University of California, Berkeley
Physics 110B Spring 2004 (*Strovink*)

EXAMINATION 4

Directions: Do all three problems, which have unequal weight. This is a closed-book closed-note exam except for Griffiths, Pedrotti, a copy of anything posted on the course web site, and anything in your own original handwriting (not Xeroxed). Calculators are not needed, but you may use one if you wish. Laptops and palmtops 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. (20 points)
A plane wave of initial irradiance I_0 propagating along $\hat{z}$ is incident upon a screen lying in the $z = 0$ plane. The screen is totally absorbing, except that one *quadrant* of it (the piece with $0 < x, y < \infty$) is missing. An observer stationed at $(0, 0, z)$, where $kz \gg 1$, detects an irradiance I'. What is I'/I_0, and why?

Problem 2. (40 points)
(**a.**) (20 points)
Consider four equally spaced long ($\Delta y = \infty$) thin slits, located in the $z = 0$ plane at $x = \pm\frac{d}{2}$ and $x = \pm\frac{3d}{2}$. As usual, $\tan\psi_x = \frac{dx}{dz}$ of the outgoing wavefront. Consider the aperture function for these four slits to be the convolution of a pair of δ-functions separated by d and another pair of δ-functions separated by $2d$ (both pairs are symmetric about $x = 0$). In the Fraunhofer limit, write down the irradiance pattern

$$\mathcal{R}(\psi_x) \equiv \frac{I(\psi_x)}{I(\psi_x = 0)}$$

as the product of two two-slit $\mathcal{R}$'s.

(**b.**) (20 points)
Consider an opaque baffle in the $z = 0$ plane in which a 4×4 array of 16 tiny holes is drilled. The holes are arranged on a square grid, with vertical and horizontal hole-to-hole separation equal to d. The entire array is centered at the origin (where there is no hole). In the Fraunhofer limit, defining $\tan\psi_x = \frac{dx}{dz}$ and $\tan\psi_y = \frac{dy}{dz}$ of the outgoing wavefront, deduce the resulting irradiance pattern

$$\mathcal{R}(\psi_x, \psi_y) \equiv \frac{I(\psi_x, \psi_y)}{I(\psi_x = 0, \psi_y = 0)} .$$

Please justify your answer.

Problem 3. (40 points)
A monochromatic beam traveling in medium "0" is normally incident upon a substrate *"T"*. Three films ("1", "2", and "3") are interposed between the two media, such that film 1 adjoins medium 0 and film 3 adjoins medium T. The refractive indices are frequency-independent and equal, respectively, to n_0, n_1, n_2, n_3, 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. Films "1" and "3" have thickness $\lambda_i/4$ (where λ_i is the wavelength of the beam in the particular material of which that film is made), while film "2" has thickness $\lambda_i/2$.

(**a.**) (20 points)
Work out a condition on n_0, n_1, n_2, n_3, and n_T that allows no light to be reflected.

(**b.**) (20 points)
Now the frequency of the monochromatic beam is *doubled* (red light becomes blue light), while all three films retain their *same* physical thicknesses (in meters). As a function of the (unrestricted) five refractive indices, what is the ratio R of the reflected to incident *irradiance*?