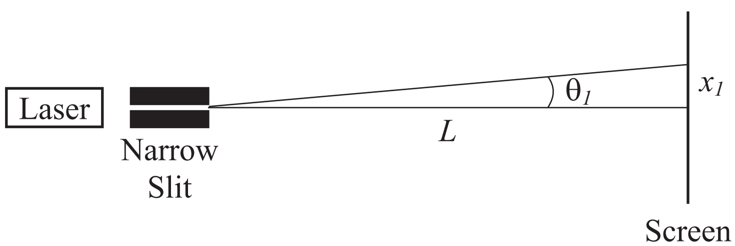
3. (a) Laser Pointer (λ = 635 nm), Screen, Meterstick, Metric ruler

(b) Top view of the apparatus:

(c) Place the screen 5 to 10 meters from the narrow slit. The exact placement is not important, but measuring and recording the exact distance from the narrow slit to the screen with a meterstick is important. Call this distance *L*. A beam from the laser pointer should be directed to pass through the narrow slit and onto the screen creating a diffraction and interference pattern of alternating fringes of light (constructive interference) and dark lines (destructive interference). The central fringe will be twice as wide (and brighter) than the other fringes. Use the metric ruler to measure the distance between the middle of the central fringe and one of the dark lines that border this central fringe. This distance, *x*, is the distance between m = 0 and m = 1 in the analysis of the interference pattern. Alternately, one could measure the distance between the two dark lines bordering the central fringe and divide this distance by two to get *x*.

(d)



From the geometry of the setup pictured above, θ_1 can be found by $\tan\theta_1 = \frac{x_1}{L}$. Substitute this angle into the equation describing this interference pattern, $m\lambda = D\sin\theta$, where m = 1 and solve for *D*, which is the width of the narrow slit.

(e) Since m and λ are constants, as *D* gets larger, θ_1 will become smaller $\left(\frac{m\lambda}{D} = \sin\theta\right)$, which in turn will cause the distance between the fringes to decrease (x_1 will get smaller).

5. (a) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$(1.00)\sin 40 = (1.65)\sin\theta_2$

$\boxed{\theta_2 = 23°}$

(b) The direction of the beam would be have to be adjusted so the incident angle θ_1 is smaller causing θ_2 to be smaller resulting in a larger θ_3. As θ_3 becomes larger, it approaches the critical angle.

Note: Calculations are not required, however, for those interested in using mathematical justification, start at the second surface of the prism and work towards the incident surface to calculate the necessary incident angle to produce total internal reflection.

$n_1 \sin\theta_3 = n_2 \sin 90$

$(1.65)\sin\theta_3 = (1.00)\sin 90$

$\theta_3 = 37.3°$

$\theta_2 + \theta_3 = 60°$ (the apex angle)

$\theta_2 + 37.3° = 60°$

$\theta_2 = 22.7°$

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

$(1.00)\sin\theta_1 = (1.65)\sin 22.7$

$\boxed{\theta_1 = 39.5°}$

(c)

i. $\lambda_n = \dfrac{\lambda}{n} = \dfrac{6.65 \text{ x } 10^{-7} \text{ m}}{1.38}$

$\boxed{\lambda_n = 4.82 \text{ x } 10^{-7} \text{ m}}$

ii. $\left(m + \frac{1}{2}\right)\lambda_n = 2t$

$\left(0 + \frac{1}{2}\right)\left(4.82 \text{ x } 10^{-7} \text{ m}\right) = 2t$

$\boxed{t = 1.20 \text{ x } 10^{-7} \text{ m}}$

6. (a) $c = \lambda f$

$3 \text{ x } 10^8 \text{ m/s} = \left(550 \text{ x } 10^{-9} \text{ m}\right) f$

$\boxed{f = 5.45 \text{ x } 10^{14} \text{ Hz}}$

(b) $\left(m + \frac{1}{2}\right)\lambda = d\sin\theta$

$\left(0 + \frac{1}{2}\right)\left(550 \text{ x } 10^{-9} \text{ m}\right) = \left(1.8 \text{ x } 10^{-5} \text{ m}\right)\sin\theta_{\frac{1}{2}}$

$\theta_{\frac{1}{2}} = 0.875^\circ$ which represents the angle between the perpendicular bisector of the slit extended to the screen and the line joining the intersection of the slit and its perpendicular bisector and the location of the first destructive interference (dark fringe) on the screen. Since this angle would be equivalent on the other side of the perpendicular bisector of the slit, the total angular dispersion between fringes would be double this value or $\theta = 0.030^\circ$.

$\tan\theta = \dfrac{x}{L}$ where x is the distance between dark fringes on the screen

$\tan\left(1.75^\circ\right) = \dfrac{x}{2.2 \text{ m}}$

$\boxed{x = 0.067 \text{ m} = 6.7 \text{ cm}}$

(c) $\boxed{f = 5.45 \text{ x } 10^{14} \text{ Hz}}$ - frequency does not change as a wave passes from one medium to another.

(d)

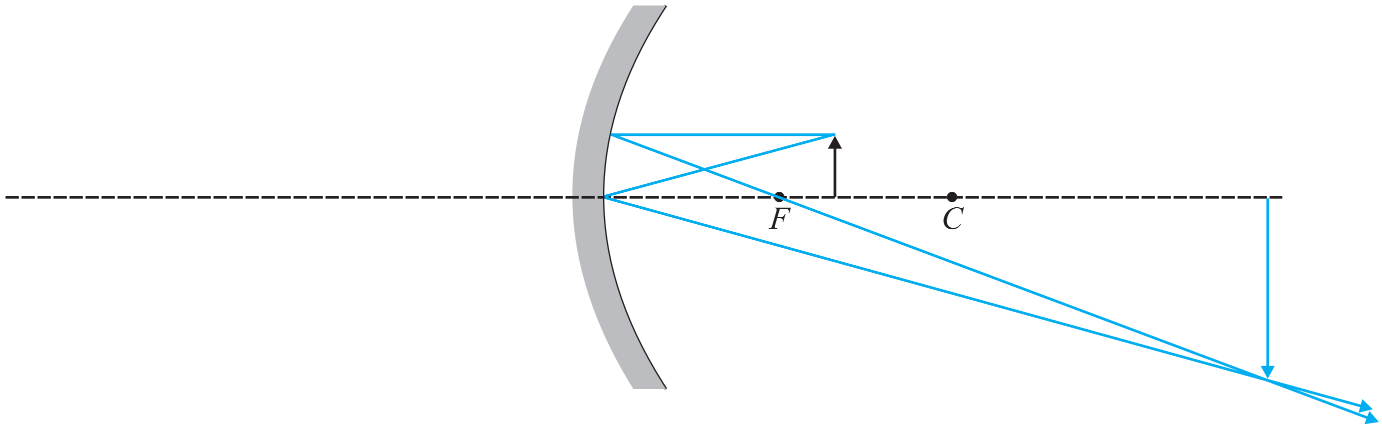
___ Increase _X_ Decrease ___ Remain the same

$\left(m + \frac{1}{2}\right)\lambda = d\sin\theta$

$\sin\theta = \dfrac{\left(m + \frac{1}{2}\right)\lambda}{d}$ and $\tan\theta = \dfrac{x}{L}$ or $x = L\tan\theta$ where $m,\ d,$ and L are constants

Since the wavelength is compressed (decreased) in the fluid, the angular dispersion would be decreased because both the sine and tangent functions decrease as the angle gets smaller.

6. (a)



(b)

_X_ Real   ___ Virtual

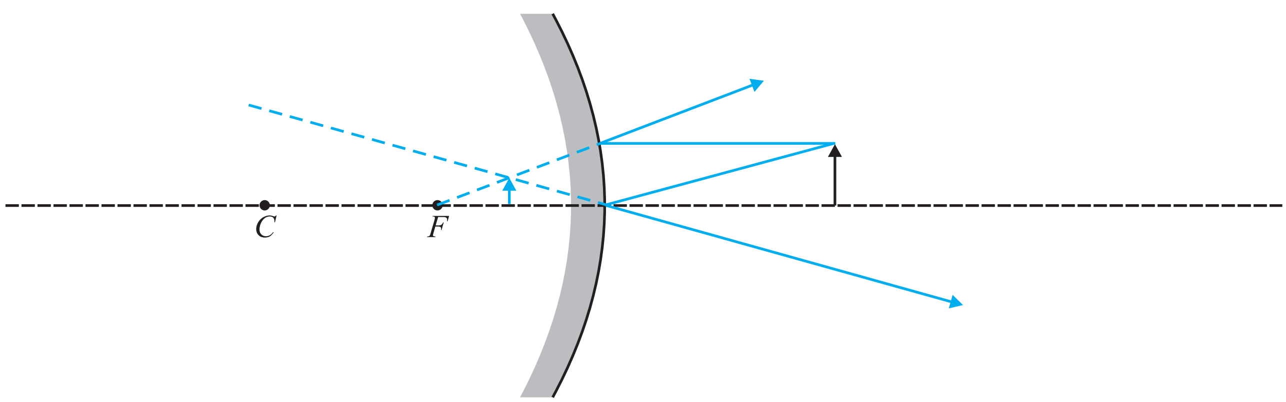
The light rays pass through the image as shown in the diagram above. Whenever an object is placed outside the focal length of a concave mirror, the resulting image will be real.

(c) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$$\frac{1}{8.0\text{ cm}} + \frac{1}{d_i} = \frac{1}{6.0\text{ cm}}$$

$\boxed{d_i = 24\text{ cm}}$ The image will appear 24 cm from the mirror on the same side as the object.

(d)



___ Larger than the object   _X_ Smaller than the object   ___ The same size as the object

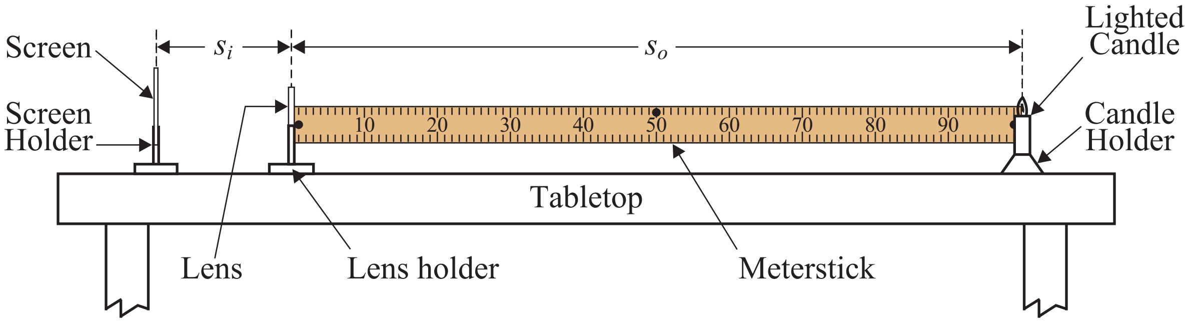
The image from a convex mirror is always smaller in size than the object. It is a diverging optical instrument.

6\. (a) The focal length of the lens is the image distance for an object at infinity. The object (tree) distance is essentially infinity compared to the focal length of the lens. Place a the lens between the distant tree and a screen (piece of paper or index card). Move the screen closer and farther to the lens until the clearest image of the tree is observed. Measure the distance that the screen is from the lens and that distance is the approximate focal length of the lens.

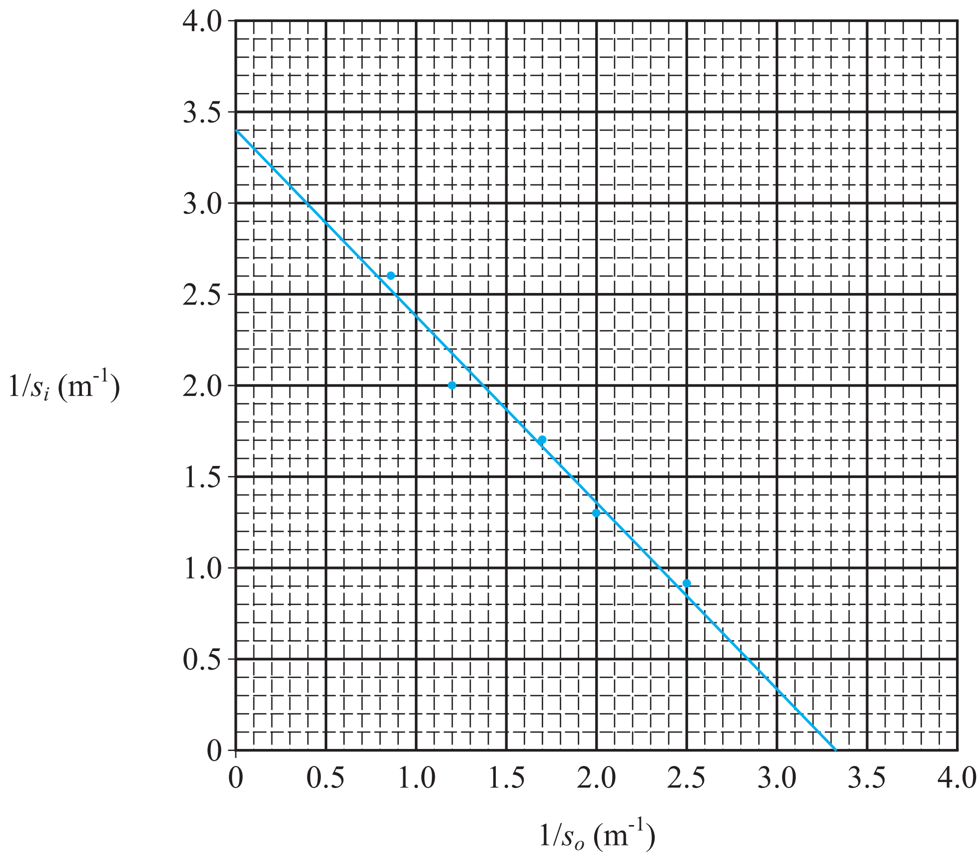
(b)

x Lighted candle	x Candleholder	___ Desk lamp	___ Plane mirror
___ Vernier caliper	x Meterstick	x Ruler	x Lens holder
___ Stopwatch	x Screen	___ Diffraction grating	

(c)



(d)

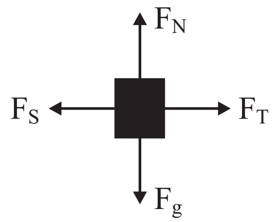


(e) $\frac{1}{f} = \frac{1}{s_i} + \frac{1}{s_o}$, or, rearranged, $\frac{1}{s_i} = -\frac{1}{s_o} + \frac{1}{f}$, which is of the form $y = mx + b$,

where $y = \frac{1}{s_i}$, $m = -1$, $x = \frac{1}{s_o}$, and $\frac{1}{f}$ is the y-intercept. The y-intercept on this graph is 3.4 m^{-1}, so

$f = \frac{1}{3.4\ \text{m}^{-1}} = \boxed{0.29\ \text{m} = f}$

1.(a)



(b) $\sum F = F_T - F_g = 0$

$F_T = mg = (4.0\text{ kg})(9.8\text{ m/s}^2)$

$F_T = 39.2\text{ N}$

(c) $\sum F = F_T - F_x = 0$

$F_T = kx$

$39.2\text{ N} = k\,(0.05\text{ m})$

Note: $x = L - L_0 = 0.25\text{m} - 0.20\text{ m} = 0.05\text{ m}$

$k = 784\text{ N/m}$

(d) $y = y_0 + v_0 t + \frac{1}{2}at^2$

$0\text{ m} = 0.70\text{ m} + (0\text{ m/s})t + \frac{1}{2}(-9.8\text{ m/s}^2)t^2$

$t = 0.267\text{ s}$

(e) $f = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}} = \dfrac{1}{2\pi}\sqrt{\dfrac{784\text{ N/m}}{8.0\text{ kg}}}$

$f = 1.58\text{ Hz}$

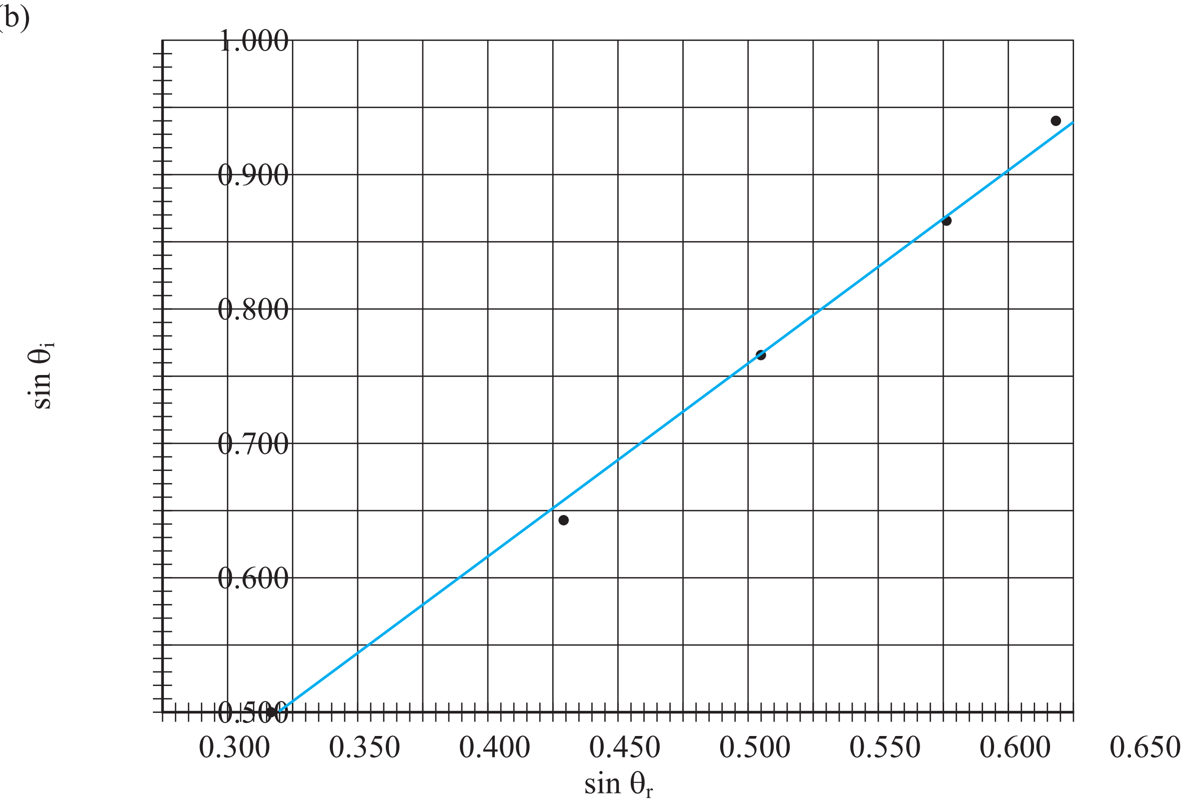
(f) $v_0 = 2\pi f A = 2\pi(1.58\text{ Hz})(0.05\text{ m})$

$v_0 = 0.495\text{ m/s}$

4. (a)

Trial	θ_i	θ_r	$\sin\theta_i$	$\sin\theta_r$
1	30°	20°	0.500	0.342
2	40°	27°	0.643	0.454
3	50°	32°	0.766	0.530
4	60°	37°	0.866	0.602
5	70°	34°	0.940	0.643

(b)



(c) $n = \frac{\sin\theta_i}{\sin\theta_r} = \text{Slope} = m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.939 - 0.500}{0.650 - 0.345} = \boxed{1.44 = n}$

(d)

__X__ The air-oil interface only

____ The oil-water interface only

____ Both interfaces

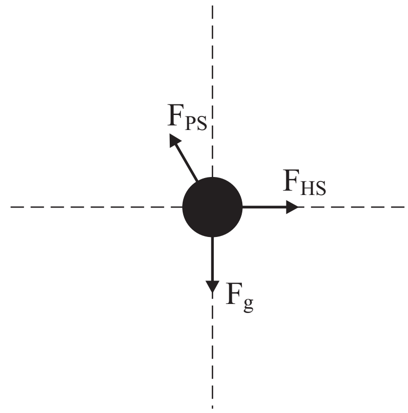
____ Neither interface

(e) $\left(m + \frac{1}{2}\right)\lambda = 2t$

$\left(0 + \frac{1}{2}\right)(600\text{ nm}) = 2t$

$\boxed{t = 150\text{ nm}}$

2. (a)



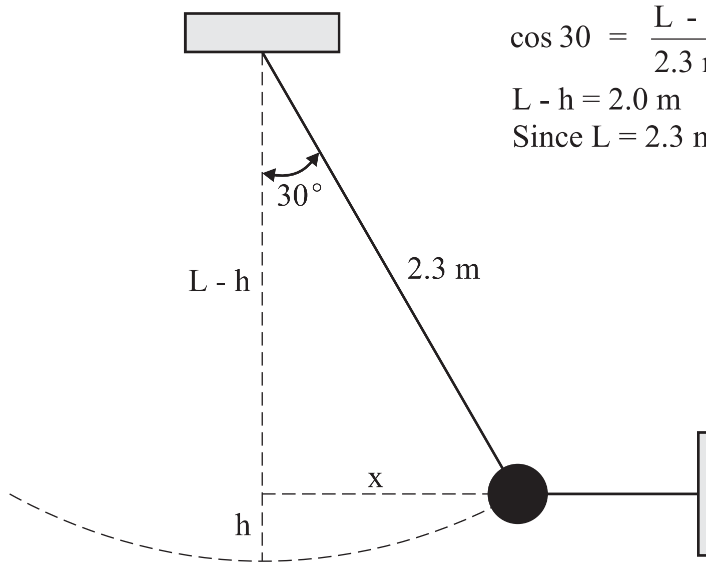
(b) $\Sigma F_y = F_{PSy} - F_g = ma$
$F_{PS}\sin 60 - mg = m(0)$
$F_{PS}\sin 60 - (1.8\text{ kg})(9.8\text{ m/s}^2) = 0$
$F_{PS} = 20.4\text{ N}$

$\Sigma F_x = F_{HS} - F_{PSx} = ma$
$F_{HS} - (20.4\text{ N})\cos 60 = m(0)$

$F_{HS} = 10.2\text{ N}$

(c) $GPE_1 = KE_2$
$\not{m}gh = \frac{1}{2}\not{m}v^2$
$gh = \frac{1}{2}v^2$
$v = \sqrt{2gh}$
$v = \sqrt{2(9.8\text{ m/s}^2)(0.3\text{ m})}$

$v = 2.4\text{ m/s}$



$\cos 30 = \frac{L - h}{2.3\text{ m}}$
$L - h = 2.0\text{ m}$
Since $L = 2.3$ m, $h = 0.3$ m.

Note: This could have been solved using $v_o = 2\pi fA$. The frequency of a pendulum is $f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$. The amplitude could be determined by converting 30° to 0.52 radians and using $l = r\theta$ where l is the maximum arc length of the pendulum swing, or l is the amplitude, A, and r is the radius of the circle, or the length of the string.

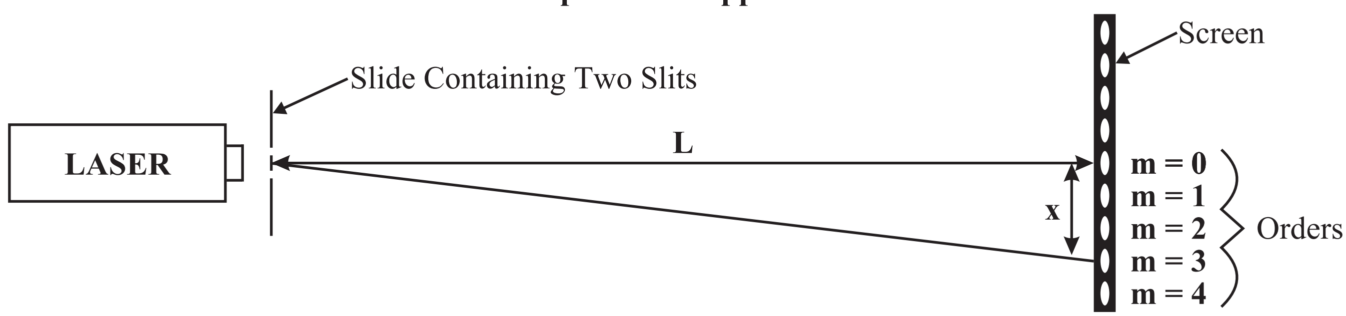
4. (a)

_X_ Meterstick ___ Ruler ___ Tape measure ___ Light-intensity meter

_X_ Large screen ___Paper _X_ Slide holder ___ Stopwatch

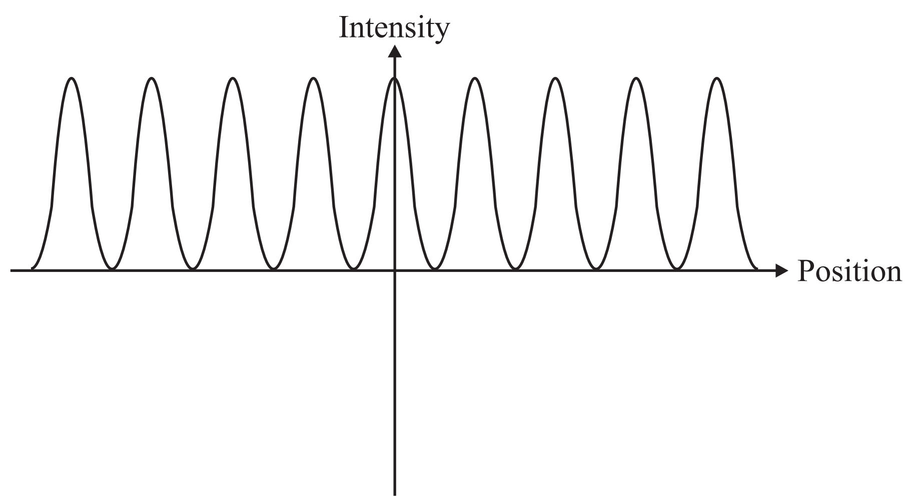
b.)

Top View of Apparatus



L -Distance between the Slide with the double slits and the Screen
x-Distance between light fringes (areas of constructive interference where light is visible)

(c)



(d) Place the slide in the slide holder and orient the laser and slide holder such that the beam of light from the laser passes through the double slit (two closely spaced slits) and onto a large screen on the other side of the room as shown in the diagram above in part (b). Using the meterstick measure L, the length of the room between the slide holder and the screen), and x, the distance between light fringes that appear on the screen.

4. (a) $v = \lambda f$

$343 \text{ m/s} = \lambda(2500 \text{ Hz})$

$\boxed{\lambda = 0.137 \text{ m}}$

(b) $(m + \tfrac{1}{2})\lambda = d\sin\theta$ destructive interference

$(0 + \tfrac{1}{2})(0.137 \text{ m}) = (0.75 \text{ m})\sin\theta$

$\theta = 5.24°$

$\tan\theta = \dfrac{Y}{L}$

$\tan 5.24° = \dfrac{Y}{5.0 \text{ m}}$

$\boxed{Y = 0.459 \text{ m}}$

(c) $(m + \tfrac{1}{2})\lambda = d\sin\theta$ destructive interference

$(1 + \tfrac{1}{2})(0.137 \text{ m}) = (0.75 \text{ m})\sin\theta$

$\theta = 15.9°$

$\tan\theta = \dfrac{Y}{L}$

$\tan 15.9° = \dfrac{Y}{5.0 \text{ m}}$

$\boxed{Y = 1.42 \text{ m}}$

(d) i. The distance, Y, would be larger if the speakers were moved closer together because moving the speakers closer together means d gets smaller which will make θ get larger [$(m + \tfrac{1}{2})\lambda = d\sin\theta$]. As θ gets larger, the tan θ gets larger, thus Y will get larger.

ii. The distance, Y, would be smaller if the frequency emitted by the two speakers was increased because the wavelength, λ, would get smaller since wavelength and frequency are inversely proportional in a given medium (constant velocity). As λ got smaller, θ would get smaller [$(m + \tfrac{1}{2})\lambda = d\sin\theta$]. As θ gets smaller, the tan θ gets smaller, thus Y will get smaller.

4. (a) To begin, the following defintions will be used. Object distance is the distance that the object, in this case the lit candle, is from the mirror, while image distance is the distance of the image from the mirror. Magnification is the ratio of the height of the image to the height of the object. Geometrically, it can be shown that this ratio is the same as the ratio of the image distance to the object distance. Principal axis is an imaginary axis that is the perpendicular bisector of the mirror. Focal point is the point where rays of light parallel to the principal axis will meet after reflecting off a concave mirror. Focal length is the distance that the focal point is from the mirror.

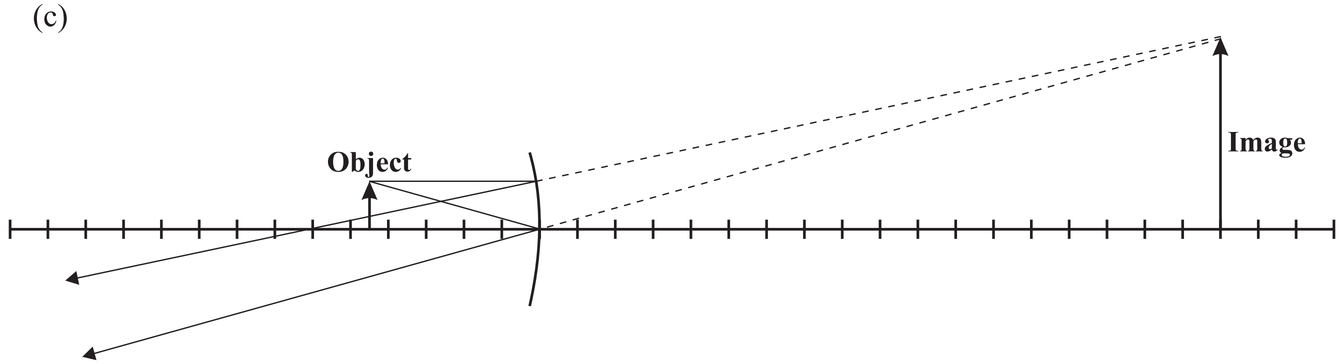
One way to produce an image with a magnification greater than one in a concave mirror is to place the lit candle inside the focal length of the concave mirror. This produces a virtual image that cannot be viewed with a screen.

Place the concave mirror in its holder on the optical bench and place the candle in its holder somewhere on the optical bench in front of the concave mirror and measure the object height, or diameter, and the image height, or diameter. The image height can be measured by placing a ruler against the mirror parallel to the image of the candle. Calculate the magnification as defined above. Diameters of the object and image can be used in place of the heights in that definition. Diameters are convenient when the image height exceeds the diameter of the mirror. Adjust the position of the lit candle and repeat the measurement of the image height or diameter until the magnification is exactly four.

(b)

____ convex mirror in holder	____ cancave lens in holder	____ convex lens in holder
X meter stick	**X** ruler	____ screen in holder

(c)



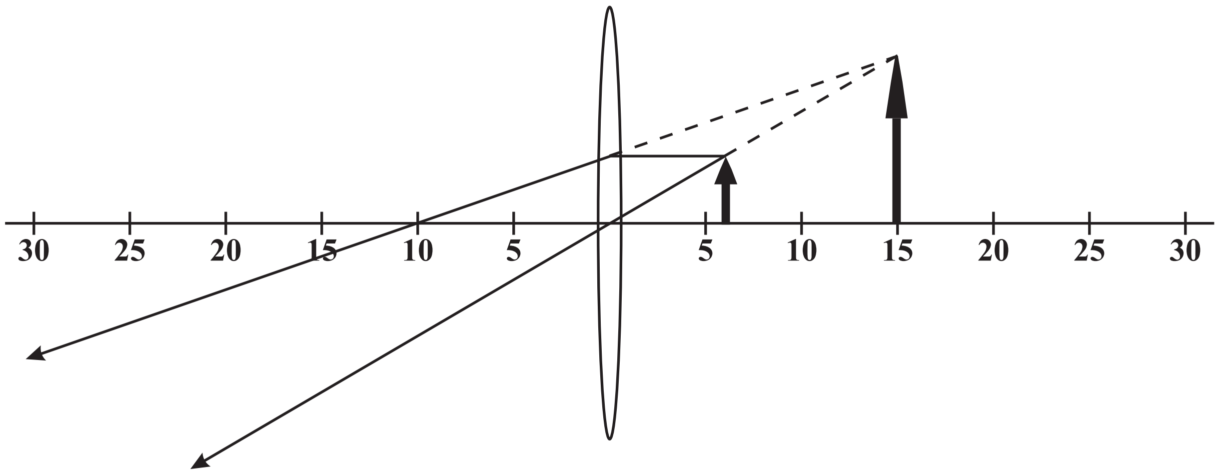
(d)

____ real	**X** upright	**X** larger than object
X virtual	____ inverted	____ smaller than object

(e) A real image can be produced if the candle is placed between the focal length (30 cm) and twice the focal length (60 cm). Calculations will show that this distance is 37.5 cm.

In addition, all spherical mirrors have spherical aberrations such that rays that are parallel to the principal axis do **NOT** reflect through a common point as described above, but merely in close proximity. The further these parallel rays are from the center of the mirror, the more they miss the focal point (due to the increased angle of incidence, which is the angle between the direction of the light ray and the normal to the surface, because of the curvature of the mirror. Rays that are parallel that strike the edges of the mirror miss the principal axis the most and create a circle of rays (from the edges) that is caleed the circle of confusion. Due to these flaws, and huamn error, particularly in measuring the image height or diameter, results may vary.

4. (a)



(b) The image is virtual because the light rays that come from the arrow do **NOT** actually pass through the image. The brain assumes that the image is where the light rays from the arrow originated.

(c) $\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f}$

$\frac{1}{d_i} + \frac{1}{6\text{ cm}} = \frac{1}{10\text{ cm}}$

$\boxed{d_i = -15\text{ cm}}$

(d) $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

$m = -\frac{-15\text{ cm}}{6\text{ cm}}$

$\boxed{m = +2.5}$

(e) The image will be real (on the opposite side of the lens), inverted, the same size as the object, and the same distance from the lens (20 cm) as the object's distance from the lens.

$\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f}$

$\frac{1}{d_i} + \frac{1}{20\text{ cm}} = \frac{1}{10\text{ cm}}$

$d_i = +20\text{ cm}$

$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

$m = -\frac{20\text{ cm}}{20\text{ cm}}$

$m = -1$

4. (a) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$n_1 = n_2 \frac{\sin\theta_2}{\sin\theta_1} = 1.00\left(\frac{0.4}{0.25}\right)$$

$$\boxed{n_1 = 1.6}$$

(b) i. $c = \lambda f$

3.00×10^8 m/s $= (6.75 \times 10^{-7}$ m$)f$

$$\boxed{f = 4.44 \times 10^{14} \text{ hz}}$$

ii. $n_1 = \dfrac{c}{v}$

$$1.6 = \frac{3x10^8 \, m/s}{v}$$

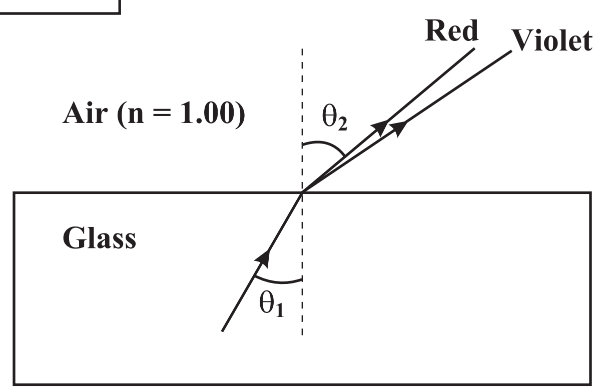
$$\boxed{v = 1.88 \times 10^8 \text{ m/s}}$$

iii. $v = \lambda' f$

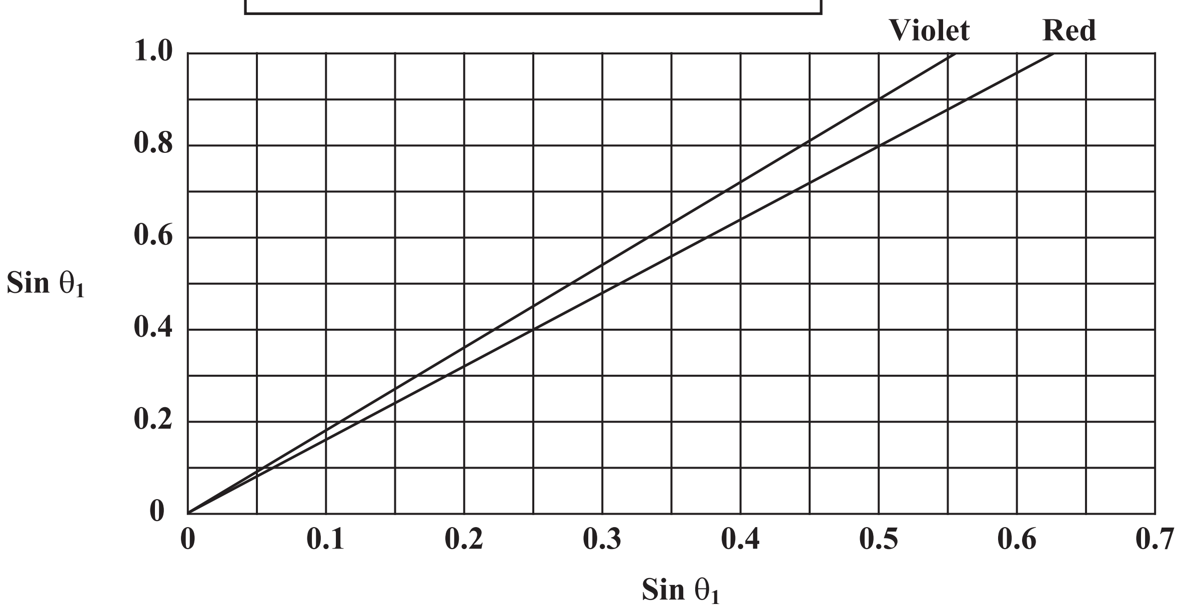
$$\lambda' = \frac{v}{f} = \frac{1.88x10^8 \, m/s}{4.44x10^{14} \, hz}$$

$$\boxed{\lambda' = 4.24 \times 10^{-7} \text{ m} = 424 \text{ nm}}$$

(c) i.



ii.

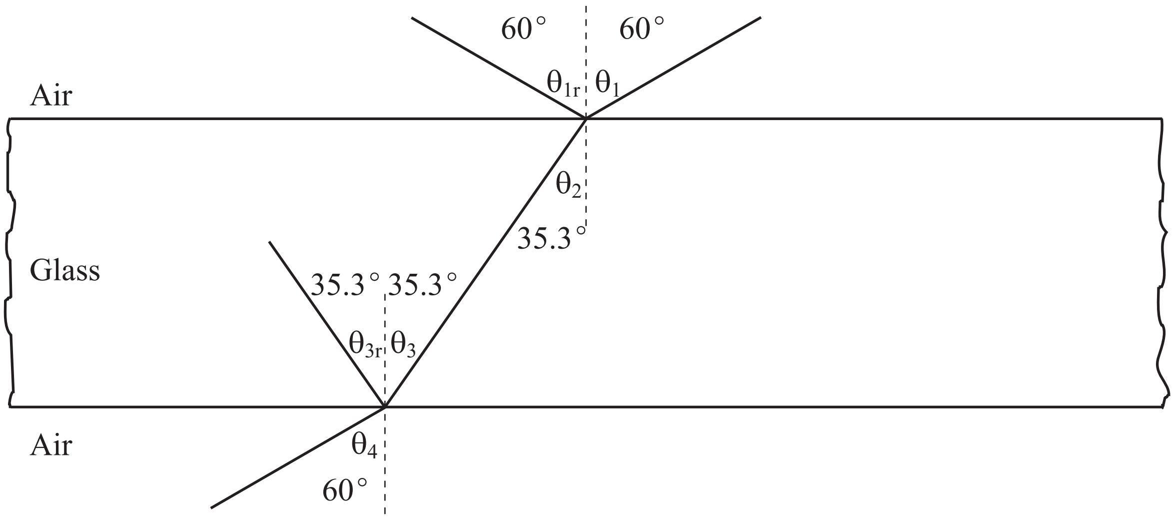


(e.) $n_1 \sin\theta_C = n_2 \sin\theta_2$

$(1.66)\sin\theta_C = (1.00)\sin(90°)$

$$\boxed{\theta_C = 37.0°}$$

4. (a)



$n_a \sin\theta_1 = n_g \sin\theta_2$
$(1.00)\sin 60 = (1.50)\sin\theta_2$
$\theta_2 = 35.3°$

$\theta_1 = \theta_{1r}$
$\theta_2 = \theta_3$
$\theta_3 = \theta_{3r}$

$n_g \sin\theta_3 = n_a \sin\theta_4$
$(1.50)\sin 35.3 = (1.00)\sin\theta_4$
$\theta_4 = 35.3°$

(b) i. $c = \lambda f$

$$f = \frac{c}{f} = \frac{3x10^8\, m/s}{5.25x10^{-7}\, m}$$

$f = 5.71 \text{ x } 10^{14}$ hz

ii. $f = 5.71 \text{ x } 10^{14}$ hz

iii. $$\lambda_g = \frac{\lambda_a}{n_g} = \frac{525nm}{1.38}$$

$\lambda_g = 380$ nm

iv. $2t = m\lambda$
$2t = (1)(3.80 \text{ x } 10^{-7}$ m

$t = 1.90\ \ 10^{-7}$ m = 190 nm