Phyx 320
Modern Physics

February 15, 2021

Reading: 38.1 – 38.4

Homework #4 and Reading Reflection Next Tuesday 11:59 pm

Nuclear Model of Atom

Experimenters starting observing phenomena that could not be explained by mechanics + electromagnetism

Spectra allowed us to study how light and matter interact

Cathode ray tubes lead to the discovery of electrons

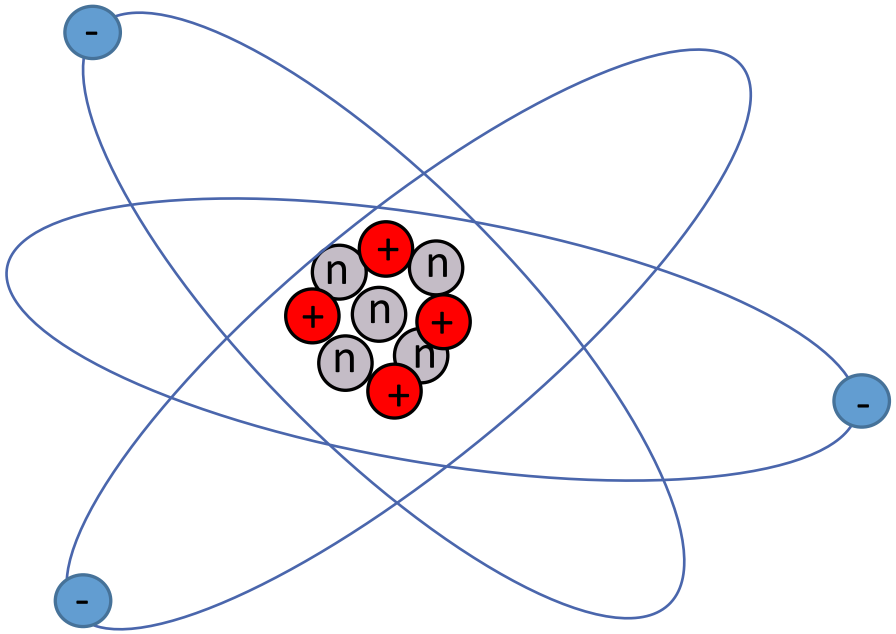
Gold foil target experiments lead to the nuclear model of the atom

Atoms are made of:

- Protons (+e, nucleon)
- Neutrons (neutral, nucleon)
- Electrons (-e, orbit nucleus)

Number of nucleons → $^{9}Be^{+}$ ← Total Charge

Element



Photoelectric Effect

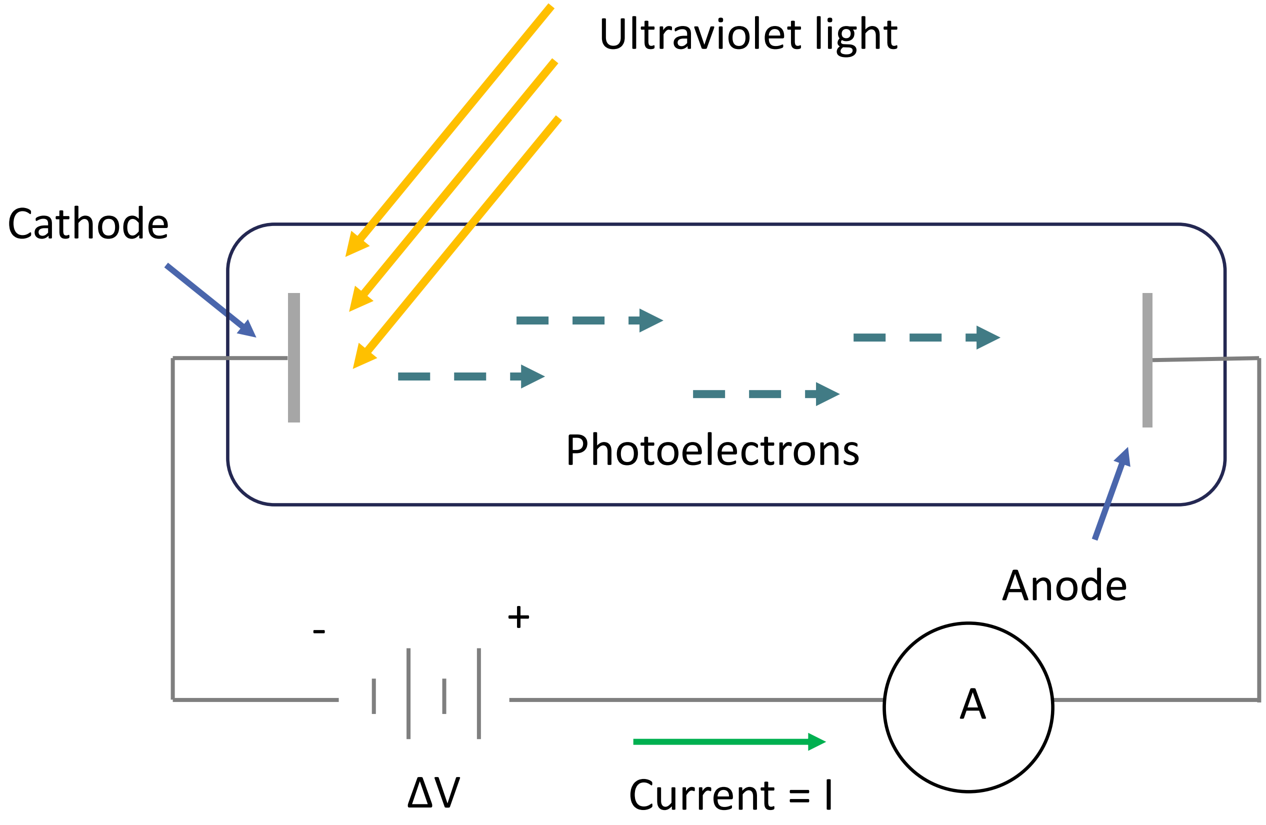
If ultraviolet light strikes the cathode in a cathode ray tube, then electrons are emitting

Called photoelectrons to denote that they come from light

In darkness no current flows but with light current is measured by ammeter

Add a potential difference to study how electric potential changes results

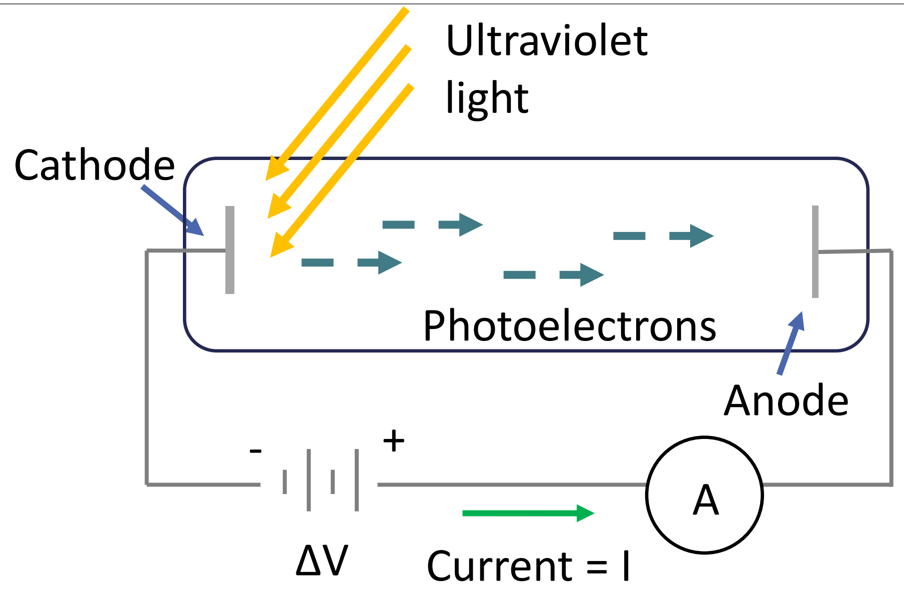
Physics underpinning solar panels



Photoelectric Effect

Observations:

- Current is directly proportional to intensity of light
- No delay between light and current
- Electrons are only emitted if light is above a threshold frequency
- Threshold frequency depends on cathode material
- The current can be stopped by applying a voltage called the stopping voltage
- Stopping voltage is independent of light intensity



Classical Explanation

Classically photoelectric effect can explain the stopping voltage and the proportionality of current and intensity

There is a minimum amount of energy needed to liberate an electron from the metal = work function

Light can add energy to the metal and thus emits electrons

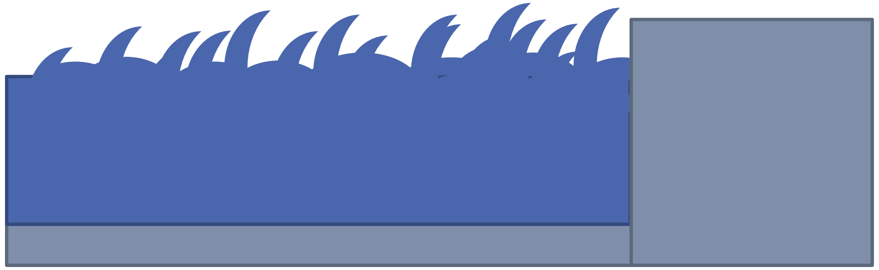
Analogous to removing water from a pool

Minimum energy to take a drop out of pool

Adding energy makes waves which can throw water out of pool

No Energy

With Energy



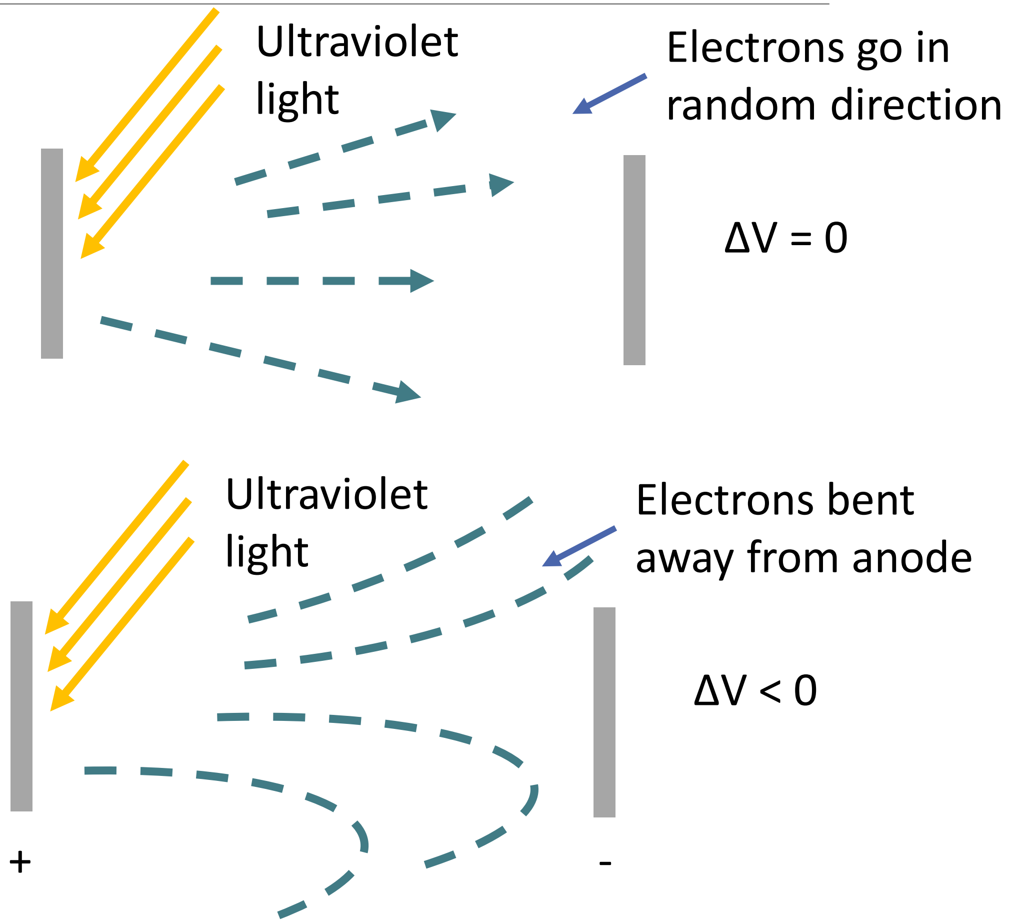
Classical Explanation

Stopping potential is just the canceling out of kinetic energy of electrons by electric field

$\Delta V = 0$ electrons go in random direction so only some get to anode

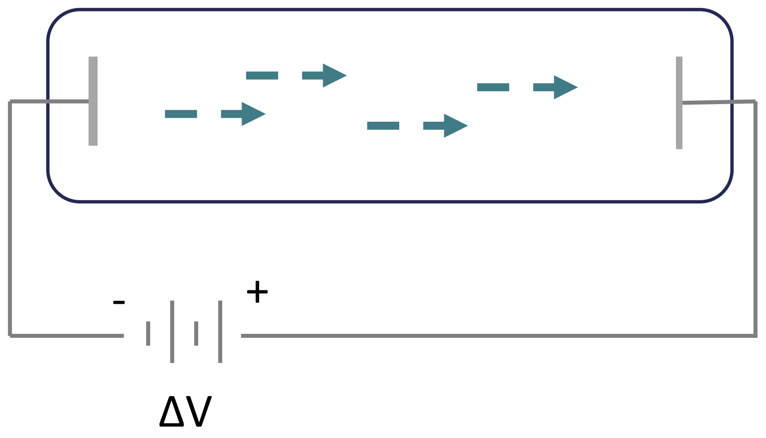
$\Delta V > 0$ electrons are attracted to anode until all electrons are collected

$\Delta V < 0$ electrons are repelled by anode until none reach anode



Classical Explanation

Let's study the energy of the electrons as they pass the gap



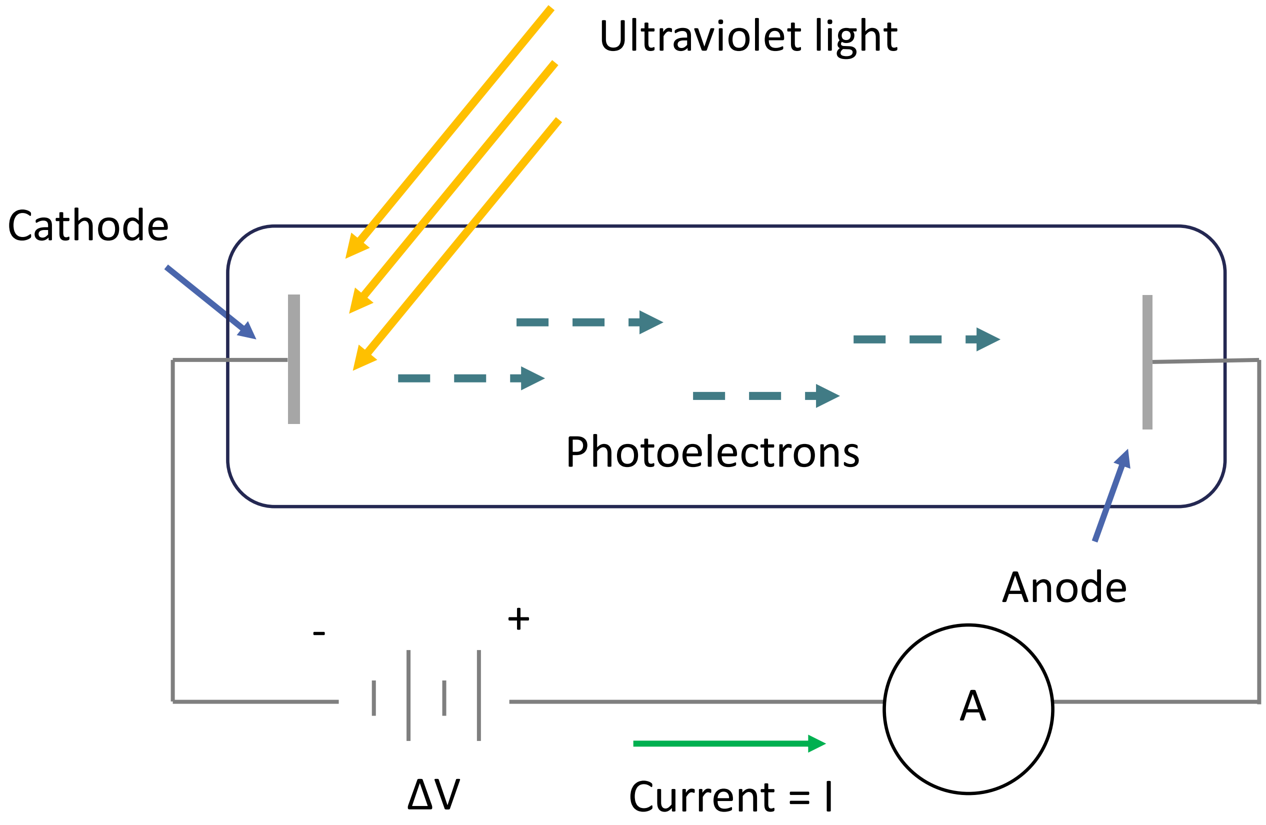
Classical Explanation

Stopping potential tells us the maximum kinetic energy of the electrons

But what about the frequency dependence?

Why does it start instantly instead of needing to heat up electrons?

Why is stopping potential independent of intensity of light? Should more intense light make more energetic electrons?

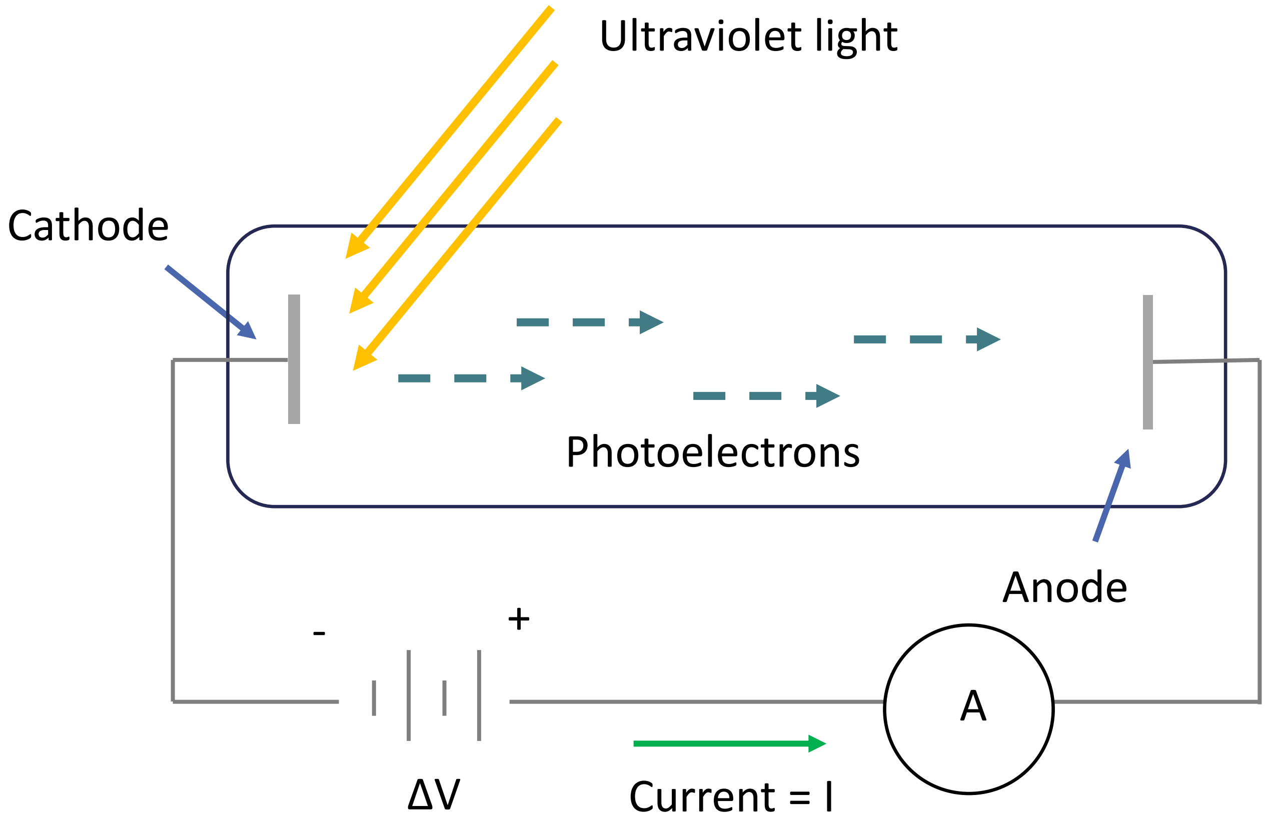


Quantum Explanation

Planck had found that in order to correctly calculate blackbody radiation, one needed to introduce discrete energy levels

$E = 0, hf, 2hf, \ldots$ where f is the frequency of vibration and $h = 6.63 \times 10^{-34} J\ s$ is Planck's constant

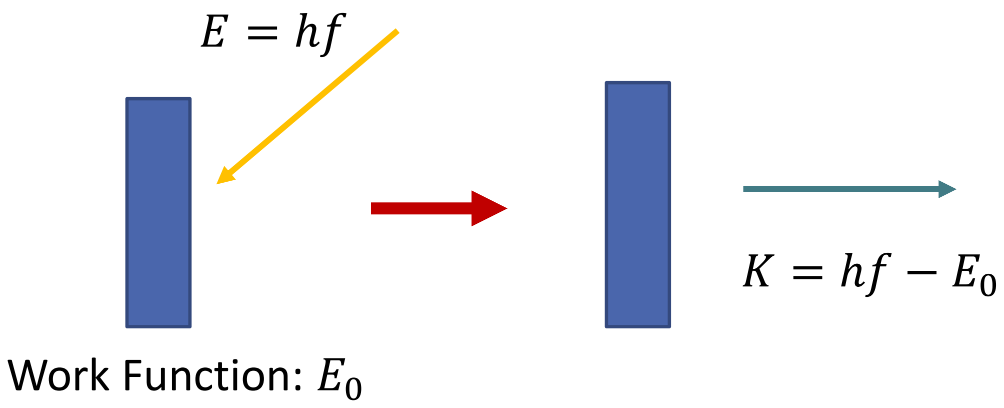
Einstein used this idea to explain the photoelectric effect by postulating that light is quantized into energy packet with $E = hf$ where f is the frequency of light



Quantum Explanation

Einstein postulated that

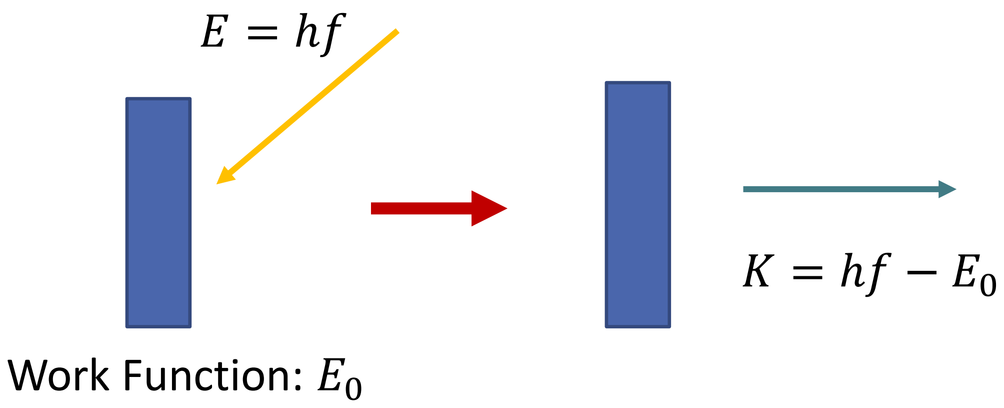
- Light is quantized to energy packets of $E = hf$ where f is the frequency of light
- Each quanta is absorbed or emitted completely or not at all
- Light quanta only interact with one electron



Quantum Explanation

Explains every feature of photoelectric effect

- Threshold frequency corresponds to work function
- More intense light = more electrons not more energetic electrons
- Stopping potential depends on frequency
- Electrons that absorb light instantly have enough energy to escape
- Predicts that the stopping voltage is linear in frequency with slope h/e



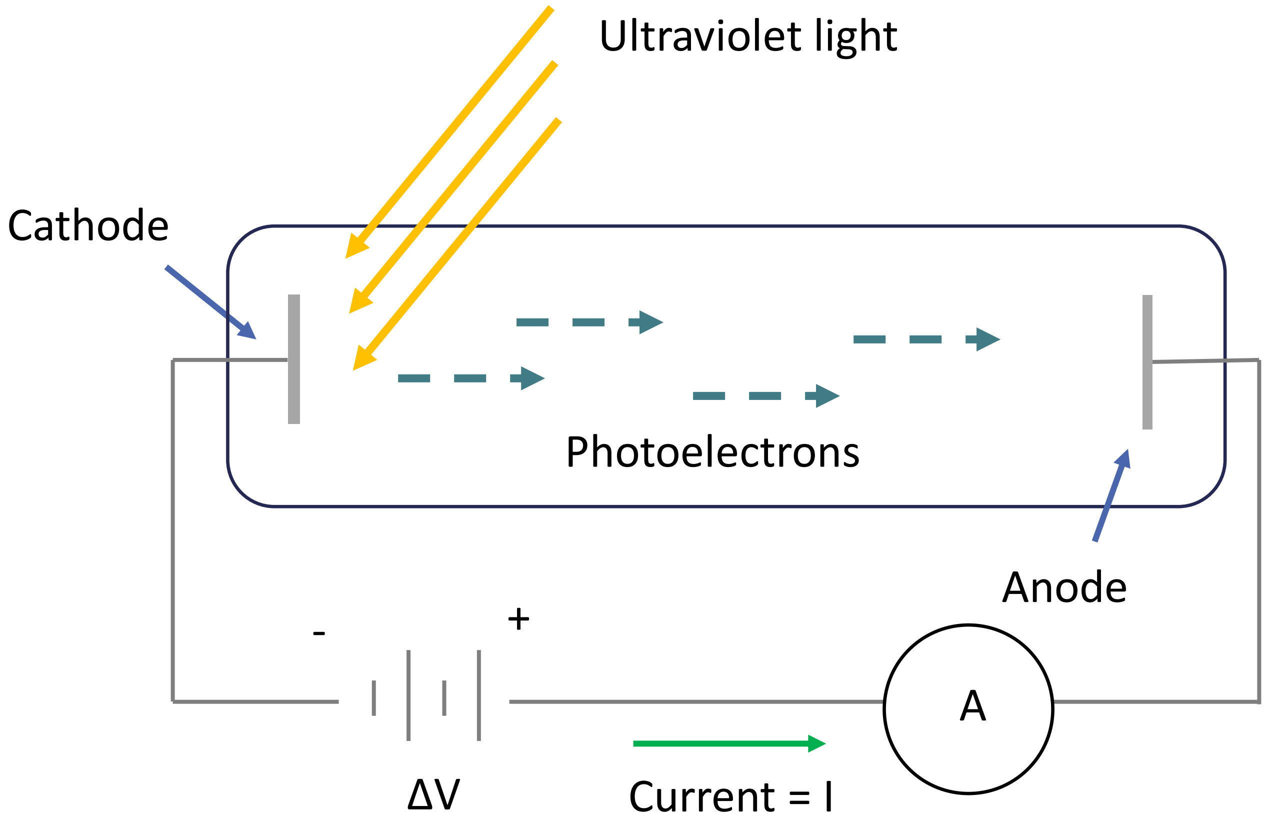
Quantum Explanation

In order to describe the photoelectric effect, we had to quantize the energy of light

Light went from a continuous wave to a stream of discrete packets (photons)

First quantum description of physics

Just the beginning of the quantum revolution



Quiz 3 Solutions

Muons (μ^-) are the heavier cousins of electrons and have a mass of 1.884×10^{-28} kg. Like electrons, muons have an antiparticle counterpart called antimuons (μ^+). If a muon and an antimuon collide, the particles annihilate each other leaving only light.

1. If we accelerate a muon to a velocity of 0.98 c, what is its momentum?
2. Let’s say we take this muon and collide it with an antimuon with the same momentum. How much energy would be released (in the form of light) during this interaction?

Quiz 3 Solutions

Homework Questions

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