E & M, OPTICS EXAM

Instructions:

All questions must be answered, starting a new sheet of paper for each new question. If you choose not to answer a question include a blank sheet with the question number on it.

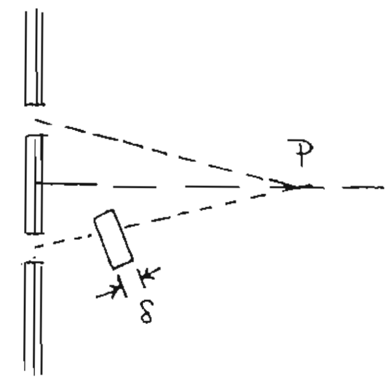
Caution, partial credit will be given only when correct and clearly explained components of the problems solution are presented. Explanatory text is very useful in this regard. By being both explicit and clear in your solution you will receive the maximum partial credit.

1. The diagram below shows a double-slit experiment in which coherent monochromatic light of wavelength λ from a distant source is incident upon the two slits, each of width w ($w >> \lambda$), and the interference pattern is viewed on a distant screen. A thin piece of glass of thickness δ, index of refraction n, is placed between one of the slits and the screen perpendicular to the light path. Assume that the glass does not absorb or reflect any light. If the intensity for $\delta = 0$ is given by I_0,

(a) What is the intensity at point P as a function of δ?

(b) For what values of δ is the intensity at P a minimum?

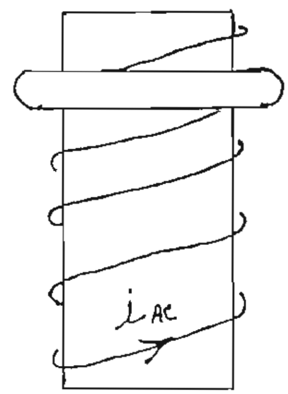
(c) Suppose the width w of one of the slits is now increased to $2w$, the other width remaining unchanged. What is the intensity at point P as a function of δ?



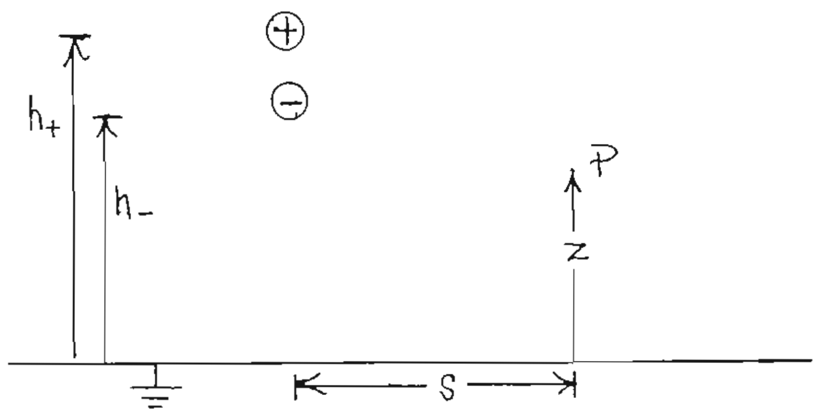
2. In a standard lecture demonstration one has a coil with an AC current through it and a conducting ring held down on top of the coil (see figure below). When the ring is released it jumps up in the air.

(a) If the impedance of the ring is purely resistive, show that there would be no net (average over time) repulsion.

(b) If the impedance of the ring is purely inductive (a simple extreme case) show that there is a net repulsive interaction.



3. In the following figure, two closely spaced, opposite charges $+Q$ and $-Q$, are placed a large distance above a grounded conducting plate.



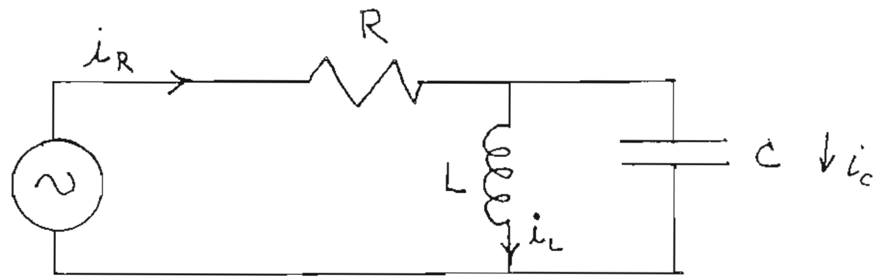
The positive charge is distance h_+ above the plate and the negative charge is distance h_-.

(a) Calculate the electric potential at a general point P in the space above the plate where P has cylindrical coordinates (s, ∅, z).

(b) Show that your expression for the potential satisfies the boundary conditions of this problem.

You may assume that the separation between the charges is very small compared to all other distances in the problem.

4. Consider the following circuit



The generator emf has time dependence

$$\mathcal{E} = \mathcal{E}_0 \sin \omega t$$

Analyze the circuit to obtain the time dependence of the current i_R including expressions for its magnitude and relative phase in terms of $\mathcal{E}_0$, ω, R, L and C. What is the current i_L in the inductor as a function of frequency? Make a graph of the magnitude of the current i_R and i_L as a function of frequency.

5. Ampere's law for magnetostatic phenomena is given by

$$\nabla x \bar{H} = \frac{4\pi}{c}\bar{J}$$

Using the continuity equation for change conservation, derive an equivalent equation for time varying currents. In this equation H is the magnetic field, J is the current density, and c is the velocity of electromagnetic waves in free space.

6. A stationary wire carries a current moving to the left. When the wire is at rest with respect to the observer it carries no net electric charge. An electron moves to the right with a velocity $\overline{v}$ with respect to the wire and parallel to its axis.

(a) What is the force on the electron in the reference frame at rest with respect to the wire.

(b) If the electrons <u>in</u> the wire also move at a speed $|\overline{v}|$ what is the origin of the force acting on the electron as viewed from a rest frame on the electron. Is there a paradox? First discuss the origin of the force qualitatively then derive a quantitative relation.