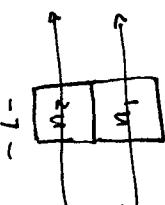


35-9  $\lambda_0 = 620\text{nm}$   $n_1 = 1.45$   $n_2 = 1.65$   $\lambda_2 = \frac{\lambda_0}{n_2}$   
 $\lambda_1 = \frac{\lambda_0}{n_1}$



\*1  
history

initial  $\pi$  or  $-\pi$  shift

travel air  
 $\frac{L}{\lambda_2} 2\pi$  transit block 1  
travel air  
 $\frac{L}{\lambda_1} 2\pi$  transit block 2  
travel air

phase difference between ray 2 - ray 1

$$\Delta\phi = \left[ \frac{L}{\lambda_2} 2\pi \pm \pi \right] - \left[ \frac{L}{\lambda_1} 2\pi \right]$$

$$\lambda_1 = \frac{\lambda_0}{n_1}$$

$$\Delta\phi = \left[ \frac{n_2 L}{\lambda_0} 2\pi \pm \pi \right] - \left[ \frac{n_1 L}{\lambda_0} 2\pi \right]$$

$$\Delta\phi = \frac{(n_2 - n_1)L}{\lambda_0} 2\pi \pm \pi$$

The waves will add constructively  
when  $\Delta\phi = 0, 2\pi, 4\pi, \dots$

Use the (-) sign

$$\Delta\phi = \frac{(1.65 - 1.45)L}{620} 2\pi - \pi$$

$$0 = \frac{(1.65 - 1.45)L}{620} 2\pi - \pi$$

$$L = 1550\text{ nm}$$

$$2\pi \quad \Delta\phi = 0 \quad 0 = \frac{(1.65 - 1.45)L}{620} 2\pi - \pi$$

$$L = \frac{9300}{4650} \text{ nm}$$

$$2\pi \quad \Delta\phi = 2\pi \quad 2\pi = \frac{(1.65 - 1.45)L}{620} 2\pi - \pi$$

35-17



35-21

$$d = 5 \text{ mm}$$

$$\text{green } \lambda = 480 \text{ nm}$$

$$\text{yellow } \lambda = 600 \text{ nm}$$

Treat this as a two-slit interference problem

Interference maxima will be located at

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

$$2 \sin \theta = m \cdot 0.5$$

$m$	$\frac{\sin \theta}{0}$	$\frac{\theta}{0^\circ}$	these all in one quadrant	
0	0	0		
1	0.25	14.8°		
2	0.5	30°		
3	0.75	48.6°		
4	1.0	90°		

interference max located at  
 $d \sin \theta = m\lambda$

$$\frac{\text{green } m=3}{\text{yellow } m=5}$$

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

$$(5 \times 10^{-3}) \sin \theta = 3(480 \times 10^{-9})$$

$$\theta = 1.65 \times 10^{-2} \text{ degrees}$$



$$\tan \theta = \frac{y_3}{1}$$

$$y_3 = 2.880 \times 10^{-4} \text{ m}$$

$$\theta = 2.663 \times 10^{-2} \text{ degrees}$$

$$(5 \times 10^{-3}) \sin \theta = 3(600 \times 10^{-9})$$

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

$$\text{yellow } m=3$$

$$\tan \theta = \frac{y_5}{1}$$

$$y_5 = 3.60 \times 10^{-4} \text{ m}$$

$$\theta = 2.01 \times 10^{-2} \text{ degrees}$$

$$(5 \times 10^{-3}) \sin \theta = 3(600 \times 10^{-9})$$

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

$$\text{yellow } m=3$$

$$\tan \theta = \frac{y_3}{1}$$

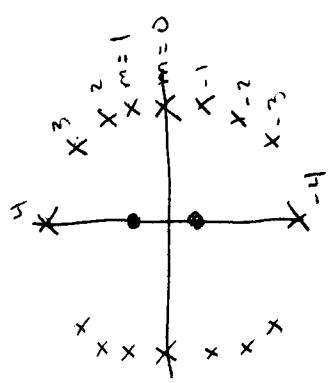
$$y_3 = 2.880 \times 10^{-4} \text{ m}$$

$$\theta = 1.65 \times 10^{-2} \text{ degrees}$$

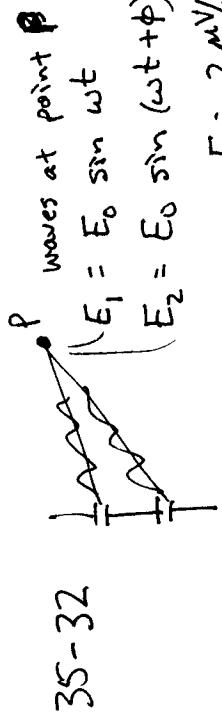
$$(5 \times 10^{-3}) \sin \theta = 3(480 \times 10^{-9})$$

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

$$\text{green } m=3$$



16 total maxima



33-35

$$E_1 = E_0 \sin \omega t$$

$$E_2 = E_0 \sin (\omega t + \phi)$$

$$E_0 = 2 \text{ mV/m}$$

$$\omega = 1.26 \times 10^{15} \text{ rad/s}$$

$$\phi = 39.6 \text{ rad}$$

a)  $E_{\text{tot}} = E_1 + E_2$       use  $\sin \alpha + \sin \beta = 2 \cos(\frac{\beta-\alpha}{2}) \sin(\frac{\alpha+\beta}{2})$

$$E_{\text{tot}} = \frac{2E_0 \cos \phi/2}{\text{amp}} \sin (\omega t + \phi/2)$$

$$\text{Amp } \beta = 2 \left(2 \frac{\text{mV}}{\text{m}}\right) \cos(39.6/2)$$

$$= 2.33 \text{ mV/m}$$

b) Compare Intensity at point P to Intensity straight on.  
The total E field straight-on will not have a phase diff between the 2 waves.

$$\text{Recall Intensity of } E^2$$

$$\frac{\text{Intensity}}{\text{Intensity}_0} \propto \frac{E^2}{E_0^2} = \frac{(2.33)^2}{(1)^2} = 0.34$$

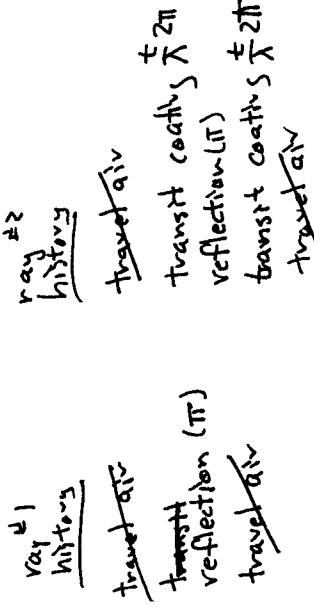
c) They are basically asking how many complete oscillations ( $\sim$  wavelength) the phase 39.6 rad corresponds to

$$\frac{39.6}{2\pi} = 6.3$$

- So the point P in question lies between the 6<sup>th</sup> & 7<sup>th</sup> interference max
- d)  $\omega = 1.26 \times 10^{15} \text{ rad/sec}$
- e) At point P, the phase difference is 39.6 rad.

33-35

$$t \quad \begin{array}{c} \lambda_0 \\ \hline \text{coatings} \\ \text{glass} \\ \hline \end{array} \quad \begin{array}{c} \lambda_0 \\ \hline \text{coatings} \\ \text{air} \\ \hline \end{array} \quad t \quad \begin{array}{c} \lambda_0 \\ \hline \text{coatings} \\ \text{air} \\ \hline \end{array} \quad \text{Non-reflective}$$



$$\text{phase difference} = \Delta\phi = \left[ 2 \frac{t}{\lambda} 2\pi + \pi \right] - [\pi]$$

$$= 2 \frac{t}{\lambda} 2\pi$$

$$\text{with } \lambda = \frac{\lambda_0}{1.25}$$

To get cancellation

$$\Delta\phi = \pi = 2 \frac{t}{\lambda} 2\pi$$

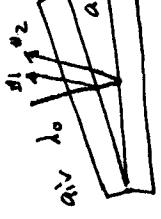
$$= 2 \frac{\eta t}{\lambda_0} 2\pi$$

$$\pi = 2 \frac{1.25 t}{600} 2\pi$$

$$t = 120 \text{ nm}$$

35-37 air  $\lambda_0 = 560 \text{ nm}$

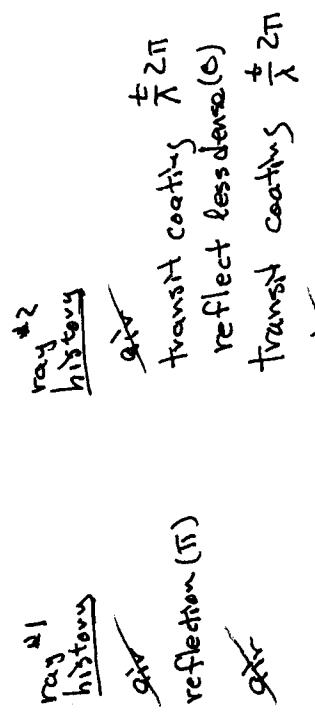
35-71



$$\lambda = \frac{\lambda_0}{2} = 280 \text{ nm}$$

$$t = 1.50$$

$$\lambda_0 = 500 \text{ nm}$$



phase difference

$$\Delta\phi = [2 \frac{t}{\lambda} 2\pi + 0] - [\pi]$$

$$\Delta\phi = 2 \frac{t}{\lambda} 2\pi - \pi$$

Want brilliant reflection, constructive,  $\Delta\phi = 0$

$$0 = 2 \frac{t}{\lambda} 2\pi - \pi$$

$$0 = 2 \frac{t}{500} 2\pi - \pi$$

$$t = 700 \text{ nm}$$

$$\text{phase difference} = \Delta\phi = [2 \frac{t}{\lambda} 2\pi + \pi] - [\pi]$$

$$\Delta\phi = 2 \frac{t}{\lambda} 2\pi + \pi$$

Notice at the left side of drawing,  $t=0$ , and the  $\Delta\phi = \pi$  there which is dark cancellation.

Moving ~~the~~ slightly to the right by 1.2 mm, we encounter another dark cancellation, this must be for  $\Delta\phi = 3\pi$

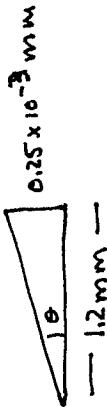
$$3\pi = 2 \frac{t}{\lambda} 2\pi + \pi$$

$$3 = 2 \frac{t}{500} 2 + 1$$

$$t = 250 \text{ nm} = 250 \times 10^{-9} \text{ m}$$

$$= 0.250 \times 10^{-3} \text{ mm}$$

Draw the wedge on the left side



$$S = r \theta$$

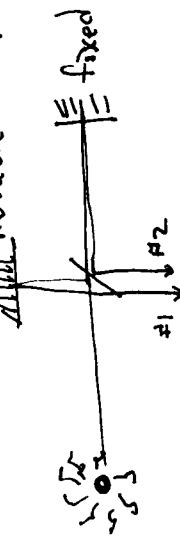
$$0.25 \times 10^{-3} = 1.2 \theta$$

$$\theta \approx 2.1 \times 10^{-4} \text{ rad}$$

35-79

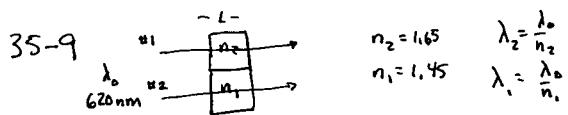
Michelson Interferometer

$$\text{distant mirror } \Delta x = 0.233 \text{ m}$$

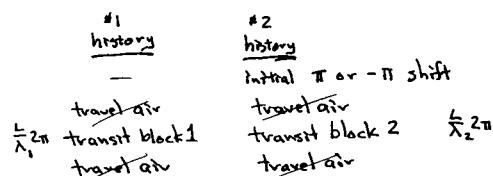


A shift of 1 fringe occurs for every path difference of  $\lambda$  which is a movement of the mirror of  $\frac{1}{2}\lambda$ .  
So for a shift of 792 fringes corresponds to

$$792 \left(\frac{1}{2}\lambda\right) = \Delta x$$
$$792 \left(\frac{1}{2}\lambda\right) = 0.233 \times 10^{-3} \text{ m}$$
$$\lambda = 5.88 \times 10^{-7} \text{ m}$$
$$\sim 588 \text{ nm}$$



$$\Delta\phi = \frac{(n_2 - n_1)L}{\lambda_0} 2\pi - \pi$$



initial  $\pi$  or  $-\pi$  shift

phase difference between ray #2 - ray #1

$$\Delta\phi = \left[ \frac{L}{\lambda_2} 2\pi \pm \pi \right] - \left[ \frac{L}{\lambda_1} 2\pi \right]$$

$$\lambda_2 = \frac{\lambda_0}{n_2}$$

$$\Delta\phi = \left[ \frac{n_2 L}{\lambda_0} 2\pi \pm \pi \right] - \left[ \frac{n_1 L}{\lambda_0} 2\pi \right]$$

$$\Delta\phi = \frac{(n_2 - n_1)L}{\lambda_0} 2\pi \pm \pi$$

The waves will add constructively

when  $\Delta\phi = 0, 2\pi, 4\pi \dots$

Use the (-) sign

Try  $\Delta\phi = 0$

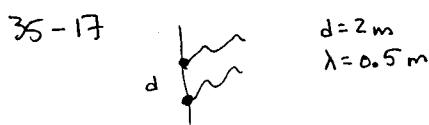
$$0 = \frac{(1.65 - 1.45)L}{620} 2\pi - \pi$$

$$L = 1550 \text{ nm}$$

Try  $\Delta\phi = 2\pi$

$$2\pi = \frac{(1.65 - 1.45)L}{620} 2\pi - \pi$$

$$L = 4650 \text{ nm}$$



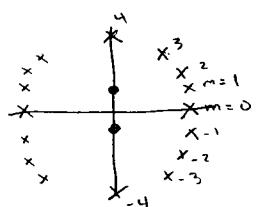
Treat this as a two-slit interference problem  
Interference maxima will be located at

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

$$2 \sin\theta = m 0.5$$

m	$\frac{\sin\theta}{\lambda}$	$\theta$
0	0	0°
1	0.25	14.8°
2	0.5	30°
3	0.75	48.6°
4	1.0	90°

These are all in 1st quadrant



16 total maxima

35-21

~~green~~ ~~yellow~~  $d = 5 \text{ mm}$   
green  $\lambda = 480 \text{ nm}$   
yellow  $\lambda = 600 \text{ nm}$

interference max located at  
 $d \sin\theta = m\lambda$

green  $m=3$

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

$$(5 \times 10^{-3}) \sin\theta = 3(480 \times 10^{-9})$$

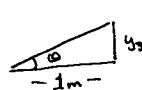
$$\theta = 1.650 \times 10^{-2} \text{ degrees}$$

yellow  $m=3$

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

$$(5 \times 10^{-3}) \sin\theta = 3(600 \times 10^{-9})$$

$$\theta = 2.663 \times 10^{-2} \text{ degrees}$$



$$\tan\theta = \frac{y_3}{1}$$

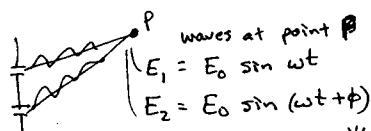
$$y_3 = 2.880 \times 10^{-4} \text{ m}$$

$$\tan\theta = \frac{y_3}{1}$$

$$y_3 = 3.60 \times 10^{-4} \text{ m}$$

Then  $\Delta y = 0.72 \times 10^{-4} \text{ m}$   
= 72  $\mu\text{m}$

35-32



$$\begin{aligned}E_0 &= 2 \text{ mV/m} \\ \omega &= 1.26 \times 10^{15} \text{ rad/s} \\ \phi &= 39.6 \text{ rad}\end{aligned}$$

a)  $E_{\text{tot}} = E_1 + E_2$  use  $\sin \alpha + \sin \beta = 2 \cos(\frac{\beta-\alpha}{2}) \sin(\frac{\alpha+\beta}{2})$

$$E_{\text{tot}} = 2E_0 \cos \frac{\phi}{2} \sin(\omega t + \frac{\phi}{2})$$

$$\text{Amp } \delta = 2 (2 \text{ mV}) \cos(39.6/2) = 2.33 \text{ mV/m}$$

b) Compare intensity at point P to intensity straight on.  
The total E field straight on will not have a phase diff between the 2 waves.

Recall Intensity  $\propto E^2$ 

$$\frac{\text{Intensity}}{\text{Intensity}_0} \propto \frac{E_p^2}{E_{00}^2} = \frac{(2.33)^2}{(1)^2} = 0.34$$

c) They are basically asking how many complete oscillations ( $\sim$  wavelength) the phase 39.6 rad corresponds to

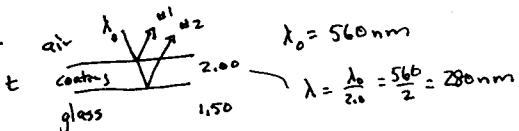
$$\frac{39.6}{2\pi} = 6.3$$

so the point P in question lies between the 6<sup>th</sup> & 7<sup>th</sup> interference max

d)  $\omega = 1.26 \times 10^{15} \text{ rad/sec}$

e) at point P, the phase difference is 39.6 rad.

35-37



$$\lambda = \frac{\lambda_0}{n} = \frac{560}{2} = 280 \text{ nm}$$

ray #1 history  
air  
reflection (R)  
air

ray #2 history  
air  
transit coating  $\frac{t}{\lambda} 2\pi$   
reflect less dense (e)  
transit coating  $\frac{t}{\lambda} 2\pi$   
air

phase difference

$$\Delta\phi = [2 \frac{t}{\lambda} 2\pi + 0] - [\pi]$$

$$\Delta\phi = 2 \frac{t}{\lambda} 2\pi - \pi$$

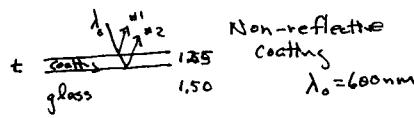
Want brilliant reflection, constructive,  $\Delta\phi = 0$ 

$$0 = 2 \frac{t}{\lambda} 2\pi - \pi$$

$$0 = 2 \frac{t}{280} 2\pi - \pi$$

$$t = 700 \text{ nm}$$

33-35



ray #1 history  
travel air  
transit reflection ( $\pi$ )  
travel air

ray #2 history  
travel air  
transit reflection ( $\pi$ )  
travel air

$$\text{phase difference} = \Delta\phi = [2 \frac{t}{\lambda} 2\pi + \pi] - [\pi] = 2 \frac{t}{\lambda} 2\pi$$

$$\text{with } \lambda = \frac{\lambda_0}{n}$$

To get cancellation

$$\Delta\phi = \pi = 2 \frac{t}{\lambda} 2\pi \quad \lambda = \frac{\lambda_0}{n}$$

$$\cancel{\lambda} = 2 \frac{1.25}{600} 2\pi$$

$$t = 120 \text{ nm}$$

35-71



$$\lambda_0 = 500 \text{ nm}$$

ray #1 history  
travel air  
crosses upper slide  
reflects off air gap (0)  
crosses upper slide  
travel air

ray #2 history  
travel air  
crosses upper slide  
jumps gap  $\frac{t}{\lambda} 2\pi$   
reflects off bottom slide ( $\pi$ )  
jumps gap  $\frac{t}{\lambda} 2\pi$   
crosses upper slide  
travel air

$$\text{phase difference} = \Delta\phi = [2 \frac{t}{\lambda} 2\pi + \pi] - [0]$$

$$\Delta\phi = 2 \frac{t}{\lambda} 2\pi + \pi$$

Notice at the left side of drawing,  $t=0$ , and the  $\Delta\phi=\pi$  there which is dark cancellation.

Moving ~~0.25~~ slightly to the right by 1.2 mm, we encounter another dark cancellation, this must be for  $\Delta\phi = 3\pi$

$$3\pi = 2 \frac{t}{\lambda} 2\pi + \pi$$

$$3 = 2 \frac{t}{500} 2 + 1$$

$$t = 250 \text{ nm} = 250 \times 10^{-9} \text{ m} = 0.250 \times 10^{-3} \text{ mm}$$

Draw the air gap on the left side

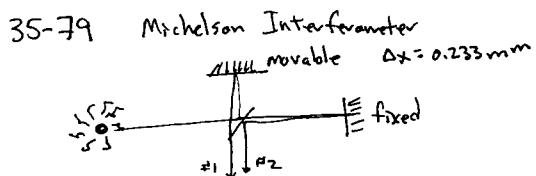


$$1.2 \text{ mm} -$$

$$0.250 \times 10^{-3}$$

$$1.2 \theta$$

$$\theta \approx 2.1 \times 10^{-4} \text{ rad}$$



A shift of 1 fringe occurs for every path difference of  $1\lambda$  which is a movement of the mirror of  $\frac{1}{2}\lambda$ .  
 So for a shift of 792 fringes corresponds to

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$$792 \left(\frac{1}{2}\lambda\right) = 0.233 \times 10^{-3} \text{ m}$$

$$\lambda = 5.88 \times 10^{-7} \text{ m}$$

$$\sim 588 \text{ nm}$$