**PHYSICS 3204**
*QUANTUM PHYSICS*
WORKSHEET #2 PHOTOELECTRIC EFFECT

The photoelectric effect refers to the emission of electrons from metallic surfaces usually caused by incident light. The incident light is absorbed by electrons thus giving them sufficient energy to break from the metallic surface. It is a phenomenon that was explained by Albert Einstein, and he received a Noble Peace prize for it in 1921.

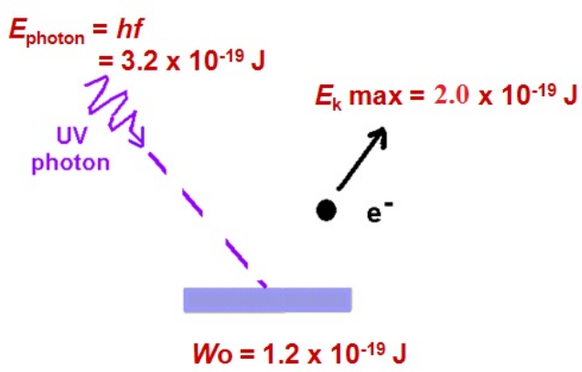
Evidence of the particle nature of light comes from the photoelectric effect. A photon is a package (quantum) of electromagnetic energy. When a single photon is absorbed by a metal surface, its energy is transferred to a single electron, which may then be released from the metal. This process is called photoelectric emission and the released electron is known as a photoelectron.

The minimum energy, E, required to release the photoelectron from the metal surface is called the work function, $W_o$, of the metal. For photoelectric emission to occur, the energy of the photon must be equal to or greater than the work function.
If the photon's energy, E, is just enough to release a photoelectron, then its frequency is called the threshold frequency, $f_0$:

$$E_{Photon} = hf_o = W_o$$

If the energy of the photon is greater than the work function, then the photoelectron can acquire some kinetic energy. By energy conservation:

photon energy = work done in releasing the electron + kinetic energy of electron




where h is the Planck constant ($6.63 \times 10^{-34}$ J• s). This can be written as

$$E_{photon} = W_o + KE_{electron}$$

or

$$hf = W_o + \frac{1}{2}m_e v^2$$

or

$$h\frac{c}{\lambda} = W_o + \frac{1}{2}m_e v^2$$

Photoelectrons may have less than the maximum kinetic energy if they transfer energy to the metal on their way to the surface.

If the photon energy is less than the work function, the energy absorbed by the metaljust causes a slight amount of heating.

**Stopping Voltage**

If the metal surface is connected to a positive potential, the photoelectron is attracted back to it. To escape from the surface, the kinetic energy of the photoelectron is used to do work against the electrostatic force. If the potential is increased, eventually even the most energetic electrons fail to escape, and the potential is called the stopping voltage, $\mathbf{V_s}$. The charge on each electron is **e**. So

$$\frac{1}{2}m_e v_{max}^2 = eV_s$$

**PART A: MULTIPLE CHOICE**

*Instructions:* *Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided*

1. If light is incident on a metal surface, which property of the light will determine if electrons will be emitted?

   (A) Amplitude
   (B) Exposure time
   (C) Frequency
   (D) Intensity

2. What is the stopping potential of an electron that has $7.30 \times 10^{-19}$ J of kinetic energy in a photoelectric cell?

   (A) 0.200 eV
   (B) 0.200 V
   (C) 4.56 eV
   (D) 4.56 V

3. When light of frequency $8.6 \times 10^{14}$ Hz is incident on a metal surface, the maximum kinetic energy of the photoelectrons is 0.500 eV. What is the work function of the metal?

   (A) 0.50 eV
   (B) 3.1 eV
   (C) 3.5 eV
   (D) 4.1 eV

4. Light of a particular wavelength is incident on a metal surface. If electrons are emitted from this surface, what situation would result in more electrons per unit time with less kinetic energy per electron?

| | Intensity | Wavelength |
|---|---|---|
| (A) | Decrease | Decrease |
| (B) | Decrease | Increase |
| (C) | Increase | Decrease |
| (D) | Increase | Increase |

5. Which is used in the production of movie sound?

   (A) DeBroglie waves
   (B) Diffraction
   (C) Photoelectric effect
   (D) Resistance

6. If the stopping potential of a photoelectric cell is 5.60 V, what is the maximum kinetic energy of the photoelectrons emitted?

(A) $2.90 \times 10^{-20}$ J
(B) $8.96 \times 10^{-19}$ J
(C) $5.60 \times 10^{1}$ J
(D) $3.50 \times 10^{19}$ J

7. A metal has a work function of 4.50 eV. What is the maximum kinetic energy of the ejected electrons if the wavelength of the incident light is $2.50 \times 10^{-7}$ m?

(A) 0.37 eV
(B) 0.46 eV
(C) 4.97 eV
(D) 9.47 eV

8. A photon with energy $E_o$ strikes a free electron. The photon is deflected in the opposite direction, with energy E. What is the resulting kinetic energy of the electron?

(A) $E_o$
(B) E
(C) $E_o$ -E
(D) $E_o$ + E

9. Blue light is shone on a metal surface and electrons are ejected at a given rate and with a certain amount of energy. If the intensity of the blue light is increased, which describes the rate and the energy per electron of the ejected electrons?

| | Rate | Energy per electron |
|---|---|---|
| (A) | Decreases | Constant |
| (B) | Increases | Constant |
| (C) | Constant | Decreases |
| (D) | Constant | Increases |

10. Which phenomenon supports the particle theory of light?

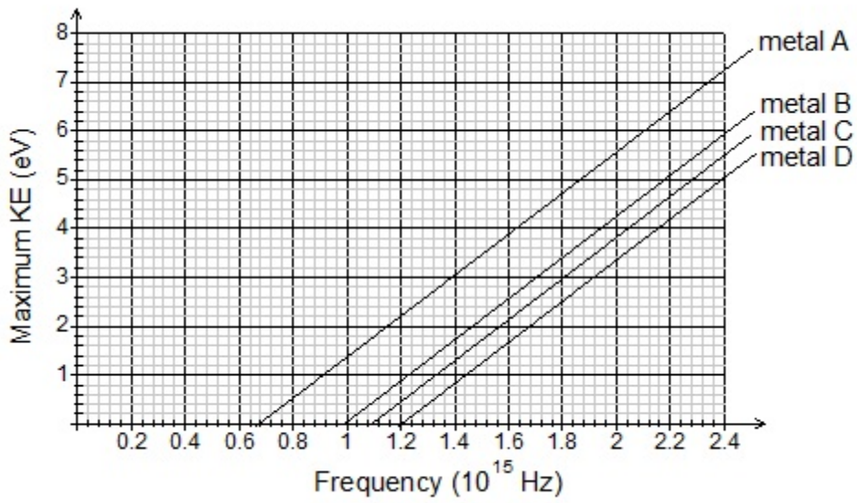
(A) Diffraction
(B) Interference
(C) Photoelectric effect
(D) Refraction

11. What is the minimum energy that will allow electrons to be ejected from a metal surface during the photoelectric effect?

(A) Black-body radiation
(B) Planck's constant
(C) Stopping potential
(D) Work function

12. The graph provided shows the maximum kinetic energy of ejected electrons plotted against the frequency of the light shone on four different metals, A, B, C and D. What is the unknown metal if light of wavelength $1.87 \times 10^{-7}$ m shines on it and the maximum kinetic energy of the ejected electrons is 2.5 eV?

(A) A
(B) B
(C) C
(D) D




13. If the wavelength of light is 250 nm, what is the maximum kinetic energy of the photoelectrons in a metal that has a work function of 4.5 eV?

(A) 0 eV
(B) 0.37 eV
(C) 0.47 eV
(D) 0.53 eV

14. If an electron has a speed of $1.0 \times 10^{4}$ m/s, what potential difference must be applied to stop the electron?

(A) $4.6 \times 10^{-23}$ V
(B) $8.4 \times 10^{-20}$ V
(C) $2.8 \times 10^{-4}$ V
(D) $5.2 \times 10^{-1}$ V

**PART B: WRITTEN RESPONSE**

1. A $2.72 \times 10^{15}$ Hz photon acquires $1.1 \times 10^{-18}$ J of kinetic energy. What is the work function of the metal? JUNE 2004

2. If the work function of silver is 3.83 eV, what is the longest wavelength of sunlight that can eject an electron from a silver surface?

3. An emitted photon of 122 nm hits a photocell, inducing the photoelectric effect. If the work function of the metal is $3.68 \times 10^{-19}$ J, what is the maximum kinetic energy of the emitted electron? JUNE 2005

4. A metal surface has a work function of 4.20 eV. What is the kinetic energy, in joules, of the emitted electrons if the wavelength of light is 250 nm? JUNE 2006

5. Light is incident on a metal that has a work function of 2.28 eV. If the maximum kinetic energy of the emitted electrons is $2.34 \times 10^{-20}$ J, calculate the wavelength of the incident light. AUGUST 2007

6. Calculate the maximum wavelength that will cause photoelectric emission from a metal surface having a work function of 2.00 eV.

7. The stopping potential of a metal is 2.4 V. Calculate the work function if light incident on the metal has a wavelength of $4.0 \times 10^{-7}$ m. AUGUST 2009

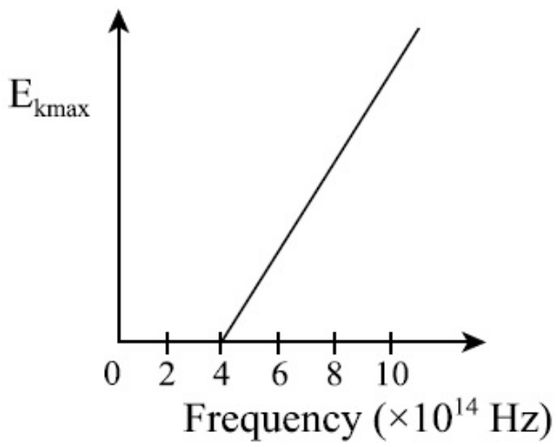
8. A light source of wavelength $\lambda$ illuminates a metal and ejects photoelectrons with a maximum kinetic energy of 1.00 eV. A second light source of wavelength $\lambda/2$ shines on the same metal and ejects photoelectrons with a maximum kinetic energy of 4.00 eV. Calculate the work function of the metal. AUGUST 2009

9. Calculate the maximum wavelength that will cause photoelectric emission from a metal surface having a work function of 2.00 eV. June 2008

10. There are some characteristics of light and subatomic particles that cannot be explained by the wave theory of light. Identify one of these characteristics and describe how quantum theory can explain it. AUGUST 2007

11. When light having frequency $3.0 \times 10^{15}$ Hz is shone on a certain metal, electrons are ejected. If the stopping potential of these electrons is 7.0 V, calculate the work function of this metal.

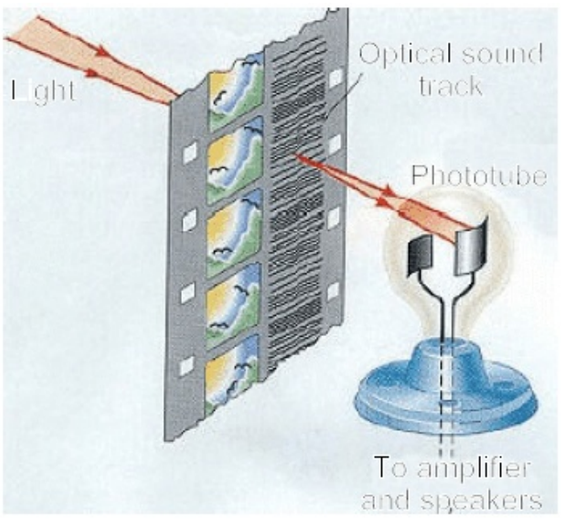
12. In a photoelectric effect experiment, light is shone on a metal surface. The graph below illustrates the maximum kinetic energy of ejected electrons versus frequency of the incident light of the photons. JUNE 2007




(i) Use the graph to determine a frequency at which the photoelectric effect will not occur, and explain why it will not occur.

(ii) Determine the work function of the metal.

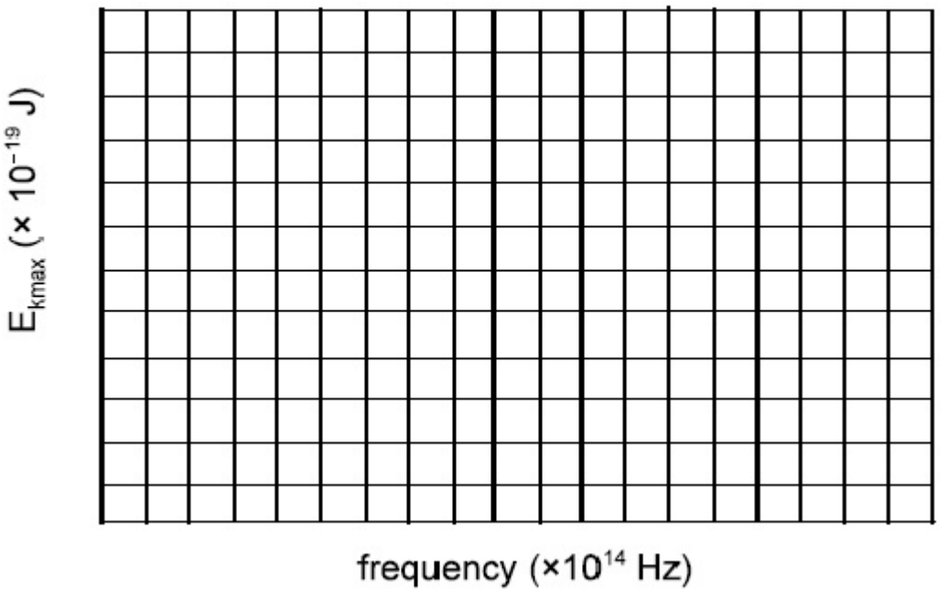
13. The analog system for the sound track of a motion picture film is shown below. How does a series of broad, clear and dark strips on the sound track affect the voltage and the current produced by the photocell? JUNE 2005



14. In a photoelectric effect experiment, light was shone on a metal surface and the data below were recorded. JUNE 2008

| Frequency of incident light ($\times 10^{14}$ Hz) | Maximum kinetic energy of ejected electrons ($\times 10^{-19}$ J) |
|---|---|
| 6 | 1 |
| 7 | 1.6 |
| 8 | 2.3 |
| 9 | 2.9 |

i) Graph these results, including the line of best fit.




ii) Use the graph to determine the work function for this metal surface.

15. If the work function of silver is 3.83 eV, what is the longest wavelength of sunlight that can eject an electron from a silver surface? AUGUST 2004

16. When a light bulb in a movie projector is replaced with a bulb that has the same intensity but different frequency, the sound does not work. With reference to the photoelectric effect, explain why this occurs
JUNE 2006