#### ECE 3318

#### Applied Electricity and Magnetism

**Exam 2**

#### April 29, 2021

**Please read carefully the Zoom instructions on the first page and the general instructions on the second page.**

**Zoom Instructions**

* You are not allowed to use your computer, or any other device, to communicate with anyone other than the instructor during the exam.
* If you wish to ask a question during the exam, please use the “chat” feature of Zoom to chat with the instructor (please chat only with the instructor, not with “everyone”).
* Please leave your camera on during the entire exam.
* Please leave yourself muted unless the instructor asks you to unmute yourself.
* By taking this exam, you agree to the UH Academic Honesty Policy. You understand that the penalty for violating the UH Academic Honesty Policy will be most severe, including getting an F in the course and/or getting expelled from the university.
* The exam has three parts (three problems). Make sure that you upload your solution (as a pdf file) to each problem during the allowed time window. Late submissions may not be accepted, or will be assigned a penalty.

**General Instructions**

1. This exam is open-book and open-notes.
2. Show all of your work. No credit will be given if the work required to obtain the solutions is not shown.
3. Write neatly. You will not be given credit for work that is not **easily** legible.
4. Leave answers in terms of the parameters given in the problem.
5. Show units in all of your final answers.
6. Circle your final answers.
7. Double-check your answers. For simpler problems, partial credit may not be given.
8. If you have any questions, ask the instructor. You will not be given credit for work that is based on a wrong assumption.

**TABLE OF INTEGRALS**

****

****

****

****

****

****





Problem 1 (30 pts.)

A semi-infinite uniform line charge density is located along the negative *z* axis as shown below.

a) Calculate the potential function  at an observation point located at  in cylindrical coordinates, assuming that the potential is zero at infinity.

b) How would your answer change if the potential is now zero on the *z* axis at a point 1 meter above the origin?



**Solution**

Note that we will assume that this line source extends from  to . Although *L* can be large, we cannot let it be actually infinity, since the integral will then not converge (this was an error in the exam).

**Part (a)**

The formula for the potential from a charge (assuming zero volts at infinity) is:

.

If we assume that the line source extends from  to , we have



We have

.

Hence, we have

.

Next, use

****.

This gives us



or

.

If we wish to have zero volts one meter up on the *z* axis, we then have

.

We then have

.

Solving for *C*, we then have



Problem 2 (35 pts.)

An engineer is using a voltmeter (assumed to be an ideal voltmeter) to measure the voltage across a resistor in a circuit as shown below. Two parallel leads are used to connect the voltmeter to the resistor as shown. The separation between the two leads is *h* and the length of the leads is *L*. The leads start at *x* = *a* and reach the resistor at *x* = *a* + *L*. There is a wire carrying a current in the room, and this produces a magnetic flux density that is given by

.

Assuming that the actual voltage across the resistor is called , what would the voltage  be that the voltmeter reads?



**Solution**

We have from Faraday’s law that

.

Let’s choose a counterclockwise path around the rectangular contour *C*. The LHS of Faraday’s law becomes

.

The flux through the loop in the RHS of Faraday’s law (with the unit normal being in the positive *z* direction) is

.

Hence,

.

We then have

.

The result is then

.

Problem 3 (35 pts.)

A transmission line runs in the *z* direction. It consists of two cylindrical wires, one of radius *a* and one of radius *b*, as shown below.

a) Find the capacitance per unit length  for this transmission line, assuming that the wires are in air. You may assume that any charge that you put on either wire distributes uniformly around the circumference of the wire.

b) Now assume that there is a material with a conductivity *σ* surrounding the wires instead of air. What would the conductance per unit length  be between the two wires?

****

**Solution**

Let us assume that we have [C/m] on the left (anode) wire and  [C/m] on the right (cathode) wire. The capacitance per unit length is given by

.

Along the *x* axis between the two wires, the electric field is

.

The voltage drop between the two wires is given by

.

Hence, we have

.

The capacitance per unit length is then

.

Using the RC analogy method, we have

.