PHOTOELECTRIC EFFECT

19 AUGUST 2014

Lesson Description

In this lesson we:

- Discuss the photoelectric effect
- Work through calculations involved with the photoelectric effect

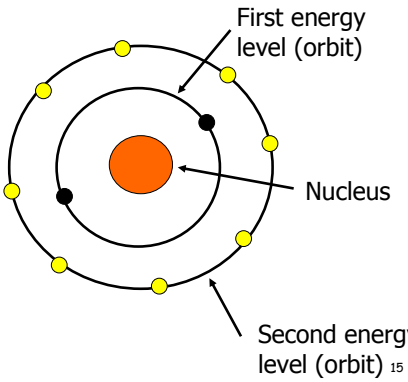
Summary

The Photoelectric Effect

In order to understand the photoelectric effect, we need to remind ourselves of Bohr's atomic model.

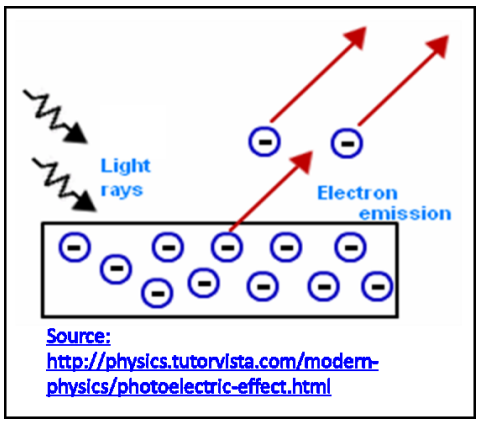
According to Bohr's model

- More than 1 electron could move in each orbit.
- Electrons release and absorb energy as they move between energy levels.
- Electrons move as waves within the orbitals.



Light has a wave nature which is shown by its ability to be reflected, refracted and diffracted.

Light also has a particle nature. The particles in light are called photons.



Source: http://physics.tutorvista.com/modern-physics/photoelectric-effect.html

When a photon of high enough energy collides with an electron near the surface of a metal, it transfers all its energy to the electron. If there is enough energy for that particular metal, then the electron that the photon collided with is knocked out of the metal.

If there is not quite enough energy to remove the electron from the metal, then the energy excites electrons into the next energy level, which then fall back emitting energy (the metal looks shiny).

Metal energy levels are close together and metal electrons are delocalised and can, therefore, be relatively easily removed from the lattice.

Work is done in removing an electron from the surface of a metal. The minimum amount of energy needed to remove an electron from the metal is called the Work Function.

$W_o = hf$	W_o = work function (J) h = Plank's constant = 6,63x10^{-34} J.s f = threshold frequency (Hz)
$c = f\lambda$	c = speed of light = 3 x 10^{8} m.s^{-1} f = frequency of light (Hz) λ = wavelength (m)

The Threshold Frequency is the minimum frequency of the light that can eject an electron from a certain metal.

If light with a frequency greater than the threshold frequency is shown on the metal then the kinetic energy of an electron that has been ejected can be found using the following equation:

$$E = W_o + E_k$$

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

E = energy of the photon (J)
W_o = work function (J)
E_k = kinetic energy of ejected electron (J)
h = Planck's constant = 6,63 x 10^{-34} J.s
f = frequency of light (Hz)
m = mass of electron = 9,11 x 10^{-31} kg
v = speed of ejected electron ($m.s^{-1}$)

Test Yourself

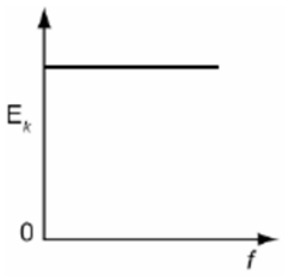
Select the most correct answer from the options given. Write down only the correct letter

Question 1

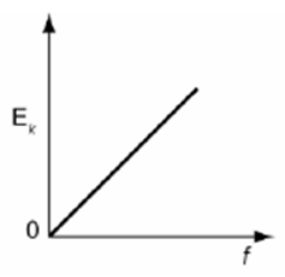
A metal is illuminated with light of frequency *f* and the electrons emitted have a maximum kinetic energy of E_k.

Which ONE of the following graphs best illustrates the relationship between kinetic energy (E_k) of the emitted electrons and frequency *(f)* of the incident light?

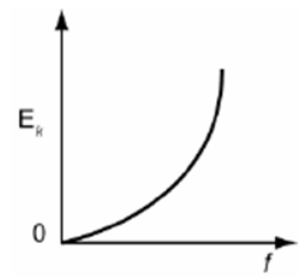
A



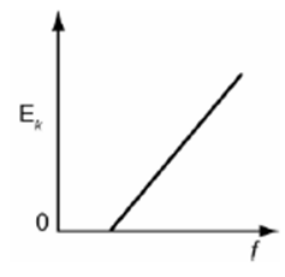
B



C



D



Question 2

Which ONE of the following phenomena provides the most conclusive evident for the wave nature of light?

A. Photoelectric effect
B. Refraction
C. Reflection
D. Diffraction

Question 3

A particular metal with a work function W_o, emits photoelectrons when irradiated with light of wavelength 150 nm. When irradiated with light with which ONE of the following wavelengths will the metal emit photoelectrons with the greatest kinetic energy?

A. 140 nm

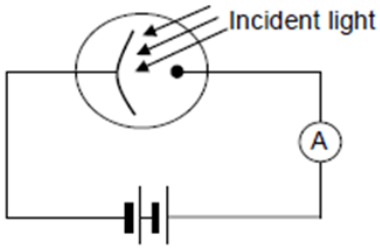
B. 130 nm

C. 120 nm

D. 110 nm

Question 4

The diagram below shows light incident on the cathode of a photocell. The ammeter registers a reading.

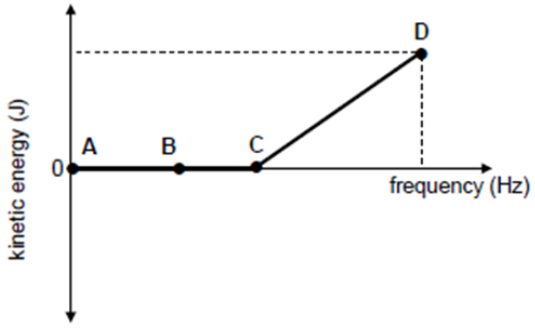


Which ONE of the following correctly describes the relationship between the intensity of the incident light and the ammeter reading?

	INTENSITY	AMMETER READING
A	Increases	Increases
B	Increases	Remains the same
C	Increases	Decreases
D	Decreases	increases

Question 5

When light shines on a metal plate in a photocell, electrons are emitted. The graph below shows the relationship between the kinetic energy of the emitted photoelectrons and the frequency of the incoming light.



Which ONE of the points (A, B, C or D) on the graph represents the threshold frequency?

A. A

B. B

C. C

D. D

Improve your skills

Question 1

(Adapted from DBE Feb – March Paper 1 2009)

The work function of three metals is shown in the table below.

Metal	Work function (W_o) in J
Aluminium	$6,54 \times 10^{-19}$
Zinc	$6,89 \times 10^{-19}$
Silver	$7,56 \times 10^{-19}$

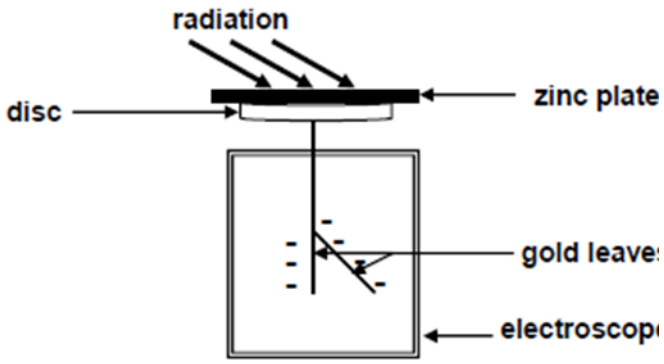
1.1. Give a reason why different metals have different work functions.

1.2. Light of wavelength $2,3 \times 10^{-7}$ m is shone onto a metal X. The average speed of the emitted electrons is $4,78 \times 10^{5}$ m.s^{-1}. Identify metal X by performing a relevant calculation.

Question 2

(Adapted from DBE Feb – March Paper 1 2011)

2.1. A group of learners perform an investigation to compare the effect of two types of radiation on the emission of photoelectrons from zinc. They place a zinc plate on top of the disc of a negatively charged electroscope. Ultraviolet and red light are shone alternately onto the zinc plate as shown below, with the electroscope fully charged in each case.



They record the following observations:

Radiation	Observation
Ultraviolet light	Gold leave collapse
Red light	No effect on the deflection of gold leaves

2.1.1. Write down an investigative question for this investigation.

2.1.2. Explain the observation made for ultraviolet light.

2.1.3. What conclusion can be drawn from this investigation?

2.2. The learners have access to the following information:

Work function of zinc	$6{,}88 \times 10^{-19}$ J
Frequency of ultraviolet light	$7{,}89 \times 10^{14}$ Hz
Frequency of red light	$4{,}39 \times 10^{14}$ Hz

2.2.1. Define the term work function of a metal.

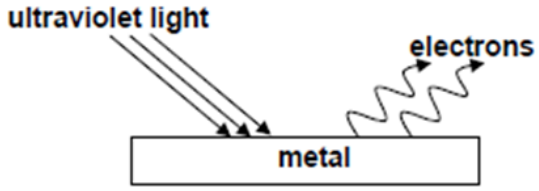
2.2.2. Use a calculation to explain why red light fails to emit photoelectrons from the surface of the zinc plate.

Question 3

(Adapted from DBE November Paper 1 2011)

A metal surface is illuminated with ultraviolet light of wavelength 330 nm. Electrons are emitted from the metal surface.

The minimum amount of energy required to emit an electron from the surface of this metal is $3{,}5 \times 10^{-19}$ J



3.1. Name the phenomenon illustrated above.
3.2. Give one word or term for the underlined sentence in the above paragraph.
3.3. Calculate the frequency of the ultraviolet light.
3.4. Calculate the kinetic energy of a photoelectron emitted from the surface of the metal when the ultraviolet light shines on it.
3.5. The intensity of the ultraviolet light illuminate the metal is now increased. What effect will this change have on the following:
  3.5.1 Kinetic energy of the emitted photoelectrons. (Write down only INCREASES, DECREASES or REMAINS THE SAME)
  3.5.2 Number of photoelectrons emitted per second (Write down only INCREASES, DECREASES or REMAINS THE SAME)