##### DO NOT BEGIN THIS EXAM UNTIL TOLD TO START

# Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**PeopleSoft ID: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

#### ECE 3317

#### Applied Electromagnetic Waves

**FINAL EXAM**

#### May 7, 2013

1. This exam is open book and open notes. However, you are not allowed to use a computer or any electronic device other than a calculator. Any devices that may be used to communicate are not allowed.
2. Show all of your work. No credit will be given if the work required to obtain the solutions is not shown.
3. Perform all your work on the exam in the space allowed.
4. Write neatly. You will not be given credit for work that is not **easily legible**.
5. Leave answers in terms of the parameters given in the problem.
6. Show units in all of your final answers.
7. Circle your final answers.
8. Double-check your answers. For simpler problems, partial credit may not be given.
9. If you have any questions, ask the instructor. You will not be given credit for work that is based on a wrong assumption.
10. Make sure you sign the academic honesty statement on the next page.

**Academic Honesty Statement**

I agree to abide by the UH Academic Honesty Policy during this exam. I understand that the punishment for violating this policy will be most severe, including getting an F in the class and getting expelled from the University.

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Signature









































































































































































































Problem 1 (40 pts.)

A step function of amplitude *V*0 = 2.0 [V] is applied at the input to the transmission line circuit shown below. Each of the two transmission lines has a length *L* that is 3.0 [m]. Each line has a different effective relative permittivity, however.

a) Construct a bounce diagram that extends to a time of 50 [ns], labeling with 10 [ns] divisions on your time scale. (Make your bounce diagram on the next page.)

b) Make an accurate “snapshot” trace of the voltage on the line at *t =* 35 [ns]. Make your snapshot trace on the graph shown below, plotting out to 2*L*. Label all voltage values on your plot as well as all *z* values at which the voltage on your plot changes. Also, indicate in which direction (to the left or right) each “wavefront” (point of voltage discontinuity) is moving.

*z =* 0

*RL* = 100 [Ω]

*z =* 2*L*

*vg*(*t*)

*Rg* = 25 [Ω]

*Z*0 = 25 [Ω]

+

-

*Z*0 = 50 [Ω]

*z = L*

*εreff =* 4.0

*εreff =* 9.0

*t*

Room for Work

*z*

*v*(*t*) [V]

2*L*

 *z*

2.0

1.0

*L*

1.5 *L*

0.5 *L*

4/3

1.0

0

0.25*L*

1.5*L*

4/3

1/3

1.0

10 [nS]

20 [nS]

30 [nS]

40 [nS]

50 [nS]

*L*

2*L*

0

1.0

4/3

0

0

4/3

Problem 2 (40 pts.)

A rectangular waveguide has a dominant TE10 mode that has an electric field that is given by

.

The waveguide is filled with a lossless material having a relative permittivity *εr*.

a) Find the complex power flow P*f* that is flowing in the *z* direction down the waveguide at any frequency *f*. (Evaluate all integrals so that your result is a closed-form expression.)

b) Find the time-average power flowing down the waveguide when *f* > *fc*. Your result should be in closed form. Do not leave any “Re” or “Im” operators in your answer.

c) Find the VARS flowing down the waveguide when *f* < *fc*. Your result should be in closed form. Do not leave any “Re” or “Im” operators in your answer.

*x*

*y*

*z*

*a*

*b*

*εr*

Room for Work

The transverse component of the magnetic field is

,

where

.

The complex power flow is then

.

This gives us

.

Above the cutoff frequency the wavenumber is real (*α* = 0) and we have

.

Below the cutoff frequency we have

.

Hence

.

Problem 3 (40 pts.)

 A TE*z* plane wave at a frequency of 1.0 GHz is incident on the ocean (which is nonmagnetic). The ocean has a relative permittivity of *εr* = 81 and a conductivity of *σ* = 4.0 [S/m]. The angle of incidence is *θi* = 60o.

a) Calculate the total power density in the reflected plane wave relative to that of the incident plane wave.

b) Find the distance *z* below the surface of the ocean for which the field *Ey* has attenuated by 10 dB from what it is at the surface (*z* = 0).

Ocean

TE*z*

Reflected

*θi*

*z*

*x*

Room for Work

We use



where



.

We also have

.

We have

.

We then have







The power density of the reflected wave relative to the incident wave is

.

Hence we have



The distance *z* is given by

,

where

.

At 1.0 GHz, we have



.

Hence,

.

This gives us

.

Problem 4 (60 pts.)

A plane wave from a distant transmitter is incident on a receive antenna as shown below. The incident wave is a RHCP wave and it has the mathematical form

.

The frequency is 1.0 [GHz]. The receive antenna is a resonant half-wavelength dipole wire antenna that is aligned in the *x* direction. The receive antenna is connected to a lossless transmission line of length *l*, which is then connected to a load. The load is an impedance *ZL* = 100 – *j* (50) [Ω] while the transmission line has a characteristic impedance of *Z*0 = 50 [Ω]. The length of the transmission line is *l* = *λ* / 8, where *λ* is the wavelength on the transmission line.

a) Find the Thévenin equivalent circuit for the receive antenna.

b) Find the input impedance seen by the receive antenna, using the Smith chart (attached at the end of the exam).

c) Find the power being delivered to the load.

*Z*0

*ZL*

*l*

*x*

*z*

Room for Work

The effective antenna length is



The Thévenin voltage is

,

where

.

This gives us

.

The Thévenin impedance is

.

From the Smith chart, the input impedance is

.

The power being delivered to the load is



where

.

This gives

.

Problem 5 (50 pts.)

An antenna radiates an electric field in the far field that is given by



where *E*0 is a constant.

a) Calculate the directivity *D*(*θ*, *φ*). Make sure that you evaluate all integrals to get a closed-form result.

b) Find the direction (*θmax*, *φmax*) that maximizes the directivity, and find the value of the maximum directivity; i.e., find *Dmax*= *D*(*θmax*, *φmax*).

c) If the antenna radiates 1 [W] of power, find the magnitude of the electric field vector in the direction *θ* = 0, at a distance of 1.0 [km] from the antenna.

Room for Work

The directivity is given by

.

This gives us

.

Performing the *φ* integral gives a factor of *π*, so we have

.

Performing the integrations in the denominator, we have

.

Hence we have

.

The maximum directivity occurs at

.

The angle *φ* is arbitrary. At *θ* = 0 we have



The power density radiated is given by

.

Hence,

.

Using the values given, we have

.

This gives

.



*ZinN*

*ZLN*