Extra Problems from Ch. 36, 6^{th} edition

12. What is the phase difference of the waves from the two slits when they arrive at the mth dark fringe in a Young's double-slit experiment?

27. S_1 and S_2 in Fig. 36-29 (Fig. 35-39 in 7^{th} ed.) are point sources of electromagnetic waves of wavelength 1.00 m. They are in phase and separated by d = 4.00m, and they emit at the same power.
   (a) If a detector is moved to the right along the x- axis from source S_1, at what distances from S_1 are the first three interference maxima detected?
   (b) Is the intensity of the nearest minimum exactly zero? (Hint: Does the intensity of a wave from a point source remain constant with an increase in distance from the source?)

28. The double horizontal arrow in Fig. 36-9 (Fig. 35-12 in 7^{th} ed.) marks the points on the intensity curve where the intensity of the central fringe is half the maximum intensity. Show that the angular separation $\Delta\theta$ between the corresponding points on the viewing screen is $\Delta\theta = \frac{\lambda}{2}$ if θ in Fig. 36-8 (35-10 in 7^{th} ed.) is small enough so that $\sin\theta \sim \theta$.

29. Suppose that one of the slits of a double-slit interference experiments is wider than the other, so that amplitude of the light reaching the central part of the screen from one slit, acting alone, is twice that from the other slit, acting alone. Derive an expression for the light intensity I at the screen as a function of θ, corresponding to equations 36-21(35-22 in 7^{th} ed.) and 36-22 (35-23 in 7^{th} ed.).

32. Suppose the light waves of Exercise 30 (#5 in 7^{th} ed.) are initially exactly out of phase. Find an expression for the values of L (in terms of the wavelength λ) that put the reflected waves exactly in phase.

38. In the fig. 36-32, light is incident perpendicularly on four thin layer of thickness L. The indexes of refraction of the thin layers and of the media above and below these layers are given. Let λ represent the wavelength of the light in air, and n_2 represent the index of refraction of the thin layer in each situation. Consider only the transmission of light that undergoes no refection or two reflections, as in Fig. 36-32 (a). For which of the situations does the expression $\lambda = \frac{2Ln_2}{m}$, for m = 1,2,3,... give the wavelengths of the transmitted light that undergoes fully constructive interference?

44. In Fig. 36-33 (Fig. 35-44 in 7^{th} ed.), white light is sent directly downward through the top plate of a pair of glass plates. The plates touch at the left end and are separated by a wire of diameter 0.048 mm at the right end: the air between the plates acts as a thin film. An observer looking down through the top plate sees bright and dark fringes due to that film.
   (a) Is a dark fringe or a bright fringe seen at the left end?
   (b) To the right of that end, fully destructive interference occurs at different locations for different wavelengths of the light. Does it occur first for the red end or the blue end of the visible spectrum?

Homework conversion list from 6th ed to 7th ed

6th ed	7th ed
Ch.34	Ch 33
1	
5	111
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6th ed	7th ed
Ch.35	Ch. 34
6	4
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24	69-79 (similar)
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6th ed	7th ed
Ch. 36	Ch.35
3	3
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9	13
12	
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19	21
20	25 (similar)
24	30
25	31 (similar)
27	
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29	
30	5
32	
34	113
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39	55
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51	77
52	123
55	79
56	82
57	81

6th ed	7th ed
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	5
10	11
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29	31
30	32
32	35
34	38(similar)
37	41
38	42
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47	51
48	52
	108
51	109

52 – (a) In terms of the angle θ locating a line produced by a grating, find the product of that line's half-width and the resolving power of the grating. (b) Evaluate that the product

ch. 34 1, 5, 7, 12, 16, 18, 24, 25, 36, 37, 38, 40, 41
49, 51, 58, 59, 62

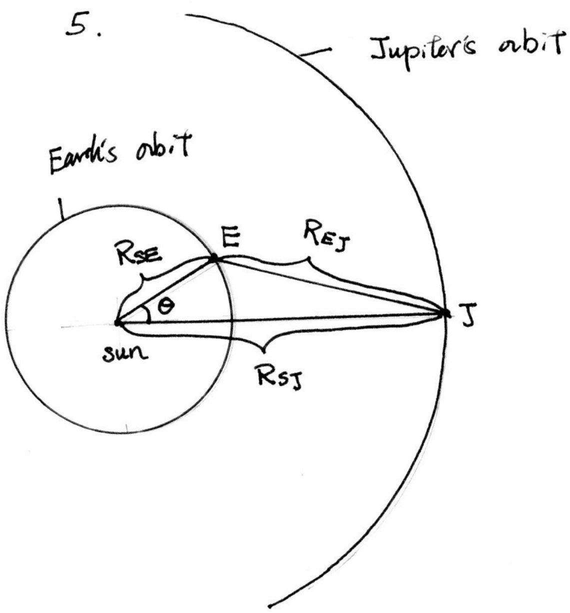
1. (a) $t = \frac{D}{V} = \frac{1.5 \times 10^5 \, m}{3.0 \times 10^8 \, m/sec} = \underline{\underline{5 \times 10^{-4} \, sec}}$

(b) $t = \frac{D}{V} = \frac{1.5 \times 10^8 \, km + 2 \times 3.5 \times 10^5 \, km}{3 \times 10^8 \, m/sec} = 502.\dot{3} \, sec = \underline{\underline{8.37\dot{2} \, min}}$

(c) $t = \frac{D}{V} = \frac{1.3 \times 10^9 \, km \times 2}{3 \times 10^5 \, km/sec} = 866\dot{6}.\dot{6} \, sec = \underline{\underline{2.\dot{4}\dot{0}\dot{7} \, hrs}}$

(d) Dist. = 6500 lys → light takes 6500 yrs to reach us.
⇒ super nova event happened 6500 yrs before 1054 A.D.
1054 AD − 6500 ~ $\underline{\underline{5446 \text{ BC}}}$

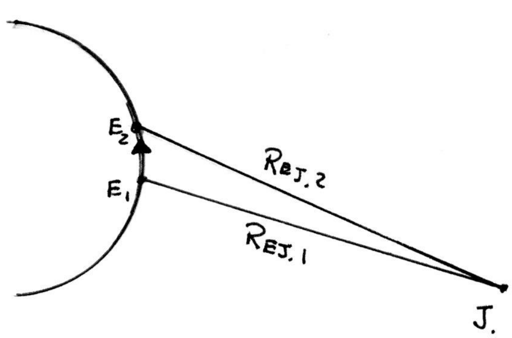
5.



R_{SE} : Dist. between the sun & Earth
R_{SJ} : Dist. between the sun & Jupiter
R_{EJ} : Dist. between Earth & Jupiter

θ : ∡ between R_{SE} & R_{SJ}

P : orbital Period of the Moon



at a certain time t_1, Jupiter's Moon is starting its cycle, but Earth does not observe this yet because light has to travel $R_{EJ,1}$ to reach us. So, Earth observes this at $t_1 + \frac{R_{EJ,1}}{c}$. While the Moon completes its cycle, Earth moves from E_1 to E_2. So the distance changes from $R_{EJ,1}$ to $R_{EJ,2}$

Earth observes the beginning of the second cycle at:

$$t_{2,E} = \underbrace{\left(t_1 + \frac{d_1}{c}\right)}_{t_{1,E}} + P + \left(\frac{R_{EJ,2} - R_{EJ,1}}{c}\right)$$

beginning of the 1st cycle — Delay — orbital period of the moon — Extra delay because E-J dist. changed.

So, from the earth's observation, orbital period of the Moon is

$$t_{2,E} - t_{1,E} = P + \left(\frac{R_{EJ,2} - R_{EJ,1}}{c}\right)$$

How far does the distance change ($R_{EJ,2} - R_{EJ,1}$) while the Moon orbits once? (see the first diagram)

$$R_{EJ}^2 = R_{SE}^2 + R_{SJ}^2 - 2R_{SE}R_{SJ}\cos\theta \quad \text{(Law of cos)}$$

$$\therefore R_{EJ} = \left(R_{SE}^2 + R_{SJ}^2 - 2R_{SE}R_{SJ}\cos\theta\right)^{1/2}$$

to find the rate of change of R_{EJ} we do $\frac{d(R_{EJ})}{dt}$

$$\therefore \frac{d(R_{EJ})}{dt} = \frac{2R_{SE}R_{SJ}\sin\theta}{\left(R_{SE}^2 + R_{SJ}^2 - 2R_{SE}R_{SJ}\cos\theta\right)^{1/2}} \frac{d\theta}{dt}$$

(Also $R_{SE}\frac{d\theta}{dt}$ is the orbital speed of the earth

$$= \frac{2R_{SJ}\sin\theta}{\left(R_{SE}^2 + R_{SJ}^2 - 2R_{SE}R_{SJ}\cos\theta\right)^{1/2}} \cdot V_E$$

So, at the location "x", $\theta = 0$.

$$\frac{d(R_{EJ})}{dt} = 0.$$

Distance between E-J will not change (No change in period)

at "y", $\theta = 90°$

$$\frac{d(R_{EJ})}{dt} = \frac{2R_{SJ}V_E}{\left(R_{SE}^2 + R_{SJ}^2\right)^{1/2}}$$

(This is $\Delta R_{EJ} = R_{EJ,2} - R_{EJ,1}$)

$$t_{2,E} - t_{1,E} = P + \frac{2R_{SJ}V_E}{c\left(R_{SE}^2 + R_{SJ}^2\right)^{1/2}}$$

(b) at the location "x", we can measure "P". since there is no extra delay.

at the location "y", we need to know other variables R_{SE}, R_{SJ}, V_E, & $(t_{2,E} - t_{1E})$ (earth observed period)

7. $\lambda = 550\ nm = 550 \times 10^{-9} m$

$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8\ m/sec}{550 \times 10^{-9} m} = 5.45 \times 10^{14}\ Hz$

$\omega = 2\pi\nu = 3.42719198 6 \times 10^{15}\ rad/sec$

$\omega = \sqrt{\frac{1}{LC}} \Rightarrow \omega^2 = \frac{1}{LC}$

$L = \frac{1}{\omega^2 C} = \underline{\underline{5.008 \times 10^{-21}\ H}}$

12 $\oint I \cdot dA =$ Power of the source

$I = \frac{P_s}{4\pi r^2}$

$= \frac{1\ \mu W}{4\pi \left(4.3\ lys \cdot \frac{365.25\ days}{1\ yr} \cdot \frac{24\ 1.\ hour}{1\ 1.\ day} \cdot \frac{3600\ 1.\ S.}{1\ 1.\ h} \cdot \frac{3 \times 10^8\ m}{1\ 1.\ s}\right)^2}$

$= \underline{\underline{4.8 \times 10^{-29}\ w/m^2}}$

16. $I_{rms} = 1.40\ kw/m^2$

$I = \frac{1}{\mu_0 c} E^2$

$\therefore E_{rms} = \sqrt{I_{rms} \cdot \mu_0 c} = 726.4878938\ N/c$

$\underline{\underline{E_{max} = \sqrt{2}\ E_{rms} = 1027.411861\ N/c}}$

$\underline{\underline{B_{max} = \frac{E_{max}}{c} = 3.424706202 \times 10^{-6}\ T}}$

18.

(a) $$P_{received} = \frac{P_{received\ by\ the\ Earth}}{A\ of\ the\ Earth} \cdot A_{antenna}$$

$$= \frac{1\times10^{-12}\,w}{4\pi(6.37\times10^{6}m)^2} \cdot \pi \cdot \left(\frac{300m}{2}\right)^2$$

$$= \underline{\underline{1.386256713\times10^{-22}\,w}}$$

(b) $$P_s = I \cdot 4\pi r^2$$

$$= \frac{1\times10^{-12}\,w}{4\pi(6.37\times10^{6})^2} \cdot 4\pi \cdot (2.2\times10^{4}\,ly)(9.46\times10^{15}\,m/ly)^2$$

$$= \underline{\underline{1.1\times10^{15}\,w.}}$$

24.

(a) $$I = \frac{P_s}{Area}$$

dia $= 2\lambda \Rightarrow r = \lambda$

$$= \frac{5\times10^{-3}\,w}{\pi(633\times10^{-9}m)^2}$$

$$= \underline{\underline{3.972031753\times10^{9}\,w/m^2}}$$

(b) $$P_r = \frac{I}{c} = 13.24\ N/m^2\ (Pa)$$

(c) $$F = P_r \cdot A$$

$$= 13.24\,N/m^2 \cdot \pi r^2$$

$$= 13.24\,N/m^2 \cdot \pi(6.33\times10^{-9}m)^2$$

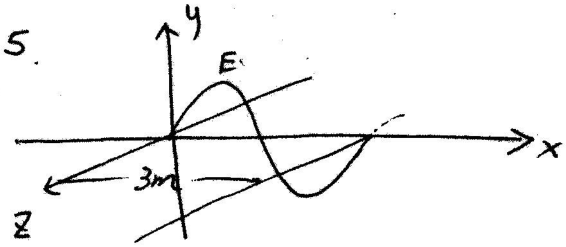
$$= \underline{\underline{1.6\times10^{-11}\,N}}$$

(d) $$a = \frac{F}{m}$$

$$\left(m = \rho \cdot Vol = 5\times10^{3}\,kg/m^3 \cdot \frac{4}{3}\pi(6.33\times10^{-9})^3 = 5.31\times10^{-15}\,kg\right.$$

$$= \frac{1.6\times10^{-11}N}{5.31\times10^{-15}kg} = \underline{\underline{3.137465839\times10^{3}\,m/sec^2}}$$

25.



$E = 300\ V/m$

(a) $C = \lambda \nu \Rightarrow \nu = \dfrac{c}{\lambda} = \dfrac{3\times10^8\ m/sec}{3m} = \underline{\underline{1\times10^8\ Hz}}$

(b) Since $\vec{E}\times\vec{B} = \vec{V}$ $\vec{B}$ has to be along z-axis & corresponds $\vec{E}$ (when $\vec{E}$ is position, so is $\vec{B}$)

(c) $\dfrac{E_m}{B_m} = C \Rightarrow B_m = \dfrac{E_m}{c} = \dfrac{300\ V/m}{3\times10^8\ m/sec} = \underline{\underline{1\times10^{-6}\ T}}$

$E = E_{max} \sin(kx - \omega t)$

when $X = 3m$, it is one cycle. so $kx \Rightarrow 2\pi$ rad

$3k = 2\pi$

$\underline{\underline{k = \dfrac{2\pi}{3}\ rad/m}}$

$\omega = 2\pi\nu = \underline{\underline{2\pi\times10^8\ rad/sec}}$

So

$\underline{\underline{E = E_{max} \sin\left(\dfrac{2\pi}{3}x - 2\pi\times10^8 t\right)}}$

(d) $I = \dfrac{(E_{rms})^2}{\mu_0 c} = \dfrac{\left(\dfrac{E_{max}}{\sqrt{2}}\right)^2}{\mu_0 c} = \dfrac{(E_{max})^2}{2\mu_0 c} = \dfrac{(300\ V/m)^2}{2\cdot4\pi\times10^{-7}\ 3\times10^8}$

$= \underline{\underline{119.3662073\ W/m^2}}$

(e) $\dfrac{dp}{dt} = F = \dfrac{IA}{c} = \dfrac{119.366\cdot 2}{3\times10^8} = \underline{\underline{7.957747155\times10^{-7}\ N}}$

$P_r = \dfrac{F}{A} = \dfrac{I}{c} = \dfrac{119.366}{3\times10^8} = \underline{\underline{3.978873577\times10^{-7}\ N/m^2\ (Pa)}}$

36.

$I_1 = I_0 \cos^2\theta$

$I_2 = I_1 \cos^2(90-\theta) = 0.1\, I_0$

$\therefore \quad 0.1\, I_0 = I_0 \cos^2\theta \underbrace{\cos(90-\theta)}$

$0.1 = \cos^2\theta \sin^2\theta$

$(\cos\theta \sin\theta) = \sqrt{0.1}$

$\cancel{\sin(\frac{\theta}{2}) = \sqrt{0.1}}$ $\qquad \frac{1}{2}\sin(2\theta) = \sqrt{0.1}$

$\cancel{\frac{\theta}{2} = \sin^{-1}\sqrt{0.1}}$ $\qquad 2\theta = \sin^{-1}(2\sqrt{0.1})$

$\theta = \frac{1}{2}\sin^{-1}(2\sqrt{0.1})$

$\cancel{\theta = 2\sin^{-1}(\sqrt{0.1}) = 36.^\circ 86989765}$ $\qquad \therefore \theta = 19.^\circ 61576024$

37

$I_1 = I_0 \cos^2 70^\circ$

$I_2 = I_1 \cos^2(90^\circ - 70^\circ)$

$I_2 = I_0 \cos^2 70^\circ \cos^2 20^\circ$

$= 43\ W/m^2 \cos^2 70^\circ \cos^2 20^\circ$

$= 4.441641045\ W/m^2$

38.

$I_1 = \frac{1}{2} I_0$

$I_2 = I_1 \cos^2(90^\circ - 70^\circ)$

$= \frac{1}{2} I_0 \cos^2(90^\circ - 70^\circ)$

$= \frac{1}{2}\, 43\ W/m^2 \cos^2(20^\circ)$

$= 18.98497776\ W/m^2$

40. $E_{\text{Total before}} = (E_x, E_y) = (2.3 \text{ units}, 1 \text{ unit})$

$E_{\text{Total after}} = (E_x, E_y) = (0, 1 \text{ unit})$

$I_{\text{Total before}} \propto \Sigma E_i^2 = 6.29 \text{ units}$ $\quad (I = \frac{1}{\mu_0 c} E^2)$

$I_{\text{Total after}} \propto \Sigma E_i^2 = 1 \text{ unit}$

(a) $\dfrac{I_{\text{after}}}{I_{\text{before}}} = \dfrac{1}{6.29} = \underline{\underline{0.15898 \times}}$

(b) The vertical polarizer is now horizontal

$E_{\text{Total after}} = (E_x, E_y) = (2.3 \text{ units}, 0)$

$I_{\text{Total after}} \propto = \Sigma E_i^2 = 5.29 \text{ units}$

$\therefore \dfrac{I_{\text{after}}}{I_{\text{before}}} = \dfrac{5.29}{6.29} = \underline{\underline{0.841017488 \times}}$

41

(a) 2 sheets

(b) to pass the maximum intensity each filter should be set w/ a minimum $\measuredangle$ (because of $\cos^2\theta$).
However if one $\measuredangle$ is very small, we have to end up w/ 90° net, other $\measuredangle$ might be large. To optimize this, each θ should be the same.

ex. . 2 sheets. (each should be $90°/2 = 45°$)

$I_1 = I_0 \cos^2 45° = \frac{1}{2} I_0$

$I_2 = I_1 \cos^2 45° = \frac{1}{2} I_0 \cdot \frac{1}{2} = \frac{1}{4} I_0$ — $\underline{25\%}$ (Not enough)

. 3 sheets ($\theta = 30°$)

$I_1 = I_0 \cos^2 30°$

$I_2 = I_1 \cos^2 30° = I_0 \cos^2 30° \cdot \cos^2 30°$

$I_3 = I_2 \cos^2 30° = I_0 \cos^2 30° \cdot \cos^2 30° \cdot \cos^2 30° = I_0 (\cos^2(\frac{90}{n}))^n = 0.421875 I_0$

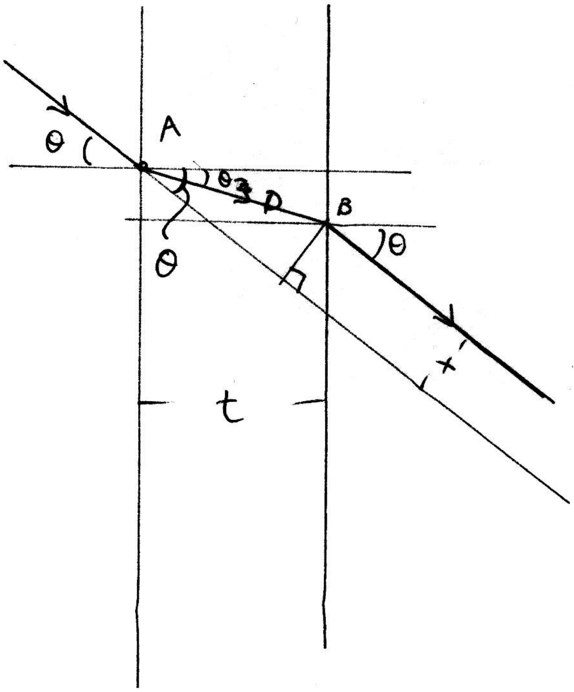
. 4 sheets

$I_4 = I_0 (\cos^2(\frac{90}{4}))^4 = 0.53079 I_0$

5 sheets

$$I_5 = I_0 \left(\cos^2\left(\frac{90}{5}\right)\right)^5 = \underline{60.5429\, I_0 \ !}$$

49



at the point A:

$$\cancel{n_{air}}\,1 \ \cancel{\sin}\,\theta = n\,\cancel{\sin\theta_2}\,\theta_2 \qquad \begin{pmatrix} \sin\theta \sim \theta \\ \sin\theta_2 \sim \theta_2 \end{pmatrix}$$

$$\theta_2 = \frac{\theta}{n} \quad \text{— ①}$$

let $\overline{AB} = D$

$$\cos\theta_2 = \frac{t}{D}$$

$$\therefore \ D = \frac{t}{\cos\theta_2} \sim t \quad \text{— ②}$$

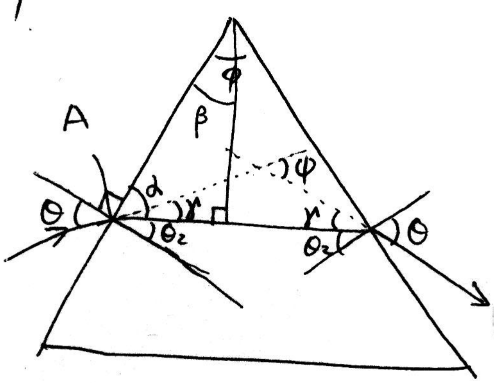
$$X = D \sin(\theta - \theta_2) \leftarrow ① \ \& \ ②$$

$$\sim t \sin\left(\theta - \frac{\theta}{n}\right)$$

$$= t \sin\left(\theta\, \frac{n-1}{n}\right)$$

$$\sim \underline{\underline{t\, \theta\, \frac{n-1}{n}}} \qquad \sin\left(\theta \frac{n-1}{n}\right) \sim \theta \frac{n-1}{n}$$

51



$$\cancel{n}\,1 \sin\theta = n \sin\theta_2$$

$$\therefore n = \frac{\sin\theta}{\sin\theta_2} \overset{?}{=} \frac{\sin\frac{1}{2}(\psi + \phi)}{\sin\frac{1}{2}\phi}$$

So let us prove $\theta = \frac{1}{2}(\psi + \phi)$

& $\theta_2 = \frac{1}{2}\phi$.

at point A.

$\alpha + \theta_2 = 90°$ $\Rightarrow$ $\beta = \theta_2$ (because $\alpha + \beta = 90°$)

the same thing happens on the left triangle at the summit

$\therefore \ \phi = 2\beta = 2\theta_2 \ \Rightarrow \ \underline{\underline{\theta_2 = \frac{1}{2}\phi}}$

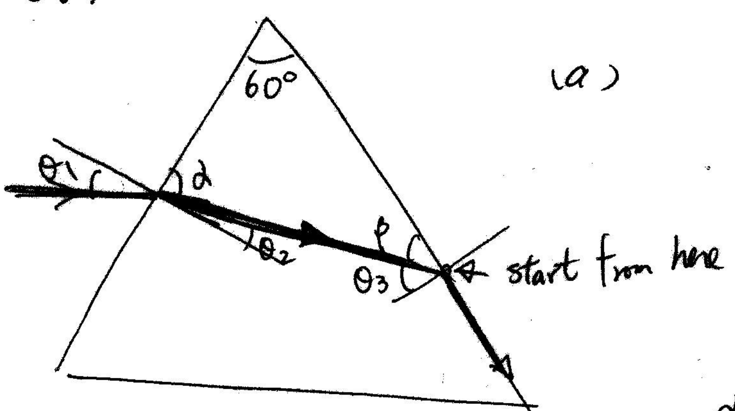
$$2\gamma = \psi \Rightarrow \gamma = \frac{1}{2}\psi$$

And

$$\theta = \gamma + \theta_2 = \frac{1}{2}\psi + \frac{1}{2}\phi = \underline{\underline{\frac{1}{2}(\psi + \phi)}}$$

$$\therefore \quad n = \frac{\sin\theta}{\sin\theta_2} = \frac{\sin\frac{1}{2}(\psi+\phi)}{\sin\frac{1}{2}\phi}$$

58.



(a)

$$n \sin\theta_3 = \cancel{\sin 90^\circ}\ 1$$

$$\theta_3 = \sin^{-1}\frac{1}{1.6} = 38.^\circ 682$$

$$\theta_3 + \beta = 90^\circ \Rightarrow \beta = 51.^\circ 3178$$

$$\alpha + \beta + 60^\circ = 180^\circ \Rightarrow \alpha = 68.^\circ 68$$

$$\alpha + \theta_2 = 90^\circ \Rightarrow \theta_2 = 21.^\circ 3178$$

$$\sin\theta_1 = n \sin\theta_2$$

$$\theta = \sin^{-1}(n \sin\theta_2)$$

$$= \sin^{-1}(1.6 \sin(21.^\circ 3178))$$

$$= \underline{\underline{35.^\circ 56776223}}$$

(b) To have a beam like #51, $\alpha = \beta = 60^\circ$ $(\theta_2 = \theta_3 = 30^\circ)$

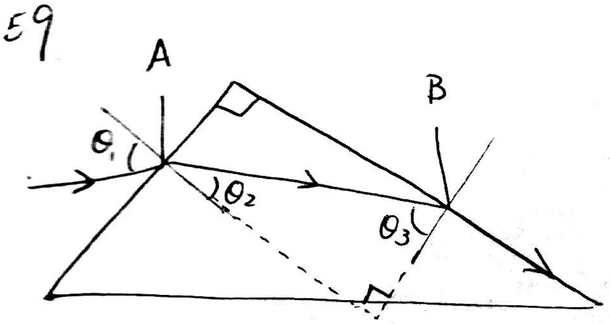
$$\theta_1 = \sin^{-1}(n \sin 30^\circ)$$

$$= \sin^{-1}(1.6 \cdot 0.5)$$

$$= \sin^{-1}(0.8)$$

$$= \underline{\underline{55.^\circ 1}}$$

59



(a) point A

$1 \sin\theta_1 = n \sin\theta_2 \longrightarrow \sin\theta_2 = \frac{\sin\theta_1}{n}$ — ①

point B

$n \sin\theta_3 = 1 \cancel{\sin 90°}\ 1$ & $\theta_3 = 90 - \theta_2$

$\Rightarrow n \sin(90 - \theta_2) = 1$

$n \cos\theta_2 = 1 \rightarrow \cos\theta_2 = \frac{1}{n}$ — ②

$①^2 + ②^2 = 1$

$\left(\frac{\sin\theta_1}{n}\right)^2 + \left(\frac{1}{n}\right)^2 = 1$

$\sin^2\theta_1 + 1 = n^2$

$\therefore n = \sqrt{\sin^2\theta_1 + 1}$

(b) max $\sin\theta_1 = 1$

$\therefore n = \sqrt{1^2 + 1} = \sqrt{2}$

(c) θ_3 increased → Total internal reflection

decreased → some will be refracted into the air

62. page 820, Fig. 34-19.

$n_{400nm} = 1.47$

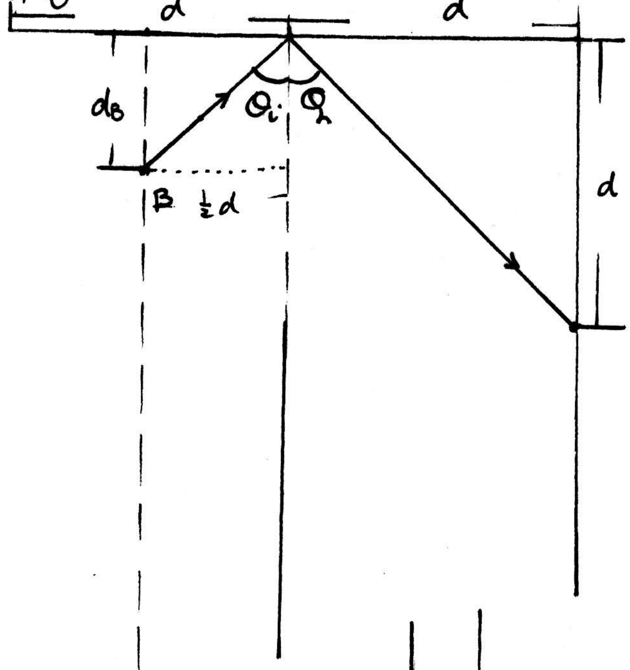
$n_{700\,nm} = 1.456$

$\theta_{B,400nm} = \tan^{-1} 1.47 = \underline{\underline{55.77^\circ}}$

$\theta_{B,700\,nm} = \tan^{-1} 1.456 = \underline{\underline{55.52^\circ}}$

ch 35 6, 10, 14, 15, 18, 20, 21, 24, 25, 29, 30, 33, 34, 36, 37

#6



Law of reflection : $\theta_i = \theta_r$

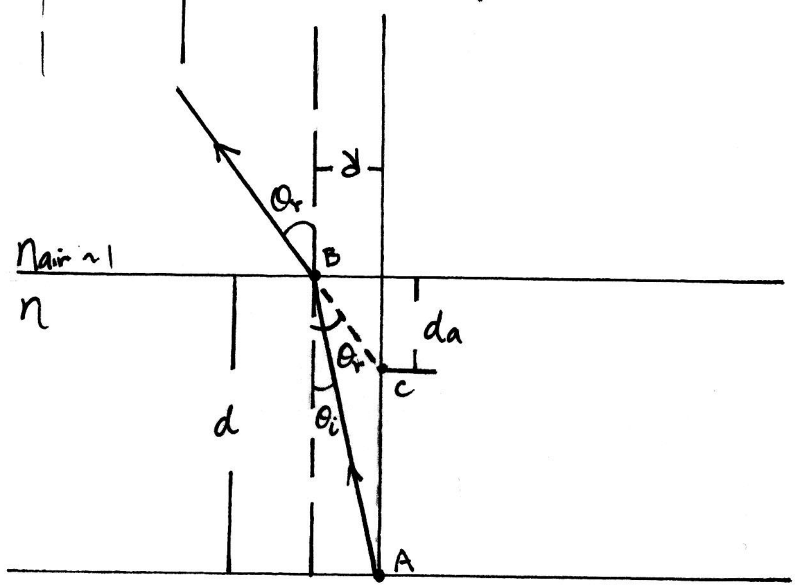
$\theta_r = \tan^{-1}\frac{d}{d} = 45°$

$\therefore \theta_i = 45° = \tan\frac{\frac{1}{2}d}{d_B}$

$\therefore d_B = \frac{1}{2}d = \frac{1}{2}\cdot 3m = \underline{\underline{1.5m}}$

(You should see the burglar <u>directly</u> before you see her in the mirror.)

#15



$$\overline{AB}\sin\theta_i = \overline{BC}\sin\theta_r = \gamma$$

$$d\tan\theta_i = d_a\tan\theta_r$$

$$\therefore d_a = d\frac{\tan\theta_i}{\tan\theta_r} \sim d\frac{\theta_i}{\theta_r} \quad — ①$$

Also,

$$n\sin\theta_i = n_{air}\sin\theta_r$$

$$n\sin\theta_i = \sin\theta_r$$

$$n\theta_i = \theta_r \Rightarrow \frac{\theta_i}{\theta_r} = \frac{1}{n} \quad — ②$$

① ← ②

$$\underline{\underline{d_a = d\frac{\theta_i}{\theta_r} = \frac{d}{n}}}$$

10.

	Type	f	r	i	p	m	Real or Virtual?	Invert or upright?
a	Concave	20	**40**	**-20**	+10	**+2**	**V**	**upright**
b	**flat**	**infinity**	**2Xinfinity**	**-10**	+10	+1.0	V	**upright**
c	**concave**	+20	**40**	**60**	+30	**+2**	**Real**	**invert**
d	**concave**	**+20**	**40**	**+30**	+60	-0.5	**real**	**invert**
e	**convex**	**-20**	-40	-10	**+20**	**+0.5**	**V**	**upright**
f	**convex**	20	**-40**	**-18**	**+180**	+0.10	**V**	**upright**
g	Convex	**-20**	40	4.0	**+5**	**+0.8**	**V**	**upright**
H	**concave**	**+8**	**+16**	**+12**	+24	0.50	**real**	Invert

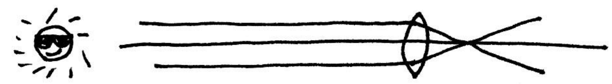
14.

	n_1	n_2	p	i	r	invert or upright?
a	1.0	1.5	+10	**-18**	+30	**upright**
b	1.0	1.5	+10	-13	**-32.5**	**upright**
c	1.0	1.5	**71**	+600	+30	**invert**
d	1.0	**0**	+20	-20	-20	**upright**
e	1.5	1.0	+10	-6.0	**30**	**upright**
f	1.5	1.0	**10**	-7.5	-30	**upright**
g	1.5	1.0	+70	**-26**	+30	**upright**
h	1.5	**-0.035**	+100	+600	-30	**invert**

24.

	type	f	r_1	r_2	i	p	n	m	Real or virtual	Upright or invert
a	C	10			**+20**	+20		**-1.0**	**real**	**invert**
b	**C**	+10			**-10**	+5.0		**+2.0**	**virtual**	**upright**
c	**C**	10			**-10**	+5.0		>1.0	**virtual**	**upright**
d	**D**	10			**-3.3**	+5.0		<1.0	**virtual**	**upright**
e	**C**	**30**	+30	-30	**-15**	+10	1.5	**+1.5**	**virtual**	**upright**
f	**D**	**-30**	-30	+30	**-7.5**	+10	1.5	**+0.75**	**virtual**	**upright**
g	**D**	**-120**	-30	-60	**-9.2**	+10	1.5	**+0.92**	**virtual**	**upright**
h	**D**	**-10**			**-5.0**	+10		0.5	**virtual**	upright
i	**C**	**+3.3**			**+5.0**	+10		-0.5	**real**	**invert**

18 $\quad |m| = \dfrac{h'}{h}$



$\therefore h' = h\,|m|$

$= h\,\left|\dfrac{i}{p}\right|$

$= h\,\left|\dfrac{f}{p}\right|$ (in this case)

Because the object is so far away, the image appears at the focal pt $\Rightarrow i = f$

$= \underset{R_\odot}{2 \times (2.96 \times 10^8 m)} \left|\dfrac{0.2m}{1.5 \times 10^{11} m}\right|$

$= \underline{\underline{1.856\ mm}}$

20

(a) $\quad \dfrac{1}{p} + \dfrac{1}{i} = \dfrac{1}{f} = (n-1)\left(\dfrac{1}{r_1} - \dfrac{1}{r_2}\right)$

$\dfrac{1}{f} = (1.5-1)\left(\dfrac{1}{0.2} - \dfrac{1}{\infty}\right)$

$= 0.5 \left(\dfrac{1}{0.2}\right)$

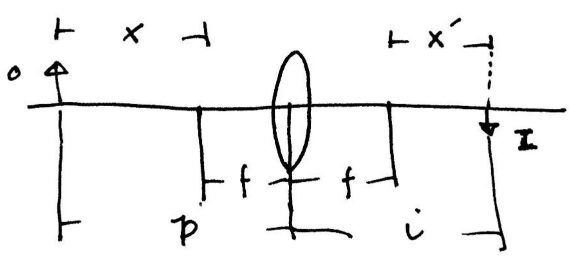
$= \dfrac{5}{2} = 2.5$

$f = \dfrac{10}{2.5} = 0.4\ m = \underline{\underline{40 cm}}$

(b) $\quad \dfrac{1}{0.4} + \dfrac{1}{i} = \dfrac{1}{0.4}$

$\underline{\underline{i = \infty}}$

21



$p = x + f$

$i = x' + f$

$\dfrac{1}{p} + \dfrac{1}{i} = \dfrac{1}{f}$

$\dfrac{1}{x+f} + \dfrac{1}{x'+f} = \dfrac{1}{f}$

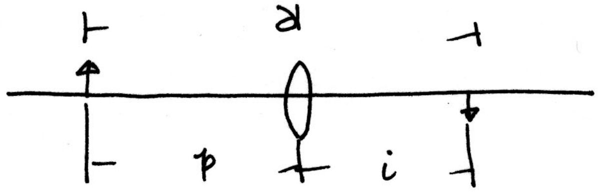
$\dfrac{(x'+f)+(x+f)}{(x+f)(x'+f)} = \dfrac{1}{f}$

$\rightarrow f(x'+f+x+f) = (x+f)(x'+f)$

$fx' + f^2 + xf + f^2 = xx' + xf + fx' + f^2$

$\underline{\underline{f^2 = xx'}}$

25.



$$d = p + i \Rightarrow i = d - p$$

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

$$\frac{1}{p} + \frac{1}{d-p} = \frac{1}{f}$$

$$\frac{d - p + p}{p(d-p)} = \frac{1}{f}$$

$$\frac{d}{p(d-p)} = \frac{1}{f}$$

Solve for d (the total dist.)

$$d f = p(d - p)$$

$$d f - d p = -p^2$$

$$d(f - p) = -p^2$$

$$\therefore \quad d = \frac{-p^2}{(f-p)} \qquad \text{——————} \quad ①$$

d as a fcn. of p. If we can show the smallest $d = 4f$, then the proof is done.

to minimize d:

$$\frac{dd}{dp} = \frac{-2p}{(f-p)} - \frac{p^2}{(f-p)^2} = \frac{-2p(f-p) - p^2}{(f-p)^2} = \frac{-2pf + 2p^2 - p^2}{(f-p)^2}$$

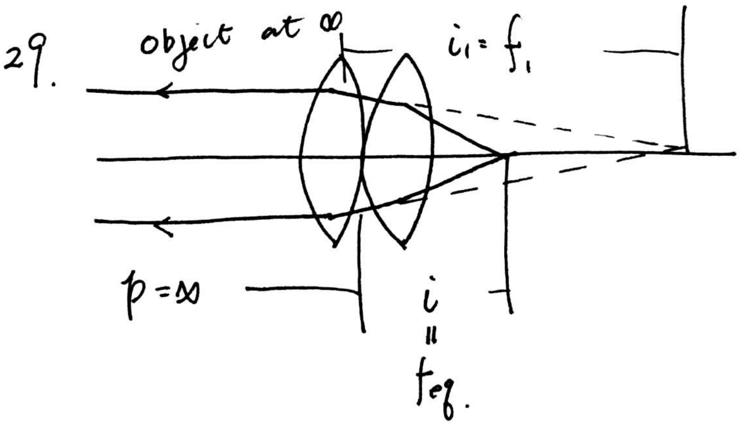
$$= \frac{-2pf + p^2}{(f-p)^2} = \frac{p(-2f + p)}{(f-p)^2} = 0$$

$\therefore \quad p = 0$ or $2f$. (0 is not possible)

Eqn. ①. @ $p = 2f$

$$d = \frac{-(2f)^2}{(p-2f)} = \underline{\underline{4f}}$$

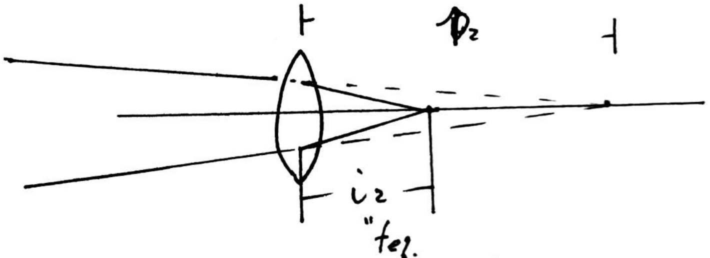
29.



1st lens.

$$\cancel{\frac{1}{p_1}}^{\,0} + \frac{1}{i_1} = \frac{1}{f_1} \qquad \therefore\ i_1 = f_1$$

2nd lens



Notice that for the second lens.
the image created by the first
lens is p_2

$\therefore\ i_1 = f_1 = p_2$

$$\frac{1}{p_2} + \frac{1}{i_2} = \frac{1}{f_2}$$

$$-\frac{1}{f_1} + \frac{1}{f_{eq}} = \frac{1}{f_2}$$

Because the image forms on the same side of the object (the image created by the 1st lens)

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$= \frac{f_1 + f_2}{f_1 f_2}$$

$$\therefore\ f_{eq} = \frac{f_1 f_2}{f_1 + f_2}$$

30 (a) convex

(b) $m = \frac{i}{p} = 0.5$ & $p + i = 40cm$

$i = 0.5p$

$\therefore p + 0.5p = 40cm$

$1.5p = 40cm$

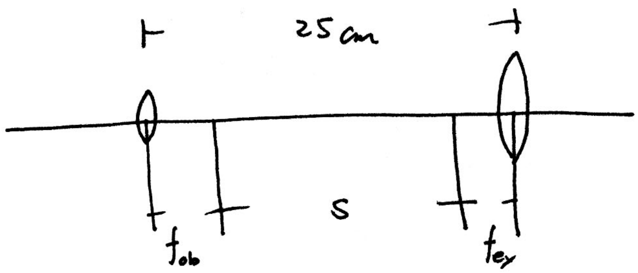
$p = 26.\dot{6}\,cm$ ($i = 13.\dot{3}\,cm$)

(c) $\frac{1}{i} + \frac{1}{p} = \frac{1}{f}$

$\frac{1}{13.\dot{3}} + \frac{1}{26.\dot{6}} = \frac{1}{f}$

$\therefore f = 8.\dot{8}\,cm$

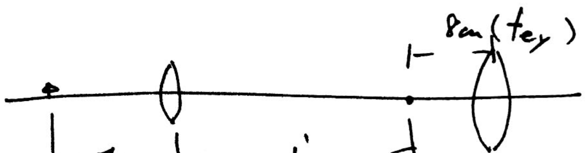
33



(a) $S = 25cm - f_{ob} - f_{ey}$

$= 25\,cm - 4\,cm - 8\,cm = 13\,cm$

(b)



$i = 25cm - 8cm = 17cm$

$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$

$\frac{1}{p} + \frac{1}{17} = \frac{1}{4}$

$\frac{1}{p} = \frac{1}{4} - \frac{1}{17} = 0.19117647$

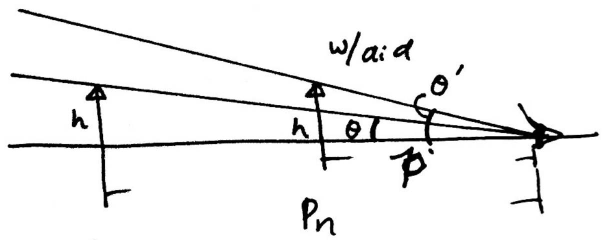
$p = 5.23\,cm$

(c) $m = -\frac{i}{p} = -\frac{17}{5.23} = \underline{\underline{-3.25}}$

(d) $m_\theta = \frac{25\text{ cm (for average?)}}{f_{ey}} = \underline{\underline{3.125}}$

(e) $M = m\, m_\theta = \underline{\underline{-10.15625}}$

34



(a) w/o. aid

$$m_\theta = \frac{\theta'}{\theta} = \frac{\tan^{-1}\frac{h}{p}}{\tan^{-1}\frac{h}{p_n}} = \frac{\frac{h}{p}}{\frac{h}{p_n}} = \frac{p_n}{p} \quad \text{—— ①}$$

Also

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

another negative because both p & i are on the same side

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{i} = \frac{1}{f} + \frac{1}{p_n}$$

$$= \frac{p_n + f}{f p_n} \quad \text{—— ②}$$

① ← ②

$$m_\theta = p_n \cdot \left(\frac{p_n + f}{f p_n}\right) = \underline{\underline{\frac{p_n + f}{f}}}$$

(b) sine $i = \infty$

$$\frac{1}{p} = \frac{1}{f}.$$

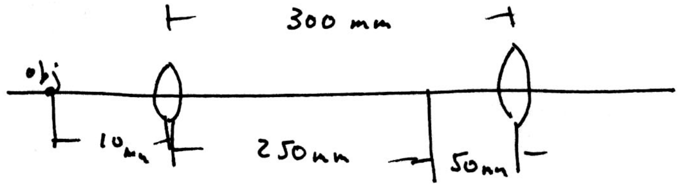
Eqn 1.

$$m_\theta = \frac{p_n}{p} = \underline{\underline{\frac{p_n}{f}}}$$

(c) If $p_n = 25\text{cm}$,

(a) $m_\theta = \frac{25+10}{10} = \underline{\underline{3.5}}$ (b) $m_\theta = \frac{25}{10} = \underline{\underline{2.5}}$

36



$$f_{ey} = 50mm$$

$$\frac{1}{p_{ob}} + \frac{1}{i_{ob}} = \frac{1}{f_{ob}}$$

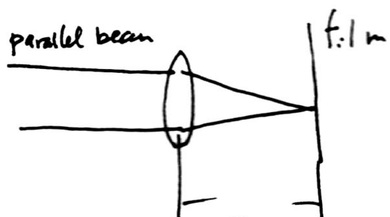
$$\frac{1}{10} + \frac{1}{250} = \frac{1}{f_{ob}} \Rightarrow f_{ob} = 9.615384615 mm$$

$$M = m m_\theta = -\frac{S}{f_{ob}} \frac{25cm}{f_{ey}}$$

$$S = 300 - 9.615.. - 50 = 240.3840134 mm$$

$$\therefore M = -\frac{240.3840134 mm}{9.61538461 mm} \cdot \frac{250 mm}{50 mm} = \underline{\underline{-125}}$$

37



$$50mm = 5cm = i = f$$

(a)

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

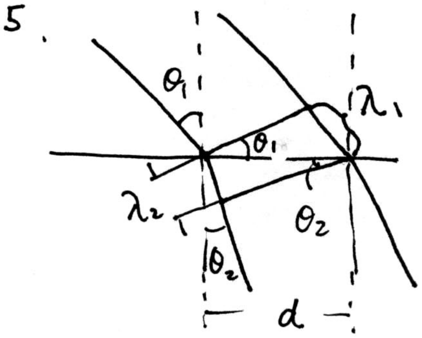
$$\frac{1}{100} + \frac{1}{i} = \frac{1}{5} \Rightarrow i = \underline{\underline{5.263157895 cm}}$$

(b) the diff. $= \underline{\underline{0.263157895 cm}}$

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. $v = \frac{c}{n} \Rightarrow n = \frac{c}{v} = \frac{3\times10^8 \text{ m/sec}}{1.92\times10^8 \text{ m/sec}} = \underline{\underline{1.5625}}$

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

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

$\therefore \frac{\sin\theta_2}{\sin\theta_1} = \frac{\lambda_2}{\lambda_1} = \frac{\frac{v_2}{\nu}}{\frac{v_1}{\nu}} = \frac{v_2}{v_1}$ $\left[\begin{matrix} v = \lambda\nu \\ \lambda = \frac{v}{\nu} \end{matrix}\right]$

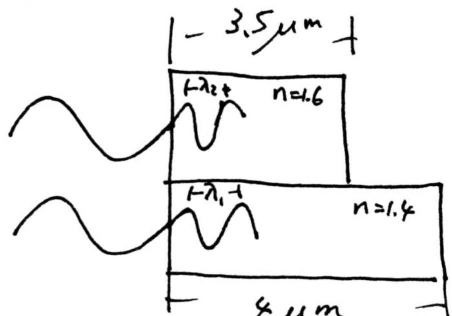
$\sin\theta_2 = \frac{v_2}{v_1}\sin\theta_1$

$\theta_2 = \sin^{-1}\left[\frac{v_2}{v_1}\sin\theta_1\right]$

$= \sin^{-1}\left[\frac{3}{4}\sin 30^\circ\right] = \underline{\underline{22.^\circ 0243128}}$

9.

(a)



$\lambda = 600\times10^{-9}$ m

$\lambda_2 = \frac{600\times10^{-9}\text{ m}}{1.6} = 375$ nm

$\lambda_1 = \frac{600\times10^{-9}\text{ m}}{1.4} = 428.5714286$ nm

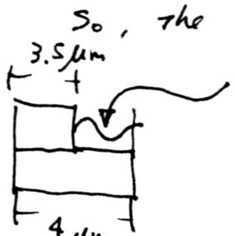
How many λ's in the media?

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

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

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

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

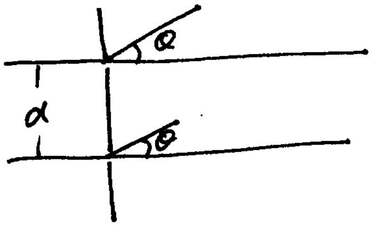


This difference causes ϕ. Also λ is back to 600 n.m.

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

(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

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

Second

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

third

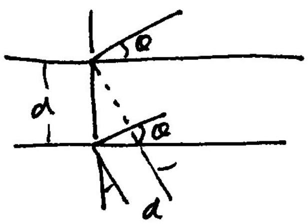
$d\sin\theta = 2.5\lambda \rightarrow 5\pi$ rad off

$\vdots$

m th

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

15.



for $\theta < 10°$

$d\sin\theta = m\lambda$

$d\theta \sim m\lambda$

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

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

& $\theta_2 = \frac{m\lambda_2}{d}$ (different λ's & the same mth spot)

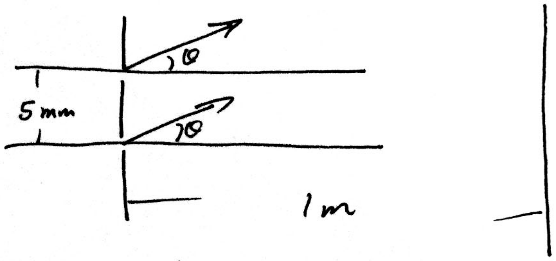
& $\theta_1 = 10\%$ greater than $\theta_2 = 1.1\theta_2$

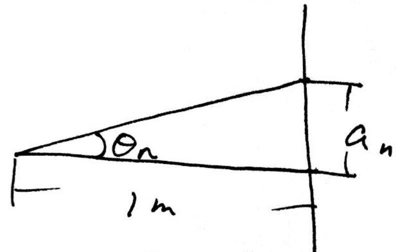
$$\frac{\theta_1}{\theta_2} = \frac{\frac{\cancel{m}\lambda_1}{\cancel{d}}}{\frac{\cancel{m}\lambda_2}{\cancel{d}}} = \frac{1.1\theta_2}{\theta_2}$$

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

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

19.





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

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

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

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

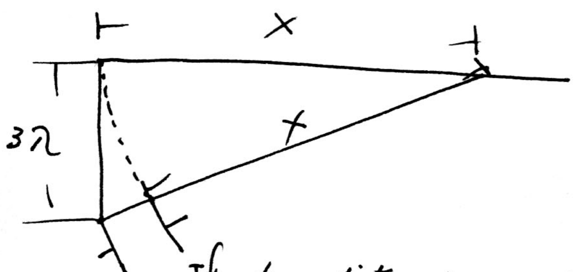
$a_1 - a_2$

$\Delta a = a_1 - a_2$

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

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

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

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

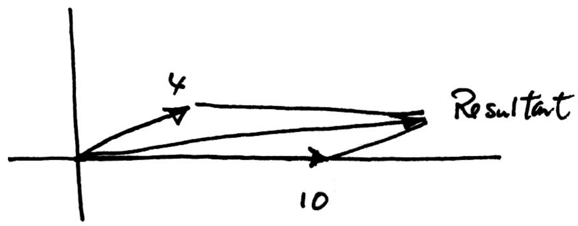
$x^2+(3\lambda)^2 = (x+\frac{1}{2}\lambda)^2$

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

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

24. at $t=0$

$$y_1 = 10 \quad \text{———} \quad 10\hat{i} + 0\hat{j}$$
$$y_2 = 8 \sin(\omega t + 30°) \rightarrow 8\cos 30°\hat{i} + 8\sin 30°\hat{j}$$



$$y_T = y_1 + y_2 = (10 + 8\cos 30°)\hat{i} + (0 + 8\sin 30°)\hat{j}$$
$$= 16.92820323\hat{i} + 4\hat{j}$$
$$|y_T| = 17.39436876$$
$$\phi = \tan^{-1}\frac{y_{T,\hat{j}}}{y_{T,\hat{i}}} = 13.29468619°$$

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

25 Same method used in #24

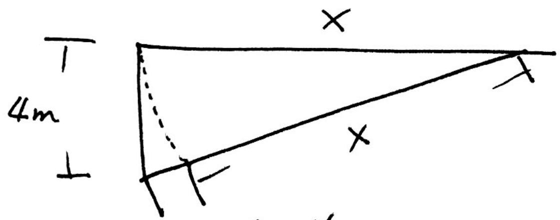
at $t=0$

$$y_1 = 10\hat{i} + 0\hat{j}$$
$$y_2 = 15\cos 30°\hat{i} + 15\sin 30°\hat{j}$$
$$y_3 = 5\cos(-45°)\hat{i} + 5\sin(-45°)\hat{j}$$
$$= 5\cos(45°)\hat{i} - 5\sin(45°)\hat{j}$$

$$y_T = (10 + 15\cos 30° + 5\cos 45°)\hat{i} + (0 + 15\sin 30° - 5\sin 45°)\hat{j}$$
$$= 26.52591496\hat{i} + 3.964466094\hat{j}$$

$$|y_T| = 26.82053609$$
$$\phi = \tan^{-1}\frac{y_{T,\hat{j}}}{y_{T,\hat{i}}} = 8.500299048°$$
$$\underline{\underline{y = 26.82 \sin(\omega t + 8.50°)}}$$

27.



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

$m = 1$

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

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

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

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

$2x = 15$

$\underline{x = 7.5m}$

$m = 2$

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

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

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

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

$4x = 12$

$\underline{x = 3m}$

$m = 3$

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

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

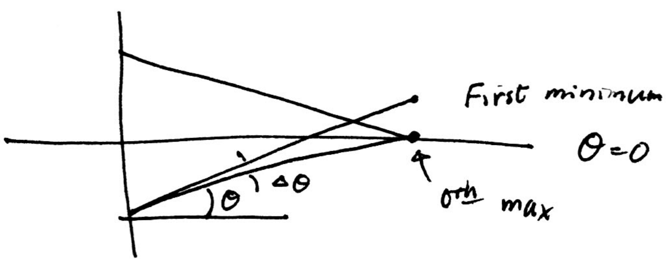
$x^2+4^2 = (x+3)^2$

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

$6x = 7$

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

28.



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

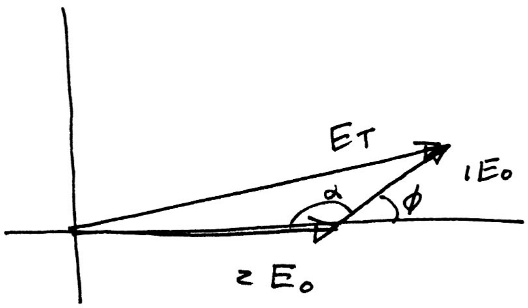
because $\theta = 0$ for the 0th so "θ" = "$\Delta\theta$" in this case

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

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

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

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.

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

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

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

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

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

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

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

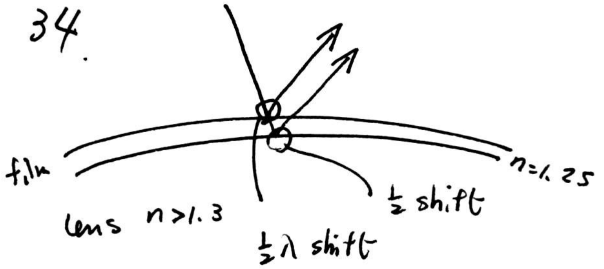
1st $L = \frac{1}{4}\lambda$

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

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

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

34.

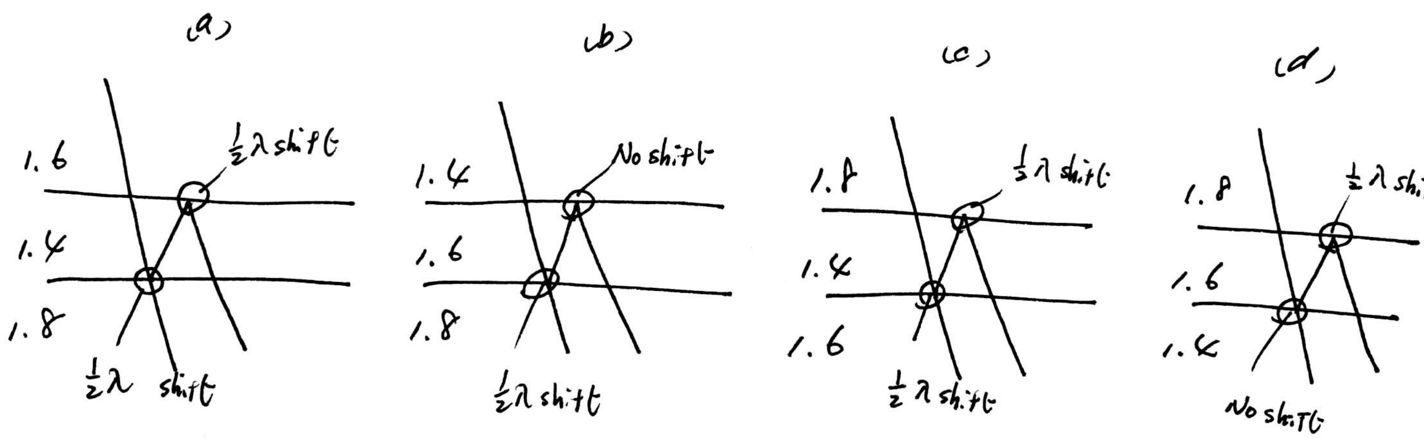


To cancel the reflected beams, 2d should be equal to $\underline{\underline{\frac{1}{2}\lambda}}$ (be careful that λ is changed in the film)

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

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

38



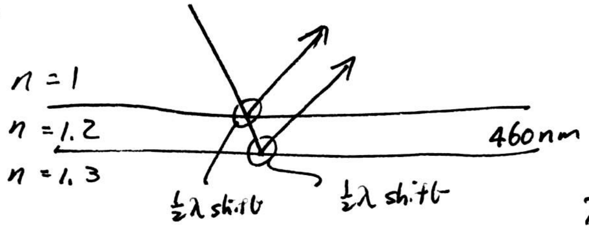
shift Total 1λ   ½λ   1λ   ½λ

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)

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

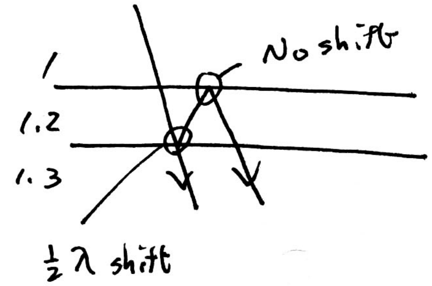
$$\lambda = \frac{2Ln_2}{m}$$

$$\lambda_1 = 2Ln_2 = 2\cdot 460nm\cdot 1.2 = \underline{1104\ nm}$$

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

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

(b)



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

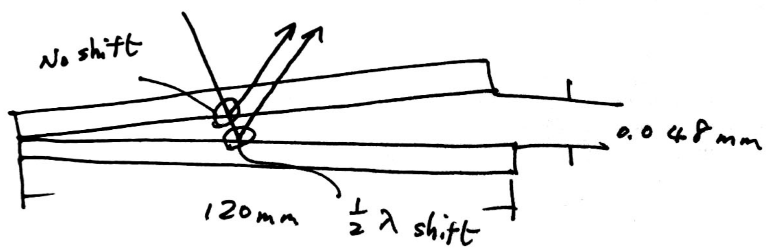
$$\lambda = \frac{2Ln_2}{m+\frac{1}{2}}$$

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

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

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

43.



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

Solve for m.

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

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

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

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

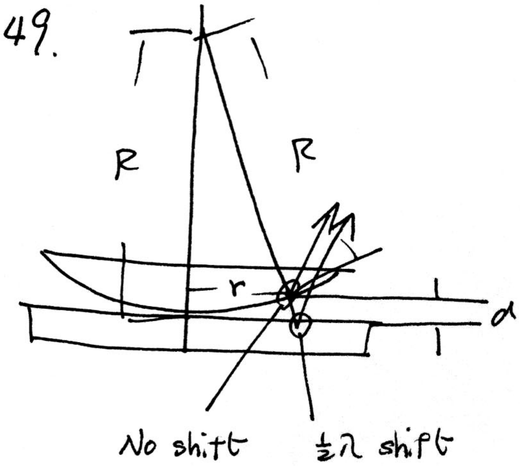
(b) $2L = (m+\frac{1}{2})\lambda$ bright

$2L = m\lambda$ dark.

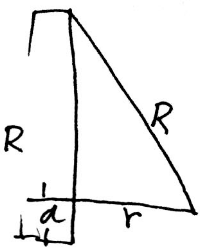
shorter the λ, shorter the L.

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

49.



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



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

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

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

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

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

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

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

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

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

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

50. Solving for m

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

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

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

Since m starts with "0", 33 means <u>34 fringes</u>

(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.

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

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

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

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

52. Binomial theorem

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

So the eqn. derived in #49

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

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

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

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

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

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

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

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

(b)

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

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

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

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

$\frac{1}{4m} \approx 0$ 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.

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

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

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

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

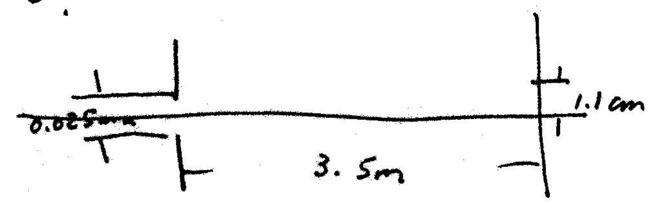
$$n_A = \frac{60\lambda}{2L} + 1$$

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

$$= 1.0003$$

ch. 37 $\quad$ 10. 11. 28, 29. 30. 32, 34, 37, 38, 41, 45, 47. 48
51, 52

10.



$\lambda = 538\,nm$

$\tan^{-1} \frac{1.1\,cm}{3.5\,m} = 0.°18007185$

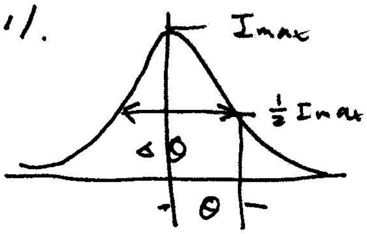
(a)

$$\frac{1}{2}\phi = \frac{\pi a}{\lambda}\theta =$$

$$\phi = 0.45880707\ rad \quad \rightarrow \quad \alpha = \frac{1}{2}\phi$$

$$I(\theta) = I_{max}\left(\frac{\sin\alpha}{\alpha}\right)^2 = \underline{0.93177215\ I_{max}}$$

11.



(a) $I(\theta) = I_{max}\left(\frac{\sin\alpha}{\alpha}\right)^2 = \frac{1}{2} I_{max}$

$$\therefore \sin^2\alpha = \frac{\alpha^2}{2}$$

when $\alpha = 1.39\ rad$

(b) $\frac{\sin^2\alpha}{\alpha^2} = 0.500837064$ ✓ ($\frac{1}{2}$ max)

(c) $\alpha = \frac{\pi a}{\lambda}\sin\theta$

$$\therefore \theta = \sin^{-1}\frac{\alpha\lambda}{\pi a} = \sin^{-1}\left(\frac{1.39\lambda}{\pi a}\right) = \sin^{-1}\left((0.44245071)\frac{\lambda}{a}\right)$$

$$\underline{\underline{\Delta\theta = 2\theta = 2\sin^{-1}\left(\frac{0.44245..}{a}\lambda\right)}}$$

(d)

$a = 1\lambda$ $\quad \Delta\theta = 2\sin^{-1}\left(0.44245..\ \frac{\lambda}{\lambda}\right) = \underline{0.91665924\,3\ rad}$

$= \underline{52.°5207591}$

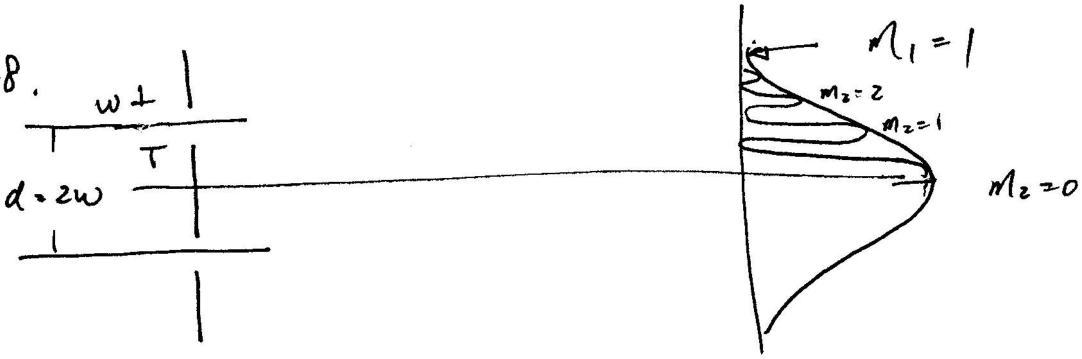
$a = 5\lambda$ $\quad \Delta\theta = \quad ''\left(\ ...\ \frac{\lambda}{5\lambda}\right) = \underline{0.08860604\,4\ rad}$

$= \underline{5.°07675 2379}$

$a = 10\lambda$ $\quad \Delta\theta = \quad ''\left(\quad \frac{\lambda}{10\lambda}\right) = \underline{0.088519045\ rad}$

$= \underline{5.°07176 7719}$

28.



Single slit $\quad a \sin\theta = m_1 \lambda$ (dark) ⟶ ①

Double slit $\quad d \sin\theta = m_2 \lambda$ (bright) — ②

From the ~~ot~~ order to the first dark region, how many m_2's can we have?

where does first dark occur?

Eq ①. $\quad a \sin\theta = m_1 \lambda$

$$\sin\theta = \frac{\lambda}{a} \quad (m_1 = 1\text{st}) \quad — ①'$$

② ⟵ ①'

$$d\left(\frac{\lambda}{a}\right) = m_2 \lambda$$

$$m_2 = \frac{d}{a} = \frac{2a}{a} = 2$$ → w/ the center the total is $\underline{\underline{3}}$

29. If the first minimum $(m_1 = 1)$ due to the single slit happens at the same spot that bright happens due to the double slitness then they cancel (In this case $m_2 = 4$)

(a)

$$\begin{cases} a \sin\theta = 1\lambda & \rightarrow \sin\theta = \frac{\lambda}{a} \quad — ① \\ d \sin\theta = 4\lambda & ——— ② \end{cases}$$

② ⟵ ①

$$d\,\frac{\lambda}{a} = 4$$

$$\therefore \underline{\underline{d = 4a}}$$

(b)

$$\begin{cases} a \sin\theta = m_1 \lambda & — ① \\ 4a \sin\theta = m_2 \lambda & — ② \end{cases}$$

② ⟵ ①

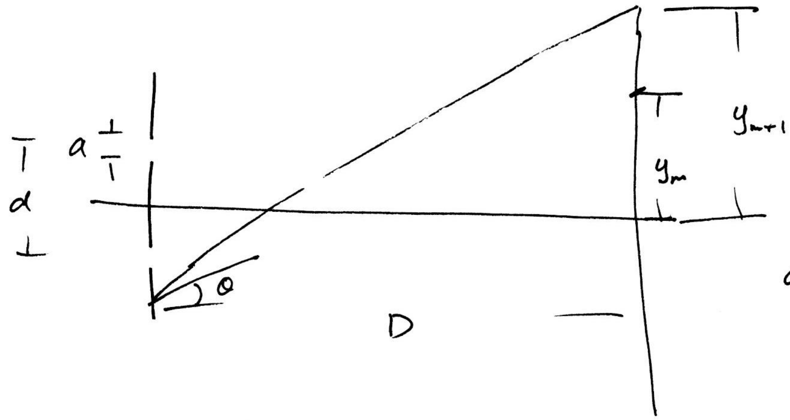
$$4(m_1 \lambda) = m_2 \lambda$$

$$4m_1 = m_2$$

Missing bright spots are when

$\underline{\underline{m_2 = 4, 8, 12, \ldots}}$

30



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

$$\Rightarrow \sin\theta = \frac{m\lambda}{d} \quad \text{—①}$$

$$y = D\sin\theta$$

$$\Delta y = \Delta(D\sin\theta) \leftarrow ①$$

$$= \Delta\left(D\frac{m\lambda}{d}\right)$$

$$= \frac{D\lambda}{d}\cdot\Delta m \qquad \text{since the diff. is } (M+1)\ \&\ m \to 1$$

$$= \frac{D\lambda}{d}$$

32. (a) the first maximum occurs at 5°

$$a\sin\theta = \lambda$$

$$\therefore a = \frac{\lambda}{\sin\theta} = \frac{440\,nm}{\sin 5^\circ} = 5.048433828\ \mu m$$

(b) 4^{th} is missing $d = 4a = 20.19373531\ \mu m$

(c) $I(\theta) = I_{max}\left(\frac{\sin\alpha}{\alpha}\right)^2$ (this intensity should be the same w/ I with Double slit eqn.)

$$\alpha = \frac{\pi a \sin\theta}{\lambda}$$

$$d\sin\theta = m_2\lambda \quad \text{when } m_2 = 1$$

$$\theta = \sin^{-1}\frac{\lambda}{d} = 1.248512858^\circ$$

$$\alpha = 0.785398163\ \text{rad}$$

$$= 7\left(\frac{mW}{cm^2}\right)\left(\frac{\sin\alpha}{\alpha}\right)^2 = 5.673986\ \frac{mW}{cm^2}$$

this matches w/ the graph!

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

$$\sin\theta = \frac{m\lambda}{d} = \frac{5\lambda}{d} < 1$$

$$\lambda < \frac{d}{5} = \frac{\frac{1\,mm}{315}}{5} = \underline{634.9206\ nm}$$

$\underline{\underline{\text{any } \lambda \text{ shorter than } 634.9206\,nm}}$

37

$\sin\theta_m = 0.2$ — m^{th}

$\sin\theta_{m+1} = 0.3$ — $(m+1)^{th}$

(a) $d \sin\theta = m\lambda$

$d(0.2) = m\lambda$ —— ①

$d(0.3) = (m+1)\lambda$ —— ②

② − ①

$$\begin{array}{rl} 0.3d = & (m+1)\lambda \\ -)\ 0.2d = & m\lambda \\ \hline 0.1d = & \lambda \end{array}$$

$$d = \frac{\lambda}{0.1} = \frac{600\,nm}{0.1} = \underline{\underline{6\,\mu m}}$$

(b)

$$\begin{cases} a \sin\theta = m_1\lambda & (m_1 = 1) \text{ — Single slit} \\ d \sin\theta = m_2\lambda & (m_2 = 4) \text{ — Double slit} \end{cases}$$

Solve for a

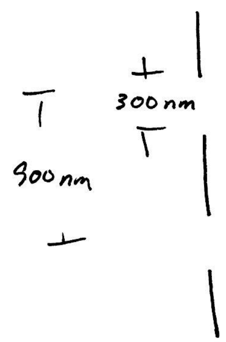
$$a\frac{m_2\lambda}{d} = m_1\lambda \Rightarrow a = \frac{d}{m_2} = \frac{6\,\mu m}{4} = \underline{\underline{1.5\,\mu m}}$$

(c) $d \sin\theta = m\lambda$

$$m = \frac{d \cancel{\sin\theta}\, 1}{\lambda} = \frac{6\,\mu m}{600\,nm} = 10$$

$m = 10^{th}$ at $90°$ but it is not possible → $\underline{\underline{m_{max} = 9}}$

38



(a) $d \sin \theta = m \lambda$

for θ_{max}, $m = max \rightarrow \sin\theta = 1$

$d = m\lambda$

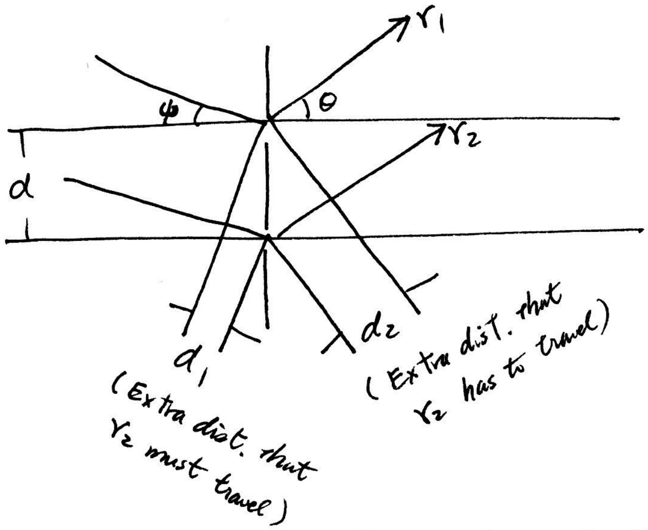
$$m = \frac{d}{\lambda} = \frac{900\ nm}{600\ nm} = 1.5$$

So, we have, 0^{th}, $\pm 1^{st} \Rightarrow \underline{\underline{3}}$

(b) $$\theta_{hw} = \frac{\lambda}{Nd\cos\theta} = \frac{d\sin\theta}{Nd\cos\theta} = \frac{1}{N}\tan\theta$$

$$= \frac{1}{1000}\tan\theta = \underline{\underline{0.051}}$$

41



so r_2 must travel the total dist of d_1 & d_2. If this total dist. is a multiple of λ, it construct.

$d_T = d_1 + d_2 = d\sin\phi + d\sin\theta = \underline{\underline{d(\sin\phi + \sin\theta) = m\lambda}}$

$m = 0, 1, 2 \ldots$

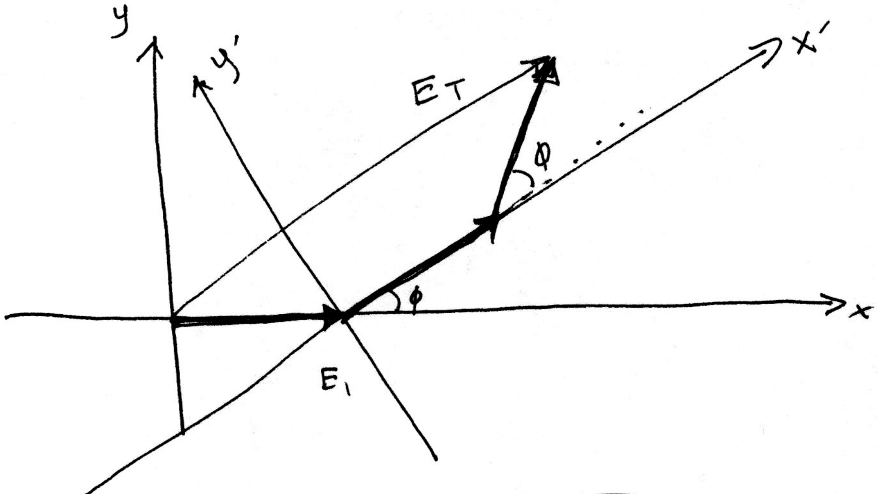
45.

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

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

$E_3 = E_0 \sin(\omega t + 2\phi)$

Each has E_0 magnitude & they are off by ϕ each



$$\phi = 2\pi \frac{d \sin\theta}{\lambda}$$

using $x'-y'$ coordinate system.

$$E_T = E_0 \cos\phi + E_0 + E_0 \cos\phi$$
$$= E_0 (1 + 2\cos\phi)$$

(Notice $E_y = 0$ w/ this system)

$$I_0 \propto (3E_0)^2 = 9E_0^2 \Rightarrow E_0^2 \propto \frac{1}{9} I_0$$

$$I \propto (E_T)^2 = E_0^2 (1 + 2\cos\phi)^2 = E_0^2 (1 + 4\cos\phi + 4\cos^2\phi)$$
$$= \frac{1}{9} I_0 (1 + 4\cos\phi + 4\cos^2\phi)$$

47

$$N m = R = \frac{\lambda_{AVE}}{\Delta\lambda}$$

$$\therefore N = \frac{\lambda_{ave}}{m \Delta\lambda} = \frac{656.3\,nm}{0.18\,nm} = 3650 \text{ rulings}$$

(m = 1)

48.

(a)

$$Nm = R = \frac{\lambda_{Ave}}{\Delta\lambda}$$

$$\Delta\lambda = \frac{\lambda_{ave}}{Nm} = \frac{500\,nm}{(600/mm \cdot 5\,mm) \cdot 3} = 0.056\,nm$$

(b)

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

$$m_{max} = \frac{d \sin\theta}{\lambda} = 3.3$$

($\sin\theta$ = 1)

$m_{max} = 3 \rightarrow$ No higher than 3

51

$$R = \frac{\lambda_{ave}}{\Delta\lambda} = Nm$$

(a)

$$\Delta\lambda = \frac{\lambda_{ave}}{Nm} \quad \text{—— ①}$$

Also $\quad C = \lambda \nu$

$$dC = d\lambda \cdot \nu + \lambda \cdot d\nu = 0 \quad (\text{since } C \text{ is const})$$

$$|d\lambda| = \left| -\frac{\lambda\, d\nu}{\nu} \right| \quad \text{—— ②}$$

① ← ②

$$\frac{\lambda d\nu}{\nu} = \frac{\lambda_{ave}}{N \cdot m}$$

$$d\nu = \frac{\nu \cancel{\lambda_{ave}}}{\cancel{\lambda} N m} = \underline{\underline{\frac{c}{\lambda N m}}} \quad \text{—— ①}'$$

(b)

$$L = (N-1)\, d \sin\theta$$

$$\therefore \underline{\underline{t = \frac{(N-1)\, d \sin\theta}{c}}} \qquad \text{for large } N, \quad \underline{\underline{t \approx \frac{N d \sin\theta}{c}}} \quad \text{—— ③}$$

(c)

$$\underset{①'}{d\nu} \cdot \underset{③}{t} = \frac{c}{\lambda N m} \cdot \frac{N d \sin\theta}{c} = \frac{d \sin\theta}{m\lambda} = 1$$

52

$$\Delta\theta_{hw} = \frac{\lambda}{N d \cos\theta}, \qquad R = \frac{\lambda_{ave}}{\Delta\lambda} = Nm$$

(a)

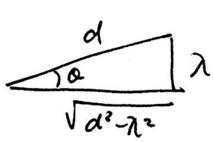
$$\Delta\theta_{hw} \cdot R = \frac{\lambda}{N d \cos\theta} \cdot Nm = \frac{m\lambda}{d\cos\theta}$$

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

$$= \frac{d\sin\theta}{d\cos\theta} = \underline{\underline{\tan\theta}}$$

(b) $\quad$ for $m = 1 \qquad d\sin\theta = \lambda$

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



$$\rightarrow \tan\theta = \frac{\lambda}{\sqrt{d^2-\lambda^2}} = \frac{600\text{ nm}}{\sqrt{(900\text{nm})^2 - (600\text{ nm})^2}} = \underline{\underline{0.89}}$$