

# Electromagnetic radiation and quantum phenomena

## 1 The photoelectric effect

The photoelectric effect - Metals liberate electrons when hit by photons

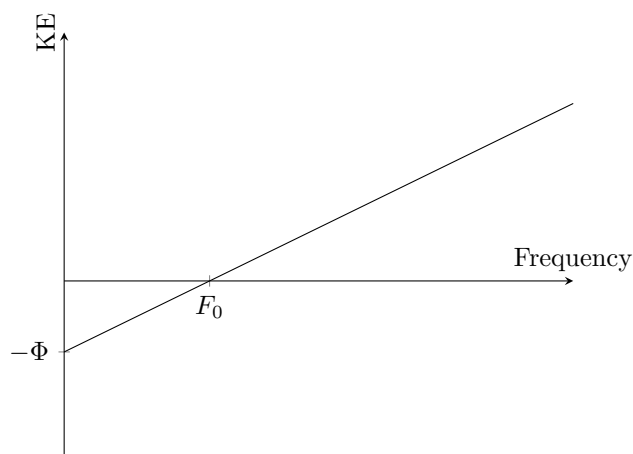
Observation	Explanation
There is a minimum frequency required to liberate an electron, called the threshold frequency	At the minimum frequency $KE=0$ so the frequency must be Planck's Constant $\times$ Frequency
Above the threshold frequency electrons are emitted immediately, regardless of intensity	Energy is immediately passed on
Intensity and electrons per second are directly proportional	1 photon liberates 1 electron
Below the threshold frequency no electrons are emitted, no matter the intensity	At the minimum frequency $KE=0$ so the frequency must be Planck's Constant $\times$ Frequency
The electrons are emitted with a range of speeds unrelated to intensity	Through the metal the collisions for each electron vary, varying KE
Increasing frequency increases maximum speed but not number liberated per second	1 Photon liberates 1 electron

### 1.1 Why the photoelectric effect can't be explained by the wave model

Waves transfer energy, it would be expected that the more intense the source the more energy the electrons would have.

Given enough time electrons should be emitted with waves

### 1.2 Millikan's experiment



$F_0$  - Threshold Frequency

$-\Phi$  - Negative work function

**Gradient** - Planck's Constant

Equation of line -  $E_K = hf - \phi$

## 2 Collisions of electrons with atoms

**Ionisation** - The adding or removal of electrons from an element

**Excitation** - The moving of an electron to a higher energy level

### 2.1 How a fluorescent lamp works

1. In a sealed unit with a phosphor coating on the inside of the glass. A small amount of mercury and an inert gas at a low pressure
2. When the voltage is switched on electrons move from the cathode to the anode
3. The electrons collide with the mercury, turning it into a vapour
4. Once a vapour, the moving electrons can then collide with the mercury gas atoms, exciting the bound electrons
5. The fired electron has undergone collisional excitation so has less energy
6. The mercury excitation produces UV rays
7. The phosphor coating is a chemical designed so it has UV excitation energy similar to the mercury excitation energy
8. The phosphor absorbs photons and emits visible light

## 3 Energy levels and photon emission

### 3.1 Absorption Spectra

This happens when a cool material is placed between a hot light and the observer.

This causes dark lines in the spectrum

From this it can be inferred that atoms only absorb radiation of certain frequencies.

This technique can be used to identify different atoms

The difference in absorption is caused by different numbers of electrons

### 3.2 Emission spectra

This is caused when a gas is heated

The lines have the same wavelengths as absorption but the lines are light, rather than dark

This is caused by electrons becoming excited and so emitting an electron

Observation	Reason
Discrete lines	The electrons are absorbing/emitting photons
The spectrum does not depend on the isotope	The electrons are arranged in shells
The spectral lines get closer together as the energy increases	The photons need a certain amount of energy to excite an electron

### 3.3 The hydrogen atom

The hydrogen atom is used as the example for energy level calculations. The ground state is the state of minimum energy, calculations can be performed for all the energy levels

## 4 Wave-Particle Duality

Electron diffraction suggests that particles possess wave properties. The photoelectric effect suggests electromagnetic waves have a particle nature.

The amount of diffraction changes when the momentum of the particle changes as it has a different de Broglie wavelength.