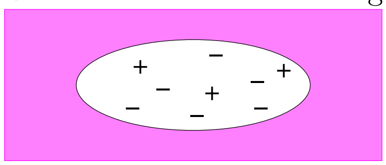
Physics 222 – Test 2 – Spring 2009

One-page reminder sheet allowed. *Show all work – no credit given if work not shown!*

1. Imagine a hollow cavity inside a conducting block. Show that the net charge inside the cavity, including charge on the cavity wall, is zero. Hint: Apply Gauss's law to a Gaussian surface containing the cavity but completely embedded in the conductor.



2. The scalar and vector potential for an electromagnetic wave in a vacuum are assumed to be $\phi = 0$ and $\mathbf{A} = (A, 0, 0)\sin(kz - \omega t)$ where A is a constant.

   (a) Verify that the scalar and vector potentials together satisfy the Lorentz condition.

   (b) What do you know about the ratio ω/k?

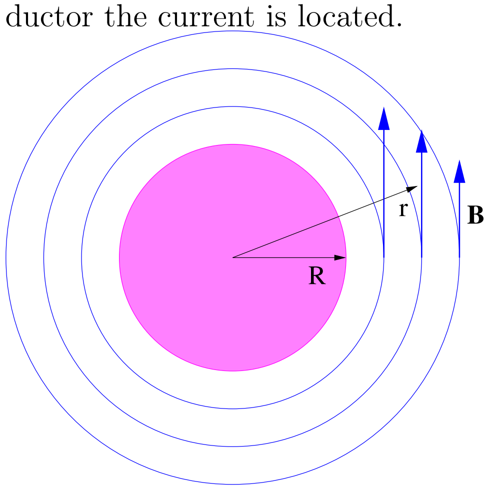
   (c) Compute the electric and magnetic field vectors and show that these fields are perpendicular to the direction of wave propagation and to each other.

   (d) Show that the ratio of the magnitudes of the electric and magnetic fields equals the speed of light in this case.

3. Imagine a long, cylindrical conductor of radius R oriented perpendicular to the page as shown below. The magnitude of the magnetic field outside the conductor as a function of distance r from the axis of the conductor is $B = C/r$ where C is a constant. The magnetic field lines circulate around the conductor as indicated by the circles. Inside the conductor the magnetic field is zero.

   (a) Determine the current flowing in the conductor.

   (b) Given the zero magnetic field inside the conductor, determine where in the conductor the current is located.



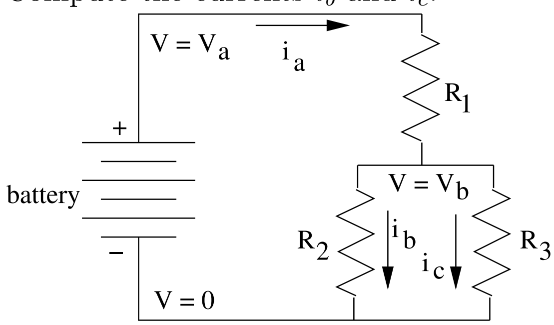
4. Compute the ratio of the electric and magnetic energy densities in an electromagnetic wave propagating in a vacuum. (Hint: You may find the results of problem 2d to be useful.)

5. Consider the circuit below where $V_a = 15$ V, $R_1 = 5$ ohms, $R_2 = 15$ ohms, and $R_3 = 30$ ohms.

   (a) Compute the current i_a. (Hint: R_2 and R_3 are in parallel; R_1 and the combined R_2, R_3 are in series.)

   (b) Compute the voltage V_b.

   (c) Compute the currents i_b and i_c.



6. An electron with momentum of magnitude p scatters off a proton by exchanging a virtual photon with momentum of magnitude q and zero energy as illustrated below.

   (a) Does the photon emission change the energy of the electron? Explain.

   (b) What is the magnitude of the electron's momentum after the scattering event?

   (c) What is the virtual mass of the photon?

   (d) Estimate how close the electron had to come to the proton to make this scattering event possible. (Hint: Recall that the real mass of the photon is zero.)