3 Quantum Phenomena

3.1 The Photoelectric Effect

Conduction electrons move about freely inside the metal. It was found that sparks produced by a **spark detector** when ultraviolet radiation was directed at the spark gap.

Further investigation showed that electrons are emitted from the surface of a metal when electromagnetic radiation above a certain frequency was direct at the metal. This is known as the **photoelectric effect**.

- Photoelectric emission of electron from a metal surface does not take place if the frequency of the incident electromagnetic radiation is below a certain value known as the **threshold frequency**.
- The number of electron emitted per second is proportional to the intensity of the incident radiation, provided the frequency is greater than the threshold frequency.
- Photoelectric emissions **occur without delay** as soon as the incident radiation is directed at the surface. Provided the frequency exceeds the threshold frequency, and reguardless of the intensity.

Observations from the photoelectric effect could not be explained using the **wave theory** of light.

- The **existence of a threshold frequency** - each conduction electron at the surface of a metal should gain some energy from the incoming waves.
- Why photoelectric emission **occurs without delay**.

The Photon Model of Light

The photon theory of light was put forward to explain the photoelectric effect.

- Light is composed of **wavepackets** or photons.
- Each photon has energy $E = hf = hc/\lambda$.

To explain the photoelectric effect

- When light is incident on a metal surface, an electron at the surface **absorbs a single photon** from the incident light and therefore gains energy equals to hf - the energy of a photon.
- An electron can leave the metal surface if the energy gained from a single photon exceeds the **work function** ϕ of the metal.
  - The **work function** is the minimum energy needed by an electron to escape from the metal surface.
  - Excess energy gained by the photoelectron becomes its kinetic energy.

The maximum kinetic energy is given by

$$E_{\text{Kmax}} = hf - \phi$$

Emissions can take place provided $E_{\text{Kmax}} > 0$, so the threshold frequency of the metal is

$$f_{\text{min}} = \frac{\phi}{h}$$

Stopping Potential

Electrons that escape from the metal plate can be **attracted back** by giving the plate a sufficient positive charge.

- The minimum potential needed to stop photoelectric emission is called the **stopping potential** V_s.
- At this potential, the maximum kinetic energy of the emitted electron is reduced to zero because each electron must do extra work $e \times V_s$ to leave the surface.

Conclusive experimental evidence of the photon theory was obtained by

- Measuring the stopping potential for a range of metals.
- Using light of different frequencies.

The results fitting the photoelectric equation very closely.