Photoelectric Effect Simulation Activity

[Physics Aviary Photoelectric Effect simulation](http://www.thephysicsaviary.com/Physics/Programs/Labs/PhotoelectricEffect/) link
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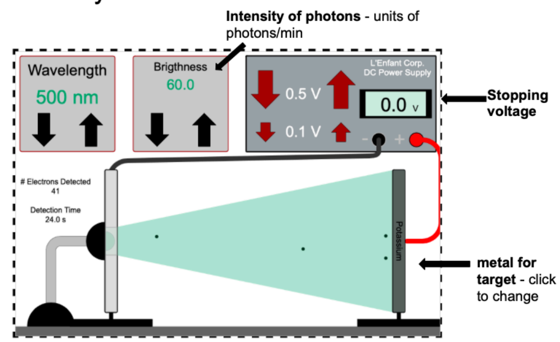
Physics Aviary Simulation Tools



Purpose: Students will determine the factors that are involved for an electron to be emitted from a metal by light.

Investigation: There are 4 factors that can be manipulated in this simulation: 1) the wavelength of the light that is shined on the target metal, 2) the intensity of the light, 3) the type of metal that makes up the target, and 4) the voltage of the battery. We will look at each of these factors separately and then determine what effect, if any, they have on the outcome.

***Notes:** the "ON" button is the Brightness, use the up/down arrows to change values, give the simulation a few seconds to show any changes that may happen – they are not instantaneous, and to change the target metal, click on the metal name at the right.

1) Wavelength of light shining on the target metal

a) Control settings: metal for Target: **Potassium**; Brightness: **60** γ/min); Battery voltage: **0.00 V** Complete the table for each of the wavelengths. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

λ (nm)	**700**	**600**	**500**	**400**	**300**	**200**	**100**
e^- emitted?	NO	NO	YES	YES	YES	YES	YES
Observations			Electrons move toward detector	Electrons move a little faster	Electrons move even faster	Electrons move still faster	Electrons move very fast

Find the wavelength where the electrons just begin to be emitted from the metal (keep changing the wavelength until this happens). **Record that wavelength here: _530_ nm**
Describe the motion of the electrons at this wavelength.

The electrons move fairly slowly toward the cathode (away from the metal plate).

ANSWERS ARE GIVEN FOR EACH OF THE METALS SHOWN IN THE SIMULATION. STUDENTS DO NOT HAVE TO DO ALL OF THESE.

b) Control settings: metal for Target: **(Platinum, Sodium, Silver, Cesium, Gold, or Copper)** (circle or highlight the one you are investigating); Brightness: **60** γ/min; Battery voltage: **0.00 V** Complete the table for each of the wavelengths. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

λ (nm)	**700**	**600**	**500**	**400**	**300**	**200**	**100**
e^- emitted?	NO	NO	NO	NO	NO	YES	YES
Observations						Electrons move quickly	Electrons move very fast

Find the wavelength where the electrons just begin to be emitted from the metal (keep changing the wavelength until this happens). **Record that wavelength here: _210_ nm**
Describe the motion of the electrons at this wavelength.

Electrons move at a moderate speed toward the cathode (away from the metal plate).

b) Control settings: metal for Target: **(Platinum, Sodium, Silver, Cesium, Gold, or Copper)** (circle or highlight the one you are investigating); Brightness: **60** γ/min; Battery voltage: **0.00 V**
Complete the table for each of the wavelengths. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

λ (nm)	**700**	**600**	**500**	**400**	**300**	**200**	**100**
e^- emitted?	NO	NO	NO	YES	YES	YES	YES
Observations				Electrons move at moderate speed	Electrons move faster	Electrons move even faster	Electrons move very fast

Find the wavelength where the electrons just begin to be emitted from the metal (keep changing the wavelength until this happens). **Record that wavelength here: _450_ nm**
Describe the motion of the electrons at this wavelength.

Electrons move rather slowly toward the cathode (away from the metal plate).

b) Control settings: metal for Target: **(Platinum, Sodium, Silver, Cesium, Gold, or Copper)** (circle or highlight the one you are investigating); Brightness: **60** γ/min; Battery voltage: **0.00 V**
Complete the table for each of the wavelengths. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

λ (nm)	**700**	**600**	**500**	**400**	**300**	**200**	**100**
e^- emitted?	NO	NO	NO	NO	NO	YES	YES
Observations						Electrons move fast	Electrons move very fast

Find the wavelength where the electrons just begin to be emitted from the metal (keep changing the wavelength until this happens). **Record that wavelength here: _260_ nm**
Describe the motion of the electrons at this wavelength.

Electrons move slowly toward the cathode (away from the metal plate).

b) Control settings: metal for Target: **(Platinum, Sodium, Silver, Cesium, Gold, or Copper)** (circle or highlight the one you are investigating); Brightness: **60** γ/min; Battery voltage: **0.00 V**
Complete the table for each of the wavelengths. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

λ (nm)	**700**	**600**	**500**	**400**	**300**	**200**	**100**
e^- emitted?	NO	NO	YES	YES	YES	YES	YES
Observations			Electrons move at moderate speed	Electrons move quickly	Electrons move fast	Electrons move even faster	Electrons move very fast

Find the wavelength where the electrons just begin to be emitted from the metal (keep changing the wavelength until this happens). **Record that wavelength here: _580_ nm**
Describe the motion of the electrons at this wavelength.

Electrons move very slowly toward the cathode (away from the metal plate).

b) Control settings: metal for Target: **(Platinum, Sodium, Silver, Cesium, Gold, or Copper)** (circle or highlight the one you are investigating); Brightness: **60** γ/min; Battery voltage: **0.00 V**

Complete the table for each of the wavelengths. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

λ (nm)	700	600	500	400	300	200	100
e^- emitted?	NO	NO	NO	NO	NO	YES	YES
Observations						Electrons move fast	Electrons move very fast

Find the wavelength where the electrons just begin to be emitted from the metal (keep changing the wavelength until this happens). **Record that wavelength here: _230_ nm**
Describe the motion of the electrons at this wavelength.

Electrons most at moderate speed toward the cathode (away from the metal plate).

b) Control settings: metal for Target: **(Platinum, Sodium, Silver, Cesium, Gold, or Copper)** (circle or highlight the one you are investigating); Brightness: **60** γ/min; Battery voltage: **0.00 V**
Complete the table for each of the wavelengths. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

λ (nm)	700	600	500	400	300	200	100
e^- emitted?	NO	NO	NO	NO	NO	YES	YES
Observations						Electrons move quickly	Electrons move very fast

Find the wavelength where the electrons just begin to be emitted from the metal (keep changing the wavelength until this happens). **Record that wavelength here: _250_ nm**
Describe the motion of the electrons at this wavelength.

Electrons move slowly toward the cathode (away from the metal plate).

2) Intensity (Brightness) of light shining on target metal
Control settings: metal for Target: **Potassium**; wavelength of light: 500 nm; Battery voltage: 0.00 V
Observe the emitted electrons at the different intensities and record your observations.

Light Intensity (γ/min)	10	60	120
Observations	An electron is emitted each time a photon hits the metal. Since the intensity is low, very few electrons are emitted.	Since the intensity is greater, more photons hit the metal and, therefore, more electrons are emitted.	More photons hit the metal since the intensity is even greater. So, more photons are emitted from the metal. It appeared that the electrons were moving with the same speed as the other 2 intensities.

3) Type of metal that makes up the target
Control settings: Brightness: **60** γ/min; wavelength of light: **300 nm**; Battery voltage: **0.00 V**
Complete the table for each type of metal at the given wavelength. Record "YES" if electrons are emitted or "NO" if electrons are not emitted. Record any observations you make.

Metal	Potassium	Platinum	Sodium	Silver	Cesium	Gold	Copper
e^- emitted?	YES	NO	YES	NO	YES	NO	NO

Observations	Electrons move fast		Electrons move fast		Electrons move fast		

4) Battery Voltage
Control settings: Brightness: **120** γ/min; wavelength of light**: 300 nm**; metal for Target: **Potassium**
Observe the emitted electrons as you vary the battery voltage. Record your observations.

Voltage (V)	Observations of emitted electrons
0	Electrons move at moderate speed toward the cathode (away from the metal).
+1.00	Electrons move at moderate speed toward the cathode (away from the metal). (Perhaps a bit slower than when battery is 0V?)
+2.00	Electrons move at moderate speed toward the detector but then slow down and reverse direction. The electrons never reach the detector; they return to the metal.
+3.00	Electrons move toward the detector but only go a little more than halfway and then return to the metal.
+4.00	Electrons move toward the detector but only go about halfway and then return to the metal.

Change the voltage until you find the value where the electrons no longer get to the detector. Use the Control settings for this section. **stopping voltage= _1.9_ V**

Make a prediction.
The battery voltage needed to stop the current will **REMAIN THE SAME / CHANGE** (circle or highlight your answer) when the wavelength of the light changes.

Record the voltage(s) in the table.

Wavelength (nm)	300	250	450
Voltage (V)	1.9	2.7	0.5

Conclusions:
Complete each of the sentence stems below based on your and your classmates' observations and the class discussion.

1) **Wavelength of light shining on the target metal**
The wavelength of the light shining on the target metal (**has / does not have**) an effect on the number of electrons that are emitted from the target metal.
I know this because as the wavelength of the light was made smaller, the number of electrons emitted from the metal target increased. The speed with which the electrons moved also increased as the wavelength decreased.
* Remember: there is an inverse relationship between wavelength and energy [$E = \frac{h}{\lambda}$] but a direct relationship between frequency and energy [$E = h\nu$].

The type of metal used as the target (**does / does not**) make a difference.
I know this because not all the metals emitted electrons at the same wavelength. Cesium, Potassium, and Sodium (580 nm, 530 nm, and 450 nm, respectively) started emitting electrons at higher wavelengths than Silver, Copper, Gold, and Platinum (260 nm, 250 nm, 230 nm, and 210 nm, respectively) which all had much lower wavelengths.

2) **Intensity (Brightness) of light shining on target metal**
The intensity of the light shining on the target metal (**has / does not have**) an effect on the number of electrons that are emitted from the target metal.

I know this because when the intensity was lower (10 γ/min) there were very few electrons emitted compared to when the intensity was 60 γ/min and when the intensity was 120 γ/min, there were even more electrons emitted. The electrons were moving at the same speed regardless of the intensity.

3) Type of metal that makes up the target

The number of electrons emitted from the target metal (**is / is not**) dependent on the type of metal used for the target.

I know this because some of the metals did not emit electrons at the control wavelength (300 nm).

4) Battery Voltage

The emitted electrons are affected by the battery voltage in the following ways:

- when the battery voltage is set to 0 V, the electrons move from the target to the detector.

- when the battery voltage is set to a positive value (+1 V), the electrons move from the metal target to the detector with a little less speed than when the battery voltage was 0 V. As the battery voltage is increased, the speed of the electrons continues to decrease.

- when the battery voltage reached +2.0 V, the electrons no longer reached the detector. The electrons would move toward the detector but would slow, stop, and reverse direction. As the voltage was increased, the electrons moved a shorter distance away from the target metal before returning to it.

The battery voltage necessary to stop the emitted electrons for a certain metal target (**remains the same / is different**) when the wavelength of the light is changed.

This may be due to the energy of the photons in the light that is hitting the target metal.

*(Students may not be able to make this connection yet.)