Department of Physics

Preliminary Exam January 3–7, 2012

Day 2: Electromagnetism and Optics

Wednesday, January 4, 2012

9:00 a.m. – 12:00 p.m.

Instructions:

1. Write the answer to each question on a separate sheet of paper. If more than one sheet is required, staple all the pages corresponding to a *single* question together in the correct order. But, do *not* staple all problems together. This exam has *six* questions.

2. Be sure to write your exam identification number (*not* your name or student ID number!) and the problem number on each problem sheet.

3. The time allowed for this exam is three hours. All questions carry the same amount of credit. Manage your time carefully.

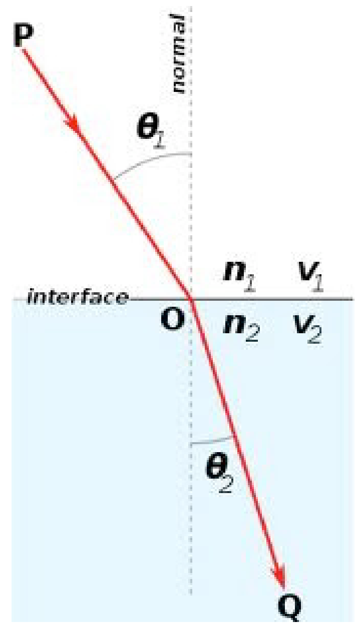
4. If a question has more than one part, it may not always be necessary to successfully complete one part in order to do the other parts.

5. The exam will be evaluated, in part, by such things as the clarity and organization of your responses. It is a good idea to use short written explanatory statements between the lines of a derivation, for example. Be sure to substantiate any answer by calculations or arguments as appropriate. Be concise, explicit, and complete.

6. The use of electronic calculators is permissible and may be needed for some problems. However, obtaining preprogrammed information from programmable calculators or using any other reference material is strictly prohibited. The Oklahoma State University Policies and Procedures on Academic Integrity will be followed.

Problem 1

The sketch at the right is for parts (a) and (b) only. Light traveling in medium 1 is incident on an interface with medium 2, and one possible case is illustrated.



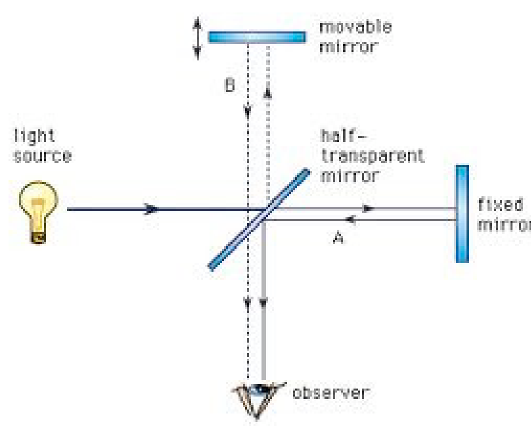
(a) Find θ_2 in terms of θ_1, n_1, and n_2. If $n_1 > n_2$, then find the condition on θ_1 so that θ_2 exists.

(b) Let the light have frequency and wavelength ω_1, λ_1 in medium 1, and ω_2, λ_2 in medium 2. Find ω_2, λ_2 in terms of ω_1, λ_1.

(c) (This part is independent of the previous two parts.) Determine whether the two waves $\hat{x}E_1 \cos(kz - \omega t)$ and $\hat{y}E_2 \sin(kz - \omega t)$ can interfere. Here $\hat{x}$ and $\hat{y}$ are the unit vectors along the x and y axes respectively.

Problem 2

Explain how a Michelson interferometer, with one mirror moving at constant speed (perhaps several mm/s), can be used to measure an optical wavelength. The source produces monochromatic light, and the "observer" is actually a detector such as a photomultiplier. Find an expression that relates the wavelength to the mirror speed and one other measured quantity.



Problem 3

A charge q is located at the point with coordinates $(x, y, z) = (d, d, 0)$. Two grounded conducting sheets lie along the x-z and y-z planes. Calculate the force on q.

Problem 4

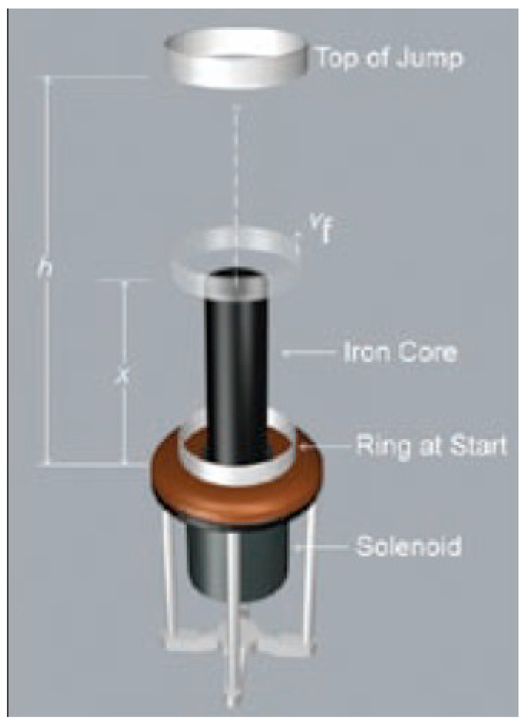
Consider a finite line charge with uniform charge density, oriented parallel to the z axis and intersecting the x-y plane at (x_0, y_0). Let the line charge extend from the point $(x_0, y_0, -b)$ to the point $(x_0, y_0, +b)$. Find the potential at any point in the x-y plane except at (x_0, y_0).

Problem 5

A long flexible spring has n coils per unit length, a circular cross section of radius a, length L, and negligible mass. The spring is oriented vertically, so that a mass can be hung from its lower end. When a current I is passed through the spring, it does not extend when a mass m is attached. Derive an expression for the current I.

Problem 6

This problem concerns the jumping-ring apparatus illustrated at right. A solenoid of many turns is wrapped around the iron core, which extends above the top of the solenoid. A conducting ring, at rest at the top of the solenoid, surrounds the extended core. In the usual demonstration, the solenoid is connected to a voltage source through a switch, and the ring jumps off the core when the switch is closed.



(a) Assume a constant dc current through the solenoid. The ring is placed around the top of the iron core and released. What happens?

(b) Assume a constant-amplitude 60-Hz ac current through the solenoid. When the ring is placed around the top of the core and released, it falls partway down the core and then floats in place. Explain.