Key

PHY 1520 Equations

Quiz 2

1 nm = 1×10^{-9} m

Interference of two sources that are in phase:

$$\begin{aligned} \text{Constructive:} \quad & \text{path difference} = m\lambda \\ \text{Destructive:} \quad & \text{path difference} = \left(m + \frac{1}{2}\right)\lambda \end{aligned}$$

Single slit diffraction:

$$\begin{aligned} w &= \frac{2\lambda L}{a} \\ a\sin(\theta_p) &= p\lambda \quad p = 1, 2, 3...\text{for dark fringes} \\ y_p &\approx \frac{p\lambda L}{a} \quad p = 1, 2, 3...\text{for dark fringes and small angles} \end{aligned}$$

Young's double slit experiment.

$$\begin{aligned} \text{bright fringes at} \quad & d\sin\theta_m = m\lambda \quad y_m \approx \frac{m\lambda L}{d} \quad \text{m=0, 1, 2, ...} \\ \text{dark fringes at} \quad & d\sin\theta'_m = \left(m + \frac{1}{2}\right)\lambda \quad y'_m \approx \left(m + \frac{1}{2}\right)\frac{\lambda L}{d} \quad \text{m=0, 1, 2, ...} \end{aligned}$$

Thin film interference.

$$\begin{aligned} \text{Constructive: 0 or 2 phase changes} \quad & 2t = m\frac{\lambda}{n} \\ \text{Constructive: 1 phase change} \quad & 2t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n} \\ \text{Destructive: 0 or 2 phase changes} \quad & 2t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n} \\ \text{Destructive: 1 phase change} \quad & 2t = m\frac{\lambda}{n} \end{aligned}$$

linear magnification:

$$m = \frac{-s'}{s} = \frac{h'}{h}$$

Physics 1520, Fall 2012
Quiz 2, Form: A

Name: _____

Date: _____

Section 1. Exercises

1. Red light has a wavelength of approximately 700 nm. Blue light has a wavelength of about 475 nm. Which light has a greater frequency?

   $v = \lambda f = c$ $\quad \lambda \propto \frac{1}{f}$

   (a) Red light
   (b) Blue light — shorter $\lambda \rightarrow$ higher f
   (c) Neither, because they have the same frequency.

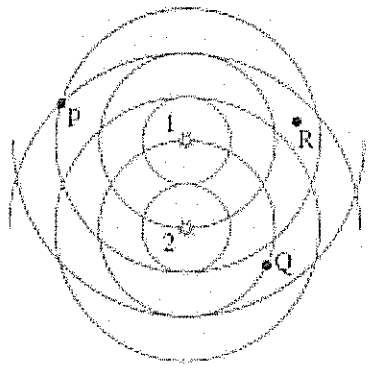
2. Suppose that red light from a laser travels from air into water. In going from the air to water, the wavelength of the light decreases and the frequency stays the same.

   (a) increases; decreases
   (b) increases; stays the same
   (c) stays the same; stays the same
   (d) decreases; increases
   (e) decreases; stays the same

   $n_{air} < n_{water}$

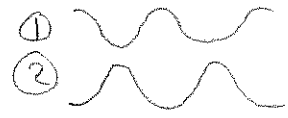
   $\lambda = \frac{\lambda_{vac}}{n}$ $\quad f$ is the same

Questions 3–4: The figure below shows circular wave fronts emitted by two sources.



3. At location Q, is the interference constructive or destructive?

   (a) constructive
   (b) destructive — a crest from source 2 is added to a trough from source 1.



4. At location Q, the path difference for the waves from the two sources is

   (a) λ.
   (b) 2λ.
   (c) $(1/2)\lambda$.
   (d) $(3/2)\lambda$.
   (e) 3λ.

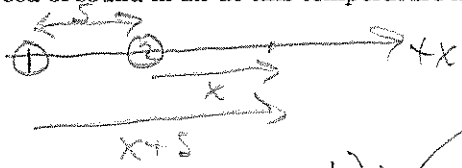
   distance from ① is 3.5λ

   distance from ② is 2λ

   path diff $= 3.5\lambda - 2\lambda = 1.5\lambda = \frac{3}{2}\lambda$

5. Two loudspeakers in a 20°C room emit 200 Hz sinusoidal sound waves. If the speakers emit the sound in phase, at what minimum distance apart should the speakers be separated in order to cancel the sound along the $+x$ axis. The speed of sound in air at this temperature is approximately 340 m/s.

(a) 0.29 m
(b) 0.43 m
(c) 0.59 m
(d) 0.85 m
(e) 1.7 m



destructive interference

path diff $= s = \left(m+\frac{1}{2}\right)\lambda$

$s = \frac{1}{2}\lambda = \frac{1}{2}\frac{v}{f}$

$= \frac{1}{2}\left(\frac{340\ m/s}{200\ Hz}\right) = 0.85\ m$

6. A double-slit interference experiment shows fringes on a screen. The entire experiment is then immersed in water. Do the fringes on the screen get closer together, farther apart, remain the same, or disappear entirely?

(a) closer together
(b) farther apart
(c) remain the same
(d) disappear entirely

$y_1 = \frac{\lambda L}{d}$ in water, $\lambda = \frac{\lambda_{vac}}{n}$ so

λ decreases.

Thus y_1 decreases.

7. Light from a sodium lamp ($\lambda = 589$ nm) illuminates two narrow slits. The fringe spacing on a screen 150 cm from the slits is 4.0 mm. What is the spacing (in mm) between the two slits?

(a) 0.0022 mm
(b) 22 mm
(c) 2.2 mm
(d) 0.22 mm
(e) 0.022 mm

$y_1 = \frac{\lambda L}{d} = \frac{(589\times10^{-9}\ m)(1.5\ m)}{4.0\times10^{-3}\ m} = 2.2\times10^{-4}\ m$

$(2.2\times10^{-4}\ m)\left(\frac{1000\ mm}{1\ m}\right) = 0.22\ mm$

8. A thin film with $n = 1.6$ is deposited onto glass with $n = 1.5$. Light reflected off the top surface of the thin film interferes with light that travels through the thin film and reflects off the film-glass interface. The light that reflects off the film-glass interface will undergo

(a) a phase change of 180°.
(b) no phase change.

$n_{film} > n_{glass}$

air $n = 1$
film $n = 1.6$
glass $n = 1.5$

9. You look into a bathroom mirror and see an image of yourself. This image is

(a) virtual
(b) real

10. Which lens has a greater refractive power (i.e. bends parallel light rays a greater amount), a converging lens with a 20 cm focal length or a converging lens with a 5 cm focal length?

(a) Neither; they have the same power.
(b) 20 cm lens
(c) 5 cm lens

$P = \frac{1}{f}$ shorter f, greater power

Questions 11–12: A 2.0-cm tall object is 30 cm in front of a converging lens that has a 20-cm focal length.

11. What is the distance from the lens to the image?

(a) 0.02 cm
(b) 10 cm
(c) 12 cm
(d) 50 cm
(e) 60 cm

$s = 30$ cm
$f = 20$ cm

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

$\frac{1}{s'} = \frac{1}{20\ cm} - \frac{1}{30\ cm}$

$s' = 60$ cm

12. Is the image reduced or enlarged?

$M = \frac{-s'}{s} = \frac{-60\text{cm}}{30\text{cm}} = -2$

$|M| > 1$ so enlarged (and inverted)

(a) Neither; it is the same size as the object.

(b) reduced

(c) enlarged

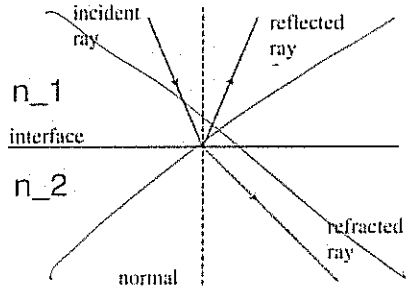
13. An object is placed a distance $1.5f$ from a concave mirror that has a focal length that is f. The image is formed on the same side of the mirror as the object. Is the image real or virtual?

This is a real image. A virtual image will be on the other side.

(a) real

(b) virtual

14. In the lab, you set up a converging lens and view the image of an object on a screen. You then slide a card in front of the lens so that it covers the top half of the lens. How will this affect the image?



Wrong image

(a) Only the top half of the image (i.e. the arrow) will be seen.

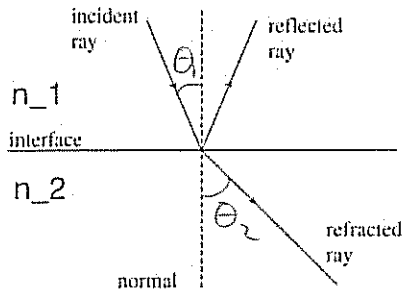
(b) Only the bottom half of the image (i.e. the arrow) will be seen.

(c) The lens will have half the focal length, and the image distance will closer to the lens.

(d) The image will be the same (i.e. unchanged from before).

(e) The image will be dimmer. Fewer rays reach the screen.

15. An incident ray (such as that from a laser) reflects and refracts as shown below. The areas on each side of the interface represent two transparent media with index of refraction n_1 and n_2, respectively.



$\theta_2 > \theta_1$ so $n_2 < n_1$.

Which of the following must be true?

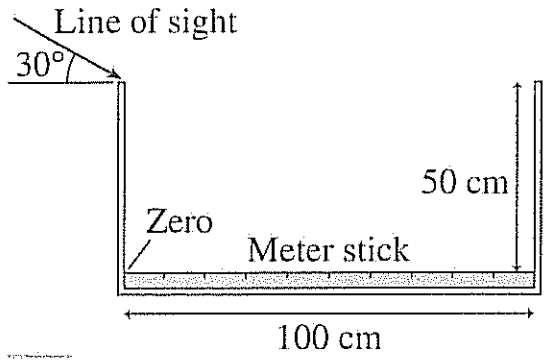
(a) $n_2 > n_1$

(b) $n_2 = n_1$

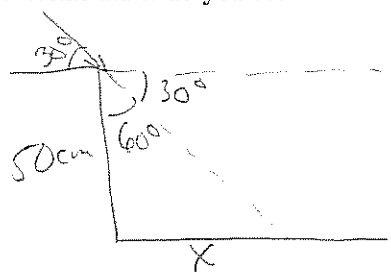
(c) $n_2 < n_1$

Section 2. Critical Thinking

The figure below shows a meterstick lying on the bottom of a 100-cm long tank with its zero mark against the left edge. You look in to the tank at a 30° angle, with your line of sight just grazing the upper left edge of the tank.



16. What mark do you see on the meterstick if the tank is empty?

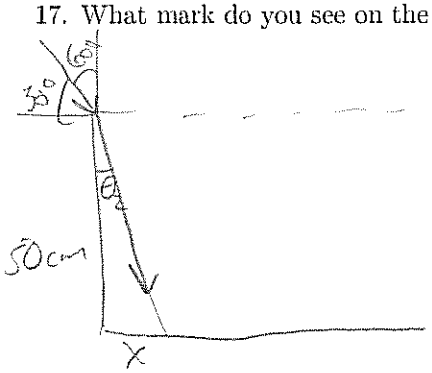


$\tan(60°) = \frac{x}{50\text{cm}}$

$x = 86.6\text{ cm}$

so roughly **87 cm**

17. What mark do you see on the meterstick if the tank is full of water ($n = 1.33$)?



the ray bends toward the normal, so x will decrease.

$n_1 = 1$

$n_2 = 1.33$

$\theta_1 = 60°$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\sin(60°) = 1.33 \sin\theta_2$

$\theta_2 = 40.6°$

$\tan(\theta_2) = \frac{x}{50\text{cm}}$ so $x = (50\text{cm})\tan(40.6°)$

$= \mathbf{43\text{ cm}}$

The optometrist prescribes glasses with a converging lens having a power of +2.5 D for a patient.

18. The patient is farsighted and would like to read a book that is at a normal near point of 25 cm from the lens. What the patient's near point?

$f = \frac{1}{P} = \frac{1}{2.5\,D} = 0.4\,m = 40\,cm$

object is at $s = 25\,cm$

$s' = ?$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s}$

$= \frac{1}{40cm} - \frac{1}{25cm}$ so $\boxed{s' = -67\,cm}$

virtual image!

19. On the attached graph paper, accurately sketch a ray diagram with 3 "easy" rays showing where the image is formed. Also sketch the image.

    Use a vertical arrow to represent the object (a book in this case). Choose a scale for the grid that is appropriately large so that diagram is reasonably large and accurate. Indicate the scale on the optic axis on your diagram.

20. On your diagram, measure the image distance and compare the result to your previous calculation. It's ok if they aren't exactly the same because there can be small amounts of error in sketching ray diagrams.

    Also, comment on whether the image is real or virtual and how you can tell from your diagram.

$s' \approx 67$ or 68 cm

The image is virtual because rays passing through the lens diverge. We have to sketch the rays backwards (i.e. virtual rays) to find where they intersect. Also, the image is on the same side of the lens as the object.

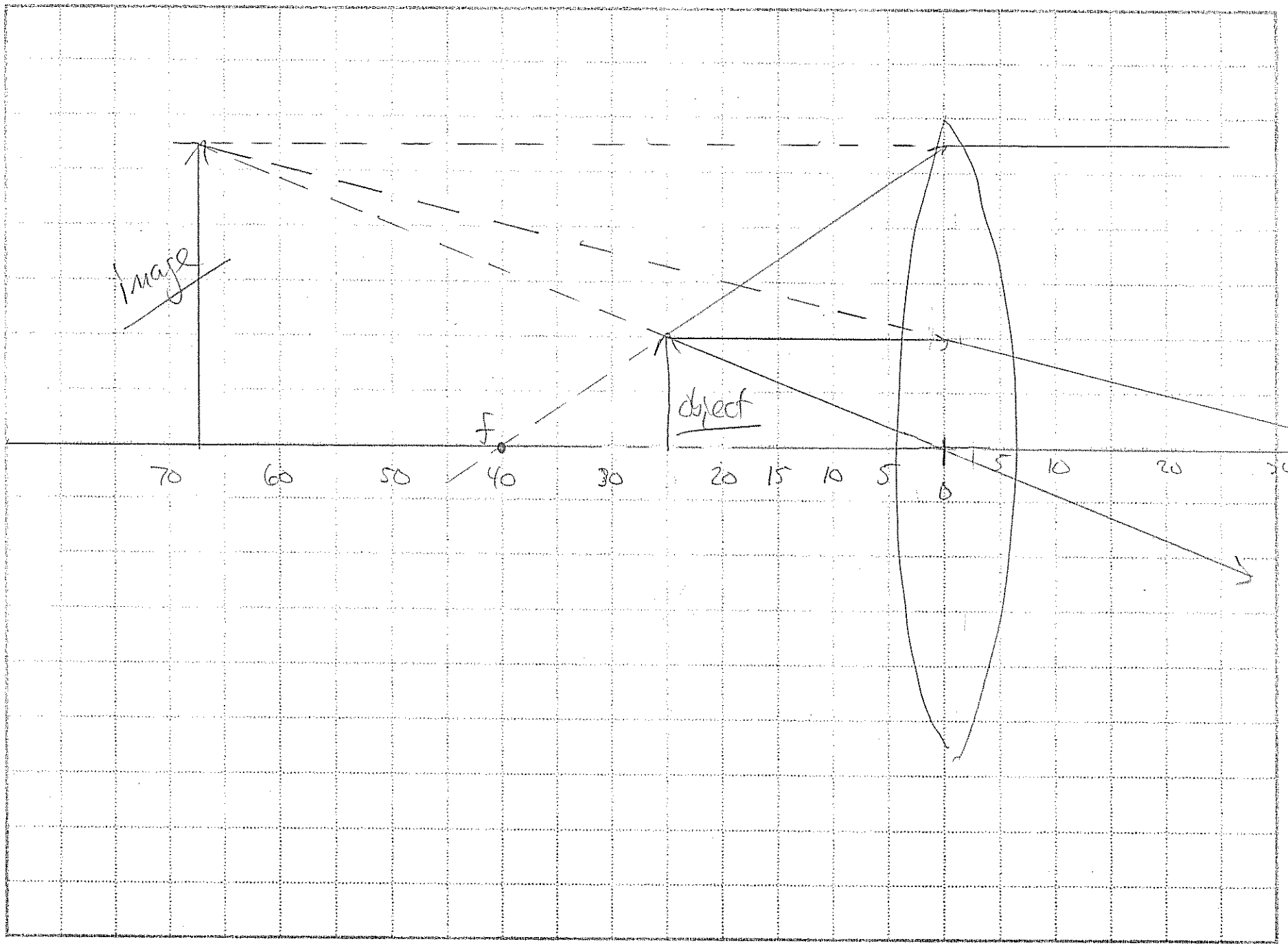


Image
object
f
70
60
50
40
30
20
15
10
5
0
5
10
20
30