

Questions

Q1.

When the photoelectric effect occurs, light incident on the surface of a metal releases electrons.

Which of the following is an experimental observation of the photoelectric effect?

- ☐ **A** Electrons are only released after light has been incident for a long time.
- ☐ **B** Increasing the frequency of the light increases the maximum kinetic energy of the released electrons.
- ☐ **C** Increasing the intensity of the light increases the maximum kinetic energy of the released electrons.
- ☐ **D** Only light with a wavelength above a threshold value releases electrons.

(Total for question = 1 mark)

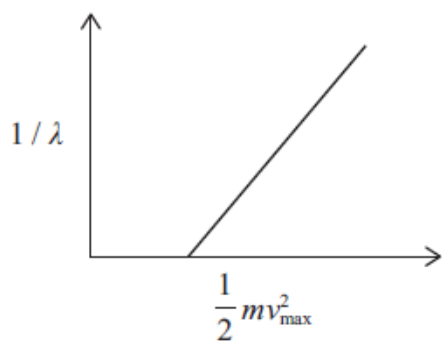
Q2.

Answer the question with a cross in the box you think is correct (☐). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☐).

Light of wavelength λ travelling at speed c is incident on a metal surface.

Photoelectrons are emitted from the surface with a maximum kinetic energy $\frac{1}{2}mv_{\text{max}}^2$.

The graph shows the relationship between $1/\lambda$ and $\frac{1}{2}mv_{\text{max}}^2$.



Which of the following shows how the gradient of the graph can be used to determine the Planck constant h ?

- ☐ **A** $h = \frac{1}{\text{gradient}}$
- ☐ **B** $h = \frac{1}{c \times \text{gradient}}$
- ☐ **C** $h = \frac{c}{\text{gradient}}$
- ☐ **D** $h = \text{gradient}$

(Total for question = 1 mark)

Q3.

Electromagnetic radiation can be described in terms of a photon model.

Which of the following demonstrates the photon model of light?

- ☐ **A** diffraction patterns
- ☐ **B** Huygens' construction
- ☐ **C** photoelectric effect
- ☐ **D** plane polarisation

(Total for question = 1 mark)

Q4.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Which of the following describes threshold frequency?

- ☐ **A** The frequency of light that causes photoelectrons to have maximum kinetic energy.
- ☐ **B** The frequency of light emitted when excited electrons fall to the ground state.
- ☐ **C** The minimum frequency of light that can cause an electron to leave a surface.
- ☐ **D** The maximum frequency of light which excites an electron in the ground state.

(Total for question = 1 mark)

Q5.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

When monochromatic light is incident on the surface of a metal, photoelectrons are emitted.

Which of the following statements is correct?

- ☐ **A** The maximum kinetic energy of the photoelectrons depends on the intensity of the incident light.
- ☐ **B** The number of photoelectrons emitted per second depends on the frequency of the incident light.
- ☐ **C** The maximum kinetic energy of the photoelectrons depends on the frequency of the incident light.
- ☐ **D** The number of photoelectrons emitted per second depends on the work function of the metal.

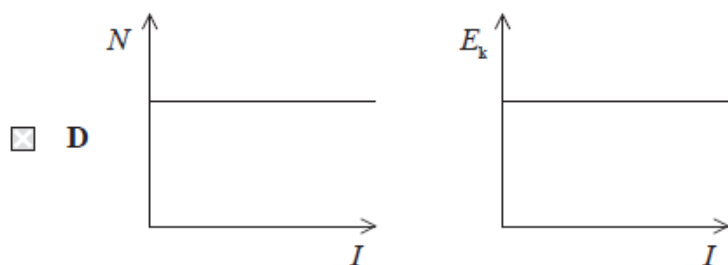
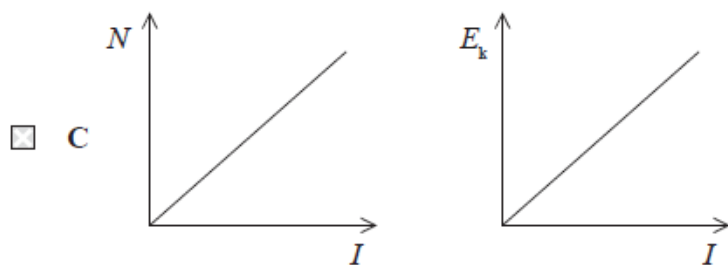
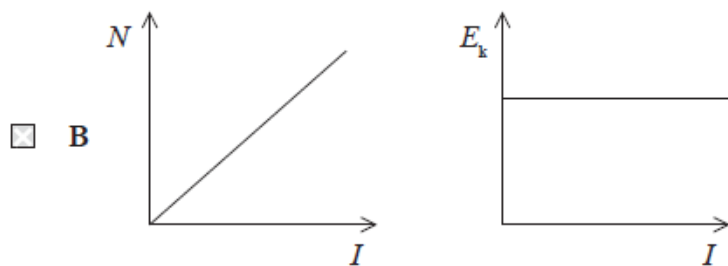
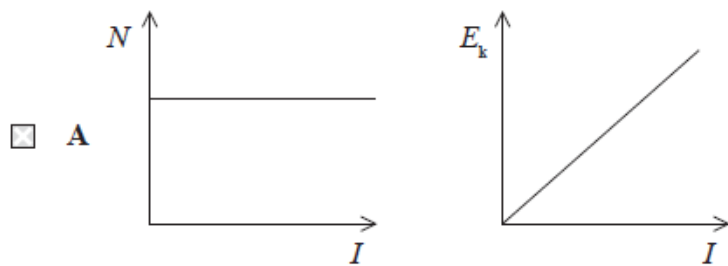
(Total for question = 1 mark)

Q6.

Ultraviolet light is incident on a metal surface and photoelectrons are released.

The number of photoelectrons released per second is N and the maximum kinetic energy of the released electrons is E_k .

Which of the following pairs of graphs shows how N and E_k vary with the intensity I of the incident light?



(Total for question = 1 mark)

Q7.

The work functions of four metals are shown in the table.

Metal	Work function / J
potassium	3.62×10^{-19}
magnesium	5.89×10^{-19}
tungsten	7.18×10^{-19}
iron	7.41×10^{-19}

(a) State what is meant by work function.

(1)

.....
.....

(b) When light with a frequency of 6.32×10^{15} Hz is incident on a metal, photoelectrons are released with a maximum kinetic energy of 3.60×10^{-18} J.

Determine which of the four metals the light is incident on.

(3)

.....
.....
.....
.....
.....
.....

(c) Ultraviolet radiation is incident on a potassium plate. If the radiation behaved as a wave, there would be a time delay before electrons were emitted from the plate.

(i) Calculate the time taken for a potassium atom to absorb enough energy to release an electron.

intensity of ultraviolet radiation = 38.0 mW m^{-2}

area over which a potassium atom absorbs energy = $8.10 \times 10^{-20} \text{ m}^2$

(3)

.....
.....

.....
.....
.....
.....

Time taken =

(ii) In practice, electrons are emitted from the plate as soon as the ultraviolet radiation is incident on the plate.

Explain how this provides evidence for the particle nature of electromagnetic radiation.

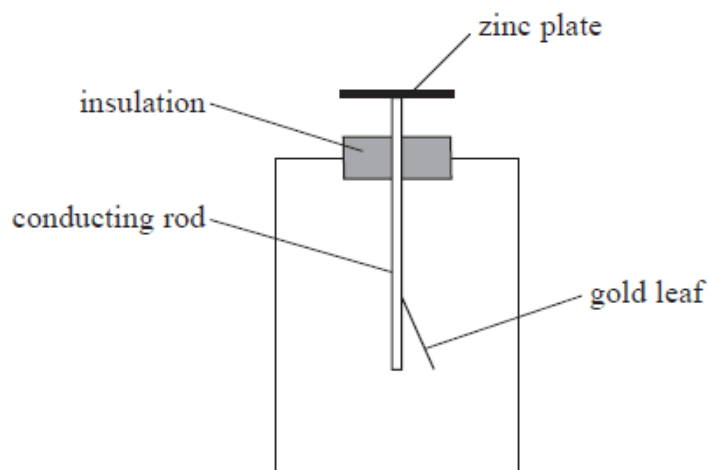
(2)

.....
.....
.....
.....

(Total for question = 9 marks)

Q8.

A gold leaf electroscope is used to demonstrate the photoelectric effect. When the zinc plate of the electroscope is given a negative charge, the conducting rod and gold leaf also become negatively charged. The gold leaf deflects away from the metal stem as shown. The deflection of the gold leaf depends on the amount of charge on the zinc plate and the conducting rod.



A beam of ultraviolet radiation is incident on the zinc plate. The gold leaf immediately begins to

fall back to the conducting rod.

(a) Explain why this observation cannot be explained by the wave model of electromagnetic radiation.

(2)

.....

.....

.....

.....

(b) Photons of ultraviolet radiation with an energy of $9.3 \times 10^{-19} \text{ J}$ are directed towards the zinc plate.

(i) Calculate the maximum speed with which electrons are released from the plate.

work function of zinc = 4.3 eV

(4)

.....

.....

.....

.....

.....

.....

.....

.....

Maximum speed of electrons =

(ii) A student suggests that a greater maximum speed of electrons could have been achieved if both:

- a metal with a lower work function than zinc was used
- ultraviolet radiation with a greater wavelength was used.

Discuss the student's suggestion.

(3)

.....

.....

.....

.....

.....

.....

(Total for question = 9 marks)

Q9.

A student used two sources, A and B, of electromagnetic radiation to investigate the photoelectric effect. Radiation from A has a photon energy of 2.0 eV.

(a) The radiation from B has a wavelength of 280 nm.

Show that this radiation has a photon energy of about 4.4 eV.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

*(b) The student used the two sources of radiation to investigate the photoelectric effect for two different metals, copper and zinc.

The following statements were made by the student.

When radiation of photon energy 2.0 eV from source A is directed towards either of the metal plates no electrons are released, even when the intensity of the radiation is increased.

When radiation of photon energy 4.4 eV from source B is directed towards the copper plate, no electrons are released. However, when the radiation is directed towards the zinc plate, electrons are released. As the intensity of radiation is increased, electrons are released at a greater rate.

Explain the conclusions that can be made from these statements.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

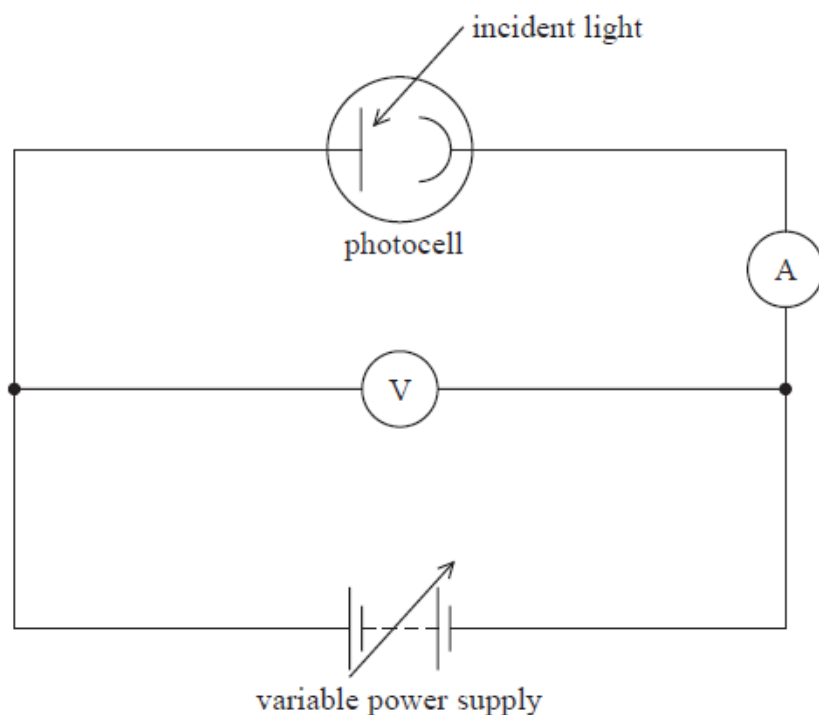
.....

.....

(Total for question = 10 marks)

Q10.

Photocells make use of the photoelectric effect. The following circuit can be used to determine the work function of a metal used in a photocell.



(a) State what is meant by the work function of a metal.

(1)

.....

.....

.....

.....

(b) This photocell works with ultraviolet light but does not work with visible light.

Explain why.

(2)

.....

.....

.....

.....

(c) An experiment was carried out using this circuit. The potential difference applied to the photocell opposes the movement of the electrons through the photocell, reducing the current.

(i) The variable power supply was initially set at 0 V and the reading on the ammeter was 2.4 μA .

The intensity of the ultraviolet light was then increased without changing the frequency.

Explain what happened to the reading on the ammeter.

(3)

.....

.....

.....

.....

.....

.....

(ii) The variable power supply was adjusted until the reading on the ammeter became 0 μA . The reading on the voltmeter was 3.59 V.

Calculate the work function, in joules, of the metal used in the photocell.

frequency of ultraviolet used = $2.00 \times 10^{15} \text{ Hz}$

(4)

.....

.....

.....

.....

.....

.....

.....

.....

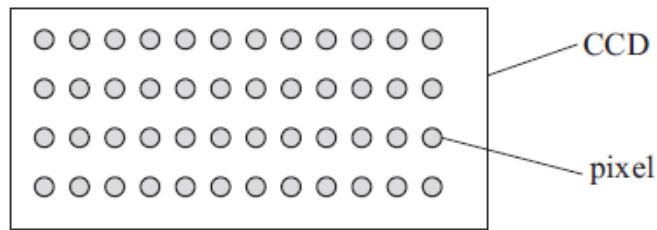
Work function = J

(Total for question = 10 marks)

Q11.

A camera detects light using a charge-coupled device (CCD).

One CCD has an array of metal pixels, as shown. The pixels release electrons when exposed to ultraviolet (UV) light.



The pixels are exposed to UV light of wavelength 380 nm.

(a) (i) Show that the energy of a photon of this light is about 5.2×10^{-19} J.

(3)

.....

.....

.....

.....

.....

(ii) The manufacturer states that about 80% of these photons incident on a pixel will cause the emission of an electron.

Deduce which sample is being tested in the refractometer.

intensity of incident light = $1.1 \mu\text{W m}^{-2}$

diameter of pixel = 1.2×10^{-5} m

number of electrons emitted by each pixel per second = 195

(5)

.....

.....

.....

.....

.....

.....

.....

.....

(b) The threshold frequency of the metal in the pixels is equal to the frequency of green light.

The pixels were exposed to white light with the same intensity as the UV light. The UV light source was removed.

Explain how this changed the percentage of photons that released electrons.

.....

.....

.....

.....

.....

.....

.....

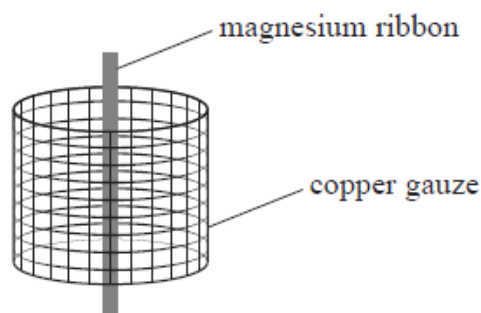
.....

(Total for question = 12 marks)

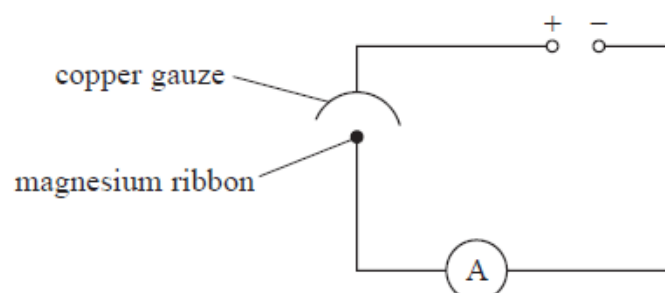
Q12.

Some students investigated the photoelectric effect.

They used a piece of magnesium ribbon placed inside a cylinder of copper gauze as shown. There was an air gap between the copper gauze and the magnesium ribbon.



The copper gauze was connected to the positive terminal of a power supply. The magnesium ribbon and a sensitive ammeter were connected to the negative terminal of the power supply, as shown.



The students made the following observations:

- when light from an ultraviolet lamp was incident on the gauze and ribbon, a current was detected by the ammeter.
- when the polarity of the power supply was reversed, the current decreased to zero.

*(a) Explain these observations.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) The students reconnected the circuit so that a current was detected when ultraviolet light was incident on the gauze and ribbon.

(i) The students replaced their original lamp with an ultraviolet lamp with a much greater intensity.

Explain the effect this had on their experiment.

(3)

.....

.....

.....

.....

.....

.....

(ii) The ultraviolet lamp was replaced by a laser which emitted red light of wavelength 633 nm.
Deduce whether the photoelectric effect will occur.

work function of magnesium = 3.7 eV

(4)

.....

.....

.....

.....

.....

.....

.....

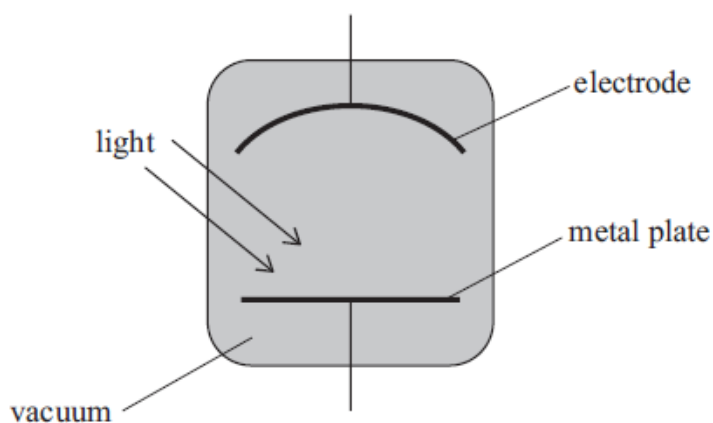
.....

.....

(Total for question = 13 marks)

Q13.

A scientist used a photocell to investigate the photoelectric effect.
A photocell consists of a metal plate and an electrode, as shown.



Light incident on the metal plate can cause the photoelectric effect.

(a) A beam of monochromatic light is directed onto the metal plate and causes the photoelectric

effect. All photons in the beam have the same energy.

Explain why the beam produces photoelectrons with a range of kinetic energies.

(3)

.....

.....

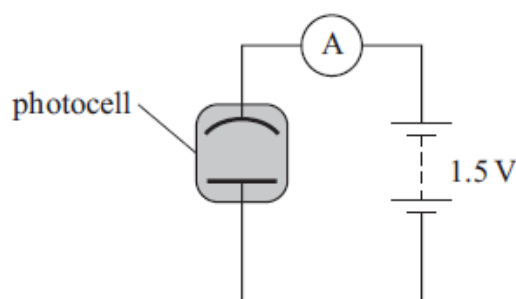
.....

.....

.....

.....

(b) The scientist connected the photocell to an ammeter and battery, as shown.



Photoelectrons are attracted to the electrode, causing a current in the circuit.

The scientist directed different frequencies and intensities of light onto the photocell.

She made the following observations:

- white light with a low intensity caused no current
- white light with a high intensity caused no current
- ultraviolet light with a low intensity caused a current.

Explain what these observations show about the nature of light.

(5)

.....

.....

.....

.....

.....

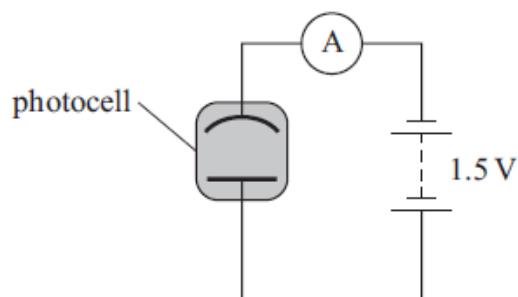
.....

.....

.....

.....

.....



The battery has negligible internal resistance.

When photoelectrons have enough kinetic energy to overcome the potential difference across the photocell, there is a current in the circuit.

Ultraviolet light of wavelength 250 nm is incident on the photocell.

Deduce whether there is a current in the circuit.

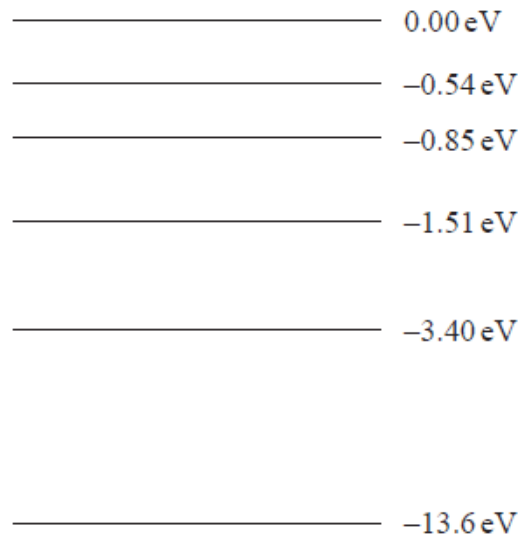
work function of metal plate in photocell = $6.9 \times 10^{-19} \text{ J}$

(5)

This image shows a full page of white paper with ten horizontal dashed lines, typical of primary school handwriting practice paper. The lines are evenly spaced and extend across the entire width of the page. There is no text or other markings on the paper.

Q14.

The diagram shows the energy levels for an atom of hydrogen.



An electron is in the -13.6 eV (ground state) level of this atom.

(a) A photon interacts with this electron.

Explain why this interaction causes the emission of another photon.

(2)

.....

.....

.....

.....

.....

(b) A photon has a wavelength of 218 nm.

(i) Determine the energy, in eV, of this photon.

(4)

.....

.....

.....

.....

.....
.....
Photon energy = eV

(ii) Explain whether the atom of hydrogen could emit a photon with this energy.

(2)

.....
.....
.....
.....
(c) Photons with energy $1.63 \times 10^{-18} \text{ J}$ are incident upon the surface of a metal plate.

The metal surface releases electrons due to the photoelectric effect.

(i) Calculate the maximum possible speed of the electrons.

work function = $5.89 \times 10^{-19} \text{ J}$

(3)

.....
.....
.....
.....
.....
Maximum possible speed of the electrons =

(ii) Explain why the photoelectric effect demonstrates light behaving as a particle, rather than a wave.

(3)

.....

(Total for question = 14 marks)

Q15.

A photomultiplier is a device that can detect very low intensity light.

In a photomultiplier, a metal plate called a photocathode is connected to the negative terminal of a power supply.

Electromagnetic radiation incident on the photocathode can cause the photoelectric effect.

(a) Describe the photoelectric effect.

(2)

.....

.....

.....

.....

(b) The photomultiplier can only detect electromagnetic radiation that causes the photoelectric effect.

Explain why the photomultiplier cannot detect some frequencies of electromagnetic radiation.

(2)

.....

.....

.....

.....

(c) Visible light has a range of wavelengths from 380 nm to 700 nm.

The work function of the material used to make the photocathode is 1.48 eV.

Deduce whether the photomultiplier can detect all wavelengths of visible light.

(4)

.....

.....

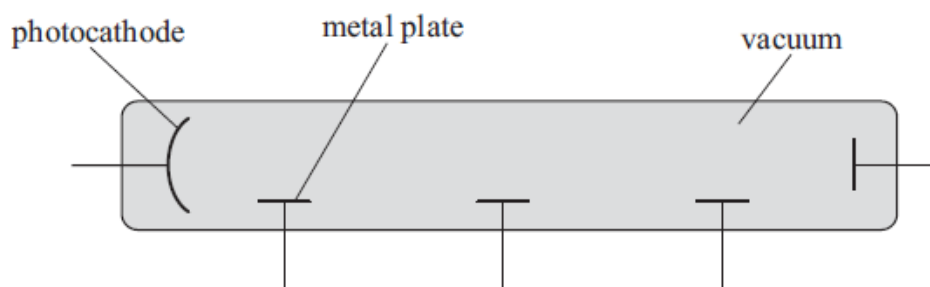
.....

.....

.....

.....

(d) In the photomultiplier, the photocathode and several other metal plates are in a vacuum, as shown.



An electron is emitted from the photocathode with a speed of $1.35 \times 10^6 \text{ m s}^{-1}$.

There is a potential difference (p.d.) of 108 V between the photocathode and the first metal plate. This p.d. causes the kinetic energy of the electron to increase.

Calculate the kinetic energy, in joules, of the electron at the instant it collides with the first metal plate.

(3)

.....

.....

.....

.....

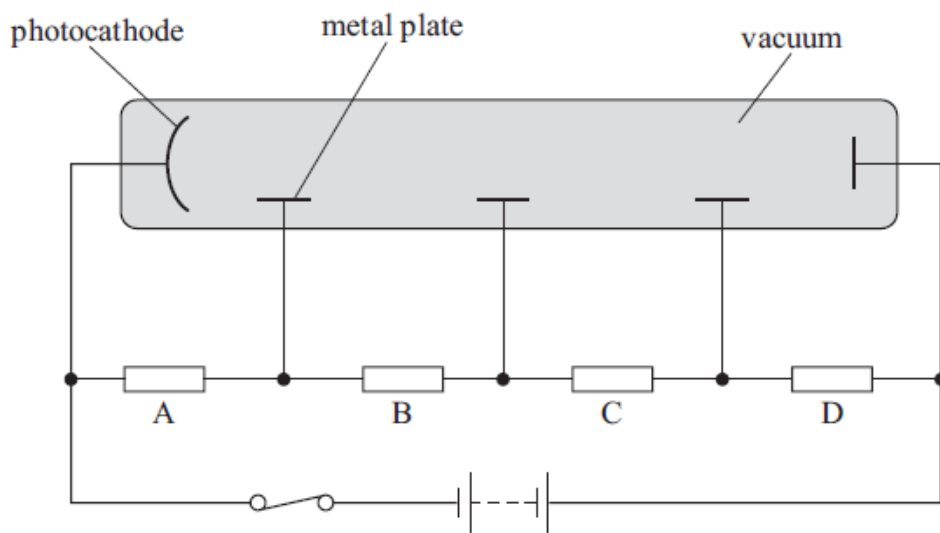
.....

.....

.....

Kinetic energy = J

(e) The electrical circuit shown includes four resistors, A, B, C and D, which apply a p.d. between adjacent metal plates.



Each resistor has a resistance of $85.0 \text{ k}\Omega$.

When the switch is open, the p.d. across the power supply is 1960 V .

When the switch is closed, the p.d. across resistor A is 108 V .

Calculate the internal resistance of the power supply.

(4)

.....

.....

.....

.....

.....

.....

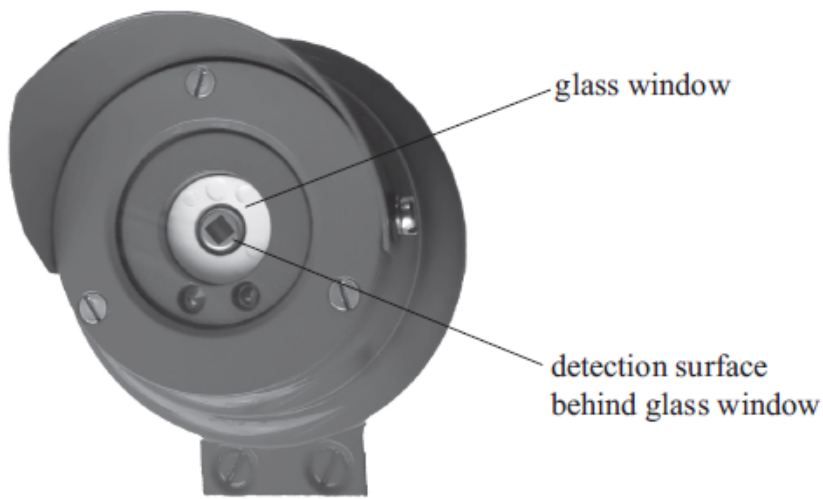
.....

Internal resistance =

(Total for question = 15 marks)

Q16.

The photograph shows a 'flame detector'. The flame detector uses the photoelectric effect to detect ultraviolet radiation from fires.



(Source: © Fisenko Evgeny/Shutterstock)

(a) Explain how electrons are released in the photoelectric effect.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

(b) A fire emits photons of ultraviolet radiation with a wavelength of 380 nm.

(i) Show that the energy of each photon is about 5×10^{-19} J.

(3)

.....

.....

.....

.....

.....

.....

(ii) Calculate the maximum kinetic energy of the released electrons in eV.

work function of metal = 2.2 eV

(3)

.....

.....

.....

.....

.....

Maximum kinetic energy = eV

(iii) Ultraviolet radiation with an intensity of 8000 Wm^{-2} is incident on the detection surface.
The detection surface has an area of 0.020 m^2 .

Determine the number of photons incident on the detection surface each second.

(3)

.....

.....

.....

.....

.....

Number of photons =

(c) The detection surface is part of an electrical circuit. The released electrons cause a current in this circuit.

The intensity of ultraviolet radiation incident on the detection surface increases.

Explain how this will affect the current in the circuit.

(3)

.....

.....

.....

.....

.....

.....

(Total for question = 16 marks)