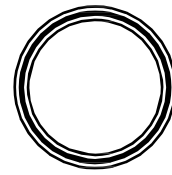


Department of Physics  
PCS 230 – Photonics and Optical Devices



Please insert in the circle the  
initial of your last name

**Please Print Clearly:**

**Student:** \_\_\_\_\_  
*Last Name* *First Name*

**Student Number:** \_\_\_\_\_ **Student Section:** \_\_\_\_\_

**Midterm Test 1– January 26, 2017**

Check the name of your professor:

**Read the following attentively**

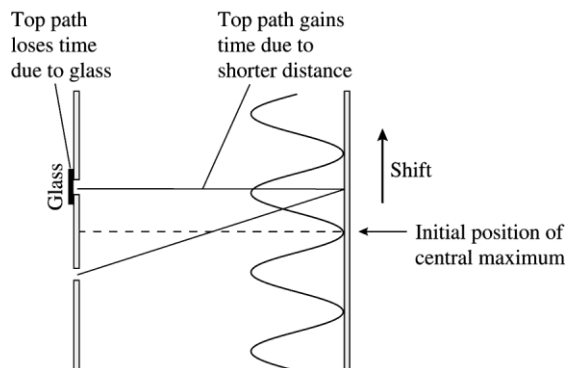
- **Ensure that your name and student number are correct in the bubble sheet.**
- Duration of the exam is 45 minutes.
- The exam consists of 1 full-answer question and 6 multiple-choice questions. Answer ALL questions.
- Each multiple-choice question earns 1 marks.
- **THE TOTAL EXAM MARK IS 10.**
- For each multiple choice question:
  - You need to show, in the space provided in this booklet, a justification for your answer. If no work or correct argument is shown, the resultant mark may be zero, even if the answer in the bubble sheet is correct.
  - The work shown in your exam booklet may be checked, **at least for one** of the questions, selected randomly.
  - **Transfer your choices to the bubble sheet only when you're sure of them.**
  - Some answers may be rounded off.
- Pagers and cell phones must be silenced and placed out of reach. Hats and earphones are not allowed. If a phone rings, its owner is responsible for disrupting the exam and the phone will be confiscated or the owner will be asked to leave the room resulting in a zero on the test.
- Sharing of pencils, erasers and calculators is not permitted.
- Talking to another student or glancing over another student's paper is not permitted and may result in a charge of academic misconduct.
- The only calculators allowed are either the model Sharp EL-546 or Casio FX-991. If you are found to have another type of calculator (even if not programmable), it will be confiscated for the duration of the test.
- The exam booklet has a total of 5 pages. You are responsible for checking that you have all pages.

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*Sign here to signify you read the instructions*

**Full Answer Question (4 marks).** MARKS WILL BE ASSIGNED ONLY FOR INTELLIGIBLE WORK. Scribble messy scrawls will not be marked. Please use the back of the front page for the draft work. Print answers in designated boxes. Always include units. Clearly write solutions below the the questions.

Light of wavelength 600 nm passes through two slits separated by 0.20 mm and is observed on a screen 1.0 m behind the slits. The location of the central maximum is marked on the screen and labeled  $y = 0$ .



a. At what distance, on either side of  $y = 0$ , are the  $m = 1$  bright fringes?

The  $m = 1$  bright fringes are separated from the  $m = 0$  central maximum by

$$\Delta y = \frac{\lambda L}{d} = \frac{(600 \times 10^{-9} \text{ m})(1.0 \text{ m})}{0.0002 \text{ m}} = 0.0030 \text{ m} = 3.0 \text{ mm}$$

b. A very thin piece of glass is then placed in one slit. Because light travels slower in glass than in air, the wave passing through the glass is delayed by  $5.0 \times 10^{-16} \text{ s}$  in comparison to the wave going through the other slit. What fraction of the period of the light wave is this delay?

The light's frequency is  $f = c/\lambda = 5.00 \times 10^{14} \text{ Hz}$ . Thus, the period is  $T = 1/f = 2.00 \times 10^{-15} \text{ s}$ . A delay of  $5.0 \times 10^{-16} \text{ s} = 0.50 \times 10^{-15} \text{ s}$  is  $\frac{1}{4}T$ .

c. With the glass in place, what is the phase difference  $\Delta \phi$  in radians between the two waves as they leave the slits?

The wave passing through the glass is delayed by  $\frac{1}{4}$  of a cycle. Consequently, the two waves are not in phase as they emerge from the slits. The slits are the sources of the waves, so there is now a phase difference  $\Delta \phi_0$  between the two sources. A delay of a full cycle ( $\Delta t = T$ ) would have no effect at all on the interference because it corresponds to a phase difference  $\Delta \phi_0 = 2\pi \text{ rad}$ . Thus a delay of  $\frac{1}{4}$  of a cycle introduces a phase difference  $\Delta \phi_0 = \frac{1}{4}(2\pi) = \frac{1}{2}\pi \text{ rad}$ .

d. The glass causes the interference fringe pattern on the screen to shift sideways. Which way does the central maximum move (toward or away from the slit with the glass)? Explain why

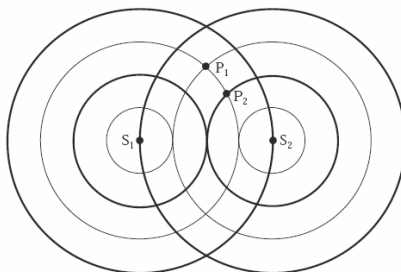
The text's analysis of the double-slit interference experiment assumed that the waves emerging from the two slits were in phase, with  $\Delta\phi_0 = 0$  rad. Thus, there is a central maximum at a point on the screen exactly halfway between the two slits, where  $\Delta\phi = 0$  rad and  $\Delta r = 0$  m. Now that there is a phase difference between the sources, the central maximum—still defined as the point of constructive interference where  $\Delta\phi = 0$  rad—will shift to one side. The wave leaving the slit with the glass was delayed by  $\frac{1}{4}$  of a period. If it travels a *shorter* distance to the screen, taking  $\frac{1}{4}$  of a period *less* than the wave coming from the other slit, it will make up for the previous delay and the two waves will arrive in phase for constructive interference. Thus, the central maximum will shift *toward* the slit with the glass. How far? A phase difference  $\Delta\phi_0 = 2\pi$  would shift the fringe pattern by  $\Delta y = 3.0$  mm, making the central maximum fall exactly where the  $m = 1$  bright fringe had been previously. This is the point where  $\Delta r = (1)\lambda$ , exactly compensating for a phase shift of  $2\pi$  at the slits. Thus, a phase shift of  $\Delta\phi_0 = \frac{1}{2}\pi = \frac{1}{4}(2\pi)$  will shift the fringe pattern by  $\frac{1}{4}(3 \text{ mm}) = 0.75$  mm. The net effect of placing the glass in the slit is that the central maximum (and the entire fringe pattern) will shift 0.75 mm toward the slit with the glass.

### MULTIPLE CHOICE QUESTIONS (1 mark each)

In the space provided show a justification for your answer

- In the expression  $y = A \sin(\mathbf{k} \cdot \mathbf{r} - \omega t + \phi)$  for a sinusoidal travelling wave the vector  $\mathbf{k}$  represents
  - The position of the source of the wave
  - The direction of the oscillations
  - The direction of the wave propagation
  - The velocity of propagation
  - Both the direction of the wave propagation and the wavelength\*  $|\mathbf{k}| = 2\pi/\lambda$
- A planar cross section through two spherical waves emanating from the sources S1 and S2 in the plane is shown in the figure. The black circles are one and two wavelengths from their respective sources. The lighter circles are one half and one and a half wavelengths distant from their respective sources. If the phase at S1 and S2 is zero at this instant, and the waves shown arriving at P2 both arrive with amplitude A, the difference in phase angle at point P2 (in radians) is

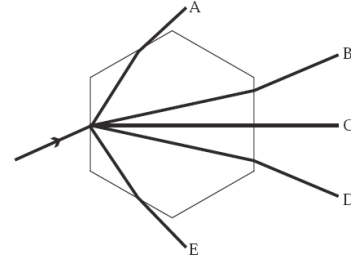
- 0
- $\pi/2$
- $\pi$
- $3\pi/2$
- $2\pi$





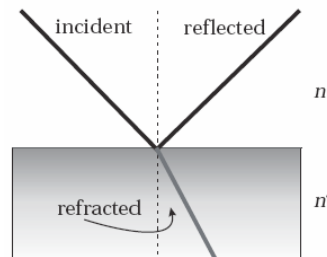
3. A light ray strikes a hexagonal ice crystal floating in the air at a  $30^\circ$  angle to one face, as shown below. The hexagonal faces of the crystal are perpendicular to the plane of the page. All the rays shown are in the plane of the page, and  $n_{\text{ice}} = 1.30$ . Which outgoing ray is the correct one?

A    B\*    C    D    E

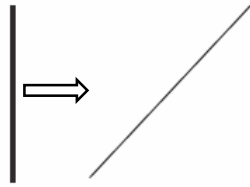


4. When light is either reflected or refracted, the quantity that does not change in either process is its
- direction of travel.
  - dispersion.
  - frequency.\*
  - speed.
  - wavelength.
5. A light ray is partially reflected and partially refracted at a boundary between two media, the upper one having index of refraction  $n$ , the lower one having index of refraction  $n'$ , as shown in the figure. The reflected ray is perpendicular to the refracted ray when

- $n' = n \tan \theta_{\text{incident}}$ .\*
- $n' = n \cot \theta_{\text{incident}}$ .
- $n' = n \sin \theta_{\text{incident}} / \sin \theta_{\text{reflected}}$ .
- $n' = n \sin \theta_{\text{incident}} / \cos \theta_{\text{reflected}}$ .
- $n' = n \sec \theta_{\text{incident}}$ .



6. The wave front shown at the left for light in air reaches the plane surface (shown by a slanted line) that bounds a medium with  $n = 1.50$ .



Which diagram below correctly shows the wave front while entering the medium at the right?



A



B



C



D



E

- a. A
- b. B\*
- c. C
- d. D
- e. E