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

#### ECE 3318

#### Applied Electricity and Magnetism

**Exam 2**

#### April 28, 2016

1. This exam is open-book and open-notes. A calculator is allowed (as long as it cannot be used to communicate), but no other device (laptop, phone, tablet, etc.) is 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 the possibility of getting an F in the class and/or getting expelled from the University.

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Signature

Problem 1 (20 pts.)

Please give a short answer to the questions below.

a) What is the “sharp tip” property in electrostatics?

The electric field becomes very strong near a sharp tip (or corner) on a conducting surface that has a charge on it, where the radius of curvature is small.

b) What is the name of the group of electrons that emerges from a cloud during a lighting strike?

The leader, or more precisely, the stepped leader.

c) Briefly explain how a lightning rod works.

The sharp tip creates a strong electric field, which initiates a strong streamer, so that the stepped leader will most likely make contact with this streamer and thus the lightning rod, so that the discharge will then be safely discharged to the earth (assuming that the lighting rod is well grounded, as it should be).

d) Briefly explain why it is that the relative permittivity of most materials is always greater than one.

This is because the electric susceptibility *χe* is positive, and *εr* = *χe* + 1. The electric susceptibility is positive because the molecular dipoles will normally tend to rotate to align with their dipole moment vectors pointing in the same direction as the applied field, not opposite to it.

Problem 2 (20 pts.)

An electric field in free space is given in spherical coordinates by

.

Determine the equation for the volume charge density *ρv* in space that will produce this electric field.

**Room for Work**

**Solution**

We use

.

Using the divergence in spherical coordinates, we have

.

Hence we have

.

This gives us



Problem 3 (30 pts.)

A twin lead transmission line consists of two parallel conducting wires, each of radius *a*, separated by a distance 2*h* between the centers of the wires, as shown below. The wires are running in the *z* direction. One wire is centered at *x* = *h*, and the other wire is centered at *x* = -*h*.

Assume that one wire has a line charge density of *ρl* on it, and the other one has a line charge density of -*ρl* on it. The charge density is assumed to spread out uniformly around the circumference on each wire.

a) Find the electric field vector *E*(*x*) along the line *y* = 0, for –(*h* – *a*) < *x* < (*h* – *a*).

b) Calculate the voltage drop *VAB* between the two wires, with *A* being the left wire.

c) Calculate the capacitance per unit length *Cl* of the twin lead transmission line.



**Room for Work**

**Solution**

**Part (a)**

The electric field is



or

.

**Part (b)**

The voltage drop is

.

Hence we have

.

This gives us

.

Evaluating this, we have



or

.

**Part (c)**

We have

.

We thus have

.

Problem 4 (30 pts.)

An engineer connects a voltmeter to a device to measure the voltage across the device. The engineer does not realize it, but there is a changing magnetic field inside the room where the measurement is being conducted. The magnetic field inside the room is given by

.

Assume that the region between the two voltmeter leads in the *xy* plane forms a region *S* with area *A* [m2] as shown below. Assume that the leads are made of perfectly conducting wires.

Because of the changing magnetic field that is inside the room, the voltmeter will not read the correct voltage that is across the device. This is because the voltage *Vm* that is across the voltmeter will be different than the voltage *Vd* that is across the device.

a) Using Faraday’s law, show that

,

where *ψ* is the magnetic flux that goes through the region *S* in the *z* direction.

b) Assume that *Vd* = 10 [V], *B*0 = 0.01 [T], *f* = 60 [Hz], and *A* = 0.25 [m2]. Find a formula for the voltage *Vm* that will be read by the voltmeter, as a function of time.



**Room for Work**



**Solution**

**Part (a)**

Faraday’s law says that

.

Let’s choose the contour *C* to run counterclockwise around the boundary of the region *S* formed by the leads, the voltmeter, and the device. We then have from the right-hand rule in Faraday’s law that the unit normal in the flux calculation definition points is the positive *z* direction, so that

.

There is no voltage drop along a perfectly conducting lead, since the electric field inside the lead is zero. Hence, breaking the contour *C* up into four parts, we have:

.

We thus have

.

**Part (b)**

We have

.

We also have

.

Hence,

.

We then have

.

Plugging in the values, we then have

.

This gives us



or

.