NZIP 2008

QUESTION ONE: THE PHOTO-ELECTRIC EFFECT

(a) Describe what is meant by the term "photoelectric effect".

The emission of electrons from the surface of a metal when light is incident upon it

A/ correct description

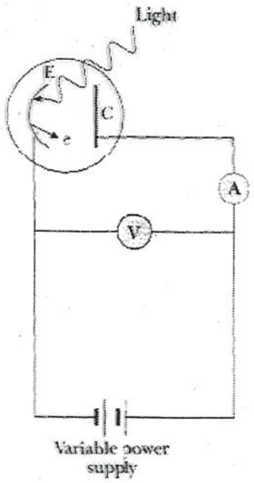
A1

(b) In a photo-emissive cell, explain the effect on the photoelectrons released, if the intensity of the light incident upon the emitter plate is increased.

A/ More photoelectrons are emitted,

M/ because brighter light has more photons which release more photoelectrons from the metal surface

AM1



(c) The diagram shows the metallic element coating of the emission plate in a photo-emissive cell illuminated with light of wavelength 3.65×10^{-7} m.

Speed of light, $c = 3.00 \times 10^{8}$ m s^{-1}

Planck's constant, $h = 6.626 \times 10^{-34}$ J s

Charge of an electron, $e = 1.60 \times ^{-19}$ C

Assessor's use only

(i) Calculate the frequency of the incident light. Give your answer to the appropriate number of significant figures.

$f = c/\lambda$

$= \frac{(3.00 \times 10^{8} ms^{-1})}{(3.65 \times 10^{-7} m)}$

$= 8.219178... \times 10^{14} Hz$ A/ correct value A2

frequency = 8.22×10^{14} Hz (3 s.f.) ✓

A/ three sig. fig. + two correct units A1

(ii) Calculate the energy of a photon in the incident light.

$E_\gamma = hf$

$= (6.626 \times 10^{-34})(8.219178... \times 10^{14} Hz)$

$= 5.4460... \times 10^{-19} J$ A/ correct value

energy = 5.45×10^{-19} J ✓ (3 s.f.)

A2

(iii) The maximum kinetic energy of the photoelectrons emitted is 1.60×10^{-19} J. Show that the work function of the emitter is 3.85×10^{-19} J. Convert this value to electron-volts.

$E_k = E_\gamma - \phi$

$\phi = E_\gamma - E_k$

$= (5.4460... \times 10^{-19} J) - (1.60 \times 10^{-19} J)$

$= 3.8460... \times 10^{-19} J$ A/ correct working & value in J

$1 eV = (1.6 \times 10^{-19}) J$ $\therefore \phi = (3.8460... \times 10^{-19} J) / (1.6 \times 10^{-19} J)(eV^{-1})$

$= 2.40 eV$ ✓ M/ correct value AM2

(d) Light of wavelength 4.35×10^{-7} m is now shown on to the emitter. Calculate the cut-off voltage for this wavelength.

$E_k = E_\gamma - \phi = hc/\lambda - \phi$

$= \frac{(6.626 \times 10^{-34} \times 3.00 \times 10^{8} ms^{-1})}{(4.35 \times 10^{-7} m)} - (3.8460... \times 10^{-19} J)$

$= 7.236 \times 10^{-20} J$ M/ valid working for E_k

Since $E_k = eV_c$ then $V_c = (7.236 \times 10^{-20} J) / (1.60 \times 10^{-19} J/eV)$

cut-off voltage = 0.452 V

E/ valid working and value ME2

Assessor's use only

(e) Describe the modification that would have to be done to the circuit shown in the diagram if the cut-off potential calculated in (d) is to be applied. Explain your answer.

A/ Description: Need to reverse the battery terminals and adjust the voltage supplied.

M/ Explanation: Because, the cut off potential is the voltage required to stop the electrons leaving the emitter. The collector needs to be negative to repel the electrons back to the emitter to provide the cut off potential.

AM,

Assessor's use only

NZIP 2007

QUESTION ONE: THE PHOTO-ELECTRIC EFFECT

A photoelectric cell has emitter plate made from an unknown metal. To identify the metal a photo-electric experiment is being carried out to find the work function of the metal.

Initially, red light with a frequency of 5.0×10^{14} Hz was shone on to the emitter plate but no photo-electrons were emitted.

(a) Calculate the energy of a photon of red light. Give your answer to the correct number of significant figures.

$E_{\gamma red} = hf$

$= (6.63 \times 10^{-34})(5.0 \times 10^{14} Hz)$

$= 3.315 \times 10^{-19} J$ A/correct value

energy = $3.3 \times 10^{-19} J$ (2s.f.)

A/2 sig. fig. plus three correct units

A_2

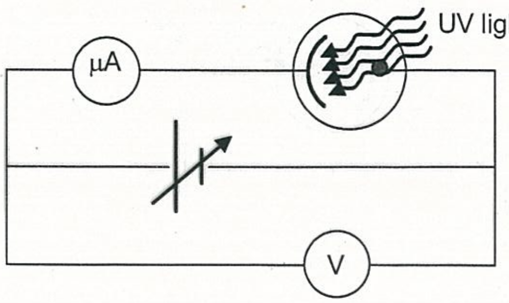
A_1

(b) State what this energy value tells you about the work function of the metal.

A/ The work function of the metal is greater than the energy in a photon of red light.

A_1

To calculate the work function of the emitter plate metal, the light used must cause electrons to be emitted and their kinetic energy must be known. The following experimental arrangement was used to find the kinetic energy of the emitted electrons when UV light of frequency of 7.5×10^{14} Hz was shone on to the emitter plate.



Assessor's use only

(c) When the voltage is set at 0.80 V no current can be detected. Show that the electric potential energy gained by the emitted electrons, as they travel from the emitter plate to the collector plate, is 1.3×10^{-19} J.

$E_p = Vq$
$= (0.80V)(1.6 \times 10^{-19} J)$
$= 1.28 \times 10^{-19} J$
$= 1.3 \times 10^{-19} J$ (2s.f.)

A/ valid working
ANSWER given in question

A_2

(d) Explain how this arrangement allows the kinetic energy of the electrons to be found.

Electrons are released with kinetic energy. Because the collector plate is negative the electrons have to do work to reach the plate and therefore gain potential energy. If their kinetic energy is insufficient to give them enough potential energy to reach the collector plate they will not flow around the circuit so there will be no current. The potential energy gained by an electron moving through a potential difference, V, is eV. Therefore, the value of V at which the current stops is the value at which all the kinetic energy has been changed to potential energy.

AME_1

(e) Calculate the work function of the emitter plate metal.

$hf = \phi + E_k$ A/ correct formula and substitution

or $\phi = hf - E_k$
$= (6.63 \times 10^{-34} \times 7.5 \times 10^{14} Hz) - (1.28 \times 10^{-19} J)$
$= 3.6925 \times 10^{-19} J$
$= 3.7 \times 10^{-19} J$ (2s.f.)

M/ correct value

AM_2

work function = ______________

Assessor's use only

NZIP 2006

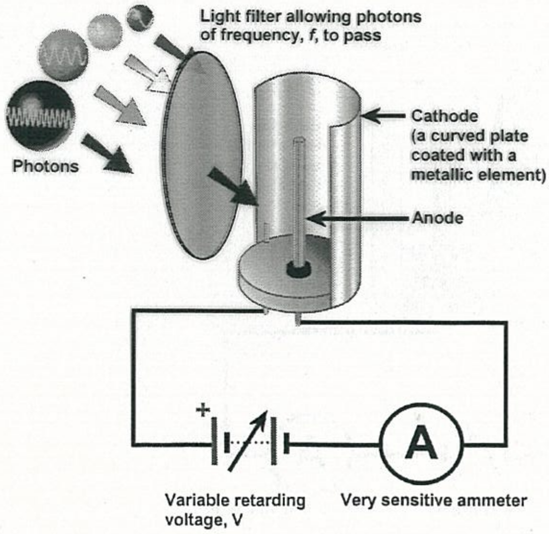
QUESTION TWO: THE PHOTOELECTRIC EFFECT

(a) Describe what photoelectric effect is.

A/ The emission of electrons from metal surfaces when electromagnetic radiation of high enough frequency falls on the metal surface.

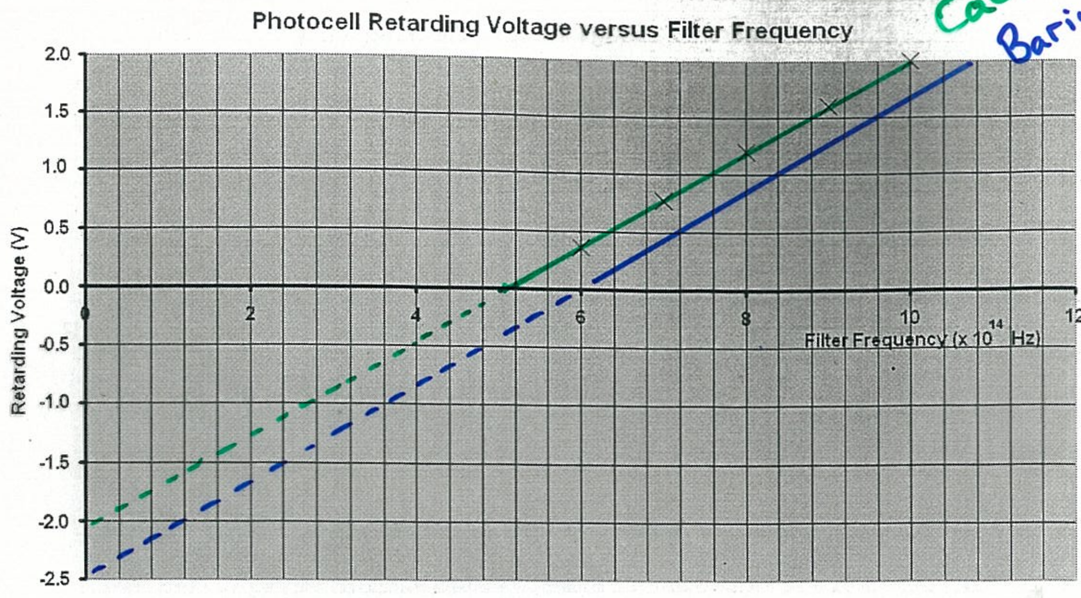
A_1

A photocell with a caesium metal coating on the cathode is used to study the relationship between the retarding (stopping) voltage and varying frequency. Light of varying frequencies is shone on to the caesium-coated cathode and the corresponding retarding voltages are recorded.



The graph on the following page shows the relationship between the retarding voltages and the frequencies of light for caesium metal.

Assessor's use only



AM$_2$

A/ parallel (OR) intercept −2.5eV

M/ ... (AND) ....

(b) Use the graph above to obtain a value for the **work function** of caesium metal in **Joules**.

From the graph work function is the y-axis intercept.

$\phi_{caesium} = (2.1 \pm 0.1)\,V \times (1.602 \times 10^{-19})$

$= 3.3642 \times 10^{-19}\,J$

Work function = $3.4 \times 10^{-19}\,J$ (2 s.f.)

A/ correct value ±

A$_2$

A barium-coated cathode now replaces the caesium-coated cathode and the experiment is repeated. The metal barium has a work function of **2.5 eV**.

(c) On the above graph draw a line to show relationship between the retarding voltage and the varying frequency of light for barium metal.

(d) From the above graph calculate the threshold frequency for caesium metal.

From the graph the threshold frequency for caesium is the x-axis intercept

Frequency = $(5.0 \pm 0.2) \times 10^{14}\,Hz$

A/ correct value ±

A$_2$

(e) Explain what happens when a photon of frequency below the threshold frequency hits the surface of the photocell with the caesium-coated metal.

A/ No photoelectron is emitted,
M/ because the photon's energy is absorbed by the electron and re-emitted as heat.

AM,

(f) Describe what would happen if light of the same frequency but double the intensity was shone on to the photocell with the caesium-coated metal. Give reasons for your answer.

A/ The larger the intensity of the monochromatic light source the more photons per second will be emitted and hence more electrons per second will be emitted, but the maximum kinetic energy of the emitted photoelectrons will remain the same.

M/ This is because light of larger intensity has a greater number of photons that will increase the collision rate hence the number of electrons per second is higher.

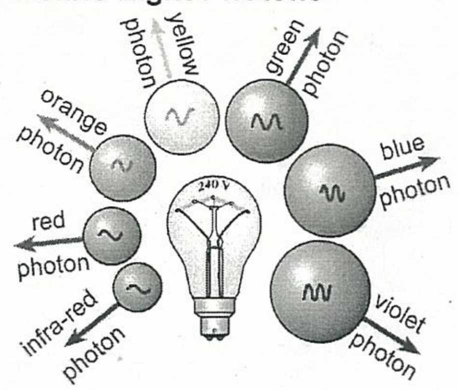
AME,

E/ clear, correct explanation.

Asses sor's use only

NZIP 2005
QUESTION TWO:

Visible Light Photons



The diagram shows the hot filament of a light bulb emitting photons.

(a) Describe a photon.

A/ Is a monochromatic (single frequency or wavelength) quantum of electromagnetic energy.

A_1

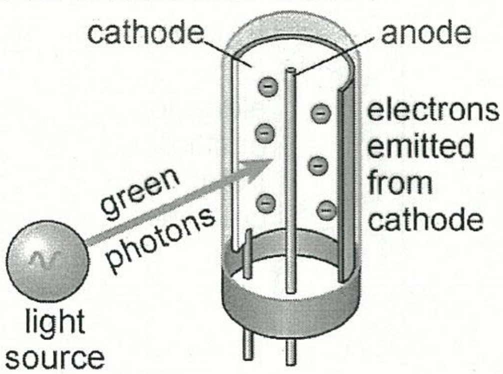
(b) Explain why red photons have a different energy size to blue photons, by making reference to Planck's law.

A/ Planck's Law states that the energy of a photon is proportional to its frequency. M/ A red photon has a smaller energy size than a blue photon E/ because it has a smaller frequency.

$E_\gamma = hf$

AME_1

Photoemissive Cell



Assessor's use only

(c) The diagram shows green photons of energy 3.72×10^{-19} J bombarding the metallic element coating of a photo-emissive cell. This coating has a work function equal to 3.16×10^{-19} J.

(i) Calculate the maximum kinetic energy of an electron emitted from the cathode.

$E_K = E_\gamma - \phi$

$= (3.72 \times 10^{-19}\,J) - (3.16 \times 10^{-19}\,J)$

$= 0.56 \times 10^{-19}\,J$ A/ correct value

A₂

(ii) Calculate the wavelength of a green photon (speed of electromagnetic energy c = 3.00×10^8 m s-1, Planck's constant $h = 6.626 \times 10^{-34}$ J s).

$E_\gamma = hf \therefore f = E_\gamma / h$

$= (3.72 \times 10^{-19}\,J) / (6.626 \times 10^{-34}\,Js)$

A/ $= 5.6142 \times 10^{14}\,Hz$ frequency correct

$\lambda = c/f = (3.00 \times 10^8\,ms^{-1}) / (5.6142 \times 10^{14}\,Hz)$ M/ valid working + value

$= 5.3435 \times 10^{-7}\,m$ $= 5.34 \times 10^{-7}\,ms^{-1}$ (3 s.f.)

AM₂

(iii) Discuss what happens if the lightsource is exchanged for another which emits red photons of energy size 2.92×10^{-19} J.

A/ The red photon does not cause the emission of a photo-electron. Instead it is absorbed by the metallic element coating and re-emitted as heat. M/ This is because the energy size of the red photon is less than the work function E/ which is the energy required for the electron to leave the metal.

AME₁