Fields and Waves I

Name ________________ ECSE-2100 Spring 2000 Section _____

Preparation Assignments for Homework #7 – Open Shop 20,21 April

Due at the start of class.

These assignments will only be accepted from students attending class.

Reading Assignments Please see the handouts for each lesson.

10 April Lesson 5.2 Electromagnetic Plane Waves in Lossless Media – No Prep.
12 April Quiz 3

13,14 April Lessons 5.3 and 5.4 Electromagnetic Waves in Lossy Media and Polarization and Propagation Direction

1. What is the wavelength in air for the WRPI frequency?
2. Write out in **vector** phasor form the electric and magnetic fields for an electromagnetic plane wave propagating in the z-direction in air at the WRPI frequency. Assume that the electric field magnitude is 1 volt/meter.
3. Is seawater a good dielectric or a good conductor at a frequency f = 1MHz?
4. If an electromagnetic wave is propagating in the +y direction and the magnetic field of this wave is in the +x direction, what is the direction of the electric field.

17 April Lesson 5.5 Normal Incidence Reflection

1. How far does a 10MHz electromagnetic wave propagate in sea water before it attenuates to e^{-1} of its original value?
2. For what range of frequencies is $a \approx b$ for an electromagnetic wave propagating in sea water?

A uniform plane wave is propagating in the z-direction and has an x-directed electric field E_x and a y-directed magnetic field H_y. Assume that there is a boundary between two media at z = 0. Write the boundary condition for E_x and the boundary condition for H_y at z = 0 for the following two cases:
3. Medium 1 (z < 0) is a dielectric and medium 2 (z > 0) is a conductor
4. Both media are dielectrics

19 April Lesson 5.6 Oblique Incidence Reflection

1. Under what two conditions will a lossless dielectric slab of finite thickness look invisible to an incident wave?

2.Write out Snell's Law and draw a diagram explaining the terms in this expression. What is the critical angle? What is Brewster's angle?

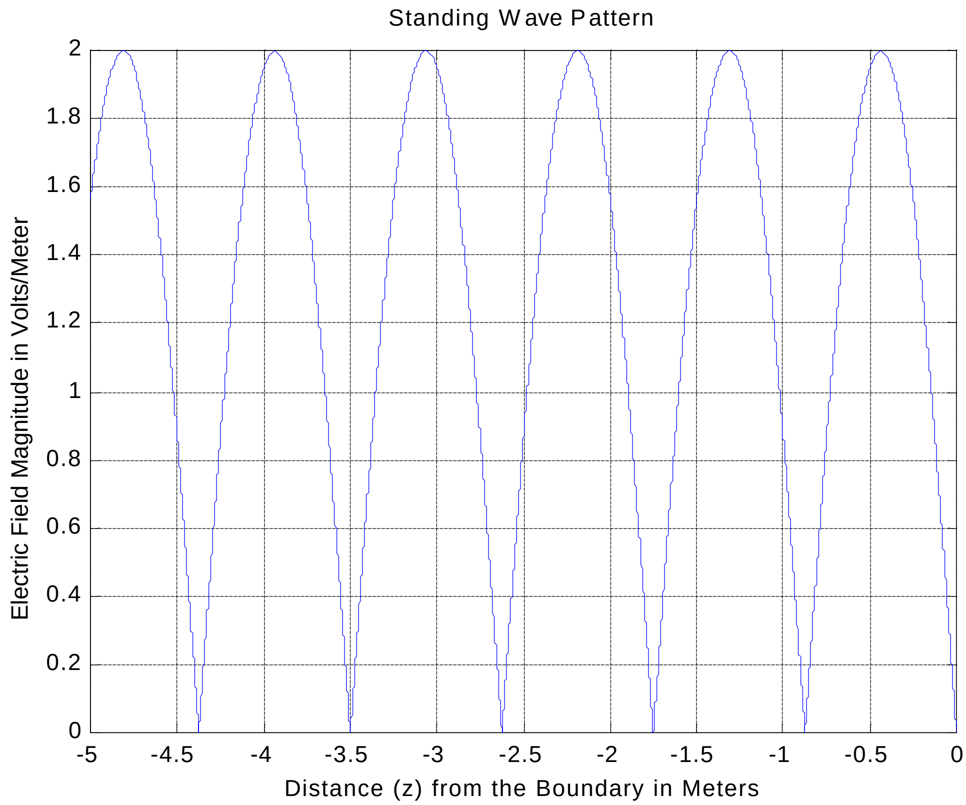
20.21 April Open Shop for Homework 7

Due at 5pm on 21 April

Homework 7

Problem 1 (10 points) Normal Incidence on a Lossless Dielectric and a Conductor

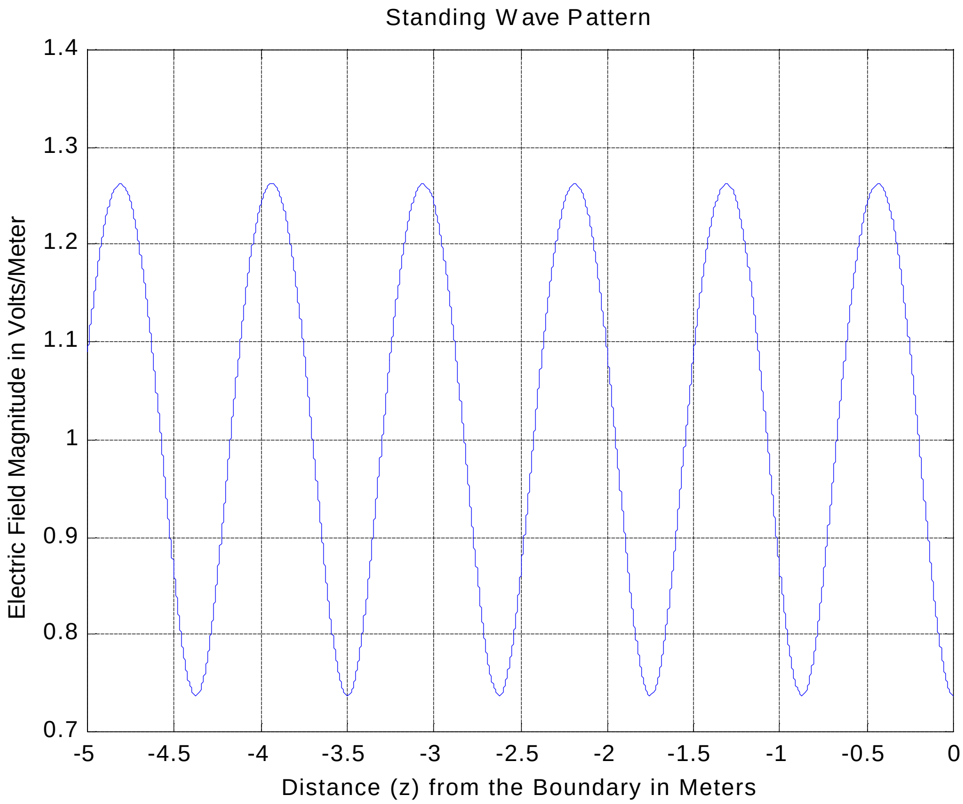
A plane wave with frequency f = 100 MHz propagating in an unknown lossless material (call it Material X), is incident normally on a perfectly conducting boundary. Inside Material X, the standing wave pattern shown below is observed. (We won't worry about how it was actually observed inside the material.)



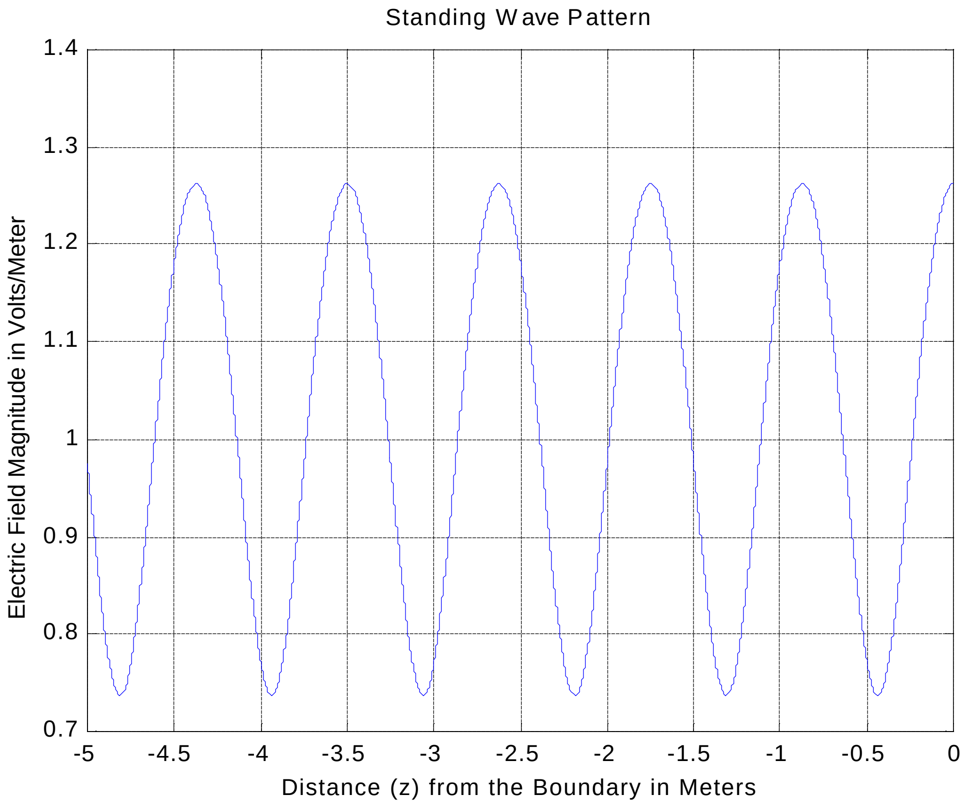
a. What is the wavelength λ, the wavenumber β, and the dielectric constant ε_r of the unknown material. What do you suppose Material X is?

b. Now the perfect conductor is removed so that the wave is now incident normally on a boundary between Material X and air ($\varepsilon_r = 1$). Which of the two standing wave patterns plotted on the next page will be observed in Material X?

c. Write expressions for the electric and magnetic field (in phasor form) that will be observed in air.

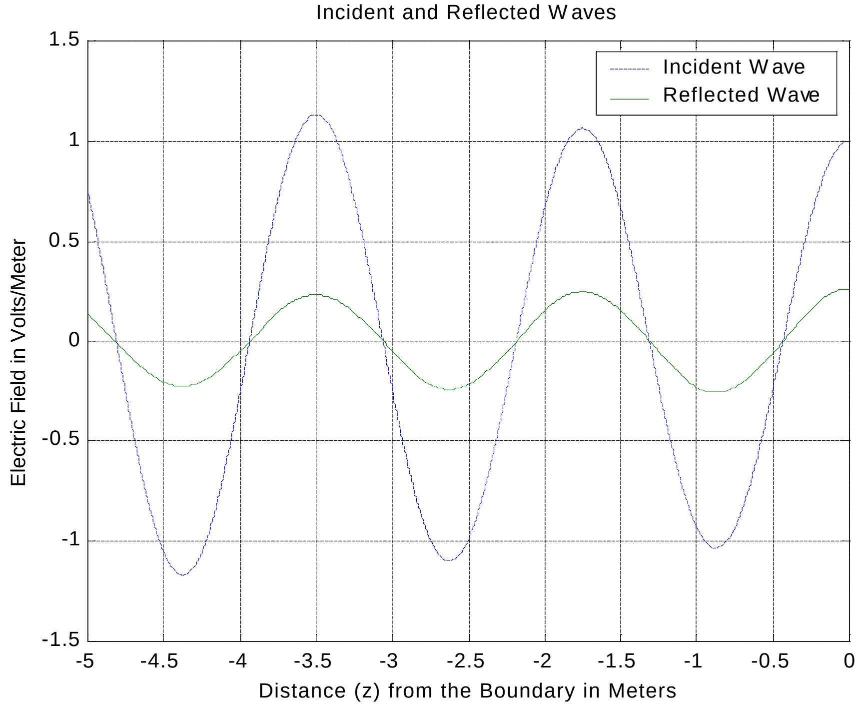


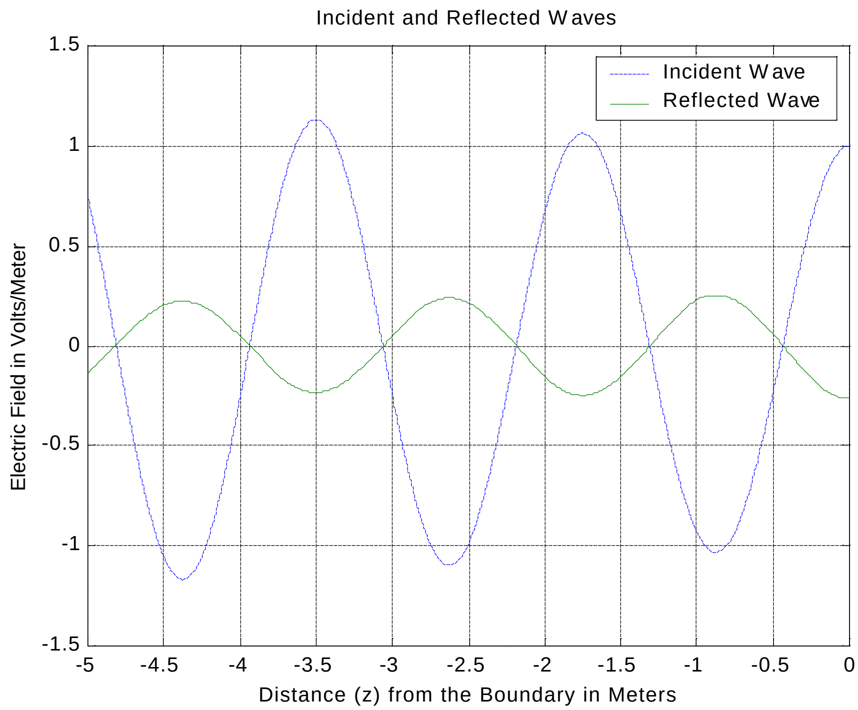
Standing Wave Pattern
Electric Field Magnitude in Volts/Meter
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
-5
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
Distance (z) from the Boundary in Meters



Standing Wave Pattern
Electric Field Magnitude in Volts/Meter
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
-5
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
Distance (z) from the Boundary in Meters

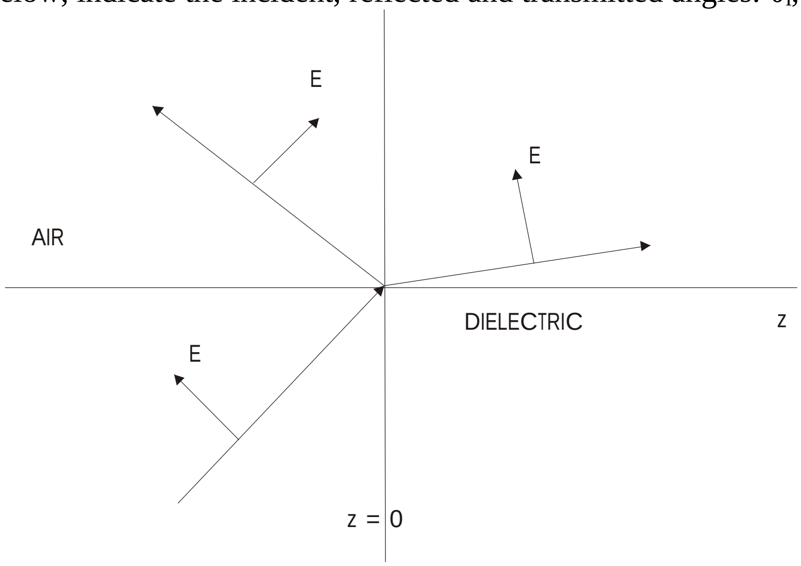
d. The analysis thus far has assumed that the unknown material is lossless, when in fact it is not. For the case where the wave in incident on an interface with air, the incident and reflected waves will look like one of the following plots. Identify which one is correct and then write the incident and reflected waves in phasor form.



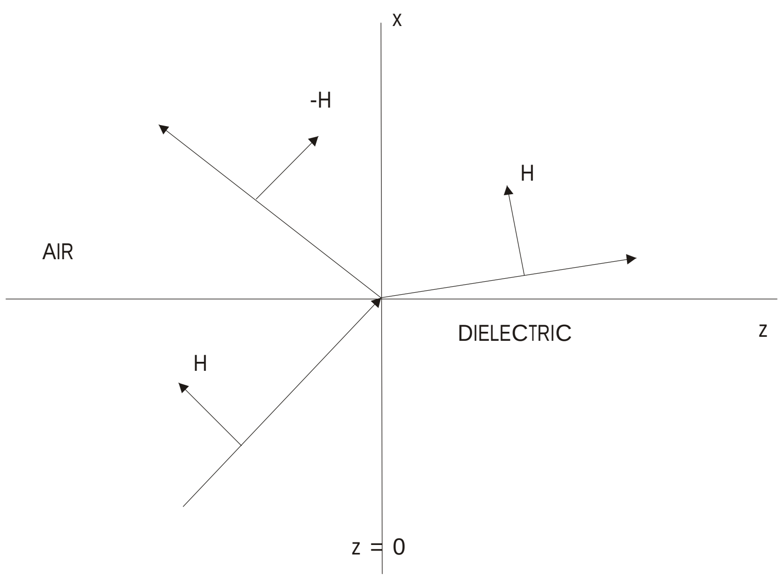


Problem 2 (10 points) Oblique Incidence

A uniform plane wave is incident obliquely in air on the boundary of a dielectric medium as shown below. The electric field vector **E** is shown, as is the direction of propagation. On the plot below, indicate the incident, reflected and transmitted angles: θ_I, θ_R, θ_t



a. For the figure above, circle the direction of **H**: (x-direction, y-direction, z-direction). *At this point, we are not concerned with the sign.* Add a symbol that shows the direction of **H** for each of the three waves to create a plot something like in Figure 6.21 of the text. Now, you should be careful about the sign in each case. Is this wave parallel or perpendicularly polarized?



Now assume that **E** is replaced by **H**, as shown above. Note that the reflected **H** field is labeled **–H** so that the same diagram can be used. By convention, we usually assume that **H** changes direction upon reflection. On the plot above, indicate the incident, reflected and transmitted angles: θ_I, θ_R, θ_t

b. Circle the general direction of **E**: (x-direction, y-direction, z-direction). *At this point, we are not concerned with the sign.* Add a symbol that shows the direction of **E** for each of the three waves to create a plot something like in Figure 6.21 of the text. Now, you should be careful about the sign in each case. Is this wave parallel or perpendicularly polarized?

c. Assume that we have measured the reflected wave power for the first type of polarization and found that there is no reflected wave at the incident angle $\theta_I = 58^o$. What is the dielectric constant ε_r of the medium in the region z > 0? What is the angle of transmission θ_t for this angle of incidence? What simple relationship exists between θ_I and θ_t?

d. Determine the reflection coefficient Γ for the first polarization for all angles of incidence $\theta_I = \theta_1$ from 0 to 90^o. Use Matlab or Maple to plot this. Be sure you input the angles in radians. Your result should look like one of the plots on the next page (when plotted vs. angle in degrees). Which one is it? To generate this plot, the following expression was used. This is a little more convenient than the expressions in the text (194a or 188a).

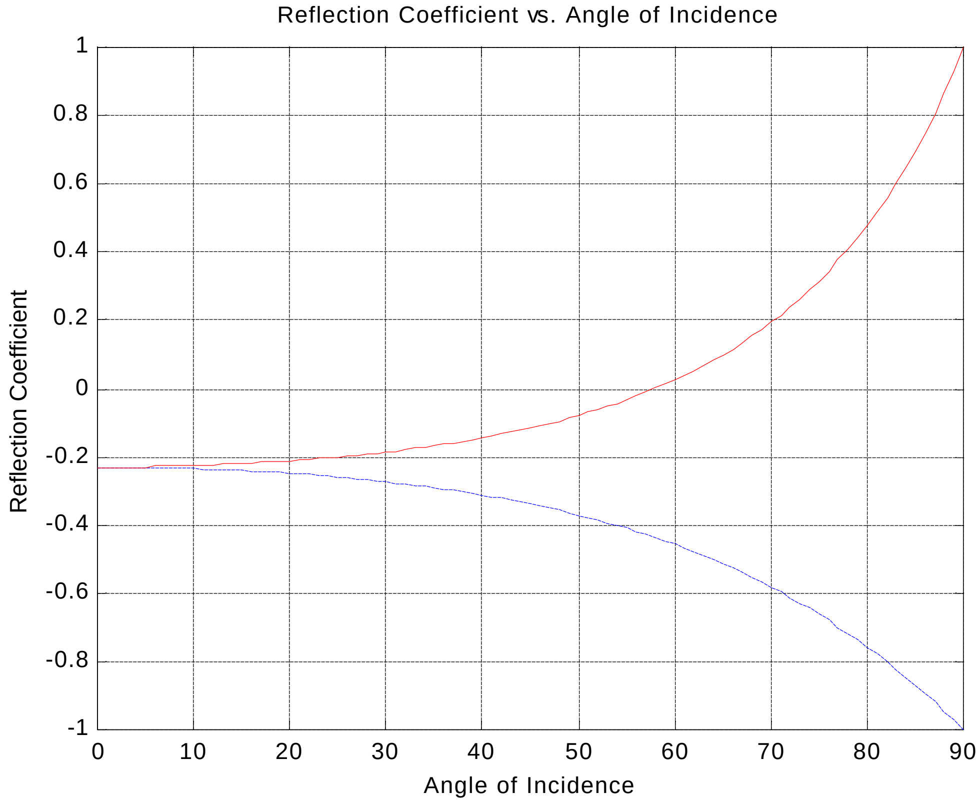
$$\Gamma_1 = \frac{-\dfrac{\varepsilon_{r2}}{\varepsilon_{r1}}\cos\theta_1 + \sqrt{\dfrac{\varepsilon_{r2}}{\varepsilon_{r1}} - \sin^2\theta_1}}{\dfrac{\varepsilon_{r2}}{\varepsilon_{r1}}\cos\theta_1 + \sqrt{\dfrac{\varepsilon_{r2}}{\varepsilon_{r1}} - \sin^2\theta_1}}$$

e. Now assume that the wave has the other polarization. Determine the reflection coefficient Γ for all angles of incidence $\theta_I = \theta_1$ from 0 to 90^o. Use Matlab or Maple to plot this. Be sure that you input the angles in radians. Your results should look like one of the plots on the next page. Which one is it? To generate this plot, the following expression was used. This is a little more convenient than the expressions in the text (194a or 188a).

$$\Gamma_2 = \frac{\cos\theta_1 - \sqrt{\dfrac{\varepsilon_{r2}}{\varepsilon_{r1}} - \sin^2\theta_1}}{\cos\theta_1 + \sqrt{\dfrac{\varepsilon_{r2}}{\varepsilon_{r1}} - \sin^2\theta_1}}$$

f. Assume that you have only a parallel polarized plane wave incident at an angle of 58^o. Write the incident, reflected and transmitted electric and magnetic field vectors in phasor form. Assume that the incident electric field amplitude is E_o. Also assume that the wave frequency is 30 MHz. *Note that the general form of these expressions are found in equation 190. Use the information you are given or have calculated to write out the field expressions for the specific case considered here.*

g. Assume that the incident power density is 10 kW/m^2. Determine E_o and the transmitted power density. Is the power density conserved in this case? Why or why not?


Reflection Coefficient vs. Angle of Incidence
Reflection Coefficient
Angle of Incidence
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60
70
80
90