Physics 52 **Final** **December 17, 1996**

Name ______________________________

Work directly on these pages and show your work clearly. Properly labeled figures are important and will figure into the grading. *Some basic equations are given at the end of the last page.*

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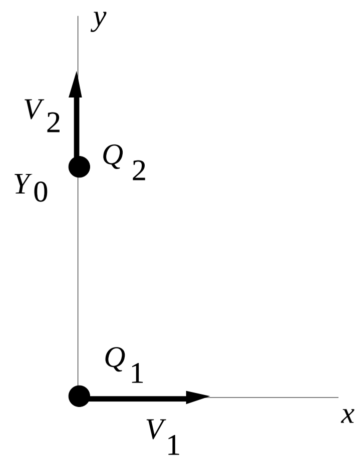
1. (20)	
2. (25)	
3. (25)	
4. (25)	
5. (20)	
6. (25)	
7. (30)	
8. (30)	
Total	

1. [*20 pts*] Two particles with positive charges Q_1 and Q_2 are moving, the first with velocity $V_1\hat{\mathbf{x}}$ and the second with velocity $V_2\hat{\mathbf{y}}$. At some particularly instant Q_1 is crossing the y axis as shown on the figure.

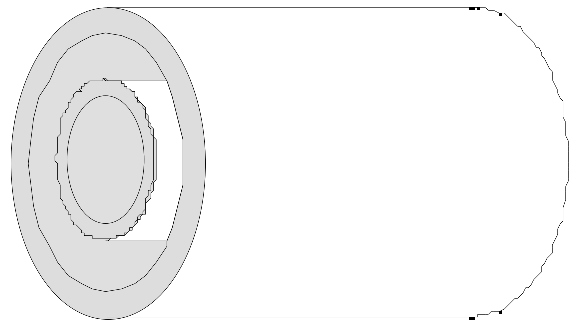
(a) Sketch the field directions and write vector expressions for the electric and magnetic fields **that act on Q_2**. Make these equations specific for this arrangement of charges.

(b) Write vector expressions for each of the forces acting on Q_2 as a result of the above fields. Make it clear to me which equations you are using to determine the various fields and use unit vectors to show the direction of all vectors.

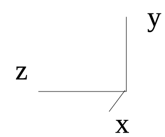


2. [25 pts] The picture shows a section of two infinitely long, thick-walled, metal pipes arranged so they have a common axis. The four radii are *A*, *B*, *C*, and *D* from inside out.

The inner pipe carries a charge per unit length 3λ, and the outer pipe carries a charge $-\lambda$.



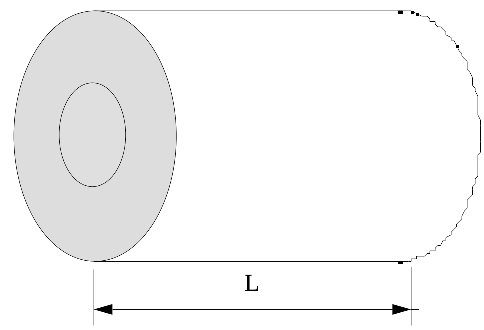
(a) Find expressions for the electric field every place where it is not zero. Make it clear where each expression applies. Define your Gaussian surface and your vectors completely, and with words or equations make it clear you know how to handle the closed surface integral.



(b) How much charge-per-unit-length is located on the **outer** surface of the **outer** pipe?

3. [*25 pts*] A solid conducting ball of radius *a* carries a total charge *Q*, and the electric field everywhere outside the ball is given by $\vec{\mathbf{E}} = \dfrac{Q\hat{\mathbf{r}}}{4\pi\varepsilon_0 r^2}$. If the energy density in an electric field is given by $\eta = \dfrac{\varepsilon_0 E^2}{2}$, determine an expression for the total energy *U* stored in the electric field of this ball. Note, the total energy can also be obtained by calculating the work that must be done to assemble this charge by bringing in pieces from infinity, but I don't want you to calculate it that way.

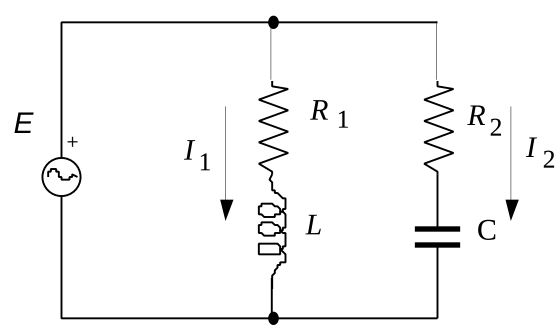
4. [*25 pts*] The picture shows a thick walled plastic pipe of length L and resistivity ρ. The inner radius is A and the outer radius is B.



(a) If both ends of the pipe are plated with a conducting metal, determine an expression for the resistance R_L of the pipe from one end to the other.

(b) Now remove the metal from the ends and instead plate the inner curved wall and the outer curved wall with metal. Determine an expression for the resistance R_R from the inside to the outside.

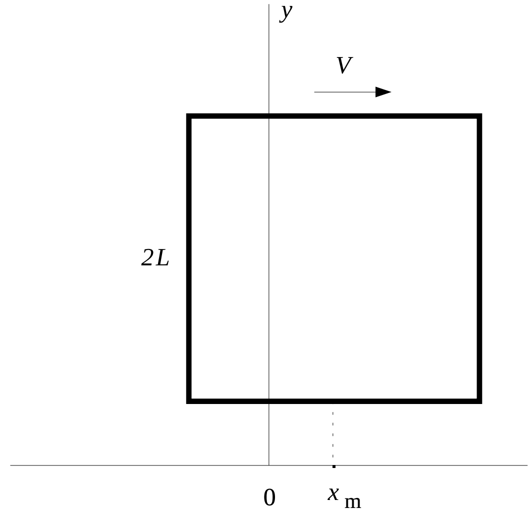
5. [*20 pts*] (a) Use the complex form of the impedances to write expressions for the currents $\mathbf{I}_1$ and $\mathbf{I}_2$.



(b) Simplify these expressions for the special case when $R_1 = R_2 = 4\ \Omega$, $\omega L = 3\ \Omega$, and $\omega C = 0.5\ \Omega^{-1}$, then make two labeled phasor plots showing the relative amplitude and phase of E with respect to each of the currents.

(c) Finally, make a single labeled phasor plot that shows the relative phase of all three phasors. I don't care about the relative magnitudes of the three phasors, but do label the angles in terms of those shown in part (b).

6. [25 pts] In this problem, make sure you properly label all of the vectors in your equations and define them in terms of appropriate unit vectors. The **square** wire frame is rigid and the point x_m indicated measures the position of the center of the frame along the x axis.



If the magnetic field is zero for x < 0 and of magnitude $B = Cx^2$ for x > 0 and directed out of the paper, determine expressions for

(a) the magnetic flux through the square loop when it is in the position shown.

(b) the electromotive force around the loop when it is in the position shown and moving to the right with speed V.

(c) the current in the loop if it has resistance R. Be sure to indicate the current direction.

(d) the net force acting on the loop when it is in the position shown. This does not reduce a lot, but simplify it as much as possible by combining terms.

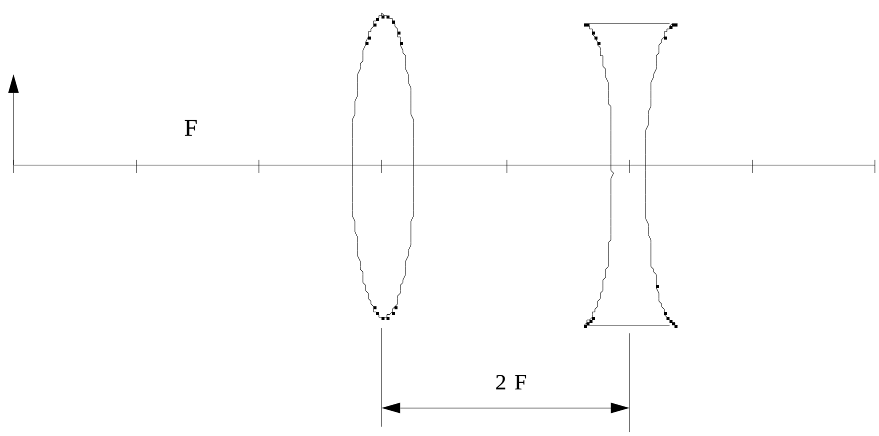
7. [30 pts] The lenses shown have focal length F and $-F$ respectively. An object is placed at distance $3F$ to the left of the first lens. The lenses are $2F$ apart. The small marks on the x axis are spaced F apart.

(a) Sketch the ray starting at the top of the object that is a principal ray for both lenses. Label it clearly.

(b) Sketch the other principal rays for the first lens and locate the intermediate image graphically.

(c) Use the lens equation to determine the position of the intermediate and final images.

(d) For each of the images, indicate whether it is real or virtual.



8. [*30 pts*] This interference question involves a grating with six narrow and equally spaced slits. In class and recitation (n=2) we found that on a distant screen the magnitude of the electric field from the *n*-th slit could be written as $E_n = E_1 e^{j(n-1)\delta} = E_1 e^{j(n-1)\omega l/c}$, where l is the difference in path length between two adjacent slits.

(a) If the screen is a distance L away from the slits, and the slit separation is d, with $L >> d$, derive a modified expression for the phase angle δ that does not contain either ω, l, or c. (The velocity of light is $c = \lambda f$.) You'll need to identify one additional variable which should be obvious if you draw a picture.

(b) What's the smallest positive value of δ (call it δ_{min}) that will produce the first minimum of the recombined fields at the screen? Draw a phasor picture showing this electric field summation and indicate all of the δ_{min} angles. (You might want to work your way up from 2, 3, or 4 slits.)

(c) A second full intensity maximum will occur when $\delta = 2\pi$ (call it δ_{max}), and it should also be obvious that another minimum will occur at a phase angle $\delta_{max} + \delta_{min}$. Determine an expression for the distance Δy between this second full intensity maximum and the next minimum on the screen in terms of d, L, and λ.

$$d\vec{\mathbf{E}} = \frac{1}{4\pi\varepsilon_0}\frac{dq\,\hat{\mathbf{r}}}{r^2}$$
$$d\Phi_E = \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}}$$
$$dV = -\vec{\mathbf{E}} \cdot d\vec{\mathbf{r}}$$
$$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r}$$
$$d\vec{\mathbf{B}} = \frac{\mu_0}{4\pi}\frac{dq\,\vec{\mathbf{v}} \times \hat{\mathbf{r}}}{r^2}$$
$$d\Phi_B = \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$$
$$\vec{\mathbf{F}} = q\vec{\mathbf{E}} + q\vec{\mathbf{v}} \times \vec{\mathbf{B}}$$

$$\mathbf{Z}_L = j\omega L$$
$$\mathbf{Z}_C = \frac{1}{j\omega C}$$
$$E = E_0 e^{j\omega(t - z/c)}$$

$$\oint_S \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{q}{\varepsilon_0}$$
$$\oint_C \vec{\mathbf{E}} \cdot d\vec{\mathbf{r}} = -\frac{d}{dt}\int_S \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$$
$$\oint_C \vec{\mathbf{B}} \cdot d\vec{\mathbf{r}} = \mu_0 i + \mu_0\varepsilon_0\frac{d}{dt}\int_S \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}}$$
$$\vec{\mathbf{S}} = \frac{1}{\mu_0}\vec{\mathbf{E}} \times \vec{\mathbf{B}}, \quad \eta_{\mathbf{E}} = \frac{\varepsilon_0 E^2}{2}, \quad \eta_{\mathbf{B}} = \frac{B^2}{2\mu_0}$$
$$P = \int_S \vec{\mathbf{S}} \cdot d\vec{\mathbf{A}} \text{ Watts}$$
$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$
$$A = 4\pi r^2$$
$$V = \frac{4}{3}\pi r^3$$