BACHELOR OF SCIENCE EXAMINATION, 2019

(2nd Year, 2nd Semester)

Electromagnetic Theory & Modern Physics - II

Paper : CORE - 10

Time : Three hours

Full Marks : 50
(25 marks from each group)

Use a separate answer script for each group.

GROUP - A

Answer ***question no. 1*** and any ***two*** from the rest.

1. Answer any <u>three:</u> **3x3=9**

(a) An electron of charge "– q" is constrained to move along the axis of a ring of charge Q and of radius a. Show that the electron will execute simple harmonic motion about the centre of the ring when x << a; here x is the position of the field point P from the center of the ring. [3]

(b) Show that any initial charge density in a conductor will dissipate in a characteristic time $\tau = \frac{\epsilon}{\sigma}$, where ϵ is the dielectric constant and σ is the conductivity of the material. Show how the characteristic time provides an index concerning the quality of a conductor. [2+1 =3]

(c) Do the electric field ($\vec{E}$) and magnetic induction ($\vec{B}$) vectors represented by scalar and vector potentials V and $\vec{A}$ unique? Comment on your answer. [2+1 =3]

(d) Show that the time average of energy flux density $\langle \vec{S} \rangle$ over a full period or large interval of time is expressed as :

$\langle \vec{S} \rangle = \frac{1}{2} Re(\vec{E} \times \overrightarrow{H^*})$, where $\vec{E}$ and $\vec{H}$ are harmonically varying complex electric and magnetic fields respectively. [3]

(e) What is skin depth (δ)? Show that for a good conductor $\delta = \frac{\lambda_c}{2\pi}$, where λ_c is the wavelength of the electromagnetic waves in the conductor. [1+2 =3]

2. (a) What is displacement current? Why Maxwell modified the Ampere's circuital law for steady current to include displacement current?

(b) Consider a parallel plate capacitor immersed in sea water and driven by a voltage $V_0 \cos 2\pi\upsilon t$. The sea water at frequency $\upsilon = 4.0 \times 10^8$ Hz has permittivity $\varepsilon = 81\ \varepsilon_0$, permeability $\mu = \mu_0$ and resistivity $\rho = 0.23\ \Omega$ m. Calculate the ratio of conduction current to displacement current densities. [$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$] **[2 + 3 + 3 =8]**

3. (a) Write down Maxwell's field equations in free space. Obtain the wave equation for electric field intensity from them.

(b) Show that for a plane electromagnetic wave propagating in free space, the unit vector in the direction of propagation, the electric field and the magnetic field vectors are mutually perpendicular.

(c) What is wave impedance? Obtain the expression of wave impedance for the electromagnetic wave propagating in free space. **[1 +2 + 3 +2 = 8]**

4. (a) Derive Poynting's theorem in the form :

$$\frac{\partial U}{\partial t} + \vec{\nabla}.\vec{S} = 0$$

where the symbols have usual meanings. Compare this equation with the equation of continuity to interpret the vector $\vec{S}$.

(b) Assuming that all the energy from a 1000 watt lamp is radiated uniformly; calculate the average values of the intensities of electric and magnetic fields of radiation at a distance of 2 meter from the lamp. [$\mu_0 = 4\pi \times 10^{-7}$ N/ Amp^2, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$] **[4 +1 + 3 = 8]**

5. Obtain the expressions for reflection and transmission coefficients when a linearly polarized light is incident obliquely at the interface of two homogeneous dielectric media. (Consider the electric field vector to be perpendicular to the plane of incidence). Hence show that the sum of the reflection and transmission coefficients is unity. How the phenomenon of "total internal reflection" in optics is arrived from the ratio of the amplitudes between the reflected and the incident beam. **[5+ 1 + 2 = 8]**

GROUP - B

Answer ***question no. 6*** and any ***two*** from the rest.

6. Answer *any* **three**: 3×3

   (a) Briefly explain the doublet structure of sodium D-lines.

   (b) What is centrifugal distortion effect in rotational spectroscopy? Define the relevant constant.

   (c) What is magnetic moment? Derive an expression for *Bohr magneton*.

   (d) State *Larmor*'s theorem. Why is it of considerable importance in atomic physics?

7. (a) Write down the expression for isotope shift. Describe in brief the effect of isotopic substitution on rotational spectra of diatomic molecules. (b) What are the conditions for occurance of normal and anomalous Zeeman effects? Describe the phenomenon of anomalous Zeeman effect with necessary energy level diagram. (c) Why ground state of an atom is always a singlet? 3+(1+3)+1

8. (a) Derive the necessary theory of Stern-Gerlach experiment. Why was silver used in the experiment? (b) Draw the phase space diagram depicting the radial motion of the electron according to Sommerfeld. (c) Write down the spectral notation for a single electron atom having principle quantum number $n = 3$. 4½+1+2½

9. (a) Derive the expression for Landé g-factor considering the interaction of orbital and spin angular momenta. (b) Discuss in brief the selection rules governing transitions in atomic energy levels. (c) What is Raman shift? Why are the anti-Stokes lines less intense? 3½+2+2½