Photoelectric Effect Simulation Activity

[PhET Photoelectric Effect simulation](https://phet.colorado.edu/en/simulation/legacy/photoelectric) link
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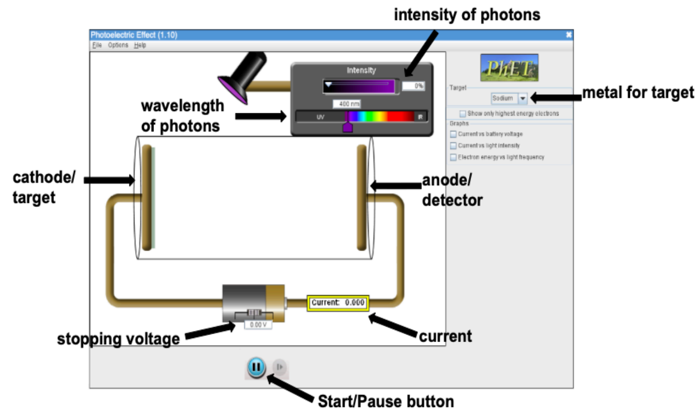
PhET Simulation Tools



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 Intensity, use the sliders or type values in to change them, give the simulation a few seconds to show any changes that may happen – they are not instantaneous, and leave the checkboxes on the right side of the screen unchecked.

1) Wavelength of light shining on the target metal

a) Control settings: metal for Target: **Sodium**; Intensity: **50%**; 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)	**750**	**600**	**540**	**535**	**450**	**350**	**250**
e^- emitted?	NO	NO	NO	YES	YES	YES	YES
Observations	NONE	NONE	NONE	Electrons move very slowly	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: _539_ nm**
Describe the motion of the electrons at this wavelength.

The electrons are just barely moving away from the cathode toward the anode.

b) Control settings: metal for Target: **(Zinc, Copper, Platinum, or Calcium)** (circle or highlight the one you are investigating); Intensity: **50%**; 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 faster

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: _288_ nm**
Describe the motion of the electrons at this wavelength.

The electrons move slowly toward the anode. They are moving faster than the electrons from the sodium trial.

b) Control settings: metal for Target: **(Zinc, Copper, Platinum, or Calcium)** (circle or highlight the one you are investigating); Intensity: **50%**; 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 slowly	Electrons move faster

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: _263_ nm**
Describe the motion of the electrons at this wavelength.

The electrons move slowly toward the anode. They are moving faster than the electrons from the sodium trial.

b) Control settings: metal for Target: **(Zinc, Copper, Platinum, or Calcium)** (circle or highlight the one you are investigating); Intensity: **50%**; 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	NO	YES
Observations							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: _196_ nm**
Describe the motion of the electrons at this wavelength.

The electrons move slowly toward the anode. They are moving faster than the electrons from the sodium trial.

b) Control settings: metal for Target: **(Zinc, Copper, Platinum, or Calcium)** (circle or highlight the one you are investigating); Intensity: **50%**; 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 Quickly	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: _427_ nm**
Describe the motion of the electrons at this wavelength.

The electrons move slowly toward the anode. They are moving faster than the electrons from the sodium trial.

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

Light Intensity	**5%**	**50%**	**100%**
Observations	Very few electrons are emitted but not many.	More electrons are emitted.	Many electrons are emitted.

3) Type of metal that makes up the target
Control settings: Intensity: **50%**; 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	**Sodium**	**Zinc**	**Copper**	**Platinum**	**calcium**
e^- emitted?	YES	NO	NO	NO	YES
Observations	Lots of fast moving electrons				Lots of fast moving electrons

4) Battery Voltage
Control settings: Intensity: **100%**; wavelength of light: **300 nm**; metal for Target: **Sodium**
Observe the emitted electrons as you vary the battery voltage. Record your observations.

Voltage (V)	**Observations of emitted electrons**
0	Electrons are moving toward anode. Some electrons are moving faster than other but all are moving toward the anode.
+1.00	All electrons are moving toward the anode with greater speed than before.
+2.00	All electrons are moving toward the anode with even greater speed than before.
-1.00	All electrons slow down. The very fast moving electrons continue to the anode and most make it but the slower moving electrons stop and begin moving back to the cathode. Only the very fast moving electrons make it to the anode.
-2.00	All electrons slow down. The very fast moving electrons make it almost all the way to the anode but are stopped before reaching it. They then return to the cathode. The slower electrons do not go as far toward the anode and are also stopped and return to the cathode.

Change the voltage until you find the value where the **current is 0.000 A**. Use the Control settings for this section. (Typing values in rather than using the slider will be less frustrating and will result in better answers.) **stopping voltage= _-1.79_ 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**	**475**
Voltage (V)	-1.79	-2.62	-0.13

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 of the metals emitted electrons at the same wavelength. Sodium and calcium (539 nm and 427 nm, respectively) started emitting electrons at higher wavelengths than zinc, copper, and platinum (288 nm, 263 nm, and 196 nm, respectively) which all had much lower wavelengths.

2) **Intensity 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 (5%) there were very few electrons emitted compared to when the intensity was 50% and when the intensity was 100%, there were even more electrons emitted.

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 cathode to the anode.
- when the battery voltage is set to a positive value (+1 V), the electrons move from the cathode to the anode with greater speed than when the battery voltage was 0 V. As the battery voltage is increased, the speed of the electrons also increases.
- when the battery voltage is set to a negative value (-1 V), the electrons move from the cathode to the anode but are slowed and many are stopped. Those electrons that were stopped return to the cathode. As the battery voltage is made more negative, more electrons are slowed and stopped and return to the cathode. There is a battery voltage at which all electrons are stopped from reaching the anode.

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.)