2. Photoelectric effect

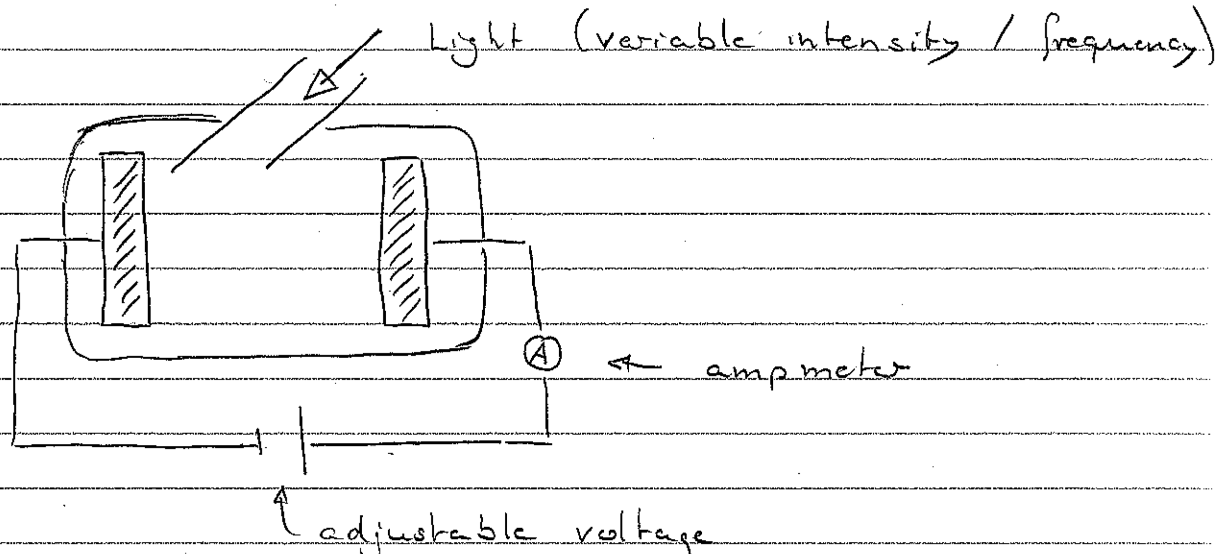
Some historical facts:

1886/87 - Hertz noticed that electroscope can be discharged by shining light on it

1899 - Thompson concluded that electrons are emitted from electrode when light shines on it.

1900 - Lenard performs measurements for photoelectric effect.

2.1. Apparatus



Two metal plates in vacuum with adjustable voltage between them. Shine light on one of the plates and measure current between plates.

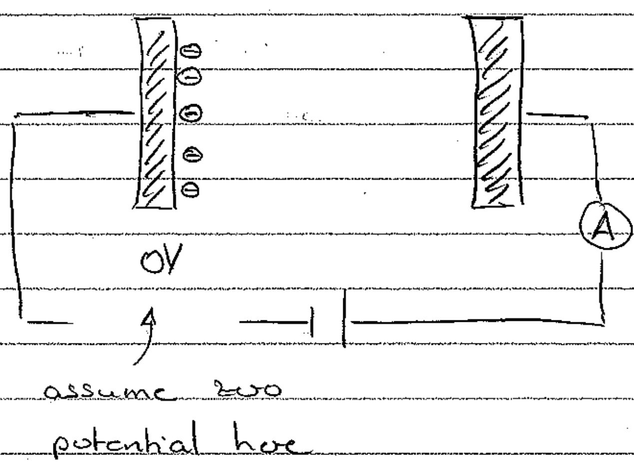
Lenard observed that by shining light on ~~ø~~ one of the plates, there is a current flowing in the the wires. Thus, the light must lead to a release of electrons from the metal plate which then move to the second plate (and further on through the wire). He measured then the current as a function of the adjustable voltage, the frequency and intensity of the light.

To understand his measurements, let's see first how the apperatus works.

<u>Without</u> light, there will be <u>no</u> electrons released from the metal plate. Consequently, there is <u>no</u> current measured in the wires.

<u>With</u> light, there are electrons released and a current flows. Let's discuss a bit later, why and how the electrons are released. Let's first understand what happens after electrons are released from the plates.

<u>Situation 1:</u> Electrons are released from rest at plate.



If the other plate is at a <u>positive potential</u> ⇒ electrons will be accelerated towards that plate and gain kinetic energy.

+ current will flow

How much kinetic energy does an electron gain?

$\Delta KE = -\Delta PE$ ← potential energy

$= -q\,\Delta V$ ← potential difference

$= -(-1.6 \times 10^{-19}\,C)\,\Delta V$

$= 1.6 \times 10^{-19}\,C\,\Delta V$

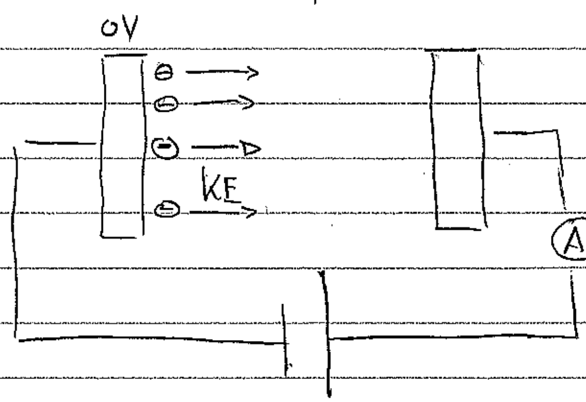
$= 1.6 \times 10^{-19}\,J = 1\,eV$

~~for $\Delta V = 1\,V$~~

Here we introduce a new energy unit: 1eV = 1 electron Volt

which is the kinetic energy gained by an electron when accelerated through 1V of potential difference.

Situation 2: Electrons starts with certain kinetic energy at plate



If other plate is at zero or positive potential, electrons will for sure reach plate and current will flow

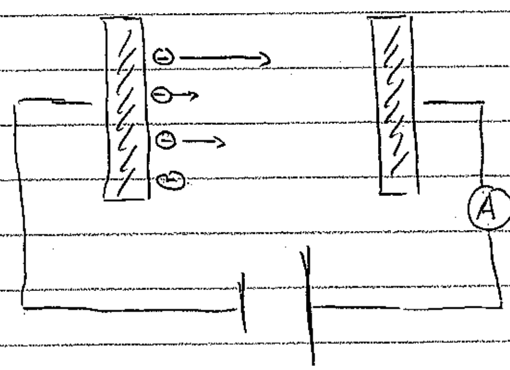
If second plate is at negative potential, electrons will be decelerated and at if

$$V = \Delta V = -\frac{KE}{q}$$ ← kinetic energy of electron at start

↑ ~~potential difference~~

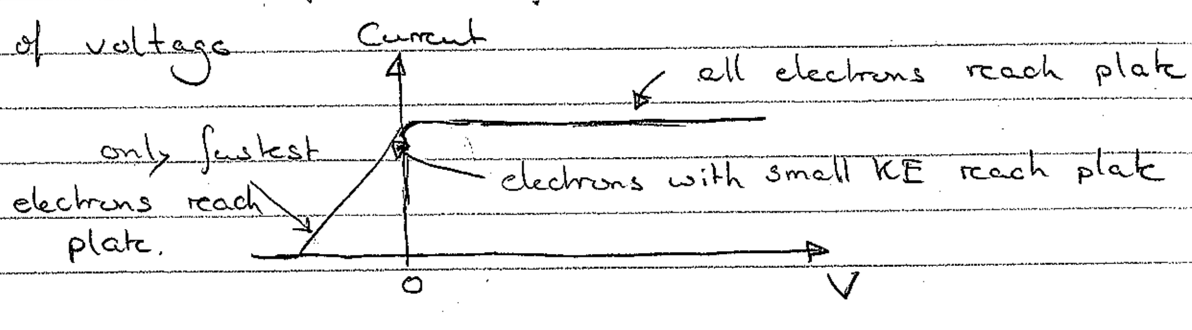
the electrons will just not reach the other plate anymore. We call this the <u>stopping voltage</u>.

<u>Situation 3</u>: Bunch of electrons that start with <u>distribution</u> of <u>kinetic energies</u> at plate



If we now apply a <u>small</u> negative voltage at plate, then the <u>slowest</u> electrons will not reach the plate

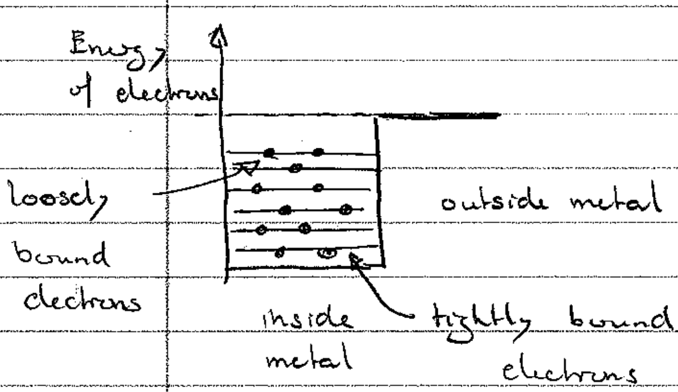
but the fastest will still make it. If we further decrease the voltage, then less and less electrons will reach the plate until finally none of the electrons reaches the plate. That means for the current as function of voltage



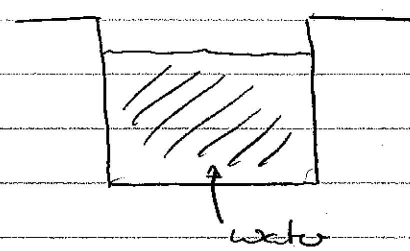
2.2 Classical Electromagnetic Wave Predictions

Lenard observed that light sets electrons in metal free? How can we understand this based on interpretation of light as classical electromagnetic wave.

In metal: Electrons are bound but can freely move



Analogy : Water in pool



Heating (by light)

- Bit of energy
  ⇒ some electrons with little energy will leave metal
- Lots of energy
  ⇒ many electrons with high max energy will leave metal

Pool party:

- Bit of splashing
  ⇒ bit of water will swap out
- Lots of splashing
  ⇒ much of water will swap out (with lots of energy)

Remember: ◦ number of electrons reaching second plate
= amount of current in photoelectric effect

◦ maximum kinetic energy in distribution
= stopping voltage in photoelectric effect.

Remember: Light as EM waves transports energy

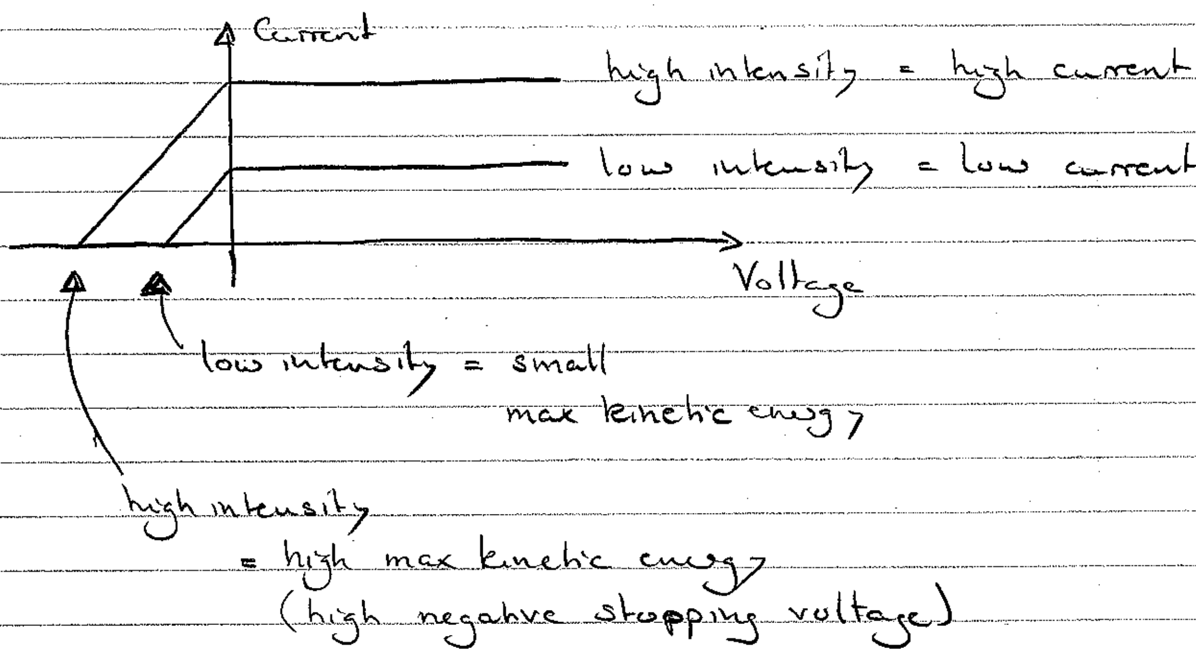
Energy ~ Intensity of light but

Energy independent of frequency

⇒ Classical wave expectations for photoelectric effect

(1) Increase of light intensity leads to
increase of energy in light leads to
increase of energy transfered to electrons in metal

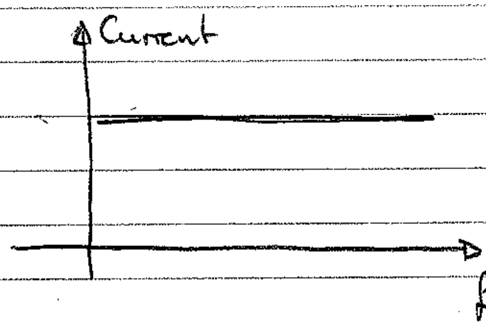
⇒ more electrons are emitted
maximum kinetic energy increases

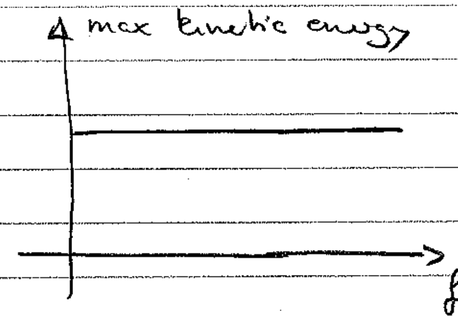


(2) Change in light frequency leads to

no change in number of electrons emitted
→ no change in current

no change in max kinetic energy of electrons
⇒ no change in stopping voltage





(3) There is a continuous accumulation of energy in metal. Electrons are set free as soon as enough energy is accumulated

⇒ Time delay between switch-on of light and measurable current