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

#### ECE 3318

#### Applied Electricity and Magnetism

**Final Exam**

#### April 30, 2020

**Remote Exam 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”).

By taking this exam, you agree to the UH Academic Honesty Policy.

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. 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.

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 (20 pts.)

An annular disk of uniform surface charge density *ρs*0 is shown below. The annular disk lies in the *z* = 0 plane and is centered at the origin, with inner radius *a* and outer radius *b*.

Find the potential Φ at a point on the *x* axis at a distance *x*0 from the origin. Assume that the potential is zero at the origin.

You do not have to evaluate any integrals that appear in your answer. However, please evaluate in closed form any constants that appear in your answer.



Problem 2 (20 pts.)

A transmission line consists of two circular conducting wires as shown below. One wire has radius *a* and the other wire has radius *b*. The structure is infinite in the *z* direction, and the conductors may be assumed to be PEC.

a) Find the capacitance per unit length *Cl* between the two conducting wires, assuming that the two conductors are in air.

b) Now assume that the same two conductors are immersed in an infinite conducting medium having a conductivity *σ*. Find the conductance per unit length *Gl* for the transmission line. (This is the conductance per meter in the *z* direction.)



Problem 3 (20 pts.)

A wireless power transfer system has a transmitting loop that is centered at the origin, lying in the *z* = 0 plane, of radius *a*. The loop has *N*1 turns (though only one turn is shown in the figure). Above the transmitting loop is a receive loop, lying in the plane *z* = *h*, with radius *b* and having *N*2 turns (only one turn is shown in the figure). The radius *b* is small compared to *a*, so that the magnetic field produced by the bottom (transmit) loop may be assumed to be approximately constant over the area of the top (receive) loop.

Note that a blown-up view of the top (receive) coil is shown in the figure below, showing the output voltage.

a) Find the open-circuit output voltage *v*(*t*) on the receive coil if the current in the bottom transmit coil is

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The frequency is low enough so that at any instance of time the magnetic field at that time can be calculated by assuming the current *i*(*t*) to be a DC current having the same value as the actual current *i*(*t*) at that time.

(You may use any formulas in the class notes to help you; you do not need to derive anything that has already been derived in the class notes.)

b) Assume that we know the resistance of the receive coil *R*2 and the inductance of the receive coil *L*2. Find a Thévenin equivalent circuit for the receive coil in the phasor domain. Clearly show what the Thévenin voltage is in the phasor domain.





Problem 4 (20 pts.)

A transmission line consists of a metal slab of thickness *t* and width *w* surrounded by two thin metal sheets of width *w*, as shown below. The transmission line is infinite in the *z* direction. Assume that the metal slab carries a current *I* in the *z* direction. Each metal sheet carries a current *I*/2 in the negative *z* direction. Assume that the width *w* is large enough so that fringing may be neglected.

Find the magnetic field vector in all five regions:

a) *y* < 0

b) 0 < *y* < *h*

c) *h* < *y* < *h*+*t*

d) *h*+*t* < *y* < 2*h*+*t*

e) *y* > 2*h*+*t*.

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Problem 5 (20 pts.)

A loop has a current *I* that flows first along the *x* axis, then along an circular arc of radius *a*, and then along the *y* axis, as shown below. The observation point is on the *z* axis at a height *h* above the *z* = 0 plane

a) Find the magnetic field vector *H* at the observation point that is produced by the current flowing on the *x* axis. Express your answer in rectangular coordinates.

b) Find the magnetic field vector *H* at the observation point that is produced by the current flowing on the *y* axis. Express your answer in rectangular coordinates.

c) Find the magnetic field vector *H* at the observation point that is produced by the current flowing on the circular part of the loop. Express your answer in rectangular coordinates.



Extra Credit (20 pts.)

A coil with *N* turns is wound on a high-permeability core as shown below. The core is square-shaped with an air gap in it. The cross-sectional area of the core is *A* square meters, and the relative permeability of the core is *μr*. The core has a horizontal length of *L*1 and a vertical height of 2*L*2+*Lg*.

a) Looking at the direction that the current is flowing in the coil, answer the following question: Is the magnetic field in the air gap going up or down?

b) Find a formula for the magnitude of the magnetic flux density vector *B* inside the air gap, in terms of the parameters given.

c) Is the magnitude of *B* inside the air gap mainly being determined by the iron core or by the air gap? Justify your answer by assuming the following parameters:



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