0 \cos \omega t$ is applied across a parallel plate capacitor having a plate separation d. Find the displacement current density through the capacitor.

(c) An electromagnetic wave is passing through a medium characterized by relative permittivity 10 and relative permeability 5. Find the wave impedance.

(d) "Ampere's Circuital law is bound to fail for non-steady currents"— Justify.

(e) Show that the equation of continuity $\vec{\nabla} \cdot \vec{J} + \frac{\partial \rho}{\partial t} = 0$ is contained in Maxwell's equations.

(f) What are the factors responsible for the shift of operating point (*Q*-point) of a transistor amplifier?

(g) Distinguish between Zener breakdown and Avalanche breakdown.

(h) What are BCD codes? Convert $(324.58)_{10}$ to BCD codes.

9. (a) Set up the e.m.f. equation for a series LCR circuit driven by a battery of e.m.f. *E* from energy considerations. 2+3

Investigate the growth of charge on the capacitor pointing out clearly the condition for an oscillating growth.

(b) A series *RC* circuit is excited by a source of constant voltage *V* switched at time $t = 0$. What is the maximum growth rate of charge on the capacitor? 2

(c) An inductive coil inductance *L* and resistance *R* are joined to a cell of e.m.f. *E*. Prove that after a time *t* seconds, the current is given by $\frac{E(1-k)}{R}$, where $L \ln k + Rt = 0$. 3

10.(a) In a series LCR circuit driven by a.c. source, find the frequency at which voltage across capacitor becomes maximum. 3

(b) Explain how R-C series circuit in case of alternating current input can serve as a low pass filter. 3

(c) An a.c. supply of 50 V, 1000 Hz is applied to a series *LR* circuit with *L* = 1000 mH and *R* = 2000 Ω. Find the r.m.s. current in the circuit, potential difference across *L* and the p.d. across *R*. Does the sum of these r.m.s. p.d. give the supply e.m.f.? How do you explain the difference if any? 4

11.(a) Starting from Maxwell's equations derive the wave equation in a homogeneous isotropic conducting medium. Hence show that a plane electromagnetic wave is attenuated as it propagate through the medium. 2+2

(b) Show that the skin depth in a poor conductor $(\sigma << \omega\varepsilon)$ is $\frac{2}{\sigma}\sqrt{\frac{\varepsilon}{\mu}}$. 2

(c) Calculate the skin depth for radio waves of wavelength 2.9 m (in free space) in copper, the electrical conductivity of copper is 5.8×50^7 S/m. 2

(d) The intensity of sunlight reaching the earth's surface is about 1350 $W.m^{-2}$. Calculate the strength of electric fields of the incoming sunlight $[\mu = 4\pi \times 10^{-7}\,H/m]$. 2

12.(a) Write down Fresnel's equation for reflection and refraction of electromagnetic wave. Hence deduce Brewster's law. 2+2

(b) Prove that the frequency of electromagnetic wave does not change on reflection and refraction. 2

(c) What is Rayleigh scattering? Why is red light used for danger signals? 2+2

13.(a) Draw the output characteristics of a n-p-n transistor in CE mode. Hence draw the d.c. load line for a transistor circuit. 2+2

(b) Draw a neat circuit diagram of CE amplifier with voltage divider bias and draw its AC equivalent circuit. 2+1

(c) What do you mean by load line and the Q-point of a semiconductor diode circuit? Explain with suitable diagram. 2+1

14.(a) A three variable truth table has high output for these input conditions: 111, 010, 100 and 110. Find the Boolean expression and corresponding logic circuit. 1+2

(b) Find the base *n* if $5_n \times 3_n = 43_n$. 2

(c) Show that $\overline{AB + \overline{A\overline{B}} + \overline{A}} = 0$ using Boolean algebraic theory. 2

(d) Draw the NOR gate using diode, transistor and resistors. Explain the operation. 3