THE PHOTOELECTRIC EFFECT EXPERIMENT

ACCESSING THE EXPERIMENT:

To view the FarLab experiment "Photoelectric Effect" use the following link:

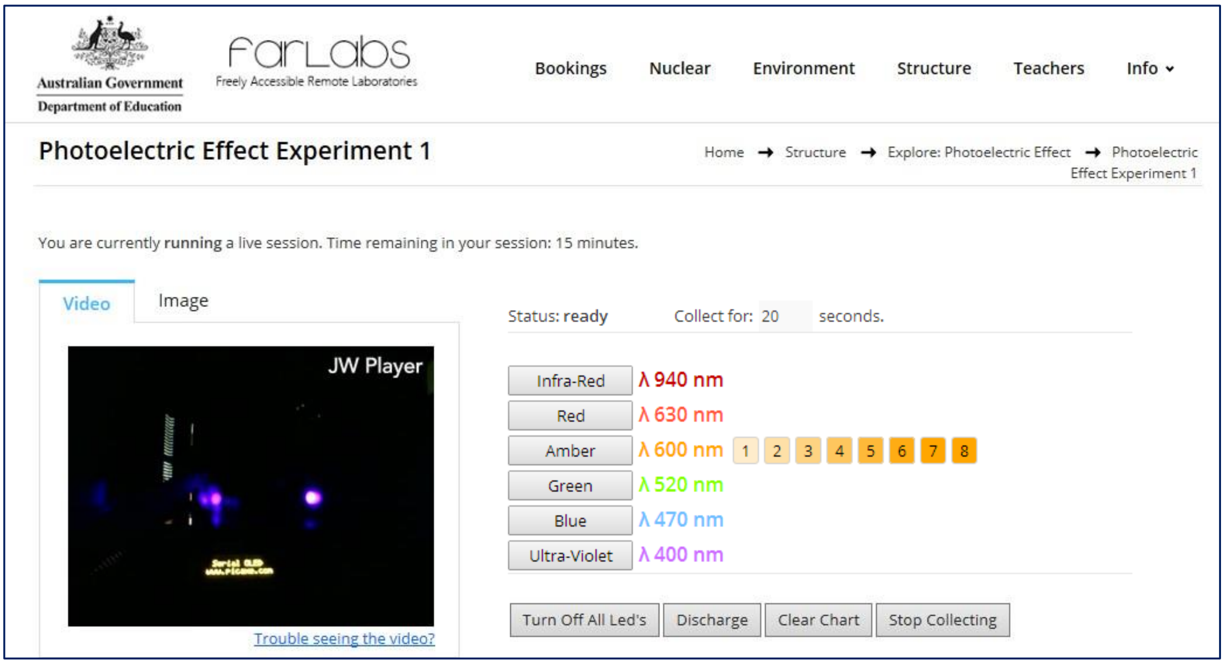
https://www.farlabs.edu.au/structure/explore-photoelectric-effect/photoelectric-effect-experiment-1/

This will allow you to view a live feed of the experiment. In order to take control of the experiment you will need to enter the student password (given to you by your teacher) and select '**Activate**'.
During the experiment you will remotely control the following pieces of equipment:

- Light sources: 6 LED's (light emitting diodes) of various colours, with known wavelengths.
- Electron emitter: a photocathode that emits electrons when hit by certain types of light.
- Electron collector: a capacitor, which will collect the electrons ejected from the photocathode.

CONTROLLING THE EXPERIMENT:

On your experiment interface, to the right of the video, are six buttons which allow you to select which colour, and what intensity, is shining on the photocathode (as in the screenshot below). When you click on an LED button (for example, 'Amber') a set of 8 intensity levels will appear. Clicking on an intensity level will tell the equipment to select that LED at the given level of intensity. It will automatically start recording the capacitor voltage as a function of time, and update the chart below the LED controls.



Test Question:
Choose a wavelength (colour) and an intensity. **Describe what happens?**

AIM

To re-create the photoelectric effect and gather evidence to identify an appropriate model which describes the nature of light.

BACKGROUND INFORMATION

Ejected Electron Energy

When an electron absorbs energy from light it remains attached to the parent metal unless the amount of energy is above a certain threshold amount which varies from metal to metal. If it absorbs more energy than this threshold amount it is ejected from the parent metal and moves away carrying kinetic energy (equal to the difference between the light energy absorbed and the threshold amount). The threshold amount of energy is called the *work function* for the metal.

If ***KE*** is the kinetic energy of an electron, ***φ*** is the work function and ***E*** is the energy of the light then

The electrons can be collected in a way that measures their kinetic energy. They collect on a *capacitor*, building up the electric charge as more and more electrons arrive at the capacitor. We can measure the amount of charge on the capacitor by measuring its voltage, as the charge goes up so does the voltage. But as the charge builds up it creates an electric field which repels electrons, the higher the voltage, the greater the energy required by an electron to reach the capacitor. Low energy electrons just don't make it. If the voltage keeps rising steadily it means the source of electrons includes very high energy electrons. If it stops rising that means the source of electrons only includes ones with energies up to a certain maximum energy and none above that. It if starts to drop that means there must be something taking electrons away faster than they are arriving.

Models for thinking about the Photoelectric Effect

To help understand the world scientists think of "models" for phenomena which they observe. In turn the models suggest new ideas and predictions which can be tested in new experiments. Some possible models for the photoelectric effect are:-

1. **Light is a continuous wave where the energy is determined by the amplitude**. Bright light has a high amplitude. As the wave hits the metal electrons absorb energy until they have enough energy to break free.

   Questions that lead to predictions:

   a. Will any wavelength of light eject an electron regardless of intensity?
   b. For low intensity light, will electrons break free immediately or not until they have had enough time to absorb the threshold amount of energy?
   c. Will there be a limit on the energy absorbed by an electron?

2. **Light comes in packets of waves where the energy of a packet is determined by the amplitude**. Bright light has a high amplitude. If a packet hits an electron it absorbs the energy and is ejected if the energy is above the threshold level.

   Questions that lead to predictions:

   a. For low intensity light will electrons break free regardless of the wavelength?
   b. Can any wavelength of light eject an electron if it is bright enough?
   c. Will the minimum brightness level that causes ejection of an electron be the same for all wavelengths?
   d. As the intensity rises will the maximum energy of the electrons rise for all wavelengths?

3. **Light comes in packets of waves where the energy of a packet is determined by the wavelength *and* the amplitude**. Bright light has high amplitude. If a packet hits an electron it absorbs the energy and is ejected if the energy is above the threshold level.

   Questions that lead to predictions:

   a. For low intensity light will electrons break free regardless of wavelength?
   b. For high intensity can any wavelength of light eject an electron?
   c. Will the minimum intensity that causes ejection of an electron be different for each wavelength?
   d. As the intensity rises will the maximum energy of the electrons rise for all wavelengths?

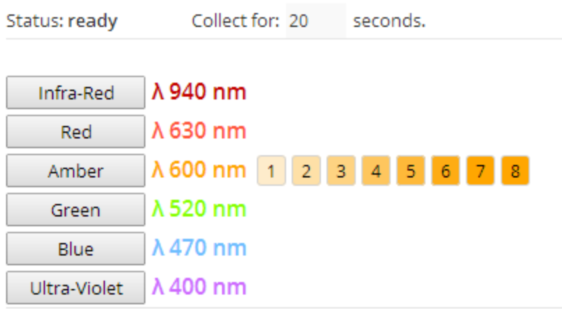
4. **Light comes in packets of waves where the energy of a packet is determined by the wavelength *only*.** Bright light has more packets arriving per second. If a packet hits an electron it absorbs the energy and is ejected if the energy is above the threshold level.

   Questions that lead to predictions:

   a. For some wavelengths will no electrons be ejected regardless of the intensity?
   b. For some wavelengths will electrons be ejected at all intensities?
   c. Will there be a cutoff wavelength where all wavelengths past this will eject electrons regardless of the intensity?
   d. For wavelengths which cause electrons to be ejected will higher intensity increase the maximum energy of the electrons?
   e. For wavelengths which cause electrons to be ejected will higher intensity increase the *rate* of ejection?

METHOD, OBSERVATIONS & DISCUSSION QUESTIONS

Now you can collect some data and try to discover which of the four models above best describes light. As you answer the questions below refer back to the four models above and see if you can strike out any of them.



1. Change the collecting time to 60 seconds, chose a middle intensity of amber or green light and watch what happens.

Does the voltage on the capacitor keep rising steadily for the entire minute? Does it show any sign of levelling out? Does it start to drop? What does this mean? If the voltage stops rising we call the level it reaches the *stopping voltage.*

2. We describe the energy of electrons using a unit called an *electron Volt* or *eV*.

For example: If the stopping voltage is 2.5 Volts that means that the maximum energy of the electrons as they leave the metal is 2.5 eV, there are no electrons with higher energies. If the stopping voltage is 5.0 volts then the maximum is 5 eV.

So the stopping voltage measures the maximum energy of the electrons, but what determines that energy? The brightness? The wavelength?

Choose a different brightness for the same wavelength OR a different wavelength but the same brightness and collect again. **What difference did that make? Is the stopping voltage the same? Did the voltage climb faster or slower?**

3. You probably still don't have enough information to answer the question "Which property of light determines the energy it carries?" so now choose the other option of different wavelength or brightness and collect some more data. **What difference does this second change make?**

4. Cement your understanding of the effect of changing wavelength and changing brightness by collecting data for one wavelength at least three different brightness levels and then at least three different wavelengths all at the same brightness level. **Record your data in the space provided below:**

5. Now have a think about what you been doing and what you have seen. If the energy is determined by the brightness then as the brightness level increases for a given wavelength you would expect the stopping energy to also increase. **Does this happen?**

6. And also if the energy is determined by the brightness then there should be no charging of the capacitor below the brightness where $E = \varphi$ regardless of the wavelength. **Can you see any evidence of this?**

7. If the energy is determined by the wavelength then as the wavelength changes for a fixed brightness the stopping voltage should also change. **Does this happen? As the wavelength increases does the stopping voltage increase or decrease?**

8. Are there any wavelengths where the stopping voltage is 0? What does this tell you?

9. Which of these statements appears to be true based on your observations?

A. The energy of the light is determined by the amplitude of the wave.
B. The energy of the light is determined by the brightness of the light.
C. The energy of the light is determined by the wavelength with long wavelengths having more energy.
D. The energy of the light is determined by the wavelength with short wavelengths having more energy.
E. Light comes as a continuous wave.
F. Light comes in packets.
G. The brightness of a light is determined by the amplitude of the waves.
H. The brightness of a light is determined by the number of packets arriving per second.

10. Which of the four models above is the best description of the behaviour of light in this experiment?

CONCLUSION

Summarise your findings about the model of light which best describes the photoelectric effect.

