PHYS 2170

General Physics 3 for Majors

Fall 2021

Lecture 24

Interference of light in thin films and between two slits

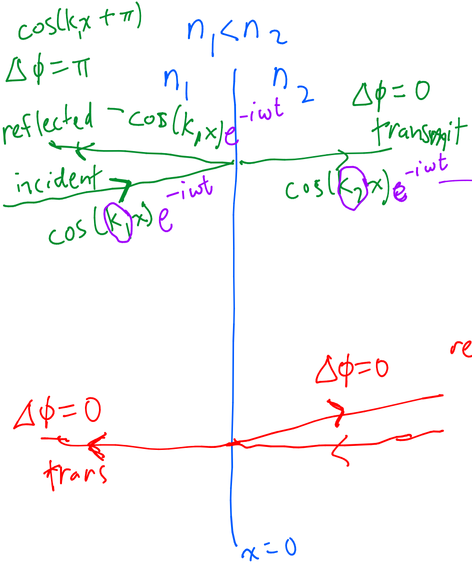
October 20

1 Discuss the boundary conditions for how light reflects at an interface between two different materials.

EM waves ("light") propagates at velocity c/n

- if no material: $n = 1$
- in a material: $n \geq 1$

$k_1 = \frac{2\pi}{\lambda_1}$ $k_2 = \frac{2\pi}{\lambda_2}$

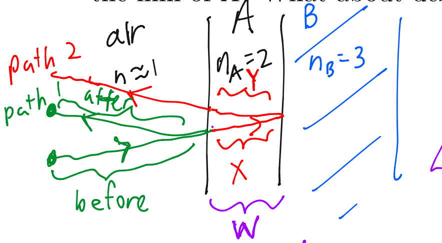


incoming frequency f_1

$f_2 = f_1$

- frequency, not wavelength, is constant across interface.

2 Materials A and B have index of refraction $1 < n_A = 2 < n_B = 3$. If a thin layer of A of width w is painted on a thick slab of B, what is the longest wavelength for which there is constructive interference due to the film of A? What about destructive interference?



Wave has wavelength λ_0 in air.

$\frac{c}{n_A} = f\lambda_A \qquad \frac{c}{1} = f\lambda_0$

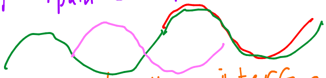
path 1: $\phi_{bef} + \pi + \phi_{aft}$ (AB refl)

path 2: $\phi_{bef} + 0$ (trans) $+ \phi_X + \pi + \phi_Y + 0$ (trans) $+ \phi_{after}$

$\lambda_A = \frac{\lambda_0}{n_A}$

$\phi_X = \phi_Y = \frac{w}{\lambda_A} 2\pi$

$\Delta\phi = \phi_{path\ 2} - \phi_{path\ 1} = 2\phi_X = \frac{4\pi w}{\lambda_A} = \frac{8\pi w}{\lambda_0}$



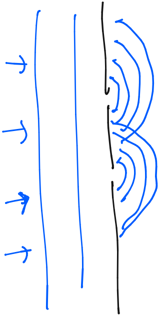
constructive interference: $\Delta\phi = 2\pi, 4\pi, \ldots$

destructive interference? $\Delta\phi = \pi, 3\pi, \ldots$

constructive: $\frac{1}{4}\lambda_0 = w$

destructive: $\frac{1}{8}\lambda_0 = w$

3 Describe how light (and waves in general) propagate away from a coherent point source.



1d:

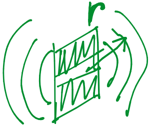
$E_y \sim e^{ik(x+ct)}$

$E_y \sim e^{ik(x-ct)}$

↑ proportional

$K = \frac{2\pi}{\lambda}$

2d:

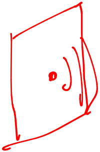


$E \sim \frac{1}{\sqrt{r}} e^{ik(r-ct)}$

$I \sim \frac{\text{energy}}{\text{volume}} \sim \frac{1}{2} \varepsilon_0 |E|^2$

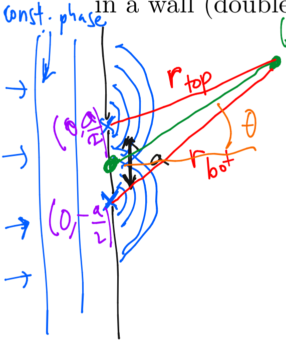
wavefront energy $\sim \pi r \times I \sim$ r-ind.

3d:



$E \sim \frac{1}{r} e^{ik(r-ct)}$

4 Describe the amplitude of light which passes through a pair of thin slits in a wall (double-slit interference).



$(x, y) = (r\cos\theta, r\sin\theta)$

$E(x,y) \approx \frac{1}{\sqrt{r_{top}}} e^{ik(r_{top} - ct)} + \frac{1}{\sqrt{r_{bot}}} e^{ik(r_{bot} - ct)}$

$r_{top} = \sqrt{x^2 + (y - \frac{a}{2})^2}$ $r \gg a$

$= \sqrt{r^2 - 2\frac{a}{2} r\sin\theta + (\frac{a}{2})^2}$

$\approx r\sqrt{1 - \frac{a}{r}\sin\theta} \approx r - \frac{a}{2}\sin\theta$

$r_{bot} \approx r + \frac{a}{2}\sin\theta$

- const phase in incoming wave
- at openings slit, light is in phase

$E \approx \frac{1}{\sqrt{r}} e^{-ikct}\left(e^{ik(r - \frac{a}{2}\sin\theta)} + e^{ik(r + \frac{a}{2}\sin\theta)}\right)$

$e^{ikr} 2\cos\left(\frac{ka}{2}\sin\theta\right)$

5 Describe the intensity of light as viewed on a screen far from the original slits.