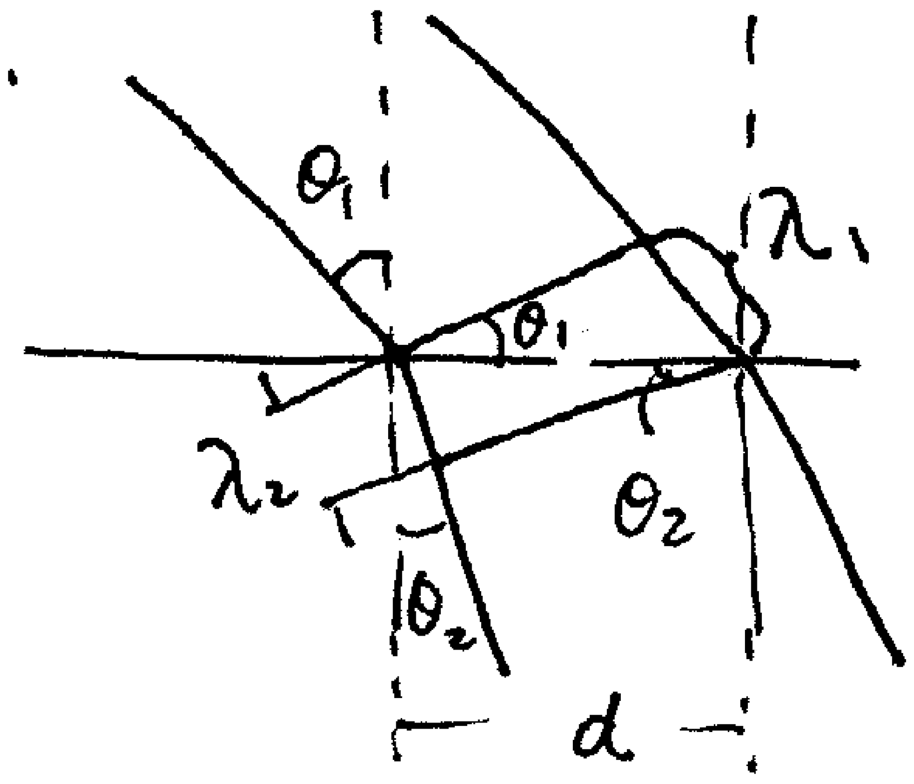
ch. 36   3, 5, 9, 12, 15, 19, 20, 24, 25, 27, 28, 29, 30, 32, 34, 38, 39, 43, 44, 49, 50, 51, 55, 56, 57

3. $V = \frac{c}{n} \Rightarrow n = \frac{c}{V} = \frac{3 \times 10^8 \text{ m/sec}}{1.92 \times 10^8 \text{ m/sec}} = \underline{\underline{1.5625}}$

5.



$d \sin\theta_1 = \lambda_1 \longrightarrow d = \frac{\lambda_1}{\sin\theta_1}$ — ①

$d \sin\theta_2 = \lambda_2$ ——— ②

② ← ①

$\frac{\lambda_1}{\sin\theta_1} \sin\theta_2 = \lambda_2$

$\therefore \frac{\sin\theta_2}{\sin\theta_1} = \frac{\lambda_2}{\lambda_1} = \frac{\frac{V_2}{\nu}}{\frac{V_1}{\nu}} = \frac{V_2}{V_1}$ $\left[\begin{matrix} V = \lambda\nu \\ \lambda = \frac{V}{\nu} \end{matrix}\right]$

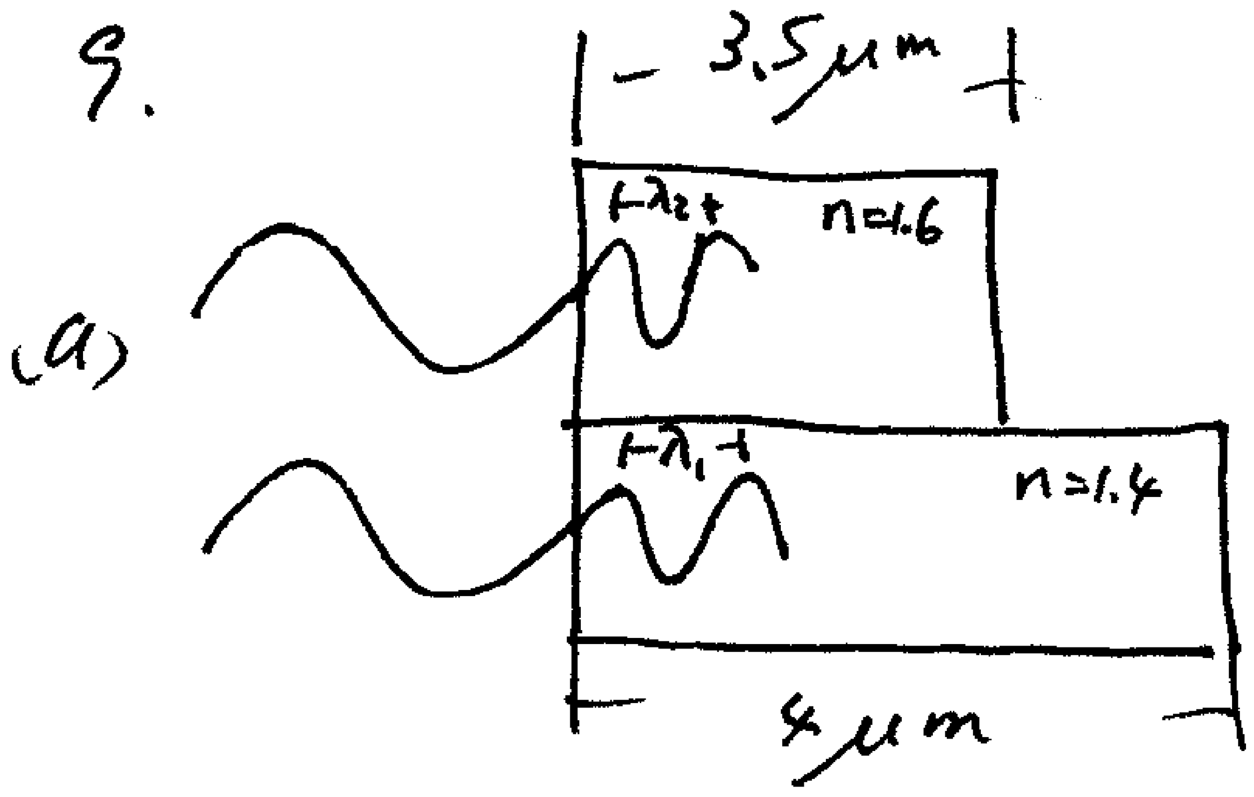
$\sin\theta_2 = \frac{V_2}{V_1} \sin\theta_1$

$\theta_2 = \sin^{-1}\left[\frac{V_2}{V_1} \sin\theta_1\right]$

$= \sin^{-1}\left[\frac{3}{4} \sin 30^\circ\right] = \underline{\underline{22.0243128}}$

9.

(a)



$\lambda = 600 \times 10^{-9} m$

$\lambda_2 = \frac{600 \times 10^{-9} m}{1.6} = 375 \text{ nm}$

$\lambda_1 = \frac{600 \times 10^{-9} m}{1.4} = 428.5714286 \text{ nm}$

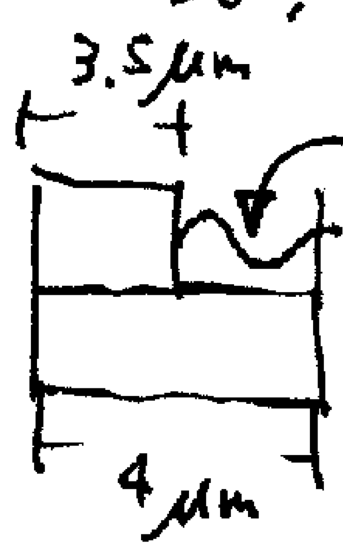
How many λ's in the media?

$\lambda_2 \rightarrow \frac{L_2}{\lambda_2} = \frac{3.5 \mu m}{375 nm} = 9.\dot{3}\ \lambda_2$'s

$\lambda_1 \rightarrow \frac{L_1}{\lambda_1} = \frac{4 \mu m}{428.57\ldots nm} = 9.3\ \lambda_1$'s

Wow! when they come out, there is no shift!

So, the diff. is λ_2 reaching the same dist. as λ_1.

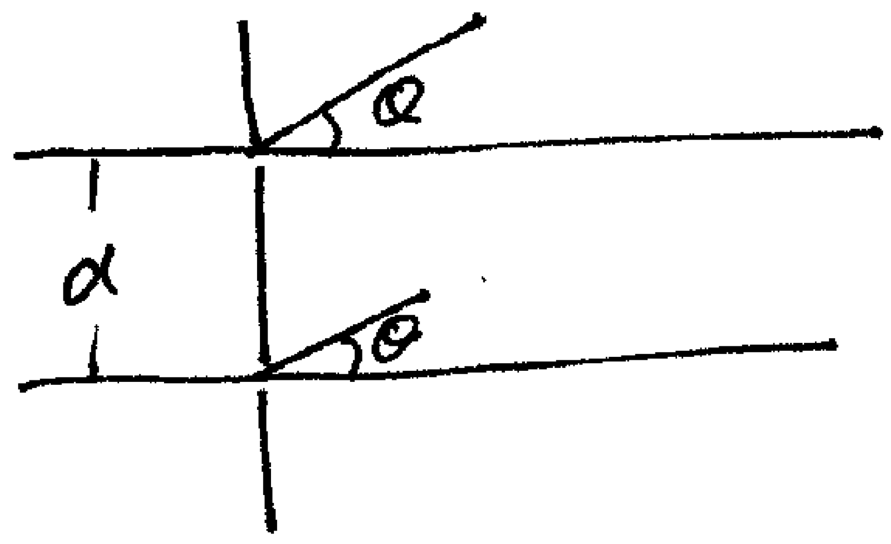


this difference causes ϕ. Also λ is back to 600 n.m.

$\phi \rightarrow \frac{0.5 \mu m}{600 n.m} = \underline{\underline{0.8\dot{3}\ \lambda \text{ diff}}}$

(b) Because they are closer to an integer ($0.1\dot{6}$ to the whole # & $0.3\dot{3}$ to the half which causes destructive wave), it is rather constructive

12.



First dark

$$d \sin\theta = 0.5\lambda \rightarrow \pi \text{ rad off}$$

second

$$d \sin\theta = 1.5\lambda \rightarrow 3\pi \text{ rad off}$$

third

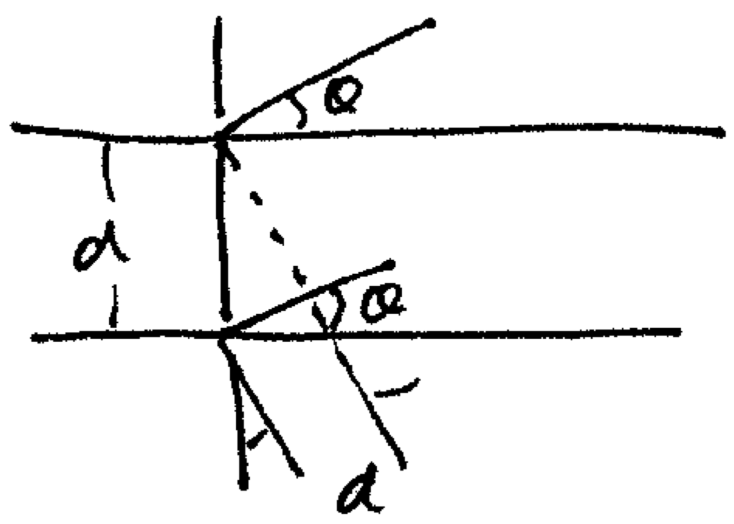
$$d \sin\theta = 2.5\lambda \rightarrow 5\pi \text{ rad off}$$

$\vdots$

m th

$$d \sin\theta = (m-0.5)\lambda \rightarrow \underline{\underline{(m-0.5)2\pi \text{ rad off}}}$$

15.



for $\theta < 10°$

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

$$d\,\theta \sim m\lambda$$

$$\therefore\ \theta = \frac{m\lambda}{d}$$

$$\theta_1 = \frac{m\lambda_1}{d}$$

& $\theta_2 = \dfrac{m\lambda_2}{d}$ (differnt λ's & the same m th spot)

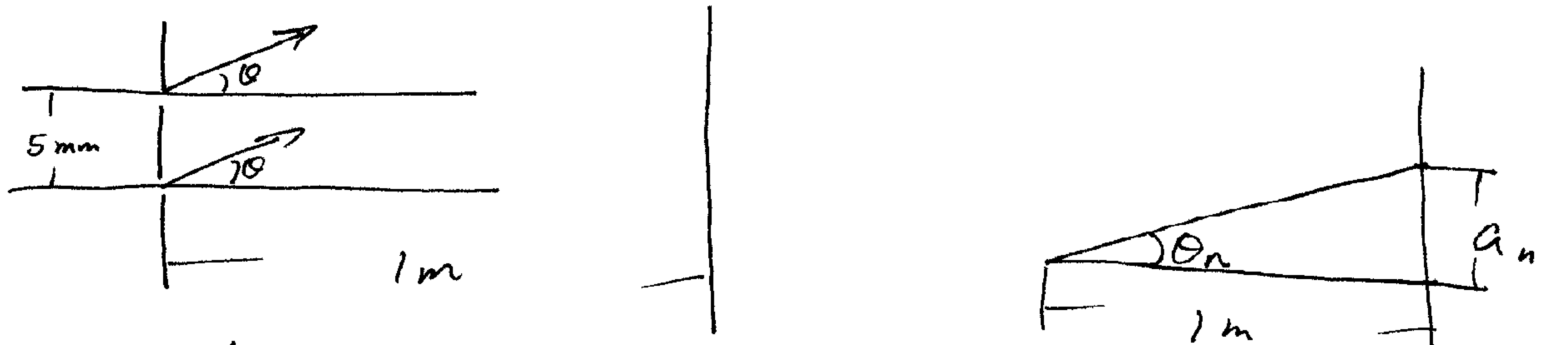
& θ_1 = 10 % greater than θ_2 = $1.1\,\theta_2$

$$\frac{\theta_1}{\theta_2} = \frac{\frac{\cancel{m}\lambda_1}{\cancel{d}}}{\frac{\cancel{m}\lambda_2}{\cancel{d}}} = \frac{1.1\,\theta_2}{\theta_2}$$

$$\frac{\lambda_1}{\lambda_2} = 1.1$$

$\lambda_1 = 1.1\,\lambda_2 = \underline{\underline{647\text{ n.m.}}}$ ($\lambda_1 = 589\text{nm}$)

19.



$d \sin\theta = m\lambda \quad (m=3)$

$a_n = 1m \cdot \tan\theta_n$

$\sin\theta_1 = \frac{3\lambda}{d} = \frac{3 \cdot 480nm}{5\times10^{3}} \Rightarrow \theta_1 = \sin^{-1}\frac{3\lambda_1}{d}$

$\sin\theta_2 = \frac{3\lambda}{d} = \frac{3 \cdot 600nm}{5\times10^{3}} \Rightarrow \theta_2 = \sin^{-1}\frac{3\lambda_2}{d}$

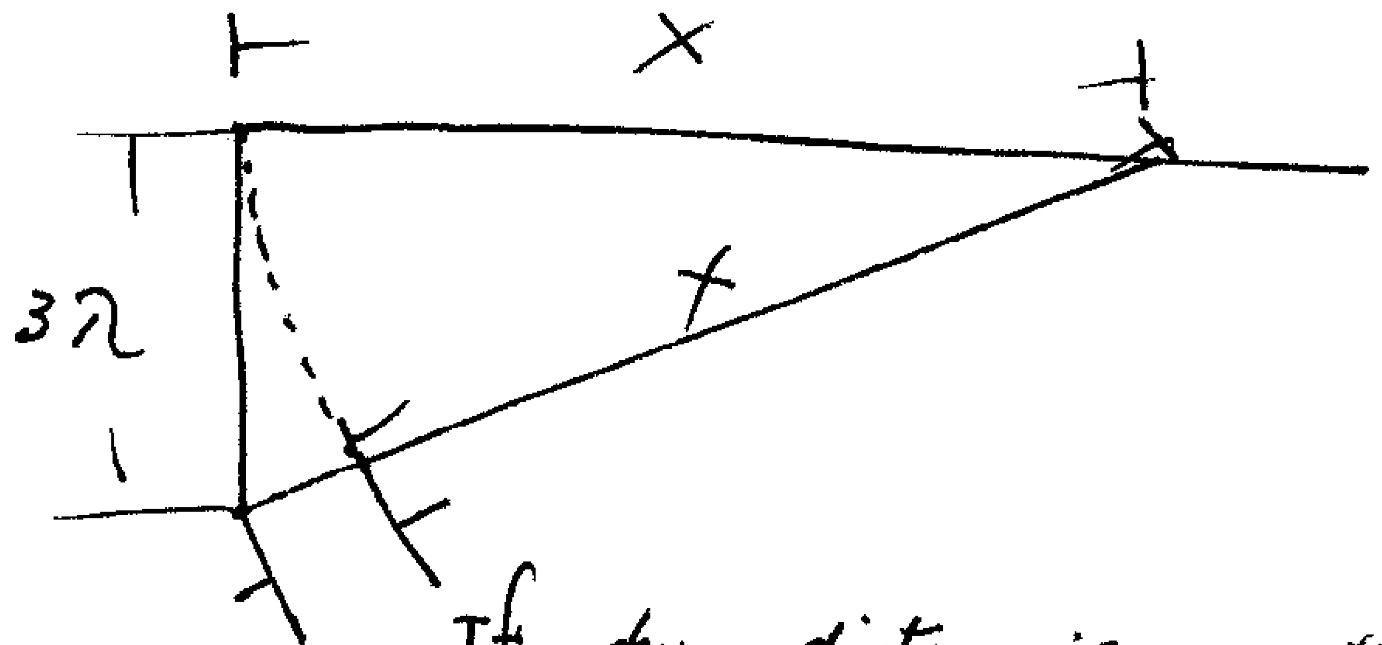
$a_1 - a_2$

$\Delta a = a_1 - a_2$

$= 1m\left\{\tan\left[\sin^{-1}\frac{3\lambda_1}{d}\right] - \tan\left[\sin^{-1}\frac{3\lambda_2}{d}\right]\right\}$

$= \underline{\underline{72\,\mu m}}$

20.



If this dist. is exactly $\frac{1}{2}\lambda$. it is the last destructive interference
(Notice as x gets larger, this becomes smaller)

this dist. $= \sqrt{x^2+(3\lambda)^2} - x = \frac{1}{2}\lambda$

Solve for x

$\sqrt{x^2+(3\lambda)^2} = x + \frac{1}{2}\lambda$

$x^2+(3\lambda)^2 = (x+\frac{1}{2}\lambda)^2$

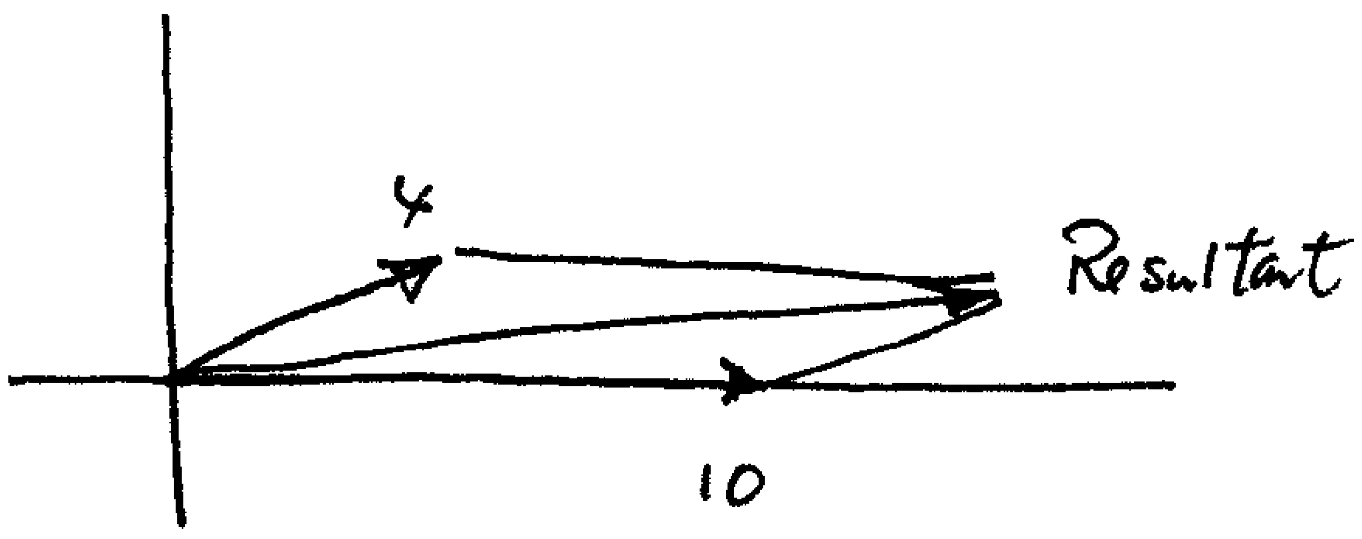
$x^2 + 9\lambda^2 = x^2 + \lambda x + \frac{1}{4}\lambda^2$

$x = 9\lambda - \frac{1}{4}\lambda = \underline{\underline{8.75\lambda}}$

24. at $t=0$

$y_1 = 10$ ——— $10\hat{i} + 0\hat{j}$

$y_2 = 8\sin(\omega t + 30°) \rightarrow 8\cos 30°\hat{i} + 8\sin 30°\hat{j}$



$y_T = y_1 + y_2 = (10 + 8\cos 30°)\hat{i} + (0 + 8\sin 30°)\hat{j}$

$= 16.92820323\hat{i} + 4\hat{j}$

$|y_T| = 17.39436876$

$\phi = \tan^{-1}\frac{y_{T,\hat{j}}}{y_{T,\hat{i}}} = 13.29468619°$

$$y_T = 17.39\sin(\omega t + 13.29°)$$

25 Same method used in #24

at $t=0$

$y_1 = 10\hat{i} + 0\hat{j}$

$y_2 = 15\cos 30°\hat{i} + 15\sin 30°\hat{j}$

$y_3 = 5\cos(-45°)\hat{i} + 5\sin(-45°)\hat{j}$

$= 5\cos(45°)\hat{i} - 5\sin(45°)\hat{j}$

$y_T = (10 + 15\cos 30° + 5\cos 45°)\hat{i} + (0 + 15\sin 30° - 5\sin 45°)\hat{j}$

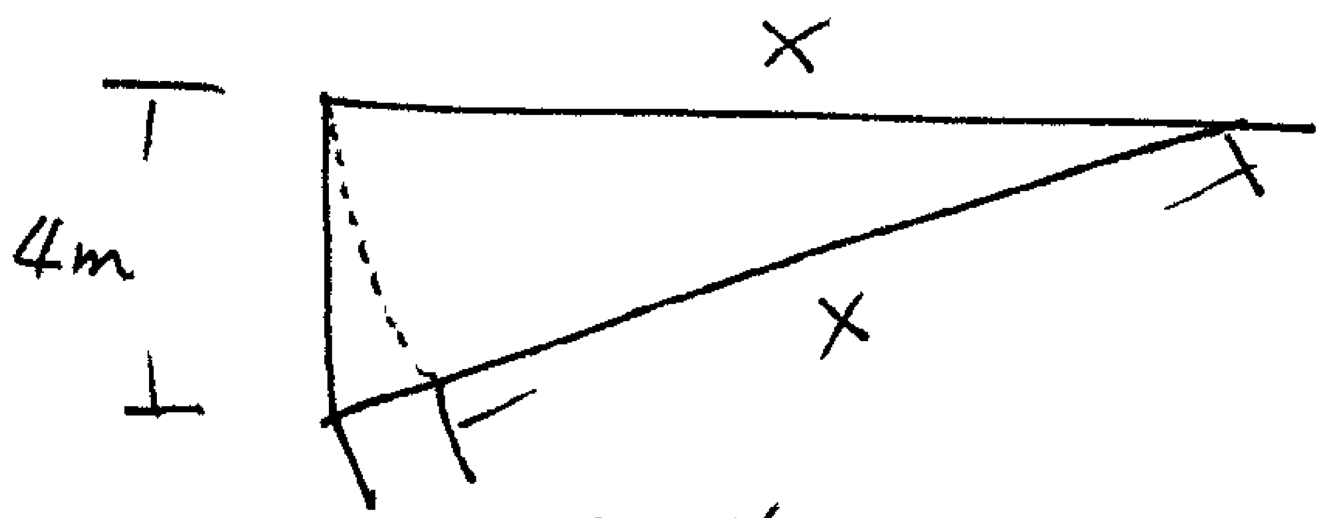
$= 26.52591496\hat{i} + 3.964466094\hat{j}$

$|y_T| = 26.82053609$

$\phi = \tan^{-1}\frac{y_{T,\hat{j}}}{y_{T,\hat{i}}} = 8.500299048°$

$$y = 26.82\sin(\omega t + 8.50°)$$

27.



$\sqrt{x^2+4^2} - x$ ← this dist $= m\lambda$ $(\lambda = 1m)$

$m = 1$

$\sqrt{x^2+4^2} - x = 1$

$\sqrt{x^2+4^2} = x+1$

$x^2+4^2 = (x+1)^2$

$x^2+4^2 = x^2+2x+1$

$2x = 15$

$\underline{x = 7.5m}$

$m = 2$

$\sqrt{x^2+4^2} - x = 2$

$\sqrt{x^2+4^2} = x+2$

$x^2+4^2 = (x+2)^2$

$x^2+4^2 = x^2+4x+4$

$4x = 12$

$\underline{x = 3m}$

$m = 3$

$\sqrt{x^2+4^2} - x = 3$

$\sqrt{x^2+4^2} = x+3$

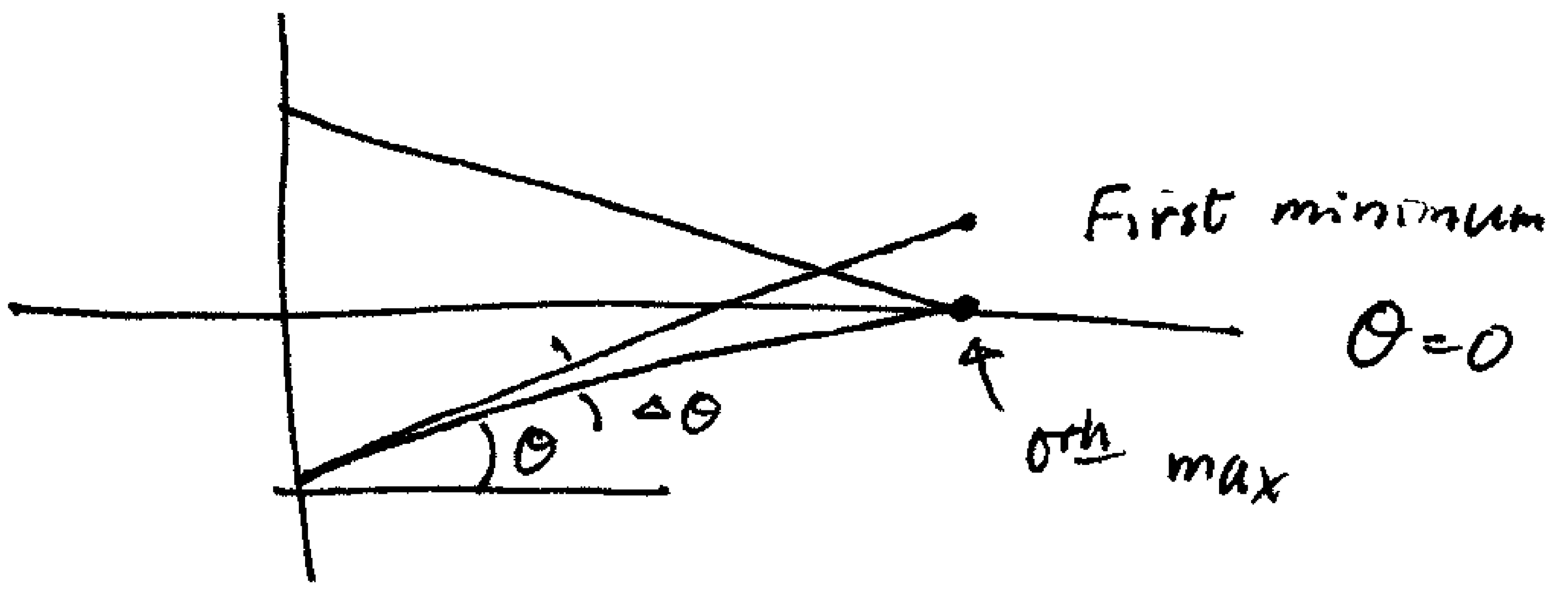
$x^2+4^2 = (x+3)^2$

$x^2+4^2 = x^2+6x+9$

$6x = 7$

$\underline{x = \frac{7}{6}m}$

28.



The First minimum is $d \sin\theta = \frac{1}{2}\lambda$

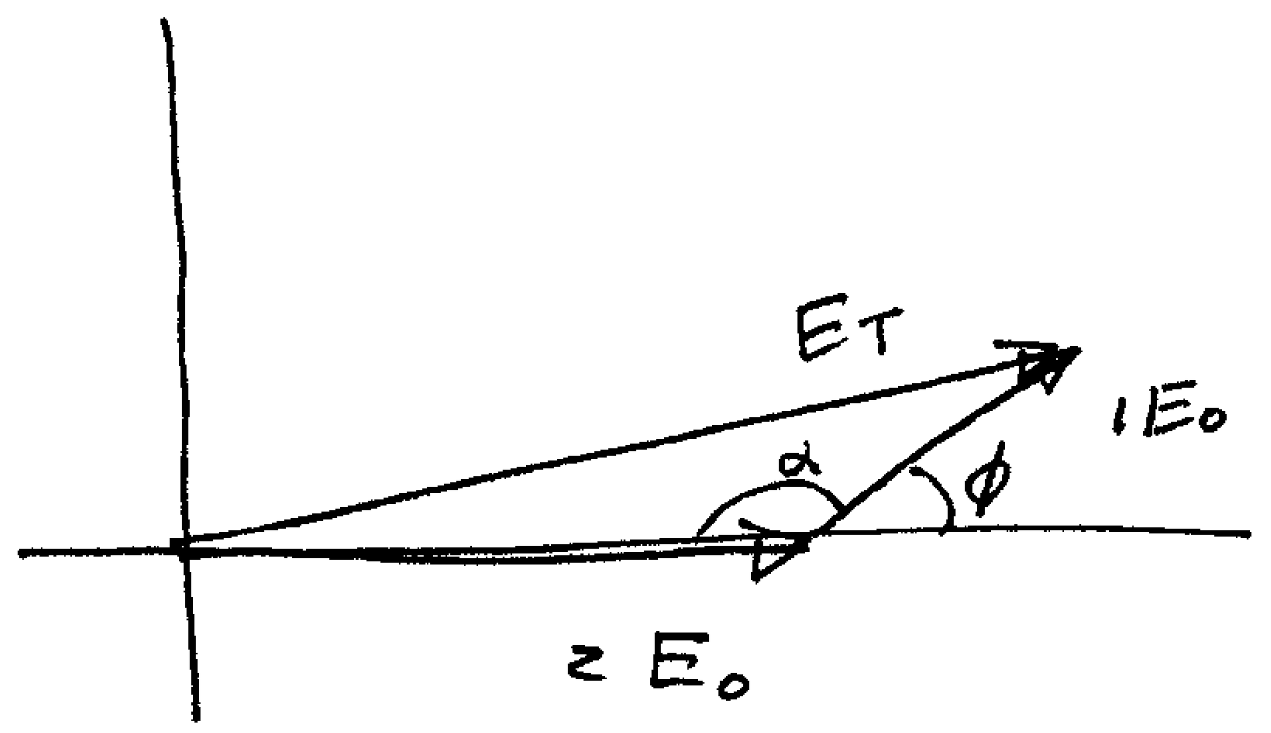
because $\theta = 0$ for the 0th so "θ" = "$\Delta\theta$" in this case

$d \sin\Delta\theta = \frac{1}{2}\lambda$

$\sin\Delta\theta = \frac{\lambda}{2d}$

$\sim \Delta\theta = \frac{\lambda}{2d}$

29. 36-21 : $I = 4I_0 \cos^2 \frac{1}{2}\phi$, $\phi = \frac{2\pi d}{\lambda} \sin\Theta$



$\alpha = 180° - \phi$ & Law of cos.

$$E_T^2 = E_0^2 + (2E_0)^2 - 2(E_0)(2E_0)\cos(180 - \phi)$$
$$= 5E_0^2 - 4E_0^2 \left(\cos 180° \cos(-\phi) - \sin(180°)\sin(-\phi)\right)$$
$$= 5E_0^2 + 4E_0^2 \cos\phi$$
$$= E_0^2 (5 + 4\cos\phi)$$

$$\therefore I = I_0 (5 + 4\cos\phi) \quad \left(\phi = \frac{2\pi d}{\lambda}\sin\Theta\right)$$

30. W_2 has extra $2L$ to travel.
If $2L = \frac{1}{2}\lambda$, they cancel

(a) $\therefore L = \frac{1}{4}\lambda = \frac{1}{4}\, 620\text{ nm} = \underline{155\text{ nm}}$

(b) The second one should be $(\frac{1}{2}\lambda)$ dist. extra

$L' = \frac{1}{2} \cdot 620\text{ nm} = \underline{310\text{ nm to move}}$

32 If $2L = \frac{1}{2}\lambda$, they construct.

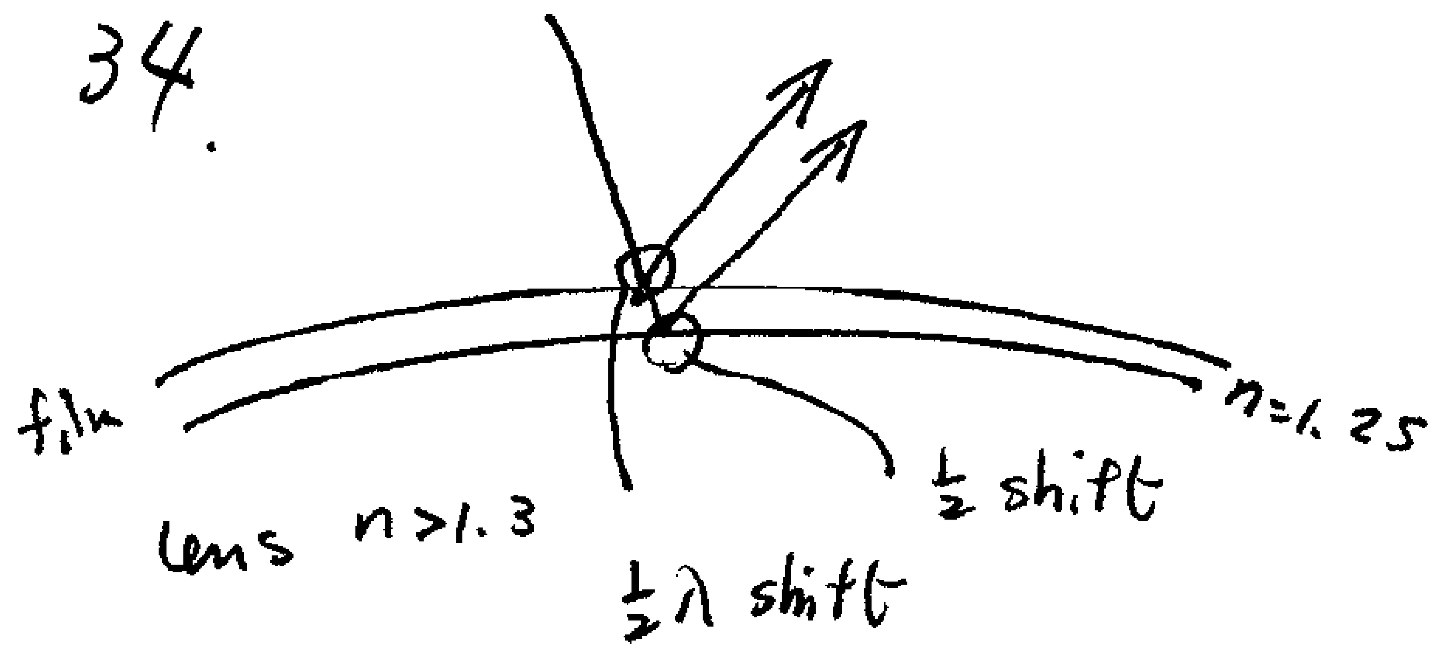
1st $L = \frac{1}{4}\lambda$

2nd add another $\frac{1}{2}\lambda$ $L = \frac{1}{4}\lambda + \frac{1}{2}\lambda$

3rd " $L = \frac{1}{4}\lambda + \lambda$

So $\underline{L = \frac{1}{4}\lambda + \frac{1}{2}m\lambda \quad m = 0, 1, 2 \cdots}$

34.



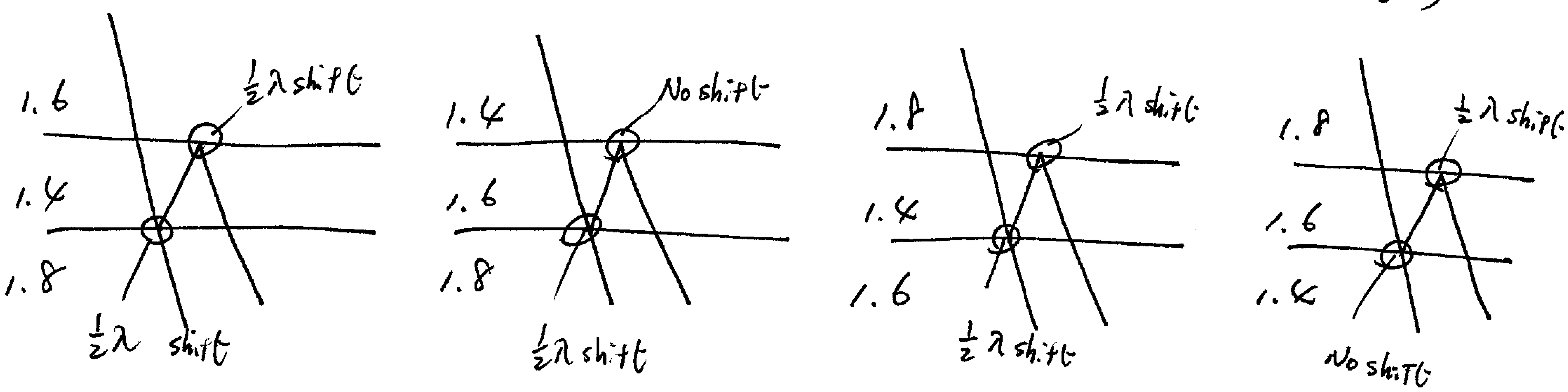
To cancel the reflected beams, $2d$ should be equal to $\frac{1}{2}\lambda$ (be careful that λ is changed in the film)

$$2d = \frac{1}{2}\lambda_{film} = \frac{1}{2}\frac{\lambda}{n_{film}}$$

$$d = \frac{1}{4}\frac{\lambda}{n_{film}} = \frac{1}{4}\cdot\frac{\lambda}{1.25} = \frac{1}{5}\lambda$$

38

(a) (b) (c) (d)



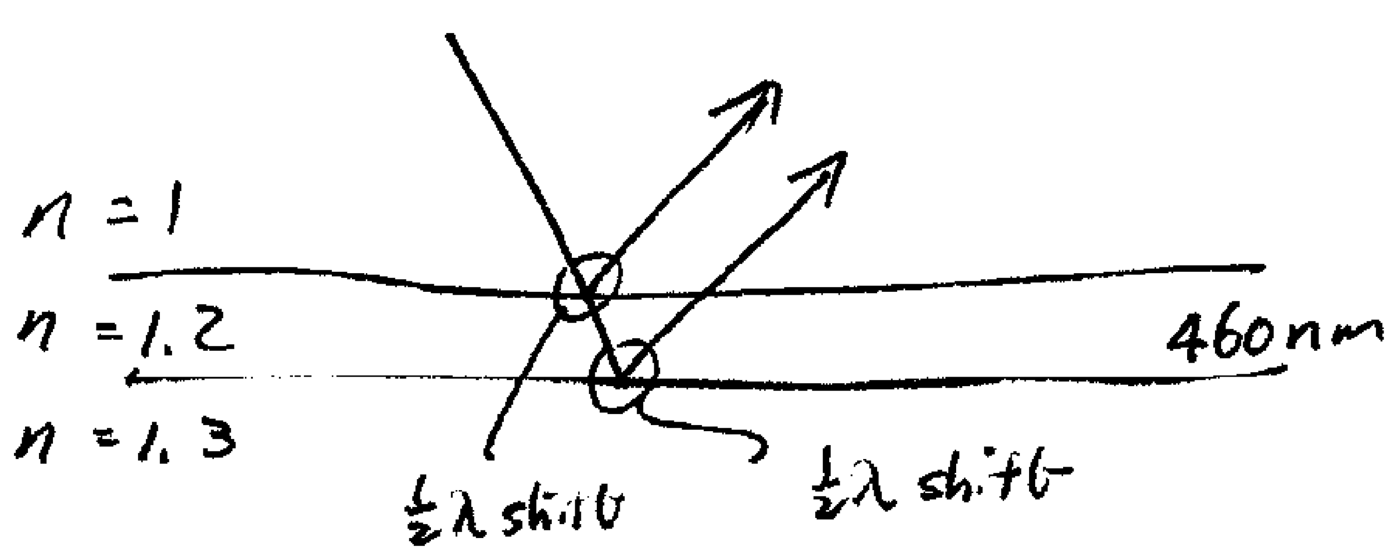
shift Total 1λ $\frac{1}{2}\lambda$ 1λ $\frac{1}{2}\lambda$

the given eqn: $\lambda = \frac{2Ln_2}{m}$

$$\Rightarrow 2L = m\frac{\lambda}{n_2}$$ this is a constructive wave eqn.

So (a) & (c) fit to this eqn.

39.



(a) $2L = m\frac{\lambda}{n_2}$ (constructive)

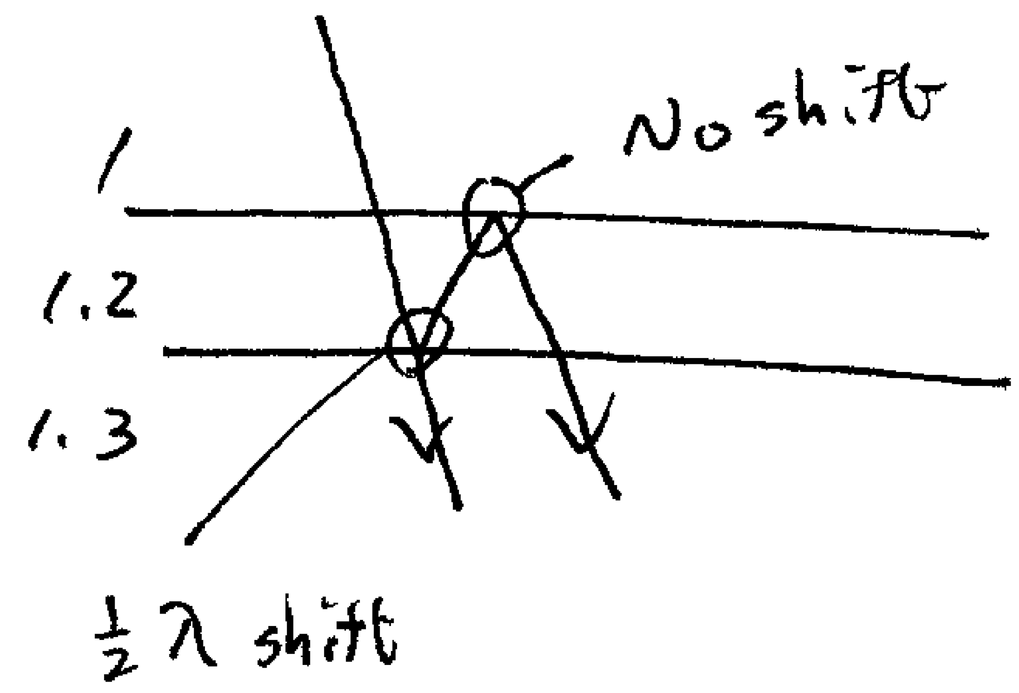
$$\lambda = \frac{2Ln_2}{m}$$

$$\lambda_1 = 2Ln_2 = 2\cdot 460nm\cdot 1.2 = 1104\ nm$$

$$\lambda_2 = \frac{2Ln_2}{2} = 552nm$$

$$\lambda_3 = \frac{2Ln_2}{3} = 368\ nm$$

(b)



So to make constructive, $2L = (m+\frac{1}{2})\frac{\lambda}{n_2}$

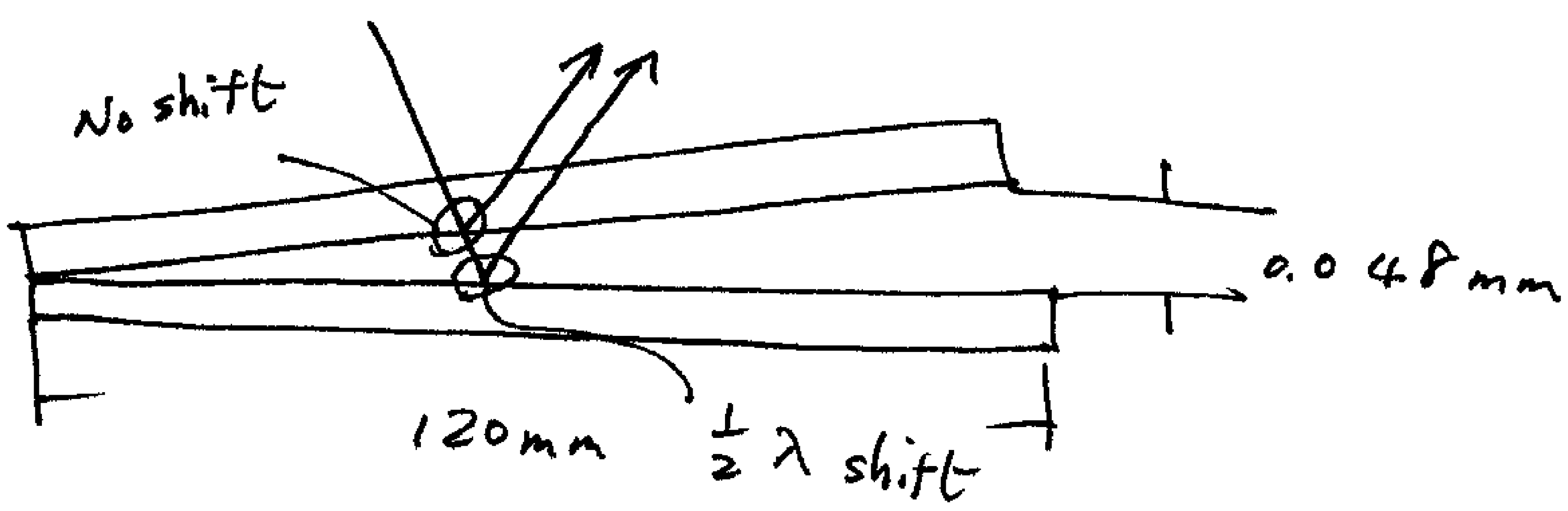
$$\lambda = \frac{2Ln_2}{m+\frac{1}{2}}$$

$m=0$ $\quad \lambda = \frac{2Ln_2}{\frac{1}{2}} = \frac{2\cdot(460)\,1.2}{\frac{1}{2}} = \underline{2208\,n.m}$

$$\lambda = \frac{2Ln_2}{1.5} = \underline{736\,nm}$$

$$\lambda = \frac{2Ln_2}{2.5} = \underline{441.6\,nm}$$

43.



If $\quad 2L = (m+\frac{1}{2})\frac{\lambda}{n}$, it is constructive $\quad (n = 1$ air$)$

Solve for m.

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

$$m = \frac{2L}{\lambda} - \frac{1}{2} = \frac{2\cdot 0.048\,mm}{683\,nm} - \frac{1}{2} = 140.056\ldots$$

$\Rightarrow$ <u>140 bright fringes</u>

44. (a) $\frac{1}{2}\lambda$ off $\rightarrow$ dark.

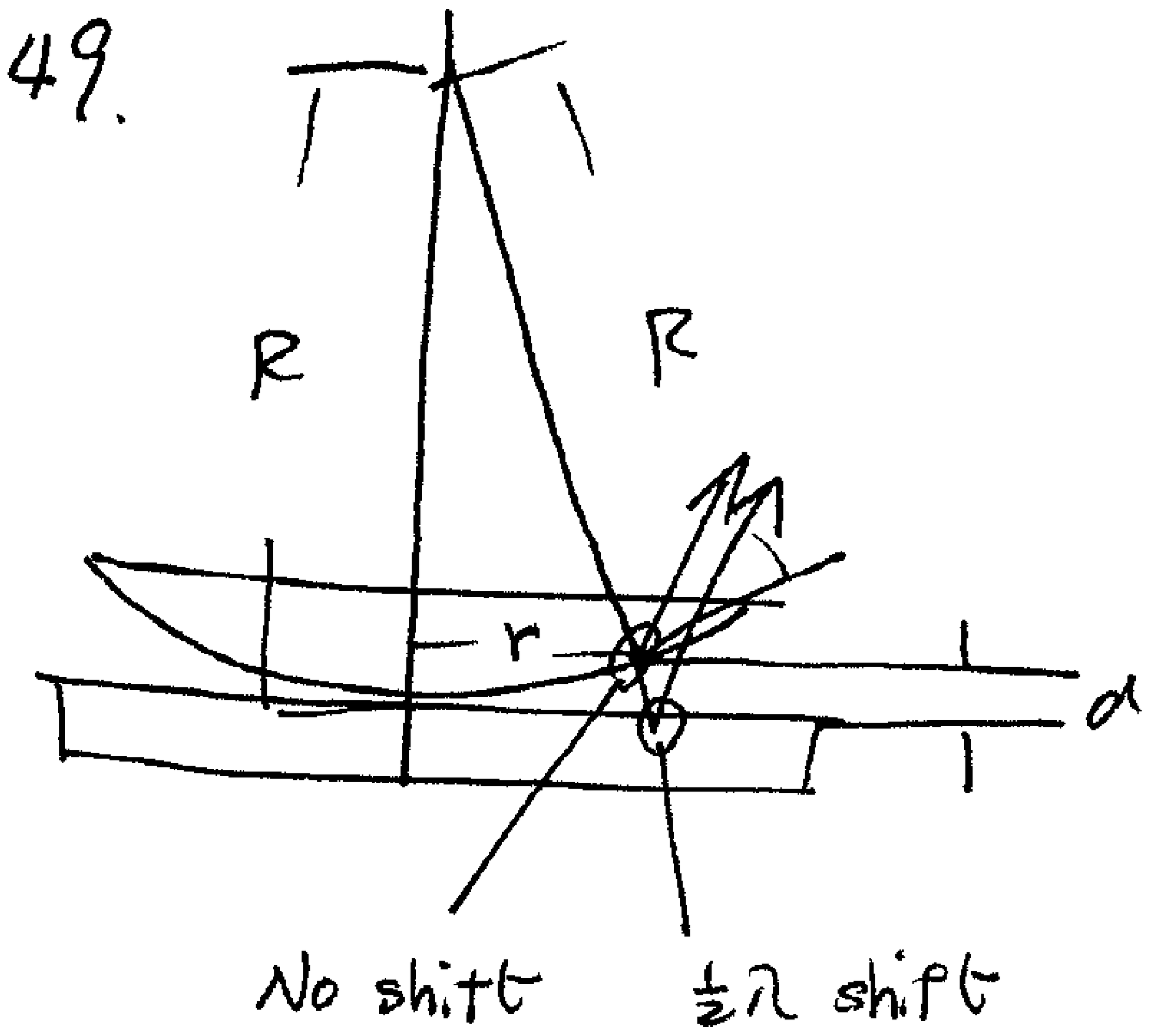
(b) $2L = (m+\frac{1}{2})\lambda$ bright

$2L = m\lambda$ dark.

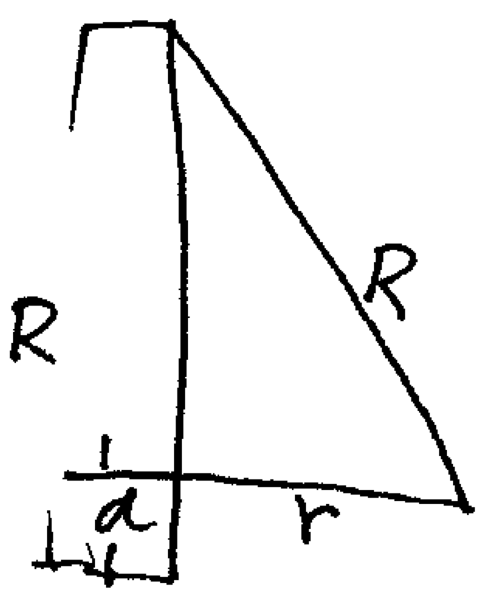
shorter the λ, shorter the L.

$\rightarrow$ <u>Blue end will get a dark fringe first</u>

49.



$$2d = \left(m+\tfrac{1}{2}\right)\frac{\lambda}{n} \qquad (n=1)$$



$$\therefore\ d = \frac{\left(m+\frac{1}{2}\right)\lambda}{2}$$

Also $\quad d = R - \sqrt{R^2-r^2}$

$$\therefore\quad R-\sqrt{R^2-r^2} = \frac{\left(m+\frac{1}{2}\right)\lambda}{2}$$

$$\sqrt{R^2-r^2} = R - \frac{\left(m+\frac{1}{2}\right)\lambda}{2}$$

$$R^2-r^2 = \left(R - \frac{\left(m+\frac{1}{2}\right)\lambda}{2}\right)^2$$

$$r^2 = R^2 - \left(R - \frac{\left(m+\frac{1}{2}\right)\lambda}{2}\right)^2$$

$$= R^2 - \left(R^2 - R\left(m+\tfrac{1}{2}\right)\lambda + \frac{\left(m+\frac{1}{2}\right)^2\lambda^2}{4}\right)$$

$$= R\lambda\left(m+\tfrac{1}{2}\right) - \frac{\left(m+\frac{1}{2}\right)^2\lambda^2}{4}$$

$$\sim R\lambda\left(m+\tfrac{1}{2}\right)$$

$$\therefore\ \underline{\underline{r = \pm\sqrt{R\lambda\left(m+\tfrac{1}{2}\right)}}}$$

50. solving for m

(a) $\quad m = \dfrac{r^2}{R\lambda} - \dfrac{1}{2}$

$r = 10\,mm \rightarrow 0.01\,m$
$R = 5\,m$
$\lambda = 589\times10^{-9}\,m$

$$= \frac{(0.01)^2}{5\cdot 589\times10^{-9}} - \frac{1}{2} = 33$$

Since m starts with "0", 33 means $\underline{\underline{34 \text{ fringes}}}$

(b) new $\lambda_w = \dfrac{\lambda}{n_w}$

$$m = \frac{r^2}{R\frac{\lambda}{n_w}} - \frac{1}{2} = \frac{(0.01)^2}{5 \cdot \frac{589\times10^{-9}}{1.33}} - \frac{1}{2} = 44.66 \rightarrow 44$$

so $\underline{\underline{45 \text{ fringes}}}$

51.

$m = n \quad : r_1 = \sqrt{R\lambda(n+\frac{1}{2})} \longrightarrow r_1^2 = R\lambda(n+\frac{1}{2})$

$m = n+20 \quad : r_2 = \sqrt{R\lambda(n+20+\frac{1}{2})} \longrightarrow r_2^2 = R\lambda(n+20.5)$

$$r_2^2 - r_1^2 = R\lambda(n+20.5) - R\lambda(n+\tfrac{1}{2})$$
$$= R\lambda\left((n+20.5) - (n+\tfrac{1}{2})\right)$$
$$= R\lambda\, 20$$

$$\therefore \quad R = \frac{r_2^2 - r_1^2}{20\lambda} = \frac{(0.00368m)^2 - (0.00162m)^2}{20 \cdot 546\times10^{-9}m}$$
$$= 0.99981849\,m$$
$$\sim \underline{\underline{1\,m}}$$

52. Binomial theorem

(a) $\sqrt{k(1+x)} = \sqrt{k}\left(1 + \frac{x}{2} + \frac{x^2}{8} + \frac{3x^3}{48} + \cdots\right)$

$\sim \sqrt{k}\left(1+\frac{x}{2}\right)$ for $x \ll 1$

So the eqn. derived in #49

$r = \sqrt{R\lambda(m+\frac{1}{2})}$ is rewritten to fit the binomial theorem

$= \sqrt{R\lambda m(1+\frac{1}{2m})}$ $\quad k = R\lambda m$ & $x = \frac{1}{2m}$

$$r_m = \sqrt{R\lambda m}\left(1+\frac{1}{4m}\right)$$

$r_{m+1} = \sqrt{R\lambda m}\left(1+\frac{3}{4m}\right)$ $\qquad r_{m+1} = \sqrt{R\lambda(m+\frac{3}{2})} = \sqrt{R\lambda m(1+\frac{3}{2m})}$

$$\Delta r = r_{m+1} - r_m$$

$$= \sqrt{R\lambda m}\left(1 + \frac{3}{4m}\right) - \sqrt{R\lambda m}\left(1 + \frac{1}{4m}\right)$$

$$= \sqrt{R\lambda m}\left(1 + \frac{3}{4m} - 1 - \frac{1}{4m}\right)$$

$$= \frac{1}{2m}\sqrt{R\lambda m} = \underline{\underline{\frac{1}{2}\sqrt{\frac{R\lambda}{m}}}}$$

(b)

$$dA = 2\pi r_m \cdot \Delta r$$

$$= 2\pi\left(\sqrt{R\lambda m}\left(1 + \frac{1}{4m}\right)\right) \cdot \left(\frac{1}{2m}\sqrt{R\lambda m}\right)$$

$$= \frac{\cancel{2}\pi}{\cancel{2}\cancel{m}} R\lambda \cancel{m}\left(1 + \frac{1}{4m}\right)$$

$$= \underline{\underline{\pi R\lambda}}$$

$\frac{1}{4m} = 0$ for large m

55

$$2L = N\lambda$$

$$\lambda = \frac{2L}{N} = \frac{2\,(0.233\text{ mm})}{792 \text{ fringes}} = \underline{\underline{588\text{ nm}}}$$

56

$$N_1 = \frac{2L}{\lambda_1}$$

$$N_2 = \frac{2L}{\lambda_2}$$

$$N_2 - N_1 = \frac{2L}{\lambda_2} - \frac{2L}{\lambda_1} = 1$$

$$L\left(\frac{2}{\lambda_2} - \frac{2}{\lambda_1}\right) = 1$$

$$L = \frac{1}{\frac{2}{\lambda_2} - \frac{2}{\lambda_1}} = \underline{\underline{354\ \mu\text{m}}}$$

57.

$$N_A = \frac{2L}{\frac{\lambda}{n_A}}$$

$$N_V = \frac{2L}{\lambda}$$

$$N_A - N_V = \frac{2L}{\frac{\lambda}{n_A}} - \frac{2L}{\lambda} = 60$$

$$\frac{2L}{\lambda}(n_A - 1) = 60$$

$$n_A = \frac{60\lambda}{2L} + 1$$

$$= \frac{60 \cdot 500\,nm}{2 \cdot 5\,cm} + 1$$

$$= \underline{\underline{1.0003}}$$