

HOMEWORK #10

$$(36-1) (a) f = \frac{c}{\lambda} = \frac{3 \times 10^8 \frac{m}{sec}}{589 \times 10^{-9} m} = \boxed{5.09 \times 10^{14} \text{ Hz}}$$

$$(b) n_{air} \lambda_{air} = n_{glass} \lambda_{glass} \quad (\text{derived in class})$$

$$\lambda_{glass} = \frac{n_{air}}{n_{glass}} \lambda_{air}$$

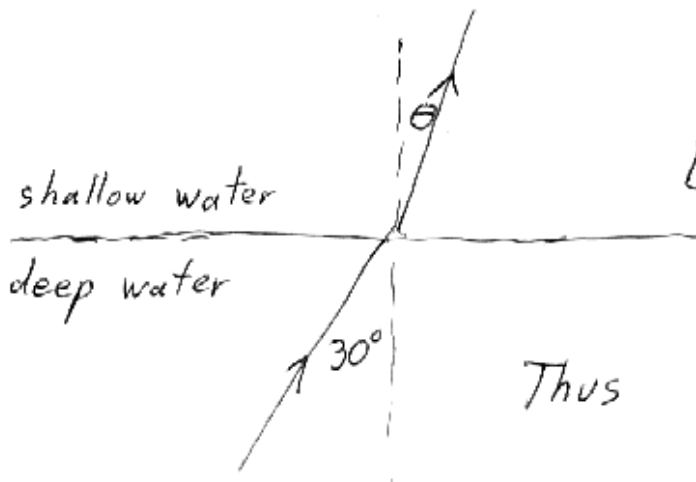
$$= \frac{1}{1.52} 589 \text{ nm} = \boxed{388 \text{ nm}}$$

$$(c) v_{glass} = f \lambda_{glass}$$

$$= (5.09 \times 10^{14} \frac{\text{cycles}}{\text{sec}}) (388 \times 10^{-9} \text{ m})$$

$$= \boxed{1.97 \times 10^8 \frac{m}{sec}}$$

(36-2)



$$n_{deep} \sin 30^\circ = n_{shallow} \sin \theta$$

$$\text{But } n = \frac{\text{constant}}{v}, \text{ so}$$

$$\frac{\sin 30^\circ}{v_{deep}} = \frac{\sin \theta}{v_{shallow}}$$

Thus

$$\sin \theta = \frac{v_{shallow}}{v_{deep}} \sin 30^\circ$$

$$\sin \theta = \frac{3 \text{ m/sec}}{4 \text{ m/sec}} \sin 30^\circ$$

$$\sin \theta = 0.375$$

$$\Rightarrow \boxed{\theta = 22.0^\circ}$$

(The constant in $n = \frac{\text{constant}}{v}$ is the wave speed in very deep water, but you don't have to know that!)

As $v_{shallow} \rightarrow 0$, $\theta \rightarrow 0^\circ$ so waves come in normal

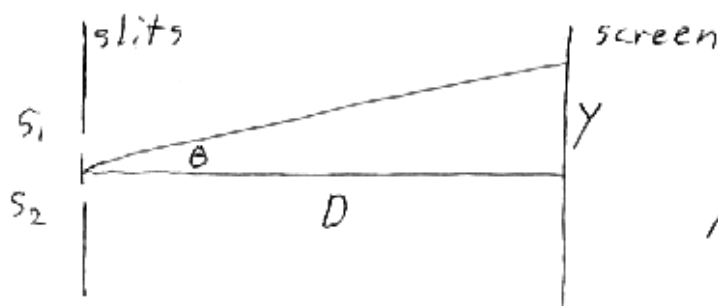
(36-3) (a) $d \sin \theta = m \lambda$ with $m=3$

$$\text{so } \sin \theta = \frac{m \lambda}{d} = \frac{3 (550 \times 10^{-9} \text{ m})}{7.7 \times 10^{-6} \text{ m}} = 0.2143$$

$$\Rightarrow \boxed{\theta = 0.216 \text{ radian}}$$

(b) $\theta = (0.216 \text{ rad}) \left(\frac{180^\circ}{\pi \text{ rad}} \right) = \boxed{12.4^\circ}$

(36-4)



Note that

$$y = D \tan \theta \approx D \sin \theta$$

for small θ

The distance of the 5th max from the central max is

$$y_5 \approx D \sin \theta_5 = D \left(\frac{5 \lambda}{d} \right)$$

The distance of the 7th min from the central max is

$$y_7 \approx D \sin \theta_7 = D \frac{(6 + \frac{1}{2}) \lambda}{d}$$

The distance between these is

$$\begin{aligned} y_7 - y_5 &= 6.5 \frac{D \lambda}{d} - 5 \frac{D \lambda}{d} \\ &= 1.5 \frac{D \lambda}{d} \\ &= 1.5 \frac{(0.2 \text{ m})(546 \times 10^{-9} \text{ m})}{0.1 \times 10^{-3} \text{ m}} \\ &= \boxed{1.64 \times 10^{-3} \text{ m}} \end{aligned}$$

(36-5) $2L = (m + \frac{1}{2}) \frac{\lambda}{n}$ for constructive interference

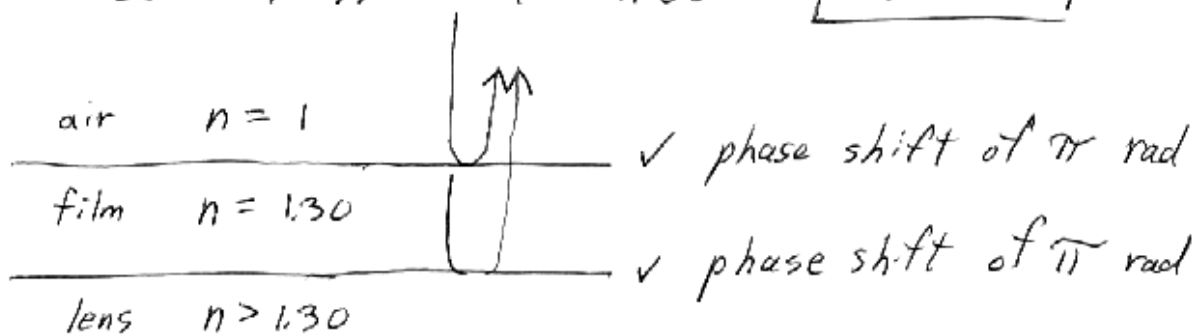
For $m = 0$,

$$L = \frac{1}{4} \frac{\lambda}{n} = \frac{1}{4} \frac{624 \text{ nm}}{1.33} = \boxed{117 \text{ nm}}$$

For $m = 1$,

$$L = \frac{3}{4} \frac{\lambda}{n} = \frac{3}{4} \frac{624 \text{ nm}}{1.33} = \boxed{352 \text{ nm}}$$

(36-6)



With two phase shifts of π radians, the condition for destructive interference is

$$2L = (m + \frac{1}{2}) \frac{\lambda}{n}$$

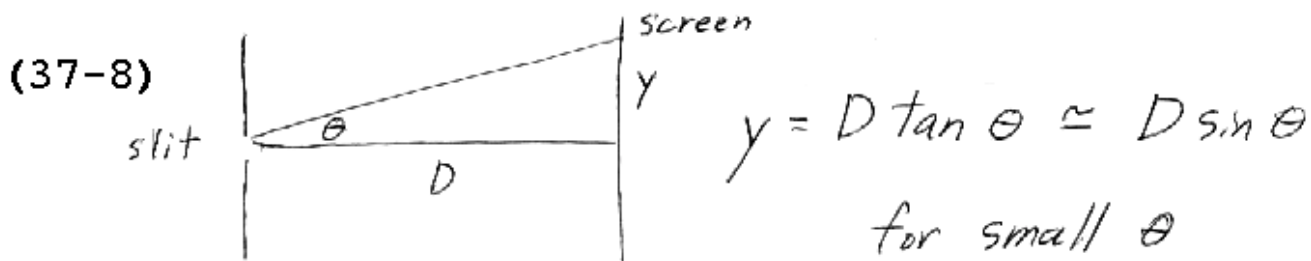
Using $m = 0$ for the minimum thickness,

$$L = \frac{1}{4} \frac{\lambda}{n} = \frac{1}{4} \frac{680 \text{ nm}}{1.30} = \boxed{131 \text{ nm}}$$

(37-7) (a) $\tan \theta = \frac{1.5 \times 10^{-2} \text{ m}}{2 \text{ m}} = 0.0075 \Rightarrow \boxed{\theta = 0.430^\circ}$

(b) $a \sin \theta = m\lambda$ with $m = 2$

$$\text{So } a = \frac{m\lambda}{\sin \theta} = \frac{2(441 \times 10^{-9} \text{ m})}{\sin 0.43^\circ} = \boxed{1.18 \times 10^{-4} \text{ m}}$$



(a) The distance of the 5th min from the central max is

$$y_5 \approx D \sin \theta_5 = D \left(\frac{5\lambda}{a} \right) \quad m=5$$

The distance of the 1st min from the central max is

$$y_1 = D \sin \theta_1 = D \left(\frac{\lambda}{a} \right) \quad m=1$$

$$\text{So } y_5 - y_1 = \frac{D\lambda}{a} (5-1) = 4 \frac{D\lambda}{a}$$

and therefore $a = 4 \frac{D\lambda}{(y_5 - y_1)}$

$$a = 4 \frac{(0.4\text{m})(550 \times 10^{-9}\text{m})}{0.35 \times 10^{-3}\text{m}}$$

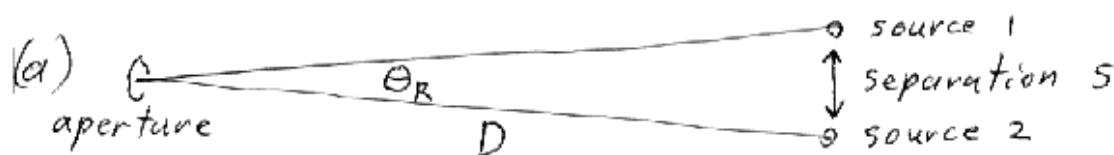
$$= \boxed{2.51 \times 10^{-3}\text{m}}$$

(b) $a \sin \theta = m\lambda$ with $m=1$

$$\text{So } \sin \theta = \frac{m\lambda}{a} = \frac{(1)(550 \times 10^{-9}\text{m})}{2.51 \times 10^{-3}\text{m}} = 2.19 \times 10^{-4}$$

$$\Rightarrow \boxed{\theta = 0.0126^\circ}$$

$$(37-9) \quad \theta_R = \frac{1.22\lambda}{d} \quad (\theta_R \text{ is in radians})$$



For small angles, $S = \theta_R D$, so

$$\begin{aligned} S &= \left(\frac{1.22\lambda}{d_{\text{eye}}} \right) D \\ &= \frac{(1.22)(550 \times 10^{-9} \text{ m})}{5 \times 10^{-3} \text{ m}} (8 \times 10^{10} \text{ m}) \\ &= \boxed{1.07 \times 10^7 \text{ m}} \end{aligned}$$

The diameter of Mars is only $6.8 \times 10^6 \text{ m}$, so your eye can not resolve any two objects on Mars!

$$\begin{aligned} (b) \quad S &= \left(\frac{1.22\lambda}{d_{\text{Palomar}}} \right) D \\ &= \frac{(1.22)(550 \times 10^{-9} \text{ m})}{5.1 \text{ m}} (8 \times 10^{10} \text{ m}) \\ &= \boxed{1.05 \times 10^4 \text{ m}} \quad \text{or } 10.5 \text{ km} \end{aligned}$$

$$(37-10) \quad d \sin \theta = m \lambda \quad \text{with } m = 1$$

Using $d = \frac{10^{-2} \text{ m}}{10^4} = 10^{-6} \text{ m}$, we find

$$\lambda = \frac{d \sin \theta}{m} = \frac{(10^{-6} \text{ m}) \sin 30^\circ}{1} = 5 \times 10^{-7} \text{ m}$$

$$\text{or } \boxed{\lambda = 500 \text{ nm}}$$

(37-11) The resolving power is $R = \frac{\lambda_{ave}}{\Delta\lambda} = Nm$

$$(a) N = \frac{\lambda_{ave}}{m\Delta\lambda} = \frac{\frac{1}{2}(415.496 + 415.487)nm}{(2)(415.496 - 415.487)nm}$$

$$= \boxed{23,100}$$

(b) $d \sin \theta = m\lambda$ with $m=2$

So $d = \frac{4 \times 10^{-2}m}{23,100} = 1.73 \times 10^{-6}m$

and thus $\sin \theta = \frac{m\lambda}{d} = \frac{2(415.5 \times 10^{-9}m)}{1.73 \times 10^{-6}m} = 0.4803$

$$\Rightarrow \boxed{\theta = 28.7^\circ}$$

(37-12) $2d \sin \theta = m\lambda$ with $m=2$

$$d = \frac{m\lambda}{2 \sin \theta} = \frac{(2)(0.12 \times 10^{-9}m)}{2 \sin 28^\circ}$$

$$\boxed{d = 2.55 \times 10^{-10}m = 0.255nm}$$