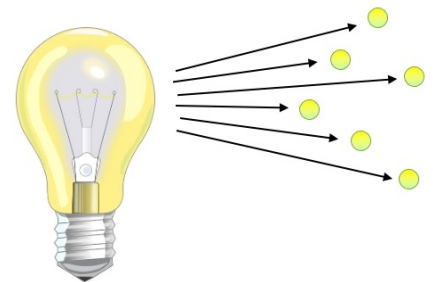
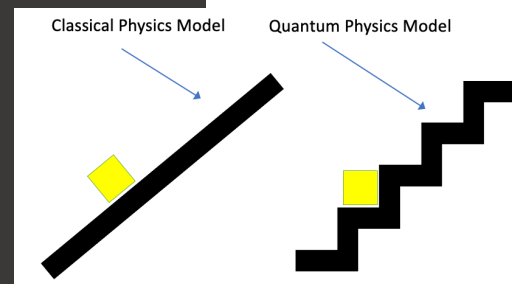
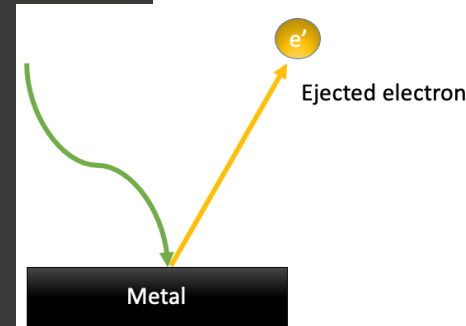


Modern Physics and the Photoelectric Effect

- Classical Physics
- Modern Physics
- Quantum Theory
- Max Planck and Energy Quantum
- Photoelectric Effect and Equation
- Conservation of Energy
- Applications of the Photoelectric Effect



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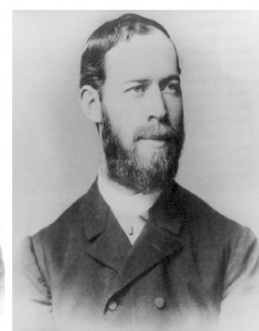
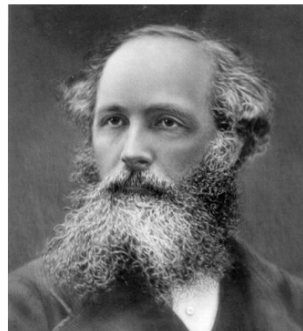
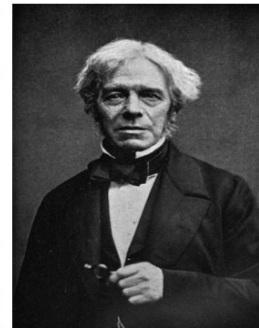
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The End of Physics?

By the end of the 19th century, many physicists felt that physics was no longer a thriving science.

However, there were a few nagging problems. When they were investigated further, it was easy to see that classical physics wasn't going to cut it.



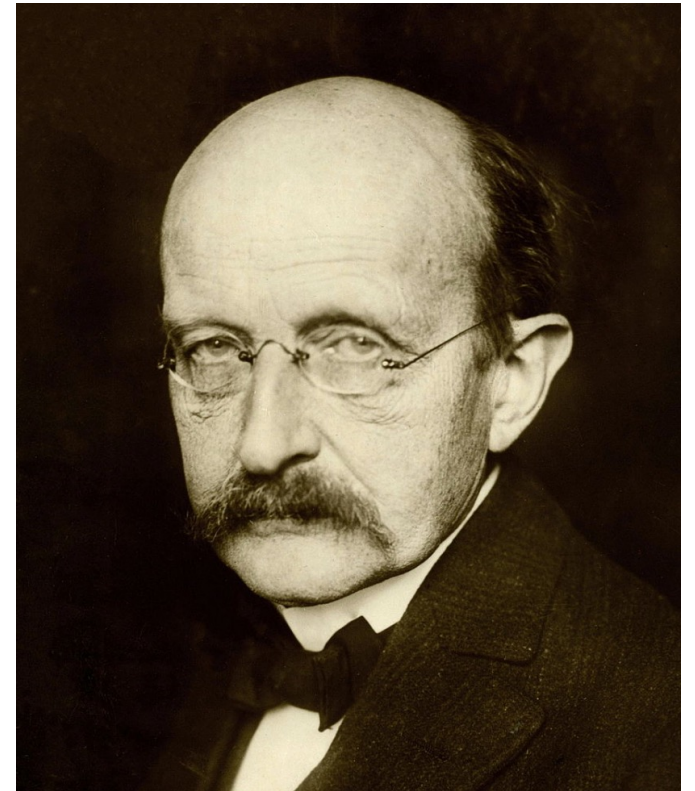
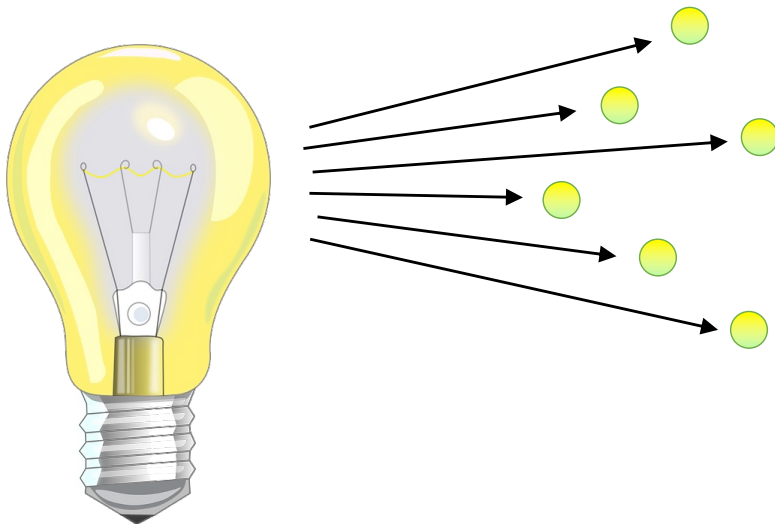
Modern Physics

- In response to these issues two main discoveries propelled physics into the modern era
- The first was Albert Einstein's development of The Special Theory of relativity in 1905
- _____



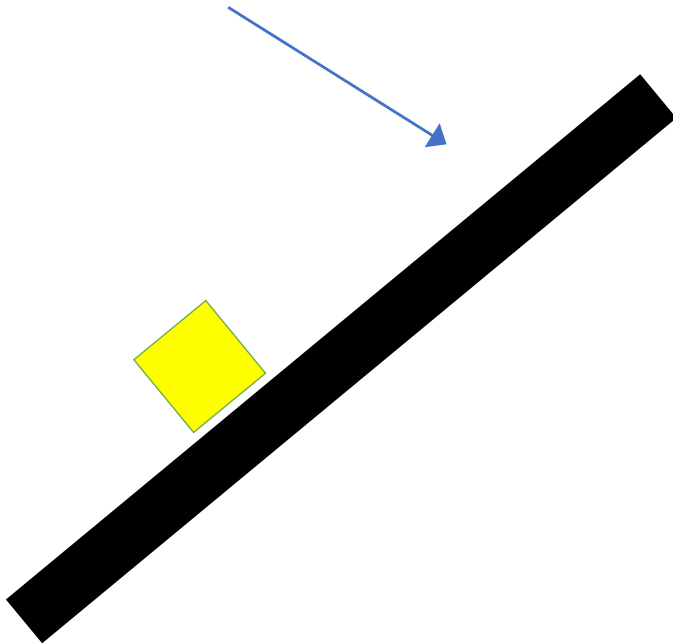
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Enter Max Planck

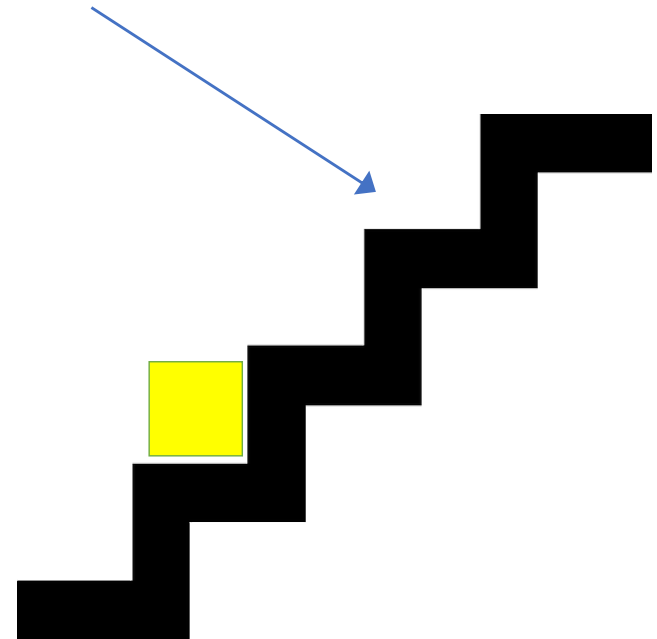


Max Planck

Classical Physics Model



Quantum Physics Model



Max Planck

- _____

$E \propto f$ and equal to the frequency multiplied by a constant

$$E = hf$$

- E is the energy in joules, f is the frequency in hertz, and h is a constant in joule seconds called Planck's constant. Its accepted value = 6.63×10^{-34} Js.

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Check Your Understanding

Calculate the energy in joules and electron volts of:

- a) a quantum of blue light with a frequency of 6.67×10^{14} Hz.
- b) a quantum of red light with a wavelength of 635 nm.

$$E = hf$$

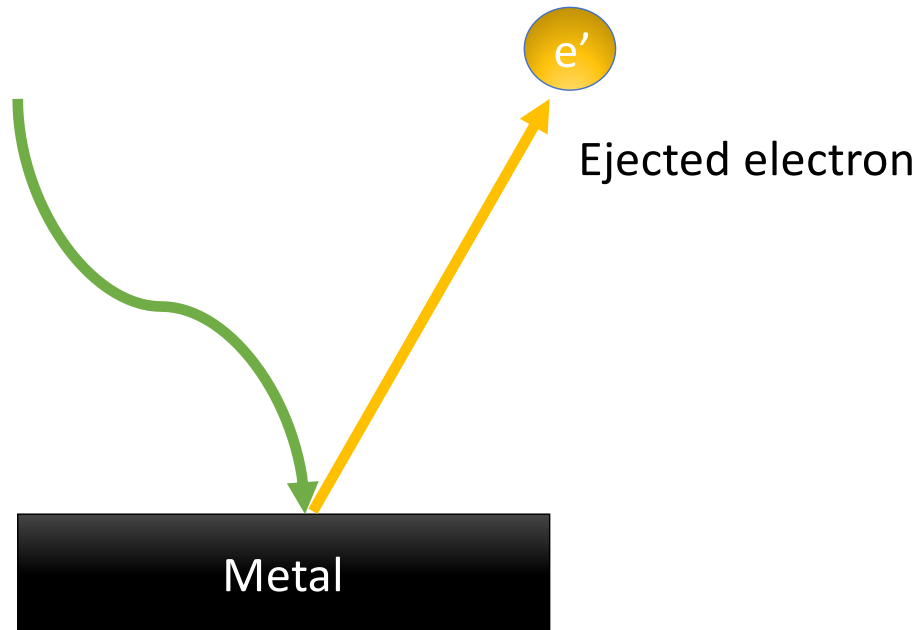
$$v = \lambda f$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

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

Photoelectric Effect

Albert Einstein won the Nobel Prize in 1921 "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect."



The Photoelectric Effect

- Photoelectric

Photo → photons

Electric → produces electricity

- Light is shown on the negatively charged, photosensitive metal surface which ejects electrons into a vacuum space

- _____



Photoelectric Effect Simulation

Significant Findings

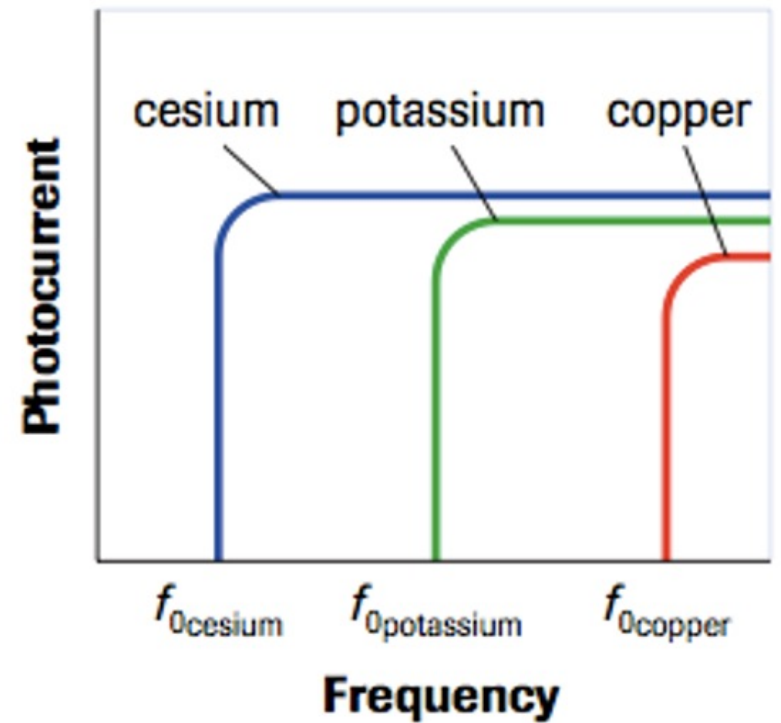
1. Electrons (photoelectrons) are emitted from the photoelectric surface when the incident light is above a certain frequency f_0 , called the threshold frequency.
-



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Significant Findings

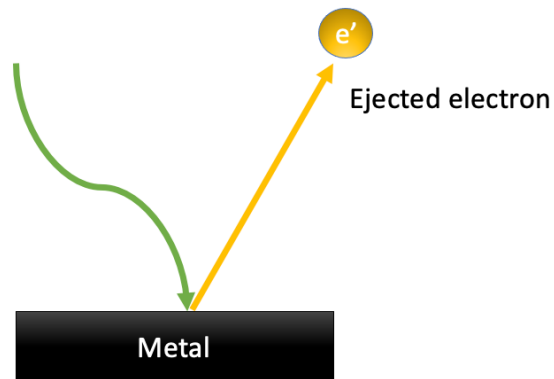
3. _____



Which has the lowest threshold frequency?

Why Does This Occur?

- Einstein reasoned that if electrons near the surface of a metal absorb the photon and gained its energy, the energy gained by the electron might be great enough for the electron to escape from the metal
- Some of the absorbed energy would be used to break away from the metal surface, with the rest being converted to kinetic energy for the electron to fly away
- _____



Why Does This Occur?

When the frequency of the incident light is too low (wavelength too high), the photon does not provide the absorbing electron with sufficient energy, and it remains bound to the surface.



Observe the Photoelectric Effect Simulation again to see this.

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Conservation of Energy

- ---
- Einstein described this mathematically as follows:
- $E_{\text{photon}} = W + E_K$
 - E_{photon} is the energy of the incident photon
 - W is the energy with which the electron is bound to the surface (called the work function)
 - E_K is the kinetic energy of the ejected electron

The Photoelectric Equation

- Since $E_{\text{photon}} = W + E_K$ and $E_{\text{photon}} = hf$

Therefore, $E_K = hf - W$

- E_K is the maximum kinetic energy and
- W is the work function, is different for different metals, and can be looked up
- You must convert your work function into Energy (J) for many problems

Element	Work Function (eV)
Cesium	2.1
Iron	4.5
Lead	4.14
Mercury	4.5
Uranium	3.6

Check Your Understanding

Orange light with a wavelength of $6.00 \times 10^2 \text{ nm}$ is directed at a metallic surface with a work function of 1.60 eV . Calculate

- a) the maximum kinetic energy, in joules, of the emitted electrons.
- b) their maximum speed.

$$1.60 \times 10^{-19} \text{ J/eV}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$E_K = hf - W$$

$$E_{\text{photon}} = W + E_K$$

$$E_K = \frac{1}{2} mv^2$$

$$E = hf \quad v = \frac{c}{\lambda}$$

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Applications of the Photoelectric Effect

- In many smoke detectors, the particles of smoke interrupt the flow of light within altering the electric current triggering the alarm
- Sensors in cameras measure the level of light based on the produced current, adjusting the shutter speed or the aperture for the correct exposure
- _____

