Bidhan Chandra College, Asansol

Department of Physics

Model Questions
4th Semester Honours
Electromagnetic Theory

A) Very short answer type questions

1. Write down the dimensions of the Poynting vector.
2. What do you mean by scattering cross section?
3. Write down the equation of motion of an electron in a radiation field
4. How does the total scattering cross-section depend on the frequency of the incident wave in Thomson scattering?
5. Define verdet's constant.
6. What is the velocity of electromagnetic waves in free space?
7. Name the conservation law on which the Poynting theorem is based.
8. Why Maxwell's equations are called correct relativistic equations?
9. Write down the equation of continuity for a steady current.
10. What do you mean by Numerical aperture of an optical fiber?
11. Show that the dimensions of displacement current is the same as that of current.
12. What is the phase difference between $\vec{E}$ and $\vec{H}$ for a good conductor?
13. How skin depth depends on the conductivity of the medium?
14. Write down the Maxwell's equation which signifies that an isolated magnetic pole is not possible.
15. A charging electric field induces a magnetic field. Write the mathematical relation to this effect.
16. Write down the dimensions of $\epsilon_0\mu_0$.
17. Write down the differential form of Poynting's theorem.
18. Write down the Maxwell's equation which is based on the Gauss' law of electrostatics.
19. How electromagnetic energy is shared between the electric and magnetic fields when an electromagnetic wave propagates through free space?
20. Write down the expression for wave impedance in terms of μ and ϵ when an electromagnetic wave propagates through a di-electric medium.

B) Short answer type questions

1. Write down the wave equations when an electromagnetic wave propagates through free space.
2. Find the unit and magnitude of the quantity $\sqrt{\frac{\mu_0}{\epsilon_0}}$.
3. What are Stoke and anti-Stokes lines in Raman spectra?
4. For silver the conductivity $\sigma = 3 \times 10^7 mho - m^{-1}$. Find the skin depth at a frequency of 10GHz.
5. Write down some applications of Optical fiber.
6. Show that for a good conductor skin depth $\delta = \frac{\lambda_c}{2\pi}$, where λ_c is the wave-length of electromagnetic waves in the conductor.
7. A step index fiber has a core of refractive index 1.52 and a cladding of refractive index 1.48. Determine its numerical aperture.

8. The intensity of light scattered by a polarizable substance is found to be 5 unit at 540nm. What will be the scattered intensity at 450nm?.
9. A plane electromagnetic wave traveling through a transparent medium is given by, $E = E_0 COS(0.4\pi \times 10^7 x - 6\pi \times 10^{14} t)$ in S.I. units. Determine the refractive index of the medium.
10. The electric field E of a plane electromagnetic wave in air is given by,
$$\vec{E} = \hat{\imath} 4 \times 10^{-6} cos\,(10^7 \pi t - kz) + \hat{\jmath} 4 \times 10^{-6} sin(10^7 \pi t - kz)\, V/m.$$
Find the value of k.
11. What do you mean by Faraday effect?
12. Starting from the equation of continuity and assuming Ohm's law, show that the charge density in a conductor obey the relation
$$\frac{\sigma\rho}{\epsilon} + \frac{\partial \rho}{\partial t} = 0$$
13. Why radio-communication in submarines becomes difficult at a depth of several meters of sea water?
14. What is the ratio of skin depth in copper at 1000Hz to that at 100MHz?
15. Write down the expression for loss tangent.

C) Long answer type questions

1. Explain how Maxwell generalized Ampere's circuital law. Hence, discuss the concept of displacement current. Distinguish between conduction current and displacement current.
2. Write down Maxwell's electromagnetic field equations. Explain the physical significance of each. Show that the equation of continuity is contained in Maxwell's equations.
3. State and establish Poynting's theorem. Express the theorem in the following differential form-
$$\frac{\partial u}{\partial t} + \vec{\nabla}.\vec{s} = 0$$
where $\vec{s}$ is the Poynting's vector and u is the total electromagnetic energy density.
4. a) Starting from Maxwell's equations derive the wave equation for electric and magnetic fields in free space.
a) Show that electric, magnetic and propagation vectors are all mutually perpendicular to each other.
b) Show that for electromagnetic waves in free space, energy is equally shared between electric and magnetic fields.
5. a) Starting from Maxwell's equations derive the wave equation in a conducting medium.
b) Hence, show that a plane electromagnetic wave is attenuated as it propagates through the medium.
c) What are skin effect and skin depth? "In the micro-wave region the surface of a pure silver waveguide and that of a silver coated brass waveguide appear to be identical"- Explain.
6. Starting from Maxwell's equations show that in a homogeneous isotropic di-electric medium of permittivity ϵ and permittivity μ-
a) the velocity of an electromagnetic wave is given by $v = \sqrt{\frac{1}{\epsilon\mu}}$
b) electric and magnetic fields are in phase.
c) energy is equally shared between electric and magnetic fields.
7. a) What is a wave-guide? Considering TE or TM waves propagating along a rectangular wave-guide with perfectly conducting walls, find the cut off wave-length (λ_c) and guide wavelength (λ_g)?
b) If (λ_0) be the corresponding free space wavelength, show that
$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$
c) What do you mean by TE, TM and TEM waves? Show that TEM waves cannot occur in a hollow wave-guide.
8. An electromagnetic wave is incident on the plane interface between two different media-

a) Show that the frequency of the wave remains unchanged upon reflection or refraction.
b) Find the relation between the angles of incidence, reflection and refraction.
c) Show that the wave vectors of the incident, reflected and refracted waves all lie on the same plane.

9. a) What do you mean by normal and anomalous dispersion? Draw the variation of refractive index of a medium with wavelength.
b) Establish Sellmeier's dispersion formula from electromagnetic theory. Discuss how Cauchy's dispersion relation can be deduced from it.
d) On the basis of Lorentz theory of dispersion, show that for a transparent di-electric solid at a given frequency,

$$\frac{n^2-1}{n^2+1}.\frac{M}{\varrho} = Constant$$

10. Derive an expression for the Rayleigh scattering cross-section. Distinguish between Rayleigh scattering and Thomson scattering.
11. Define scalar and vector potentials ϕ and $\vec{A}$ for an electromagnetic field, and show that under a gauge transformation of $\vec{A}$ and ϕ, the electromagnetic field equations are invariant.
Show that under suitable conditions ϕ and $\vec{A}$ satisfy the in-homogeneous equations

$$(\nabla^2 - \frac{1}{C^2}\frac{\partial^2}{\partial t^2})\vec{A} = -\mu_0 J \text{ and } (\nabla^2 - \frac{1}{C^2}\frac{\partial^2}{\partial t^2})\phi = -\frac{\varrho}{\epsilon_0}$$

where the symbols have their usual meanings.

12. a) What is Kerr magneto-optic effect and Kerr electro-optic effect? Write the down the differences between them.
e) What is Faraday effect? What are the conditions for observing Faraday effect?
13. a) Briefly outline the theory of scattering of electromagnetic radiation by a bound electron, and hence derive the condition for Rayleigh scattering.
b) Show that scattering cross-section in Rayleigh scattering is inversely proportional to the fourth power of the wavelength of scattering light.
c) Why is the sky at day time seen blue? Distinguish between Thompson and Rayleigh scattering.
d) Write a short note on Raman scattering. Distinguish between Raman and Rayleigh scattering.
14. a) Deduce the laws of refraction for plane waves at boundary of two di-electrics from electromagnetic theory. State Brewster's law?
b) Establish Fresnel's relations from electromagnetic theory. What do you mean by 's' and 'p' polarization?
15. a) What is Gauge transformation in connection to electric and magnetic fields? Write down the Lorentz gauge condition and hence derive the in-homogeneous wave equation for the scalar and vector potential.
b) Show that in a conductor, the magnetic field lags the electric field in time but leads the electric field in position.
16. a) What is an optical fiber? Describe the working principle of an optical fiber. Write down the applications of optical fiber.
b) What is meant by acceptance angle and numerical aperture of a fiber? Obtain an expression for numerical aperture of a step-index fiber.
17. a) Write down the wave equations when an electromagnetic wave propagates through an-isotropic di-elctric medium.
b) Explain the phenomenon of optical activity on the basis of electromagnetic theory.

D) Numerical Problems

1. Calculate the Poynting vector for a 60 W lamp at a distance 0.5 m from it.
2. Show that the displacement current in the di-electric of a parallel plate capacitor is equal to the conduction current in the connecting leads.

3. The intensity of sunlight on earth is 1300 Wm^{-2}. Assuming normal incidence, find the magnitude of the electric and the magnetic fields in sunlight.

4. a) Estimate the ratio of the skin depths in copper at frequencies of 1kHz and 10kHz.

b) Calculate the skin depth for a frequency of $10^6 Hz$. Given $\mu_0 = 4\pi \times 10^{-7} Am^{-2}$ and $\sigma = 5.8 \times 10^7 (\Omega\mathrm{m})^{-1}$.

5. The electric field associated with an electromagnetic wave is

$$\vec{E} = \hat{x}E_0 cos\,(kz - \omega t) + \hat{y}sin(kz - \omega t)$$

where E_0 is a constant. Find the corresponding magnetic field and the Poynting's vector.

6. The intensity of light scattered by a polarizable substance is found to be 5 (arbitrary unit) at 540nm. What will be the scattered intensity at $\lambda = 450\mathrm{nm}$?

7. a) Light is incident from air on a glass plate of refractive index 1.5. Calculate the Brewster's angle.

b) An electromagnetic wave of wavelength 653nm in air is incident normally on a metal surface of complex refractive index $\mathrm{n} = 0.17 + \mathrm{j}3.14$. Calculate the reflectivity of the metallic surface.

8. An electric field in free space is of the form

$$\vec{E}(\vec{r}, t) = E_0 \hat{x} sin^3(z - ct)$$

Answer the following- a) Can it be an electromagnetic wave? b) If yes, find its frequency or frequencies, c) What is the associated magnetic field?

9. A step index fiber has a core of refractive index 1.55 and a cladding of refractive index 1.53. Determine its numerical aperture and acceptance angle.

10. Show that about 4% of the light incident normally on an air-glass interface will be reflect back. Take the refractive index of glass=1.5.

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