Electromagnetic Theory OBE questions

Short Question Answers

1. When will be a plane electromagnetic wave be (a) plane polarized, and (b) circularly polarized.
2. A glass tube of length 20 cm , filled with sugar solution produces an optical rotation of 15^o . This solution is diluted to one-forth of its initial concentration, Calculate the optical rotation produced by 30 cm long tube.
3. Calculate the cut off frequency for radio communication between a space craft and mission controller on earth, given that the electron density in earth's atmosphere is $2 \times 10^{14}/m^3$.
4. Using Faraday's law, find the intrinsic impedance of free space.
5. A light ray enters from air to a fiber. The refractive index of air is 1. The fiber has refractive index of core equal to 1.5 and that of cladding equal to 1.48. Find the critical angle, the fractional refractive index and the acceptance angle?
6. Write down Maxwell's field equations in differential and integral forms and explain their physical meaning.
7. The intensity of sunlight received on earth is 2 cal $min^{-1}cm^{-2}$. Calculate the power an electric lamp should have in order to produce the same intensity as the sunlight at a distance of 1m
8. Find the skin depth at a frequency of 1.6MHz in aluminum , where σ=38.2MS/m and μ_r=1. Also find wave propagation constant and the wave velocity.

Theory Based Question

1. For a uniform plane electromagnetic wave propagating in a homogenous isotropic , dielectric medium , obtain the wave equations for the electric and magnetic field vector.
2. Consider a monochromatic plane wave whose electric field is given by $\vec{E}= E_0 e^{j(\omega t - kz)}\hat{\imath}$

(i) Show that the electric field lies in a direction perpendicular to the direction of propagation.

(ii) Determine the corresponding magnetic field.

(iii) Calculate the wave impedance and show that this is equal to the intrinsic impedance of the medium.

3. Obtain the wave equation for electromagnetic wave in a conducting medium and derive the dispersion relation for this medium. What is the physical significance of skin depth? State two of its applications

4. Show that the magnetic and electrostatic energy density are damped as the electromagnetic wave propagated in a good conducting medium. In what way does this damping manifest in the medium?
5. For a good conductor of conductivity σ and permittivity ε, show that uniform plane electromagnetic waves of angular frequency ω, such that $^{\sigma}/_{\omega\epsilon} \gg 1$,are heavily damped while propagating through the medium.
6. For plane electromagnetic wave of angular frequency ω, such that $^{\sigma}/_{\omega\epsilon} \ll 1$, show that the medium behaves like a dielectric.
7. Drive the dispersion relation for a plane monochromatic wave propagating in a conducting medium. Show that electric and magnetic fields are 45^{o} out of phase.
8. Starting from the wave equation for E and H in a conducting medium, derive an expression for the ration of the electric and magnetic energy densities and show that the E leads H by an angle of $\pi/4$.
9. Discuss the limitations of Ampere's law and prove that displacement current is equal to the time rate of change of electric displacement vector D.
10. Define a plasma, stating briefly the conditions for its existence. Starting from Maxwell's equations, derive an expression for plasma angular frequency $\omega_{p.}$
11. What is the significance of plasma frequency in relation to radio wave propagation in ionosphere taking into account waves of frequency less than $\omega_p$and more than ω_p?
12. Maxwell modified Ampere's law to make it consistent with equation of continuity. Explain the significance of displacement current.
13. Show that Maxwell's equations can be expressed as two coupled second order partial differential equations in terms of scalar and vector potentials. How does the above equations get simplified using Lorentz gauge?

Problem Based/ Application based Questions :

1. At 3 GHz, a uniform plane wave polarized in y direction propagates in +x direction in a non- magnetic medium having a dielectric constant ε_r =2.5 and a loss tangent 10^{-2}. Show that the medium behaves as a low loss dielectric. Determine the distance over which the amplitude of propagating wave will be reduced by half.

2. Communication is to be established between two stations that are 1500 km apart. Calculate the maximum frequency one may chose for communication using the ionosphere as a reflector if the height and plasma frequency of ionosphere at the point of refection are 250 km and 12MHz respectively

3. A plane wave is incident normal to the surface of seawater ($\mu_r = 1$, $\varepsilon_r = 79$, $\sigma = 3$S/m). The electric field is parallel to the surface and is 1V/m just inside water. At what depth would it be possible for a submarine to receive a signal, if the receiver required a field intensity of 10 μ V/m at 20 kHz.

4. A 100 MHz plane e.m. wave travelling in +z direction in an unbounded lossless dielectric medium with $\varepsilon_r = 4$ and $\mu_r = 2$ has a time-averaged Poynting vector of 5 Wm^{-2}. Find the (a) phase velocity, (b) intrinsic impedance of the medium (c) root mean square amplitude of electric field **E**, and magnetic field **H** respectively

5. An H field travels in the $-\mathbf{a}_z$ direction with a phase shift constant of 30.0 rad/m and the amplitude of $(1/3\pi)$ A/m . If the field has the direction $-\mathbf{a}_y$ when t=0 and z=0, write suitable expressions for E and H. Determine the frequency and wave length.

6. (a) For normal incidence upon an interface between two lossless media, we define the rations of the time-average incident, reflected, and transmitted powers as $R = \frac{(P_r)_{ave}}{(P_i)_{ave}}$ and $T = \frac{(P_t)_{ave}}{(P_i)_{ave}}$, Prove that R+T=1: that is energy conservation hold for reflevtion and transmission. (b) Express R and T interms of η_1 and η_2
7. Consider a plane polarized electric wave
8. $E = E_o exp\left\{i\omega\left[t - \frac{n}{c}(K \cdot r)\right]\right\}$ derive from Maxwell's equations the relations between E,K and the H field . Obtain the expression for the index of refraction n in terms of ω, ε,μ and σ (conductivity)

   Show that refractive index $n = \left[\frac{\mu\varepsilon}{\mu_o \varepsilon_o}\left(1 - \frac{i\sigma}{\omega\varepsilon}\right)^{1/2}\right]$
9. The magnetic field of a plane wave travelling in a non-magnetic medium is given by the following expression:

$\bar{H} = 0.05\left[a_y - ja_x\right]e^{-j6\pi z}$ A/m

(a) Find the frequency and direction of wave propagation .

(b) Find the corresponding electric field in phasor form.

(c) Determine the polarization of the wave (Linear, elliptical or circular) and state of polarization (right handed/ left handed)

(d) Compute the time-average power density associated with the wave