THE UNIVERSITY OF BRITISH COLUMBIA
Department of Electrical and Computer Engineering

ELEC 311 – Electromagnetic Fields and Waves
2025 W1

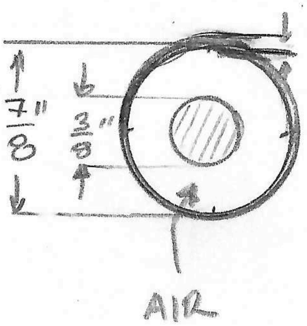
Practice Final Exam 2

Read the entire question before answering. Answers should be short and to the point. ***Use sketches to explain your solution as required****. Clarity, conciseness, and presentation all count. Solution = Intuition (strategy) + Execution (calculation). Numerical answers should include the symbol, quantity, and units, e.g.,* $\boldsymbol{\alpha} = \mathbf{5\ Np/m}$*, and be inserted within the large square brackets. The actual exam will be printed on tabloid-size paper.*

1. Transmission Lines [25]

A rigid coaxial line used in a transmitter operating at 3 GHz is fabricated from annealed copper with $\sigma = 5.8 \times 10^{7}$ S/m and has an air dielectric. The diameter of the outer shell is 7/8-inch. The thickness of the outer shell is 0.032 inch. The diameter of the inner conductor is 0.375 inch.

a. [10] Determine the per-metre values of *L, C, G,* and *R* for the line.



WE CAN REFER DIRECTLY TO THE FORMULAS FROM RAMO et al. TO OBTAIN THE ANSWERS

[L = 0.154 μH/m]

[C = 72.1 pF/m]

[G = 0 S/m]

[R = 0.699 Ω/m]

b. [10] Determine the characteristic impedance (Z_0) and propagation constant ($\gamma = \alpha + j\beta$).

WE CAN USE THE FORMULAS FROM RAMO OR $Z_0 = \sqrt{Z/Y}$ & $\gamma = \sqrt{ZY}$

[$Z_0 = 46.2 - j\,0.0056\ \Omega$]

[$\gamma = 0.0076\ \mathrm{Np/m} + j\,62.8\ \mathrm{rad/m}$]

c. [5] Determine the wavelength and velocity of propagation.

$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{62.8}$

[$\lambda = 0.10\,\mathrm{m} = 10\,\mathrm{cm}$]

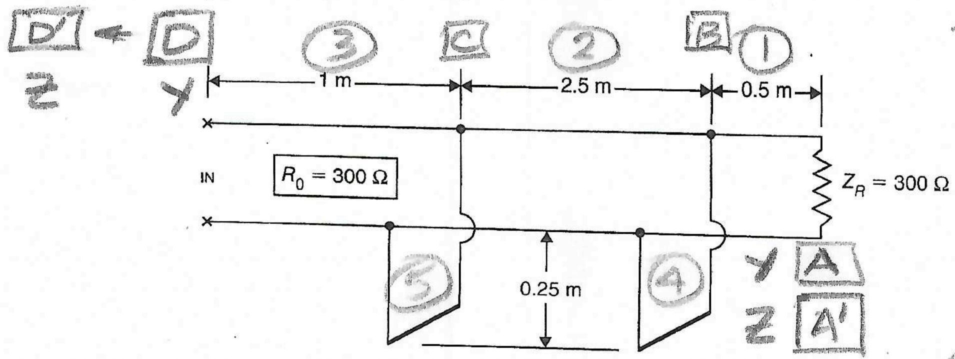
$v = \frac{\omega}{\beta} = \frac{2\pi \times 3\times10^{9}}{62.8}$

[$v = 3.00 \times 10^{8}$ m/s]

NOT A SURPRISE: TEM WAVE IN AIR-FILLED LINE

2. Smith Charts and Stubs [25]

A 4-m long, stub-supported, lossless, air-dielectric line has a characteristic impedance of 300 Ω and is driven by a 300 MHz source. As depicted in the figure below, it is terminated by a 300-Ω resistive load and supported by shorted quarter-wave stubs.



(m)	(λ)
0.25	1/3
0.5	2/3
1.0	1 1/3
2.5	3 1/3

$\lambda_0 = 0.75$ m

With no changes in the physical dimensions, the line is then operated at 400 MHz instead. For this new mode of operation:

a. [15] Use a Smith Chart to find the VSWR on each of the three sections of the line:

y_{in} (STUB) = $j0.58$

① [s = 1]
② [s = 1.75]
③ [s = 2.3]

b. [5] Use a Smith Chart to find the VSWR on the support stubs:

ON THE SUPPORT STUBS, $|\Gamma| = 1$ AND S = ∞

④ [S = ∞]
⑤ [S = ∞]

c. [5] Use a Smith Chart to find the input impedance of the line:

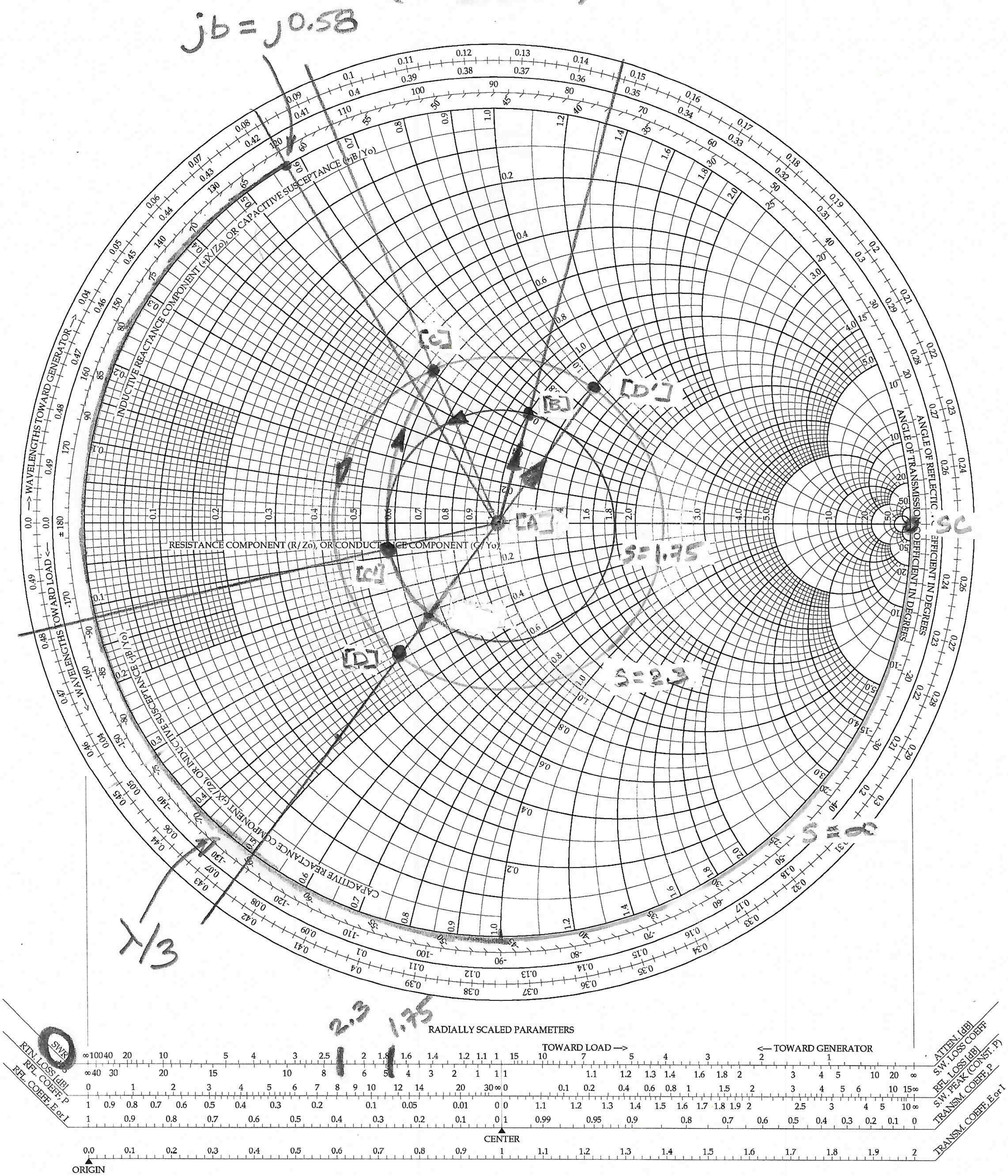
[$Z_{in} = 369 + j276\ \Omega$]
($z_{in} = 1.23 + j0.92\ \Omega$)

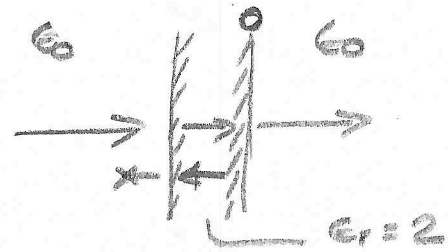
STEPS

1. PLOT $z_R = Z_R/Z_0$ [A']
2. INVERT TO YIELD y_R; [A]
3. 2λ/3 TOWARDS GENERATOR
4. ADD SUSCEPTANCE OF FIRST STUB; ASSESS 'S' [B]
5. 3 1/3 λ TOWARDS GENERATOR [C']
6. ADD SUSCEPTANCE OF SECOND STUB; ASSESS 'S' [C]
7. 1 1/3 λ TOWARDS GENERATOR [D]
8. INVERT TO YIELD z_{in} [D']

Smith Chart

(ADMITTANCE)





3. Electromagnetic Waves [25]

An electromagnetic plane wave with a frequency of 10 GHz is normally incident on a dielectric slab of thickness *t* with relative permittivity = 2.

a. [5] Find the wavelength in free space and in the slab.

$\lambda_1 = \frac{\lambda_0}{\sqrt{\epsilon_r}}$

FREE SPACE [$\lambda_0 = 3.0$ cm]

SLAB [$\lambda_1 = 2.12$ cm]

b. [5] What are the boundary conditions that must be applied at the front and rear surfaces of the slab? What boundary conditions can be ignored in this case and why?

[THE TANGENTIAL COMPONENTS OF E & H MUST BE CONTINUOUS ACROSS THE SURFACES.]

[THERE ARE NO NORMAL COMPONENTS OF D & B, SO THE REQUIREMENT THAT THEY BE CONTINUOUS ACROSS THE SURFACE CAN BE IGNORED.]

c. [5] What should the thickness of the slab be to eliminate reflections from the front face?

HALF-WAVE SECTION

[$t = 1.06$ cm $= \frac{\lambda_1}{2}$]

d. [5] What will be the VSWR in the slab?

$\Gamma_0 = \frac{\eta_0 - \eta_1}{\eta_0 + \eta_1}$; $S = \frac{1 + |\Gamma|}{1 - |\Gamma|}$ [$S = 1.412$]

e. [5] What will be the velocity of propagation in free space and in the slab?

FREE SPACE [$v = 3 \times 10^8$ m/s]

$v = \frac{c}{\sqrt{\epsilon_r}}$ SLAB [$v = 2.12 \times 10^8$ m/s]

$\eta_0 = 377\,\Omega$ $\Gamma_0 = 0.1708$

$\eta_1 = 267\,\Omega$ $S = 1.412$

THIS CAN ONLY HAPPEN IF THE WAVE IS INCIDENT AT BREWSTER'S ANGLE AND THE REFLECTED WAVE IS TE-POLARIZED.

4. Oblique Incidence [25]

An electromagnetic wave propagates from free space toward the face of a dielectric material. The angle of incidence is 75 degrees. A researcher uses a measurement apparatus to show that the reflected wave is linearly polarized regardless of the polarization of the wave.

a. [5] Find the angle of reflection.

[$\theta_r = 75°$]

FOR BREWSTER'S ANGLE INCIDENCE, $\theta_r + \theta_t = 90°$.

b. [5] Find the angle of transmission (or refraction).

[$\theta_t = 15°$]

$\epsilon_{r_1} = 1$

c. [5] Find the relative permittivity of the dielectric.

$\theta_B = \arctan\sqrt{\frac{\epsilon_{r2}}{\epsilon_{r_1}}}$

[$\epsilon_{r2} = 13.93$]

$\epsilon_{r2} = \tan^2\theta_B = \tan^2 75°$

d. [5] What is the polarization of the reflected wave?

FOR INCIDENCE AT BREWSTER'S ANGLE, THE TM-POLARIZED COMPONENT HAS NO REFLECTION.

[THE REFLECTED WAVE IS TE-POLARIZED]

e. [5] Sketch the problem scenario and indicate the relevant material media, waves, and directions: