Physics 102

Lecture 30

Mon. Nov. 22, 2004

Ch. 28

Physical Optics — Wave Optics (another model for the study of light)

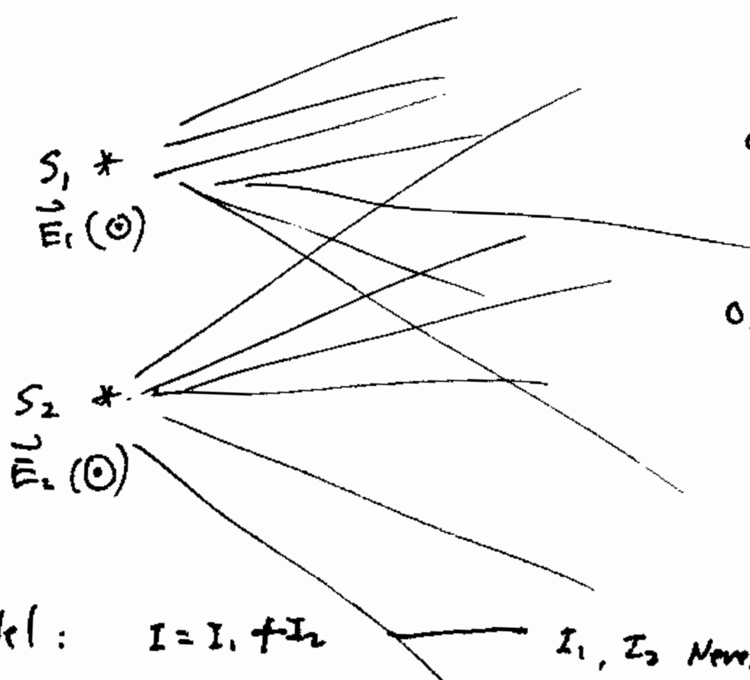
- last chapter: Geometrical Optics — Ray optics (A beam of particles)

- A fundamental behaviour of waves — superposition.

  ⇓

  interference.

e.g. Two light sources S_1, S_2.



overlaping area:

$I = I_1 + I_2$.

OR $\vec{E} = \vec{E}_1 + \vec{E}_2$?

$(I \propto E^2)$

$I = c\,\varepsilon_0 E^2$.

Particle Model: $I = I_1 + I_2$ — I_1, I_2 Never cancel

Wave Model: $\vec{E} = \vec{E}_1 + \vec{E}_2$ — $\vec{E}_1$, $\vec{E}_2$ sometimes can cancel!

↖ superposition.

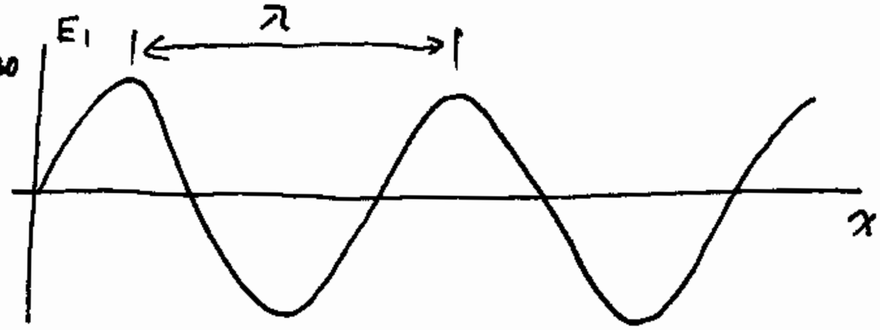
$\vec{E} = \vec{E}_0 \cos(kx - \omega t + \varphi)$, $\vec{E}_{Total} = \vec{E}_1 + \vec{E}_2$

e.g.: $\vec{E}_1 \parallel \vec{E}_2 \parallel \hat{y}$, $\vec{E}_{10} = \vec{E}_{20}$

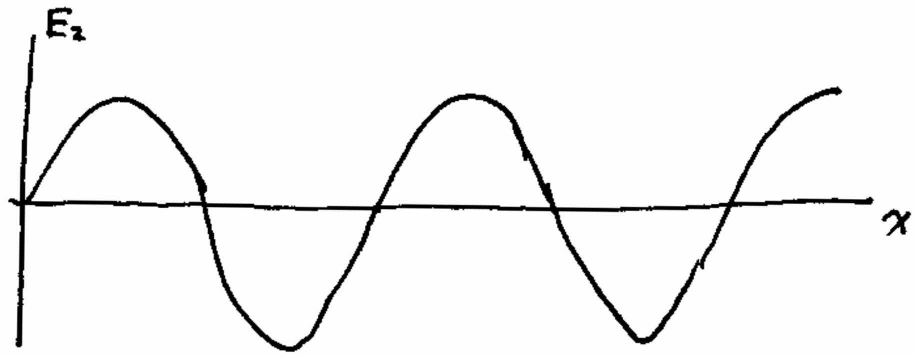
$\lambda_1 = \lambda_2$

$\omega_1 = \omega_2$

and $\varphi_1 = \varphi_2$



2 waves are in phase.

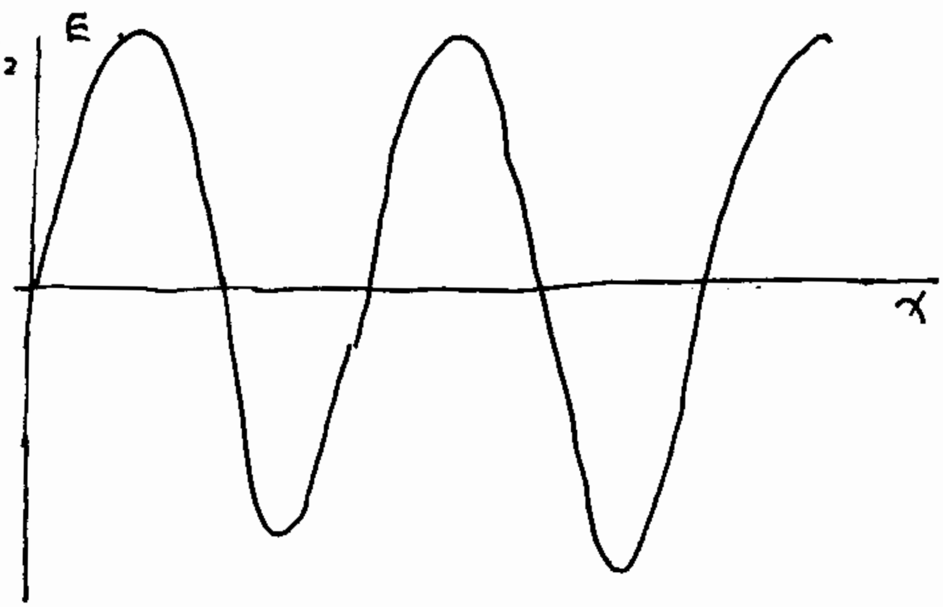


$E = E_1 + E_2$

$= 2E_1$.

$I = E^2 = 4E_1^2$

$\therefore\ I = 4I_1 \neq I_1 + I_2$



Constructive interference:

in ~~phase~~: phase shift $= 0, \pm 2\pi, \pm 4\pi \cdots$

wave shifted by: $0, \pm\lambda, \pm 2\lambda, \pm 3\lambda, \cdots\cdots$

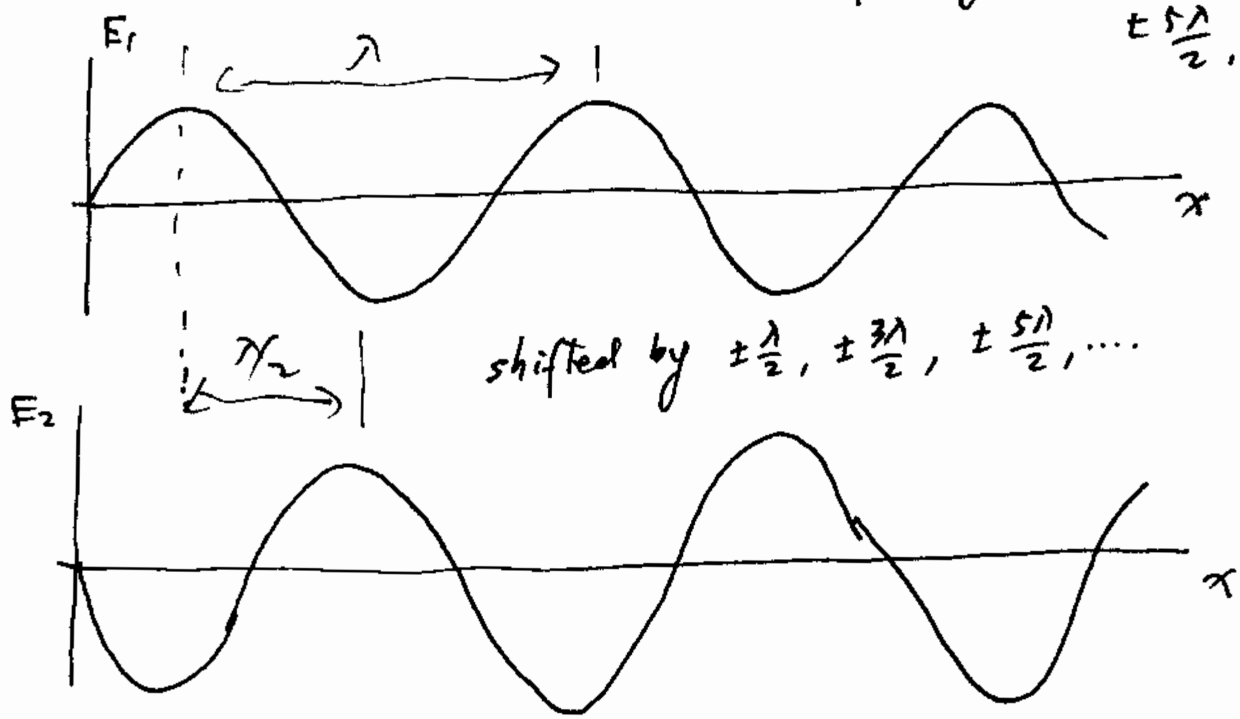
e.g. Out of phase. when $\omega_1 = \omega_2$. $(\lambda_1 = \lambda_2)$

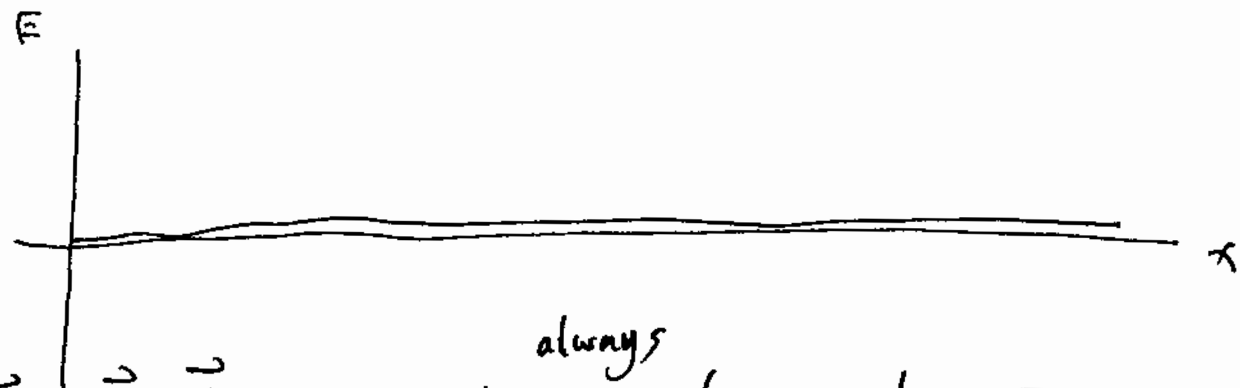
$$\varphi_2 = \varphi_1 + \pi.$$

$$\omega_1 t + \varphi_1 = \omega_2 t + \varphi_1 + \pi = \omega_1 t + \varphi_1 + \pi.$$

the phase difference between the two waves is always π, $\pm 3\pi$, ...

Two waves are shifted by $\pm\frac{\lambda}{2}$, $\pm\frac{3\lambda}{2}$, $\pm\frac{5\lambda}{2}$, ...





$\vec{E} = \vec{E}_1 + \vec{E}_2 = 0$. They always cancel ! ~~everywhere~~.

(destructive interference.)

$I = c\varepsilon_0 E^2 = 0$. $(\neq I_1 + I_2)$.

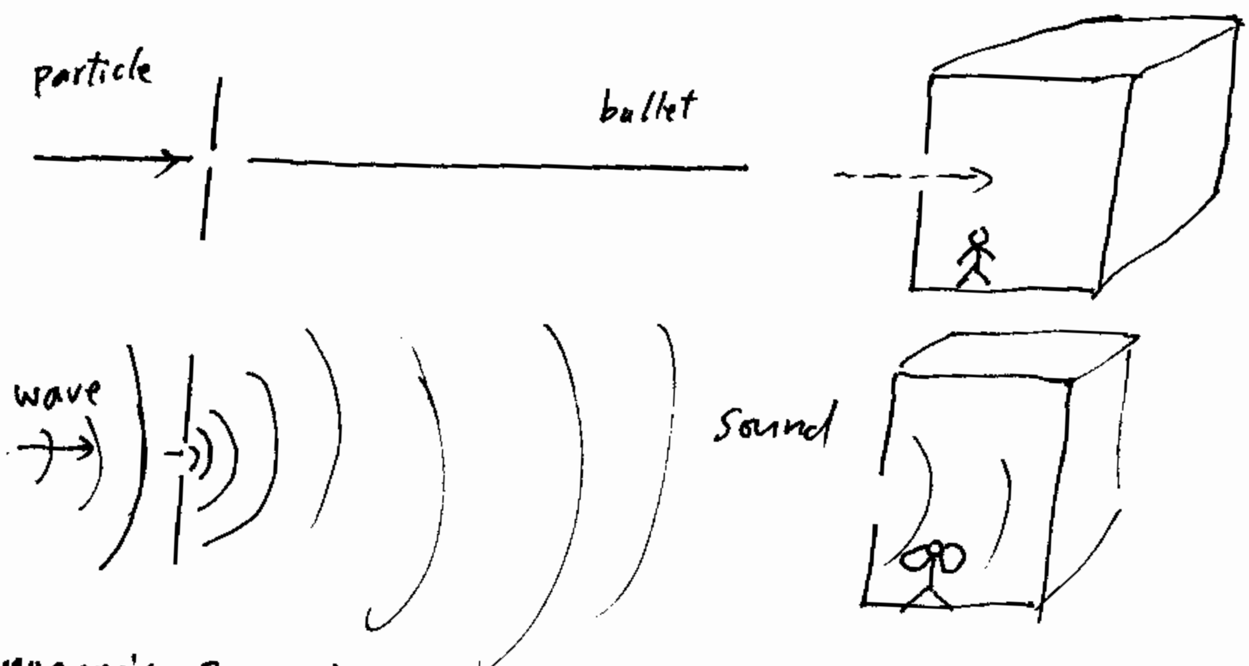
- Usually we don't see such interference effects of light. Why?

  Condition for observing interference:

  ① . Monochromatic ⟶ Two waves have the same freq.

  ② coherent ⟶ Two waves have <u>constant</u> phase relationship.
  (constant ⟵ always (Doesn't change with time).)

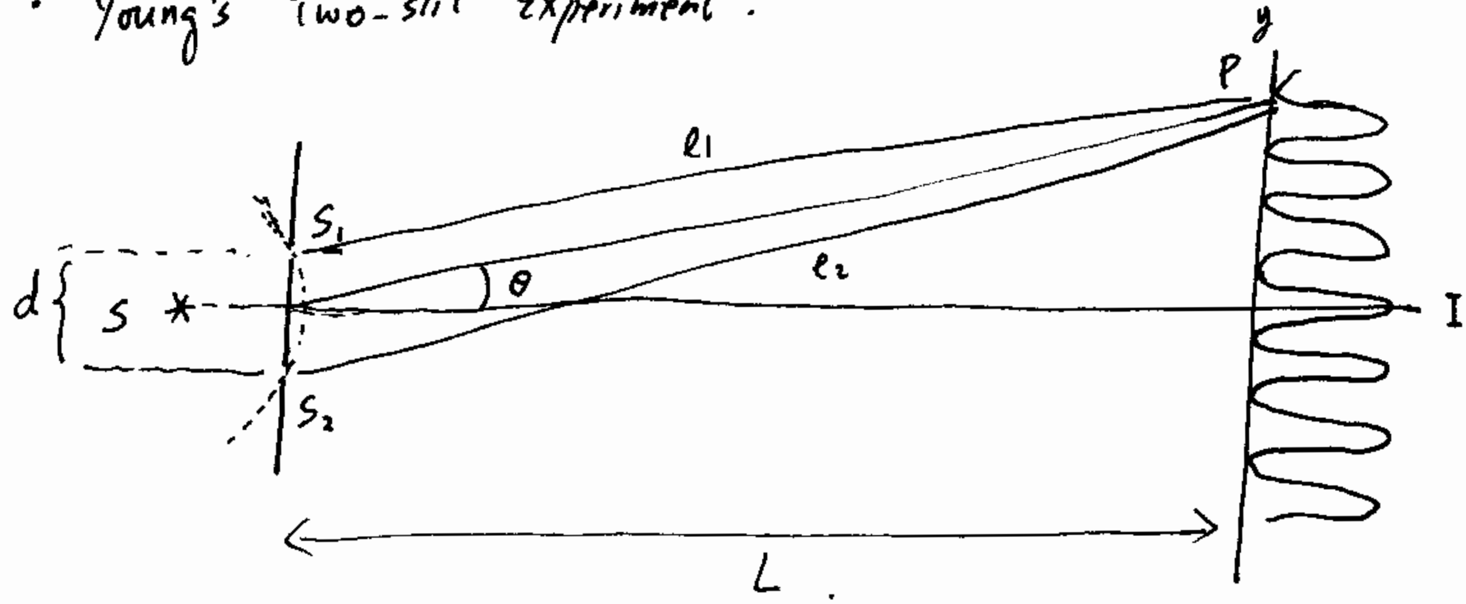
- Particle vs. wave.



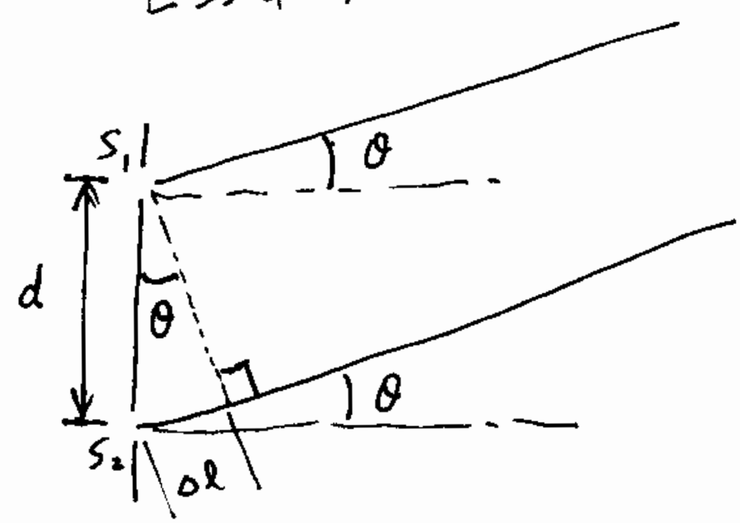
- Huygens's Principle:

  Each point on a wavefront is the source of a spherical wavelet.

• Young's Two-slit Experiment.



$L \gg d$.



S_1 and S_2 have the same phase. $(kx - \omega t + \varphi)$

At point P on the viewing screen:

wave from S_1 has a path of l_1

wave from S_2 has a path of l_2.

- Path difference

$$\Delta l = d \cdot \sin\theta$$

- Constructive interference (bright fringes)

$$\Delta l = 0,\ \pm\lambda,\ \pm 2\lambda,\ \pm 3\lambda,\ \ldots$$

OR: $\Delta l = m\lambda$.

$d \cdot \sin\theta = m\lambda$ } $m = 0, \pm 1, \pm 2, \ldots$

- Destructive interference (dark fringes).

$$d \cdot \sin\theta = (m - \tfrac{1}{2})\lambda, \quad m = 0, \pm 1, \pm 2, \cdots$$

- On the viewing screen:

$$y = L \cdot \tan\theta.$$

} To determine the location of bright and dark fringes.