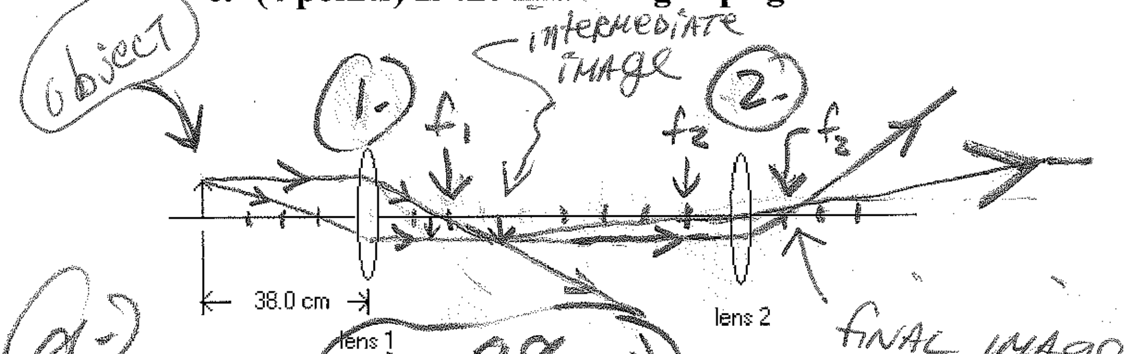
SOLUTIONS!

1. (40 POINTS) An <u>upright</u> object 1.75 cm tall is placed 38.0 cm to the left of a converging lens having a focal length $f_1 = 20.0$ cm. A converging lens of focal length $f_2 = 10.0$ cm is placed 108 cm to the right of the first lens.

a. **(28 points) Determine the final position of the final image.**
b. **(10 points) Determine the total magnification of the final image.**
c. **(4 points) Is the final image upright or inverted?**



(a)

$d_{o_1} = 38 \text{ (cm)}$

$$\frac{1}{d_{o_1}} + \frac{1}{d_{i_1}} = \frac{1}{20}$$

$$d_{i_1} = \frac{(38)(20)}{38-20} = \frac{760}{18} = 42.2 \text{ (cm)}$$

$$\begin{array}{r} 108 \\ -\ 42.2 \\ \hline 65.778 = d_{o_2} \end{array}$$

$$\frac{1}{65.778} + \frac{1}{d_{i_2}} = \frac{1}{10}$$

$$d_{i_f} = \frac{657.78}{55.778} = \boxed{11.8 \text{ cm}}$$

(b)

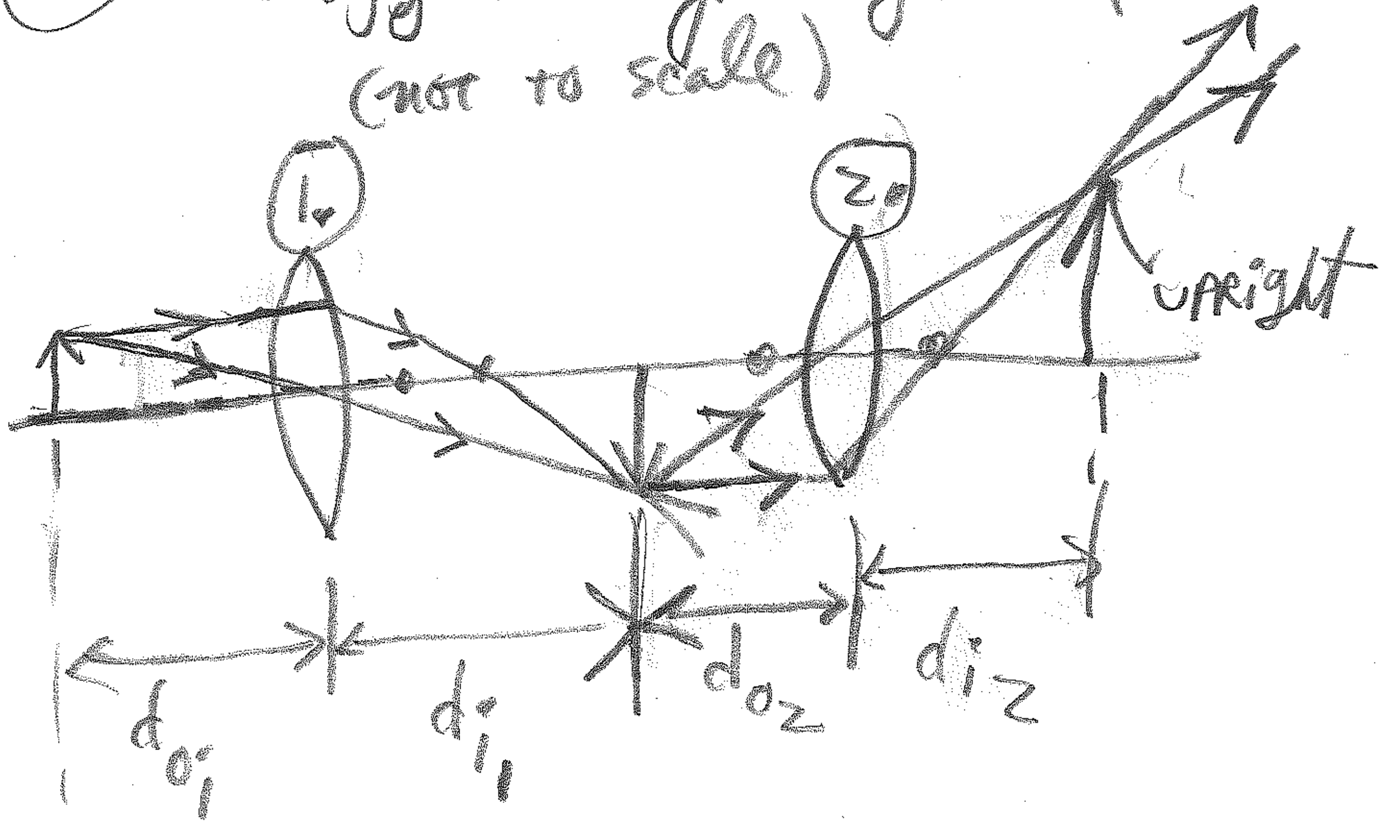
$$m_{TOT} = \left(-\frac{d_{i_1}}{d_{o_1}}\right)\cdot\left(-\frac{d_{i_2}}{d_{o_2}}\right) = \left(-\frac{42.2}{38}\right)\cdot\left(-\frac{11.8}{65.778}\right)$$

$$m_{TOT} = (-1.1105)\cdot(-0.1794) = \boxed{+0.199}$$

(c) UPRIGHT: $m > 0$ and $h_f = (0.199)(1.75) = \boxed{0.348 \text{ cm}}$

1. BIGGER RAY DIAGRAM

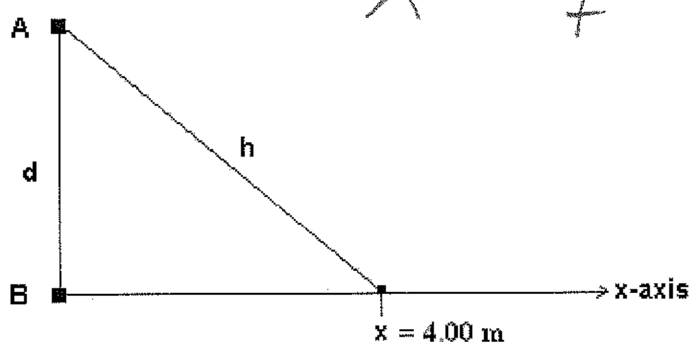
(NOT TO SCALE)



2. (40 POINTS Two identical speakers are located at vertically displaced points A and B. The speakers are a distance d apart. These two loud speakers are driven by the same amplifier. They produce sound waves with a frequency of 780 Hz. Take the speed of sound in air to be 344 m/s . A small microphone is moved out from point B along the horizontal x-axis perpendicular to the *vertical* line connecting A and B. See diagram.

(a) (20)What is the *smallest non-zero* value of d for which *constructive interference* occurs at x = 4.00 m?
(b) (20)What is the *smallest non-zero* value of d for which *destructive interference* occurs at x = 4.00 m?

$$\lambda = \frac{V}{f} = \frac{344\,m/s}{780\,Hz} = 0.441\,(m)$$



$h - 4 = 0.441$

$\sqrt{d^2+4^2} - 4 = 0.441$

$d^2+4^2 = (4.441)^2$

$d^2+16 = 19.722$

$d = \sqrt{3.722}$

$= 1.929\,(m)$

$\sqrt{d^2+4^2} - 4 = 0.225$

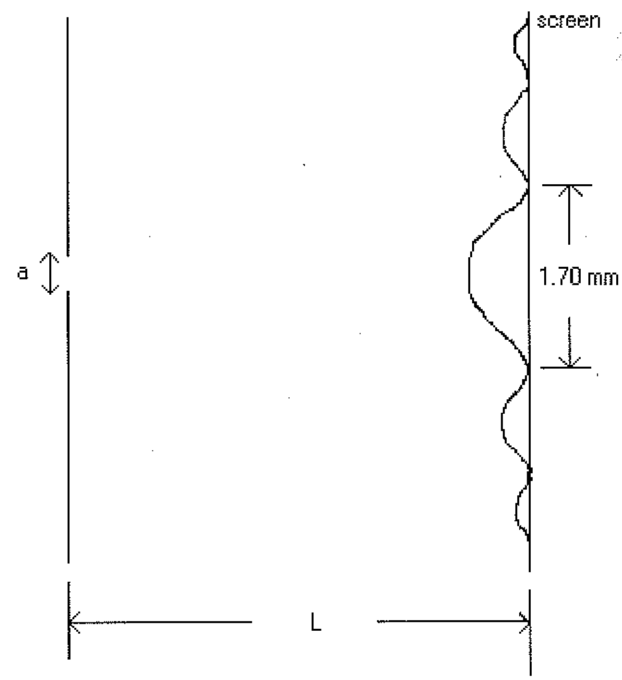
$d^2+4^2 = (4.2205)^2$

$d^2+16 = 17.8126$

$d = \sqrt{1.8126} = 1.346\,(m)$

3. (40 points)

Light of wavelength 587.5 nm illuminates a single slit of width *a* = 0. 75 mm. The width of the central maximum on the screen is 1.70 mm as shown. What is the distance L between the slit and the screen?



$$\frac{a \cdot y_1}{L} = 587.5 \times 10^{-9}$$

$$L = \frac{(0.75 \times 10^{-3}) \cdot (0.85 \times 10^{-3})}{5.875 \times 10^{-7}}$$

$$= \frac{0.6375 \times 10^{-6}}{0.5875 \times 10^{-6}}$$

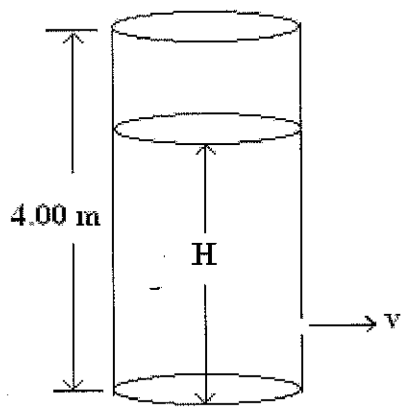
$$= 1.085\ (m) >> y_1$$

4. (40 points) A large 4.00-m high tank of water has a small hole in the side as shown below. Through this hole, water leaves the tank with speed v. Assume the hole is 0.800 m above the tank' s bottom below.

The tank is sealed at the top and has compressed air between the water surface and the top of tank. The water surface has height H as shown. As water flows out of the hole below, H decreases.

When the water surface has height H = 3.60 m, the absolute pressure of the compressed air above the water surface is $P_i = 4.1\text{x}10^5$ Pa. Assume the air above the water surface expands at constant temperature as the water level drops. Assume also atmospheric pressure is $P_{ATM} = 1.00\text{x}10^5$ Pa.

$$\frac{P_i V_i}{\cancel{T_i}} = \frac{P_f V_f}{\cancel{T_f}}$$



$$\rightarrow P_f = \frac{P_i V_i}{V_f} = 4.1\times10^5 \cdot \frac{A\cdot(0.4)}{A\cdot(1)}$$

$$= 1.64\times10^5\,Pa$$

$$\tfrac{1}{2}(1000)v^2 + (1000)(10)(0.8) + 1.00\times10^5 = (1000)(10)(3) + 1.64\times10^5$$

(a) (20) What is the water's exit speed v at the hole when H = ~~2.50~~ 3.00 m? SHOW AND EXPLAIN ALL WORK.

(b) (10) Find H when the exit speed v is one-half the value you computed in part (a) .

(c) (10) At what height H does the exit speed v = 0. Explain your answer using formula(s).

$$500v^2 + \underbrace{8000 + 100000}_{} = 30000 + 164000$$

$$500v^2 + 108000 = 194000$$

$$500v^2 = 86000$$

$$v^2 = 172$$

$$v = 13.1149\ m/s$$

(4.)

(b)

$\frac{1}{2}(1000)\frac{v^2}{4} + 8000 + 100000$

$= (1000)(10)H + 4.1\frac{(0.4)\times10^5}{(4-H)}$

$\times 10^5$

$4.1 \cdot \frac{A}{A} \cdot \frac{0.4}{4-H}$

$125V^2 + 108000 = 10000H + \frac{1.64\times10^5}{(4-H)}$

$= 10000H + \frac{164000}{4-H}$

$125(172) + 108000 = 10000H + \frac{164000}{4-H}$

$21500 + 108000 = 10000H + \frac{164000}{4-H}$

$129500 = 10000H + \frac{164000}{4-H}$

$(4-H)\cdot(129500) = 10000H\cdot(4-H) + 164000$

$518000 - 129500H = 40000H - 10000H^2 + 164000$

$10000H^2 - 169500H + 354000 = 0$

$\rightarrow 100H^2 - 1695H + 3540 = 0$

$H =$

4. (b.)

$$h = \frac{1695 \pm \sqrt{(1695)^2 - 4 \cdot (100)(3540)}}{200}$$

$$\frac{1695 \pm \sqrt{2873025 - 1416000}}{200}$$

$$\frac{1695 \pm \sqrt{1457025}}{200}$$

$$\frac{1695 \pm 1207.073}{200} = 2.44 (m)$$

choose this root.

$$h = \frac{1695 - 1207.073}{200}$$

$$= \boxed{2.44 (m)}$$

The + Root is wrong

$$\frac{1695 + 1207.073}{200}$$

$= 14.5 (m)$ impossible!

(4)

C. $\frac{1}{2}$

$$\frac{1}{2}(1000)v^2 + (1000)(10)(0.8) + 100000$$

$$= (1000)(10)\cdot H + \frac{4.1\times10^5\cdot(0.4)}{(4-H)}$$

set $v=0$

$$\Rightarrow \quad 108000 = 10000H + \frac{164000}{(4-H)}$$

$$(4-H)\cdot(108000) = (4-H)\cdot 10000H + 164000$$

$$432000 - 108000H = 40000H - 10000H^2 + 164000$$

$$\Rightarrow 10000H^2 - 148000H + 268000 = 0$$

$$10H^2 - 148H + 596 = 0$$

$$H = \frac{148 \pm \sqrt{148^2 - 4\cdot 10\cdot 268}}{20}$$

$$= \frac{148 \pm \sqrt{11184}}{20}$$

$$= 2.11\,(m)$$