The Particle-Like Properties of Electromagnetic Waves

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Contents

1 Review of Electromagnetic Waves

- Reviewing the nature of light (or electromagnetic waves)
  - A plane wave
    - A plane wave traveling in the positive x direction:

$$\begin{cases} \vec{E} = \vec{E}_o \sin(kx - \omega t) \\ \vec{B} = \vec{B}_o \sin(kx - \omega t) \end{cases}$$

    - The direction of energy transport would be $\vec{E} \times \vec{B}$
    - $|\vec{E}|$ and $|\vec{B}|$ are constant at a given t
    - The power, P, of the wave:

$$P = \frac{E}{\Delta t} = \frac{1}{\mu_o c} E_o^2 A \sin^2(kx - \omega t)$$

    - Two important features:
      1. Intensity (average power per unit area) is proportional to E_o^2

$$P_{avg} = \int_0^T P(t)\, dt$$

      2. The intensity of the system fluctuates with time

$$\frac{P_{avg}}{A}$$

  - A spherical wave
    - Spreads out uniformly along the three axis

2 The Photoelectric Effect

- Experiment performed by Heinrich Hertz (1887)
- When a metal surface is illuminated, light electrons can be emitted from the surface
- The Experiment:
  - Connect emitter and collector to an external circuit
  - Apply a negative potential to the circuit collector
  - Increase the potential difference $((-V) - (+V))$ to be more negative
  - At some point, even the most energetic electrons do not have enough kinetic energy to reach the collector

– The maximum kinetic energy to reach the collector with the stopping voltage, V_s, is:

$$K_{max} = eV_s$$

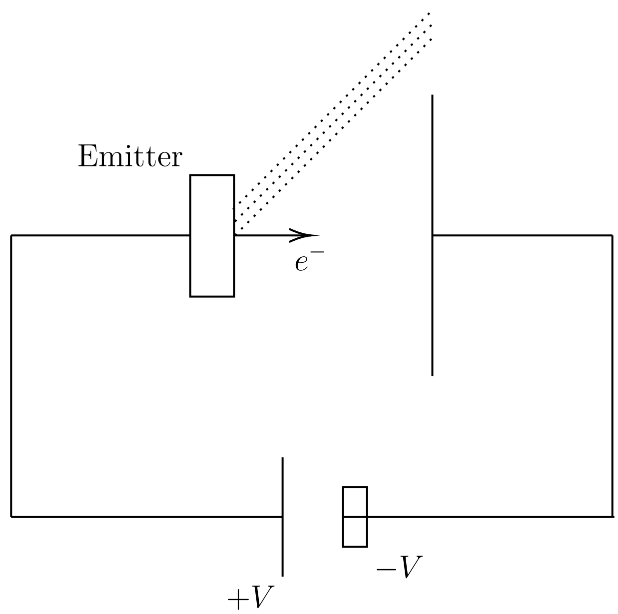

Figure 1: Set up of the Photoelectric Effect Experiment

– The classical picture: The energy of light with intensity I is absorbed by electrons, $E_{light} > E_{binding}$, e is released

– What does the classical wave theory predict?

1. K_{max} is proportional to $E_o^2 \rightarrow \boxed{I}$
2. The effect occurs for light with any frequency or wavelength
3. e^- are released