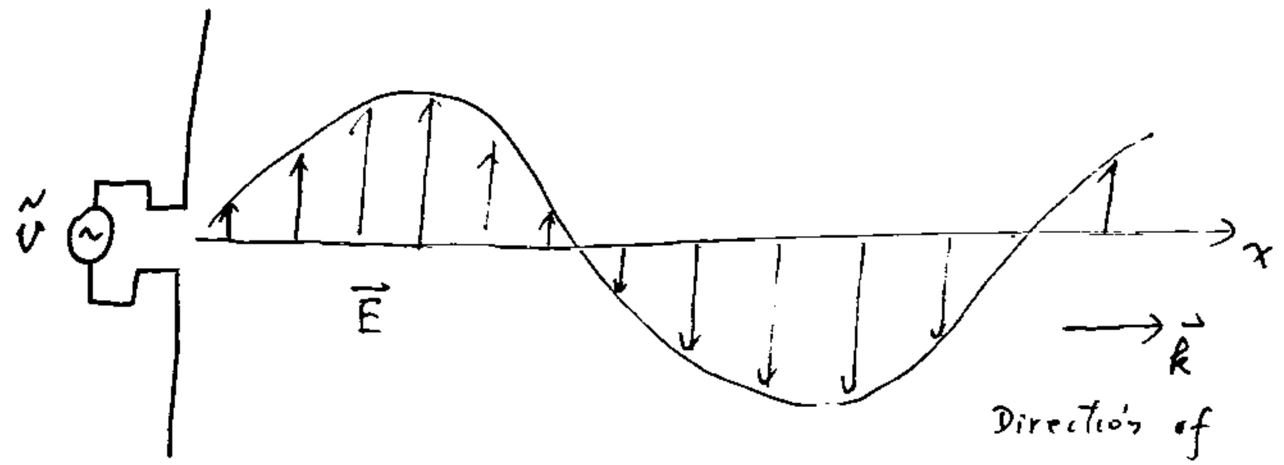
Physics 102.

Lecture 22. Monday, Nov. 1, 2004

- A way to generate an electromagnetic wave.

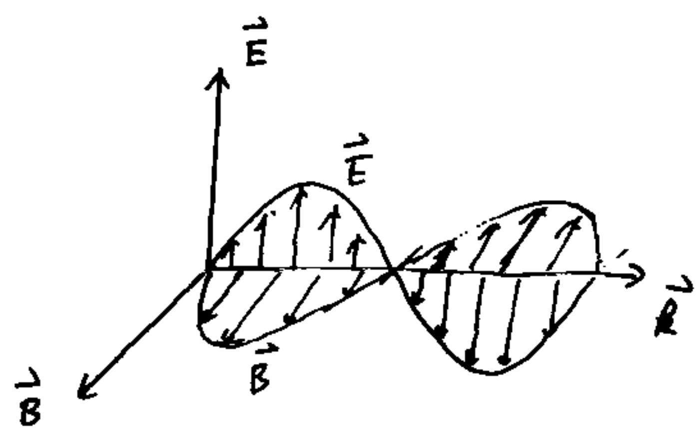


Relationship between the directions of $\vec{E}$, $\vec{B}$, $\vec{k}$:

$\vec{E} \perp \vec{B}$, $\vec{k} \perp \vec{E}$, $\vec{k} \perp \vec{B}$.

$\vec{k} \parallel (\vec{E} \times \vec{B})$ Right hand rule!

- EM wave is a transverse wave.



- Note: Light is also an EM wave!

- Polarization

In an EM wave, if $\vec{E}$ oscillates in one direction only (such as in z-direction), the wave is linearly polarized (in z-direction).

- Natural Light is unpolarized

e.g., when a wave of natural light is propagating along x-direction, the $\vec{E}$ vector is randomly distributed in the y-z plane.

Why? A beam of light is typically generated by many atoms. Each atom is an independent light source. The $\vec{E}$ direction generated by an ~~at~~ atom can be arbitrary in the plane perpendicular to the $\vec{k}$ vector.

↑ direction of propagation.

- Linear Polarizer.

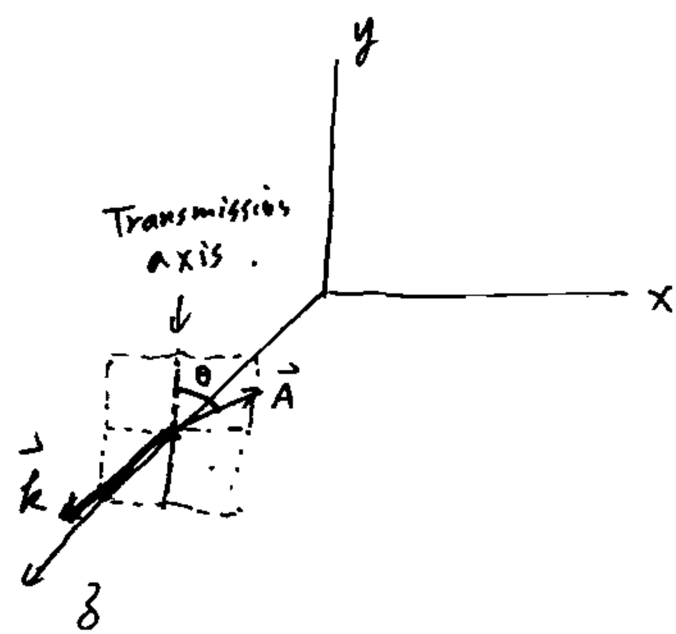
<u>Allows one direction of $\vec{E}$</u> To get Through

Transmission axis.

When a wave has an $\vec{E}$ perpendicular to the transmission axis, it will be blocked (absorbed).

e.g.: When a light beam is propagating along z-direction, if we put a linear polarizer in front of it with the transmission axis along y.

①. If the wave is linearly polarized along y. (i.e, $\vec{E} // y$). Then, the wave gets through. ($E_{out} = E_{in}$)



②. If the wave is linearly polarized along x (i.e. $\vec{E} // x$). Then the wave is blocked. ($E_{out} = 0$).

③. If the wave is linearly polarized along $\vec{A}$,

Then only thy y-component will get through.

And the wave becomes polarized along y.
$\left(E_{out} = E_{in} \cdot \cos\theta \right)$ $\left(\begin{array}{c} I_{out} = I_{in} \cdot \cos^2\theta \\ \because I \propto E^2 \end{array} \right)$

④. If the wave is unpolarized.

The the wave will become linearly polarized along y. (E_{out} is along y.)

∴ No matter what, after the wave goes through the polarizer, it will become linearly polarized along the transmission axis direction).

- Polarization analyzer.

  — to examine a wave and see if it is polarized.

A linear polarizer is a polarization analyzer at the same time because it can tell us if a wave is polarized.

Demo :

- Facts about EM waves.

① . Speed in vacuum (free space).

$$C = 3.00 \times 10^{8} \ m/s . \left(= \frac{1}{\sqrt{\varepsilon_0 \mu_0}} . \right)$$

Regardless the motion of source or observer !!

That's the base of Eistein's Relativity Theory.

② . The Doppler effect.

$$f' = f\left(1 \pm \frac{u}{c}\right)$$

u — relative speed between source and observer.

$+$ — approaching. (higher f)

$-$ — receding. (lower f).

③ Energy.

Energy density: $\vec{E}$-field: $u_E = \frac{1}{2}\varepsilon_0 E^2$.

$\vec{B}$-field: $u_B = \frac{1}{2}\frac{1}{\mu_0}B^2$.

Note: $u_E = u_B$.

$$\frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\frac{1}{\mu_0}B^2 .$$

$$E = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} B . = c \cdot B .$$

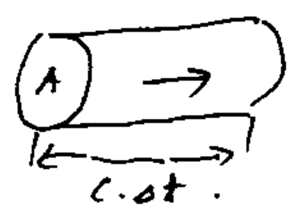
Total Energy density: $u = u_E + u_B$

$$= \varepsilon_0 E^2$$

$$= \frac{B^2}{\mu_0}.$$

- Intensity:

$$I = \frac{\text{Power}}{\text{area}} = \frac{\text{Energy}/\Delta t}{\text{area}} = \frac{u \cdot \text{Volume}/\Delta t}{\text{area}}.$$



$$\therefore \quad I = \frac{\varepsilon_0 E^2 \cdot (A \cdot c \cdot \Delta t)/\Delta t}{A} = \varepsilon_0 E^2 c = uc.$$

$$= \frac{B^2}{\mu_0} c.$$

- Momentum:

$$p = \frac{U}{c} = \frac{u \cdot (A \cdot c \cdot \Delta t)}{c} = u A \cdot \Delta t.$$

- Pressure: (absorption).

$$P_{av} = \frac{F_{av}}{\Delta t \cdot A} = u = \frac{I}{c}.$$

$p_f = 0$.

- The electromagnetic spectrum (you read) (25-3. p.825)

wavelength : $\lambda = \dfrac{c}{f}$. in vacuum.

f – frequency

in a medium : $\lambda = \dfrac{v}{f}$.

v — velocity of the wave.

$v \leq c$