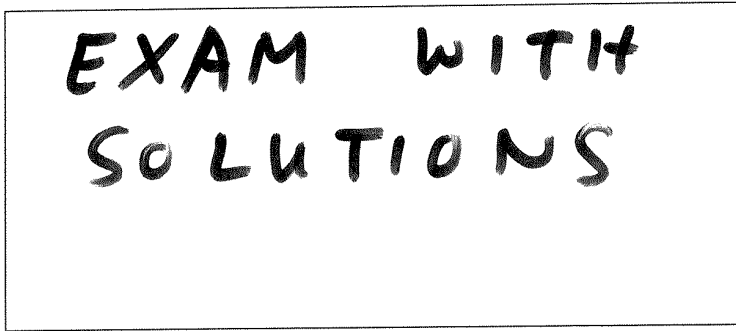


Physics 228 - First Common Hour Exam

17 February 2005

Profs. Shapiro and Bronzan

⇒  
Your name sticker with exam code  
⇒



Your signature \_\_\_\_\_

Turn off and put away cell phones now!

1. THIS EXAM INCLUDES QUESTIONS WHICH REQUIRE A NUMERICAL ANSWER.

The format on the machine-graded answer sheets requires that you express your answer in a very specific format. Several examples are shown below:

5.30 should be entered as **+5.30+00**  
437 should be entered as **+4.37+02**  
0.62458 should be entered as **+6.25-01**

$-1.602176 \times 10^{-19}$  should be entered as **-1.60-19**.

Note that all answers should be accurate to three **significant** digits. A sample fragment of the mark-sense form is shown. Make sure you darken the circles!

				<b>E</b>						<b>-</b>	<b>1</b>	<b>6</b>	<b>0</b>	<b>E</b>	<b>1</b>	<b>9</b>	
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Form for numerical answers. The electron's charge entered.

**NOTE THAT MULTIPLE CHOICE QUESTIONS START WITH THE FIFTH QUESTION, BUT ITS NUMBER IS 16; ENTER THE ANSWERS ON THE MARK SENSE FORM ACCORDING TO THEIR PROBLEM NUMBERS, WHICH INCREASE HORIZONTALLY ACROSS THE FORM.**

2. The exam will last from 9:10 PM to 10:30 PM. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.
3. In the section labelled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
4. Under STUDENT # enter your 9-digit student ID.
5. Enter 228 under COURSE, and your section number (see label above) under SEC.
6. Under CODE enter the exam code given above.
7. During the exam, you may use pencils, a calculator, and one **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.
8. There are 16 questions on the exam. Several questions require you to enter a numerical answers as described above. **Be sure to fill in the circles as well as writing your answer in the boxes.** The remainder are multiple-choice. For each multiple-choice question, mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. **At the end of the exam, hand in the answer sheet and the cover page.** Retain the rest for future reference and study.
9. When you are asked to open the exam, make sure that your copy contains all 16 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
10. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.

$c = 2.998 \times 10^8 \text{m/s}$

1. A source emits lines of wavelengths 555.113 nm and 555.432 nm. The light is incident on a diffraction grating 0.0313 m wide. What is the maximum distance between slits that will allow these lines to be resolved in second order ( $m=2$ )? Give your answer (in meters) to three significant figures.

resolution  $R = Nm = \frac{\lambda}{\Delta\lambda} = \frac{555.3}{0.319} = 1741$   
 $N = 870 = \frac{W}{d}$ ,  $d = \frac{W}{870} = \frac{0.0313 \text{ m}}{870} = 3.60 \times 10^{-5} \text{ m}$

2. A convergent lens has a focal length of 0.359 meters. How far in front of the lens must we place an object so it forms an inverted image of size 0.579 times the size of the object? Give your answer in meters to three significant figures.

$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} = \frac{1}{0.359}$   
 $m = -\frac{q}{p} = -0.579$  so  $q = 0.579p$ ,  $\frac{1}{p} + \frac{1}{0.579p} = \frac{2.727}{p} = \frac{1}{0.359}$   
 $p = 2.727 \times 0.359 = 0.979 \text{ m}$

3. A radio receiver is equidistant from two identical transmission towers, A and B. The towers are connected to the same transmitter and therefore broadcast signals of the same amplitude and frequency. However, the signals are out of phase because the cables connecting the towers to the transmitter have different lengths. When only A is transmitting, the signal received has intensity  $I_0$ . When A and B are both transmitting, the intensity is  $3.75 I_0$ . What is the minimum (positive) phase difference that can cause this change? Give your answer in radians, to three significant figures.

$I = 4I_0 \cos^2 \frac{\phi}{2}$   
 $\phi/2 = \arccos(\sqrt{3.75/4}) = 14.48^\circ = 0.2527 \text{ rad}$   
 $\phi = 0.505 \text{ radians}$   
 $E = 2E_0 \cos \phi/2$

4. A sound wave of wavelength 0.427 meters is normally incident on a doorway 1.25 meters wide. The intensity of the sound transmitted through the doorway in the forward direction, at a certain distance is  $5.77 \times 10^{-4} \text{ watts/m}^2$ . What is the intensity at the same distance, but at an angle 55.7 degrees away from the forward direction? Give your answer in  $\text{watts/m}^2$ , to three significant figures.

$\beta = \frac{2\pi a}{\lambda} \sin 55.7^\circ = 15.19 \text{ radians}$   
 $I = I_0 \left( \frac{\sin \beta/2}{\beta/2} \right)^2 = 5.77 \times 10^{-4} \times \left[ \frac{\sin(7.597 \text{ rad})}{7.597} \right]^2$   
 $= 9.35 \times 10^{-6} \text{ W/m}^2$

16. A cylindrical tank with opaque sides but an open top has a diameter of 4.0 m and is completely filled with water ( $n=1.33$ ). When the setting sun reaches an angle of  $28^\circ$  above the horizon, sunlight ceases to illuminate any part of the bottom of the tank. How deep is the tank?

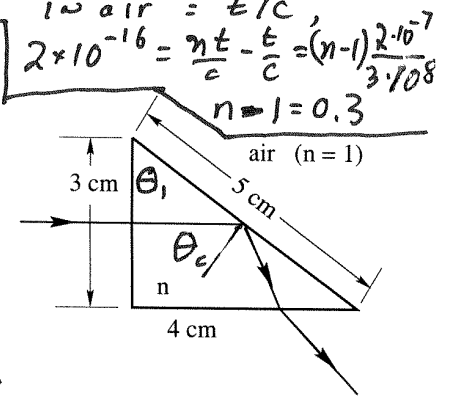
$\sin \theta_i = n_w \sin \theta_2$   
 $\theta_2 = \arcsin\left(\frac{\sin 62^\circ}{1.33}\right) = 41.6$   
 $\tan \theta_2 = \frac{d}{h}$   
 $h = \frac{d}{\tan \theta_2} = \frac{4.0}{.8877} = 4.5 \text{ m}$

17. In a certain experiment, it is found that the time it takes a pulse of light to travel between two points is  $2 \times 10^{-16}$  sec longer if a  $0.2 \mu\text{m}$  thick film is placed in its path. We can conclude that the index of refraction of the film is:

a) 1.3   b) 0.7   c) 2.3   d) 0.3   e) 1.0  
 $\text{time to cross film} = \frac{t}{c/n}$  time to cross same in air  $= t/c$   
 $2 \times 10^{-16} = \frac{nt}{c} - \frac{t}{c} = (n-1) \frac{2 \cdot 10^{-7}}{3 \cdot 10^8}$   
 $n-1 = 0.3$

18. A beam of light enters the  $3 \text{ cm} \times 4 \text{ cm} \times 5 \text{ cm}$  triangular prism shown. The minimum value of  $n$  for which the light undergoes total internal reflection at the  $5 \text{ cm}$  surface is:

a) 1.33   b) 1.25   c) 1.67   d) 1.75   e) 1.50  
 $n \sin \theta_c = 1$   
 $\theta_c = \theta_1$   
 $\sin \theta_1 = 4/5$   
 $\text{so } n = 5/4$

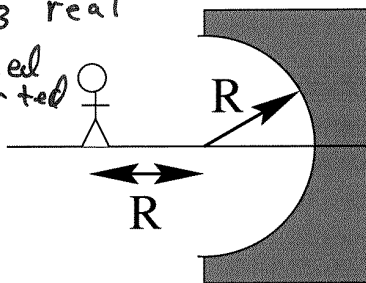


19. An object is placed 4 cm from a mirror that is silvered on both sides. In one orientation, the mirror is concave; in the reversed orientation it is convex. If it is used as a concave mirror, the image is found to lie 6 cm from the mirror, on the same side as the object. If the mirror is then turned around so that it becomes convex, how far from the mirror will the image lie?

a) 3 cm      **Concave**       $\frac{1}{4\text{cm}} + \frac{1}{6\text{cm}} = \frac{2}{R} = \frac{5}{12\text{cm}}$   
**b) 1.5 cm**  
 c) 6 cm      **Convex**       $\frac{1}{4\text{cm}} + \frac{1}{q} = -\frac{2}{R} = -\frac{5}{12\text{cm}}$   
 d) 4 cm       $\frac{1}{q} = -\frac{8}{12\text{cm}}; q = -1.5\text{cm}$   
 e) 12 cm

20. Tom is standing a distance of two radii from the vertex of a concave spherical mirror as shown. His image is:

$\frac{1}{2R} + \frac{1}{q} = \frac{2}{R}, q = 2R/3$  real  
 $m = -q/p = -1/3$  reduced & inverted



- a) Virtual, erect, reduced  
 b) Real, erect, reduced  
 c) Virtual, erect, enlarged  
 d) Virtual, inverted, enlarged  
**e) Real, inverted, reduced**

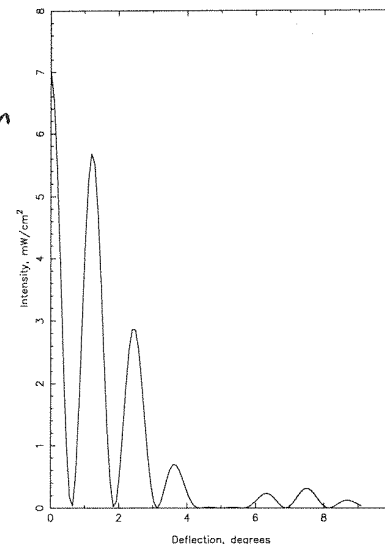
21. An object is placed 3 cm from a lens. The image is found to lie 12 cm from the lens, on the same side as the object. What is the focal length  $f$  of the lens, and is the image upright or inverted?

- a)  $f = +4.0$  cm; upright image**  
 b)  $f = +2.4$  cm; upright image  
 c)  $f = -4.0$  cm; upright image  
 d)  $f = +2.4$  cm; inverted image  
 e)  $f = -2.4$  cm; inverted image

$p = 3\text{cm}, q = -12\text{cm}$   
 $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$   
 $m = -q/p > 0$  upright

The two slit interference has maxima at  $\sim 1.25^\circ, 2.5^\circ, 3.7^\circ$ . So  $d \sin(\sim 3.7^\circ) = 3\lambda$   
 $d \sim 3 \cdot 440\text{nm} / \sin 3.7^\circ = 20\mu\text{m}$

22. Light of wavelength 440 nm passes through a double slit, yielding the diffraction pattern of intensity  $I$  versus deflection angle  $\theta$  shown. What is the separation,  $d$ , between the slits?



- a)  $5.0 \times 10^{-2}$  mm  
 b)  $6.7 \times 10^{-3}$  mm  
**c)  $2.0 \times 10^{-2}$  mm**  
 d)  $1.1 \times 10^{-2}$  mm  
 e)  $4.5 \times 10^{-3}$  mm

23. Two sources of wavelength  $\lambda$  are coherent and in phase. A point P is a distance  $x_1$  from one source and  $x_2$  from the other source. The waves from the two sources differ in phase by (in radians)

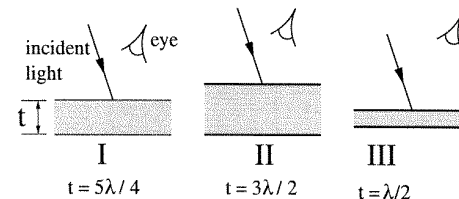
- a)  $2\pi(x_2 - x_1)/\lambda$**   
 b)  $2\pi$   
 c)  $\lambda/(x_2 - x_1)$   
 d)  $2\pi\lambda/(x_2 - x_1)$   
 e)  $(x_2 - x_1)/\lambda$

$\Delta\phi = \frac{2\pi}{\lambda} \Delta L = \frac{2\pi}{\lambda} (x_2 - x_1)$

constructive:  $\Delta\phi = 2\pi m$   
 $= 2\pi \frac{\Delta L}{\lambda} - \pi = 4\pi, 5\pi, \pi$  for phase change I, II, III.

24. Three experiments involving a thin film (in air) are shown. If  $t$  denotes the film thickness and  $\lambda$  denotes the wavelength of the light *in the film*, which experiments will produce constructive interference as seen by the observer? **only I has constructive**

- a) II and III only.  
**b) I only.**  
 c) I and III only.  
 d) III only.  
 e) II only.



25. Helium-neon laser light ( $\lambda = 632.8 \text{ nm}$ ) is sent through a 0.300-mm-wide single slit. What is the full width (not the half width) of the central maximum on a screen 1.00 m from the slit?

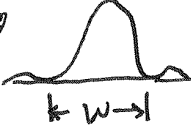
- a) 6.33 mm
- b) 2.11 mm
- c) 4.22 mm
- d) 8.44 mm
- e) 1.24 mm

$$\frac{\text{half-width}}{1.00} = \tan \theta \text{ where}$$

$$a \sin \theta = \lambda$$

$$\sin \theta = \frac{\lambda}{a} = .00211 \approx \tan \theta$$

$$\frac{w}{2} = \text{half-width} = .00211 \text{ m}$$

$$w = 0.00422 \text{ m}$$


26. What is the approximate distance between two bright point sources of light on Earth that astronauts can just resolve by eye when they are orbiting 250 km above the Earth? Assume a wavelength of 500 nm, and a pupil diameter of 6 mm. Assume index of refraction of the eye = 1.00.

- a) 0.025 m
- b) 61.3 m
- c) 135 m
- d) 40.6 m
- e) 25.4 m

$$\theta = 1.22 \frac{\lambda}{D} = 1.02 \times 10^{-4} \text{ rad}$$

$$\Delta x = L \tan \theta = 2.5 \times 10^5 \cdot 1.02 \cdot 10^{-4}$$

$$= 25.4 \text{ m}$$

27. When a diffraction grating is illuminated by light of wavelength 500 nm, it is found that of the principal maxima, two consecutive ones lie at  $30^\circ$  and  $36.87^\circ$ . What is the slit spacing? (Choose the answer that is closest to your calculation).

- a)  $1 \mu\text{m}$
- b)  $0.83 \mu\text{m}$
- c)  $2 \mu\text{m}$
- d)  $1.66 \mu\text{m}$
- e)  $5 \mu\text{m}$

$$d \sin 30^\circ = m \lambda = 0.500 d$$

$$d \sin 36.87^\circ = (m+1) \lambda = 0.600 d$$

$$0.1 d = \lambda = 0.5 \mu\text{m}$$

$$d = 5 \mu\text{m}$$