Review

$\vec{E} = E_m \sin(kx-\omega t)\,\hat{j}$

$\vec{B} = B_m \sin(kx-\omega t)\,\hat{k}$

plane wave

direction of propagation: $\vec{E}\times\vec{B}$

pressure

$p = \frac{I}{c}$

$p = \frac{2I}{c}$

$$\frac{E_m}{B_m} = c \qquad c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$$\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B} = \frac{\text{power}}{\text{area}} \qquad S_{avg} = I$$

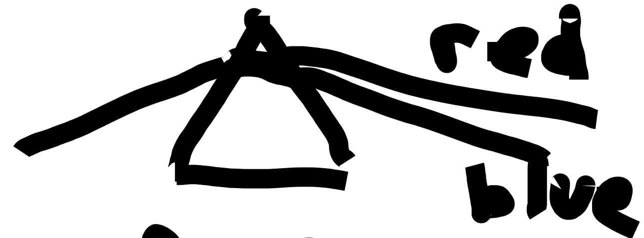
$$u = \frac{\text{energy}}{\text{volume}} \qquad \boxed{u \cdot c = S}$$

$u = u_E + u_B$ | $u_E = \frac{1}{2}\varepsilon_0 E^2$; $u_B = \frac{B^2}{2\mu_0}$

in a medium:

$$v = v(k) = \frac{\omega}{k} = \lambda f = \frac{c}{n}$$

$$n = \frac{c}{v} \;;\quad n(\lambda) = \frac{c}{v(\lambda)}$$

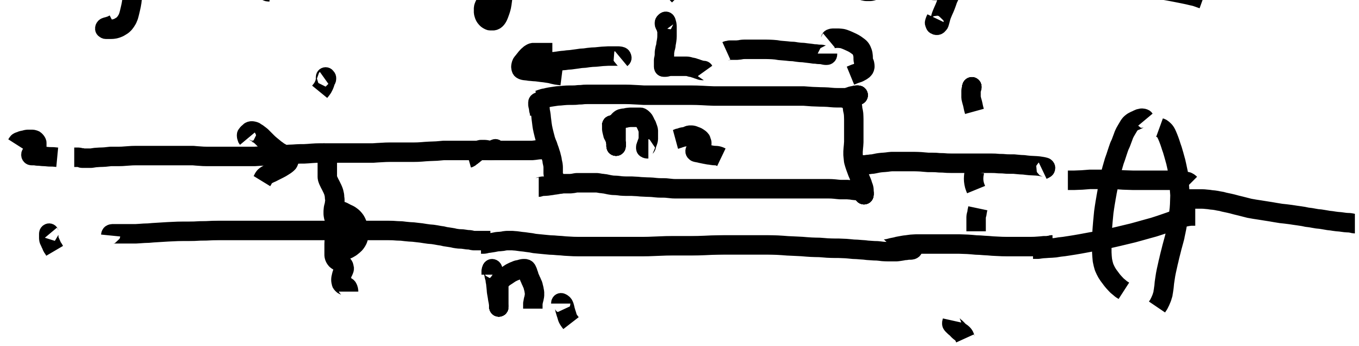


$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

f doesn't change

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

N = # of wavelengths in length L

1) 

$N_1 = \frac{L}{\lambda_{n_1}}$; $N_2 = \frac{L}{\lambda_{n_2}}$

$N_2 - N_1 = \frac{L}{\lambda}(n_2 - n_1) = \Delta N$

constructive : $\Delta N = m$ (integer)

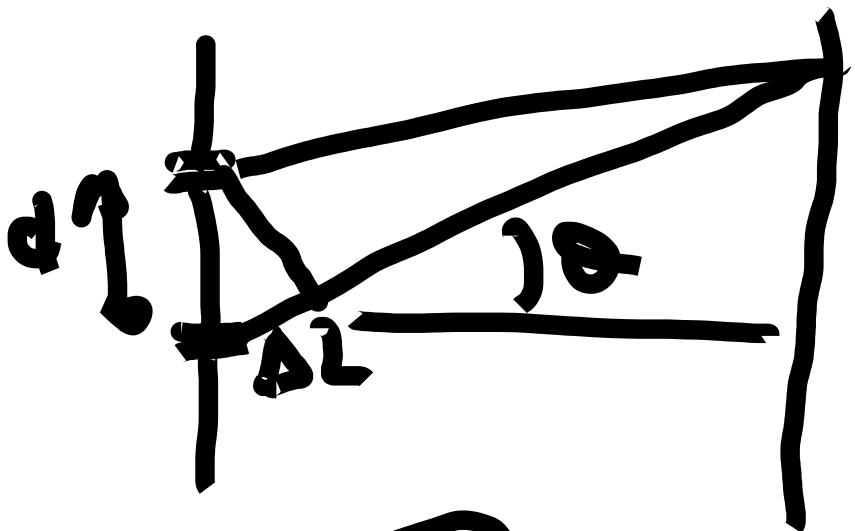
destructive : $\Delta N = m + \frac{1}{2}$

$\boxed{\Delta\phi = 2\pi \Delta N}$

$\Delta\phi = 2\pi m$

$\Delta\phi = 2\pi(m + \frac{1}{2})$

2) $\Delta N = \dfrac{\Delta L}{\lambda}$ $\quad\Delta\phi = 2\pi \dfrac{\Delta L}{\lambda}$

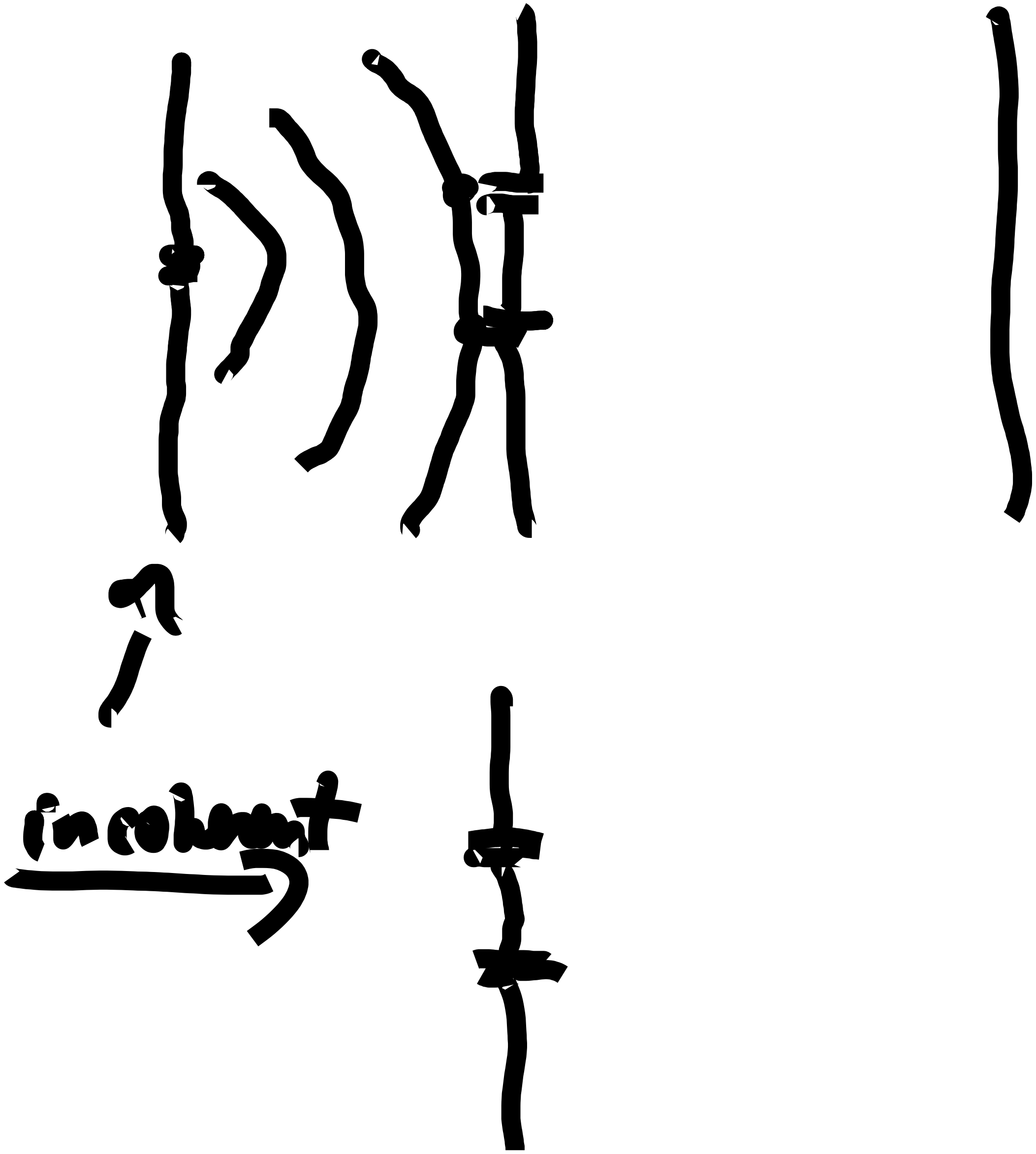


Young

$\Delta L = d \sin\theta$

$\sin(kx - \omega t)$

$k = \dfrac{2\pi}{\lambda}$ $\quad\Delta\phi = k\Delta x = \dfrac{2\pi}{\lambda}\Delta x$


incoherent

Interference

$E_1 = E_0 \sin\omega t$

$E_2 = E_0 \sin(\omega t + \phi)$

$$E = E_1 + E_2 = 2\cos\frac{\phi}{2}\, E_0 \sin\left(\omega t + \frac{\phi}{2}\right)$$

$I \propto E^2$

$\mathrm{Im}\, e^{i\omega t} = \sin\omega t$

$e^{i(\omega t + \phi)}$

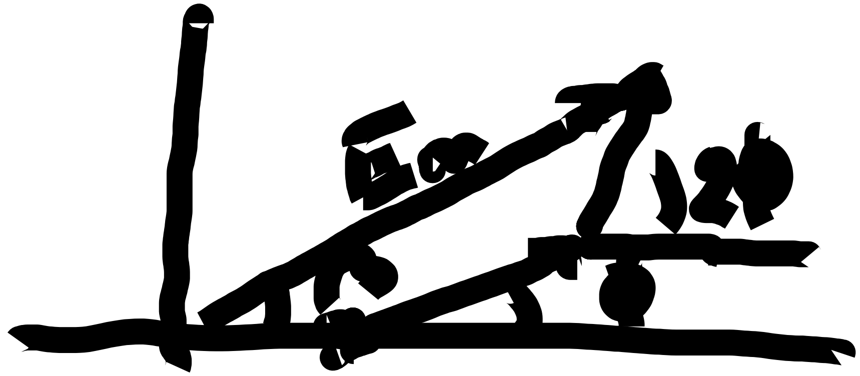
$$1 + e^{i\phi} = e^{i\phi/2}\left(e^{-i\phi/2} + e^{i\phi/2}\right) = 2\cos\frac{\phi}{2}\, e^{i\phi/2}$$

$I =$

$E_1 = E_0 \sin(\omega t)$

$E_2 = E_0 \sin(\omega t + \phi)$

$E_3 = E_0 \sin(\omega t + 2\phi)$



$E = E_1 + E_2 + E_3 = E_m \sin(\omega t + \beta)$

$E_h = E_0(1 + \cos\phi + \cos 2\phi)$

$E_v = E_0(\sin\phi + \sin 2\phi)$

$E_m = \sqrt{E_h^2 + E_v^2}$

$\tan\beta = E_v / E_h$

$\beta = \phi$

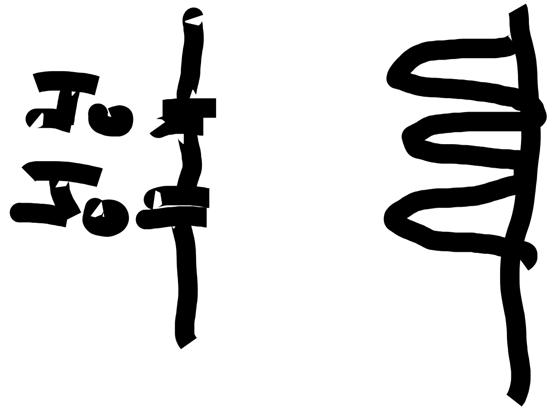
$E = e^{i(\omega t + \phi)} \underbrace{(1 + 2\cos\phi)E_0}_{E_m}$

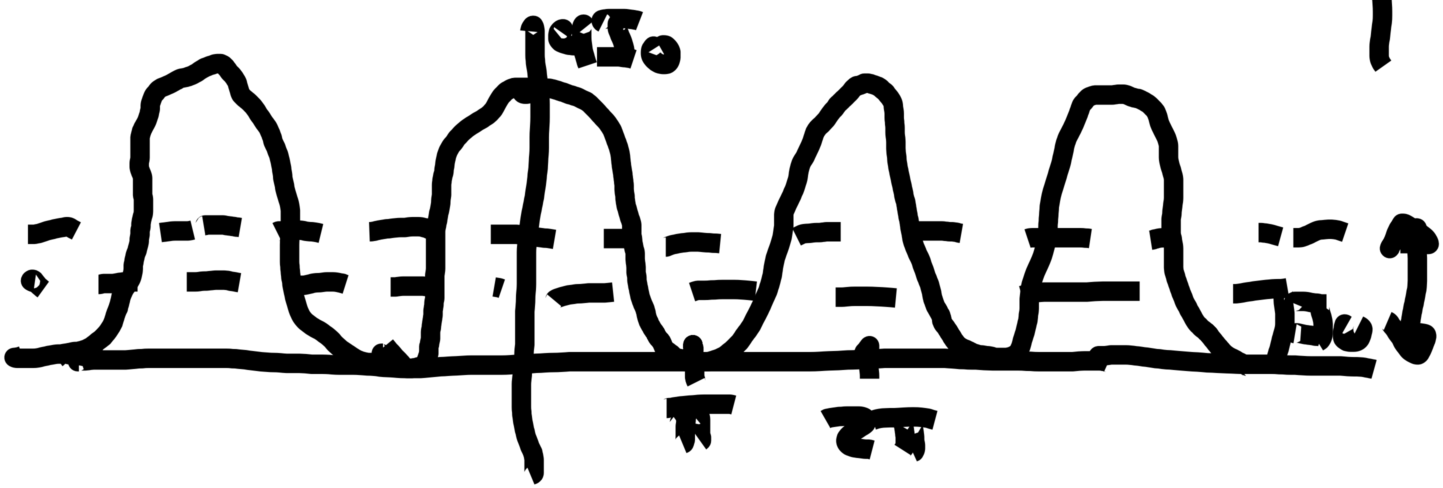
$1 + e^{i\phi} + e^{2i\phi} = e^{i\phi}(1 + e^{-i\phi} + e^{i\phi}) =$

$= e^{i\phi}(1 + 2\cos\phi)$

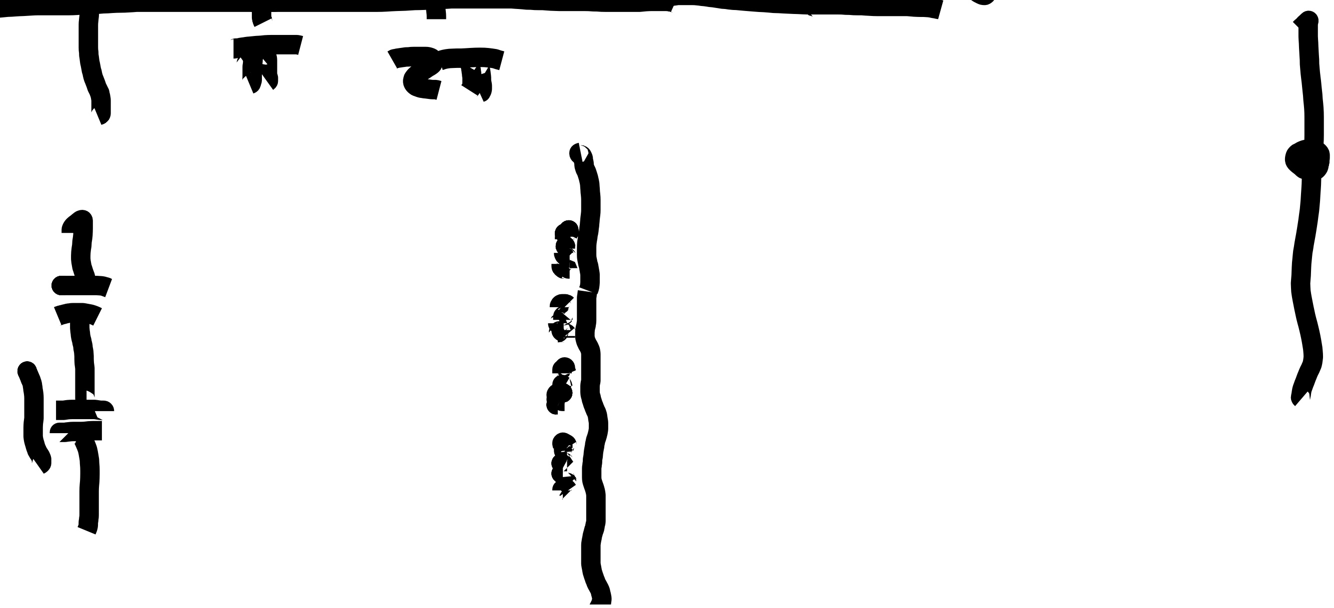
$$E = E_1 + E_2 = 2 E_0 \cos\frac{\phi}{2} \sin(\omega t + \phi/2)$$

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





beam of electrons



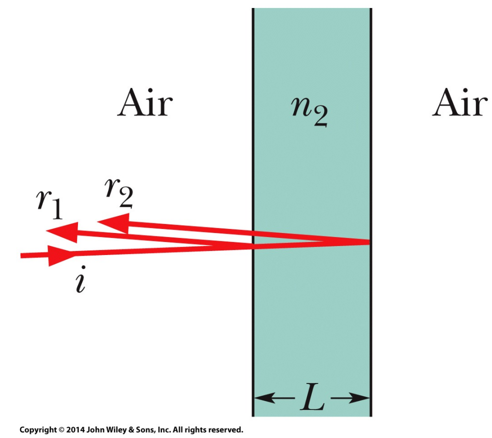
35-4 Interference from thin films

When light is incident on a thin transparent film, the light waves reflected from the front and back surfaces interfere. For near-normal incidence, the wavelength conditions for maximum and mini- mum intensity of the light reflected from a film with air on both sides are

$$2L = (m + \tfrac{1}{2})\frac{\lambda}{n_2}, \quad \text{for } m = 0, 1, 2, \ldots \quad \text{(maxima—bright film in air).}$$

and

$$2L = m\frac{\lambda}{n_2}, \quad \text{for } m = 0, 1, 2, \ldots \quad \text{(minima—dark film in air).}$$



Reflections from a thin film in air.

where n_2 is the index of refraction of the film, L is its thickness, and λ is the wavelength of the light in air.

If a film is sandwiched between media other than air, these equations for bright and dark films may be interchanged, depending on the relative indexes of refraction.

If the light incident at an interface between media with different indexes of refraction is initially in the medium with the smaller index of refraction, the reflection causes a phase change of π *rad*, or half a wavelength, in the reflected wave. Otherwise, there is no phase change due to the reflection. Refraction causes no phase shift.

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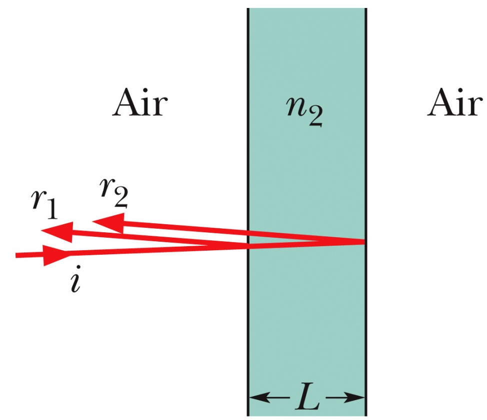

Reflections from a thin film in air.

ar

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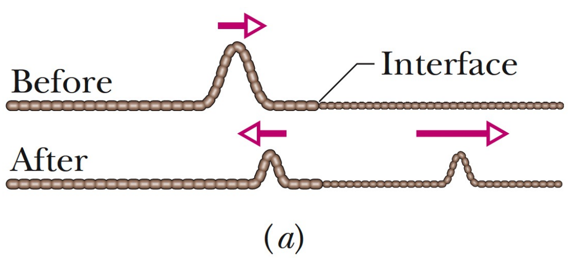
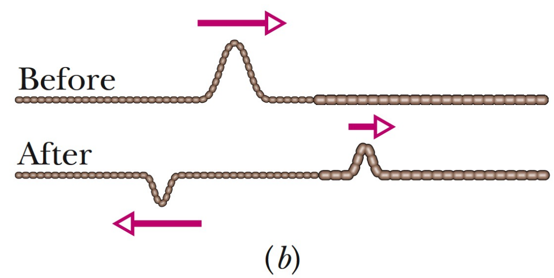


(*a*)

The incident pulse is in the denser string.

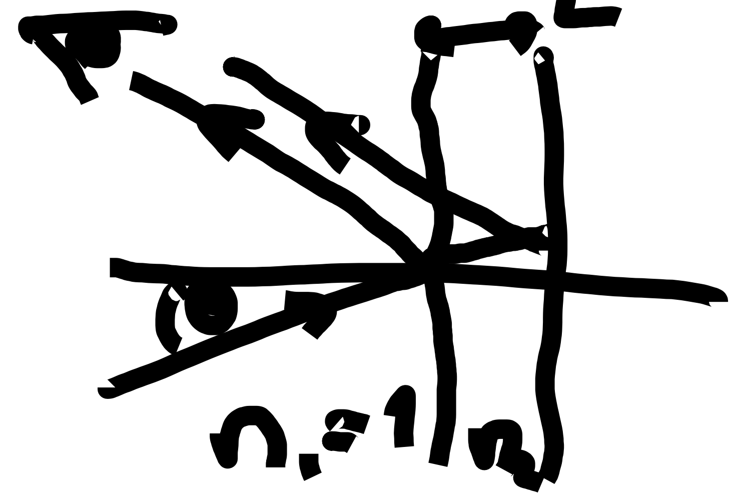
Reflection	Reflection phase shift
Off lower index	0
Off higher index	0.5 wavelength



(*b*)

The incident pulse in the lighter string. Only here is there a phase change, and only in the reflected wave.

Thin films



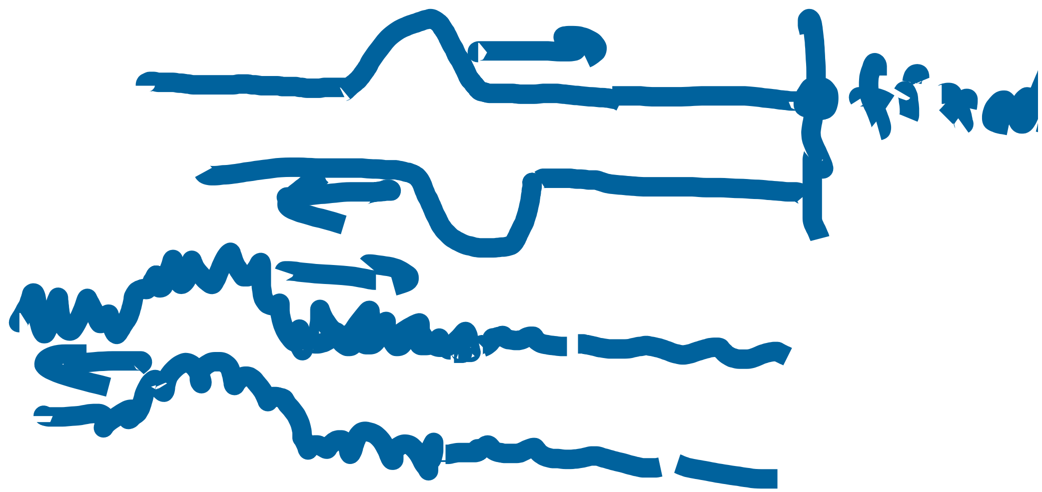
$$\frac{\overbrace{\Delta L}^{2L}}{\lambda_n} \rightarrow \text{half integer}$$

constructive bright

$$\frac{\Delta L}{\lambda_n} = \text{integer : dark}$$

reflection can cause π phase shift

when if $\underline{n_1 < n_2}$



$$\lambda_n = \frac{\lambda}{n_2}$$