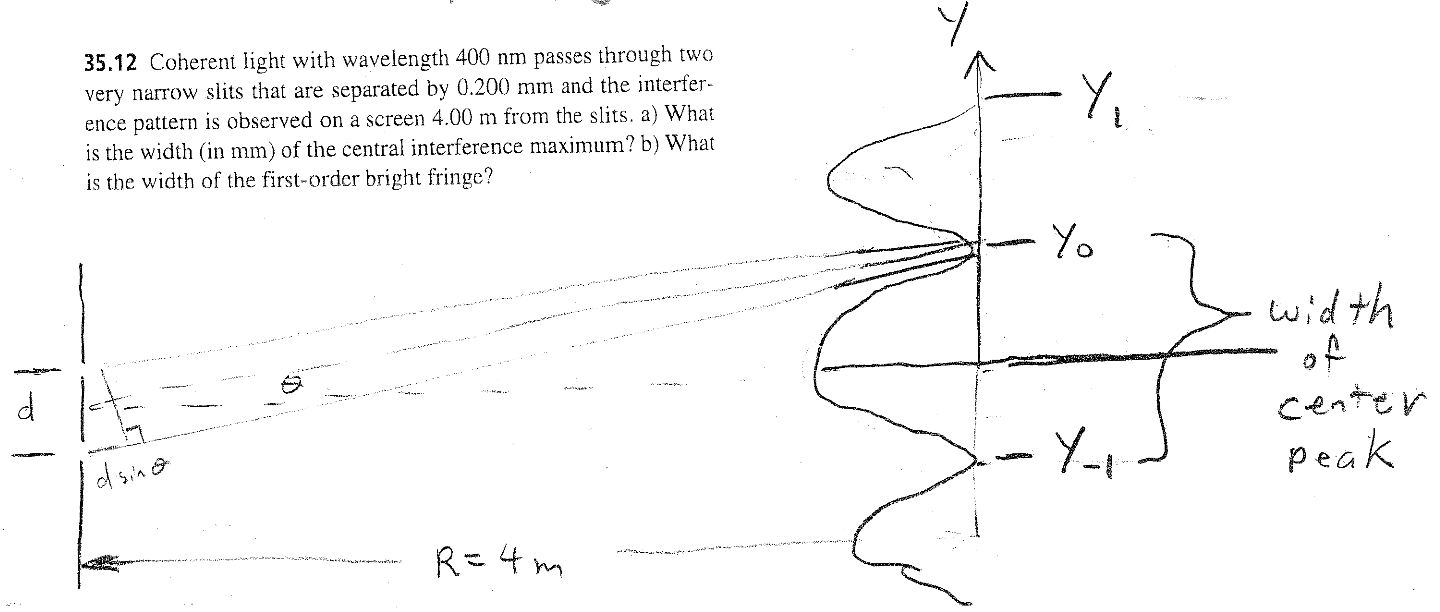
HW 28 From text

35.12 Coherent light with wavelength 400 nm passes through two very narrow slits that are separated by 0.200 mm and the interference pattern is observed on a screen 4.00 m from the slits. a) What is the width (in mm) of the central interference maximum? b) What is the width of the first-order bright fringe?



$d = 0.2\,mm$

$$d \sin\theta \simeq d\frac{Y}{R} = \left(m+\tfrac{1}{2}\right)\lambda$$

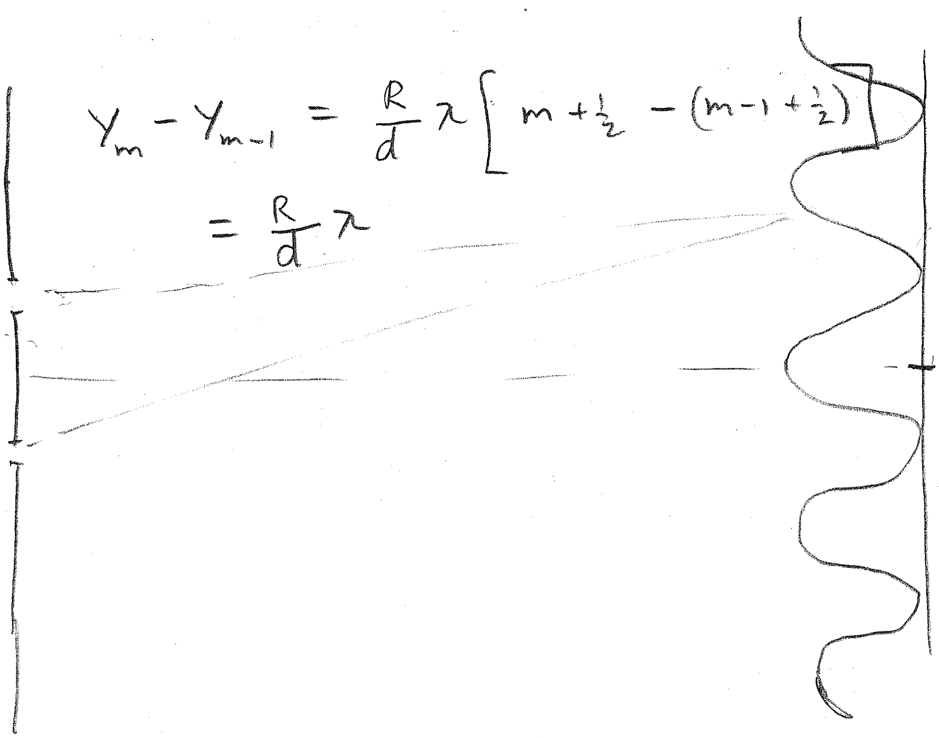
$$\Rightarrow Y_m = \frac{R\left(m+\frac{1}{2}\right)\lambda}{d} \Rightarrow Y_0 - Y_{-1} = \frac{R\left(\frac{1}{2}\right)\lambda}{d} - R\left(\tfrac{3}{2}\right)\frac{\lambda}{d}$$

$$\Rightarrow Y_0 - Y_{-1} = \frac{R}{d}\lambda \quad \frac{4\,m}{2\times10^{-3}\,m}\left(400\times10^{-9}\,m\right) = \boxed{8\,mm}$$

$$Y_1 - Y_0 = \frac{R}{d}\frac{3}{2}\lambda - \frac{R}{d}\frac{\lambda}{2} = \frac{R}{d}\lambda = \boxed{8\,mm}$$ same

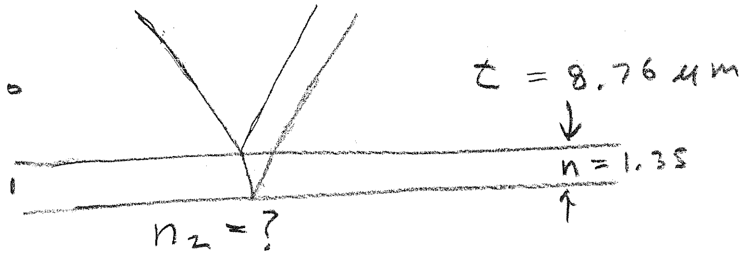
$$Y_m - Y_{m-1} = \frac{R}{d}\lambda\left[m+\tfrac{1}{2} - \left(m-1+\tfrac{1}{2}\right)\right]$$

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



They are all the same width

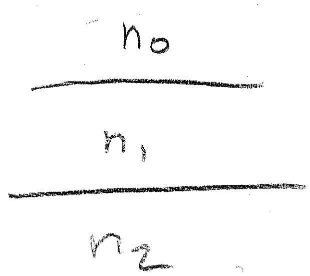
35.32 Light with wavelength 648 nm in air is incident perpendicularly from air on a film 8.76 μm thick and with refractive index 1.35. Part of the light is reflected from the first surface of the film, and part enters the film and is reflected back at the second surface, where the film is again in contact with air. a) How many waves are contained along the path of this second part of the light in its round-trip through the film? b) What is the phase difference between these two parts of the light as they leave the film?



a) $\lambda_1 = \frac{v}{f_0} = \frac{c}{n}\frac{1}{f_0} = \frac{\lambda_0}{n}$

$m = \frac{2t}{\lambda_1} = \frac{2t\,n}{\lambda_0} = \frac{2(8.76\times10^{-6}\,m)(1.35)}{648\times10^{-9}\,m} = \boxed{36.5}$

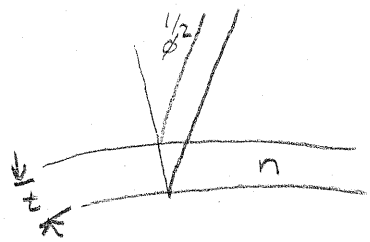
b) The index of refractive index of the lower most material was not given.



if $n_2 > n_1 \Rightarrow$ out of phase

if $n_2 < n_1 \Rightarrow$ in phase

35.34 What is the thinnest soap film (excluding the case of zero thickness) that appears black when illuminated with light with wavelength 480 nm? The index of refraction of the film is 1.33, and there is air on both sides of the film.



$$2t = \lambda$$

$$\Rightarrow \quad 2t = \frac{\lambda_0}{n} \quad \Rightarrow \quad t = \frac{\lambda_0}{2n} = \frac{480 \times 10^{-9}\ \text{m}}{2(1.33)} = 1.8 \times 10^{-7}\ \text{m}$$

$$= \boxed{0.18\ \mu\text{m}} = \boxed{180\ \text{nm}}$$

/

35.38 Jan first uses a Michelson interferometer with the 606-nm light from a krypton-86 lamp. He displaces the movable mirror away from him, counting 818 fringes moving across a line in his field of view. Then Linda replaces the krypton lamp with filtered 502-nm light from a helium lamp and displaces the movable mirror toward her. She also counts 818 fringes, but they move across the line in her field of view opposite to the direction they moved for Jan. Assume that both Jan and Linda counted to 818 correctly. a) What distance did each person move the mirror? b) What is the resultant displacement of the mirror?

Jan $\Delta x_1 = \frac{m\lambda}{2} = \frac{818\,(606\,\text{nm})}{2} \cong$ **0.248 mm**

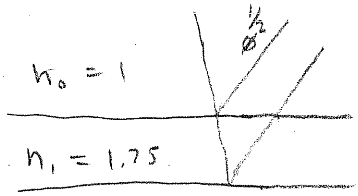
Linda $\Delta x_2 = \frac{m\lambda}{2} = \frac{818\,(502\,\text{nm})}{2} \cong$ **0.205 mm**

$\Delta x = \Delta x_1 - \Delta x_2 \cong$ **0.0425 mm**

35.49 A thin uniform film of refractive index 1.750 is placed on a sheet of glass of refractive index 1.50. At room temperature (20.0°C), this film is just thick enough for light with wavelength 582.4 nm reflected off the top of the film to be canceled by light reflected from the top of the glass. After the glass is placed in an oven and slowly heated to 170°C, you find that the film cancels reflected light with wavelength 588.5 nm. What is the coefficient of linear expansion of the film? (Ignore any changes in the refractive index of the film due to the temperature change.)

α linear thermal expansion

Section 17.4



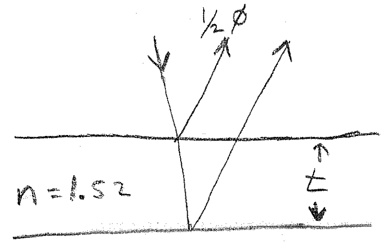
$$2t = \lambda = \frac{\lambda_0}{n_1}$$

$$\Rightarrow t = \frac{\lambda_0}{2n_1} \qquad t' = \frac{\lambda_0'}{2n_1}$$

$$\alpha = \frac{(t'-t)}{t\,\Delta T} = \left(\frac{t'}{t} - 1\right)\frac{1}{\Delta T} = \left(\frac{\lambda_0'}{\lambda_0} - 1\right)\frac{1}{(170°C - 20°C)}$$

$$= \left(\frac{588.5}{582.4} - 1\right)\frac{1}{150°C} = \boxed{6.98 \times 10^{-5}\ \frac{1}{C°}}$$

35.52 White light reflects at normal incidence from the top and bottom surface of a glass plate ($n = 1.52$). There is air above and below the plate. Constructive interference is observed for light whose wavelength in air is 477.0 nm. What is the thickness of the plate if the next longer wavelength for which there is constructive interference is 540.6 nm?



$$2t = \left(m + \tfrac{1}{2}\right)\frac{\lambda_1}{n} \quad \& \quad 2t = \left(m - 1 + \tfrac{1}{2}\right)\frac{\lambda_2}{n}$$

2 equations
2 unknowns

$$\Rightarrow \left(2t = m\frac{\lambda_1}{n} + \frac{\lambda_1}{2n}\right) \times \lambda_2$$

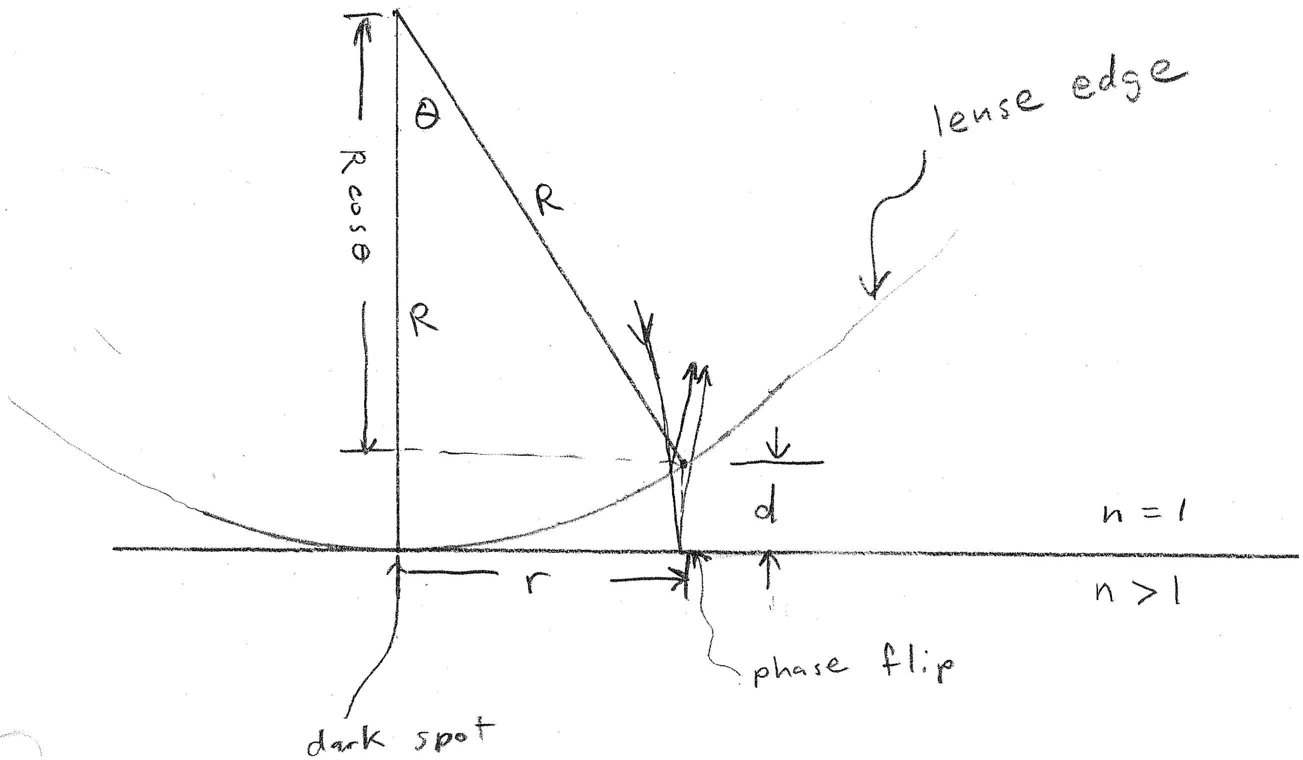
$$+ \left(2t = m\frac{\lambda_2}{n} + \frac{\lambda_2}{2n} - \frac{\lambda_2}{n}\right) \times (-\lambda_1)$$

$$2t(\lambda_2 - \lambda_1) = \frac{\lambda_2 \lambda_1}{n}$$

$$\Rightarrow 2t = \frac{\lambda_2 \lambda_1}{(\lambda_2 - \lambda_1)n} \Rightarrow t = \frac{\lambda_2 \lambda_1}{(\lambda_2 - \lambda_1)2n}$$

$$\Rightarrow t = \frac{(477\text{ nm})\,540.6}{(540.6 - 477)\,2n} \cong \boxed{1333.7 \text{ nm}}$$

35.57 The radius of curvature of the convex surface of a plano-convex lens is 95.2 cm. The lens is placed convex side down on a perfectly flat glass plate that is illuminated from above with red light having a wavelength of 580 nm. Find the diameter of the second bright ring in the interference pattern.



For positive interference $d = \left(m\frac{1}{2} + \frac{1}{4}\right)\lambda$ $\quad m = 0, 1, 2, 3 \ldots$

$R - R\cos\theta = d$, $\quad r = R\sin\theta$

$\Rightarrow \cos\theta = \frac{\sqrt{R^2 - r^2}}{R}$

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

$\Rightarrow R - \sqrt{R^2 - r^2} = d \Rightarrow R^2 - r^2 = (R-d)^2$

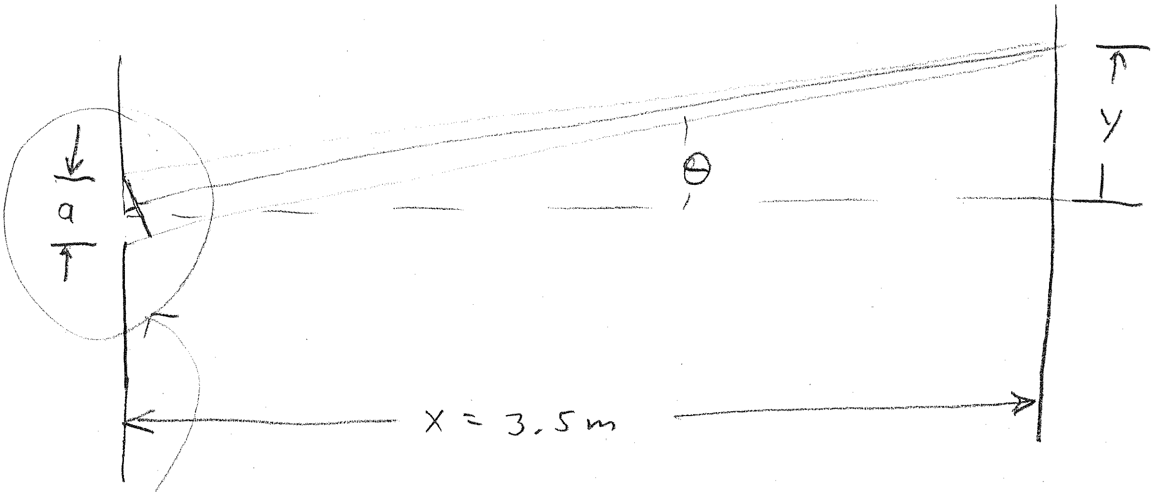
$\Rightarrow r^2 = R^2 - (R-d)^2 \Rightarrow r = \sqrt{R^2 - (R-d)^2}$

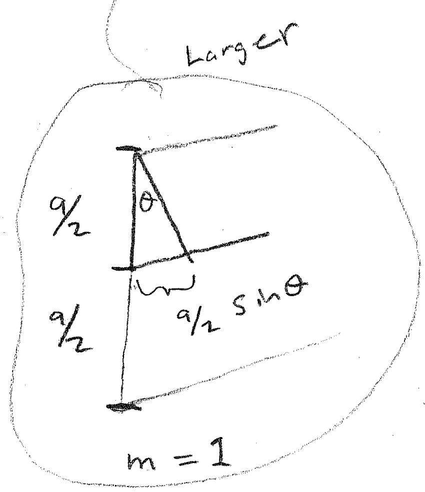
$\Rightarrow r = \sqrt{R^2 - (R^2 - 2dR + d^2)} = \sqrt{2dR - d^2} \simeq \sqrt{2dR}$

$\Rightarrow r_{2nd} = \sqrt{2\left(\frac{1}{2} + \frac{1}{4}\right)\lambda R} = \sqrt{\frac{3}{2}(580\times10^{-9}\,m)(0.952\,m)} = \boxed{0.91\,mm}$

dia $= \boxed{1.82\,mm}$

36.4 Light of wavelength 633 nm from a distant source is incident on a slit 0.750 mm wide, and the resulting diffraction pattern is observed on a screen 3.50 m away. What is the distance between the two dark fringes on either side of the central bright fringe?





for min $\frac{a}{2}\sin\theta = m\frac{\lambda}{2}$

$\sin\theta \cong \frac{Y}{X} \Rightarrow a\left(\frac{Y}{X}\right) = \pm\lambda$

$m = \pm 1$

$\Rightarrow Y_{\pm 1} = \frac{\pm\lambda X}{a} = \frac{\pm 633\,nm \ 3.5m}{(0.75\,mm)}$

$\Rightarrow \Delta Y = Y_1 - Y_{-1} = \boxed{5.908\,mm}$