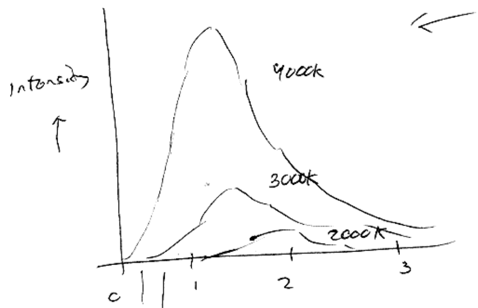
PHYS 2020 Blackbody Radiation, Photoelectric Effect.

high temperature objects glow and radiate heat in the form of electromagnetic radiation (waves, light, etc)

↓ objects can be modeled as Black-bodies, ideal systems that absorb all radiation and will emit radiation purely based on temperature.

Talk about radio, infared and UV rays before all this

Intensity of Energy radiated vs. ~~Fe~~ Frequency



← peak at shorter wavelengths as temperature increases

wien's displacement law

$\lambda_{max} T = 0.2898 \times 10^{-2} m \cdot K$

visible light. ← hot objects at 1500K just begin to emit visible light. most energy is infared

Total intensity according to over all wavelengths

Stefan's Law

$e_{total} = \sigma T^4 \qquad \sigma = 5.67 \times 10^{-8} W \cdot m^{-2} K^{-4}$

power per unit area

However, the challenge is to predict the shape of the curve using accepted physical principles and statistics.

~~Problem:~~ ~~Classical~~ Model: Blackbody contains "resonators" of unknown character that can emit radiation at their specific frequency.

Problem: At shorter wavelengths (higher frequency) more frequencies are available, and even though the total intensity at each frequency becomes smaller, the total intensity in the ultraviolet range is predicted to be infinite!

high frequency resonators emit very little Energy.

Planck's Idea: what if there was a minimum energy that could be emitted at each frequency. Or what if energy could only be emitted in discrete chunks

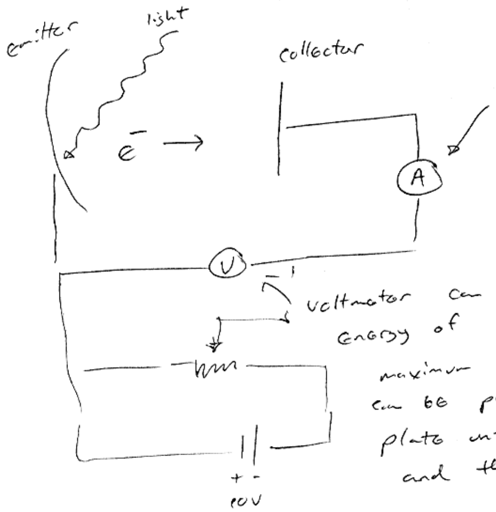
$E = nhf$ $\quad h = 6.626 \times 10^{-34}$ J·s $\quad f$ is frequency

n an integer

If you use this theory in combination with accepted laws and statistics, you get the correct curve.

So apparently, just like charge is quantized, so is the energy of an electromagnetic wave.!

Photoelectric Effect when light (especially UV light) hits a conductor, it may eject electrons

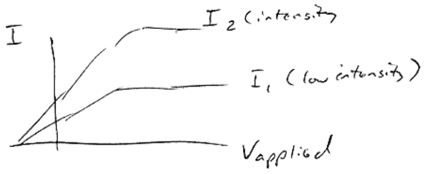


very sensitive ammeter detects the current level

voltmeter can determine the kinetic energy of electrons by finding the maximum negative voltage that can be put on the negative collector plate until electrons no longer hit it and the current stops

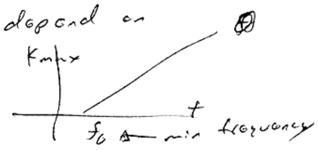
$K_{max} = \frac{1}{2} m_e v_{max}^2 = eV_s$ ← the stopping voltage.

Graph of current vs. voltage



V_s does not depend on light intensity.

It **does** depend on frequency



Review Energy of Electromagnetic Waves

$$\underset{\text{intensity}}{I} = \frac{E_{max} B_{max}}{2\mu_0} = \frac{E_{max}^2}{2\mu_0 c} = \frac{c}{2\mu_0} B_{max}^2 \qquad U = \overset{\text{intensity}}{I}\underset{\text{area}}{A} \Delta t$$

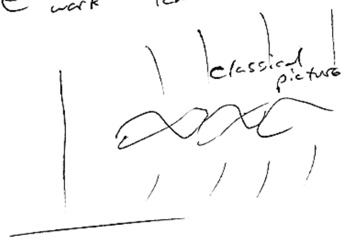
Notice energy is not related to frequency but rather intensity.! However, low frequency light no matter how intense, releases no electrons

- Higher frequency means higher kinetic energy of ejected electrons, but higher intensity just means more ejected electrons.
- Even at low intensities, electrons are released immediately

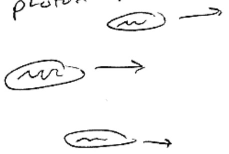
How to explain this? Maybe the waves come in "packets" of Energy with $E = hf$ ← much like emitted energies in blackbody resonators

Lets call these wave packets photons

$$\underset{\text{energy of electrons}}{KE_{max}} = hf - \phi \leftarrow \text{work fcn of the metal.}$$



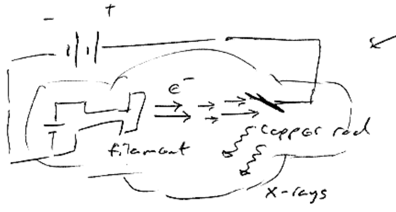
photon picture



little packets that behave like waves (they interfere)

Cathode Ray Tubes

V = 100,000V



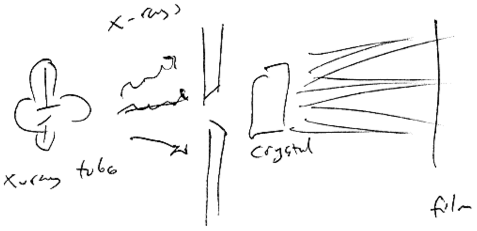
← when electrons decelerate they emit high energy rays.

they cause flourescent screens to glow and will penetrate soft tissue. They will rearrange your dna molecules if you arent careful!

X-ray wavelengths are tiny, diffraction experiments showed around 0.1 nm (compare to 550nm for visible light!)

(this is about the size of an atom!! So one could study crystals as diffraction gratings

Talk about Brownian motion and such if time permits



diffraction pattern.

Calculate electron energy to estimate wavelength if an electron loses all its kinetic energy at once

electron energy $E = eV = 1.6\times10^{-19}\,C)(1\times10^{5}\,V) = 1.6\times10^{-14}\,J$

photon energy $E = hf \qquad f = \frac{E}{h} = 2.4\times10^{19}\,Hz$

$c = \lambda f \qquad \lambda = \frac{c}{f} = 1.24\times10^{-11}\,m$

$= 12.4\ pm$

$= 0.0124\ nm$

$= 0.124\ \mathring{A}$ ← angstrom