THE UNIVERSITY OF BRITISH COLUMBIA
Department of Electrical and Computer Engineering

ELEC 311 – Electromagnetic Fields and Waves
2025 W1

Practice Midterm 3 - In-Class

Chapter 11 – Uniform Plane Waves
Chapter 12 – Plane Wave Reflection and Dispersion

The purpose of this midterm exam is to assess your mastery of the fundamental techniques used to analyze transmission lines.

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). Make both explicit.

1. Uniform Plane Waves

A 1 MHz plane wave travels in the z-direction in a non-magnetic conducting medium in which the conductivity is 58 MS/m.

a. Calculate the intrinsic impedance, propagation constant, wave velocity, skin depth and penetration depth. Briefly explain your strategy and reasoning for each calculation. Use sketches where required. Briefly explain the physical significance of each quantity. [10]

b. Explain how the general expressions for the intrinsic impedance and propagation constant can be greatly simplified in this case. [5]

c. A plane wave with a power density of 100 W/m^2 is observed at $z = 0$. What power density will be observed at $z = 10$ microns $= 10^{-5}$ m? [5]

2. Uniform Plane Waves

a. A plane wave with electric field strength of 10 V/m and frequency of 5 GHz is travelling in the positive z direction through a perfect dielectric with relative permittivity = 2.5 and relative permeability = 1. Give the corresponding Helmholtz equations and find expressions for the field components of the wave and intrinsic impedance of the medium. [5]

b. A medium has relative permittivity = 2.5, relative permeability = 1 and conductivity = 50 S/m. Find the intrinsic impedance of the medium and the velocity of propagation, wavelength, loss tangent, and complex propagation constant of a 50 MHz plane wave that is travelling through it. [5]

c. Consider an AWG 30 copper wire of length 15 cm. What is the skin depth and resistance at 2 GHz? How deeply does the current penetrate? What are the attenuation and phase constants? [5]

d. A plane wave with electric field strength of 10 V/m and frequency of 5 GHz is travelling in free space in the positive z direction. Calculate the peak and time averaged power density that passes through $z = 0$ and the total power that passes through an aperture of dimensions 50 cm x 50 cm. [5]

3. Plane Wave Reflection and Dispersion

a. What boundary conditions must be satisfied when a plane wave is incident upon the interface between two different material media? [5]

b. What is meant by TM polarization? How is it different from TE polarization? Use a sketch to explain your answer. [5]

c. Design a surface that will not reflect TM polarized waves when the angle of incidence is 81 degrees. Explain your strategy and reasoning for each calculation. Use sketches where required. What name do we give to this angle of incidence? [5]

d. What will the reflection coefficient be for a TE polarized wave incident at the same angle? [5]

4. Plane Wave Reflection and Dispersion

   a. Derive the boundary conditions for the normal and tangential components of static electric and magnetic fields at the boundaries between two media. [5]

   b. A plane wave with electric field strength of 10 V/m and frequency of 5 GHz is travelling in the positive z direction. At $z = 0$, it is incident upon a perfect dielectric with relative permittivity = 10 and relative permeability = 1. Derive expressions for and determine the strength of the transmitted and reflected waves. [5]

   c. A plane wave with electric field strength of 30 V/m and frequency of 10 GHz is travelling in the positive x direction. At $x = 0$, it is incident upon a perfect dielectric slab, relative permittivity = 10 and relative permeability = 1. Derive expressions for and determine the strength and power density of the transmitted and reflected waves when:

      i. the thickness of the slab is 0.75 cm. [2.5]

      ii. the thickness of the slab is 0.237 cm. [2.5]

   d. A circularly polarized wave is obliquely incident upon a pure dielectric with relative permittivity of 4. If the angle of incidence is 63.43 degrees, what is the angle of refraction? What is the electric and magnetic strength and polarization of the reflected wave? [5]