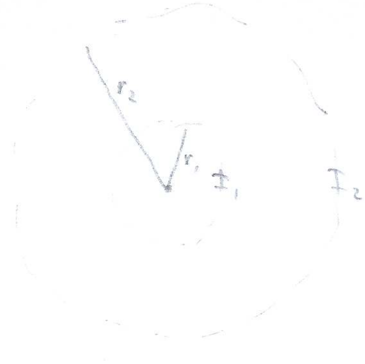
1.

$I_1 = 10.0 \ W/m^2$

$I_2 = 1.0 \times 10^{-6} \ W/m^2$

$r_1 = 30.0 \ m$



a.

$$\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

$$r_2 = r_1 \sqrt{\frac{I_1}{I_2}}$$

$$\boxed{r_2 = 95{,}000 \ m}$$

b.

Inverse square law $\Rightarrow \left(r \to 2r \Rightarrow I \to \frac{I}{4} \right)$

$$\boxed{I_3 = 2.5 \times 10^{-7} \ W/m^2}$$

c.

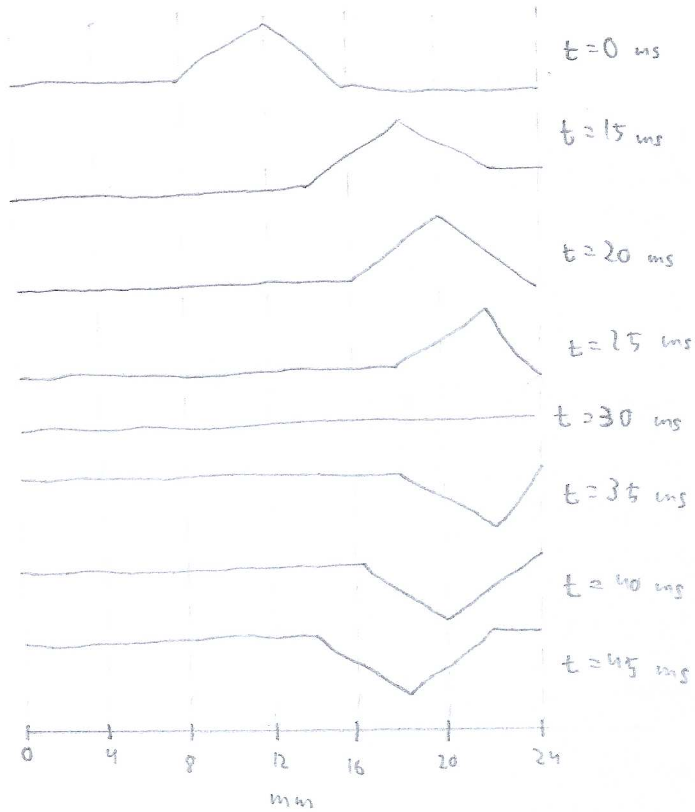
$$I_1 = \frac{\bar{P}}{4\pi r_1^2}$$

$$\bar{P} = 4\pi I_1 r_1^2$$

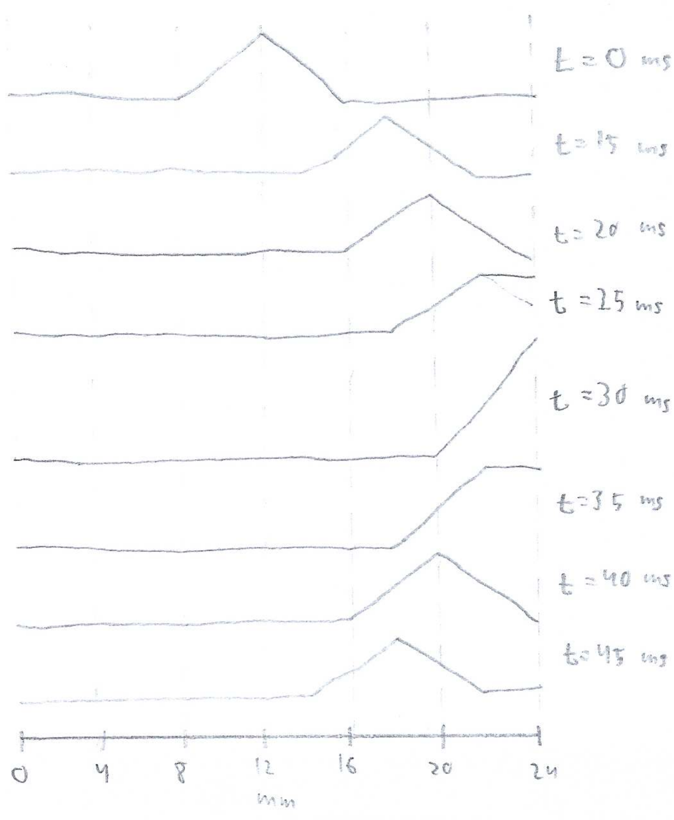
$$\boxed{\bar{P} = 113{,}000 \ W}$$

2.

a.


t = 0 ms
t = 15 ms
t = 20 ms
t = 25 ms
t = 30 ms
t = 35 ms
t = 40 ms
t = 45 ms
0
4
8
12
16
20
24
mm

b.


t = 0 ms
t = 15 ms
t = 20 ms
t = 25 ms
t = 30 ms
t = 35 ms
t = 40 ms
t = 45 ms
0
4
8
12
16
20
24
mm

3.

$f_1 = 524\ \text{Hz}$

a.

$$L = 1 \cdot \frac{\lambda}{2}$$

$$= 1 \cdot \frac{v_{sound}}{2 f_1}$$

$$\boxed{L = 0.328\ \text{m}}$$

b.

$$L = \frac{\lambda}{4}$$

$$\lambda = 4L$$

$$\boxed{\lambda = 1.31\ \text{m}}$$

c.

$$v_{sound} = \lambda f$$

$$f = \frac{v_{sound}}{\lambda}$$

$$\boxed{f = 263\ \text{Hz}}$$

4.

$d = 12.0\ m$

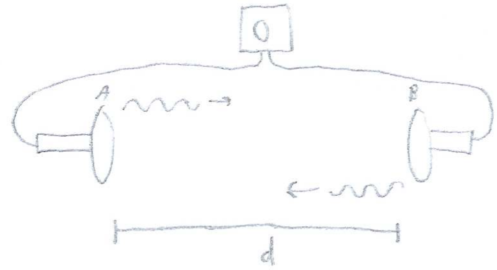
$f = 688\ Hz$

$v = \lambda f$

$\lambda = \frac{v}{f}$

$\lambda = 0.5\ m$

$\boxed{0.125\ m}$



5.

a.

$f = 2000 \text{ Hz}$

$v_T = 20.0 \text{ m/s}$

$v_F = 30.0 \text{ m/s}$

There are two wave propagations we have to analyze: The emission from the fire engine toward the truck, and the reflection from the truck back toward the fire engine. For the first propagation, we have to scale the initial frequency by two Doppler shifts: one corresponding to a departing observer (the truck), and one corresponding to an approaching source (the fire engine). For the second one, we have the opposite scalars, as the observer (fire engine) approaches and the source (truck) departs.

$$f' = \left(\frac{v}{v + v_T} \cdot \frac{v + v_F}{v} \right) \cdot \left(\frac{v}{v - v_F} \cdot \frac{v - v_T}{v} \right) \cdot f$$

$$\boxed{f' = 2120 \text{ Hz}}$$

b.

$$v - v_F = \lambda_1 f \qquad v - v_T = \lambda_1 f_2 \qquad v + v_T = \lambda_2 f_2$$

$$\lambda_1 = \frac{v - v_F}{f} \qquad f_2 = \frac{v - v_T}{\lambda_1} \qquad \lambda_2 = \frac{v + v_T}{f_2}$$

$$= \frac{v + v_T}{v - v_T} \cdot \lambda_1$$

$$= \frac{v + v_T}{v - v_T} \cdot \frac{v - v_F}{f}$$

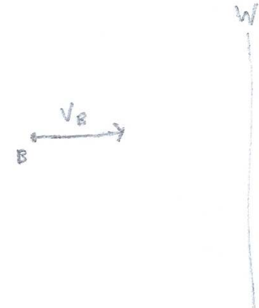
$$\boxed{\lambda_2 = 0.176 \text{ m}}$$

6.

$f = 1700$ Hz

$\Delta f = 8.00$ Hz

$$f' = \frac{v + v_B}{v} \cdot \frac{v}{v - v_B} \cdot f$$



$$\Delta f = f' - f$$

$$= \frac{v + v_B}{v - v_B} \cdot f - f$$

$$\Delta f (v - v_B) = (v + v_B) \cdot f - (v - v_B) \cdot f$$

$$= 2 v_B f$$

$$v \Delta f = 2 v_B f + v_B \Delta f$$

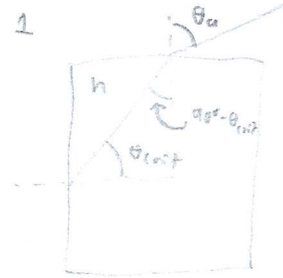
$$v_B = \frac{v \Delta f}{2f + \Delta f}$$

$$\boxed{v_B = 0.801 \text{ m/s}}$$

7.

$n = 1.38$

$$\theta_{crit} = \sin^{-1}\left(\frac{1}{n}\right)$$



$$n \sin(90° - \theta_{crit}) = \sin \theta_a$$

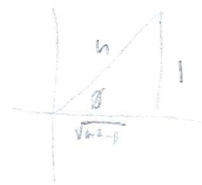
$$n \cos \theta_{crit} = \sin \theta_a$$

$$\theta_a = \sin^{-1}(n \cos \theta_{crit})$$

$$= \sin^{-1}\left(n \cos\left(\sin^{-1}\left(\frac{1}{n}\right)\right)\right)$$

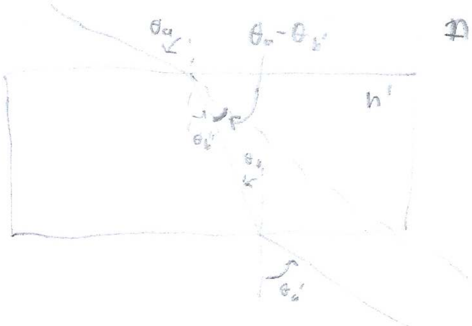
$$= \sin^{-1}\left(\sqrt{n^2-1}\right)$$

$$\boxed{\theta_a = 72.0°}$$



8.

a.



$n \sin\theta_a = n' \sin\theta_b'$

$n \sin\theta_a' = n' \sin\theta_b$

$\theta_b = \theta_b'$ by alternate interior angles

$\therefore \sin\theta_a = \sin\theta_a'$

$\theta_a = \theta_a'$

$\square$

b. We have shown that $\theta_a = \theta_a'$ regardless of n', so when light comes out of any plate, it's ready to go into the next plate the same way it went into the former.

c.

$\cos\theta_b' = \frac{t}{l}$

$l = \frac{t}{\cos\theta_b'}$

$\sin(\theta_a - \theta_b') = \frac{d}{l}$

$d = l \sin(\theta_a - \theta_b')$

$\boxed{d = t \cdot \frac{\sin(\theta_a - \theta_b')}{\cos\theta_b'}}$

d.

$\theta_a = 66.0^\circ$

$t = 0.0240\,m$

$n = 1.80$

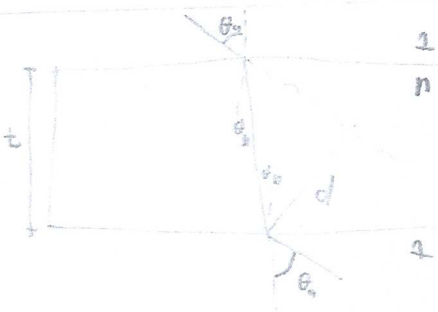
$\theta_b = ? = 30.5^\circ$

$1 \sin\theta_a = n \sin\theta_b$

$\theta_b = \sin^{-1}\left(\frac{\sin\theta_a}{n}\right)$

$d = t \cdot \frac{\sin(\theta_a - \theta_b)}{\cos\theta_b}$

$\boxed{d = 0.0162\,m}$



9.

$f = 262\ Hz$

$f' = 440\ Hz$

$$f' = \frac{v + v_p}{v - v_p} \cdot f$$

$$f'v - f'v_p = fv + f\,v_p$$

$$f'v - fv = f'v_p + f\,v_p$$

$$v_p = \frac{f' - f}{f' + f} \cdot v$$

$$\boxed{v_p = 87.0\ m/s}$$