Unit 1
Particles, Quantum Phenomena and Electricity

3.1 Photo-electricity

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3.1 Photo-electricity 1

Electrons are emitted from the surface of a metal when electromagnetic radiation above a certain **threshold frequency** (or below a certain **threshold wavelength**) is shone onto it. This is known as the **photoelectric effect**.

Important facts about photoelectric emission

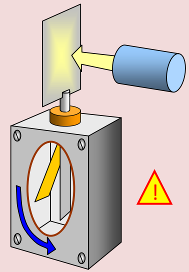
- The more intense the radiation, the greater the number of electrons per second emitted.
- Below the threshold frequency, no electrons are emitted however intense the radiation is.
- No matter how weak the radiation, if it is above the threshold frequency, electrons are emitted immediately.

Why classical wave theory cannot explain this

Since waves carry energy, the continuous arrival of waves at the metal surface, whatever their frequency, means the continuous arrival of energy. So even radiation of low energy (low frequency) should release electrons as long as you shine it on for long enough.

Demonstrating the Photoelectric Effect with a Gold Leaf Electroscope

- If the electroscope is charged negatively, the leaf falls when ultraviolet radiation is shone onto the plate. This does not happen with violet or other visible light or with any electromagnetic radiation of lower frequency than ultraviolet.



- When the electroscope is charged positively, the leaf does not fall whatever type of electromagnetic radiation is shone onto it.
- The ultraviolet radiation releases electrons from the surface of the zinc plate. Light of lower frequency cannot do this. When the plate is positively charged, electrons released by the ultraviolet radiation cannot escape because of the strong attraction of the positive plate, so the electroscope cannot discharge. This shows that it is negatively charged particles that are released during photoelectric emission.

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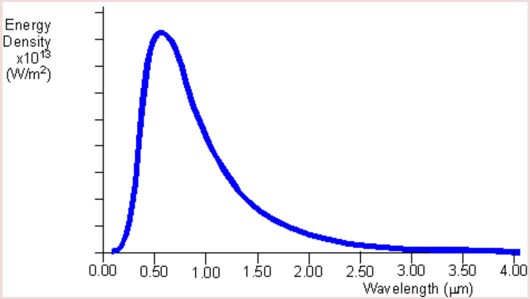
- Radiation of low intensity means waves of low energy (or low amplitude), so low intensity radiation should take longer to release electrons than high intensity radiation. In other words, a very dim ultraviolet lamp **will** release electrons from a zinc plate – and straightaway. An extremely intense red laser beam will **never** release electrons from a zinc plate, however long you shine it on for.
- For the reasons above, classical wave theory could not explain the photoelectric effect. A new theory was needed.

The Ultraviolet Catastrophe

Another failure of classical physics at the end of the 19th century was that it could not explain the way the intensity of radiation from a hot object varies with its wavelength.

Experiments produced the intensity graph opposite. Classical theory predicted that the intensity should keep on rising as the wavelength decreased, so that, at ultraviolet wavelengths, the intensity should be heading off to infinity. It meant that if you sat in front of your own fire, you should be incinerated.
Planck explained this graph using his quantum theory.
He said that atoms could only emit energy in units (called quanta), where hf was the energy one quantum. He didn't know why. It simply fitted the experimental results.



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