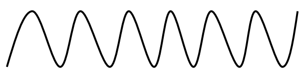
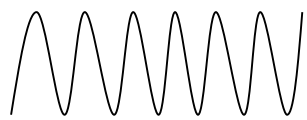
pHet Lab: Photoelectric Effect

Waves were pretty well understood by the late 1800's. It was known that greater amplitude meant greater energy. Think of it this way: To displace our large spring in class, creating a transverse wave, work must be done on the spring. This work displaces the coils from equilibrium to a maximum amplitude. The elastic nature of the spring asks the coils to come back to equilibrium, thus creating the wave and wave energy is moving along the spring. The more work done on the spring, the greater the amplitude and the greater the energy of this wave. In fact, energy of a wave is directly proportional to the square of the amplitude.

$$E \propto A^2$$

Accepted Wave theory: Increasing the amplitude of a wave increases its energy.

Wave	result of increase amplitude
	

Sound = louder & more energy

Water wave = higher & more energy

Light = brighter & more energy

So amplitude determines brightness of light
whereas wavelength determines 'colour' of light. (EMR spectrum)
(p. 497 in text)

In the late 1800's, experiments were being done with electricity and light as a wave. In 1887, Heinrich **Hertz** (who also discovered the first EMR waves – radio waves) noticed that light shone on a metal plate would cause electrons to be released. This link between light and released electrons was known as the 'photoelectric effect'. The explanation for this was not so easy and baffled scientists for several decades. Young's double slit experiment had unequivocally determined light to be a wave; however, the wave theory could not fully explain this photoelectric effect.

Max **Planck**, a German scientist, contributed novel ideas in 1900 but it wasn't until 1905 that Albert **Einstein** finally nailed it. It is his explanation of the photoelectric effect using Planck's 'quantum' idea that earned him his Nobel Prize and ushered in the new era of 'Quantum Physics'.

www.britannica.com/science/photoelectric-effect   www.nobelprize.org

So this is……………………………….

Max Planck
(1858-1947)

And this is……………………………….

Before Photoelectric Phet Simulation

Find a diagram of the photoelectric effect (P.E.) in your text. Sketch and label the photoelectric apparatus.

Cathode = negative plate   Anode = positive plate

Ee = qV   When we are dealing with electrons… Ee → usually masured in eV because we are dealing with very small amounts of energy

Also remember…. eV is a unit of energy.   1 eV = 1.6 x10^{-16} J

Photoelectric Phet Simulation – Google 'phet'!   ;)

Experiment #1 - PE Effect:

Starting conditions:
Blue light @ 50% intensity
Sodium target

A) Initial condition - see target box top right ______________

Other metals (pull down) _________ , ___________, _____________, ______________   Return to **Sodium**

B) Set intensity to 50%. The light should come on. Physicists of the day couldn't see electrons as you do in this simulation. So what did they observe?? (qualitative and quantitative answer please).

Blue light____

Red light____

K & U

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Experiment #2 - Varying Intensity/Amplitude:

Starting conditions:
Red light @ 50% intensity
Sodium target

You should have noticed that red light did NOT liberate (free) electrons from the cathode under the above conditions. Evidently, the 50% red light did NOT have enough energy to free an electron. According to current wave theory of the day, increasing the brightness of the light (greater wave amplitude) would add energy. Using this theory,

Predict - what you expect to see if red light intensity is increased ______________________________

Observe – what you see when red light intensity is increased. ______________________________

Explain – does this fit with the wave theory of light of the day? Why or why not?

____

Starting conditions:
100 nm light @ 75% intensity Sodium target

Experiment #3 - Varying Wavelength:

Visible light is often measured in nanometers. What is a nanometer? ie: 1 nm = __________m .

Check the box that says "show only the highest energy electrons" in the top right of your screen. Start at 100 nm and slowly slide across from 100 nm UV radiation to 850 nm infrared radiation. Pay attention to the electrons liberated.

Observe → As the wavelength increases, ______________________________

Determine: Where is the 'cut-off' wavelength? ie: Identify the wavelength at which if it is changed one way, more electrons are released from the sodium target and if the wavelength is changed the other way, no electrons are released. ______________

Experiment #4 – Visualizing Photons

Thinking about light as being made of photons helps explain what determines the number of electrons liberated from a metal surface. How many electrons do you think a single photon can remove from the surface? To check this, first unclick 'show only highest energy electrons' an experiment a bit.

How many electrons can a photon liberate? ______________

App

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