Kharagpur College
Dept. of Physics

Solve the Following Problems on E-M Theory (C13T)

Q.1 (a) Write down Maxwell's electromagnetic field equations and explain physical significance of each. 4

(b) Derive the law of conservation of charge from Maxwell's field equation. 2

c) What is displacement current? Explain why and how Ampere's circuital law for steady current was modified to include displacement current. 1+3

d) Consider a medium of dielectric constant K=80 and conductivity $\sigma = 10^{-3}$ S/m. Compare the value of conduction current and displacement current densities at frequencies 100 Hz and 100 MHz. 4

e) A parallel plate capacitor with circular plates of radius 1m has a capacitance of 1 nF. At t=0, it is connected for charging in series with a resister R=1 MΩ across a 2 Volt battery (see Fig-1). Calculate the magnetic field at a point P, halfway between the center and the periphery of the plates, after t= 10 ms. (The charge on the capacitor at time t is $q(t) = CV(1-\exp(-t/\tau))$, where the time constant τ is equal to CR). 5

f) Show that $\vec{B} = \frac{1}{c}(\vec{n} \times \vec{E})$, where $\vec{n}$ the unit vector in the direction of propagation and c is the speed of light in free space. 1

g) Show that for electromagnetic waves in free space, energy is equally shared between electric and magnetic fields. 2

h) Calculate the electric and magnetic fields produced by the radiation coming from a 1kW bulb at a distance of 3 m in free space. Assume the efficiency of the bulb is 25% and it is a point source. 4

i) Calculate the average value of Poynting's vector for a plane wave travelling in free space having an electric field amplitude $E_o = 50$ μV/m. 2

j) Calculate the frequency at which skin depth in sea water is 1 m. Given for sea water, conductivity $\sigma = 4.3\ (\Omega\ m)^{-1}$ and relative permittivity equal to 1. 2

k) Establish Poynting's theorem. Write down the Poynting's vector with its unit. 3+1