1.

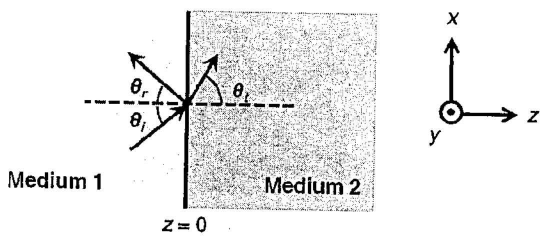
(a) (2%) Write down the differential form of Ampère-Maxwell equation (i.e. Ampère's circuital law incorporating Maxwell's displacement current term).

(b) (2%) Write down the differential form of the equation of continuity.

(c) (2%) Write down the differential form of Gauss's law.

(d) (4%) Derive Gauss's law from Ampère-Maxwell equation and the equation of continuity.

2. Consider a plane wave obliquely impinging upon a boundary between two lossless dielectric materials with different permittivities as illustrated in the figure below. Both medium 1 and medium 2 are nonmagnetic, i.e. their permeabilities are both μ_0. The relative permittivities of medium 1 and medium 2 are 12 and 4, respectively.



The E field of the incident wave is as follows.

$$\vec{\mathbf{E}}_i(x,z,t)=5\left(\vec{\mathbf{a}}_x\cos\theta_i-\vec{\mathbf{a}}_z\sin\theta_i\right)\cos\left(\omega t-\beta_1 x\sin\theta_i-\beta_1 z\cos\theta_i\right)\quad \text{(V/m)},$$

where $\vec{\mathbf{a}}_x$ and $\vec{\mathbf{a}}_z$ are unit vectors pointing in x and z directions, respectively, and β_1 is the phase constant of medium 1.

(a) (4%) Write down the phasor expression for the E-field of the incident wave, i.e. $\vec{\mathbf{E}}_i(x,z)$.

(b) (2%) What is the polarization of the incident wave? (e.g., linear polarization, right-hand circular polarization, left-hand elliptical polarization.)

(c) (2%) Calculate the intrinsic impedance of medium 2.

(d) (2%) Calculate the Brewster angle for parallel polarization. Express it in degree.

(e) (2%) Calculate the Brewster angle for perpendicular polarization. Express it in degree.

(f) (2%) If the angle of incidence θ_i is 30°, determine the angle of refraction θ_t. Express it in degree.

(g) (4%) If θ_i is 30°, find the phasor expression for the E-field of the reflected wave, i.e. $\vec{\mathbf{E}}_r(x,z)$.

(h) (2%) Let β_2 be the phase constant of medium 2. Express β_2 in terms of β_1.

(i) (5%) If θ_i is 30°, find the phasor expression for the E-field of the transmitted wave, i.e. $\vec{\mathbf{E}}_t(x,z)$.

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3. For a transmission line with four distributed parameters R, L, G, and C. The line is in the medium with constitutive parameters (ε, μ, σ).
   (a) (10%) Explain why $G/C = \sigma/\varepsilon$.
   (b) (10%) Explain why $L\,C = \mu\,\varepsilon$.
   (c) (10%) Assume there is such a transmission line of very short length $\triangle z$. Draw its equivalent circuit.

4.
   (a) (2%) What is the dominant mode of the rectangular waveguide? What is the dominant mode of a parallel-plate waveguide?
   (b) (3%) Why the TEM waves cannot exist in the rectangular waveguide?
   (c) (5%) What should be the size of an air-filled cubic cavity made of copper in order for it to have a dominant frequency of f_0 GHz?
   (d) (5%) Define the quality factor of the cavity resonator. Assuming the copper conductivity is σ, find the quality factor at that frequency.

5. (20%) A signal generator is to feed equal power through a lossless air transmission line with a characteristic impedance 50 Ω to two separate loads, Z_{LA} = 100 + j100 (Ω), and Z_{LB} = 200 – j100 (Ω). As shown in Fig. 1, a single-stub method is used to match the loads to the line. Use the Smith Chart as shown in next page to determine the required lengths, l_A, l_B, and l_C of the transmission lines. (You should provide 4 possible solutions, and draw all your results in your answer sheets.)

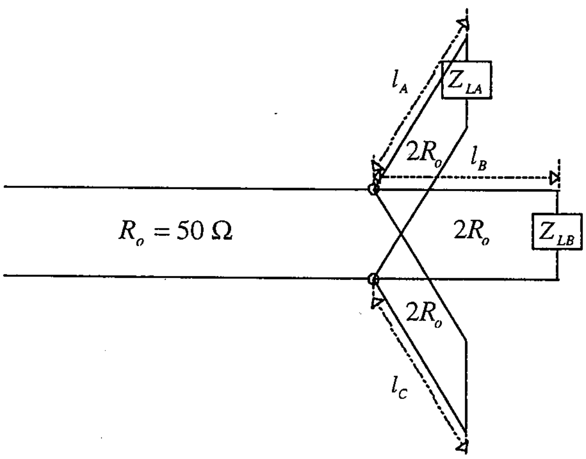

Fig. 1

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The Smith Chart