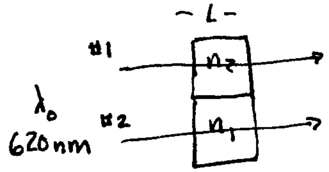
35-9



$n_2 = 1.65$ $\quad \lambda_2 = \frac{\lambda_0}{n_2}$

$n_1 = 1.45$ $\quad \lambda_1 = \frac{\lambda_0}{n_1}$

#1 history	#2 history
—	initial π or $-\pi$ shift
~~travel air~~	~~travel air~~
$\frac{L}{\lambda_1} 2\pi$ transit block 1	transit block 2 $\frac{L}{\lambda_2} 2\pi$
~~travel air~~	~~travel air~~

phase difference between ray #2 - ray #1

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

$\lambda_2 = \frac{\lambda_0}{n_2}$ $\quad \lambda_1 = \frac{\lambda_0}{n_1}$

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

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

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

Use the (−) sign

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

Try $\Delta\phi = 0$

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

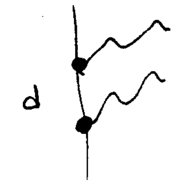
$L = 1550$ nm

Try $\Delta\phi = 2\pi$

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

$L =$ ~~9300 nm~~ 4650 nm

35 - 17



$d = 2\,m$

$\lambda = 0.5\,m$

Treat this as a two-slit interference problem

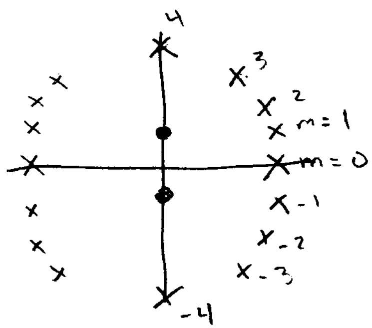
Interference maxima will be located at

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

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

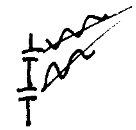
m	$\sin\theta$	θ
0	0	0°
1	0.25	14.8°
2	0.5	30°
3	0.75	48.6°
4	1.0	90°

these are all in 1st quadrant



16 total maxima

35-21



$d = 5\,mm$

green $\lambda = 480\,nm$

yellow $\lambda = 600\,nm$

interference max located at

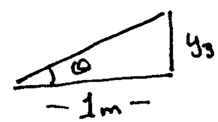
$$d \sin\theta = m\lambda$$

green $m=3$

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

$$(5\times10^{-3}) \sin\theta = 3(480\times10^{-9})$$

$$\theta = 1.650\times10^{-2} \text{ degrees}$$



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

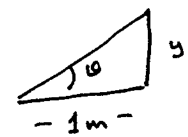
$$y_3 = 2.880\times10^{-4}\,m$$

yellow $m=3$

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

$$(5\times10^{-3}) \sin\theta = 3(600\times10^{-9})$$

$$\theta = 2.063\times10^{-2} \text{ degrees}$$



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

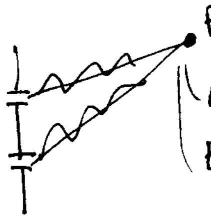
$$y_3 = 3.60\times10^{-4}\,m$$

Then

$$\Delta y = 0.72\times10^{-4}\,m$$

$$= 72\,\mu m$$

35-32



waves at point P

$E_1 = E_0 \sin \omega t$

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

$E_0 = 2\ \mu V/m$

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

$\phi = 39.6$ rad

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

$$E_{TOT} = \underbrace{2E_0 \cos \phi/2}_{\text{ampl}} \sin(\omega t + \phi/2)$$

$$\text{Ampl} = 2\ (2\ \tfrac{\mu V}{m}) \cos(39.6/2)$$

$$= 2.33\ \mu V/m$$

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 $\propto E^2$

$$\frac{\text{Intens}_P}{\text{Intens}_{0^\circ}} \propto \frac{E_P^2}{E_{0^\circ}^2} = \frac{(2.33)^2}{(4)^2} = 0.34$$

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

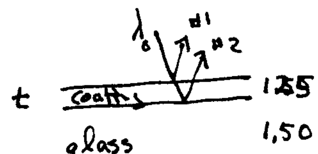
$$\frac{39.6}{2\pi} = 6.3$$

So the point P in question lies between the 6^{th} & 7^{th} interference max

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

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

33-35



Non-reflective Coating

$\lambda_0 = 600$ nm

ray #1 history

~~travel air~~

~~transit~~ reflection (π)

~~travel air~~

ray #2 history

~~travel air~~

transit coating $\frac{t}{\lambda} 2\pi$

reflection (π)

transit coating $\frac{t}{\lambda} 2\pi$

~~travel air~~

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

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

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

To get cancellation

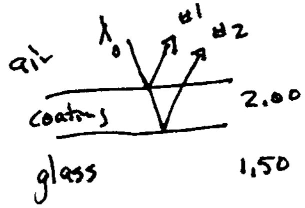
$$\Delta\phi = \pi = 2\frac{t}{\lambda}2\pi \qquad \lambda = \frac{\lambda_0}{n}$$

$$= 2\frac{nt}{\lambda_0}2\pi$$

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

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

35-37



$\lambda_0 = 560\text{nm}$

$\lambda = \frac{\lambda_0}{2.0} = \frac{560}{2} = 280\text{nm}$

ray #1 history	ray #2 history
~~air~~	~~air~~
reflection (π)	transit coating $\frac{t}{\lambda}2\pi$
~~air~~	reflect less dense (0)
	transit coating $\frac{t}{\lambda}2\pi$
	~~air~~

phase difference

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

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

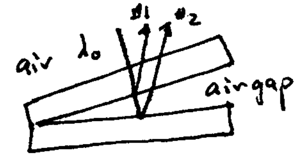
Want brilliant reflection, constructive, $\Delta\phi = 0$

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

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

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

35-71



$\lambda_0 = 500\text{nm}$

ray #1 history	ray #2 history
~~travels air~~	~~travels air~~
~~crosses upper slide~~	~~crosses upper slide~~
reflects off air gap (0)	jumps gap $\frac{t}{\lambda}2\pi$
~~crosses upper slide~~	reflects off bottom slide (π)
~~travels air~~	jumps gap $\frac{t}{\lambda}2\pi$
	~~crosses upper slide~~
	~~travels air~~

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

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

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

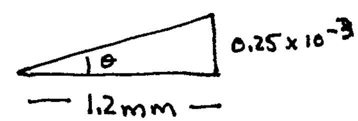
Moving slightly to the right by 1.2mm, we encounter another dark cancellation, this must be for $\Delta\phi = 3\pi$

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

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

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

Draw the air gap wedge on the left side



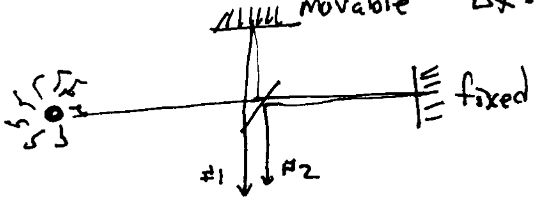
$$s = r\theta$$

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

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

35-79 Michelson Interferometer

$\Delta x = 0.233\,mm$



A Shift of 1 fringe occurs for every path difference of 1λ which is a movement of the mirror of $\frac{1}{2}\lambda$.

So for a shift of 792 fringes corresponds to

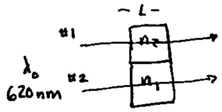
$$792\left(\tfrac{1}{2}\lambda\right) = \Delta x$$

$$792\left(\tfrac{1}{2}\lambda\right) = 0.233\times10^{-3}\,m$$

$$\lambda = 5.88\times10^{-7}\,m$$

$$= 588\,nm$$

35-9



$n_2 = 1.65$ $\quad \lambda_2 = \frac{\lambda_0}{n_2}$

$n_1 = 1.45$ $\quad \lambda_1 = \frac{\lambda_0}{n_1}$

#1 history	#2 history
—	initial π or $-\pi$ shift
~~travel air~~	~~travel air~~
$\frac{L}{\lambda_1}2\pi$ transit block 1	transit block 2 $\frac{L}{\lambda_2}2\pi$
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phase difference between ray #2 - ray #1

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

$\lambda_2 = \frac{\lambda_0}{n_2}$ $\quad \lambda_1 = \frac{\lambda_0}{n_1}$

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

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

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

Use the (−) sign

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

Try $\Delta\phi = 0$

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

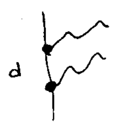
$L = 1550$ nm

Try $\Delta\phi = 2\pi$

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

$L =$ ~~9300~~ ~~nm~~ 4650 nm

35-17



$d = 2$ m

$\lambda = 0.5$ m

Treat this as a two-slit interference problem

Interference maxima will be located at

$d \sin\theta = m\lambda$

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m	$\sin\theta$	θ
0	0	0°
1	0.25	14.8°
2	0.5	30°
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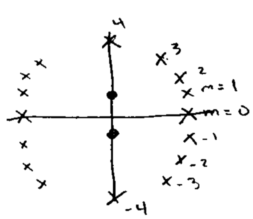
these are all in 1st quadrant



16 total maxima

35-21

$d = 5$ mm

green $\lambda = 480$ nm

yellow $\lambda = 600$ nm

interference max located at

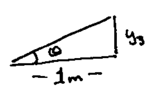
$d \sin\theta = m\lambda$

green $m=3$

$d \sin\theta = m\lambda$

$(5\times10^{-3}) \sin\theta = 3(480\times10^{-9})$

$\theta = 1.650\times10^{-2}$ degrees



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

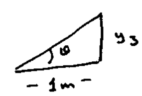
$y_3 = 2.880\times10^{-4}$ m

yellow $m=3$

$d \sin\theta = m\lambda$

$(5\times10^{-3}) \sin\theta = 3(600\times10^{-9})$

$\theta = 2.063\times10^{-2}$ degrees



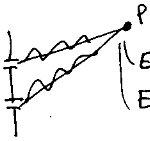
$\tan\theta = \frac{y_3}{1}$

$y_3 = 3.60\times10^{-4}$ m

Then $\Delta y = 0.72\times10^{-4}$ m

$= 72\ \mu$m

35-32



waves at point P

$E_1 = E_0 \sin \omega t$

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

$E_0 = 2\ \mu V/m$

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

$\phi = 39.6$ rad

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

$E_{TOT} = \underbrace{2E_0 \cos \phi/2}_{ampl} \sin(\omega t + \phi/2)$

$Amp_P = 2\ (2 \frac{\mu V}{m}) \cos(39.6/2)$

$= 2.33\ \mu V/m$

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 $\propto E^2$

$\frac{Intens_P}{Intens_{0°}} \propto \frac{E_P^2}{E_{0°}^2} = \frac{(2.33)^2}{(4)^2} = 0.34$

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

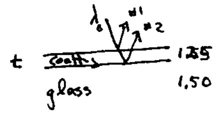
$\frac{39.6}{2\pi} = 6.3$

so the point P in question lies between the 6th & 7th interference max

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

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

33-35



Non-reflective Coating

$\lambda_0 = 600$ nm

ray #1 history	ray #2 history
~~travel air~~	~~travel air~~
reflection (π)	transit coating $\frac{t}{\lambda}2\pi$
~~travel air~~	reflection (π)
	transit coating $\frac{t}{\lambda}2\pi$
	~~travel air~~

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

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

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

To get cancellation

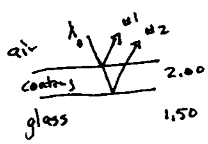
$\Delta\phi = \pi = 2\frac{t}{\lambda}2\pi$ $\lambda = \frac{\lambda_0}{n}$

$= 2\frac{nt}{\lambda_0}2\pi$

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

$t = 120$ nm

35-37



$\lambda_0 = 560$ nm

$\lambda = \frac{\lambda_0}{2.0} = \frac{560}{2} = 280$ nm

ray #1 history	ray #2 history
~~air~~	~~air~~
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~~air~~	reflect less dense (0)
	transit coating $\frac{t}{\lambda}2\pi$
	~~air~~

phase difference

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

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

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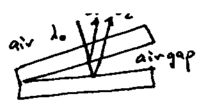
35-71



$\lambda_0 = 500$ nm

ray #1 history	ray #2 history
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~~crosses upper slide~~	~~crosses upper slide~~
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~~crosses upper slide~~	reflects off bottom slide (π)
~~travels air~~	jumps gap $\frac{t}{\lambda}2\pi$
	~~crosses upper slide~~
	~~travels air~~

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

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

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

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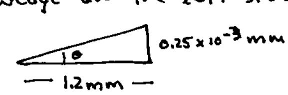

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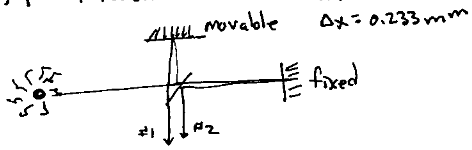
$\theta \simeq 2.1 \times 10^{-4}$ rad

35-79 Michelson Interferometer



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$$792\left(\tfrac{1}{2}\lambda\right) = 0.233\times10^{-3}\,\text{m}$$

$$\lambda = 5.88\times10^{-7}\,\text{m}$$

$$= 588\ \text{nm}$$