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

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

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

#### ECE 3317

#### Applied Electromagnetic Waves

**FINAL EXAM**

#### May 8, 2012

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 (25 pts)

A measurement on a transmission line at 1.0 GHz reveals that a voltage maximum occurs at the position *z* = -31 [cm]. The magnitude of the voltage there is 1.5 [V]. The closest voltage minima (i.e., the minima that are the closest to the indicated voltage maximum) occur at *z* = -34 [cm] and *z* = -28 [cm]. The magnitude of the voltage there is 0.5 [V]. The transmission line has a known characteristic impedance of 50 Ω but the permittivity of the line is unknown. An unknown load is at *z* = 0.

1. What is the relative permittivity of the line?



1. What is the impedance of the unknown load? (Show your work on the first Smith chart.)



1. Calculate where on the line (i.e., at what value of *z* in cm) you would add a short-circuited stub line in order to get a perfect match seen from the main feed line. Choose a value of *z* that is as small as possible in magnitude. (Show your work on the second Smith chart.)



1. Calculate the length (in cm) of the stub line. Assume that the stub line is made from the same transmission line as the main line. (Show your work on the third Smith chart.)



**Room for work**

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Problem 2 (20 pts)

An air-filled rectangular waveguide has a width in the *x* direction of *a* = 1.0 cm and a height in the *y* direction of *b* = 0.5 cm. The air has a dielectric breakdown field strength of *Ec* = 3.0 ×106 [V/m].

1. Calculate the cutoff frequency of the dominant mode.



1. Calculate the attenuation in dB after the dominant mode travels one cm down the guide at 5 GHz.



1. Calculate the velocity at which a pulse will move down the waveguide. The pulse consists of a 20 GHz carrier wave that is modulated by a digital pulse signal.



1. Calculate how much power can flow down the waveguide at 20 GHz before the air inside the waveguide begins to breakdown.



**Room for work**

Problem 3 (20 pts)

Sunlight contains equal power densities in both the parallel and perpendicular polariza­tions. Assume that sunlight is incident at a 45o angle (measured from the vertical) on a puddle of water. Because the water is relatively pure fresh water, it is nonconductive and has a dielectric constant (relative permittivity) of *εr* = 1.78. The water is nonmagnetic. A person who is wearing Polaroid sunglasses looks at the puddle. The sunglasses completely block the perpendicular polarization. The sunglasses let through the parallel polarization, but with a 50% attenuation in the power.

What percentage of the incident power density in the sunlight gets through the sunglasses to the observer?

Puddle of water

Sunlight

Polaroid sunglass lens











**Room for work**

Problem 4 (15 pts)

A parabolic dish antenna located on a person’s house is being used to receive direct broadcast satellite (DBS) TV reception from a satellite in geosynchronous orbit, meaning that the satellite is at an altitude of *r* = 35,786 [km] from the surface of the earth. The antenna on the satellite radiates a power of 100 [W] at a frequency of 12 GHz. The directivity of the antenna on the satellite in the direction of the user is 25 [dB] with respect to isotropic. Assume that the satellite dish on the house captures 90% of the power that is incident on the aperture of the dish, which it delivers to a receiver by means of a coaxial cable connection. The aperture of the dish is circular in shape with a radius of *a* = 25 [cm].

1. Calculate the total power that the receiving dish antenna is able to collect and deliver to the receiver.
2. Assume that the coaxial cable transmission line has a 50 [Ω] characteristic impedance. Assume that the receiver has a 50 [Ω] input impedance. Calculate the magnitude of the voltage at the receiver.



*r*

Satellite

2*a*

DBS dish

**Room for work**

**Part (a)**







Hence



**Part (b)**



Hence



Problem 5 (20 pts)

Suppose we wish to communicate between a base-station antenna and a cell-phone antenna that is located on a user’s cell phone. Assume that the cell-phone antenna is modeled as a simple resonant dipole antenna. The cell phone operates at 2.0 [GHz]. The base station antenna is radiating a total power of 60 [W]. Assume that the base-station antenna is modeled as a vertical resonant dipole antenna. The person is as a distance of *r* = 2.0 [km] from the base station.

1. Determine how much power the cell-phone antenna will deliver to a 50 [Ω] load, which models the receiver circuit inside the phone. Assume that user holds the phone so that the cell-phone antenna is vertical.
2. How would the answer change if the user holds the phone so that the cell-phone antenna is now at an angle of 45o with respect to vertical?
3. How would the answer change if the user holds the phone so that the cell-phone antenna is now horizontal?
4. How would the answer change if the cell-phone antenna is horizontal, but the base-station now radiates 60 [W] using circular polarization instead of vertical polarization? Assume that the directivity of the CP base-station antenna is still the same as it was for the vertical base-station antenna.

Base Station



Person with cell phone

*r*

**Room for work**

**Part (a)**













.

**Part (b)**

The voltage changes by a factor of .

The power thus changes by a factor of 1/2.

 (This ignores the fact that the effective length will also change slightly due to the change in angle *θ*, reducing by a factor of 0.88.)

 .

**Part (c)**

Voltage changes by a factor of .

.

**Part (d)**

Half of the power of the CP wave is in vertical polarization, and half is in horizontal polarization. The cell phone antenna only receives the horizontal polarization. Hence, the received power would be half of what is was before, when the transmitting and receiving antennas were vertically polarized.

