Problem 1.2

What are the numerical values of \( k \) and \( \omega \) for the EM wave

\[
E = E_0 \sin \left( (9.72 \times 10^6 \text{ m}^{-1}) \times -(2.92 \times 10^{15} \text{ s}^{-1})t \right)
\]

From these values, determine the wavelength \( \lambda \), frequency \( \nu \), and evaluate \( \lambda \nu \).

Solution

\[
k = 9.72 \times 10^6 \text{ m}^{-1} \quad \lambda = \frac{2\pi}{k} \quad \nu = \frac{\omega}{2\pi}
\]

\[
\omega = 2.92 \times 10^{15} \text{ s}^{-1} \quad \lambda = \frac{2\pi}{(9.72 \times 10^6 \text{ m}^{-1})} \quad \nu = \frac{(2.92 \times 10^{15} \text{ s}^{-1})}{2\pi}
\]

\[
\lambda \nu = \left( 6.46 \times 10^{-7} \text{ m} \times 4.65 \times 10^{14} \text{ s}^{-1} \right) \quad \rho s 1: \ c = \frac{\nu}{k} \quad \Rightarrow \ c = \frac{\nu}{2\pi k} = \frac{\lambda}{\nu}
\]

More general waves: \( \lambda \nu = \nu (\text{speed of wave}) \).

Last time: Light as an EM wave (more on this soon).
Today: Light as a particle (photon).

Experimental evidence \( \Rightarrow \) In microscopic world, light = discrete photons of energy \( E = h\nu \).

- Photocelectric effect

\[
\text{light} \rightarrow e^- \quad V < 0
\]

\[
e^- e^- e^- \quad V = 0
\]

Perform experiment with retarding potential to measure kinetic energy of \( e^- \).
Experimental parameters:

Intensity of light $I \propto \frac{E^2}{\lambda}$

Frequency of light $\nu$

Type of metal "Work function" $W = \text{energy to remove } e^- \text{ from metal.}$

Measure: photocurrent $= e \times \left( \frac{\text{# photoelectrons}}{\text{time}} \right)$

Max kinetic energy $K$ of photoelectrons.

Results (at fixed freq $\nu$):

- $\text{photocurrent}$
  - Larger intensity $I$  
  - Current ceases when $V = -\phi_0$ (Stopping potential)
  - $V$ independent of light intensity

Potential difference $V$

$K = e\phi_0$

At any $I$:

$K$

Slope $h$ (Planck's constant)

Kinetic energy of an $e^-$ after leaving metal is

$K = h\nu - W$

Unphysical $K < 0$

Min freq to eject $e^-$: $K = 0 \Rightarrow \nu_0 = \frac{W}{h}$

Quantum picture "throwing billiard balls"

Classical picture "filling a bucket"

$e^-$ energy

$K = \frac{1}{2}mv^2$

$\Delta t, \text{eject } \sim 0$

At $\approx 1/I$

$\nu > \nu_0$

Eject $e^-$ for any $\nu$

$K \propto I$ independent of $I$

$K \propto I$ (classical)

$\Delta \nu = c$

$E = h\nu = \frac{hc}{\lambda}$

$\checkmark$

$X$