AP PHYSICS 2: LIGHT AND GEOMETRIC OPTICS

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

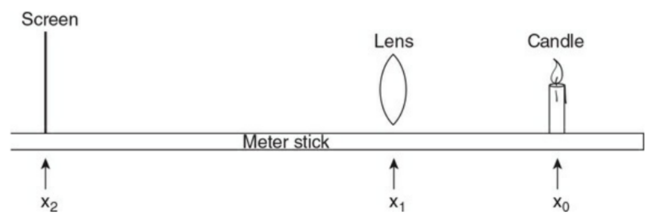
Note: To simplify calculations, you may use $g = 10\,\mathrm{m/s^2}$ in all problems.

1. In a laboratory experiment, you shine a green laser past a strand of hair. This produces a light and dark pattern on a screen. You notice that the lab group next to you has produced a similar pattern on a screen, but the light and dark areas are spread farther apart. Which of the following could cause the light and dark pattern to spread? (Select two answers.)
   (A) The second group used thinner hair.
   (B) The second group is using a red laser.
   (C) The second group had the screen closer to the hair.
   (D) The second group held the laser farther from the hair.

2. An observer can hear sound from around a corner but cannot see light from around the same corner. Which of the following helps to explain this phenomenon?
   (A) Sound is a longitudinal wave, and light is an electromagnetic wave.
   (B) Sound is a mechanical wave, and light is a transverse wave.
   (C) Light travels at a speed much faster than that of sound.
   (D) Light has a much smaller wavelength than sound.

3. A mirror produces an upright image one-half the height of the object when the object is 12 cm from the mirror's surface. What is the focal length of the mirror?
   (A) $-12\,\mathrm{cm}$
   (B) $-4\,\mathrm{cm}$
   (C) $4\,\mathrm{cm}$
   (D) $6\,\mathrm{cm}$

4. A light ray with a wavelength of λ_w and a frequency of f_w in water ($n = 1.33$) is incident on glass ($n = 1.61$). In the glass, the wavelength and frequency of the light is λ_g and f_g. How do the values of wavelength and frequency of the ray of light in water compare to those in glass?
   (A) $\lambda_w > \lambda_g$, and $f_w = f_g$
   (B) $\lambda_w > \lambda_g$, and $f_w > f_g$
   (C) $\lambda_w < \lambda_g$, and $f_w = f_g$
   (D) $\lambda_w < \lambda_g$, and $f_w < f_g$



5. An optics bench is set up on a meter stick, as shown in the figure. The light source is a candle placed at x_0 . The lens is located at x_1. The screen is moved until a sharp image appears at location x_2. The data is recorded in a table, the lens is moved to a new location (x_1), and the screen is adjusted until the image is sharp again. Which of the following procedures will allow a student to determine the focal length of the lens?
   (A) Plot x_2 as a function of x_0. The focal length will be the vertical axis intercept.
   (B) Plot $(x_2 - x_1)$ as a function of $(x_0 - x_1)$. The focal length will be the vertical axis intercept.
   (C) Plot $1/x_2$ as a function of $1/x_0$. The focal length will be the inverse of the vertical axis intercept.
   (D) Plot $1/(x_2 - x_1)$ as a function of $1/(x_0 - x_1)$. The focal length will be the inverse of the vertical axis intercept.

6. A laser beam passes through a prism and produces a bright dot of light a distance of x from the prism, as shown in the figure. Which of the following correctly explains the change in distance as the angle (θ) of the prism is decreased?

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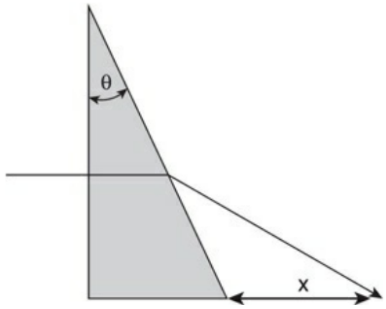

(A) The distance increases because the angle on incidence increases.
(B) The distance increases because the angle of incidence decreases.
(C) The distance decreases because the angle on incidence increases.
(D) The distance decreases because the angle of incidence decreases.

7. In the human eye, the distance from the lens to the retina, on which the image is focused, is 20 mm. A book is held 30 cm from the eye, and the focal length of the eye is 16 mm. How far from the retina does the image form, and what lens should be used to place the image directly on the retina?

	Distance of image from retina	Corrective lens
(A)	3.1 mm in front of the retina	Concave lens
(B)	3.1 mm in front of the retina	Convex lens
(C)	14 mm behind the retina	Concave lens
(D)	14 mm behind the retina	Convex lens

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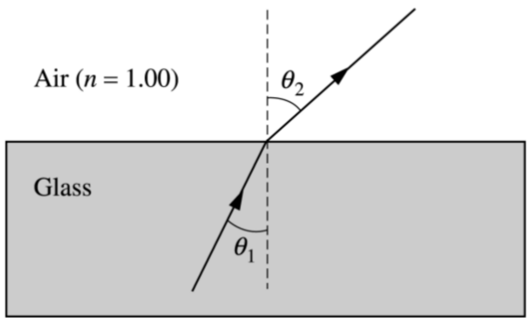
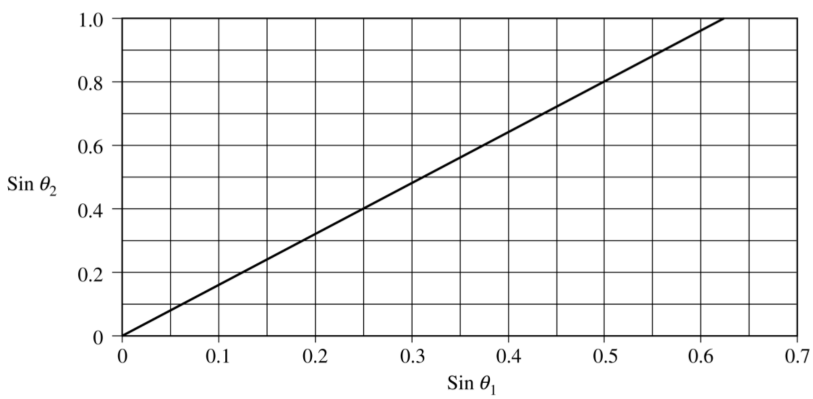
SECTION II
6 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.



1. In an experiment a beam of red light of wavelength 675 nm in air passes from glass into air, as shown above. The incident and refracted angles are θ_1 and θ_2, respectively. In the experiment, angle θ_2 is measured for various angles of incidence θ_1, and the sines of the angles are used to obtain the line shown in the following graph.



(a) Assuming an index of refraction of 1.00 for air, use the graph to determine a value for the index of refraction of the glass for the red light. Explain how you obtained this value.

(b) For this red light, determine the following.

i. The frequency in air

ii. The speed in glass

iii. The wavelength in glass

(c) The index of refraction of this glass is 1.66 for violet light, which has wavelength 425 nm in air.

i. Given the same incident angle θ_1 , show on the ray diagram on the previous page how the refracted ray for the violet light would vary from the refracted ray already drawn for the red light.

ii. Sketch the graph of $\sin\theta_2$ versus $\sin\theta_1$ for the violet light on the figure on the previous page that shows the same graph already drawn for the red light.

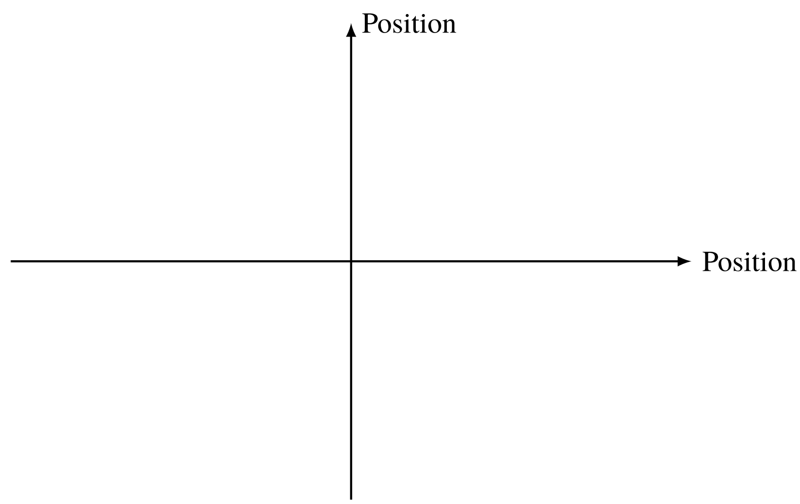
(d) Determine the critical angle of incidence θ_c for the violet light in the glass in order for total internal reflection to occur.

2. Your teacher gives you a slide with two closely spaced slits on it. She also gives you a laser with a wavelength $\lambda = 632\,\text{nm}$. The laboratory task that you are assigned asks you to determine the spacing between the slits. These slits are so close together that you cannot measure their spacing with a typical measuring device.

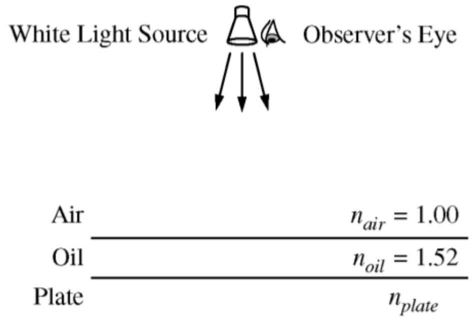
   (a) From the list below, select the additional equipment you will need to do your experiment by checking the line next to each item.

   ____ Meterstick
   ____ Ruler
   ____ Tape measure
   ____ Light-intensity meter
   ____ Large screen
   ____ Paper
   ____ Slide holder
   ____ Stopwatch

   (b) Draw a labeled diagram of the experimental setup that you would use. On the diagram, use symbols to identify carefully what measurements you will need to make.



   (c) On the axes below, sketch a graph of intensity versus position that would be produced by your setup, assuming that the slits are very narrow compared to their separation.



Note: Figure not drawn to scale.

3. A thin layer of transparent oil is placed on top of a transparent plate. The oil film is then illuminated by white light shining onto the oil's surface, as shown in the figure above. To an observer standing right next to the light source and looking straight down on the oil film, the oil film appears green, corresponding to a wavelength of 520 nm in air. The oil has an index of refraction of 1.52.

   (a) Determine the frequency of the green light in the air.

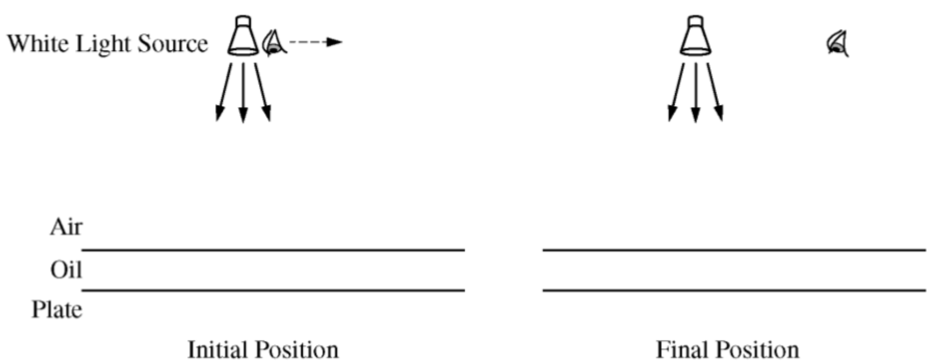
   (b) Determine the frequency of the green light in the oil film.

   (c) Calculate the wavelength of the green light in the oil film.

   (d) The oil film thickness is half of the wavelength you found in part (c). Is the index of refraction of the plate greater than, less than, or equal to that of the oil?

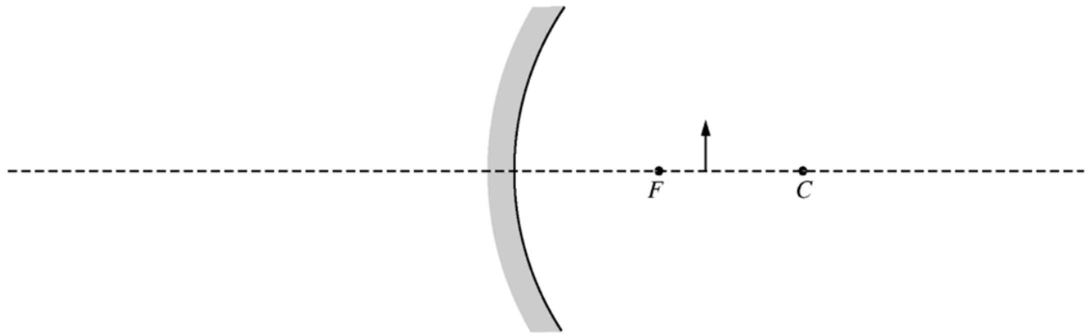
   ____ Greater than ____ Less than ____ Equal to

   Justify your answer.



Note: Figure not drawn to scale.

   (e) As the observer starts moving to the right away from the light source, as shown in the figures above, the film appears to change color. Describe the color change and give an explanation for this phenomenon.



4. The figure above shows a converging mirror, its focal point F, its center of curvature C, and an object represented by the solid arrow.

   (a) On the figure above, draw a ray diagram showing at least two incident rays and the image formed by them.

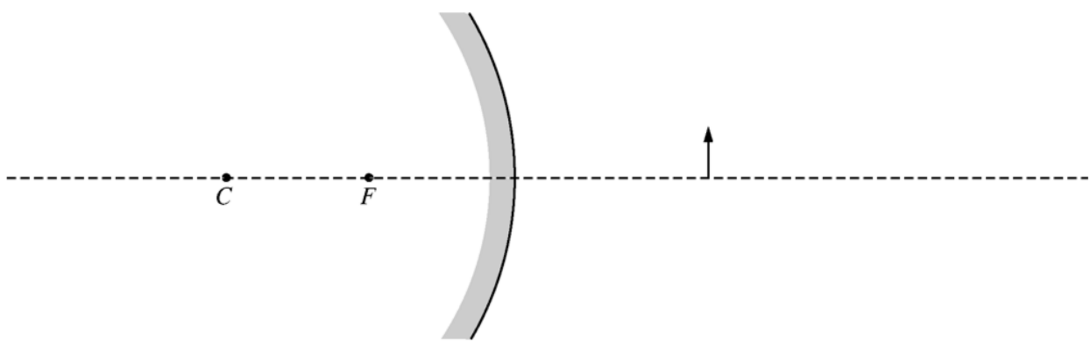
   (b) Is the image real or virtual?

   _____ Real _____ Virtual

   Justify your answer.

   (c) The focal length of this mirror is 6.0 cm, and the object is located 8.0 cm away from the mirror. Calculate the position of the image formed by the mirror. (Do NOT simply measure your ray diagram.)

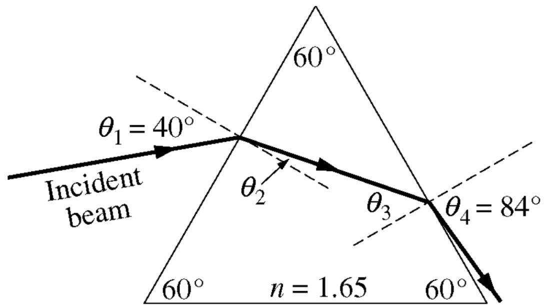
   (d) Suppose that the converging mirror is replaced by a diverging mirror with the same radius of curvature that is the same distance from the object, as shown below.



   For this mirror, how does the size of the image compare with that of the object?

   _____ Larger than the object _____ Smaller than the object _____ The same size as the object

   Justify your answer.



Note: Figure not drawn to scale.

5. As shown above, a beam of red light of wavelength 6.65×10^{-7} min air is incident on a glass prism at an angle θ_1 with the normal. The glass has index of refraction $n = 1.65$ for the red light. When $\theta_1 = 40°$, the beam emerges on the other side of the prism at an angle $\theta_4 = 84°$.

   (a) Calculate the angle of refraction θ_2 at the left side of the prism.

   (b) Using the same prism, describe a change to the setup that would result in total internal reflection of the beam at the right side of the prism. Justify your answer.

   (c) The incident beam is now perpendicular to the surface. The glass is coated with a thin film that has an index of refraction $n_f = 1.38$ to reduce the partial reflection of the beam at this angle.

      i. Calculate the wavelength of the red light in the film.

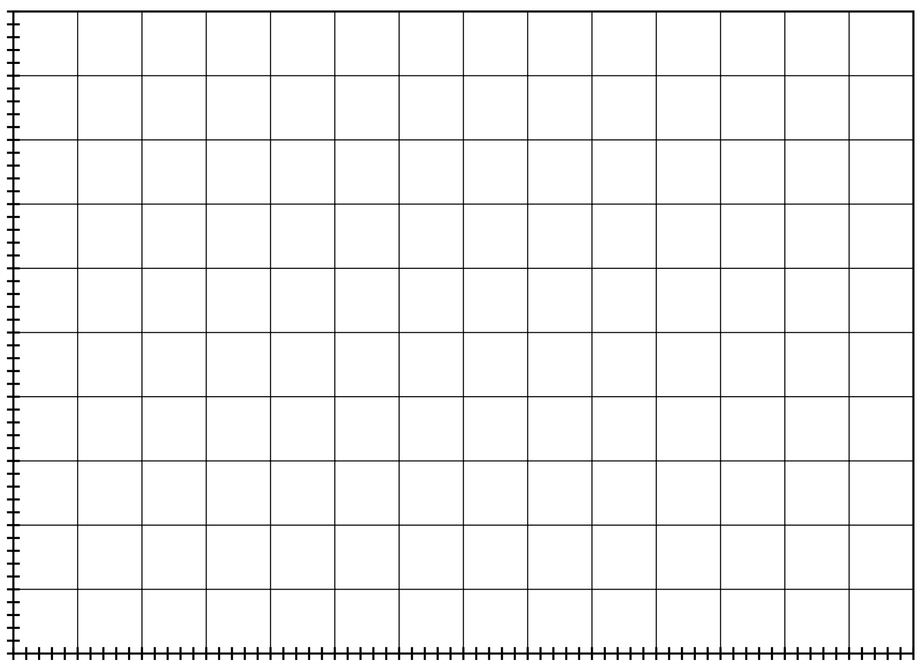
      ii. Calculate the minimum thickness of the film for which the intensity of the reflected red ray is near zero.

6. A student performs an experiment to determine the index of refraction n of a rectangular glass slab in air. She is asked to use a laser beam to measure angles of incidence θ_i in air and corresponding angles of refraction θ_r in glass. The measurements of the angles for five trials are given in the table below.

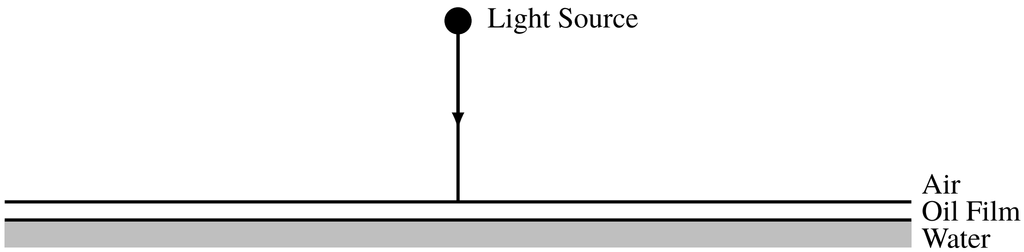
Trial	θ_i	θ_r		
1	30°	20°		
2	40°	27°		
3	50°	32°		
4	60°	37°		
5	70°	40°		

(a) Complete the last two columns in the table by calculating the quantities that need to be graphed to provide a linear relationship from which the index of refraction can be determined. Label the top of each column.

(b) On the grid below, plot the quantities calculated in (a) and draw an appropriate graph from which the index of refraction can be determined. Label the axes.



(c) Using the graph, calculate the index of refraction of the glass slab.



The student is also asked to determine the thickness of a film of oil ($n = 1.43$) on the surface of water ($n = 1.33$). Light from a variable wavelength source is incident vertically onto the oil film as shown above. The student measures a maximum in the intensity of the reflected light when the incident light has a wavelength of 600 nm.

(d) At which of the two interfaces does the light undergo a 180° phase change on reflection?

______ The air-oil interface only ______ The oil-water interface only ______ Both interfaces
______ Neither interface

(e) Calculate the minimum possible thickness of the oil film.