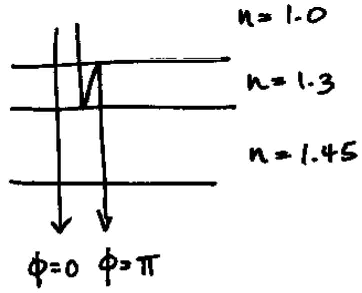
Phy 101 Part III Answers

(1)



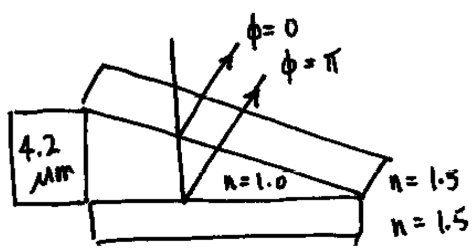
- Sources are out of phase
- We want destructive interference

$\Rightarrow pd = m\lambda_n \qquad \lambda_n = \frac{\lambda}{n}$

$\Rightarrow 2t = m\frac{\lambda}{n} \qquad m = 1, 2, 3 \ldots$

$\Rightarrow t = \frac{1}{2}\left(m\frac{\lambda}{n}\right) = \frac{1}{2}\left(1 \cdot \frac{500}{1.3}\right) = 192\text{nm}$

(2) a)



We want constructive interference for sources that are out of phase

$\Rightarrow pd = (m+\frac{1}{2})\lambda_n \qquad m = 0, 1, 2 \ldots$

$\Rightarrow 2t = (m+\frac{1}{2})\lambda_n$

$\Rightarrow 2(4.2 \times 10^{-6}) = (m+\frac{1}{2})434 \times 10^{-9}$

$\Rightarrow m = 18.85 \Rightarrow m = 18 \Rightarrow$ 19 bright bands

[m started at m=0]

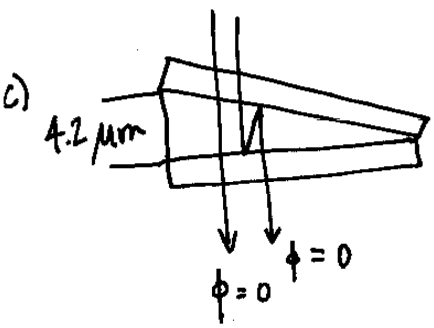
b) under water $\lambda_n = \frac{\lambda}{1.3}$

$\Rightarrow 2t = (m+\frac{1}{2})\frac{\lambda}{1.3} \qquad m = 0, 1, 2 \ldots$

$\Rightarrow 2(4.2 \times 10^{-6}) = (m+\frac{1}{2})\left(\frac{434 \times 10^{-9}}{1.3}\right)$

$\Rightarrow m = 24.66 \Rightarrow m = 24 \Rightarrow$ 25 fringes

c)



Sources are in phase

$pd = m\lambda_n \qquad m = 1, 2, 3 \ldots$

$2t = m\lambda$

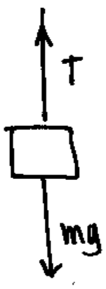
$2(4.2 \times 10^{-6}) = m(434 \times 10^{-9})$

$m = 19.35$

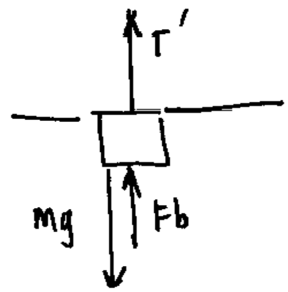
$\Rightarrow m = 19 \Rightarrow$ 19 fringes

[m started at m=1]

(3)



$$T = mg = 1(9.8) = 9.8\,N$$



$$T' + F_b = mg$$

$$T' + \rho_{H_2O} V_{block} \cdot g = mg$$

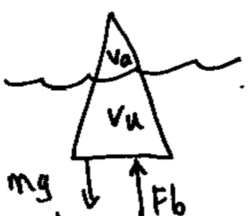
$$T' + \rho_{H_2O} \frac{m_{block}}{\rho_{Al}} \cdot g = mg$$

$$T' = 1(9.8) - \frac{1000}{2.7\times10^3} \cdot 1 \cdot 9.8$$

$$T' = 6.2\,N$$

$$\Rightarrow \Delta T = 9.8 - 6.2 = \underline{\underline{3.6\,N}}$$

(4)



V_a = Vabove
V_u = Vunder

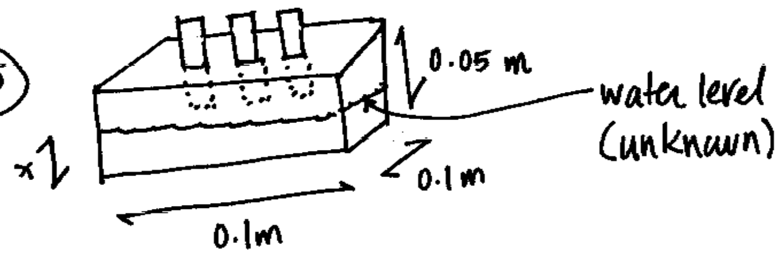
$$F_b = V_{under} \cdot \rho_{H_2O} \cdot g = mg$$

$$\Rightarrow V_u \cdot \rho_{H_2O} \cdot \cancel{g} = (V_a + V_u)\rho_{ice} \cdot \cancel{g}$$

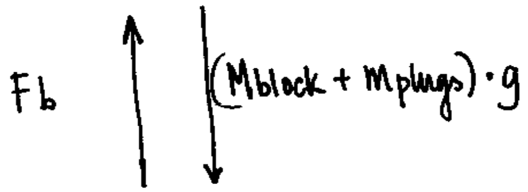
$$\Rightarrow \frac{V_u}{V_u + V_a} = \frac{\rho_{ice}}{\rho_{H_2O}}$$

$$\Rightarrow \text{fraction submerged} = \frac{917}{1000} = 0.917$$

5



a)



$$M_{block} = \rho_{block} \cdot V_{block}$$

$$M_{block} = (500)\left((0.1)(0.1)(0.05) - 3 \times 10 \times 10^{-6}\right)$$

$$M_{block} = 0.235 \text{ kg}$$

$$M_{plugs} = (3)(20 \times 10^{-6})(3300)$$

$$M_{plugs} = 0.198 \text{ kg}$$

$$\Rightarrow F_g = (0.235 + 0.198)(9.8) = 4.24 \text{ N}$$

$$F_b = V_{submerged} \cdot \rho_{H_2O} \cdot g = F_g$$

$$\Rightarrow (0.1)(0.1)(x) \cdot 1000 \cdot 9.8 = 4.24$$

$$x = 0.0433 \text{ m}$$

$$x = 4.33 \text{ cm}$$

b) When upside down there is 30 cm^3 more water displaced because of the protruding plugs

$$\Rightarrow F_g = V_{submerged} \cdot \rho_{H_2O} \cdot g$$

$$\Rightarrow 4.24 = (0.1^2 \cdot x + 3 \times 10 \times 10^{-6}) \cdot 1000 \cdot 9.8$$

$$\Rightarrow x = 4.03 \times 10^{-2} \text{ m}$$

$$\Rightarrow x = 4.03 \text{ cm}$$

(6) $d\sin\theta = m\lambda_1 \quad m = 0, 1, 2 \ldots \qquad d\sin\theta = k\lambda_2 \quad k = 0, 1, 2 \ldots$

but $d\sin\theta$ = same because the bright fringes overlap

$\Rightarrow m\lambda_1 = k\lambda_2$

$\Rightarrow m(400) = k(500)$

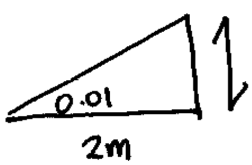
$\Rightarrow m = 5$ and $k = 4$

$\Rightarrow d\sin\theta = 5 \cdot 400 \times 10^{-9}$

$\Rightarrow 2\times10^{-3} \sin\theta = 2000 \times 10^{-9}$

$\Rightarrow \sin\theta = 0.01$

$\Rightarrow \theta \simeq 0.01$

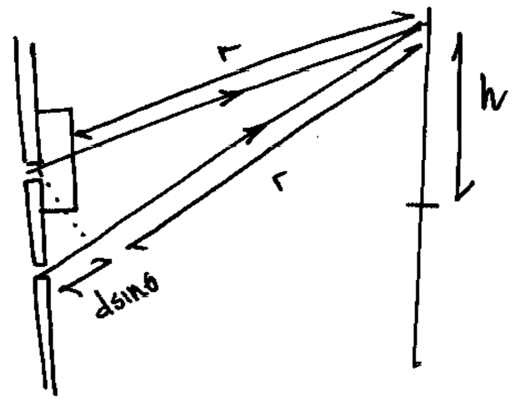


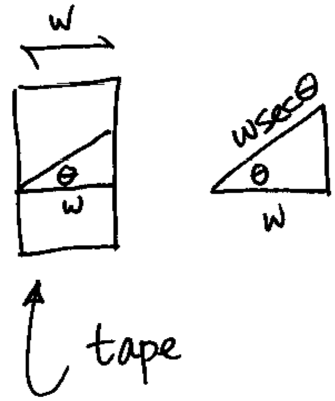
$\ell = 2\tan\theta$

$\ell = 2\tan(0.01)$

$\ell \simeq 0.02$ m

7





$$p_{\ell_1} = r - w\sec\theta + n w\sec\theta$$

$$p_{\ell_2} = r + d\sin\theta$$

$$pd = p_{\ell_2} - p_{\ell_1} = d\sin\theta + w\sec\theta - n w\sec\theta$$

$$pd = d\sin\theta + (1-n) w\sec\theta$$

for central bright fringe $pd = 0$

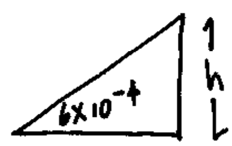
$$\Rightarrow \quad 0 = d\sin\theta + \frac{(1-n)w}{\cos\theta}$$

$$\Rightarrow \quad d\sin\theta\cos\theta = (n-1)w$$

$$\Rightarrow \quad d\,\frac{\sin 2\theta}{2} = (n-1)w$$

$$\Rightarrow \quad \sin 2\theta = \frac{2(n-1)w}{d} = \frac{2(0.3)(3\times10^{-6})}{1.5\times10^{-3}}$$

$$\Rightarrow \quad \theta \cong 6\times10^{-4}$$



$$h = 1.2\tan(6\times10^{-4})$$

$$h \cong 7.2\times10^{-4}\,m$$

(7) 2nd Dark Fringe

$$pd = (m+\tfrac{1}{2})\lambda \qquad m = 1$$

$$\Rightarrow d\sin\theta + (1-n)w\sec\theta = \tfrac{3}{2}(500\times10^{-9})$$

$$\Rightarrow 1.5\times10^{-3}\sin\theta - (0.3)(3\times10^{-6})\sec\theta = \tfrac{3}{2}\cdot 500\times10^{-9}$$

for small θ $\sec\theta \approx 1$ (This is because $\frac{1}{\cos\theta} = \sec\theta$ and $\cos(0) = 1$)

$\sin\theta \approx \theta$

$$\Rightarrow 1.5\times10^{-3}(\theta) - 0.3(3\times10^{-6}) = \tfrac{3}{2}\cdot 500\times10^{-9}$$

$$\Rightarrow \theta \approx 1.1\times10^{-3}\text{ rad}$$

$$\Rightarrow h = (1.2)\tan\theta \cong 1.32\times10^{-3}\text{m}$$

Exact solving using Newton's method yields $\theta = 1.13\times10^{-3}$ so our approximation is pretty good.

8 a) $d\sin\theta = (m+\frac{1}{2})\lambda$ for dark fringes

adjacent dark fringes will be given by

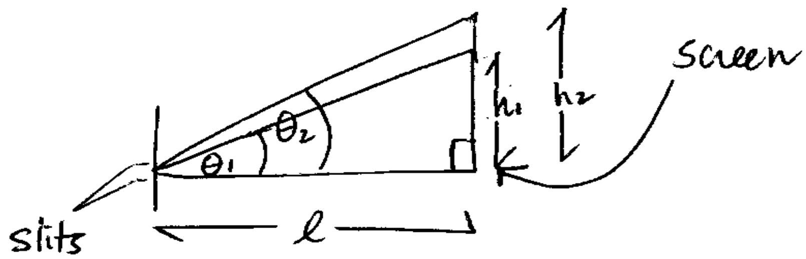
$d\sin\theta_1 = (m+\frac{1}{2})\lambda$ and $d\sin\theta_2 = (m+3/2)\lambda$

$$d(\sin\theta_2 - \sin\theta_1) \cong d\,\Delta\theta \text{ (for small } \theta) = (\tfrac{3}{2}-\tfrac{1}{2})\lambda = \lambda$$

$$\Rightarrow d\,\Delta\theta \cong \lambda$$

$$\Rightarrow \Delta\theta \cong \lambda/d = 600\times10^{-9}/0.200\times10^{-3} = 3.0\times10^{-3}$$

8 a) cont'd



$$h_1 = \ell \tan\theta_1 \quad h_2 = \ell \tan\theta_2$$

$$\Rightarrow h_2 - h_1 = \ell(\tan\theta_2 - \tan\theta_1)$$

$$\cong \ell(\theta_2 - \theta_1) \text{ for small } \theta$$

$$\cong \ell \Delta\theta$$

$$\cong (2.00)(3\times10^{-3})$$

$$= \boxed{6.00\times10^{-3}\ m}$$

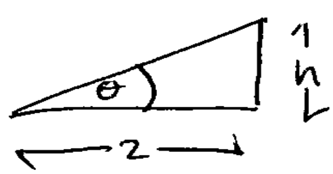
8b) for diffraction minima

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

$$\Rightarrow 0.0500\times10^{-3}\sin\theta = 1.600\times10^{-9}$$

$$\Rightarrow \sin\theta = 1.2\times10^{-2}$$

$$\Rightarrow \theta \cong 1.2\times10^{-2}$$



$$h = 2\tan\theta \cong 2\theta = \boxed{2.4\times10^{-2} m}$$

8c) The locations of interference maxima are

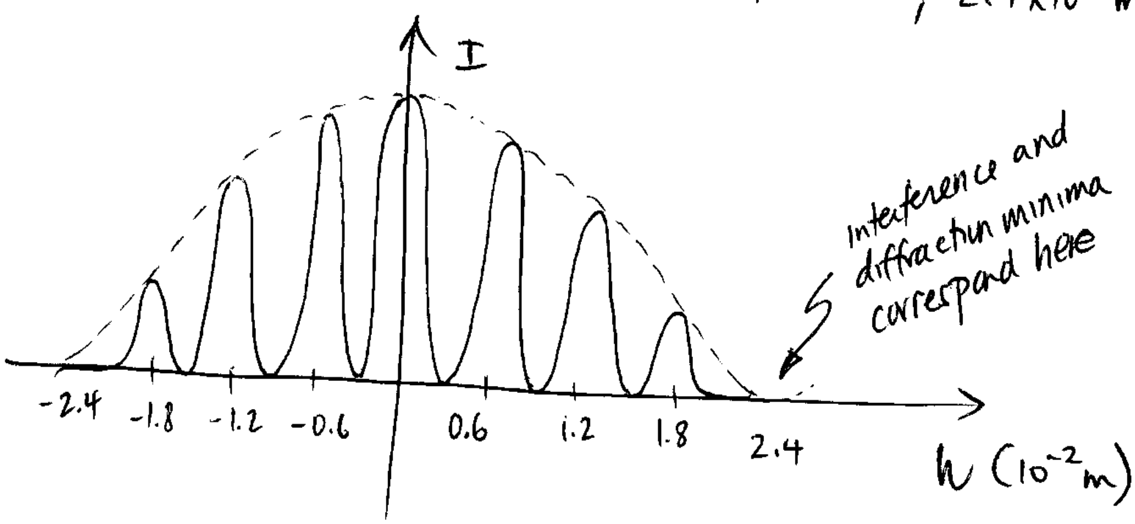
$$d\sin\theta = m\lambda$$

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

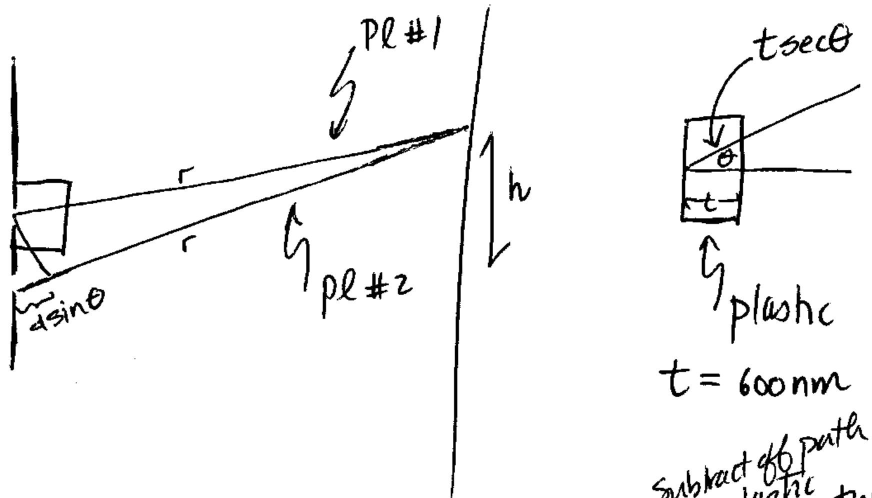
$$\Rightarrow \theta \approx \frac{m\lambda}{d} \quad m = 0, 1, 2, 3 \ldots$$

$$\Rightarrow \theta = 3\times10^{-3},\ 6\times10^{-3},\ 9\times10^{-3},\ 1.2\times10^{-2},\ 1.5\times10^{-2} \ldots$$

$$\Rightarrow h = \ell\tan\theta \cong \ell\theta = 6\times10^{-3},\ 1.2\times10^{-2},\ 1.8\times10^{-2},\ 2.4\times10^{-2}\,\text{m} \ldots$$



8d) The two slit pattern will be shifted due to an intrinsic increase in effective path length due to the plastic film. In particular, the beam that goes through the plastic travels further in the following way:



$t = 600\,nm$

subtract off path in plastic

then add it back but lengthened by a factor of n

$pl\#2 = r + d\sin\theta$

$pl\#1 = r - t\sec\theta + nt\sec\theta$

$pl\#1 = r + (n-1)t\sec\theta$

$pd = |pl\#2 - pl\#1| = d\sin\theta + (1-n)t\sec\theta = m\lambda$ for bright fringes

$\Rightarrow d\sin\theta + (1-n)t\sec\theta = m\lambda$

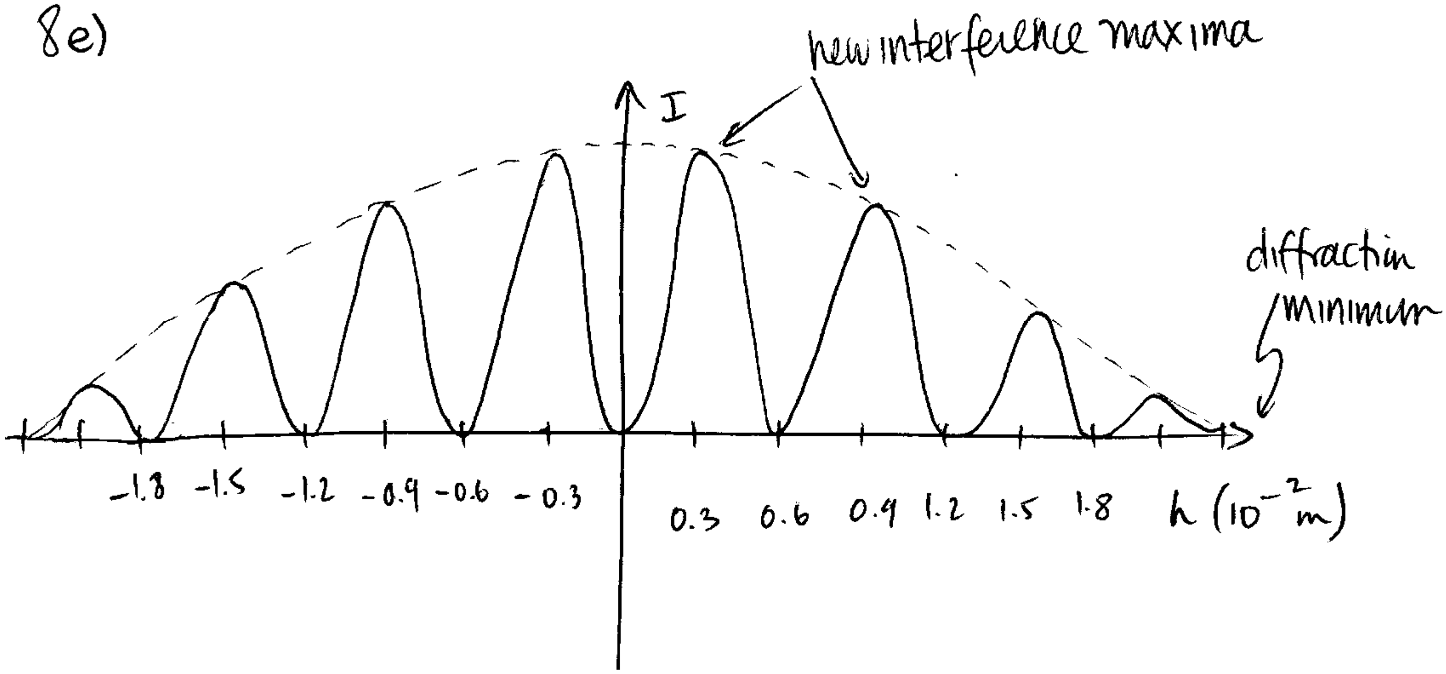
but $\sec\theta \approx 1$ for small θ (since $\cos\theta \approx 1$ for small θ)

$\Rightarrow d\sin\theta - (0.5)(600)\times10^{-9} = m(600)\times10^{-9}$

$\Rightarrow \sin\theta = \dfrac{(600m + 300)\times10^{-9}}{(0.2\times10^{-3})} = 1.5\times10^{-3},\ 4.5\times10^{-3},\ 7.5\times10^{-3}, \ldots$

$\Rightarrow h = \ell\tan\theta \approx \ell\theta = 3.0\times10^{-3},\ 9.0\times10^{-3},\ 1.5\times10^{-2}\,m \ldots$ for bright fringes

8e)


new interference maxima
I
diffraction minimum
-1.8
-1.5
-1.2
-0.9
-0.6
-0.3
0.3
0.6
0.9
1.2
1.5
1.8
h (10⁻² m)