Phys 202

Recitation 7

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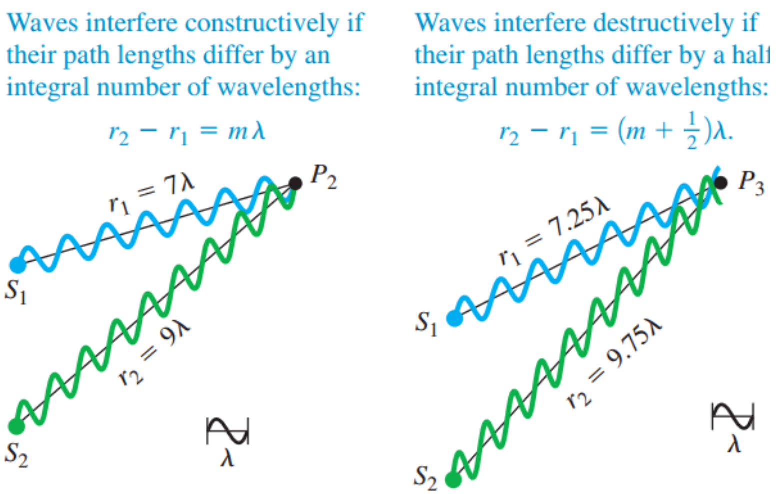
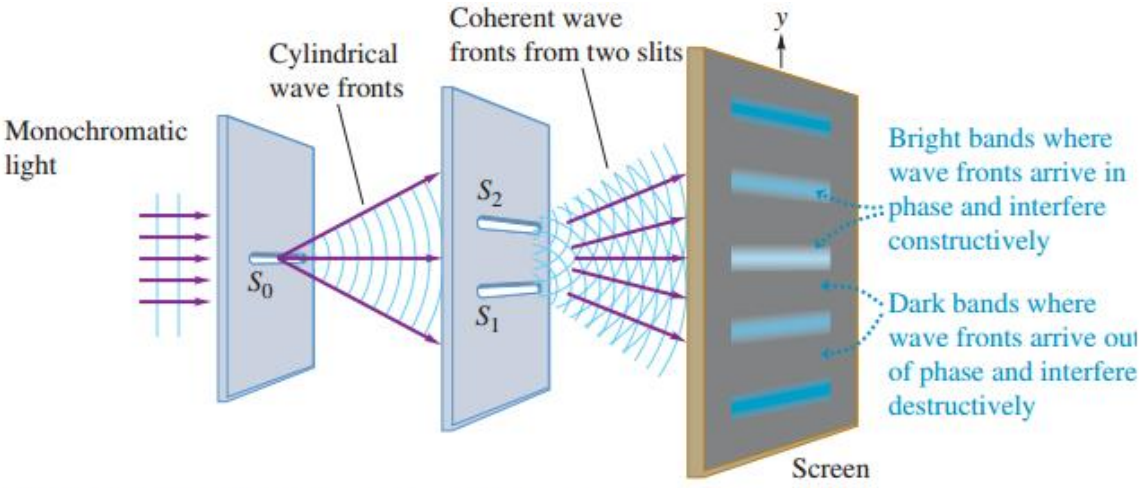
Interference



(b) Condition for constructive interference

(c) Condition for destructive interference



(a) Interference of light waves passing through two slits

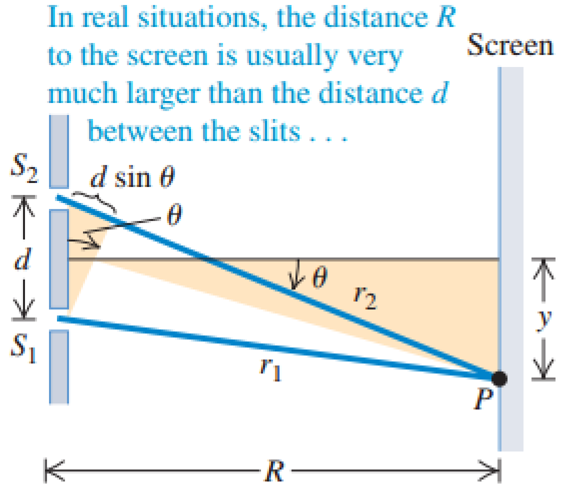
Constructive and destructive interference, two slits

Constructive interference occurs at angles θ for which

$$d\sin\theta = m\lambda \qquad (m = 0, \pm 1, \pm 2, \cdots). \tag{26.4}$$

Similarly, destructive interference (cancellation) occurs, forming dark regions on the screen, at points for which the path difference is a half-integral number of wavelengths, $(m + \frac{1}{2})\lambda$:

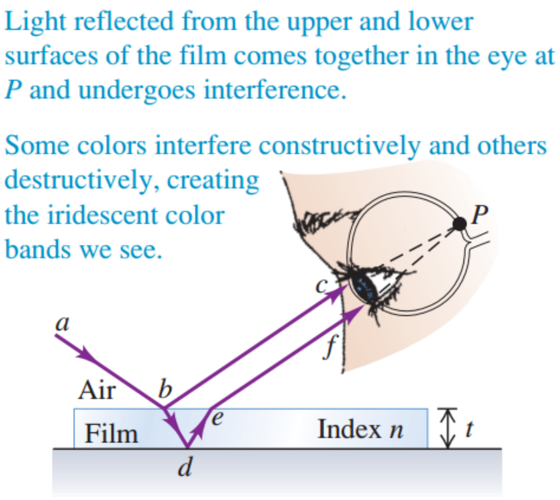
$$d\sin\theta = \left(m + \tfrac{1}{2}\right)\lambda \qquad (m = 0, \pm 1, \pm 2, \cdots). \tag{26.5}$$



Constructive interference, Young's experiment

$$y_m = R\frac{m\lambda}{d} \qquad (m = 0, \pm 1, \pm 2, \cdots).$$

THIN FILMs



We can summarize this discussion symbolically: For a film with thickness t and light at normal (perpendicular) incidence, the reflected waves from the two surfaces interfere *constructively* if neither or both have a half-cycle reflection phase shift whenever the condition

$$2t = m\lambda \qquad (m = 0, 1, 2, \cdots),$$

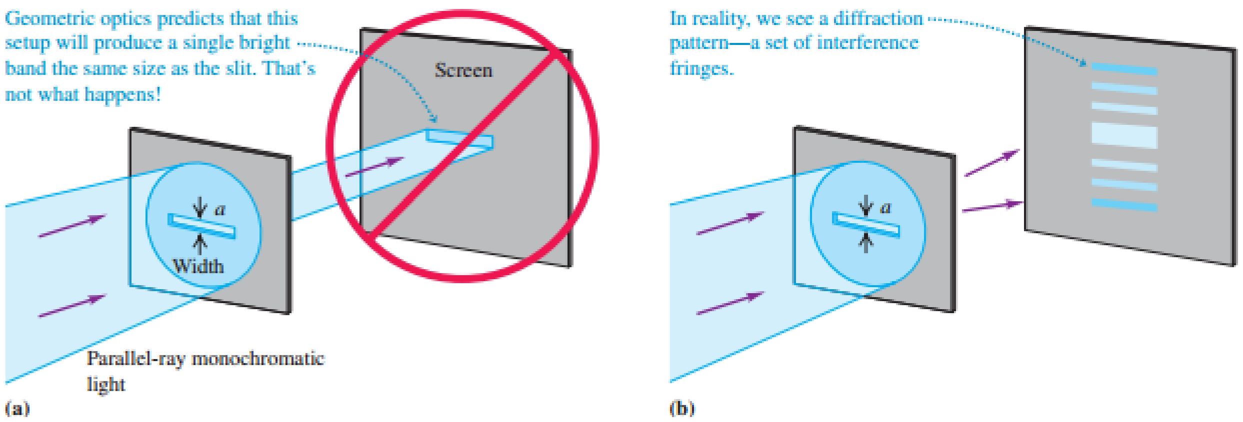
(where λ is the wavelength *in the film*), is satisfied. However, when *one* of the two waves has a half-cycle reflection phase shift, the same equation is the condition for *destructive* interference.

for *destructive* interference in the reflected waves is

$$2t = \left(m + \tfrac{1}{2}\right)\lambda \qquad (m = 0, 1, 2, \cdots).$$

However, if one wave has a half-cycle phase shift, the same equation is the condition for *constructive* interference.

Diffraction



the condition for a *dark* fringe is $\sin\theta = \dfrac{m\lambda}{a} \qquad (m = \pm 1, \pm 2, \pm 3, \cdots).$

7. • Coherent light from a sodium-vapor lamp is passed through a filter that blocks everything except for light of a single wavelength. It then falls on two slits separated by 0.460 mm. In the resulting interference pattern on a screen 2.20 m away, adjacent bright fringes are separated by 2.82 mm. What is the wavelength of the light that falls on the slits?

26.7. Set Up: The values of y_m are much smaller than the distance R to the screen, so the approximate expression $y_m = R\frac{m\lambda}{d}$ is accurate.

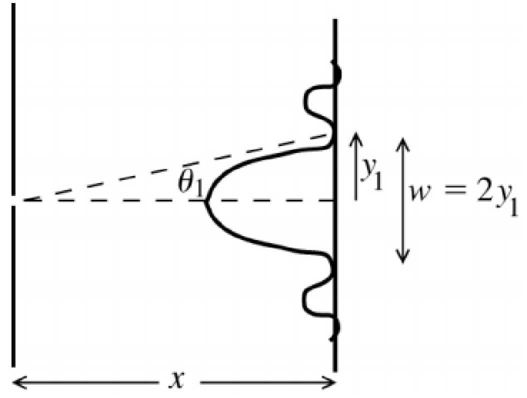
Solve: $\Delta y = y_{m+1} - y_m = \frac{R\lambda}{d}$. $\lambda = \frac{d\,\Delta y}{R} = \frac{(0.460\times 10^{-3}\text{ m})(2.82\times 10^{-3}\text{ m})}{2.20\text{ m}} = 590\text{ nm}$

23. •• A researcher measures the thickness of a layer of benzene $(n = 1.50)$ floating on water by shining monochromatic light onto the film and varying the wavelength of the light. She finds that light of wavelength 575 nm is reflected most strongly from the film. What does she calculate for the minimum thickness of the film?

26.23. Set Up: Since the film reflects 575 nm strongly, we must have constructive interference at that wavelength. The light reflected from the air-benzene interface experiences a 180° phase inversion (since $n_{\text{air}} < n_{\text{benzene}}$), but the light reflected from the benzene-water interface does not experience a phase inversion (since $n_{\text{benzene}} > n_{\text{water}}$). Thus, the condition for constructive interference is $2t = m\dfrac{\lambda}{2n}$, where $m = 1, 3, 5, \ldots$ and $\dfrac{\lambda}{n}$ is the wavelength of the light in the benzene (which is where the path-difference occurs).

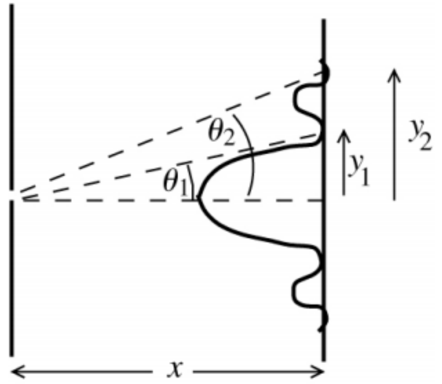
Solve: The minimum required thickness occurs when $m = 1$. This gives, $t = \dfrac{\lambda}{4n} = \dfrac{575 \text{ nm}}{4(1.50)} = 95.8 \text{ nm}$.

29. •• Red light of wavelength 633 nm from a helium–neon laser passes through a slit 0.350 mm wide. The diffraction pattern is observed on a screen 3.00 m away. Define the width of a bright fringe as the distance between the minima on either side. (a) What is the width of the central bright fringe? (b) What is the width of the first bright fringe on either side of the central one?



Solve: (a) The first minimum is located by $\sin\theta_1 = \frac{\lambda}{a} = \frac{633\times10^{-9}\ \text{m}}{0.350\times10^{-3}\ \text{m}} = 1.809\times10^{-3}$. Solving we obtain $\theta_1 = 1.809\times10^{-3}$ rad.

We can now find the distance between the center of the central fringe and the first minimum: $y_1 = x\tan\theta_1 = (3.00\ \text{m})\tan(1.809\times10^{-3}\ \text{rad}) = 5.427\times10^{-3}\ \text{m}$. The width of the central bright fringe is: $w = 2y_1 = 2(5.427\times10^{-3}\ \text{m}) = 1.09\times10^{-2}\ \text{m} = 10.9\ \text{mm}$.



(b) The width of the first bright fringe adjacent to the central fringe is $w = y_2 - y_1$, where $y_1 = 5.427\times10^{-3}$ m from part (a). To find y_2 we note that $\sin\theta_2 = \frac{2\lambda}{a} = 3.618\times10^{-3}$ so that $\theta_2 = 3.618\times10^{-3}$ rad. Thus, $y_2 = x\tan\theta_2 = 1.085\times10^{-2}$ m and the width of the bright fringe adjacent to the central one is $w = y_2 - y_1 = 1.085\times10^{-2}\ \text{m} - 5.427\times10^{-3}\ \text{m} = 5.4\ \text{mm}$.

Quiz

17. • A thin film of polystyrene of refractive index 1.49 is used as a nonreflecting coating for Fabulite (strontium titanate) of refractive index 2.409. What is the minimum thickness of the film required? Assume that the wavelength of the light in air is 480 nm.