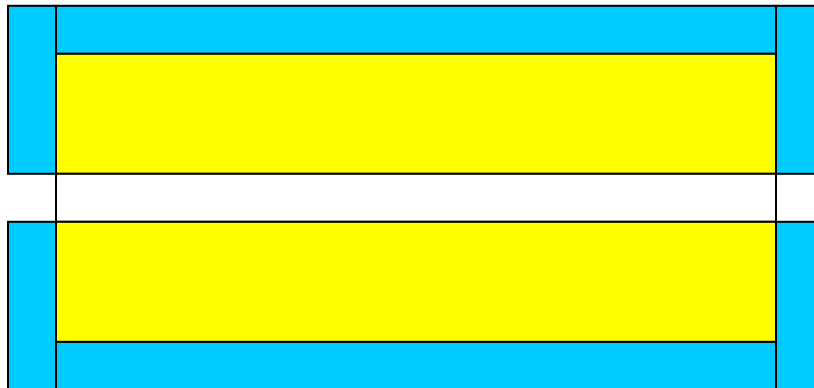


Homework #6
Due 11 April**1. Inductance with New Materials**

- a. Assume we have a standard RG58 cable (recall the properties from the transmission line part of the course). From the dimensions and materials used in a standard cable of this type, calculate the inductance per unit length. Also give the propagation velocity v and the characteristic impedance Z_o for the cable. This information will be used to compare with a cable where we have replaced the insulator with a material that is also magnetic.
- b. The insulating material is replaced with magnetic glass. Such materials could make it possible to build transformers without eddy current losses. We will make up some material properties to see how using such glass would change the performance of the cable. Assume that the relative permittivity is $\epsilon_r = 4$ and the relative permeability is $\mu_r = 800$. If we just use this material, but leave the dimensions of the cable the same, what is the new inductance per unit length, capacitance per unit length, propagation speed and characteristic impedance of the line?
- c. Find a real value for the properties of some magnetic glass (look online).

2. Advanced Paper Clip Launcher

One possible improvement that has been considered for the coil we use to launch paper clips is to provide a flux path around the coil by surrounding it with iron. The configuration is shown below. Making any reasonable assumptions, you are to use the magnetic circuit method to find the inductance of the coil with no projectile.



In the figure, the blue regions are iron and the yellow region is the coil. To make the analysis simpler, we will assume that the wires are wound only in a single layer so that we do not need to address their thickness. The simplified diagram is on the next page.

Homework #6
Due 11 April

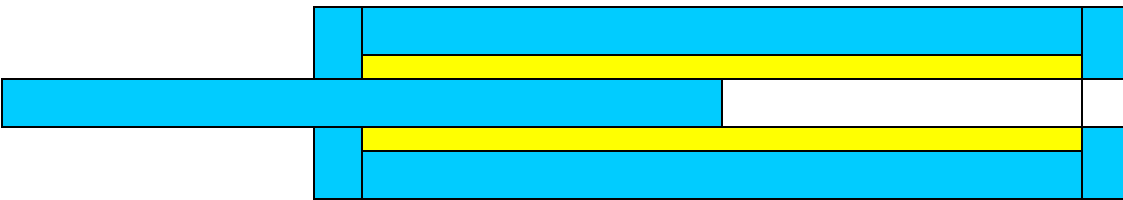


The thickness of the outer cylinder and the two washer-like regions on each end is t . The radius of the hole down the center is a and the inner radius of the outer cylinder is b . The length of the coil is d . The overall radius (the outer radius) is c . The number of turns is N .

- a. Determine the external inductance of the coil surrounded by the iron structure. You may want to sketch this configuration in 3 dimensions. Assume that the relative permeability of the iron is μ_r .
- b. Now assume that the central region (formerly the hole in the middle) has a piece of cylindrical iron in it (like a piece of paper clip) with the same relative permeability μ_r . Find the external inductance for this case.
- c. For a given current I in the coil, determine the energy of the two configurations.

You have just considered the two cases where the projectile is not in the coil and where it is fully in the coil. Assume that, as the projectile moves into the coil, the inductance increases linearly with position. The configuration with the projectile partially in the coil is shown below.

- d. Given this assumption, determine the force on the projectile.



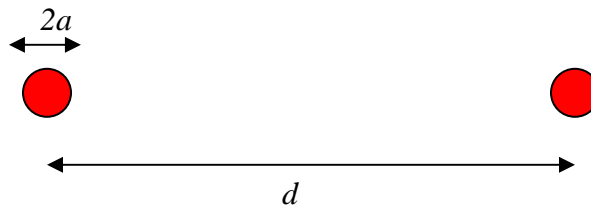
- e. Find a real value for the relative permeability of iron.

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Due 11 April

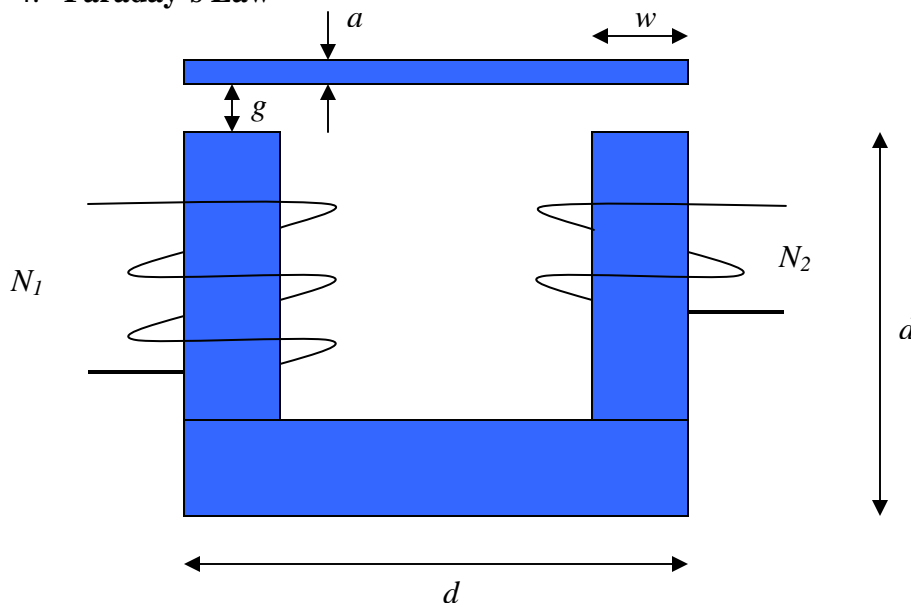
3. Forces Between Conducting Wires

Two long parallel circular wires carry a very large current to and from a load of some kind. The wires are separated by a distance d and have a radius a . Assuming that $a \ll d$, find the force per unit length on the wires due to the current they are carrying.

- Determine the field produced by the wire at the left at the position of the wire at the right. Assume that the current at the left is into the page and the current to the right is out of the page.
- Determine the force per unit length experienced by the wire at the right.
- Is the force such that the wires are attracted together or repelled from one another?



4. Faraday's Law



In this problem, we consider a field produced by one coil and sensed by another as the physical structure changes with respect to time. The coil at the left has N_1 turns and the coil at the right has N_2 turns. Assume that there is a steady current I in the left coil. The width of the C core at the bottom is w and the thickness of the bar at the top is a . The depth of all pieces is w . The gap dimension is g . The permeability of the core material is very much larger than that of free space. $\mu_r \gg \mu_0$

Homework #6

Due 11 April

- a. Using the method of magnetic circuits, determine the inductance of the coil at the right for this configuration.
- b. Determine the magnetic flux in this system and the total flux linked by the coil at the right due to the current in the coil at the left.

Now assume that the plate at the top moves up and down due to changes in some physical parameter being measured. For example, it could be the bottom of a pressure chamber and the position of this plate could give information on the pressure in the chamber.

There is an interesting discussion of such sensors at the sensorland website

<http://www.sensorland.com/HowPage012.html> For simplicity, we will assume that the plate is moving up and down such that the gap dimension changes sinusoidally with time.

$g(t) = g_o \cos \omega t$. The voltage we observe across the coil at the right can give us information on the position of the plate and thus on the pressure it is sensing.

- c. Determine the flux linked by the coil at the right as a function of time.
- d. Determine the voltage appearing across the coil at the right as a function of time.