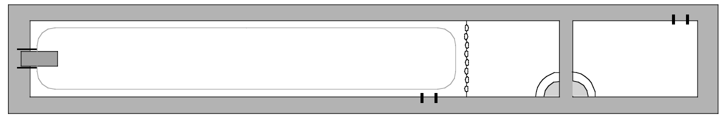
PhyzSpringboard:
The Photoelectric Effect



Photoelectric Effect
Light can strike a metal surface and cause an electron to be released. This is the *photoelectric effect*. It suggests that light has particle characteristics. When we treat light as a stream of particles, those particles are called *photons*.

Photons can be said to have energy and frequency, among other things. The energy of a photon is related to its frequency: $E = hf$.

The incident photon has a certain amount of energy. The electron that gets ejected when the photon hits the metal is called a *photoelectron*. As a particle with mass and speed, it has kinetic energy: $KE = \frac{1}{2}mv^2$.

Intensity and Frequency
Consider the following findings.

Exposure to dim red light: no emission of photoelectrons.
Exposure to dim yellow light: no emission of photoelectrons.
Exposure to dim blue light: emission of a few low energy photoelectrons.
Exposure to dim violet light: emission of a few high energy photoelectrons.

Exposure to bright red light: no emission of photoelectrons.
Exposure to bright yellow light: no emission of photoelectrons.
Exposure to bright blue light: emission of many low energy photoelectrons.
Exposure to bright violet light: emission of many high energy photoelectrons.

Conclusions (fill in the blanks with the term “number” or “energy.”)
1. The color of the light determines the ____________________ of incident photons.
2. The brightness of the light determines the ____________________ of incident photons.
3. The kinetic energy of the emitted photoelectrons is determined by the ____________________ of the incident photons.
4. The number of the emitted photoelectrons is determined by the ____________________ of the incident photons.

Work Function
For the photoelectric effect to occur, the incident photon must have more than a certain minimum energy. Consider the following findings.

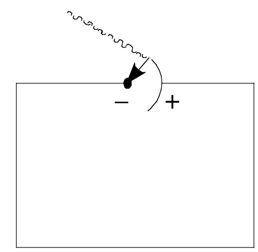
Incident photons with 1 eV of energy result in no emission of photoelectrons.
Incident photons with 2 eV of energy result in no emission of photoelectrons.
Incident photons with 3 eV of energy result in no emission of photoelectrons.
Incident photons with 4 eV of energy result in emission of photoelectrons with essentially no kinetic energy.
Incident photons with 5 eV of energy result in emission of photoelectrons with 1 eV of kinetic energy.
Incident photons with 6 eV of energy result in emission of photoelectrons with 2 eV of kinetic energy.
Incident photons with 7 eV of energy result in emission of photoelectrons with 3 eV of kinetic energy.
Incident photons with 8 eV of energy result in emission of photoelectrons with 4 eV of kinetic energy.

Notice that the kinetic energy of the emitted photoelectrons always lags behind the energy of the incident photons. The amount of this lagging behind is called the *work function* (Φ). It's the amount of energy that the metal absorbs. The frequency of the incident photon that carries energy equal to the work function is called the *threshold frequency* (f_0). Thus the work function is related to the threshold frequency by the following equation:
$\Phi = hf_0$.

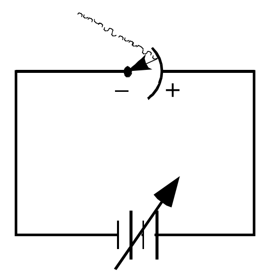
The work function for the material above is ____________________.

The energy of the ejected photoelectrons is
$KE = E - \Phi$ or $KE = h(f - f_0)$

PhotoCircuits
An electric circuit can be constructed as shown to test the photoelectric effect. Light is shone on the curved metal plate. Light at the threshold frequency will liberate photoelectrons. Higher frequency light will liberate photoelectrons with more kinetic energy. Electrons collect on the metal bulb opposite the curved surface. As a result, the curved surface grows positive while the bulb becomes negative. Excess electrons on the bulb travel through the wire back to the curved surface where they can again be liberated by energetic photons.



A variable voltage power supply can be added as shown. When photoelectrons are being liberated, the voltage can be adjusted so that the curved surface is given a positive charge from the power supply. This positive charge prevents photoelectrons from emerging (since they're instantly drawn back to the positive surface). The voltage that prevents further flow of photoelectrons is called the cut-off potential. If the frequency of incident light is increased, however, photoelectrons will once again flow. If the retarding voltage is increased, however, the photoelectrons will again be cut off.



It is known that if the photoelectrons are cut off by a retarding potential of V, they would have a kinetic energy equal to qV if they were ejected in the absence of the retarding potential.

$KE = {}^1/{}_2mv^2 = h(f - f_0) = qV$