

THE UNIVERSITY OF BRITISH COLUMBIA
Department of Electrical and Computer Engineering

ELEC 311 – Electromagnetic Fields and Waves
2025 W1

Practice Final Exam 1

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., $\alpha = 5 \text{ Np/m}$, and be inserted within the large square brackets. The actual exam will be printed on tabloid-size paper.

1. Time-Varying Fields and Materials [25]

A non-magnetic material has $\sigma = 5.0 \text{ S/m}$ and $\epsilon_r = 1$. The electric field is directed in the z direction and has intensity $E = 250 \sin 10^{10}t \text{ V/m}$.

a. [5] Find expressions for:

i. the conduction current density: []

ii. the displacement current density: []

b. [5] Find the frequency at which the conduction and current densities are equal:

[]

c. [5] Define the loss tangent and give a numerical value at this frequency:

[]

A non-magnetic material has $\sigma = 5 \times 10^{-3} \text{ S/m}$ and $\epsilon_r = 8$.

d. [5] Would the material be considered a dielectric or conductor at 1 MHz? Justify your answer.

[]

e. [5] At what frequencies may it be considered a ‘very good’ dielectric with $\tan \delta < 0.01$.

[]

2. Transmission Lines [25]

Consider a lossless air-filled line where $Z_0 = 50 \Omega$ and the load is $Z_L = 25 + j 25 \Omega$. The line is 25 cm long. The signal generator outputs 1 W at 150 MHz.

- a. [5] Use a Smith Chart to find the input impedance and voltage reflection coefficient at the load:

[]
[]

- b. [5] Use a Smith Chart to find the input impedance and voltage reflection coefficient at the generator:

[]
[]

- c. [5] Find the power absorbed by, and reflected from, the load:

[]
[]

- d. [5] Use a Smith Chart to find the distance and length of a single-stub that will achieve an impedance match. Draw a sketch with dimensions.

[]
[]

- e. [5] Find the distance, length, and impedance of a quarter-wave section that will achieve an impedance match. Draw a sketch with dimensions.

[]
[]
[]

3. Electromagnetic Waves [25]

An electromagnetic plane wave with a frequency of 1.6 MHz is propagating in aluminum where the conductivity is 38.2 MS/m and the relative permeability is 1.

- a. [5] Define the loss tangent and give a numerical value at this frequency:

[]

- b. [5] Define the skin depth and penetration depth of the material and give numerical values at this frequency:

[]

[]

- c. [5] Find the real and imaginary components of the propagation constant:

[]

[]

- d. [5] Find the velocity of propagation in the material:

[]

- e. Find the resistance of an aluminum wire of length 1 metre and diameter 1.0 mm at both DC and 1.6 MHz:

[]

[]

4. Oblique Incidence [25]

An electromagnetic wave propagates through a dielectric material toward the interface with free space. A researcher uses a measurement apparatus to show that the critical angle is 20 degrees.

- a. [5] Find the relative permittivity of the dielectric material:

[]

- b. [5] Find the angle of reflection.

[]

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

[]

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

- e. [5] Suppose the same wave propagates in free space towards the dielectric. What is the critical angle in this case?

[]