Physics 1C, Summer 2011 (Session 1)

Midterm 2 (50+4 points) Solutions

Problem 1 (5x2 = 10 points)

Label the following statements as True or False, with a one- or two-sentence explanation for why you chose your answer. Even if you get the answer correct, you will receive no credit unless your explanation is clear.

a. When light travels from air into water, its frequency remains unchanged.

b. A lens with a refractive power of 4 diopters has a shorter focal length than a lens with a refractive power of 2 diopters.

c. A lens can produce an upright, magnified image on the same side from the lens as the object.

d. When unpolarized light passes through a polarizer, the intensity of transmitted light depends on the orientation of the transmission axis of the polarizer.

e. When looking at an interference pattern due to two slits, the bright spots increase in distance from each other as the frequency of light incident on the slits increases.

Solution

a. True: frequency refers to the number of wave peaks (or crests, or whatever unique part of a wave during one wavelength) that go through a point in one second. This does not change as light passes through an interface: it is the wavelength that changes when the speed of light in the different media are different.

b. True: The 4 diopter lens has a focal length 0.25 meters, and the 2 diopter lens has a focal length of 0.50 meters.

c. True: This can happen for an object placed within the focal length of a converging lens (a picture should be drawn to illustrate this).

d. False: the intensity will always drop down to 50% of its initial value.

e. False. The distance between bright spots for an interference pattern is $d\sin(\theta) = m\lambda$. If frequency increases, λ decreases, θ decreases by the above equation, and the bright spots get closer together.

Problem 2 (4+2+2+2 = 10 points)

A ray of green light in air (wavelength 540.0 nm) hits an air-glass surface with angle of incidence 40 degrees to the normal. The index of refraction for this type of glass is 1.60.

a. What is the angle between the reflected ray and the refracted ray?

b. What is the speed of light in the glass?

c. What is the frequency of the light in the glass?

d. What is the wavelength of the light in the glass?

Solution:
a. The reflected ray makes an angle of 40 degrees with respect to the normal, and the refracted ray makes an angle of $\theta = \sin^{-1}[\sin(40^0)(1/1.6)] = 23.7^0$. Therefore, the angle between the reflected and refracted ray is $180^0 - 40^0 - 23.7^0 = 116.3^0$.

b. The speed of light in the glass is $v_{glass} = c(n_{air}/n_{glass}) = c(1.00/1.60)$, where c = the speed of light in air, or 3.00×10^8 m/s. Therefore, $v_{glass} = 1.88 \times 10^8$ m/s.

c. The frequency of the light in the glass is the same as it is outside of the glass. Outside the glass, the frequency is $f = c/\lambda = (3.00 \times 10^8 \text{m/s})/(540.0 \times 10^{-9} \text{m}) = 5.56 \times 10^{14}$ Hz.

d. The wavelength of the light in the glass is the speed of light in the glass divided by the frequency inside the glass. $\lambda_{glass} = (1.88 \times 10^8 \text{m/s})/(5.56 \times 10^{14} \text{Hz}) = 338$ nm.

Problem 3 (5+5 = 10 points)

When yellow sodium light, $\lambda = 589$ nm, falls on a diffraction grating, its first order peak on a screen 60.0 cm away falls 3.32 cm from the central peak. Another source produces a line 3.71 cm from the central peak.

a. How many lines/cm are on the grating?

b. What is the wavelength of the new source?

Solution
a. $d\sin(\theta) = d(y/L) = m\lambda \rightarrow d = (mL\lambda)/y = (1)(589\text{x}10\text{^-}9)(0.600)/(0.0332)$ meters. Thus, the spacing between slits is d = 1.06 x 10^-5 meters, which means that there are about 93900 slits in a meter. Therefore, there are about 939 lines per cm on the grating.

b. The above equation implies y is proportional to λ, so $\lambda_{new} = \lambda_{old} (y_{new}/y_{old})$. This gives us λ_{new} = (589 x 10^-9)(0.0371/0.0332) meters = 658 nm.

Problem 4 (6+4+4 = 14 points)

Suppose you have a convex (diverging) mirror with radius of curvature -20.0 cm. You place an object at a distance of 5.0 cm from the mirror.

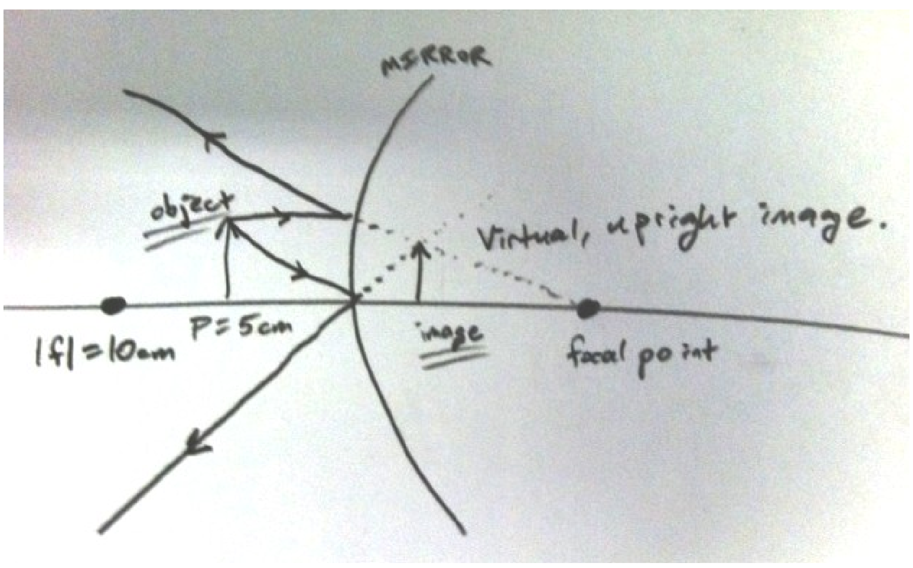
a. Draw a (neat) ray diagram to show where the resulting image forms. From your diagram, is the image real or virtual? Upright or inverted?

b. How far is the image from the mirror? Find this exactly (that is, solve for it using an appropriate equation, and not by guessing from your diagram above).

c. What is the magnification (with correct sign) of the mirror? Does this answer look reasonable compared to your ray diagram in part a?

Solution

a. Note that the focal length is half of the radius of curvature for a mirror, and so f = -10.0cm. From the following picture it is evident the image is upright and virtual:



b. 1/p + 1/q = 1/f. Plugging in f = -10.0cm and p = +5.0cm, we obtain q = -3.3 cm. Therefore, the image is 3.3 cm to the right of the mirror.

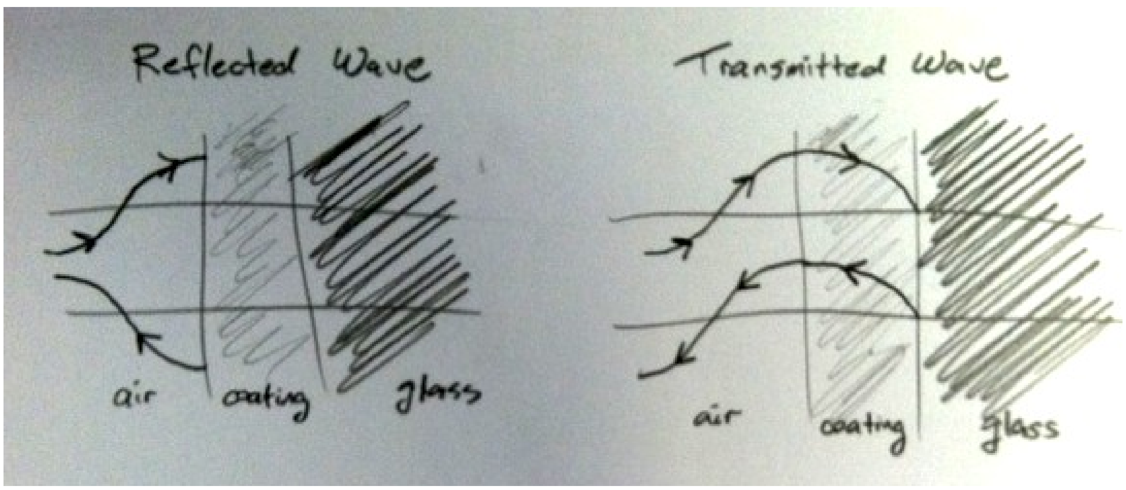
c. M = -q / p = 3.3/5.0 = +2/3. This looks reasonable from our diagram: the image is a little smaller than the object, and it is upright (hence the positive sign for M).

Problem 5 (6 points)

It is necessary to coat a glass lens with a non-reflecting layer. If the wavelength of the light in the coating is λ, the best choice is a layer of material having an index of refraction between those of glass and air, and a thickness of what (in terms of λ)? If many answers exist, choose the one with the smallest wavelength (greater than zero). Note that a picture will definitely help, not only in finding the final answer, but also in getting partial credit.

Solution

The answer is $\lambda/4$. See the picture below, and note that with the thickness equal to $\lambda/4$, the two waves add together destructively after reflection:



Extra Credit (4 points)

Suppose Alice is myopic and puts on glasses to correct for this. Bob, Alice's stalker, watches her put on her glasses. After she puts on glasses, do Alice's eyes appear larger, smaller, or remain the same size as seen by Bob? Explain.

Solution:

Alice's eyes look smaller. A diverging lens is used to correct for myopia. Therefore, Alice's eye (as an object, viewed by Bob on the other side of the lens) forms an image closer to the lens and smaller than her actual eye. For full credit a ray diagram should be shown.