THE UNIVERSITY OF BRITISH COLUMBIA
Department of Electrical & Computer Engineering

ELEC 311 – Electromagnetic Fields and Waves

2025 W1

Recitation Questions for

Chapter 11 – The Uniform Plane Wave

in W. H. Hayt, Jr. and J. A. Buck, *Engineering Electromagnetics*, McGraw-Hill, 2019, pp. 369-408.

The purpose of these recitation questions is to assist the reader in assessing their mastery of the key concepts introduced in this chapter. The answers can be found in the textbook. ELEC 311 students should be prepared to provide answers to these questions in class or on an exam.

Introduction

1. What is the focus of this chapter?
2. Why are uniform plane waves of particular practical interest?

11.1 Wave Propagation in Free Space

1. What are the defining aspects of propagation in free space?

11.1.1 Wave Equation for the Uniform Plane Wave

1. What does *sourceless* mean?
2. How can one infer wave motion from inspection of Maxwell's equations in point form?
3. How do we derive the wave equation that corresponds to a uniform plane wave?
4. Upon what parameters does the velocity of wave propagation in free space depend?

11.1.2 Solutions of the Wave Equation

1. What is the general form of the equation that describes a propagating wave?
2. What is the wavenumber and how is it related to frequency, wavelength and velocity of propagation?

11.1.3 Vector Helmholtz Equation in Free Space

1. What is the principal difference between the vector wave equation and the vector Helmholtz equation?
2. What is the vector Helmholtz equation that has a uniform plane wave as a solution?

11.1.4 Relation Between E and H; Intrinsic Impedance

1. What is the relationship between E and H in a uniform plane wave?
2. What is the intrinsic impedance of free space and how is it defined?
3. What are the units of intrinsic impedance?

11.2 Wave Propagation in Dielectrics

1. What is meant by a homogeneous and isotropic medium?

11.2.1 Propagation in Lossy Media

1. What distinguishes the propagation constant *k* in dielectrics from *k* in free space?
2. What are the attenuation and phase constants, their symbols, and units?
3. What is a Neper?
4. Define complex permittivity.
5. Give expressions for the propagation, attenuation and phase constants in terms of the properties of the medium.
6. Give expressions for the phase velocity, wavelength, and intrinsic impedance of a homogeneous and isotropic dielectric.

11.2.2 Propagation in Conducting Media

1. How is the imaginary component of complex permittivity related to the conductivity of the material and the frequency of the wave?
2. What is the significance of the loss tangent, and how can it be expressed?

11.2.3 Good Dielectric Approximation

1. What criterion can we apply to determine whether a material is a good dielectric?
2. What is a useful test of whether a material can be considered a good dielectric?

11.3 Poynting's Theorem and Wave Power

1. What does Poynting's Theorem state?
2. Recite equation (70) and explain the physical significance of each term.
3. Define the Poynting vector.
4. Define the time-averaged Poynting vector.

11.4 Propagation in Good Conductors

1. What is the basic problem considered in this section?

2. What modification of the basic problem is also considered?

11.4.1 Good Conductor Approximations

1. How do the general expressions for the attenuation and phase constants simplify when the loss tangent is very high, *i.e.,* in a good conductor?

2. Give an expression for the E_x component of a wave traveling in the $+z$ direction within a good conductor.

3. Give an expression for the conduction current density **J** at any point within the conductor.

11.4.2 Skin Effect

1. How does current density vary as a wave penetrates into a good conductor?

2. What is meant by skin depth? How is it calculated? (See the Chapter Supplement, too.)

3. What are typical values of the skin depth?

4. How does knowledge of skin depth affect engineering design? Give examples.

11.4.3 Intrinsic Impedance and Power Density in Good Conductors

1. Give a simplified and approximate expression for the intrinsic impedance of a good conductor.

2. Give an expression for the time-average Poynting vector and explain how it was calculated.

3. What is the power density at a distance of one skin depth relative to its value at the surface?

11.4.4 Skin Effect Resistance in Conductors

1. What is skin-effect resistance and why is it important?

2. How does the current density vary as the wave propagates into a conductor?

3. How is the resistance of a conductor with rectangular or circular cross section calculated?

4. How is the power loss within a conductor with skin effect present calculated?

11.5 Wave Polarization

1. How is wave polarization defined?

2. Why is specifying the direction of the electric field sufficient to describe wave polarization?

11.5.1 Linear Polarization

1. Describe linear polarization and the conditions under which it occurs.
2. Into what can any polarization state be decomposed?

11.5.2 Phase-Displaced Field Components: Elliptical Polarization

1. Describe elliptical polarization and the conditions under which it occurs.
2. Why is elliptical polarization described as the most general polarization state of a wave?

11.5.3 Circular Polarization

1. Describe circular polarization and the conditions under which it occurs.
2. How are left- and right-handed polarization defined?
3. Why would a designer choose to use circular polarization in a wireless system?
4. What is a quarter-wave plate and how is it used?