Φ2020: CH 23 – 57, 59, 61
CH 25: 3, 29, 33, 47

(57) Consider a 3.50 cm focal length converging lens. (a) What object distance will make an inverted image 5.00 cm from the lens? Verify with a ray trace. (b) What type of image is it? (c) What is the magnification?

(a) From the lensmaker's Eqn:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{d_i - f}{f \cdot d_i} \Rightarrow \boxed{d_o = \frac{f \cdot d_i}{d_i - f}}$$

The magnification is: $m = (-)\frac{d_i}{d_o} = (-)\frac{d_i}{f \cdot d_i / d_i - f} = \boxed{\frac{f - d_i}{f}}$

NUMERICS

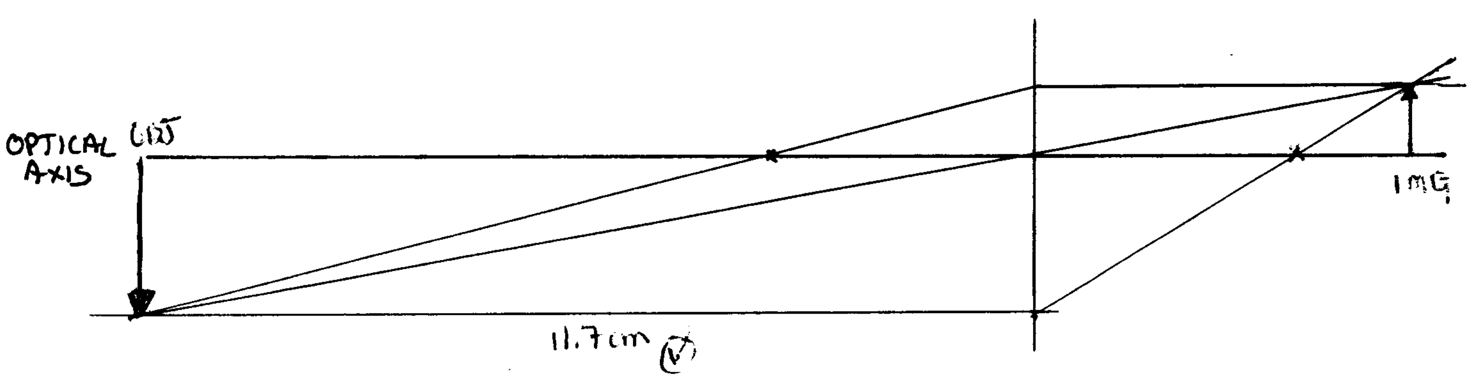
$f = 3.50\text{cm}$

$d_i = 5.00\text{ cm}$

so// $d_o = \frac{3.5\text{cm} \cdot 5.0\text{cm}}{5.0\text{cm} - 3.5\text{cm}} = 11.67\text{ cm}$

$m = \frac{3.5\text{cm} - 5.0\text{cm}}{3.5\text{cm}} = (-)0.43$ (INVERTED REAL)

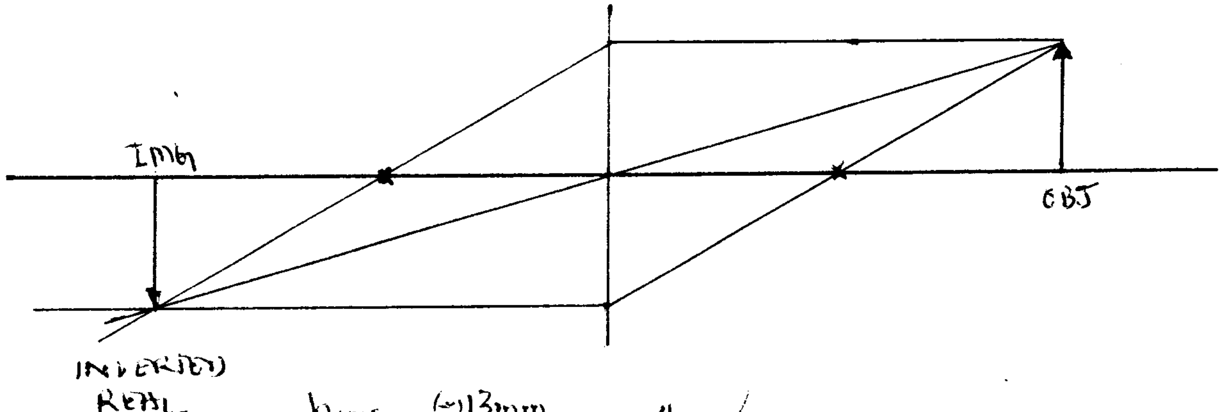
RAY TRACE: SCALE: FULL



$\frac{h_{img}}{h_{obj}} = \frac{(-)9.0\text{mm}}{21\text{mm}} = (-)0.43 = m$ ✓

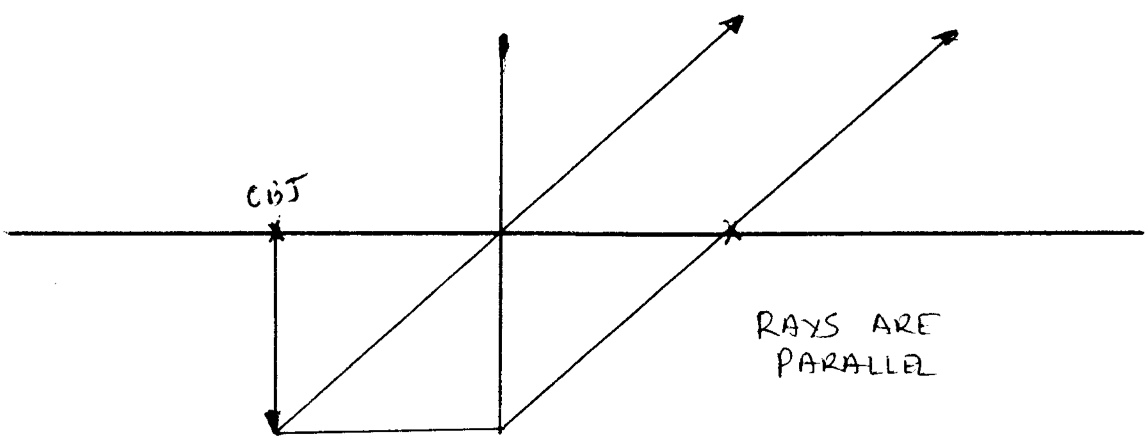
INVERTED

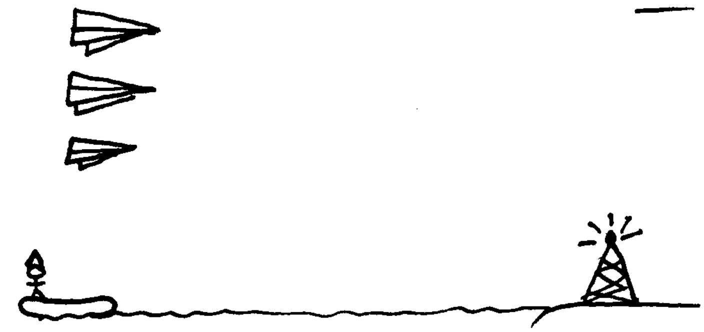
(59) SKETCH the ray trace for an object at $d_o = 2f$. for a converging lens and verify $m = (-)1$ and image is real.



$$\frac{h_{img}}{h_{OBJ}} = \frac{(-)13mm}{13mm} = (-)1 \checkmark$$

(61) Sketch the ray trace to show for a converging lens, an object at the focal length has parallel rays on the far side (IMG @ ∞).

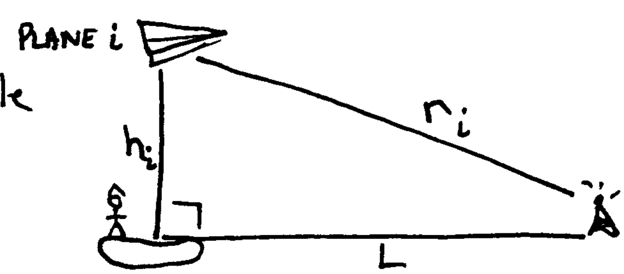




③ My students set me adrift in a rubber life raft with a radio 102 km offshore and send me an unending barrage of old AIR SUPPLY tunes. The Coast Guard is looking for me (to point and laugh), and flies 780 m, 975 m and 1170 m above me. At each instance I see destructive interference from the reflected waves. What frequency are my students broadcasting at?

DESTRUCTIVE INTERFERENCE is all about PATHLENGTH differences. In this case I get destructive interference from each airplane height, so I know that the total path difference to each plane compared to another (TOWER → PLANE → COOL INSTRUCTOR) is different by 1λ. The destructive interference along one of these paths is with the direct beam (TOWER → COOL INSTRUCTOR) which must ultimately give $\frac{1}{2}\lambda$ shift in waves.

Each plane makes a right triangle like the one at right. The path of interest is $(r_i + h_i)$ where:



$$r_i = \sqrt{h_i^2 + L^2} \qquad \text{so//} \quad (r_i + h_i) = h_i + \sqrt{h_i^2 + L^2}$$

For any pair of planes then: $c = \lambda f \Rightarrow f = \frac{c}{\lambda}$

and//

$$\lambda = (r_2 + h_2) - (r_1 + h_1) \qquad \text{or//} \quad f = \frac{c}{(r_2 + h_2) - (r_1 + h_1)}$$

→

Sol'l

$$f = \frac{c}{(h_2 - h_1) + (r_2 - r_1)} = \boxed{\frac{c}{(h_2 - h_1) + \sqrt{h_2^2 + L^2} - \sqrt{h_1^2 - L^2}}}$$

NUMERICS:

$c = 3.00 \times 10^8 \, m/s$

$L = 102 \, km = 1.02 \times 10^5 \, m$

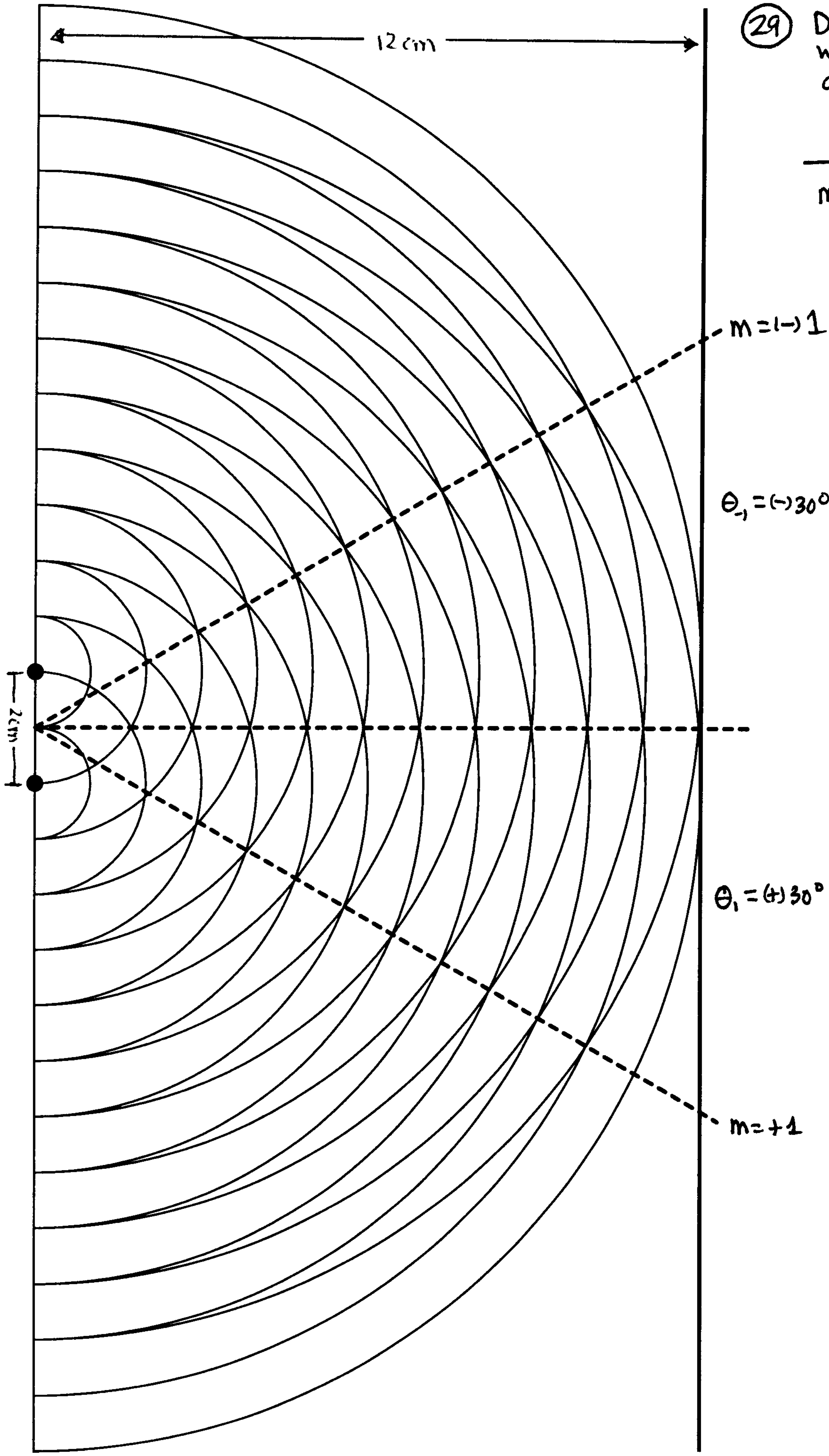
$h_1 = 780 \, m$

$h_2 = 975 \, m$

Sol'l

$$f = \frac{3.00 \times 10^8 \, m/s}{(975m - 780m) + \sqrt{(975m)^2 + (1.02 \times 10^5 m)^2} - \sqrt{(780m)^2 + (1.02 \times 10^5 m)^2}}$$

$$= \frac{3.00 \times 10^8 \, m/s}{196.68 \, m} = \boxed{1.53 \times 10^6 \, Hz}$$ (ANS)



(29) Double slit interference with compass. Find angular location of $m = \pm 1$ maxima

---

Maxima at:

$$d \sin\theta = m\lambda$$

or//

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

$\lambda = 1.0\,\text{cm}$

$d = 2.0\,\text{cm}$

so//

$$\theta = \sin^{-1}\left(\frac{1}{2}\right)$$

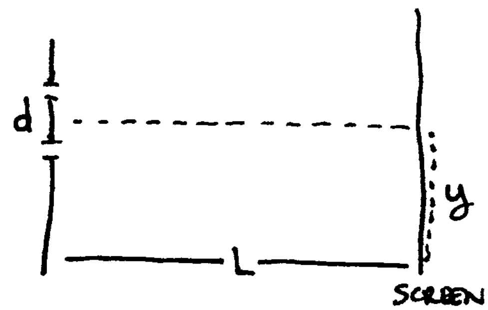
$$= 30°$$

(AS EXPECTED!)

:)

(33) I shoot my HeNe phaser at a pair of slits. ($\lambda = 630\,nm$) An interference pattern appears on a screen 1.5m behind the slits, with bright fringes separated by 1.35cm. What is the slit separation?

Since the screen is far away (L) and the spacing between fringes is small (y) I can use the small angle approximation to write:



$$\frac{y}{L} = \tan\theta \simeq \sin\theta$$

The location of double slit maxima are: $m\lambda = d\sin\theta$

or//

$$m\lambda = d \cdot \frac{y}{L} \Rightarrow d = \frac{m\lambda L}{y}$$

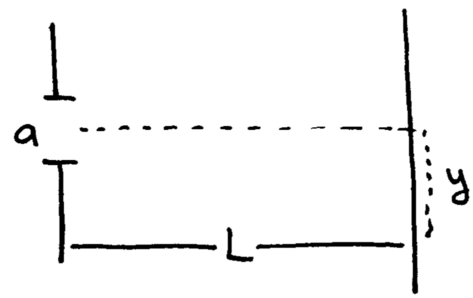
Looking at the m=1 maxima then:

$$d = \frac{(1)(630\times10^{-9}m)(1.5m)}{(0.0135m)} = \boxed{7.0\times10^{-5}m = 70\mu m}$$

(ANS)

(47) The first 2 dark fringes on one side of a single slit pattern are 1.0mm apart. If light $\lambda = 610nm$, and the screen is 1.0m from the slit, what is the slit width.

The screen is far away (L) compared to the fringe spacing (y) so I can use the small angle approximation:



$$\frac{y}{L} \simeq \tan\theta \simeq \sin\theta$$

The location of single slit minima are given by : $a\sin\theta = m\lambda$

or// $\frac{a\,y}{L} = m\lambda$

This gives: $a = \frac{m\lambda L}{y}$

or// for $m = 1$:

$$a = \frac{(1)(610\times10^{-9}m)(1.0m)}{(1.0\times10^{-3}m)} = \boxed{610\times10^{-6}\,m = 610\,\mu m = 0.61\,mm}$$

(ANS)