University of California, Berkeley
Physics 110B Fall 2008 (*Strovink*)

EXAMINATION 2

Directions: Do all 3 problems, which have unequal weight. This is a 50-minute closed-book closed-note exam except for Griffiths and Pedrotti, a copy of anything posted on the course web site, and anything in your own handwriting (not a Xerox of someone else's writing). You may use the result of any assigned problem-set problem without proving it. Calculators, palmtops, laptops, and cellphones should be turned off. Use a bluebook. Do not use scratch paper – otherwise you risk losing part credit. Show all your work. Cross out rather than erase any work that you wish the grader to ignore. Justify what you do. Express your answer in terms of the quantities specified in the problem. Box or circle your answer.

Problem 1. (25 points)
Consider a pair of coaxial circular rings of radius b, separated by a distance $\sqrt{2}\,b$. Put the origin on their axis, halfway between the rings. Each ring carries a uniformly distributed static charge q; a static point charge $-2q$ is placed at the origin.

In most directions, at distance $r \gg b$ from the origin, the static electric field is found to vary approximately as r^{-n}. What is n, and why?

Problem 2. (35 points)
The irradiance I_0 of a mystery light beam is attenuated by each of four devices, applied one at a time: (A) a grey filter passing half the incident irradiance; (B) an $\hat{x}$ polarizer; (C) a $\frac{1}{\sqrt{2}}(\hat{x}+\hat{y})$ polarizer; and (D) a device consisting of a quarter-wave plate (QWP) with slow axis at $+45°$ to $\hat{x}$, followed by an $\hat{x}$ polarizer, followed by a QWP with slow axis at $-45°$ to $\hat{x}$. The attenuated irradiances observed are, respectively,

$$
\begin{aligned}
I_A &= \tfrac{1}{2} I_0 \\
I_B &= \tfrac{1}{2}\big(1+\tfrac{1}{\sqrt{2}}\big) I_0 \\
I_C &= \tfrac{1}{2} I_0 \\
I_D &= \tfrac{1}{2}\big(1+\tfrac{1}{\sqrt{2}}\big) I_0 \ .
\end{aligned}
$$

With devices (A) through (D) no longer in the picture, device (E) is inserted into the beam. It is the same as device (D) except that the $\hat{x}$ polarizer is rotated to become a $\hat{y}$ polarizer. What irradiance I_E is observed?

Problem 3. (40 points)
A monochromatic beam traveling in medium "0" is normally incident upon a substrate *"T"*. Two films ("1"and "2") are interposed between the two media, such that film 1 adjoins medium 0 and film 2 adjoins medium T. The refractive indices are frequency-independent and equal, respectively, to n_0, n_1, n_2, and n_T, with $n_0 \neq n_T$. You may assume that all materials are insulating and nonabsorbing, and that they all have the same magnetic permeability. Film 2 has thickness $\lambda_2/4$ (where λ_2 is the wavelength of the beam in the particular material of which film 2 is made). The thickness l_1 of film 1 is *nonzero*.

(a.) (20 points)
In this part, the refractive index n_1 of film 1 is not supplied by the problem, but its thickness is specified to be equal to $\lambda_1/4$ (where λ_1 is the wavelength of the beam in the particular material of which film 1 is made). Identify a combination $\{n_1, n_2\}$ for which the full beam irradiance is transmitted without any reflection. (Any correct answer, properly justified, receives full credit.)

(b.) (20 points)
In this part, the thickness l_1 of film 1 is not supplied by the problem, but its refractive index n_1 is specified to be equal to n_T. Identify a combination $\{l_1, n_2\}$ for which the full beam irradiance is transmitted without any reflection. (Any correct answer, properly justified, receives full credit.)