Key words

Interference

Huygens' principle

Propagation

Wave-front/ Wavelet

Wavelength

Index of Refraction

Phase difference

Optical path difference

Double-Slit interference

Monochromatic

Bright/ Dark Fringe

Central maximum

Second side maxima

Coherence/ Incoherence

Intensity

Thin film interference

Reflection phase shifts

Michelson's Interferometer

From chapter 33, we know that light is EM wave. If there are two EM waves and they have same ω, same λ in vacuum. When they come to a common point P, the net oscillation of that point is just the superposition of each E oscillation due to each travelling wave

$$\left.\begin{aligned}\vec{E}_1 &= \vec{E}_{10}\cos(k_1L_1-\omega t+\phi_1)\\ \vec{E}_2 &= \vec{E}_{20}\cos(k_2L_2-\omega t+\phi_2)\end{aligned}\right\}\Rightarrow \vec{E}_P=\vec{E}_1+\vec{E}_2$$

要稳定相位差

ω相同

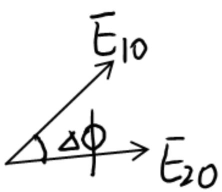
正弦型可用相图描述

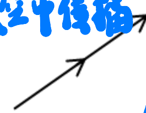
We can apply the **phasor diagram** to deal with the net E field at point P. Let's assume that $\phi_1 = \phi_2$, then the phase difference between the two E at point P is:

(认为光源处同相)

$$\Delta\phi = k_1L_1-k_2L_2=\frac{2\pi L_1}{\lambda_1}-\frac{2\pi L_2}{\lambda_2}=\frac{2\pi}{\lambda}(n_1L_1-n_2L_2) \qquad (\lambda_n=\frac{\lambda}{n})$$ nL is called optical path

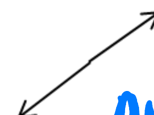
真空中传播





$n_1L_1-n_2L_2=m\lambda$

In phase: $\Delta\phi = m\times 2\pi$



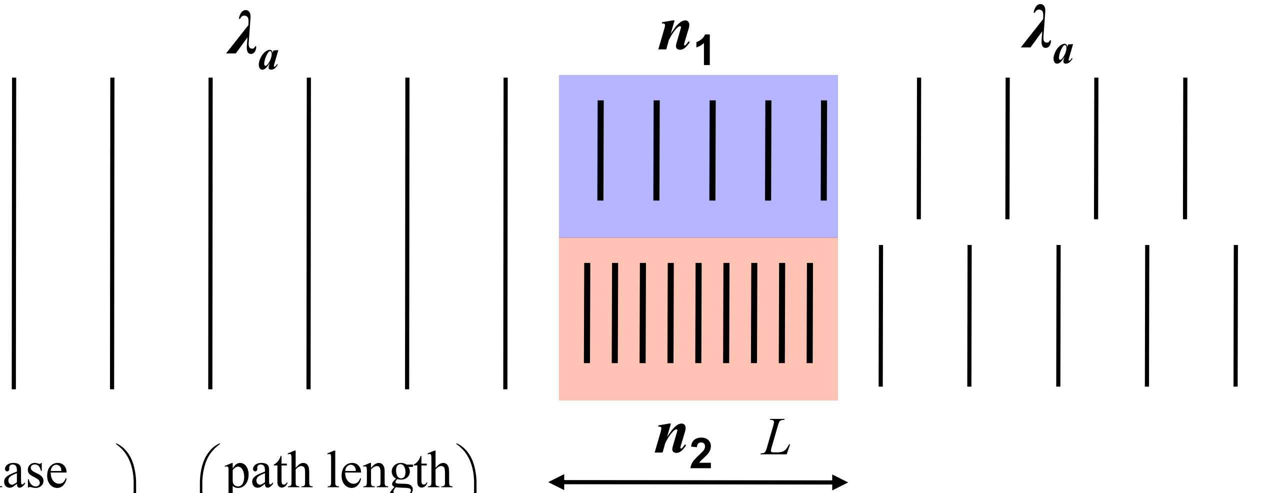
$n_1L_1-n_2L_2=(m+\frac{1}{2})\lambda$

Out of phase: $\Delta\phi=(m+\frac{1}{2})\times 2\pi$

$$\Delta\phi=\frac{2\pi}{\lambda}(n_1L_1-n_2L_2)=\begin{cases} m\times 2\pi \Rightarrow n_1L_1-n_2L_2=m\lambda, & \text{constructive interference}\\ (m+\frac{1}{2})\times 2\pi \Rightarrow n_1L_1-n_2L_2=(m+\frac{1}{2})\lambda, & \text{destructive interference}\end{cases}$$

If $n_1 = n_2 = 1$, that means two rays are both in the air, then: $n_1L_1-n_2L_2=\Delta L$

Phase difference



$$\frac{\begin{pmatrix}\text{phase}\\ \text{difference}\end{pmatrix}}{2\pi}=\frac{\begin{pmatrix}\text{path length}\\ \text{difference}\end{pmatrix}}{\lambda}$$

$$\lambda_n=\frac{\lambda}{n}$$

wavelength in vacuum/air

refractive index

No. of wavelength N_1 in medium 1 : $\dfrac{L}{\lambda_{n1}}=\dfrac{Ln_1}{\lambda_a}$

No. of wavelength N_2 in medium 2 : $\dfrac{L}{\lambda_{n2}}=\dfrac{Ln_2}{\lambda_a}$

say, if it is 3.6 we take the decimal fraction, i.e. 0.6, $\phi=1.2\pi$

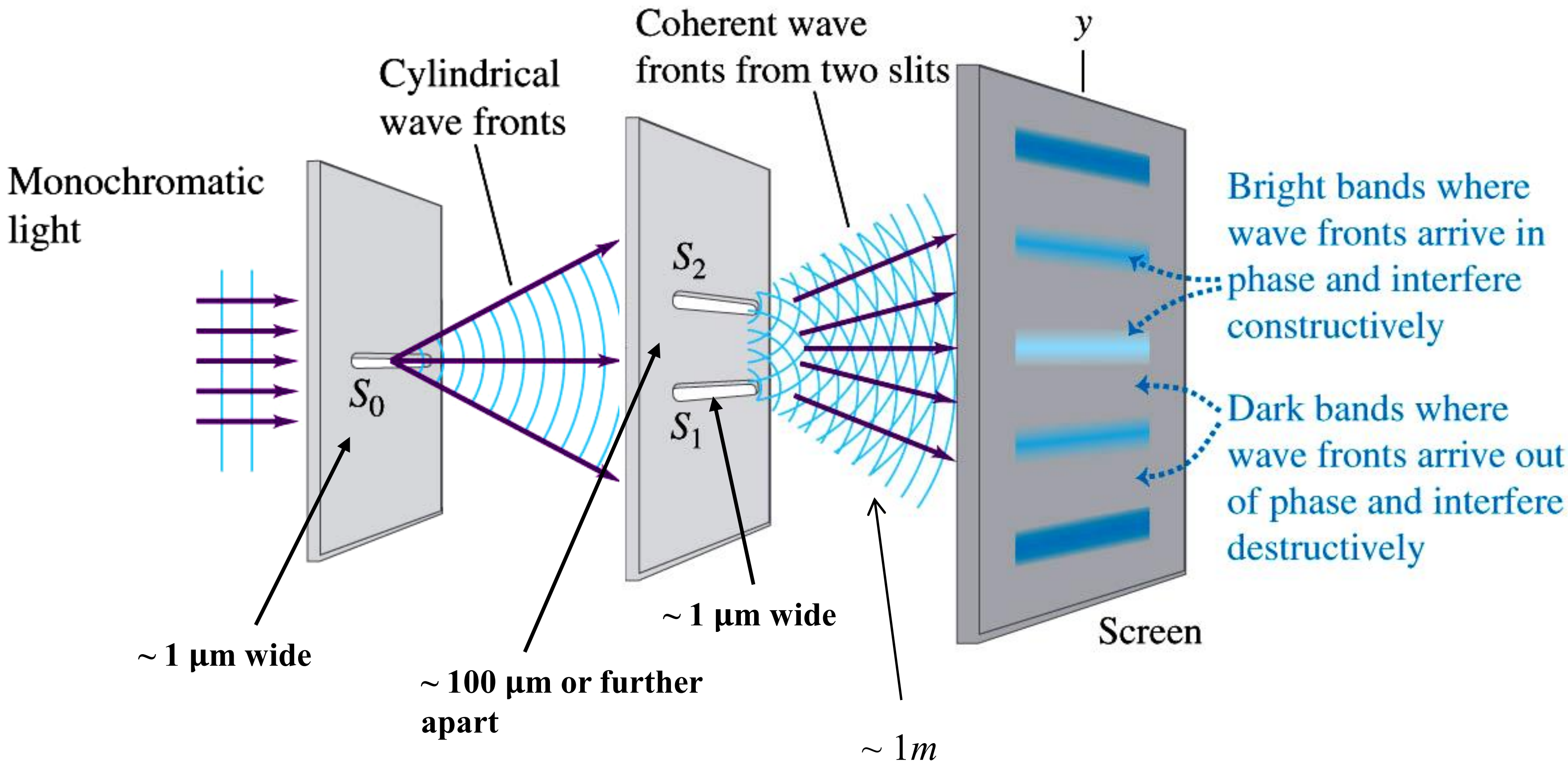
Optical path Different

Phase difference between the waves ϕ: $\dfrac{\phi}{2\pi}=\dfrac{Ln_2}{\lambda_a}-\dfrac{Ln_1}{\lambda_a}=\dfrac{L}{\lambda_a}(n_2-n_1)$

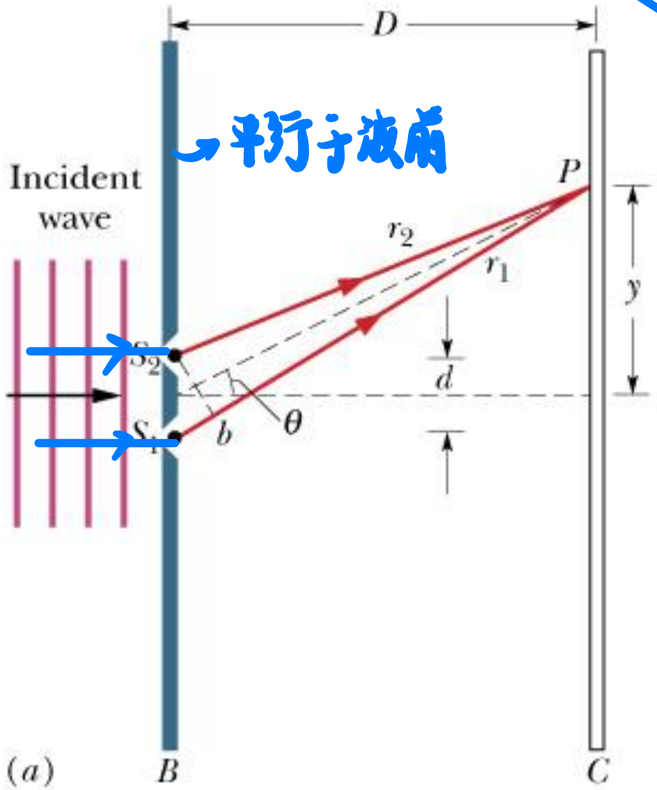
Optical path

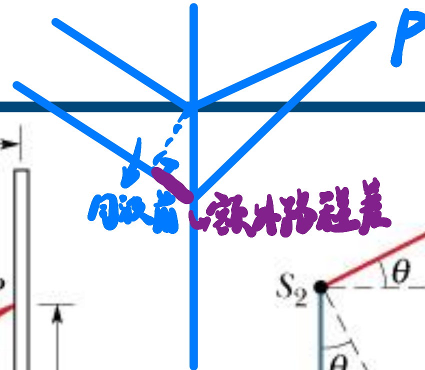
Review of Ch35

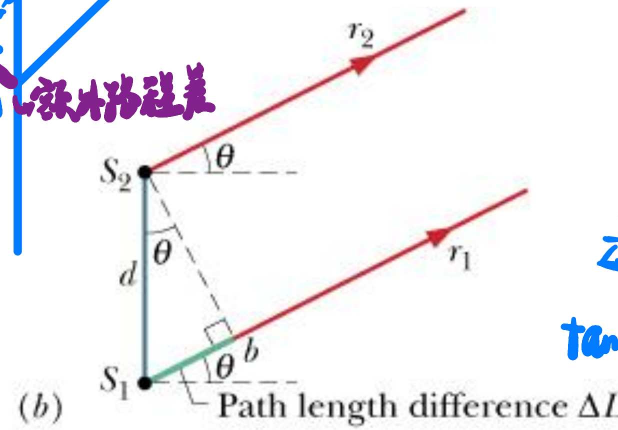
Interference of light waves passing through two slits



Review of Ch35







这章中可以小角近似

$\tan\theta \approx \sin\theta \approx \theta$

Path Length Difference: $\Delta L = d\sin\theta$

Maxima-bright fringes:

$$d\sin\theta = m\lambda \quad \text{for} \quad m = 0, 1, 2, \ldots$$

m=0 central maxima

m=1 first maxima

Minima-dark fringes:

m=0 first dark

$$d\sin\theta = \left(m + \tfrac{1}{2}\right)\lambda \quad \text{for} \quad m = 0, 1, 2, \ldots$$

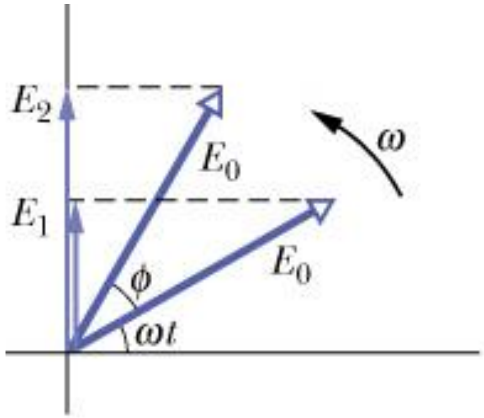
Second order bright fringe
Second side maximum

$m = 2$ bright fringe at: $\theta = \sin^{-1}(2\lambda / d)$

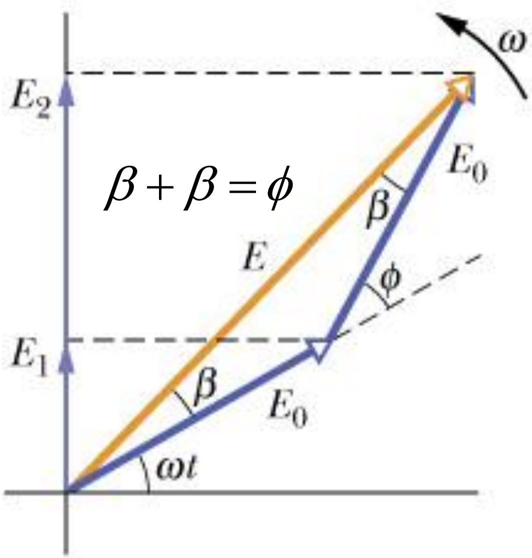
Second order dark fringe
Second minimum

$m = 1$ dark fringe at: $\theta = \sin^{-1}\left(\dfrac{1.5\lambda}{d}\right)$

Intensity in Double-Slit Interference



(a)



(b)

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

$$E = 2(E_0 \cos \beta) = 2E_0 \cos \tfrac{1}{2}\phi$$

$$E^2 = 4E_0^2 \cos^2 \tfrac{1}{2}\phi$$

是屏上一点

$$\frac{I}{I_0} = \frac{E^2}{E_0^2} = 4\cos^2 \tfrac{1}{2}\phi \rightarrow \underline{I = 4I_0 \cos^2 \tfrac{1}{2}\phi}$$

$$\frac{\begin{pmatrix}\text{phase}\\ \text{difference}\end{pmatrix}}{2\pi} = \frac{\begin{pmatrix}\text{path length}\\ \text{difference}\end{pmatrix}}{\lambda}$$

$$\begin{pmatrix}\text{phase}\\ \text{difference}\end{pmatrix} = \frac{2\pi}{\lambda}\begin{pmatrix}\text{path length}\\ \text{difference}\end{pmatrix}$$

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

$$\boldsymbol{m\lambda = d \sin\theta}$$

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

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

HW of Ch35

56 In the double-slit experiment of Fig. 35-10, the viewing screen is at distance $D = 4.00$ m, point P lies at distance $y = 20.5$ cm from the center of the pattern, the slit separation d is 4.50 μm, and the wavelength λ is 650 nm. (a) Determine where point P is in the interference pattern by giving the maximum or minimum on which it lies, or the maximum and minimum between which it lies. (b) What is the ratio of the intensity I_P at point P to the intensity I_{cen} at the center of the pattern?

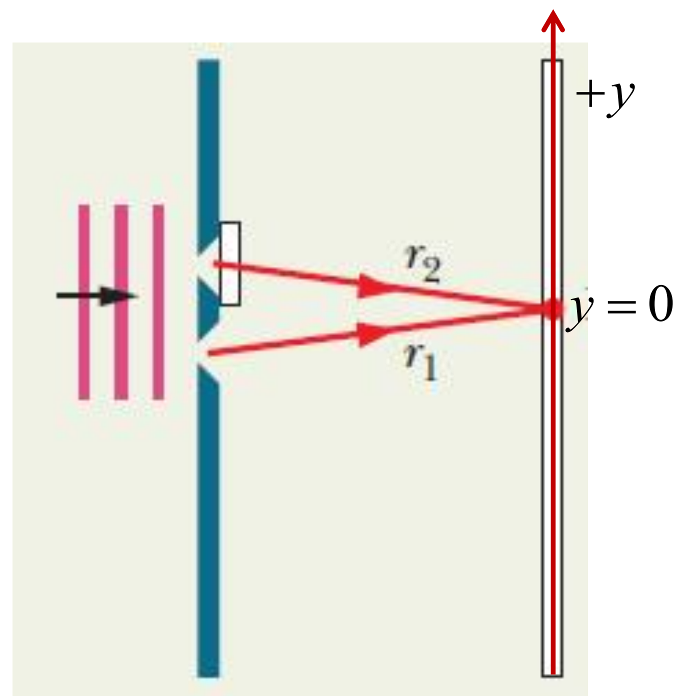
Problem 1 of Ch35

A thin flake (薄片) of mica ($n = 1.58$) is used to cover one slit of a double-slit interference arrangement. The central point on the viewing screen is now occupied by what had been the seventh bright side fringe ($m = 7$). If $\lambda = 550\ nm$

a) What is the thickness of the mica?

b) If the slit separation d=0.12mm, and the slit-screen separation D=55cm. Find the position of m=0. 可以用y/θ描述

c) Find the intensity at the position of y (Suppose intensity on the screen from each slit is I_0) 假设无反射

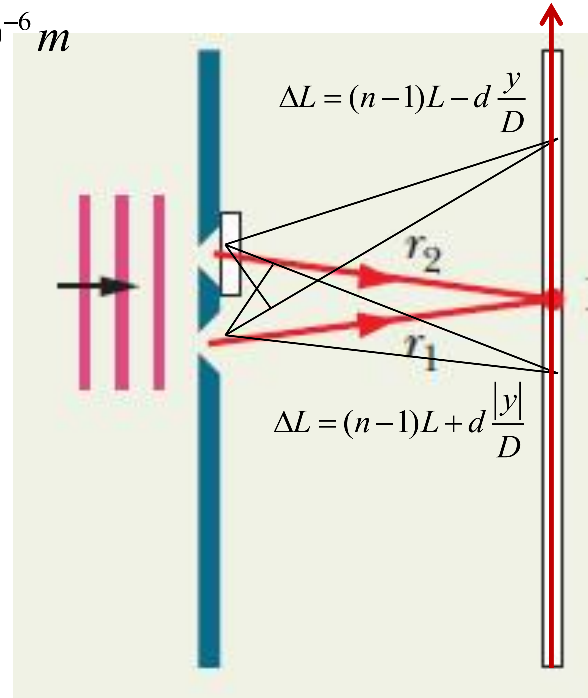


$\phi = 14\pi$

a) At the center point, $m=7$, so the phase different at the center point is：

$$\phi = 2\pi\left(\frac{L}{\lambda_n} - \frac{L}{\lambda}\right) = \frac{2\pi L}{\lambda}(n-1) = m(2\pi) = 7(2\pi) \Rightarrow L = \frac{m\lambda}{n-1} = \frac{7\times550\times10^{-9}}{1.58-1} = 6.64\times10^{-6}\,m$$

Or $\quad OPD = \underline{(n-1)L = 7\lambda} \Rightarrow L = \frac{7\lambda}{n-1} = \frac{7\times550\times10^{-9}}{1.58-1} = 6.64\times10^{-6}\,m$



b) At the point of $m=0$, the phase different is **0**

$$\phi = \frac{2\pi L}{\lambda}(n-1) - \frac{2\pi}{\lambda}d\sin\theta = 7(2\pi) - \frac{2\pi}{\lambda}d\sin\theta = 0$$

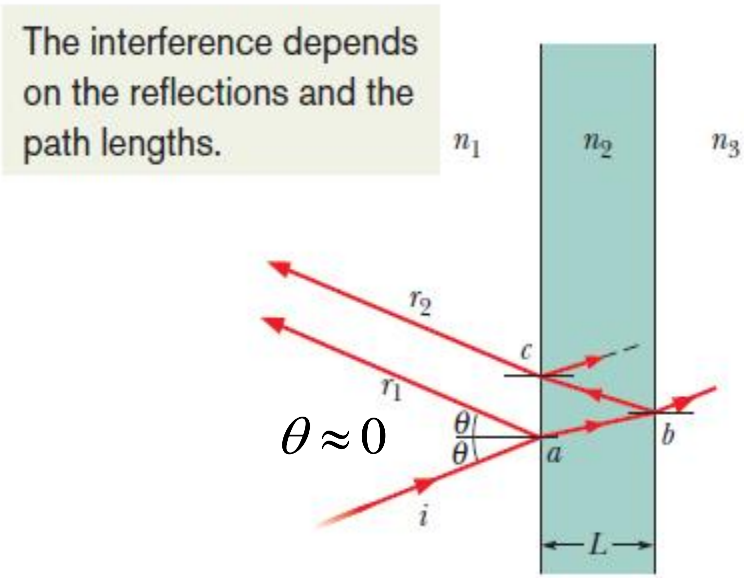
$$\Rightarrow 7\lambda = d\sin\theta \approx d\tan\theta = d\frac{y_0}{D} \Rightarrow y_0 = \frac{m\lambda D}{d} = 1.76cm$$

k · OPD

c) $$\phi = \frac{2\pi L}{\lambda}(n-1) - \frac{2\pi}{\lambda}d\sin\theta = 7(2\pi) - \frac{2\pi}{\lambda}d\frac{y}{D}$$

$$I = 4I_0\cos^2(\phi/2)$$

Interference from Thin Films



$\theta \approx 0$

Reflection phase shift

$n_1 > n_2$ No phase change

$n_1 = n_2$ No phase change

$n_1 < n_2$ Phase change, 0.5wavelength

Consider reflection and the path lengths, the Optical path difference between the incident light and reflection light is: $2Ln_2 - \frac{\lambda}{2}$

仅反射时有半波损失

$\frac{1}{2}$: 1个 phase shift

0 : 2个 phase shift

For constructive interference :

$$2L = (m + \tfrac{1}{2})\frac{\lambda}{n_2} \quad \text{for } m = 0, 1, 2, \ldots$$

For destructive interference :

$$2L = m\frac{\lambda}{n_2} \qquad \text{for } m = 0, 1, 2, \ldots$$

Condition: $n_1 > n_2 < n_3 \ or \ n_1 < n_2 > n_3$

if $L << \lambda$

we can ignore the thickness of the film always destructive interference as the phase difference is always 1/2

Problem 2

Suppose a plastic plate (n_p =1.2) and a glass plate (n_g =1.5) in figure are two microscope slides 10.0 cm long. At one end they are in contact; at the other end they are separated by a piece of paper 0.0200 mm thick. Assume monochromatic light with a wavelength in air of λ_0 = 500 nm and the light rays are almost perpendicular to the film. Seen by reflection,

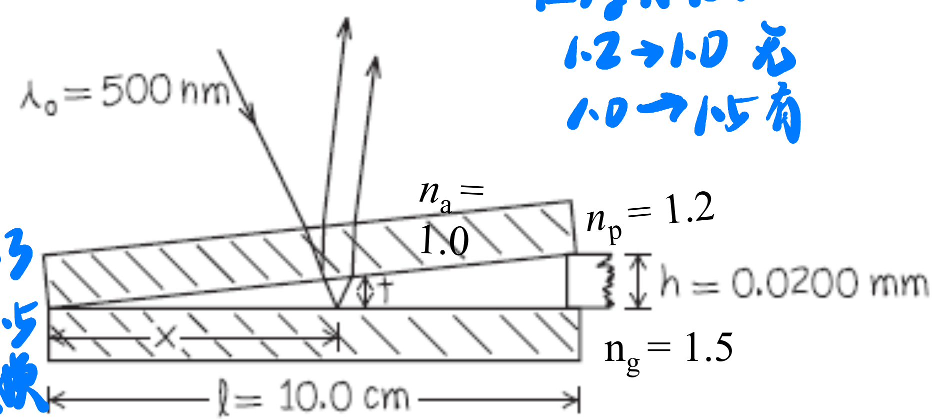
a) Is the fringe at the line of contact bright or dark?

b) How many bright fringes along the glass length?

c) What happens if the set up is immersed in the water (n_w = 1.3)

在薄膜处
1.2→1.0 无
1.0→1.5 有

1.2→1.3
1.3→1.5
2个半波损



Problem 2

We'll consider only interference between the light reflected from the upper and lower surfaces of the air wedge between the microscope slides. [The top slide has a relatively great thickness, about 1 mm, so we can ignore interference between the light reflected from its upper and lower surfaces]. The wave reflected from the lower surface undergoes a π rad phase change while the wave reflected from the upper surface does not.

a) At the line of contact, the thickness of the wedge is 0, so the phase difference between the two rays is π, thus there is a dark fringe at the line of contact.

b) At a place where the thickness of the wedge is *d*, the condition for a maximum intensity is:

$$2d = (m + 1/2)\lambda_0 \Rightarrow m = 2d / \lambda_0 - 1/2$$

$$d = 0.02mm \Rightarrow m_{\max} = [79.5] = 79$$

Since the first bright fringe corresponds to $m = 0$, $m = 79$ corresponds to the 80 bright fringes.

Problem 2

c) Now we need consider the interference pattern formed by waves reflected from the upper and lower surfaces of the water wedge. The wave reflected from the lower surface undergoes a π rad phase change and the wave reflected from the upper surface also undergoes anther π rad phase change.

At the line of contact, the thickness of the wedge is still 0, but the two rays now are in phase, thus there is a bright fringe at the line of contact.

At a place where the thickness of the wedge is *d*, the condition for a maximum intensity now should be:

$$2d = m\lambda_w \Rightarrow m = 2n_w d / \lambda_0$$
$$d = 0.02mm \Rightarrow m_{\max} = 104$$

Since the first bright fringe corresponds to m = 0, m = 104 corresponds to the 105 bright fringes.

Problem 2

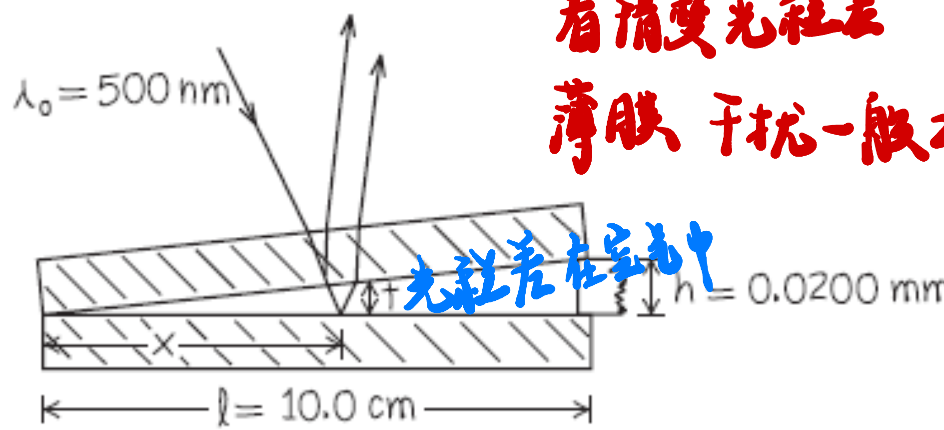
Suppose a plastic plate (n_p =1.2) and a glass plate (n_g =1.5) in figure are two microscope slides 10.0 cm long. At one end they are in contact; at the other end they are separated by a piece of paper 0.0200 mm thick. Assume monochromatic light with a wavelength in air of λ_0 = 500 nm and the light rays are almost perpendicular to the film. Seen by transmission,

d) Is the fringe at the line of contact bright or dark?

e) How many bright fringes along the glass length?

看清楚光程差

薄膜干扰一般2d



Problem 2

We'll consider only interference between the light reflected from the upper and lower surfaces of the air wedge between the microscope slides. [The top slide has a relatively great thickness, about 1 mm, so we can ignore interference between the light reflected from its upper and lower surfaces]. The wave reflected from the lower surface undergoes a π rad phase change while the wave reflected from the upper surface does not.

a) At the line of contact, the thickness of the wedge is 0, so the phase difference between the two rays is π, thus there is a dark fringe at the line of contact.

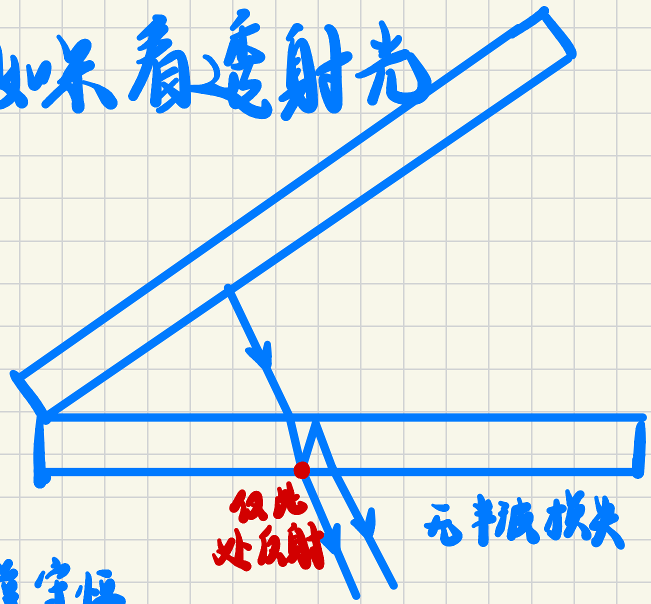
b) At a place where the thickness of the wedge is *d*, the condition for a maximum intensity is:

$$2d = (m+1/2)\lambda_0 \Rightarrow m = 2d/\lambda_0 - 1/2$$

$$d = 0.02mm \Rightarrow m_{\max} = [79.5] = 79$$

Since the first bright fringe corresponds to $m = 0$, $m = 79$ corresponds to the 80 bright fringes.

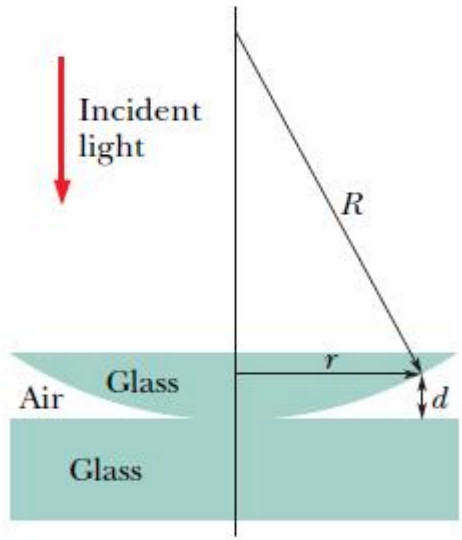
如果看透射光



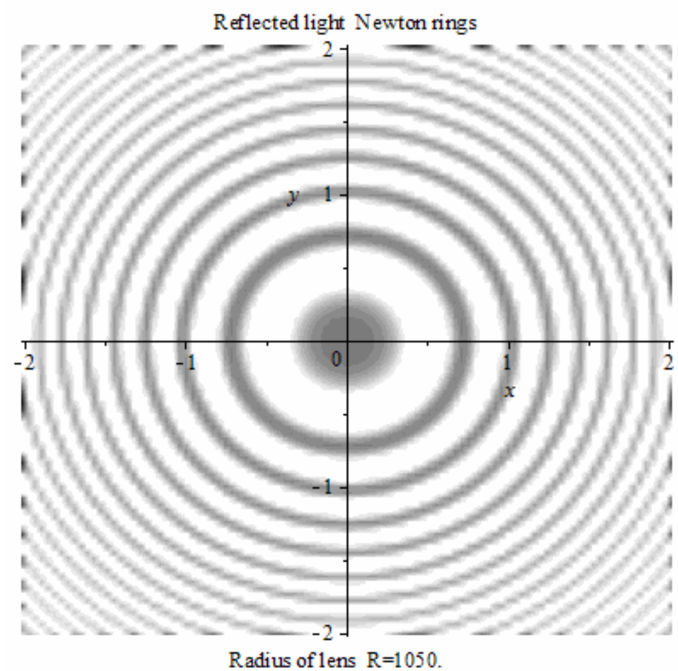
能量守恒

Problem 3 of Ch35

Figure *a* shows a lens with radius of curvature R lying on a flat glass plate and illuminated from above by light with wavelength λ. Figure *b* (a photograph taken from above the lens) shows that circular interference fringes (called *Newton's rings*) appear, associated with the variable thickness d of the air film between the lens and the plate. Find the radii r of the interference maxima. Assuming $r/R \ll 1$



(*a*)



Problem 3 of Ch35

Consider the interference pattern formed by waves reflected from the upper and lower surfaces of the air wedge. The wave reflected from the lower surface undergoes a π rad phase change while the wave reflected from the upper surface does not. At a place where the thickness of the wedge is *d*, the condition for a maximum in intensity is

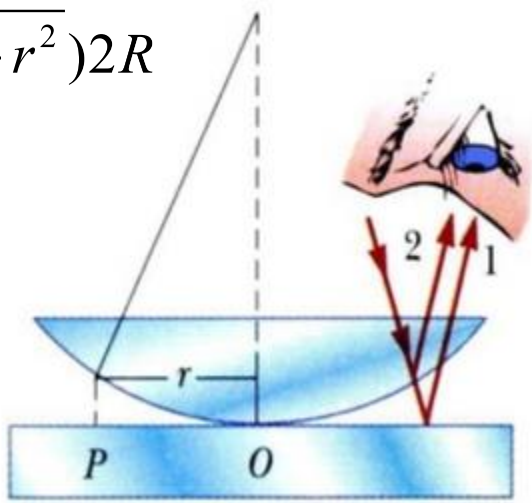
$$2d = (m + 1/2)\lambda \qquad \text{for } m = 0, 1, 2, \ldots$$

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

$$r^2 = (R - \sqrt{R^2 - r^2})(R + \sqrt{R^2 - r^2}) \cong (R - \sqrt{R^2 - r^2})2R$$

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

$$\Rightarrow \frac{r^2}{2R} = (2m+1)\lambda/4 \Rightarrow r = \sqrt{\frac{(2m+1)R\lambda}{2}}$$



Problem 3 of Ch35

If the radius of curvature *R* of the lens is 5.0 m and the lens diameter is 18mm.

(a)How many bright rings are produced? Assume that λ= 589nm

(b)How many bright rings would be produced if the arrangement were immersed in water (*n*=1.33)?

Problem 3 of Ch35

a) $$m = \frac{r^2}{R\lambda} - \frac{1}{2} = \frac{\left(9\times10^{-3}\,\mathrm{m}\right)^2}{(5.0\,\mathrm{m})\left(589\times10^{-9}\,\mathrm{m}\right)} - \frac{1}{2} = 27$$

Since the first bright fringe corresponds to $m = 0$, $m = 27$ corresponds to the 28 bright fringe.

b) We now replace λ by $\lambda_n = \lambda/n_w$

$$m_n = \frac{r^2}{R\lambda_n} - \frac{1}{2} = \frac{n_w r^2}{R\lambda} - \frac{1}{2} = \frac{(1.33)\left(9\times10^{-3}\,\mathrm{m}\right)^2}{(5.0\,\mathrm{m})\left(589\times10^{-9}\,\mathrm{m}\right)} - \frac{1}{2} = 36.$$

This corresponds to the 37 bright fringe.

Problem 3 of Ch35

c) If the radii of the *m*th and (*m*+20)th bright rings are measured and found to be 0.162 and 0.368 cm, respectively, in light of wavelength λ= 546 nm. Calculate the radius of curvature of the lower surface of the lens

when m is changed to $m + 20$, r becomes r', so

$$\frac{r^2}{R} = (m + 1/2)\lambda \Rightarrow \begin{cases} m = \dfrac{r^2}{R\lambda} - \dfrac{1}{2} \\ m + 20 = \dfrac{r'^2}{R\lambda} - \dfrac{1}{2} \end{cases}$$

$$\Rightarrow R = \frac{r'^2 - r^2}{20\lambda} = 100cm$$