MEMORIAL UNIVERSITY OF NEWFOUNDLAND
DEPARTMENT OF PHYSICS AND PHYSICAL OCEANOGRAPHY

PHYSICS 3600 FINAL EXAMINATION - WINTER 2007 - APRIL 12, 2007

NAME:_____ STUDENT NUMBER:_____

INSTRUCTIONS:

1. Put your name and student number on each page.
2. Do any 4 of the 5 questions.
3. Each question is worth 25 marks.
4. Equations and constants are provided on the next page.
5. Use only the paper provided. No other books, notes or papers are permitted.
6. Do not remove examination papers from the examination room.

CONSTANTS AND FORMULAE

$$c = 2.998 \times 10^8 \; m/s$$

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$I = I_o \left(\frac{\sin\beta}{\beta} \right)^2$$

$$I = I_o \left(\frac{\sin\beta}{\beta} \right)^2 \left(\frac{\sin N\alpha}{\sin\alpha} \right)^2$$

$$\beta = \frac{1}{2} kb \sin\theta$$

$$\alpha = \tfrac{1}{2} ka \sin\theta$$

$$TE: \quad r = \frac{\cos\theta - \sqrt{n^2 - \sin^2\theta}}{\cos\theta + \sqrt{n^2 - \sin^2\theta}}$$

$$TM: \quad r = \frac{-n^2\cos\theta + \sqrt{n^2 - \sin^2\theta}}{n^2\cos\theta + \sqrt{n^2 - \sin^2\theta}}$$

$$TE: \quad t = \frac{2\cos\theta}{\cos\theta + \sqrt{n^2 - \sin^2\theta}}$$

$$TM: \quad t = \frac{2n\cos\theta}{n^2\cos\theta + \sqrt{n^2 - \sin^2\theta}}$$

$$m = -\frac{s'}{s}$$

$$m = -\frac{n_1 s'}{n_2 s}$$

$$T = n \left(\frac{\cos\theta_t}{\cos\theta_i} \right) t^2$$

$$R = r^2$$

$$\frac{1}{f} = \frac{n_2 - n_1}{n_1} \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\cos^2 x = \frac{1 + \cos 2x}{2}$$

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1. (a) A small fish is located at a point 7.5 cm from the center of a spherical fish bowl of diameter 30.0 cm as shown in the diagram. Assuming the effects of the glass wall are negligible,

   i. Calculate the position of the fish as seen by an observer outside the bowl. [3%]

   ii. If the observer's eye is located at a distance of 10.0 cm from the surface of the bowl on the optic axis of the system (see diagram), determine the position of the image of the observer's eye as seen by the fish. [3%]

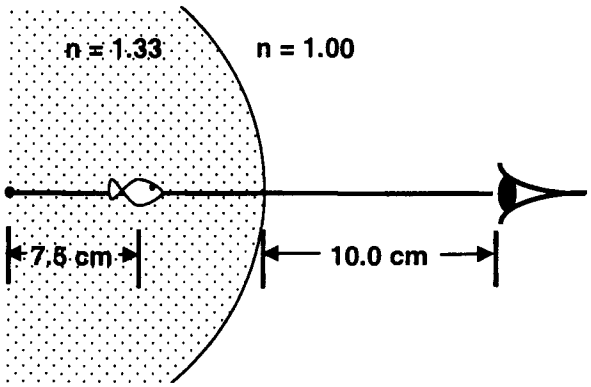
   (b) Consider an arrangement of two thin lenses in series with a separation of 28.0 cm. The first lens has a focal length of +12.0 cm is located to the left of the second which has a focal length of -14.0 cm. An object of height 0.5 cm is placed 6.00 cm to the left of the first lens.

   i. Calculate the location of the final image. Be sure to state whether the final image is located to the left or right of the second lens. [4%]

   ii. Determine the height of the final image and state whether it is inverted or upright. [2%]

   iii. Sketch a neat ray diagram to locate the final image. [4%]

   (c) Derive the Law of Refraction (*i.e.*, Snell's Law) using Fermat's Principle. [9%]



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2. (a) Monochromatic light of wavelength $\lambda = 600\ nm$ is normally incident on a soap film ($n_f = 1.40$) immersed in air. What is the minimum thickness of the soap film (in nm) if constructive interference occurs in the reflected light? [6%]

   (b) In a Young's double slit experiment using light of wavelength λ, a thin piece of Plexiglas having index of refraction n_p covers one of the slits. If the center point on the screen is a dark spot instead of a bright spot, derive an expression for the minimum thickness of the Plexiglas in terms of λ and n_p. [8%]

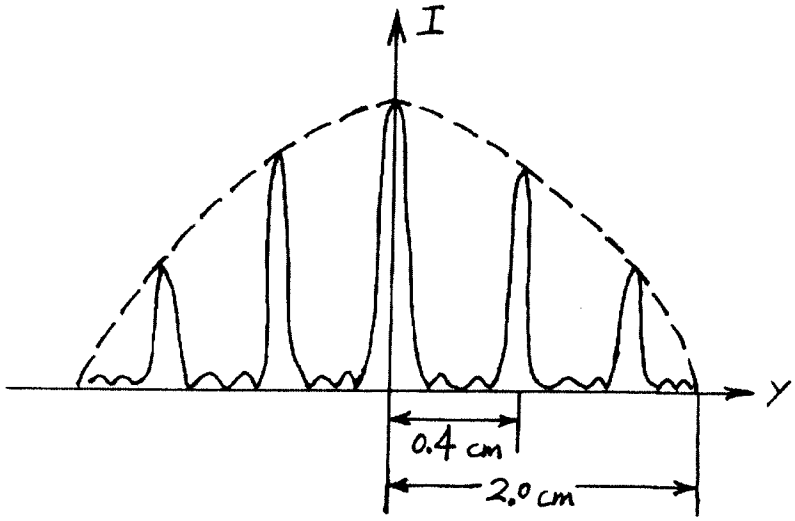
   (c) The Fraunhofer diffraction pattern for an array of N identical parallel slits is shown in the figure below. The slits have width b and a center-to-center separation of a. The distance from the slits to the screen is 20.0 m and the light that is incident on the slits has a wavelength of 600 nm.

      i. How many slits are in the array? [2%]

      ii. Determine the slit width b. [3%]

      iii. Determine the slit separation a. [3%]

      iv. Write down the expression for the envelope (i.e., the dashed curve) in the figure below and explain its physical significance. [3%]



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3. (a) A certain microscope has an eyepiece of focal length 2.50 cm and an objective of focal length 1.60 cm. The distance between objective and eyepiece is 22.1 cm. The final image formed by the eyepiece is at infinity. Treating all lenses as thin,

   i. What should be the distance from the objective to the object viewed? [5%]

   ii. What is the overall magnification of the microscope? [4%]

   (b) A beam of light is travelling through a piece of glass (index of refraction 1.50) and is incident on a planar glass-air interface. The electric field of the incident beam lies in the plane of incidence.

   i. Sketch a graph of reflectance versus angle of incidence for such a situation. [4%]

   ii. Determine the critical angle and the polarizing (Brewster) angle and label these on the graph. [4%]

   (c) Write brief explanatory notes, using diagrams where appropriate, on the following:

   i. nearsightedness and farsightedness [4%]

   ii. spherical aberration and chromatic aberration [4%]

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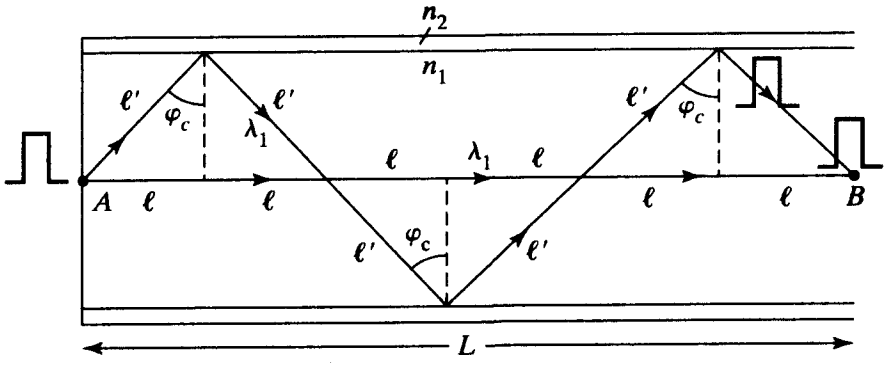
4. (a) The near infrared wavelength region ($\sim 1.3\ \mu m$) that is commonly used for fibre optics communication is determined in part by the attenuation characteristics of the best available silica-based fibres. Explain. [7%]

   (b) Explain modal distortion and material dispersion in the context of optical fibre communication systems and describe the counter measures that are taken to minimize each of these effects. [8%]

   (c) With the aid of the diagram below, show that the pulse broadening effect (in ns/km) due to modal distortion in step-index optical fibres can be expressed as

$$\delta\left(\frac{\tau}{L}\right) = \frac{n_1}{c}\left(\frac{n_1 - n_2}{n_2}\right)$$

   where n_1 and n_2 are the refractive indices of the core and cladding, respectively. [10%]



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5. (a) Show that second harmonic generation (SHG), which is a second order nonlinear effect, arises from a second-order material polarization of the following form:

$$P_2 = \frac{1}{2}\epsilon_o \chi_2 E_o^2 + \frac{1}{2}\epsilon_o \chi_2 E_o^2 \cos 2\omega t$$

where E_o and ω are the amplitude and angular frequency, respectively, of the incident light field. [9%]

(b) With the aid of a diagram, describe how you would construct an optical (on/off) switch using the Pockels Effect. [10%]

(c) Write a brief explanatory note on the Faraday Effect. Use diagrams as appropriate. [6%]