Exam-04 – Electrodynamics (also called Electromagnetics)[1]

1. Assume that water has the following properties: Resistivity ρ = 100 Ω m; Relative permittivity ε_r = 80; Magnetic susceptability $\chi_m = \mu_r - 1 = 0$. Consider the propagation of the following EM-waves (EM = Electro-Magnetic) in water: (i) an RF-wave (radio-frequency wave) with frequency 1 MHz; and (ii) a light-wave with wavelength 600 nm.
   (a) For each of the two EM-waves, determine if water is considered a "weak conductor" or a "good conductor".
   (b) The "absorption constant" α has the reciprocal $1/\alpha = \alpha^{-1}$. The quantity α^{-1} is frequently called "absorption length" and has a unit of length (e.g. meter). Explain the meaning of the "absorption length" α^{-1}.
   (c) For each of the two EM-waves, calculate the "absorption length" α^{-1}.
   (d) When considering communication with submarines, which are naturally immersed in water, what are the conclusions you draw with respect to the suitability of the two types of EM-waves?
   (e) Based on your calculation, would a distance of 25 m in water be considered as essentially transparent for visible light? Explain your answer.

2. Consider a harmonic plane EM-wave propagating in air along the *z*-direction and incident at normal incidence on a dielectric material having a relative permittivity ε_r = 10. Part of the EM-wave is reflected at the air-dielectric boundary and part of the EM-wave is transmitted through the boundary. The incident EM wave has its electric field vector along the *x*-direction and an electric field amplitude of E_{x0i} = 10 V/m.
   (a) Calculate the numerical values of the amplitude reflection coefficient, *r*, and the amplitude transmittance coefficient, *t*, at the air-dielectric boundary.
   (b) Calculate the numerical values of the electric field amplitudes of the reflected wave, E_{x0r}, and transmitted wave, E_{x0t}.
   (c) Determine the direction of the ***H*** field of the incident, reflected, and transmitted wave. Calculate the numerical values of the magnetic field amplitudes of the incident wave, H_{0i}, reflected wave, H_{0r}, and transmitted wave H_{0t}.
   (d) Calculate the numerical values of the time-averaged Poynting vector, using $\boldsymbol{S} = ½\, \boldsymbol{E} \times \boldsymbol{H}$, for the incident, reflected and transmitted wave.
   (e) Compare the calculated numerical values. Is the power density (i.e. Poynting vector) transported by the incident wave equal to the sum of the power densities transported by the reflected and transmitted wave? Explain the result.

3. Determine if the following statements are true or false. Explain your answer with a few words or a drawing.
   (a) Emitting a continuous microwave (EM wave) into an empty cavity bounded by an ideal metal (having infinite conductivity) causes the EM wave to bounce around in the cavity, thereby increasing the electric field strength so that the power "fed" into the cavity may ultimately cause sparkes that consume the power of the EM-wave.
   (b) Consider an air-dielectric boundary plane located at *y* = 0 and an *incident* EM-wave propagating along the −*y* direction and having its ***E***-vector polarized along the −*x* direction. Then the ***H***-vector of the *reflected* wave is polarized along the +z direction.

[1] Always show your work, always give units, and write your name on first page. Bold italic letters are meant to be vectors, i.e. ***E*** and ***H*** are vectors.