UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, APRIL 16, 2001

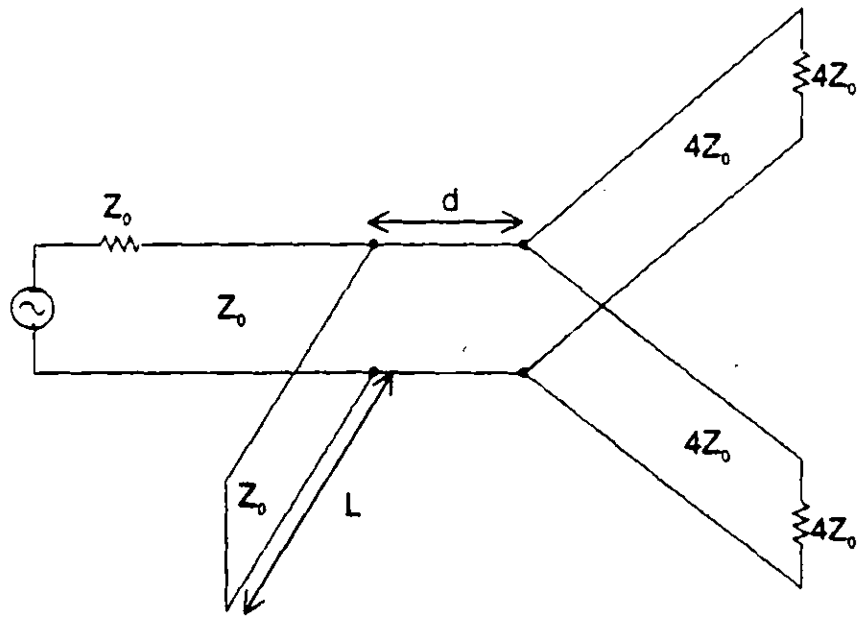
Third Year - Program: Engineering Science

ECE357 - ELECTROMAGNETIC FIELDS

Exam Type: A

Examiner: A. Lüttgen

Problem 1: **(20/120 Marks)**
Use the single-stub matching method to match the two matched $4Z_0$ lines to the Z_0 line (see figure below). Find d and L in terms of λ. All lines are lossless.



Problem 2: **(25/120 Marks)**
A uniform plane wave, represented by the phasor

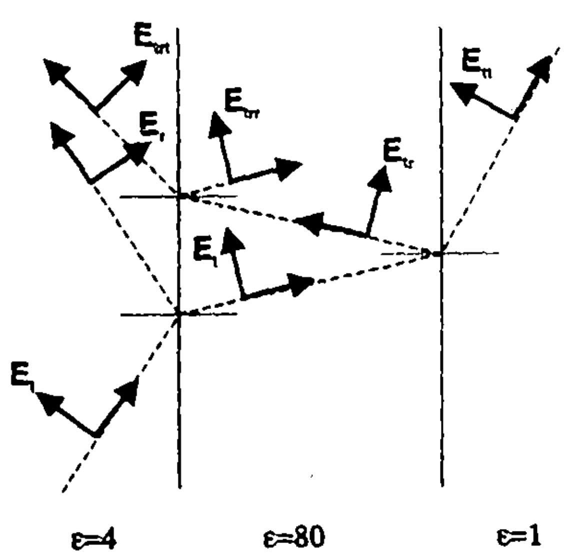
$$\underline{E}_i = E_{i0}(\hat{\underline{x}}\cos(\theta_i) - \hat{\underline{z}}\sin(\theta_i) + j\hat{\underline{y}})e^{-j(x\sin(\theta_i) + z\cos(\theta_i))}$$

for its electrical field strength, propagates in air and is incident on glass (ε_r=4) at z=0 with an angle of incidence $\theta_i = 45°$. Determine its polarization. Find the electric field phasors and their instantaneous expressions for the transmitted and reflected waves and determine their polarization.

Problem 3: **(25/120 Marks)**
A parallel-polarized uniform plane wave with the following phasor representation for its electric field

$$\underline{E}_i = E_{i0}(\hat{\underline{x}}\cos\theta_i - \hat{\underline{z}}\sin\theta_i)e^{-j\beta_1(x\sin\theta_i + z\cos\theta_i)}$$

propagates in semi-infinite medium 1 with ε_r=4 and is incident on the boundary with medium 2 (ε_r=80) at $z = -4\pi\beta_1\sqrt{1+\varepsilon_1/\varepsilon_2}$ (boundary1). The transmitted wave is incident on the boundary with semi-infinite medium 3 (ε_r=1) at z=0 (boundary 2).The angle of incidence in medium 1 is given by $\sin\theta_i = 1/(\sqrt{1.05})$.
(a) Find the Brewster angles and critical angles of no reflection for all transitions in the figure below.
(b) Find the angle θ_t for transmission from medium 1 to medium 2 at boundary 1 and the associated reflection and transmission coefficients for the incident wave.
(c) Find reflection and transmission coefficients at boundary 2 for the wave transmitted into medium 2.
(d) Find reflection and transmission coefficients at boundary 1 for the wave reflected from boundary 2.
(e) Find the amplitudes of all electric field vectors in the figure below.



Problem 4: (25/120 Marks)

At low frequencies the Earth-Ionosphere system acts as a parallel-plate waveguide. Assume the electron density in the Ionosphere to be a step function of the altitude with $N=0$ below 70km, $N=1.2\ 10^{10}\ m^{-3}$ between 70 and 90 km, $N=9.6\ 10^{10}\ m^{-3}$ between 90 and 130 km, $N=4.8\ 10^{11}\ m^{-3}$ between 130 and 210 km, $N=1.3\ 10^{12}\ m^{-3}$ between 210 and 300 km, and $N=2\ 10^{12}\ m^{-3}$ above 300 km. The ground has a relative permittivity of $\varepsilon_r=10$ and a conductivity of $\sigma=10^{-2}$ S/m. Determine at approximately what frequency this system fails to act as a waveguide and at what frequencies there might be changes to its wave guiding properties. ($(2\pi f_p)^2 = (Ne^2)/(m_e\varepsilon_0)$)

Problem 5: (25/120 Marks)

Find the array factor and plot the normalized polar radiation pattern of an array of seven isotropic elements spaced by d and having excitation amplitude ratios 1:2:3:4:3:2:1 for the following two cases:

(a) $d=\lambda/2$ and $\xi=0$.

(b) $d=\lambda/4$ and $\xi=-\pi/2$.

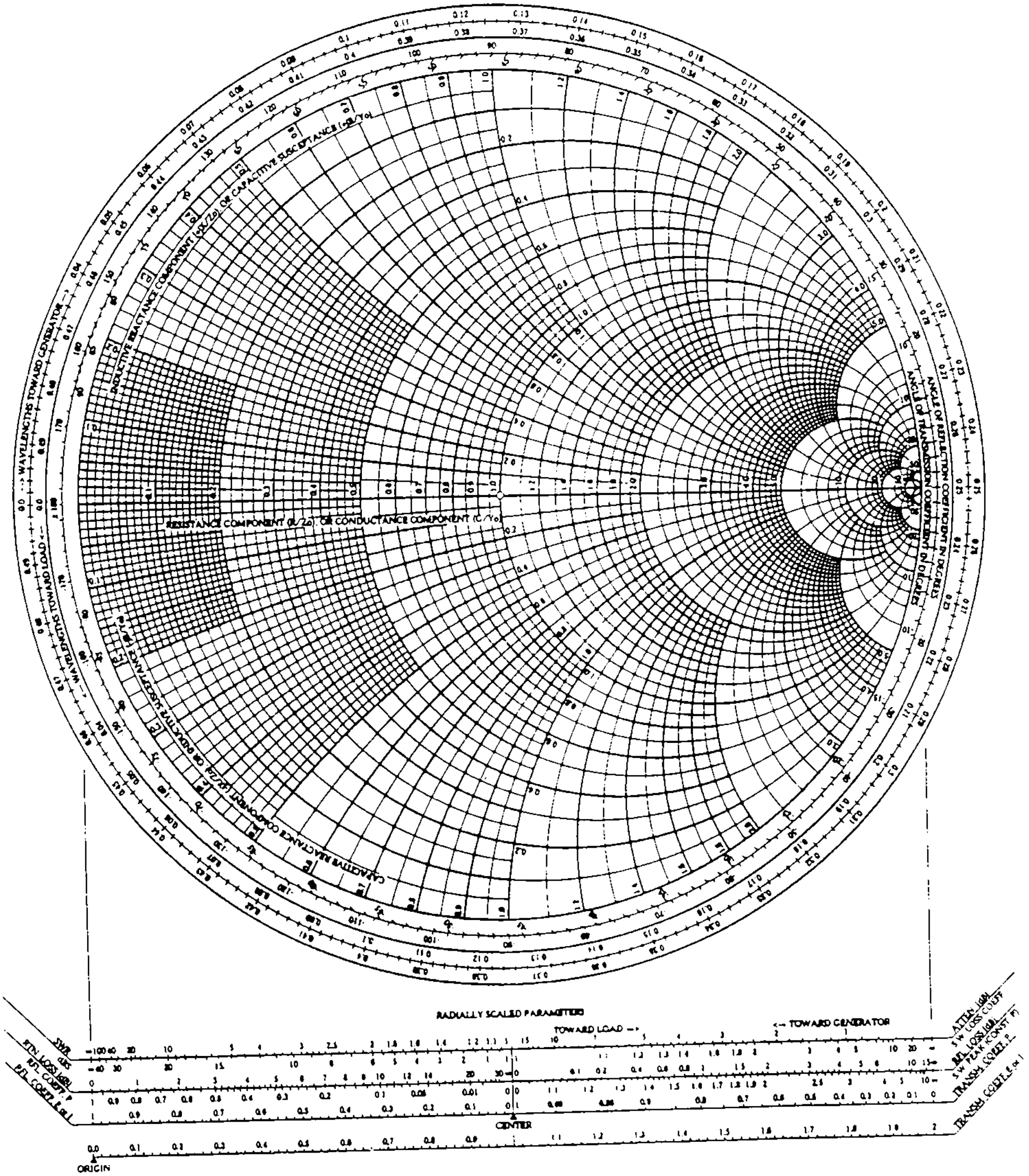
Constants:

$$\varepsilon_0 = 8.8542 \cdot 10^{-12}\left[\frac{As}{Vm}\right] \qquad \mu_0 = 4\pi \cdot 10^{-7}\left[\frac{Vs}{Am}\right]$$

$$e = 1.602 \cdot 10^{-19}[C] \qquad m_e = 9.11 \cdot 10^{-31}[kg]$$

The Complete Smith Chart

Black Magic Design



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