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

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

#### ECE 2317

#### Applied Electricity and Magnetism

**Final Exam**

#### Dec. 12, 2012

1. This exam is closed-book and closed-notes notes. A formula sheet is provided.
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.

­­­­­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Signature

FORMULA SHEET

































































































































**Electrostatic TriangleTABLE OF INTEGRALS**



****

****

****

****

****

****





TABLE OF COORDINATE SYSTEM FORMULAS

 

 

 































Problem 1 (25 pts.)

**Give short answers to the questions below.**

1. What is the name of the group of electrons that emerges from the base of a thundercloud, and zigzags its way down to earth at the beginning of a lighting strike?

Stepped leader

1. Give a brief description as to how a lightning rod works.

The sharp point creates a strong electric field which provides a good streamer to make contact with the downward traveling stepped leader. The lightning rod is well grounded in order to safely carry the discharge to earth.

1. In what city is there a museum that houses the original Van de Graaff generator produced by Robert Van de Graaff?

Boston

1. In what city is there the Faraday Museum, in which you can see the first generator ever built by Michael Faraday?

London

1. When current flows through a conducting object, the object heats up. What is the name of this law?

Joule’s law

1. What is the name of the law that tells us that there is no magnetic charge existing in nature?

Magnetic Gauss law

1. What is the name of the equation that the potential function obeys, inside a general region of charge density?

Poisson equation

1. Consider a loop with a current defined flowing clockwise in it. According to the right-hand rule for inductance, which direction would the flux be measured in? (your choices are up or down).

Down

1. When using the electric stored energy formula involving the potential function, what conditions do we have to impose on the reference point in order to make sure that the answer is correct?

The potential at infinity is zero.

1. Consider a loop with a contour defined going counterclockwise around it. According to the right-hand rule in Ampere’s law, which direction would the current enclosed be measured in? (your choices are up or down).

Up

Problem 2 (25 pts.)

During a thunderstorm the base of a cloud has a negative charge, and is at a voltage of -150 [MV] with respect to ground (ground is taken as zero volts). Assume that the base of the cloud and the ground directly below the cloud act together as a big ideal parallel-plate capacitor. The base of the cloud is at a height of *h* = 1.0 [km].

(a) What is the electric field vector at a point on the ground below the cloud?

(b) How much energy is stored in the region between the base of the cloud and the ground, assuming that the base of the cloud is taken as a circular disk that is 5.0 [km] in radius?

(c) Assume that a lighting strike occurs from the base of the cloud to the ground below. If -5 [C] of charge gets transferred from the cloud to the ground during the strike, how much energy gets dissipated during the strike?

*z*

*x*

*h*

- - - - - - - - - - - - - - - - -

+ + + + + + + + + + + + + + + - -

Earth

**Room for Work**

**Solution**

(a)

.

(b)

.

(c)

.Problem 3 (25 pts.)

A rectangular loop of wire is situated near an infinite wire as shown below. The wire is carrying a current *i* (*t*) in the *z* direction, given by



The frequency is low enough so that at any instance of time, the magnetic field produced by the wire may be taken as that due to a DC current *I* that has the same amplitude as *i* (*t*).

(a) Calculate the magnetic field *H* (*t*) from the wire in the *y* = 0 plane, for *x* > 0.

(b) Use Faraday’s law to calculate the output voltage *v*(*t*) of the loop. Please pay attention to get the sign correct!

*L*

*W*

*+L*

*-*

*d*

*z*

*i* (*t*)

*v* (*t*)

*x*

**Room for Work**

**Solution**

(a)

From ampere’s law we have

.

(b)

From Faradays law in integral form, we have

,

where *C* is a contour running around the loop counter clockwise.

The magnetic flux is

.

Hence we have

.

Hence, we have

.

Therefore,

Problem 4 (25 pts.)

A tank is used to measure the resistance of a liquid. The tank has a cylinder of height *h* and radius *b*. The wall of the tank at *ρ* = *b* is a perfect conductor, while the bottom of the tank is an insulating plate. Inside the tank is a wire of radius *a*. Between the tank and the wire is the liquid with an unknown conductivity *σ*. The resistance *R* is measured between the wire and the tank.

Because the bottom of the tank is an insulating plate, the electric field inside the tank is perfectly in the radial direction, just as it would be for a section of length *h* of coaxial cable.

Determine a formula for the conductivity of the liquid in terms of the resistance *R* that is measured.

*h*

2*a*

*b*

Liquid

**Room for Work**

**Solution**

If we have an insulating medium instead of the conducting liquid, then we would have a capacitor, and the capacitance would be

.

The RC analogy tells us that

.

Hence, we have

.

We then have

.

Problem 5 (25 pts.)

A rectangular-shaped parallel-plate transmission line structure consists of two conducting copper plates of width *w* and a thickness *h* as shown below. There is a spacing of *t* between the two plates. The copper is nonmagnetic (the relative permeability is unity). Assume that *h* << *w*, so there is no variation of the fields in the *x* direction. The structure is infinite in the *z* direction.

(a) Determine the magnetic field vector *H* (*y*) as a function of *y*, in the following regions:



(b) Calculate the inductance per unit length *LL* (per unit length in the *z* direction) by using the stored-energy method. Account for the energy that is stored both in the air region between the conductors and inside the two conductors.

# *I*

*h*

*x*

*y*

*w*

*z*

*h*

*t*

*I*

*I*

Room for Work

**Solution**

(a)

The magnetic field above the structure is zero. From Ampere’s law, the magnetic field inside the top conductor is given by

.

This gives us

.

The magnetic field between the two conductors is found by setting *y* = *h* + *t* in the above formula. Hence, we have

.

The final answer is then

.

(b)

We use

.

From symmetry, we have

.

This gives us

.

Evaluating the integrals, we have

.

Evaluating, we have

.

The final result is then

.

Problem 6 (25 pts.)

An infinite wire carrying a current *I* is bent at a 90o angle as shown below. Calculate the magnetic field *H* at a point on the *x* axis at a distance *h* from the origin.

*x*

*y*

*h*

*I*

*I*

*r*

Room for Work

**Solution**

From the Biot-Savart law, we see that the magnetic field comes only from the vertical part of the wire. We then have



where



Hence we have

.

This gives us

.

Performing the integration, we have

.

This gives us



or

.

Interestingly, this is one half of the magnetic field produced by an infinite wire along the *y* axis.

Extra Credit Problem (25 pts.)

A hollow (air-filled) solenoid has *N*1 turns and a length of *L*1, with a radius of *a*1. Inside this solenoid is a smaller hollow solenoid with *N*2 turns and a length *L*2, with of radius of *a*2. The outer solenoid is denoted as coil 1, while the inner solenoid is denoted as coil 2. Note the reference directions for the currents *I*1 and *I*2 on the two coils.

Determine the mutual inductance *M*21.

*I*2

*a*2

*z*

*I*1

*a*1

**Room for Work**

**Solution**

The mutual inductance is given by



where



and

.

Hence, we have

.

The final answer is then

.