PHYS 2025  
Test #4  
Fall 2009 (Buckley)

Short answer/conceptual. Circle the letter corresponding to the best answer for each question. Point values are listed to the right of each problem number.

1. (2 points) In an experiment with two lenses set up on a rail, the object for the second lens is:
   a. always inverted
   b. the image from the first lens
   c. the object from the first lens
   d. a and b only
   e. a and c only

2. (2 points) A laser beam shines through two closely spaced narrow slits. The bright fringes on the interference pattern formed are:
   a. the result of constructive interference
   b. spaced evenly across the interference pattern
   c. the result of destructive interference
   d. a and b only (WILL ACCEPT BUT SPACING WILL CHANGE AT LARGE θ)
   e. b and c only

3. (4 points) A red laser shines through two closely spaced narrow slits on a slide. A green laser shines through the two slits on an identical slide. The viewing screen is placed an equal distance behind each slide. What can you say about the spacing between bright fringes for the two interference patterns formed?
   a. The spacing between fringes will be the same for the red and green lasers.
   b. The spacing between fringes for the red laser will be greater than the spacing for the green laser.
   c. The spacing between fringes for the green laser will be greater than the spacing for red laser.
   d. The spacing for the bright fringes will depend on the power of each laser.
   e. a and d only
4. (4 points) Light from an unpolarized source is passed through a series of five (5) polarizers, each successive one angled at 15° to the previous one. If the initial light intensity is $I_o$, what is the light intensity after passing through the fifth polarizer?
   a. $(0.5I_o)\cos^2(15)$
   b. $(0.5I_o)\cos^4(15)$
   c. $(0.5I_o)\cos^6(15)$
   d. $(0.5I_o)\cos^8(15)$
   e. $(0.5I_o)\cos^{10}(15)$

5. (2 points) There is one temperature at which the Celsius and Fahrenheit scales read the same temperature. This temperature is:
   a. 32
   b. 40
   c. -273
   d. 273
   e. -40

6. (2 points) A sample of gas is confined to a container of volume 35.0-L. The volume of the container is doubled while keeping the temperature of the gas constant. The pressure of the gas will be:
   a. cut in half
   b. remain the same
   c. doubled
   d. will increase by a factor of four
   e. will be reduced by a factor of four

7. (4 points) A sample of gas is confined to a container of volume 35.0-L. The volume of the container is doubled and the temperature of the gas constant is cut in half. The pressure of the gas will be:
   a. cut in half
   b. remain the same
   c. doubled
   d. will increase by a factor of four
   e. will be reduced by a factor of four
Problem area. Show your work on these problems to receive credit.

8. (10 points) Suppose you have a converging lens with a focal length of 4.50 cm and another converging lens with a focal length of 2.50 cm placed 20.0 cm apart. An object 7.50 cm tall is placed 6.50 cm to the left of the first lens.

a. Sketch a drawing of this system that indicates the location of the two lenses and the object. Label distances on the drawing where you can.

b. On your drawing in part a, draw at least two rays through each lens that would help locate the image from the first lens and the image from the second lens.

c. Using the numerical values in the problem statement, find the location of the final image, its orientation, its height, and state whether it is real or virtual.

First Lens:

\[ \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \]

\[ \frac{1}{6.50\text{cm}} + \frac{1}{d_i} = \frac{1}{4.50\text{cm}} \]

\[ d_i = \frac{1}{4.30\text{cm} - 6.50\text{cm}} \]

\[ f_i = -\frac{14.6\text{cm}}{6.50\text{cm}} = -2.25 \]

Second Lens:

\[ d_o = 20.0\text{cm} - 14.6\text{cm} = 5.4\text{cm} \]

\[ d_i = \frac{1}{f} - \frac{1}{d_o} \]

\[ = \frac{1}{5.40\text{cm}} - \frac{1}{8.40\text{cm}} \]

\[ = 4.6\text{cm} \]

\[ M = \frac{d_i}{d_o} = \frac{4.6\text{cm}}{5.4\text{cm}} = -0.85 \]

Final Image is:

\[ 5.0 \text{FINAL IMAGE IS } 4.6\text{ cm to the right of the second lens.} \]

It is [REAL]

It is [VERTICAL] - Cells Involved Twice, once by each lens.

MAGNIFICATION IS

\[ M_1 \times M_2 \times (-2.25)(-0.85) = 1.9 \]

Final object is 7.5 cm tall

\[ 1.9 \times 7.50\text{cm} = [14.2\text{cm tall}] \]
9. (10 points) A He-Ne laser has a wavelength of 632.8 nm. Suppose a He-Ne laser is directed at a slide that contains two slits that are 0.500 mm apart. A viewing screen is placed 1.5 m beyond the slide.

a. What will be the separation on the viewing screen between the fourth and fifth order bright fringes?

\[
d\sin \theta = m \lambda \\
\text{for fourth order } m = 4 \\
\sin \theta = \frac{m \lambda}{d} \\
\theta = \sin^{-1} \left( \frac{m \lambda}{d} \right) \\
\frac{\theta}{d} = \tan \theta \\
\end{align}
\]

\[
\theta = \sin^{-1} \left( \frac{4 \times 632.8 \times 10^{-9} \text{ m}}{0.5 \times 10^{-3} \text{ m}} \right) = 7.59 \times 10^{-3} \text{ rad} \\
\frac{\theta}{d} = 1.5 \tan \left( \sin^{-1} \frac{4 \times 632.8 \times 10^{-9} \text{ m}}{0.5 \times 10^{-3} \text{ m}} \right) = 9.99 \times 10^{-3} \text{ m} \\
\]

\[
y_4 = 1.5 \tan \left( \sin^{-1} \frac{4 \times 632.8 \times 10^{-9} \text{ m}}{0.5 \times 10^{-3} \text{ m}} \right) = 7.59 \times 10^{-3} \text{ m} \\
y_5 = 1.5 \tan \left( \sin^{-1} \frac{5 \times 632.8 \times 10^{-9} \text{ m}}{0.5 \times 10^{-3} \text{ m}} \right) = 9.99 \times 10^{-3} \text{ m} \\
\]

\[
y_5 - y_4 = 9.99 \text{ mm} - 7.59 \text{ mm} = 2.40 \text{ mm} \\
\]

b. Now consider the intensity of the beam. We discussed in class the intensity relationship, given here as:

\[
I_o = I_0 \left[ \cos \left( \frac{\pi d}{\lambda \ell} \theta \right) \right]^2 \\
\text{where } d \text{ is the distance between slits, } \lambda \text{ the wavelength of the light, } \ell \text{ the distance from the slide to the screen, and } y \text{ the distance of the point of interest (} I_o \text{) from the center line of the interference pattern. In terms of } I_o, \text{ what is the intensity of the light (} I_0 \text{) one third of the way from the fourth to the fifth order bright fringe when the viewing screen is 1.5 m beyond the slide?}
\]

\[
\frac{1}{3} \text{ of the way from the } m = 4 \text{ to } m = 5 = 7.59 \text{ mm} + \frac{1}{3}(9.99 - 7.59) = 8.22 \text{ mm} \\
\]

\[
I_0 = I_6 \left[ \cos \left( \frac{\pi \frac{5 \times 10^{-3} \text{ mm}}{632.8 \times 10^{-9} \text{ m}} \times 8.22 \times 10^{-3} \text{ m}}{1.5 \text{ m}} \right) \right]^2 = 0.259 I_6
\]
10. (10 points) Gas Laws. Assume all gases are ideal here.
   a. A sample of Ne is confined to a piston arrangement at an initial volume of 45.0-L and a temperature of 25 °C. The piston is compressed until the volume is 20.0-L and the temperature is adjusted until the pressure returns to its original value. What is the required temperature to make this happen?

   \[ \frac{V_i}{T_i} = \frac{V_f}{T_f} \]

   \[ V_i = 45.0 \text{ L} \quad V_f = 20.0 \text{ L} \]

   \[ T_i = 25^\circ \text{C} = 298 \text{ K} \quad T_f = ? \]

   \[ \frac{V_i}{T_i} = \frac{V_f}{T_f} \]

   \[ T_f = \frac{V_i}{T_i} \cdot \frac{V_f}{T_f} \]

   \[ T_f = \frac{(20.0 \text{ L})(298 \text{ K})}{45.0 \text{ L}} = 132 \text{ K} \]

   b. A car tire is inflated to a total pressure of 30 psig (g just means gauge pressure—the actual pressure in the tire is about 15 psi higher) at 75 °F. If we assume the volume of the tire remains relatively constant upon cooling, what will the new pressure be in the tire if the temperature drops to 30 °F?

   \[ T_1 = 75^\circ \text{F} = \frac{5}{9}(75-32)^\circ \text{C} \approx 29.7 \text{ K} \]

   \[ T_2 = 30^\circ \text{F} = \frac{5}{9}(30-32) = -11^\circ \text{C} = 270 \text{ K} \]

   \[ V_1 \]

   \[ \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \]

   \[ P_2 = \frac{P_1 V_1}{T_1} \cdot \frac{T_2}{V_2} \]

   \[ P_2 = \frac{(30 \text{ psi})(298 \text{ K})}{29.7 \text{ K}} = 41 \text{ psi} \]

   c. If we assume the car tire in part b has a volume of about 10.0-L, how many grams of air are in the tire at the pressure and temperature indicated in part b. Notice it won't matter if you do the problem at 75 °F or 30 °F. The molar mass of air may be taken as 29 g/mol.

   \[ P_2 V = nRT \]

   \[ n = \frac{P_2 V}{RT} = \frac{(45 \text{ psi})(10.0 \text{ L})}{(0.08206 \text{ L atm/mol K})(298 \text{ K})} = \frac{(3.1 \text{ atm})(10.0 \text{ L})}{(0.08206 \text{ L atm/mol})(298 \text{ K})} = 1.27 \text{ mol} \]

   \[ n \times 29 \text{ g/mol} = 36.9 \text{ g air} \]

   Note: if you use \( V = 10.0 \text{ L}, P = 41 \text{ psi}, \) and \( T = 272 \text{ K} \) you still \( 1.25 \text{ mol} \) (rounding differs)
Potentially useful information:

\[ d \sin \theta = m \lambda \quad m = 0, 1, 2, 3, \ldots \]

\[ d \sin \theta = (m + \frac{1}{2}) \lambda \quad m = 0, 1, 2, 3, \ldots \]

\[ \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \]

\[ m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \]

\[ PV = nRT \]

\[ \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \]

\[ R = 0.08206 \text{ L-atm/mol-K} = 8.314 \text{ J/mol-K} \]

1 atm = 101325 Pa = 1.01325 bar = 14.7 psi