Exam-04 – Electrodynamics[1]

1. Consider a EM plane wave (EM = Electro-Magnetic) with $\hat{E}$, $\hat{H}$ and $\hat{k}$ being unit vectors along the $\vec{E}$-, $\vec{H}$-field, and propagation direction, respectively. Considering the triplet $\hat{E}$, $\hat{H}$ and $\hat{k}$ . . .
   (a) . . . determine and sketch the direction of the missing quantity, if . . .
      (i) $\vec{E}$ and $\vec{H}$ point along the –*z* and *x* direction, respectively,
      (ii) $\hat{k}$ and $\vec{H}$ point along the –*y* and *z* direction, respectively, and
      (iii) $\hat{k}$ and $\vec{E}$ point along the *x* and –*y* direction, respectively.
   (b) Determine and sketch the direction of the . . .
      (i) Poynting vector $\vec{S}$, if $\vec{E}$ and $\vec{H}$ point along the *z* and –*x* direction, respectively,
      (ii) Poynting vector $\vec{S}$, if $\hat{k}$ and $\vec{E}$ point along the –*x* and *y* direction, respectively, and
      (iii) $\vec{E}$ vector, if $\vec{S}$ and $\vec{H}$ point along the *y* and –*z* direction, respectively.
2. The frequency of EM radiation in a microwave oven is f = 2.45 GHz. A non-magnetic liquid (e.g. water with relative permittivity ε_r = 80), located in a cup, is heated in the oven. At frequency f, the liquid has a resistivity of ρ = 2 Ω m and a conductivity σ.
   (a) Draw the experimental setup. Determine, by calculation, if the liquid is a "good conductor" or "weak conductor".
   (b) Determine the absorption constant α, and the absorption length $1/\alpha$ of the EM radiation.
   (c) A cylindrical cup containing the liquid has a diameter of $2r$ = 10 cm. What is the desired relationship (inequality relationship) between $2r$ and $1/\alpha$? Is the relationship satisfied?
   (d) Determine the phase constant β of the EM wave when propagating in the liquid. Determine λ of the EM wave when propagating in air.
3. A cell phone has an EM-wave output power of 1 W. The antenna is located at the lower end of the cell phone. The center of the head of a person operating the cell phone is 20 cm away from the antenna. Sketch the experimental setup. Assuming that EM-wave is not absorbed by human tissue, determine the magnitude of the Poynting vector, $|\vec{S}_{cell}|$, at the center of the head. Compare the value of $|\vec{S}_{cell}|$ with the value of $|\vec{S}_{solar}|$ (solar radiation on Earth).
4. Visible light is incident on an air-glass boundary and air-diamond boundary. Glass (SiO_2) has a refractive index of n = 1.45. Diamond (carbon) has a refractive index of n = 2.2. The relative permittivity ε_r and the refractive index are related by $n = (\varepsilon_r)^{1/2}$.
   (a) Sketch the experimental setup for normal incidence. Determine the amplitude reflection coefficient (Fresnel coefficient) at the (i) air-glass and (ii) air-diamond boundary.
   (b) Determine the power reflection coefficients for these two cases. Explain if the results are consistent with your experience.
5. Determine if the following statements are (i) true or (ii) false. Explain your answers.
   (a) When an EM-wave (EM = Electro-Magnetic) is reflected off the surface of an ideal metal, the polarization directions of the incident $\vec{E}$-field and reflected $\vec{E}$-field are the same.
   (b) Superimposing a right-rotating circularly polarized wave with a left-rotating circularly polarized wave can result in a linearly polarized wave.

[1] Always give units! Show your work! Put your name on the first page.