Introduction to Computers and Engineering Problem Solving
Spring 2012
Problem Set 1: Calculating the inductance of an antenna
Due: 12 noon, Friday, February 17, 2012

Introduction

In this problem set, we will explore how to perform a set of calculations. We will calculate the values of electromagnetic phenomena associated with antennae, when provided with the values of different parameters. We simplify the physics and don't state all the assumptions, though those of you who took 8.02 can refer to your past notes for more background. The background is not necessary to complete this assignment; we provide all definitions for the calculations that are required.

Magnetic Inductance

In this homework, we will calculate the magnetic inductance of three types of antennae: line, coil, and rectangular. The magnetic inductance equation for each is provided below.

Line Antenna
The magnetic inductance around a straight, linear antenna is (Equation 1):

$$B = \frac{\mu I}{2\pi r}$$

where

B= magnetic inductance (volt-seconds per meter squared)
μ= magnetic field constant (1.257×10^{-6} volt-seconds/ampere)
I= current (amperes)
r= distance from antenna (meters)

In this problem set, we will work with line antennae that receive 10mA of current.

Coil Antenna
The magnetic inductance along the center line of a round coil antenna is (Equation 2):

$$B = \frac{\mu I N R^2}{2\sqrt{(R^2 + x^2)^3}}$$

where

N= number of windings
R= radius (meters)

x= distance from the center of the coil along the (vertical) center line; see the figure. We assume the windings are spaced very closely; the figure exaggerates the spacing.

In this problem set we will work with coil antennae that have a current of 20mA.

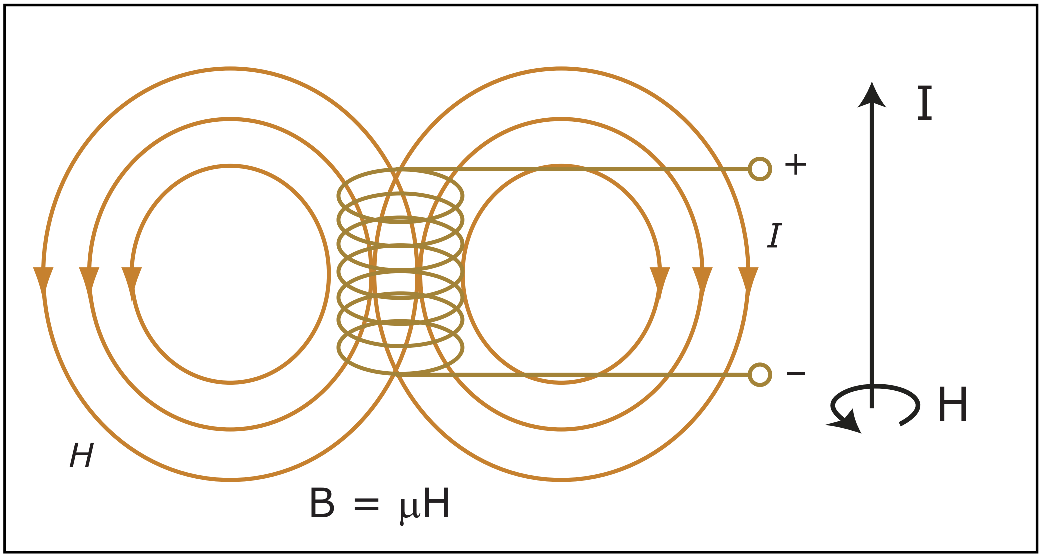


Image by MIT OpenCourseWare. Adapted from Figure 4.2 Finkenzeller, Klaus (2003). RFID Handbook (2nd Edition). Wiley.

(FIGURE FROM FINKENZELLER, RFID HANDBOOK. B= µH.)

Rectangular Antenna

The magnetic inductance along the center line of a rectangular antenna is (Equation 3):

$$B = \frac{\mu N I a b}{4\pi\sqrt{(\frac{a}{2})^2 + (\frac{b}{2})^2 + x^2}} \cdot \left(\frac{1}{(\frac{a}{2})^2 + x^2} + \frac{1}{(\frac{b}{2})^2 + x^2}\right)$$

where

a= width of antenna (meters)
b= length of antenna (meters)
I= current (amperes)
x=distance from antenna (meters)
N=number of windings

In this problem set we will work with rectangular antennae that have a current of 30mA and only have 1 winding.

Mutual Inductance

We will also calculate the mutual inductance of two combinations of antennae: two coil antennae, and a rectangular antenna adjacent to a straight antenna.

Two Coil Antennae

The mutual inductance of two coil antennae is given by (Equation 4):

$$M = \frac{\mu N_1 {R_1}^2 N_2 {R_2}^2 \pi}{2\sqrt{({R_2}^2 + x^2)^3}}$$

where

M = mutual inductance (volts-seconds per meter squared)
N_1 = number of windings in the smaller coil antenna 1
R_1 = radius of the smaller coil antenna 1 (meters)
N_2 = number of windings in the larger coil antenna 2
R_2 = radius of the larger coil antenna 2 (meters)
x= distance between the two coil antennae (meters)

The two coil antennae are in the same plane and nearby, as shown in the figure below.

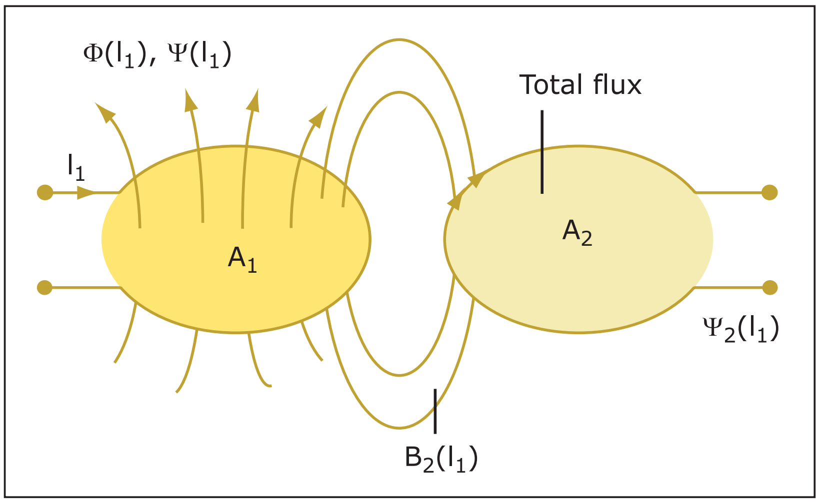


Image by MIT OpenCourseWare. Adapted from Figure 4.8 Finkenzeller, Klaus (2003). RFID Handbook (2nd Edition). Wiley.

(FIGURE FROM FINKENZELLER)

In this problem set, when working with one coil antenna (when measuring magnetic inductance), we will assume that it has:

N_1 = 100 windings
R_1 = 0.1m

When working with a second antenna (when measuring mutual inductance) we will assume the second antenna has the following characteristics:

N_2 = 200 windings
R_2 = 0.15m

Rectangular Antenna adjacent to a Line Antenna

The mutual inductance of a line antenna and a rectangular antenna is given by (Equation 5):

$$M = \frac{\mu a}{2\pi} \ln\left(\frac{x+b}{x}\right)$$

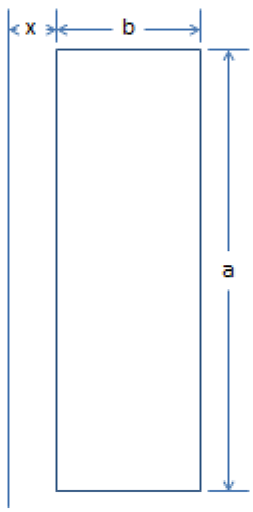
where

a= dimension of rectangle antenna parallel to line antenna (meters); assume this is also the width of the antenna in equation 3.
b= dimension of rectangle antenna perpendicular to line antenna (meters); assume this is also the length of the antenna in equation 3.
x= distance between rectangle antenna and line antenna (meters)

See the figure below.

In this assignment we have a rectangle antenna with the following specifications:

a= 0.3m
b= 0.2m



You must calculate these different inductances for the antennae we have described (line, coil and rectangle). The calculations that you must implement are:

- Line antenna:
    - Compute magnetic inductance (equation 1)
- Coil antenna:
    - Compute magnetic inductance (equation 2)
    - Compute mutual inductance with another coil antenna (equation 4)
- Rectangle antenna:
    - Compute magnetic inductance (equation 3)
    - Compute mutual inductance with a line antenna (equation 5)

Only some of these calculations will need to be done – depending on the type of antenna

2. Program

Your program should:

1. Allow the user to specify an antenna type using a `JOptionPane`.
2. Given the selected antenna, prompt the user to enter a minimum and maximum distance value for the antenna type, *r* in equation 1, *x* in equations 2-5.
3. With these user inputs, compute the associated inductance value(s) using the values provided above. If either a coil or rectangle antenna is selected, both magnetic and mutual inductance should be computed at each distance value.
4. Calculate and print the inductances for a range of distance values in 0.05m increments between the minimum and maximum distances.
5. Prompt the user with a `JOptionPane` to either enter new inputs or quit. If the user chooses to enter new inputs, the program should start again from the beginning.

Turn In

For this problem set:

a. Place a comment with your full name, section, TA name and assignment number at the beginning of **all** .java files in your solution.
b. Place all of the files in your solution in a single zip file.
c. Do not turn in electronic or printed copies of compiled byte code (.class files) or backup source code (.java~ files)
d. Do not turn in printed copies of your solution.

2. Submit this single zip file on the 1.00 Web site under the appropriate section and problem set number. For directions see **How To: Submit Homework** on the 1.00 Web site.
3. Your solution is due at noon. Your uploaded files should have a timestamp of no later than noon on the due date.
4. After you submit your solution, please recheck that you submitted your .java file. If you submitted your .class file, you will receive **zero credit.**

Penalties

For <u>each</u> problem set:

- 30 points off if you turn in your problem set after Friday noon but before noon on the following Monday. You have one no-penalty late submission per term for a turn-in after Friday noon and before Monday noon.
  - Problem set 6 is due Wednesday noon because of a Friday holiday. You may turn it in for the late penalty by the following Monday at noon.

- No credit if you turn in your problem set after noon on the following Monday.

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