Part I

1.) For a sour-free polarized medium where ρ=0, **J**=0, and $\mu=\mu_0$, but where there is a volume density of polarization **P**, a single vector potential $\boldsymbol{\pi}_e$ may be defined such that

$$\vec{H} = j\omega\varepsilon_0\nabla\times\vec{\pi}_e$$

a) Express electric field intensity E in terms of $\boldsymbol{\pi}_e$ and **P. (8%)**

b) Show that $\boldsymbol{\pi}_e$ satisfies the nonhomogeneous Helmholtz's equation

$$\nabla^2\pi_e + k_0^2\pi_e = -\frac{P}{\varepsilon_0}$$

The quantity $\boldsymbol{\pi}_e$ is known as the ***electric Hertz potential.* (7%)**

2.) The magnetic field intensity of a linearly polarized uniform plane wave propagating in the +y-direction in seawater [ε_r=80, μ_r=1 σ=4 S/m] is

$$\vec{H} = \vec{a}_x 0.1\sin(10^{10}\pi t - \frac{\pi}{3})\text{at y=0.}$$

a) Determine the attenuation constant, the phase constant, the intrinsic impedance, the phase velocity, the wavelength, and the skin depth. (9%)

b) Find the location at which the amplitude of H is 0.01 (A/m).(3%)

c) Write the expressions for **E**(y,t) and **H**(y,t) at y=0.5 m as functions of t.(3%)

3.) There is a continuing discussion on radiation hazards to human health. The following calculations will provide a rough comparsion.

(a) The U.S. standard for personal safety in a microwave envirement is that the power density be less than 10 mW/cm^2. What are the corresponding electric and magnetic fields of the U.S. standard? (5%)

(b) It is estimated that the earth receives radiant energy from the sun at a rate of about 1.3kW/m2 on a sunny day. Assuming a monochromatic plane wave, calculate the equivalent amplitudes of the electric and magnetic field intensity vectors. (5%)

4.) A right-hand circularly polarized plane wave represented by the phasor

$$\vec{E}(z) = E_0(\vec{a}_x - j\vec{a}_y)e^{-j\beta z}$$

impinges normally on a perfectly conducting wall at z=0

a) Determine the polarization of the reflected wave. (5%)

b) Find the induced current on the conducting wall. (5%)

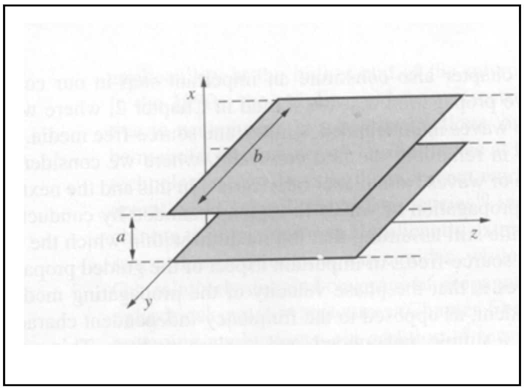
(μ_0= 4π x 10^{-7} H/m, ε_0=(1/36π) x 10^{-9} F/m=8.854 x 10^{12} F/m, c=3 x 10^8 m/s)

Part II

1. (a) A uniform plane wave, in which $\vec{E}_i(z) = \hat{x}E_{i0}e^{-j\beta_1 z}$ and $\vec{H}_i(z) = \hat{y}\frac{E_{i0}}{\eta_1}e^{-j\beta_1 z}$ where $\beta_1 = \omega\sqrt{\mu_1\varepsilon_1}$ and $\eta_1 = \sqrt{\mu_1/\varepsilon_1}$ are, respectively, the propagating constant and the impedance for medium1, propagating in the +z direction in a simple lossless ($\sigma_1 = 0$, μ_1, ε_1) medium occupying the half-space $z < 0$ and normally incident from the left on a lossless dielectric ($\sigma_2 = 0$, μ_2, ε_2) medium that occupying the $z > 0$ half-space. Find the reflective wave, transmission wave, reflective coefficient, and transmission coefficient. (20 points)

   (b) Calculate the reflection and transmission coefficients for a radio-frequency uniform plane wave traveling in air incident normally upon a calm lake. Assume the water in the lake to be lossless with a relative dielectric constant of $\varepsilon_r = 81$. Note that for water, we have $\mu_r = 1$. (5 points)

2. (a) In an ideal parallel-plate waveguide, the plates are assumed to be infinite in extent in the y and z directions. In practice, the width b of the guide in the y direction is finite but is typical much larger than a. The material between the plates is assumed to be a lossless dielectric. Find the field solutions for TE and TM waves. (16 points)



   (b) An air filled parallel-plate waveguide has a plate separation of 1.25 cm. Find (i) the cutoff frequencies of the TE_0, TM_0, TE_1, TM_2, and TM_2, (ii) the phase velocities of those modes at 15 GHz, (iii) the lowest-order TE and TM mode that cannot propagate in this waveguide at 25 GHz. (9 points)

Part III

1. (10 %) For air-filled rectangular waveguide design, please show the cutoff frequency of TE_{mn} modes.
2. (10 %) Show the TEM wave cannot exist in a single-conductor waveguide. The coaxial line can support TEM modes?
3. (10 %) Determine the lowest order of resonator frequency of an air-filled rectangular resonator that measures 1 cmX10 cmX10 cm.
4. (10 %) Two parallel plates lies in the plates z=0 and z=d, the plates are the potentials $\Phi = 0$ and $\Phi = -V_0$ respectively. An electron enters the region between the plates at the origin and t=0 and with an initial velocity $\tilde{\mathbf{v}} = \hat{\mathbf{y}}\mathrm{v}_\mathrm{a} + \hat{\mathbf{z}}\mathrm{v}_\mathrm{b}$. Find the velocity and position of the electron as a function of time.
5. (10 %) Explain the difference of Hertzian dipole antenna and the half-wave dipole antenna.