Practice Test for ECE 3065: Electromagnetic Applications

Note: This practice test was constructed from old or leftover test questions. This is meant for practice and, since no attempt was made to regulate the cumulative time for answering all the questions, taking the "practice test" may require more time than taking the actual in-class test. The in-class test includes all necessary equations in either the problems statements or on attached formula sheets.

1. **Short Answer Section**

   (a) ________________
   If you have transmission line with real-valued characteristic impedance, Z_0, then we know that line is *Answer*.

   (b) ________________
   As you lengthen a transmission line, the value of the load-transformed equivalent impedance repeats itself every *Answer* wavelength.

   (c) ________________
   For grazing incidence, the reflection coefficient of a plane wave is approximately *Answer*, regardless of specific material properties.

   (d) ________________
   If the properties of a propagation medium are independent of the polarization of fields, we say that the medium is *Answer*.

   (e) ________________
   If the properties of a propagation medium are identical everywhere in space, we say that the medium is *Answer*.

   (f) ________________
   In a propagation medium, you measure flux densities and field strengths, finding that simple constant μ and ϵ relate the magnetic and electric field quantities, respectively. This medium is *Answer*.

   (g) ________________ (1) ________________ (2)
   You find a medium that has non-zero conductivity. Furthermore, that conductivity depends on the orientation of electric field, such that it is best modeled as a 3×3 matrix. What two conditions for a simple medium are violated in this case?

(h) ______________ (1) ______________ (2)

We call the plane waves because the [*Answer 1*] surfaces form successive planes in space, each separated by [*Answer 2*].

(i) ______________

True or False: there is no Brewster angle for reflecting plane waves with parallel polarization.

(j) ______________

Most materials are non-[*Answer*], which allows us to model them using free-space permeability.

(k) ______________

A [*Answer*] plane wave has constant amplitude in all of space.

(l) ______________

A [*Answer*] plane wave decays exponentially in the direction of propagation.

(m) ______________

The transmitted wave that clings to the dielectric interface under conditions of total reflection is called an [*Answer*] wave.

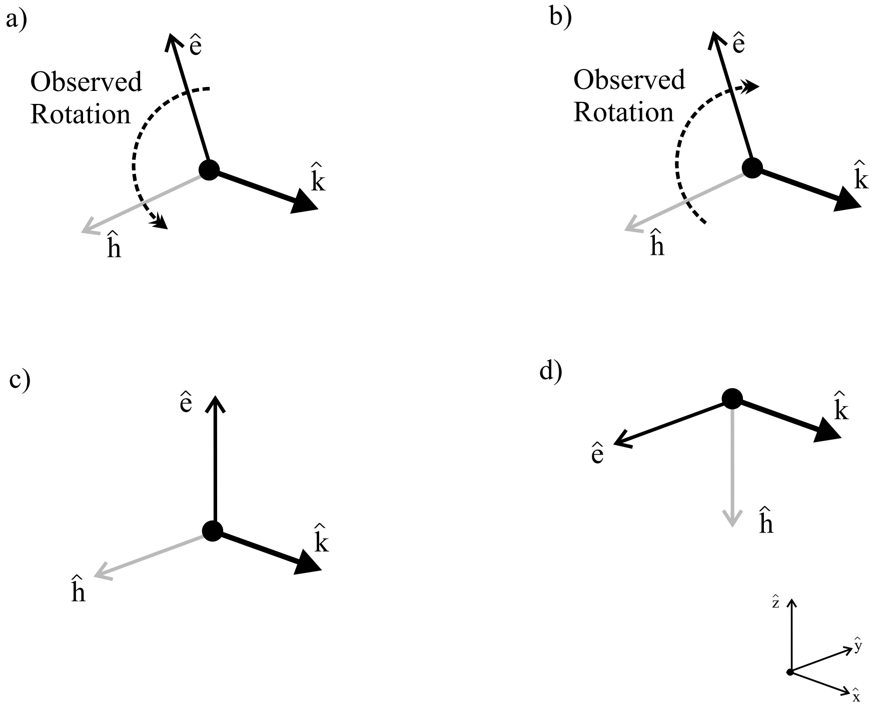
(n) ______________

The unit vector $\hat{e}$ in the plane wave equations model the [*Answer*] of the wave.

2. **Descriptive Answer Section**

Write a **concise** answer to each question in the spaces provided beneath each problem statement. **Note:** Correct answers that are extremely verbose will be penalized.

(a) **Plane Wave Polarization:** Use the letters in the diagram below to answer the following questions. Each lettered diagram sketches the field solution of a plane wave at a single point in space.



a. Real, linear combinations of polarizations ___ and ___ may be used to describe any arbitrary linear polarization.

b. Polarization ___ is left-handed circular.

c. Polarization ___ is horizontal.

d. In the space provided below, verbally explain what *elliptical* polarization is?

(b) **Optics Experiment:** You are performing an optics experiment in air ($\epsilon_r = 1$) with a laser source. The laser beam can be modeled as a plane wave with an unknown polarization. You want to convert the beam into a known linear polarization but all you have lying around the laboratory is a thick, smooth slab of non-magnetic dielectric material with $\epsilon_r = 4$. Describe exactly how you might achieve this with the dielectric slab and include any geometrical diagrams and calculations. (You may model the slab as an infinite half-space.)

(c) **Transmission Line Analogy:** In class, we stated that there were many analogies between transmission line wave propagation and unbounded plane wave propagation. Fill out the following analogy table with the most appropriate physical quantities:

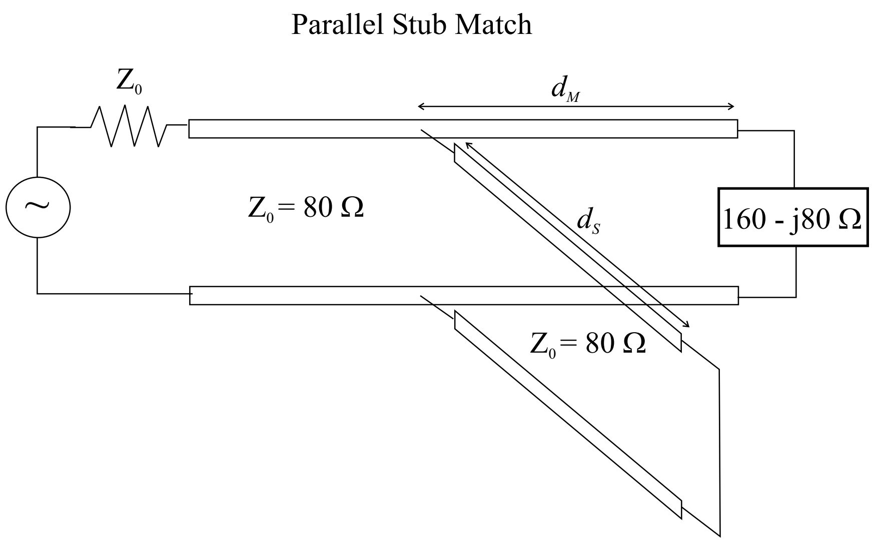
Transmission Line	Plane Wave
Voltage, V	__________
__________	Magnetic field, $\vec{\mathrm{H}}$
Impedance, Z_0	__________
Reflection Coefficient, Γ_L	__________
per unit length Inductance, L	__________
per unit length Capacitance, C	__________
__________	wavenumber, k
__________	Standing Wave Ratio, $\frac{E_{\max}}{E_{\min}}$

3. **Circular Polarization:** Below is the equation for a right-hand circular polarization propagating in the $+z$ direction.

$$\tilde{\vec{\mathrm{E}}}_i(\vec{\mathrm{r}}) = E_i \left(\frac{1}{\sqrt{2}}\hat{\mathrm{x}} + \frac{j}{\sqrt{2}}\hat{\mathrm{y}} \right) \exp(-jk\hat{\mathrm{z}} \cdot \vec{\mathrm{r}})$$

At the plane $z = 0$, the wave encounters a perfect electric conductor at normal incidence. Write the solution for the total electric field above the $z = 0$ plane. What is the polarization of the reflected wave?

4. **Parallel Stub Match:** Below is the diagram of a microstrip transmission line that is matched with a short-circuit stub line. Calculate the distances d_M and d_S (in wavelengths) to match the $160 - j80\Omega$ load with the 80Ω transmission line. Show all calculations on the attached Smith chart.



5. **Plane Wave Equation:** A homogeneous plane wave is traveling in a simple, sourceless dielectric medium in the (ϕ, θ) direction. The phasor-form E-field and H-field expressions are given by the following system of equations:

$$\tilde{\vec{E}}(\vec{r}) = \overbrace{(E_x\hat{\text{x}} + E_y\hat{\text{y}} + E_z\hat{\text{z}})}^{E_\text{o}\hat{\text{e}}} \exp\Big(j[\phi - k\hat{\text{k}}\cdot\vec{r}]\Big)$$

$$\tilde{\vec{H}}(\vec{r}) = \underbrace{(H_x\hat{\text{x}} + H_y\hat{\text{y}} + H_z\hat{\text{z}})}_{\frac{E_\text{o}}{\sqrt{\mu/\epsilon}}\hat{\text{h}}} \exp\Big(j[\phi - k\hat{\text{k}}\cdot\vec{r}]\Big)$$

$$\hat{\text{e}} \times \hat{\text{h}}^* = \hat{\text{k}} \quad \hat{\text{k}} = \cos\phi\sin\theta\hat{\text{x}} + \sin\phi\sin\theta\hat{\text{y}} + \cos\theta\hat{\text{z}} \quad k = \frac{2\pi}{\lambda} = 2\pi f\sqrt{\mu\epsilon} \quad \vec{r} = x\hat{\text{x}} + y\hat{\text{y}} + z\hat{\text{z}}$$

Answer the questions below based on these equations:

(a) Circle the amplitude of the electric field in the equations above.

(b) Box the polarization vector of the magnetic field.

(c) In the space below, show that the x-component of the E-field satisfies the scalar wave equation. In other words, show that

$$(\nabla^2 + k^2)(\hat{\text{x}} \cdot \tilde{\vec{E}}) = 0$$

Reminder: $\nabla^2 A(x, y, z) = \nabla \cdot \nabla A(x, y, z) = \frac{\partial^2 A}{\partial x^2} + \frac{\partial^2 A}{\partial y^2} + \frac{\partial^2 A}{\partial z^2}$.