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

#### ECE 3318

#### Applied Electricity and Magnetism

**Exam 2**

#### April 27, 2017

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

**TABLE OF INTEGRALS**

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Problem 1 (35 pts.)

An infinite coaxial cable is modeled as a cylinder of surface charge density *ρsa* of radius *a*, surrounded by another cylinder of surface charge density *ρsb* of radius *b*. The entire system is electrically neutral. Also, assume that the outer surface (*ρ* = *b*) is at zero volts. There is free space (vacuum) for *ρ* < *a*, *a* < *ρ* < *b*, and *ρ* > *b*.

a) Assuming that *ρsa* is given, determine *ρsb*.

b) Find the stored electric energy in a one-meter length section of the coaxial cable, putting your answer in terms of *ρsa*. Use the formula for stored energy that has the electric field in it.

c) Find the stored electric energy in a one-meter length section of the coaxial cable, putting your answer in terms of *ρsa*. Use the formula for stored energy that has the potential in it.



**Room for Work**

**Part (a)**

Since the system is neutral, the charge on the outer surface is equal and opposite to the charge on the inner surface. Therefore, for a length *h* in the *z* direction, we have



so that

.

**Part (b)**

Between the two conductors (*a* < *ρ* < *b*) we have



or

.

There is no electric field for *ρ* < *a* and for *ρ* > *b*.

The stored electric energy is therefore given by



We then have

.

Hence, we have

.

**Part (c)**

The stored energy using the potential formula is

.

Since the potential is zero on the outer surface (and at infinity), we have

.

Hence we need the potential on the inner surface.

We have

.

Hence, we have

.

Therefore, we have

.

Problem 2 (35 pts.)

A power line of radius *a* is located at a height *h* above the earth (measured from the center of the line). The earth is modeled as a perfect electric conductor. The power line has a voltage *V*0 while the earth is at zero volts.

a) Derive a formula for the maximum voltage that can be placed on the line before dielectric breakdown occurs in the air. Assume that the air has a breakdown field strength of *Ec* [V/m].

(It might be helpful to first consider where the air will breakdown first. That is, where is the electric field the highest?)

b) Derive a formula for the capacitance per unit length (per unit length in the *z* direction) between the power line and the ground plane.

**Note:** For this problem you do not need to re-derive anything that is already in the class notes. That is, feel free to use any equations that you may find there.



**Room for Work**

**Part (a)**

Modeling the power line as a line charge *ρ*l0 located at *y* = *h*, we have an image line charge located at *z* = -*h*. The electric field will be the strongest on the surface of the power line, at the bottom of the line. That is, at *x* = 0 and *h* = *y*-*a*. The electric field will be

.

Hence, we set

.

From the class notes, we have

.

Hence, we have

.

This gives us the maximum voltage on the power line as

.

**Part (b)**

The capacitance per unit length is given by

.

Using



We obtain

.

Problem 3 (30 pts.)

A square loop of uniform line charge density *ρl*0 is shown below. The side length of the square loop is *L*, and the loop lies in the *z* = 0 plane, centered at the origin.

Find the potential on the positive *z* axis at (0, 0, *z*), assuming that the potential is zero at the origin. (Do not find the electric field first.)

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**Room for Work**

If the potential is zero at infinity, we have

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The potential from each of the four sides is the same for an observation point on the *z* axis, so we can find the potential from a single segment and then multiply by four.

We then have

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From the table of integrals, we have

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Hence, we have

.

Hence, we have

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Since the potential is zero at the origin, we add a constant to the solution. We then have

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