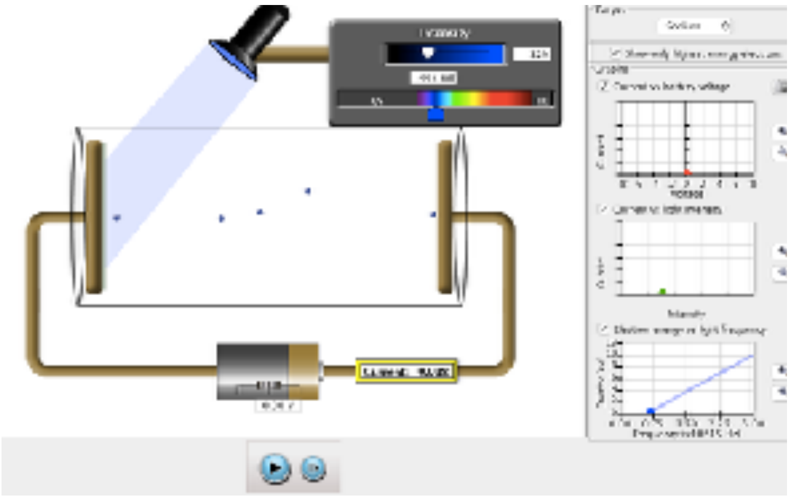
Photoelectric Effect

In this activity students will be exploring the Photoelectric Effect in Quantum Mechanics using the “Photoelectric Effect” PhET simulation.

Open the simulation by clicking on the link:

https://phet.colorado.edu/en/simulation/legacy/photoelectric

Take a look at the explanatory video via YouTube:
https://youtu.be/2RsWp9khsLs



Learning Objectives

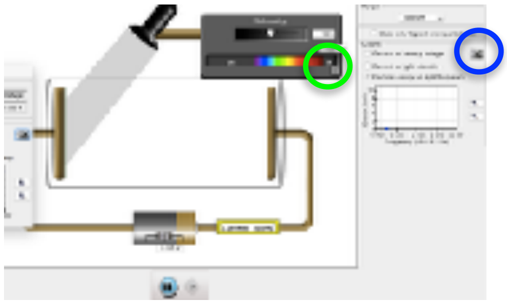
By the end of these activities it is hoped that students will have an acquired the following skills:

- Following explicit instructions to gain acquired knowledge
- Investigate the features that make up the Photoelectric Effect
- Relating the formulae of the photoelectric to the determination of energy.

Author: Simon Lees 2017

1. How does wavelength effect electron emission?

- Set up the situation as shown opposite with the metal sodium and all the graphs clicked to the ON position.
- Have the light intensity on 50%.
- Move the wavelength slider to the right. This is the largest wavelength. The slider is shown in the image opposite with the green circle.



- Move the slider slowly to the left until electrons are emitted.

Note: that the photocurrent should read 0. Keep moving the slider until just as the first electron is emitted.

- At this wavelength of light electrons are emitted for sodium.
- Add this wavelength to the table below for sodium
- Determine the wavelength for each of the different metals by doing exactly the same thing as you have done for sodium and complete the table below.

METAL	WAVELENGTH (nm)
Sodium	
Zinc	
Copper	
Platinum	
Calcium	

- Move the slider to the left beyond the point where electrons are emitted. What happens?

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- Does this occur for all the other metals? ______________________________
- What is the relationship between wavelength and electron emission?

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- Light is governed by the wave equation:

$$f = \frac{c}{\lambda}$$

Where c = speed of light = 3.0 x10^8 m/s

f = light frequency (Hz)

λ = wavelength (nm)

- Deduce the threshold frequency for each metal based on the equation above and complete the table below.

METAL	CALCULATED THRESHOLD FREQUENCY (X10^{15} Hz)
Sodium	
Zinc	
Copper	
Platinum	
Calcium	

- Max Planck showed a relationship between energy and frequency which he converted to an equation of…

$$E = hf_o$$

Where h = planks constant = 6.63 x 10^{-34} Js

E = the energy released (J)

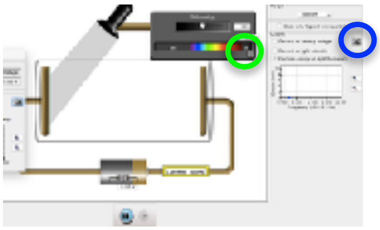
- If we combine the above 2 formulas then we get………

$$E = \frac{hc}{\lambda}$$

Use this formula and the values for wavelength to determine the energy present in each photon.

METAL	ENERGY (J)
Sodium	
Zinc	
Copper	
Platinum	
Calcium	

2. The threshold frequency is the frequency at which light causes electrons to be emitted or freed from the metal.



- Now move the slider beyond the initial wavelength to emit electrons, all the way to the far left of UV light.
- Now look at the graph that is produced in the bottom right corner. Click the camera (blue circle) on the screen above, this will take an image of the graph and the data. Take a copy of this image and place it opposite.
- From the graph the ***threshold frequency*** is the point where the line crosses the x-axis.
- Now do the same for all the other metals and take a screenshot of each of the graphs.

Screenshot of Sodium

Screenshot of Zinc

Screenshot of Copper

Screenshot of Platinum

Screenshot of Calcium

- Determine the approximate threshold frequency for all the metals from the graphs and add it to the table below.

METAL	THRESHOLD FREQUENCY ($\times 10^{15}$ Hz)
Sodium	
Zinc	
Copper	
Platinum	
Calcium	

(These values are only approximations.)

- Compare the values from those graphs and those calculated.
- How do the values look?

- The threshold frequency, f_o, and is given the formula:

$$E = hf_o$$

Where **h** = planks constant = 6.63×10^{-34} Js

E = the energy released (J)

- Use this formula to calculate the energy required to release one electron from each of the metals using the formula and the data you have collected. Complete the table below.

METAL	ENERGY (J)
Sodium	
Zinc	
Copper	
Platinum	
Calcium	

Note: that values may vary based on the approximation from the graphs

- Now compare the energies above from those calculated from the wavelength in section 1. What do you notice and what does this say about the two equations?

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3. Does light intensity have an effect on electron emission?

- Set the model on Sodium at wavelength 532nm; intensity 10%.
- Note the emission of electrons then increase the intensity gradually.
- What happens?

- Now place the wavelength on 450nm with sodium and place the intensity on 10%. Watch the photocurrent.
- Increase the intensity by 10% each time and note the photocurrent in the table below.

Light Intensity (%)	PHOTOCURRENT (µA)
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

- Based on this data what does this say about the relationship between light intensity and photocurrent?

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- Now move the wavelength below the threshold wavelength and move the intensity from 10% through to 100%.
- Does increasing the intensity have an effect on the photocurrent?

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Check with other wavelengths below the threshold wavelength to prove this.

Summary

- What is the relationship between the type of light and the generation of photocurrent?

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- What effect does light intensity have on the photocurrent?

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- What does this say about the energy contained within photons?

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- What do we call the energy that is just enough to liberate an electron from the surface of the metal?

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- If too much energy is given to an electron that is above the threshold frequency what happens to the extra energy?

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