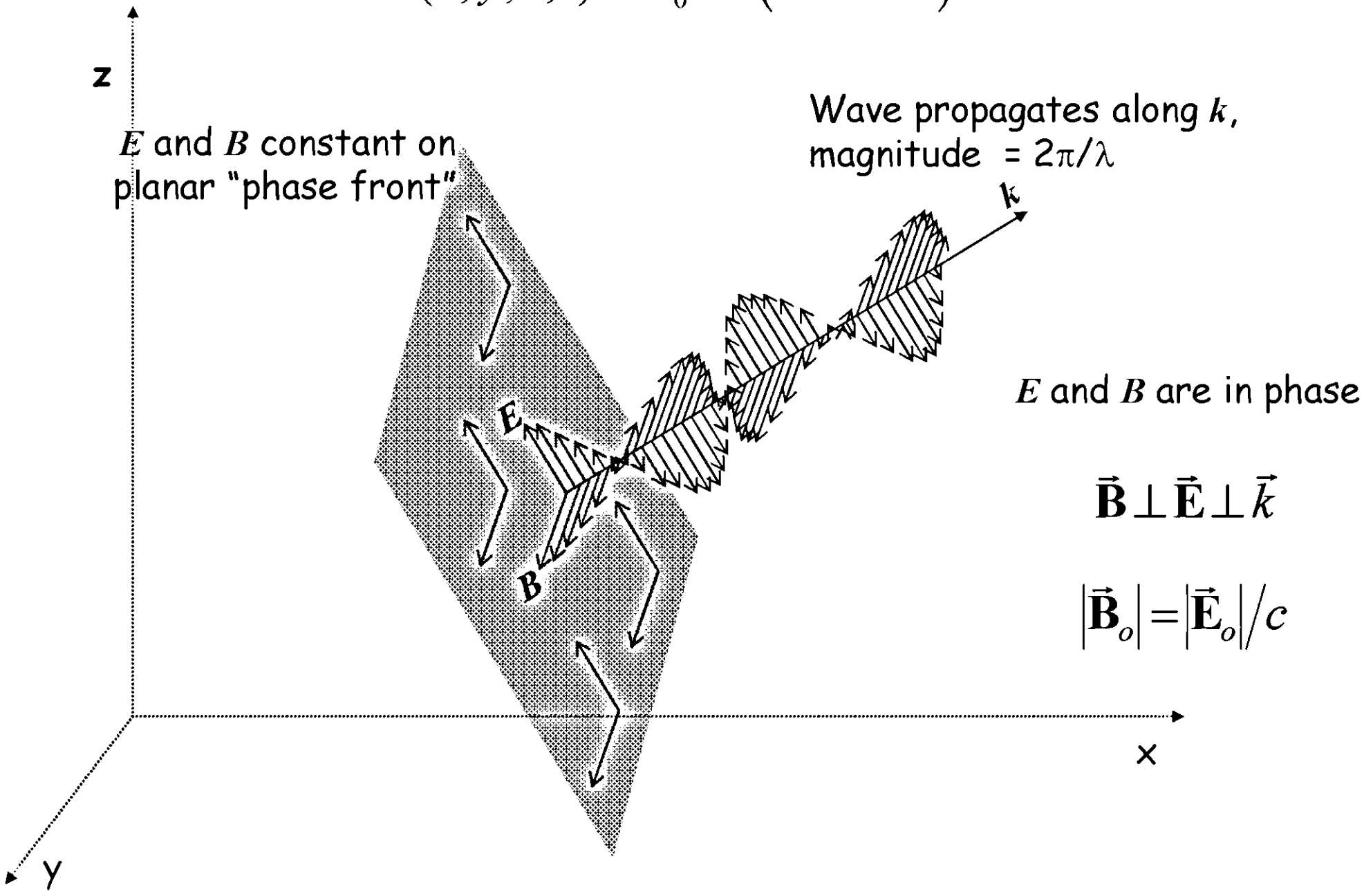
EM Plane Wave: $\vec{\mathbf{E}}(x,y,z,t) = \vec{E}_0 \sin\left(\vec{k}\cdot\vec{r} - \omega t\right)$

$$\vec{\mathbf{B}}(x,y,z,t) = \vec{B}_0 \sin\left(\vec{k}\cdot\vec{r} - \omega t\right)$$



Energy density (J/m^3) in an electrostatic field:

$$u_E = \tfrac{1}{2}\varepsilon_0 E^2$$

Energy density (J/m^3) in an magnetostatic field:

$$u_B = \frac{1}{2\mu_0} B^2$$

Energy density in an electromagnetic wave is equally divided:

$$u_E = \tfrac{1}{2}\varepsilon_0 E^2$$

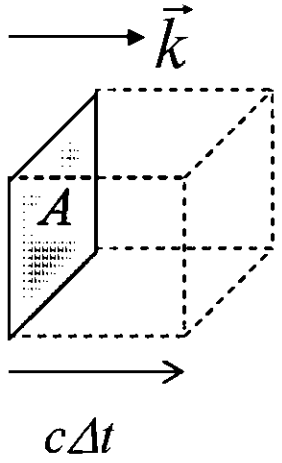
$$= \tfrac{1}{2}\varepsilon_0 c^2 B^2$$

$$= \frac{\varepsilon_0}{2\varepsilon_0\mu_0} B^2$$

$$= u_B$$

$$u_{total} = u_E + u_B = \varepsilon_0 E^2 = \frac{1}{\mu_0} B^2$$

Rate of energy transport: Power (W)



$$P = \frac{energy}{\Delta t} = \frac{u\Delta V}{\Delta t} = \frac{uAc\Delta t}{\Delta t}$$

$$P = ucA$$

Power per unit area (W/m^2):

$$S = uc$$

$$S = \varepsilon_0 c^2 EB$$

$$\vec{S} = \varepsilon_0 c^2 \vec{E} \times \vec{B}$$

~~Pointing~~ Vector

Poynting

Poynting Vector oscillates very rapidly!

$$E = E_0 \cos(\omega t) \qquad B = B_0 \cos(\omega t)$$

$$S = \varepsilon_0 c^2 E_0 B_0 \cos^2(\omega t)$$

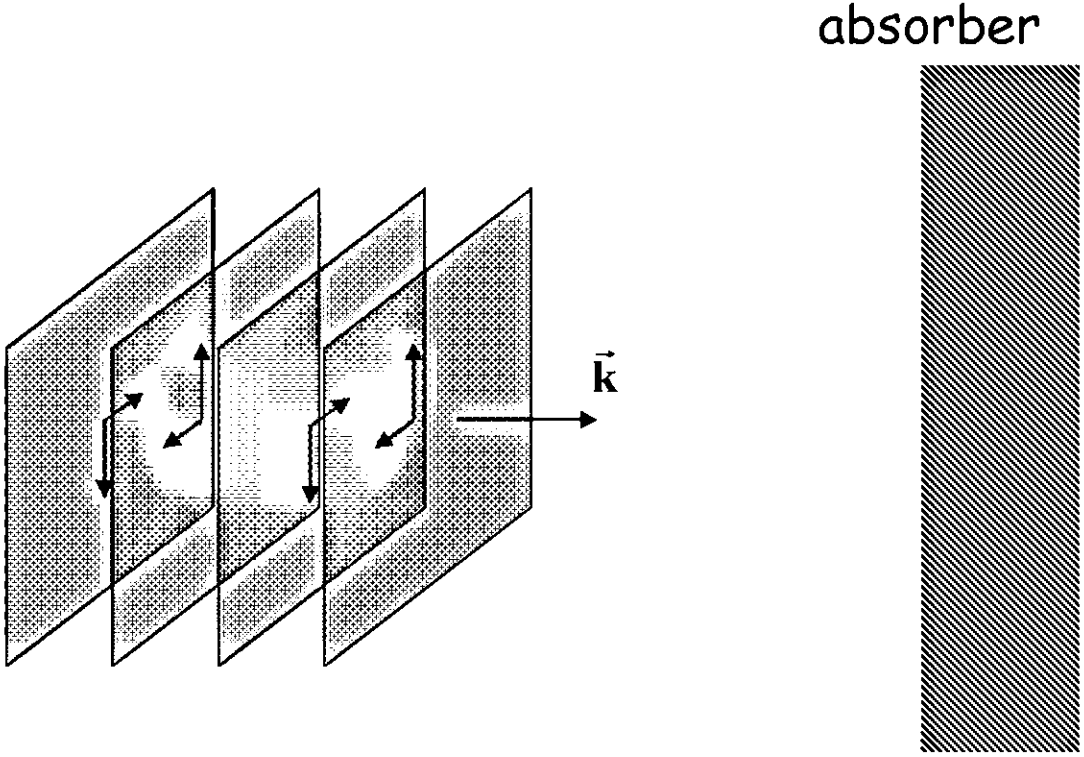
Take the time average:

$$\langle S \rangle = \varepsilon_0 c^2 E_0 B_0 \overline{\cos^2(\omega t)}$$

$$\langle S \rangle = \tfrac{1}{2} \varepsilon_0 c^2 E_0 B_0$$

$$\langle S \rangle = E_e \quad \text{"Irradiance" } (\mathrm{W/m^2})$$

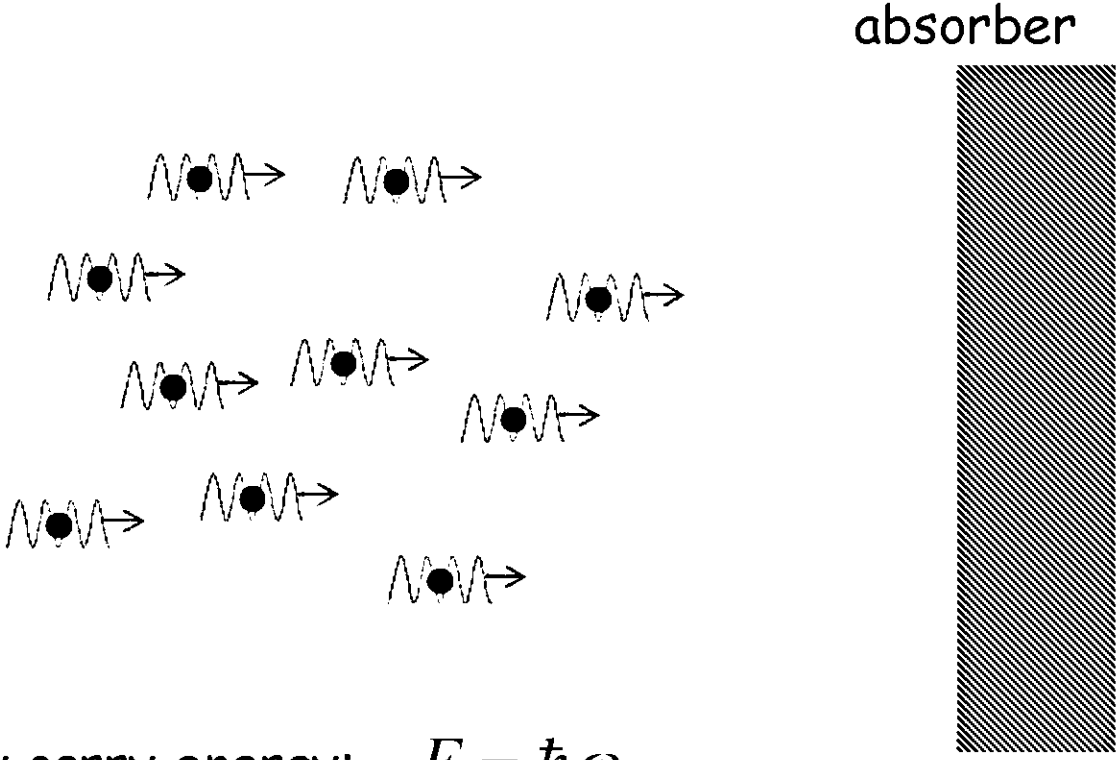
EM radiation carries momentum:



Radiation pressure $$\mathrm{P} = u_{total} = \frac{\vec{S}}{c}$$

$$\langle \mathrm{P} \rangle = \frac{E_e}{c}$$

Light is really made up of particles - photons



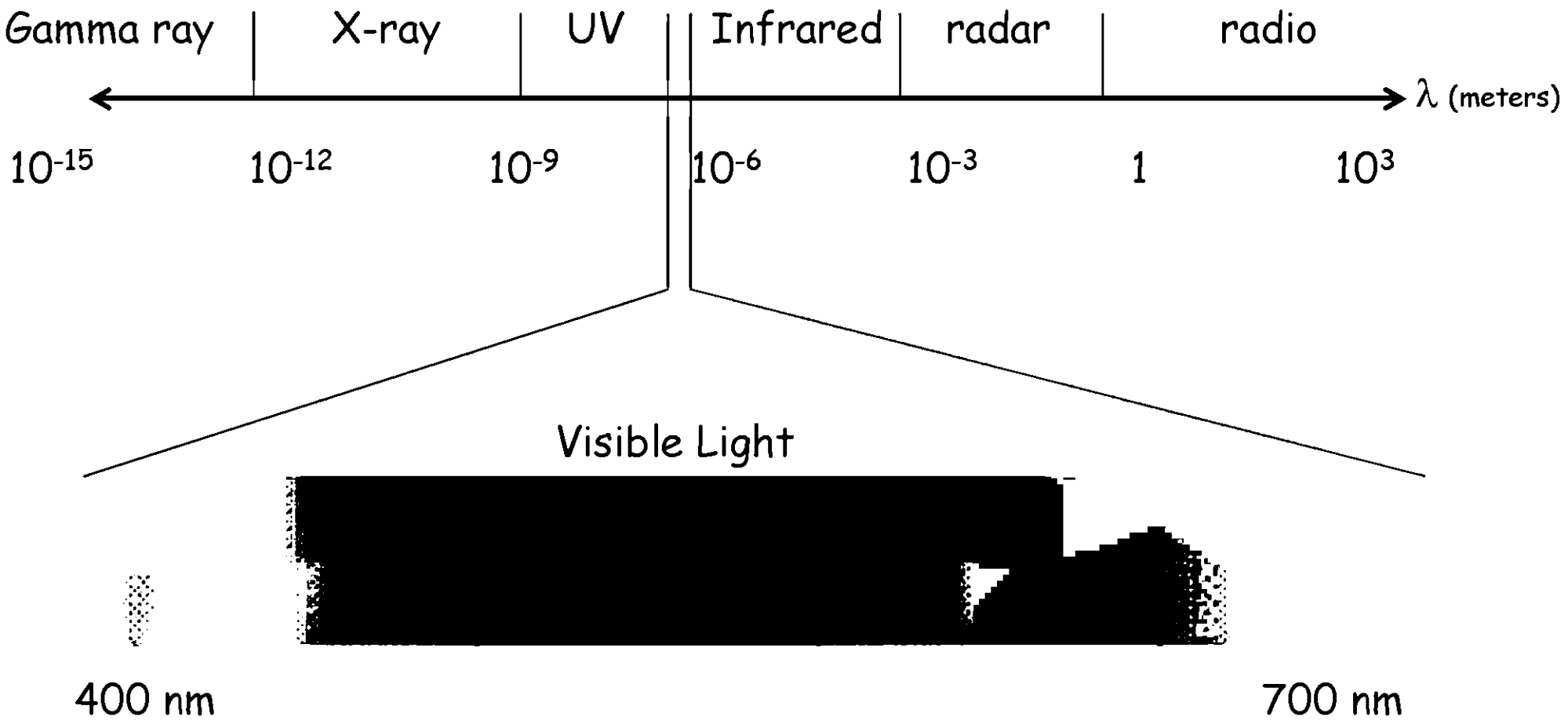
They carry energy: $E = \hbar\omega$

and momentum: $p = \hbar k$

"H-bar" is Planck's constant: $\hbar = 1.05 \times 10^{-34}\ \mathrm{Js}$

$$\vec{\mathbf{E}}(\vec{\mathbf{r}},t) = \vec{E}_0 \cos\left(\vec{k}\cdot\vec{r} - \omega t\right)$$

$$\omega = ck$$



Photometry: the measurement of EM radiation *as perceived by the eye.*

Luminous Flux	Φ_v	lumen (lm)
Luminous Exitance	M_v	lm/m^2
Illuminance	E_v	lm/m^2 or lux (lx)
Luminous Intensity	I_v	lm/sr or candela (cd)
Luminance (brightness)	L_v	cd/m^2 or nit

(Photometric value) = 685 x V(λ) x (radiometric value)