Instructor: Aneesh. S
Office: EE514, aneesh@ee.iith.ac.in

1. A plane wave traveling in free space is incident normally on a lossless dielectric medium having relative permittivity $\epsilon_r = 4.0$. Determine the fraction of the incident power that is transmitted into the medium.

2. Find the skin depth δ and attenuation constant α at frequency $f = 3 \times 10^6 Hz$ in aluminium having conductivity $\sigma = 38 \times 10^6$ S/m and relative permeability $\mu_r = 1$. Also find the complex propagation constant γ and the phase (wave) velocity v_p in the medium.

3. A plane wave in free space has electric field

$$E(x,t) = \hat{a}_z \, 24\pi \cos(\omega t - k_0 x) \text{ V/m}.$$

Consider a square of side 10cm lying in the plane $x + y = 1$. Find the total time-averaged power (in mW) crossing the square.

4. A 1 bulb radiates isotropically; its radiated power (efficiency) is 25. Find the electric and magnetic fields at $r = 3$ in free space.

5. Derive, from first principles, the expression for the intrinsic impedance of a lossy dielectric medium. Assume a one-dimensional electromagnetic wave with field components E_x and H_y propagating in the z-direction. Hint:

$$\eta = \frac{E_x}{H_y}.$$

If the lossy dielectric has intrinsic impedance $\eta = 200\angle 30^\circ \ \Omega$ at frequency ω. A plane wave propagates in the medium with magnetic field

$$\boxed{H(x,t) = 10\, e^{-\alpha x} \cos(\omega t - \tfrac{1}{2}x)\, \hat{a}_y \text{ A/m}}.$$

Find:

   (a) the electric field $E(x,t)$,
   (b) the attenuation constant α,
   (c) the skin depth δ, and

6. Using the skin depth expression

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}, \qquad \mu = \mu_0,$$

compute the skin depth for copper ($\sigma_{\text{Cu}} = 5.8 \times 10^7$ S/m) and aluminium ($\sigma_{\text{Al}} = 3.5 \times 10^7$ S/m) at $f_1 = 60$ Hz and $f_2 = 1 \times 10^6$ Hz. Further, determine:

   (a) The factor by which δ changes when frequency increases from f_1 to f_2.
   (b) The effect on δ if the conductivity of copper is doubled at f_2.