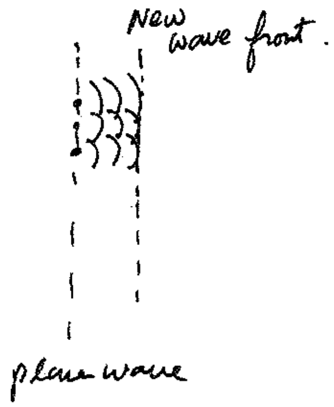
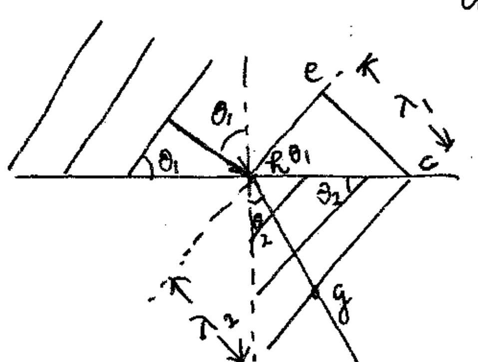
Wave optics — light as wave so as to explain interference which can't be explained by geometrical optics.

1. Huygen's principle — All pts on a wave front serves as point source of spherical secondary wavelets. After a time t, the new position of the wave front will be that of a surface tangent to these secondary wavelets.



2. The law of refraction — Snell's law
derivation with Huygens' principle



$n \equiv \frac{c}{v}$ index of refraction.

The time for wave travel from e to c $\Rightarrow t_1 = \frac{\lambda_1}{v_1}$

k to g $\Rightarrow t_2 = \frac{\lambda_2}{v_2}$

$$t_1 \overset{\text{"}}{=} t_2 \rightarrow \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

$$\sin\theta_1 = \frac{\lambda_1}{kc}, \quad \sin\theta_2 = \frac{\lambda_2}{kc} \Rightarrow \frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

But $n_1 = \frac{c}{v_1}$, $n_2 = \frac{c}{v_2}$

$$\therefore \frac{\sin\theta_1}{\sin\theta_2} = \frac{c/n_1}{c/n_2} \Rightarrow n_1 \sin\theta_1 = n_2 \sin\theta_2$$

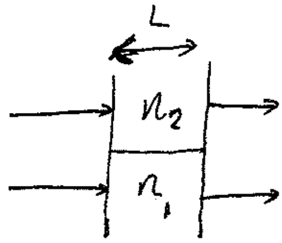
When light travels in medium other ~~that~~ than vacuum, its speed changes, but frequency remains the same. So the wavelength changes.

$$\lambda_n = \lambda \frac{v}{c} \quad \text{but} \quad \frac{1}{n} = \frac{v}{c}$$

$\therefore \lambda_n = \frac{\lambda}{n}$ Wave length changes to smaller wave length

① Wave length changes in different medium

② The phase changes in different medium.



number wave lengths in media

$$N_1 = \frac{L}{\lambda_{n1}} = \frac{L}{\frac{\lambda}{n_1}}$$

$$N_2 = \frac{L}{\lambda_{n2}} = \frac{L}{\frac{\lambda}{n_2}}$$

if $n_2 > n_1$, $N_2 - N_1 = \frac{L}{\lambda}(n_2 - n_1)$

$$\phi = ~~\text{int}~~ \; 2\pi\left[\left(\frac{L}{\lambda}(n_2-n_1)\right) - \text{Int}\left[\frac{L}{\lambda}(n_2-n_1)\right]\right] \quad \text{phase change}$$

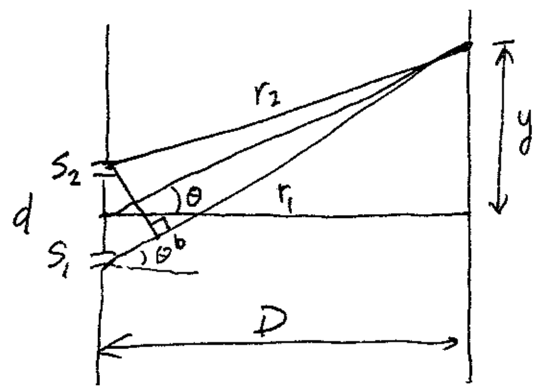
3. Diffraction and Young's interference experiment. (1801)
double slit

① Wave diffracts from slits. The smaller the slit, the bigger the diffraction. This puts a limit to geometric optics

② Young's experiment. (double slits) – proved light is a wave.

– proving light undergoes interference, as do water waves and other waves.

– Measure the average length of the sunlight. ~570 nm



path difference $= \Delta L$

if $D \gg d$. $\vec{r}_1 \parallel \vec{r}_2$

inphase → phase changes due to path different.

$\Delta L = d\sin\theta = n\lambda$ (bright spots)
(δ) $\qquad n =$ integer

$\therefore\ d\sin\theta = m\lambda \quad m = 0, 1, 2, 3 \cdot$ bright spots.
$d\sin\theta = (m+\frac{1}{2})\lambda,\ m = 0, 1, 2.$ dark Spots.

$m = 0,\ \rightarrow$ central maximum
$m = n,\ n^{th}$ order maximum.

① bright spot, $m = 1$, $\sin\theta = \frac{\lambda}{d}$, $\theta_1 = \sin^{-1}\left(\frac{\lambda}{d}\right)$
These Tells us how to find the spot on the viewing screen

② For the interference pattern to appear on the screen, the light that reach the screen should have phases don't vary with time
— coherent

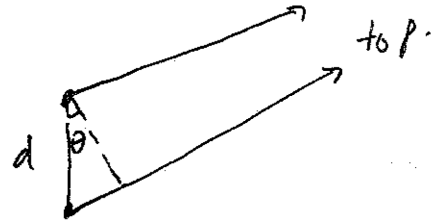
③ Intensity. — On the viewing screen, the intensity varies, but the total energy is still the same. they redistribute in terms of the phase angle ϕ.

$$E_1 = E_0 \sin\omega t = E_0 e^{i\omega t}$$
$$E_2 = E_0 \sin(\omega t + \phi) = E_0 e^{i(\omega t + \phi)}$$

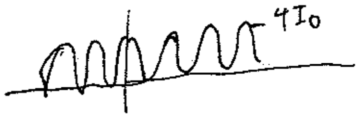
$$E = E_1 + E_2 = E_0\left[e^{i\omega t} + e^{i(\omega t + \phi)}\right]$$

$$I = E^* \cdot E = E_0^2\left[e^{-i\omega t} + e^{-i(\omega t+\phi)}\right]\left[e^{i\omega t} + e^{i(\omega t+\phi)}\right]$$
$$= E_0^2\left[1 + e^{i\phi} + e^{-i\phi} + 1\right]$$
$$= E_0^2\left(2 + e^{i\phi} + e^{-i\phi}\right) \qquad \cos\phi = \frac{e^{i\phi} + e^{-i\phi}}{2}$$
$$= E_0^2\left[2 + 2\cos\phi\right]$$
$$= E_0^2 \cdot 2\,(1 + \cos\phi)$$
$$= E_0^2 \cdot 2 \cdot 2\cos^2\frac{\phi}{2}$$
$$I = 4E_0^2\cos^2\frac{\phi}{2}$$

$$\therefore\ \boxed{I_{screen} = 4 I_0 \cos^2\frac{\phi}{2}}$$ intensity measured at the screen is a function of



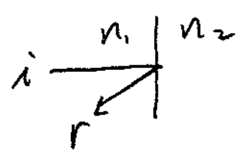
$$\frac{d\sin\phi}{\lambda} = \frac{\phi}{2\pi} \Rightarrow \boxed{\begin{array}{l}\phi = 2\pi \dfrac{d\sin\theta}{\lambda} \\ I = 4I_0\cos^2\dfrac{\phi}{2}\end{array}}$$ for double slits interference



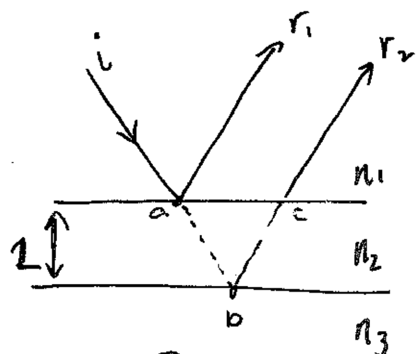
3. Thin film interference

— The color we see when sunlight illuminate a soap bobble or an oil slik are caused by the interference of light waves reflected from the front and back surfaces of a thin film.

— phase change upon reflection



① if $n_1 > n_2$, $\phi = 0$
② if $n_1 < n_2$, $\phi = \pi$



① r_1 and r_2 have π phase shift due to r_1 reflects from pt a.
② path difference is 2L for nearly normal incidence.

Combine ① and ②

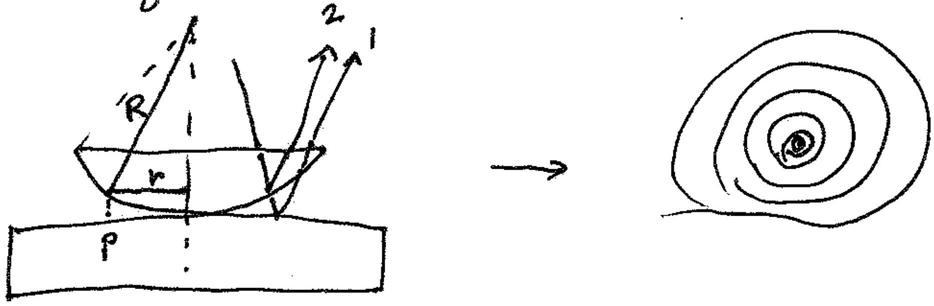
(†)
$$2L = \left(m+\frac{1}{2}\right)\frac{\lambda}{n_2}, \quad m = 0, 1, 2, \cdots \quad \text{maxima, bright}$$
(‡)
$$2L = m\frac{\lambda}{n_2}, \quad m = 0, 1, 2, \ldots \quad \text{minima, dark}$$

check ~~Fig. 36-14~~

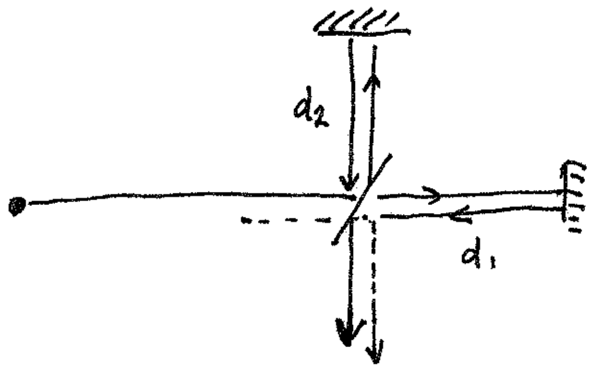
page 1191 figures

37.6

Newton's Ring:



Michelson Interferometer



Path difference $= 2d_2 - 2d_1$