Physics 228 - Analytical Physics
FIRST COMMON HOUR EXAM
Thursday, Feb. 26, 2015

SIGN HERE NOW:

1. The exam will last from 10 - 11:20 p.m. Use a #2 pencil to make entries on the answer sheet. Enter ID information items 2-5, now, on the answer sheet before the exam starts.
2. In the section labeled 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.
3. Under STUDENT # enter your 9-digit RUID Number.
4. Enter 228 under COURSE; you may ignore the section number.
5. Under CODE enter the exam code from the label above.
6. During the exam, you may use pencils, a calculator, and one 8.5 x 11 inch sheet (both sides) with formulas and notes.
7. There are 15 multiple-choice questions on the exam. For each question, clearly mark only one answer by circling it. 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 this printout with the cover page SIGNED.
8. When you are asked to open the exam, make sure that your copy contains all 15 questions.
9. Possibly useful information: the speed of light in vacuum is \( c = 3.0 \times 10^8 \) m/s.
1. In a two-slit interference pattern, the intensity at the peak of the central maximum is \( I_0 \). At a point in the pattern where the phase difference between the waves from two slits is 60°, what is the intensity? (Neglect any effects from the widths of the individual slits.)

\[
I = I_0 \cos^2 \left( \frac{2\pi d}{\lambda} \right) = I_0 \cos^2 (30°) = I_0 \left( \frac{3}{4} \right)
\]

- a) 0
- b) 0.25\( I_0 \)
- c) 0.50\( I_0 \)
- d) 0.75\( I_0 \)
- e) \( I_0 \)

\[
\Rightarrow I = 0.75 I_0
\]

2. Some light of wavelength \( \lambda = 344 \text{ nm} \) in quartz (\( n = 1.55 \)) passes from the quartz into air. What is its wavelength in air?

- a) 344 nm
- b) 533 nm
- c) 222 nm
- d) It depends on the angle of incidence with the quartz-air boundary.
- e) The light will not pass into the air, it will be totally internally reflected and stay in the quartz.

\[
\frac{\lambda_a}{\lambda_0} = \frac{n_0}{n_a} = \frac{533 \text{ nm}}{344 \text{ nm}}
\]

3. A beam of light in the glass wall (\( n = 1.54 \)) of a fish tank impinges onto the glass-water interface, at an angle of 65° with respect to the normal. For water: \( n = 1.33 \). What happens to the beam?

- a) It will be reflected back to glass, as if the interface were a mirror.
- b) The beam will pass along the interface.
- c) It will pass into water and make an angle 75° with the normal.
- d) It will pass into water at 60° to the normal.
- e) It will pass into water and make an angle 45° with the normal.

4. The total number of lines of a diffraction grating \( N \) is doubled without changing the density of lines \( n \) (or, the distance between them \( d \)). How will the interference pattern produced by the grating change, if all other parameters remain the same?

- a) The interference maxima will become twice brighter, twice narrower, their position will remain the same.
- b) The interference maxima will remain the same in brightness, but their position will move away from the center of the pattern.
- c) The interference maxima will become 4 times brighter, and twice wider, their position will remain the same.
- d) The interference maxima will not change in intensity, but they will become separated by twice greater distances on the screen.
- e) The interference maxima will become 4 times brighter, twice narrower, their position will remain the same.

5. \[ \text{Intensity} \propto N^2 \]
   \[ \text{Width} \propto \frac{1}{N} \]
5. In a double-slit interference experiment, the two slits are spaced 0.1 mm apart. If green light with a wavelength of 500 nm is used, the spacing between the adjacent bright interference fringes on the screen is 1 cm. How far is the screen from the slits?

   a) 0.5 m  
   b) 1 m  
   c) 2 m  
   d) 10 m  
   e) 15 m

   \[ d = 0.1 \text{ mm} \]
   \[ \lambda = 500 \text{ nm} \]
   \[ \Delta y = \frac{R \lambda}{d} \]
   \[ \Delta y = 1 \text{ cm} \]
   \[ R = \frac{\Delta y \cdot d}{\lambda} \]
   \[ \Rightarrow R = \frac{1 \text{ cm} \cdot 0.1 \text{ mm}}{500 \text{ nm}} = 0.02 \text{ m} \]

6. A clear optical window made out of plastic (n=1.4) is coated with a hard antiscratch coating having n = 1.8. What should be the smallest thickness of this coating to maximize the amount of light reflected in the green part of the spectrum (for \( \lambda = 500 \text{ nm in air} \))?

   a) 69 nm  
   b) 89 nm  
   c) 125 nm  
   d) 139 nm  
   e) 250 nm

   \[ n = 1.4 \quad n_{\text{coat}} = 1.8 \]
   \[ \Rightarrow 2t = (n + \frac{1}{n}) \frac{\lambda_{\text{air}}}{n_{\text{coat}}} \]
   \[ t_{\text{min}} = \frac{\lambda_{\text{air}}}{4n_{\text{coat}}} = \frac{500}{7.2} = 69 \text{ nm} \]

7. Which of the following is NOT true for a converging lens in optics?

   a) A ray parallel to the optic axis passes through the focus on the far, image side of the lens.
   b) A ray through the center of the lens is bent parallel to the optic axis.
   c) A ray originating at the focus is bent parallel to the optic axis.
   d) An object placed at the focus has an image at infinity.
   e) An object at infinity has an image at the focus.

8. An object is placed at \( s_{\text{obj}} = 1 \text{ m} \) in front of a concave spherical mirror with radius of curvature \( R = 1 \text{ m} \). What is the magnification in this case?

   a) 0  
   b) 1  
   c) \( \infty \)  
   d) -1  
   e) -\( \infty \)

   Concave mirror: \( R = (+) \text{ve} \)

   \[ s_{\text{obj}} = (+) \text{ve} \]

   \[ \Rightarrow \frac{1}{s_{\text{im}}} + \frac{1}{s_{\text{obj}}} = \frac{2}{R} \]

   \[ \Rightarrow \frac{1}{s_{\text{im}}} = \frac{2}{1} \]

   \[ \Rightarrow s_{\text{im}} = 1 \]

   \[ \Rightarrow m = -\frac{s_{\text{im}}}{s_{\text{obj}}} = -1 \]
9. A 1 cm tall object is placed at \( s_{\text{obj}} = 5 \text{ cm} \) in front of a converging lens with a focal length \( f = 10 \text{ cm} \). What is the height of the image?
   
   a) 1 cm
   b) -1 cm
   c) 2 cm
   d) -2 cm
   e) No image will be formed, because the rays are diverging in this case.

   \[
   \frac{h_{\text{im}}}{h_{\text{obj}}} = \frac{s_{\text{im}}}{s_{\text{obj}}} = -2
   \]

   Converging lens \( \Rightarrow f > 0 \text{ cm} \)

   \[
   \frac{1}{f} = \frac{1}{s_{\text{im}}} + \frac{1}{s_{\text{obj}}}
   \]

   \[
   \Rightarrow \frac{1}{s_{\text{im}}} = \frac{1}{f} - \frac{1}{s_{\text{obj}}}
   \]

   \[
   \Rightarrow s_{\text{im}} = \frac{s_{\text{obj}}}{f - s_{\text{obj}}}
   \]

   \[
   \Rightarrow s_{\text{im}} = \frac{5}{10 - 5} = -10 \text{ cm}
   \]

   \[
   \Rightarrow h_{\text{im}} = 2 \text{ cm}
   \]

10. An unpolarized beam of light reflected from the surface of an unknown material in air becomes linearly polarized in the direction perpendicular to the plane of incidence. The angle of incidence is 57.17°. Find the refractive index of the material.
   
   a) 1
   b) 1.2
   c) 1.35
   d) 1.55
   e) 1.8

   This angle must be the Brewster's angle.

   \[
   \Rightarrow n = \tan(57.17^\circ) = 1.55
   \]

11. A screen is placed 1 m from a 0.1 mm-wide single slit, which is illuminated with light of wavelength 500 nm. What is the width of the central interference maximum on the screen (that is, the distance between its peak and the nearest minimum)?

   a) 0.22 mm
   b) 0.11 mm
   c) 0.33 mm
   d) 5 mm
   e) 15 mm

   \[
   \Delta y = \frac{R \lambda}{\Delta x} = \frac{1 \times 500 \times 10^{-9}}{2 \times 0.1 \times 10^{-3}} \text{ m} = 5 \times 10^{-3} \text{ m}
   \]

12. A symmetric double convex lens with the radius of curvature \( |R| = 10 \text{ cm} \) has a focal distance \( f = 25 \text{ cm} \) (in air). Find the refractive index of the material of the lens, \( n \).

   a) 1
   b) 1.2
   c) 1.33
   d) 1.55
   e) 1.8

   Double convex lens

   \[
   \Rightarrow |R_1| = |R_2| = 10 \text{ cm}
   \]

   \[
   R_1 = 10 \text{ cm}, R_2 = -10 \text{ cm}
   \]

   \[
   \Rightarrow \frac{1}{f} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{(n-1) \left( \frac{1}{10} + \frac{1}{10} \right)} = (n-1) \frac{1}{5}
   \]

   \[
   \Rightarrow (n-1) = \frac{5}{25} = 0.2
   \]

   \[
   \Rightarrow n = 1.2
   \]
13. A beam of polarized light of intensity $I_0$ passes through an ideal polarizing filter. The angle between the polarizing axis of the filter and the direction of polarization of the light is $\theta$. The intensity of the beam after it passes through the filter is three quarters of the incident intensity ($I = 0.75I_0$). Find $\theta$.

a) $0^\circ$

b) $30^\circ$

c) $45^\circ$

d) $90^\circ$

e) $I$ does not depend on $\theta$.

Malus's law: $I = I_0 \cos^2 \theta = \frac{3}{4} I_0$

$\Rightarrow \cos \theta = \sqrt{\frac{3}{2}} = \cos 30^\circ$

$\Rightarrow \theta = 30^\circ$

14. A telescope is used to observe at a distance of 10 km two objects which are 0.12 m apart and illuminated by light of wavelength 500 nm. Estimate the diameter of the objective lens of the telescope if it can just barely resolve the two objects. Assume there are no spherical aberrations.

\[
\sin \theta = \frac{1.22 \lambda}{D}
\]

$\Rightarrow \frac{0.12}{10^4} = 1.22 \frac{500 \times 10^{-9}}{D}$

$\Rightarrow D = 5 \text{ cm}$

15. Monochromatic x-rays are incident on a crystal with the spacing between the atomic planes 1 nm. The first order Bragg reflection is observed at an angle (with respect to the crystal planes) of $5^\circ$. What is the wavelength of the x-rays?

a) 0.174 nm

b) 0.220 nm

c) 0.440 nm

d) 0.880 nm

e) 1.760 nm

\[
2d \sin 5^\circ = \lambda
\]

$\Rightarrow \lambda = \left[2 \times 1 \times \sin 5^\circ \right] \text{ nm}$

$= 0.174 \text{ nm}$