1. An infinitely long straight wire, made out of linear magnetic ($K_m \gg 1$) material, has radius a and carries a steady current I uniformly distributed throughout its cross-section.

   (a) Find $\mathbf{H}, \mathbf{B}$, and $\mathbf{M}$ everywhere (including inside the wire and in the vacuum beyond the wire). Be sure to state the direction of these vectors! Hint: Ampère's Law!

   (b) Find effective magnetization currents: $\mathbf{J}_M$ (volume current density) and $\mathbf{j}_M$ (surface current density—we called this $\mathbf{K}$ in class). What is the *total* magnetization current (in Amps) flowing just on the surface of the wire ($r = a$)?

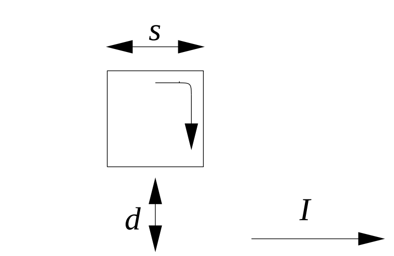
2. The wire in the previous problem is made into a coaxial cable by coating it with an insulator (with thickness zero) and then covering that with an equally thin copper shell (all of this at $r = a$). As a coaxial cable, the current flowing in the magnetic material is "returned" in the copper shell. Find the total magnetic field energy (Hint: $\mathbf{B} \cdot \mathbf{H}$) stored in a length ℓ of this wire and use this to calculate the self inductance per length of the cable.

3. Together in a plane, an infinite straight wire is a distance d away from a square wire loop (with side s). I've assigned arrows to each wire showing my choice for positive currents.

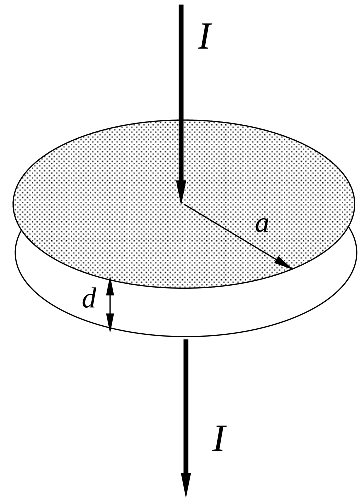
   (a) If the straight wire carries a current I, what flux exists through the square? Find the mutual inductance between the square and the wire.

   (b) Sign convention: Show the required direction of the surface normal for the square. Show the direction of the magnetic field at the loop center due to a positive current flowing in long straight wire. Report then the *sign* of the mutual inductance calculated in (a).

   (c) Consider the case where the current flow in the long straight wire is initially zero, but the current in the square loop, zero initially is starting up in the clockwise (positive) direction. In what direction would the current flow in the long straight wire? Recall: $M_{12} = M_{21}$.



4. An ideal capacitor consists of two circular plates of radius a separated by a distance d surrounded by vacuum. Assume the E-field is uniform between the plates (i.e., neglect the fringing field at the edge of the plates). The capacitor is being charged by a constant current I.



   (a) Find the electric field between the plates as a function of time.

   (b) Find the displacement current density between the plates. Using Ampère's law find the magnetic field $\vec{\mathbf{B}}(r)$ between the plates (i.e., for any $r < a$) generated by the displacement current. Clearly show directly on the diagram the direction of $\vec{\mathbf{B}}(r)$ and $\vec{\mathbf{E}}$.

   (c) Find the Poynting vector on the circumference of the capacitor. Is energy entering or leaving the capacitor?

   (d) Integrate $\vec{\mathbf{S}}\cdot\hat{\mathbf{n}}$ over the cylindrical edge of the capacitor to find the energy flowing *into* the capacitor. Show that the result is equal to the *time rate of change* in the electric energy stored between the capacitor plates. (Use the electric energy density $\frac{1}{2}\vec{\mathbf{E}}\cdot\vec{\mathbf{D}}$ to find the total electric energy between the plates.)

5. Directly on the below the circuit diagram, label your nodes. Write down the node equations for the circuit (one equation for each node; the component values are specified below, but leave them as letters in your equations). Write down the equation for the current, I_2 through R_2. Use Mathematica to solve node equations. Use Mathematica to find the resulting equation for I_2. For the following component values, plot I_2 (its amplitude) vs. ω for $\omega \in (9990, 10010)$.

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/. {V0->1, R1->1000, R2->10^6, R3->1000, c->10^-6, L->.01}
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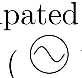
   Use Mathematica to report the complex value for I_2 at $\omega = 9999$. Find the power dissipated (Joule heating) in R_2 at $\omega = 9999$. Note: the far left device in the circuit () is an ac voltage generator of the form $V = V_0 \cos(\omega t)$ where ω is the angular frequency.