Photoelectric Effect

Tips for Teachers

The ***Photoelectric Effect*** simulation allows students to explore how the intensity and wavelength of light and the choice of metal affect the electrons ejected from a metal plate and the current between two plates, and to track the energy of individual photons and electrons.

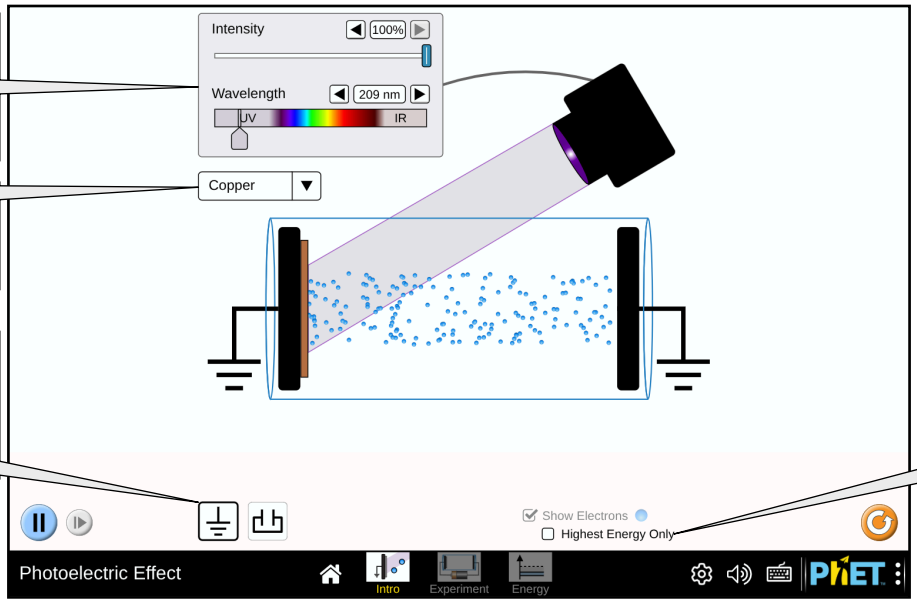
Intro Screen

Shine light on a metal plate and investigate how the intensity, wavelength, and metal affect the ejected electrons.

CHANGE light intensity and wavelength

CHOOSE the target metal

CONNECT the plates through an ammeter



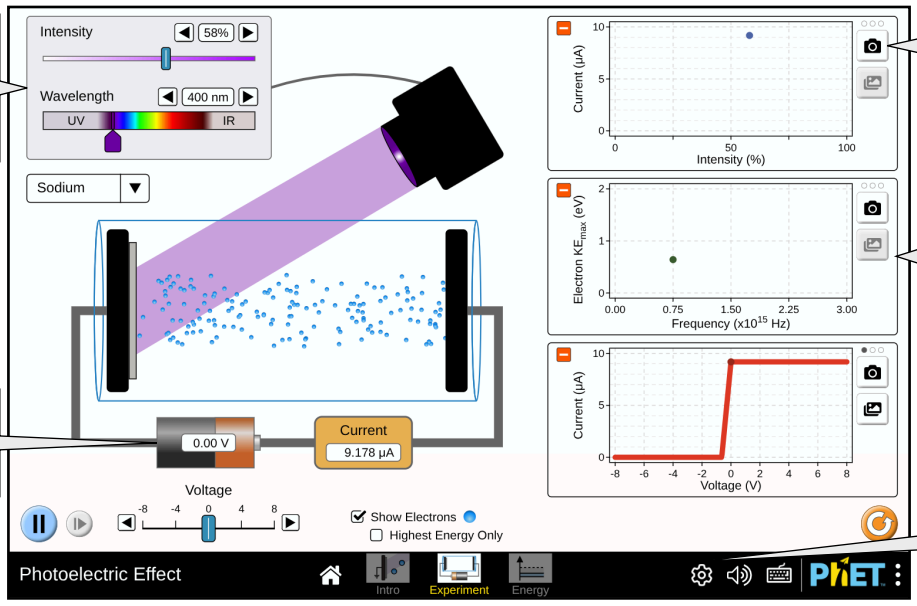
HIDE electrons or **SHOW** only the highest energy ones

Experiment Screen

Build graphs of current and electron kinetic energy by sweeping the light source and battery controls.

CHANGE light intensity and wavelength

SET the battery voltage



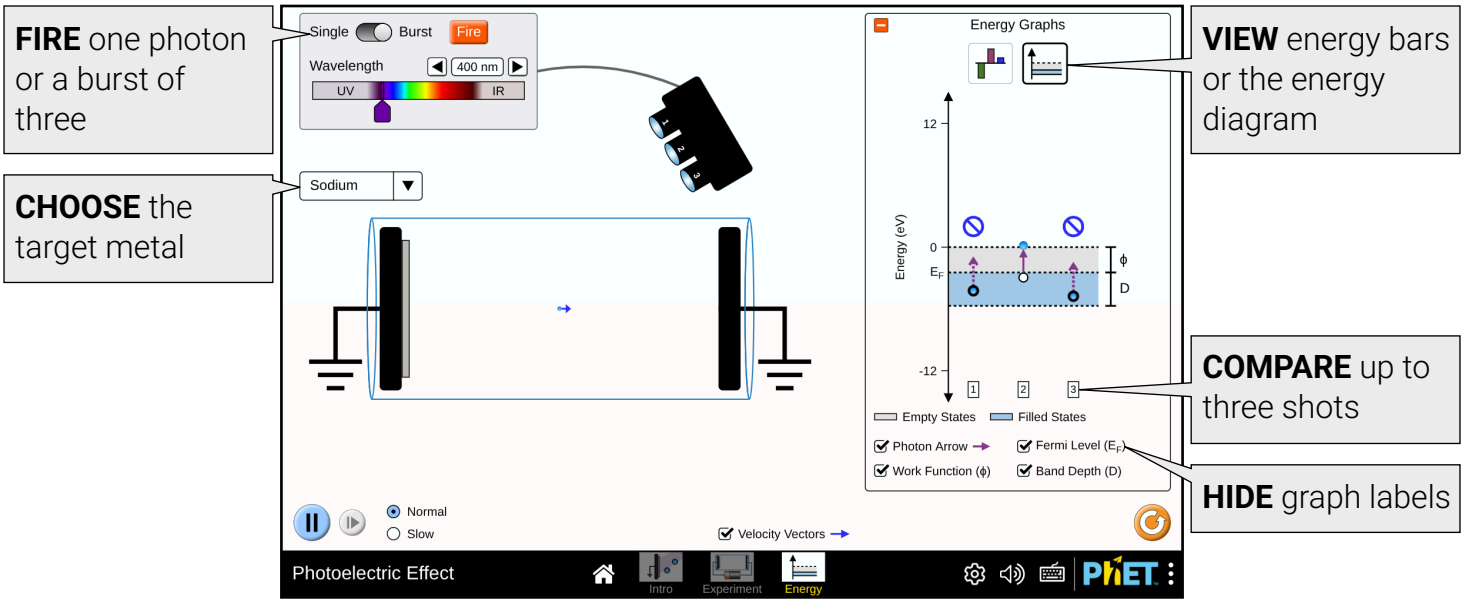
SAVE up to 3 snapshots

PLOT data as you sweep

ACCESS sim controls or add features (photons, mystery metal)

Energy Screen

Fire photons one at a time or in bursts of three and compare the energy of each photon and electron.



Insights into Student Use

- In PhET's classroom studies of the original version of this sim (McKagan et al., 2009), students debated whether faster electrons produce more current. In the sim, they can see that faster electrons still arrive at the same rate.
- On an exam question in these courses, the most common error was misapplying Ohm's law, for example claiming that a voltage is needed for current to flow.
- Many students could not predict the shape of the electron kinetic energy vs light frequency graph. In one semester, 16% drew something close to the correct graph before seeing answer choices.
- Some students and instructors expected the number of photons to stay the same when the frequency changes. With the default Normalize intensity setting, it does.
- Students rarely opened the options menu on their own, so point out any Preferences setting the lesson uses.

Suggestions for Use

See all published activities for Photoelectric Effect.

- Have students list what a wave model of light predicts (light heats electrons until they break free, brighter light gives them more energy, any color works if bright enough or shone long enough, and dim light needs time to eject an electron), then test each prediction on the Intro screen.
- On the Experiment screen, sweep the wavelength with the light on to build the Electron Kinetic Energy vs Light Frequency graph. Save a snapshot and use the Reference Line to find the slope (Planck's constant) and the threshold frequency, then calculate the work function.
- Have students measure the work function of Mystery 1 and identify it from a table of work functions (it is not one of the named metals). For a new unknown each class, add Mystery 2 from the Preferences menu and set its work function.
- Compare Current vs Voltage snapshots at two intensities, then at two wavelengths, to separate their effects on the stopping potential.

- On the Energy screen, use Single to fire photons of three different wavelengths and compare the columns, or use the Custom metal to show how the work function and band depth set the possible kinetic energies.

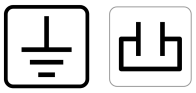
Sample Challenge Prompts

- Find the longest wavelength that ejects electrons from sodium. Does your answer depend on the intensity?
- Find the stopping potential for two wavelengths. How is it related to the photon energy?
- Why is the current the same at every positive battery voltage?
- Fire several bursts at one wavelength on the Energy screen. Why do identical photons eject electrons with different kinetic energies?

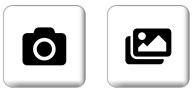
Sample Prediction Questions

- Predict the shape of the Electron Kinetic Energy vs Light Frequency graph for sodium. Then build it.
- Will a very bright red light eject electrons from sodium? Predict, then test.
- Predict how the Current vs Voltage graph will change if the intensity is cut in half.

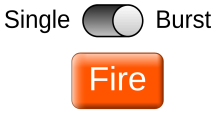
Complex Controls



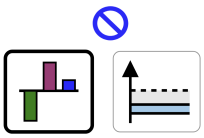
- On the Intro screen, the plate buttons switch between grounded plates and plates connected through an ammeter. Show Electrons can be unchecked only when the plates are connected.
- Highest Energy Only draws only electrons ejected from the Fermi level, so every visible electron moves at the maximum speed. In this view, about 1 in 20 photons above the threshold produces a visible electron. Neither checkbox changes the current.
- The Experiment screen graphs start collapsed, and expanding or collapsing a graph clears it. Each graph plots only the values students sweep through with its control (Intensity, Wavelength, or Voltage). Changing another setting that affects the plotted relationship clears the graph, so changing the voltage clears Current vs Intensity. Electron Kinetic Energy vs Light Frequency records only while the light is on.



- The camera button saves up to three snapshots of a graph, each labeled with the metal and the two settings held fixed. Snapshots stay when settings change. The View Snapshots button stacks them on one horizontal axis, with zoom buttons, trash buttons, and a Reference Line that reads every snapshot at the same position.



- On the Energy screen, Burst fires one photon from each lens, timed to reach the metal together, and replaces all three columns. Single fires the next lens only and replaces only its column, so students can change the wavelength between shots. Fire is unavailable until the fired photons reach the metal.
- A no-electron symbol marks a shot whose photon did not eject an electron.



- Energy Bars and Energy Diagram show the same three shots, with zero at the escape level. Energy Diagram adds the metal's filled and empty states and where each electron started.
- Choose Custom in the metal menu on the Energy screen to show Metal Properties, where students set the Work Function and Band Depth. Changing the metal or its properties clears the Energy Graphs.

- In the Preferences menu, Show photons draws individual photons instead of a beam on the Intro and Experiment screens. Add second mystery metal adds Mystery 2 to the metal menu on every screen, with a work function and band depth the teacher sets. Reset All keeps these settings.
- The Patterns preference (Visual tab) adds patterns to the energy bars.

Simulation Details

See this sim's Model Documentation for more details.

- The ammeter reading is calculated from the light, metal, and voltage settings and changes the instant a setting changes. It does not count the drawn photons and electrons, a slowed-down sample, so it can show current before the first drawn electron reaches the collector.
- Electrons in the metal have binding energies spread evenly from the work function φ to $\varphi + D$, where D is the band depth. A photon of energy E ejects an electron only if it reaches one bound by less than E, so electrons leave with a range of kinetic energies up to $E - \varphi$. The fraction of photons that eject an electron grows with photon energy until it reaches 1 at $E = \varphi + D$.
- Because of this spread, the current falls as a negative (retarding) voltage increases and reaches zero at the stopping potential, numerically equal to $E - \varphi$ in eV. When $E > \varphi + D$, it stays flat at first. At zero or positive voltage every ejected electron reaches the collector. The battery range is −8 to 8 V.
- Photons always absorb at Fermi energy level (Preferences menu) removes the spread, as in most textbook treatments. Every photon above the threshold ejects an electron with kinetic energy $E - \varphi$, and the current drops to zero abruptly at the stopping potential. Changing this setting clears the graphs and snapshots and hides Highest Energy Only.
- With Normalize intensity on (the default), Intensity sets photons per second at every wavelength, up to 5×10^{14} per second (about 80 μA). With it off, Intensity sets the power of the light, so longer wavelengths deliver more photons.
- Some electrons leave the metal very slowly, and one brought almost to rest by a retarding voltage may appear to float between the plates. This follows from the spread of energies and does not affect the current.
- Absorption and ejection are instantaneous. On-screen electron speeds are scaled to be watchable, so only relative speeds are meaningful.
- Mystery 1 uses the work function (3.63 eV) and band depth of zinc, which is not in the list of named metals.

Inclusive Features

See the simulation page for all supported inclusive features.

Alternative Input and Touchscreen Devices

- This simulation supports keyboard input for all sliders, buttons, checkboxes, the metal menu, and the time controls. In the snapshots dialog, the arrow keys move the Reference Line (hold Shift for smaller steps). See the Keyboard Shortcuts dialog in the simulation for more information.

Sound and Sonification

- This simulation includes Basic Sounds, which provides audible confirmatory feedback to indicate successful interaction, such as when pressing a button or checking a checkbox.

Interactive Description (Core)

Core description is a subset of a fully described interactive experience.

- In the snapshots dialog, the Reference Line reads every saved snapshot at its position.

- Teachers can access the Accessibility (A11y) View to see the descriptions available to screen reader users to decide if the sim's description meets their instructional needs. *Please note: A11y View is not intended for student use and will not provide a good experience for learners using screen reader software.*

Customization Options

Option 1: Use PhET Studio to configure a sim exactly how you want students to see it, save your preset, then send the preset link to your students. This is a premium product. Start a free trial today!

Option 2: Query parameters allow for customization of the simulation, and can be added by appending a '`?`' to the sim URL, and separating each query parameter with a '`&`'. The general URL pattern is:
`…html?queryParameter1&queryParameter2&queryParameter3`

For example, in Photoelectric Effect, if you only want to include the Experiment screen (`screens=2`), with Mystery 2 added (`mysteryMetal2Enabled`) and its work function set to 4.2 eV (`mysteryMetal2WorkFunction=4.2`) use:
https://phet.colorado.edu/sims/html/photoelectric-effect/latest/photoelectric-effect_all.html?screens=2&mysteryMetal2Enabled&mysteryMetal2WorkFunction=4.2

To run this in Spanish (`locale=es`), the URL would become:
https://phet.colorado.edu/sims/html/photoelectric-effect/latest/photoelectric-effect_all.html?locale=es&screens=2&mysteryMetal2Enabled&mysteryMetal2WorkFunction=4.2

⚙ Indicates this customization can be accessed from the Preferences menu within the simulation.

Query Parameter and Description	Example Links
⚙ `photonMode` - when `intensity`, Intensity sets the power of the light (Normalize intensity off). Default is `count`.	`photonMode=intensity`
⚙ `alwaysAbsorbAtFermiLevel` - every photon above the threshold ejects an electron with the maximum kinetic energy.	`alwaysAbsorbAtFermiLevel`
⚙ `showPhotons` - draws individual photons instead of a continuous beam.	`showPhotons`
⚙ `showAllGraphData` - fills the Experiment screen graphs without sweeping.	`showAllGraphData`
⚙ `energyUnits` - shows energies in joules (`joules`) instead of electron volts (default).	`energyUnits=joules`
⚙ `mysteryMetal2Enabled` - adds Mystery 2 on every screen. `mysteryMetal2WorkFunction` (1 to 10 eV) and `mysteryMetal2BandDepth` (0.5 to 15 eV) set its properties. Default is 5 for both.	`mysteryMetal2Enabled` `mysteryMetal2WorkFunction=4.2`

Query Parameter and Description	Example Links

`screens` - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center.	`screens=1`
	
	`screens=3,1`

`initialScreen` - opens the sim directly to the specified screen, bypassing the home screen.	`initialScreen=1` `initialScreen=3`
`interactiveHighlightsInitiallyEnabled` - opens the sim with interactive highlights enabled.	`interactiveHighlightsInitiallyEnabled`
⚙ `locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
`audio` - if muted, audio is muted by default. If disabled, all audio is permanently turned off.	`audio=muted` `audio=disabled`
`allowLinks` - when `false`, disables links that take students to an external URL. Default is `true`.	`allowLinks=false`
`supportsPanAndZoom` - when `false`, disables panning and zooming using pinch-to-zoom or browser zoom controls. Default is `true`.	`supportsPanAndZoom=false`

Additional PhET Resources

See PhET's Inclusive Design page to learn more about each Inclusive Feature and how to use them with your students.
For more tips on using PhET sims with your students, see Teaching with PhET.
To learn more about ways to create and facilitate sim-based lessons, visit our free Virtual Workshops.