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A Level · OCR · Physics

54 mins

5 questions

Structured Questions

The Photoelectric Effect

The Photoelectric Effect / Demonstrating the Photoelectric Effect / The Photoelectric Equation / Work Function & Threshold Frequency / Maximum Kinetic Energy & Intensity

Medium (4 questions)	/43
Hard (1 question)	/11
Total Marks	**/54**

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Medium Questions

1 (a) Define the work function of a metal.

....

(1 mark)

(b) The work function of potassium is 2.3 eV.

i) Potassium emits electrons from its surface when blue light is incident on it. Extremely intense red light produces no electrons.

Explain these observations in terms of photons and their energy.

[4]

ii) Light from a laser is incident on some potassium in a vacuum. Electrons are emitted.

The wavelength of the light is 320 nm.

Calculate the shortest de Broglie wavelength of the emitted electrons.

de Broglie wavelength = ... m **[4]**

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(8 marks)

2 (a) Fig. 19.1 shows an electric circuit.

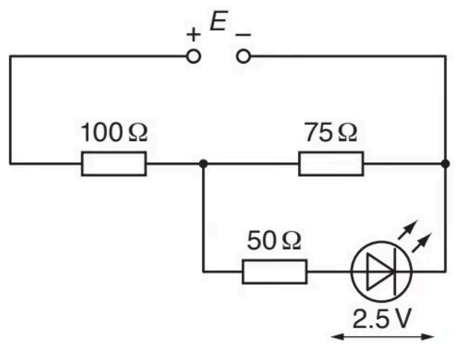

Fig. 19.1

The power supply has electromotive force (e.m.f.) *E* and negligible internal resistance.

The resistance values of the resistors are shown in Fig. 19.1. The *I*–*V* characteristic of the light-emitting diode (LED) is shown in Fig. 19.2.

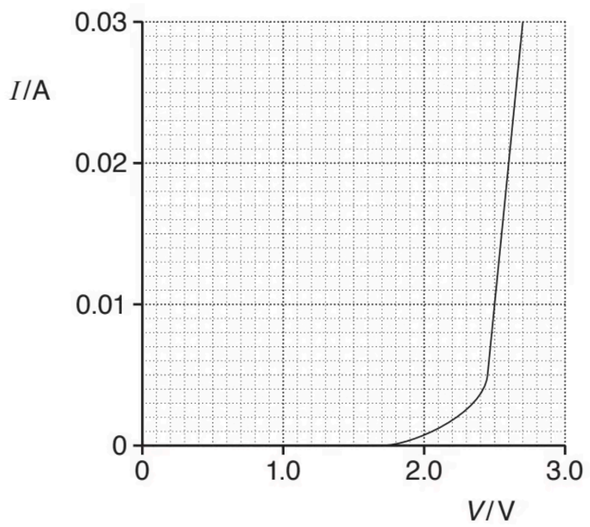

Fig. 19.2

The potential difference (p.d.) across the LED is 2.5 V.

Use Fig. 19.2 to show that the p.d. across the 50 Ω resistor is 0.50 V.

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(2 marks)

(b) Calculate the e.m.f. *E* of the power supply.

E = ... V

(3 marks)

(c) The LED emits blue light of wavelength 4.7×10^{-7}m.

i) Estimate the number of blue light photons emitted from the LED per second.

number of photons per second = ... s^{-1} **[3]**

ii) The light from the LED is incident on a metal of work function 2.3 eV.

Explain, with the help of a calculation, whether or not photoelectrons will be emitted from the surface of the metal.

[2]

(5 marks)

3 (a) Electromagnetic radiation is incident on a negatively charged zinc plate. Electrons are emitted from the surface of the plate when a weak intensity ultraviolet source is used. Electrons are not emitted at all when an intense visible light from a lamp is used.

Explain these observations.

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(4 marks)

(b) The **maximum** wavelength of the electromagnetic radiation incident on the surface of a metal which causes electrons to be emitted is 2.9×10^{-7} m.

Calculate the maximum kinetic energy of electrons emitted from the surface of the metal when each incident photon has energy of 5.1 eV.

maximum kinetic energy = ... J

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(3 marks)

(c) Electromagnetic radiation of constant wavelength is incident on a metal plate.

Photoelectrons are emitted from the metal plate. Fig. 19.1 shows an arrangement used to determine the maximum kinetic energy of electrons emitted from a metal plate.

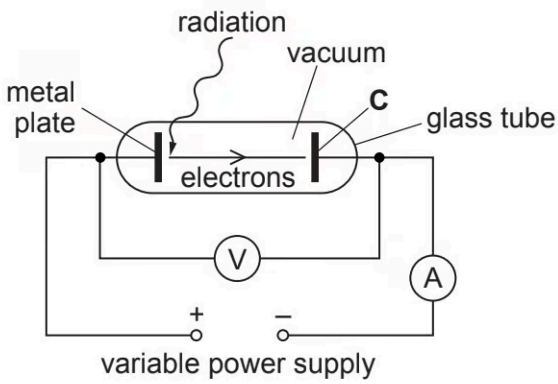

Fig. 19.1

The metal plate and the electrode **C** are both in a vacuum. The electrode **C** is connected to the negative terminal of the variable power supply.

Fig. 19.2 shows the variation of current *I* in the circuit as the potential difference *V* between the metal plate and **C** is increased from 0 V to 3.0 V.

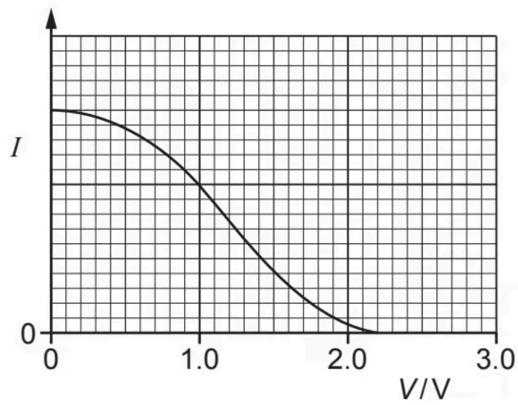

Fig. 19.2

Explain why the current decreases as *V* increases and describe how you can determine the maximum kinetic energy of the emitted electrons.

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(3 marks)

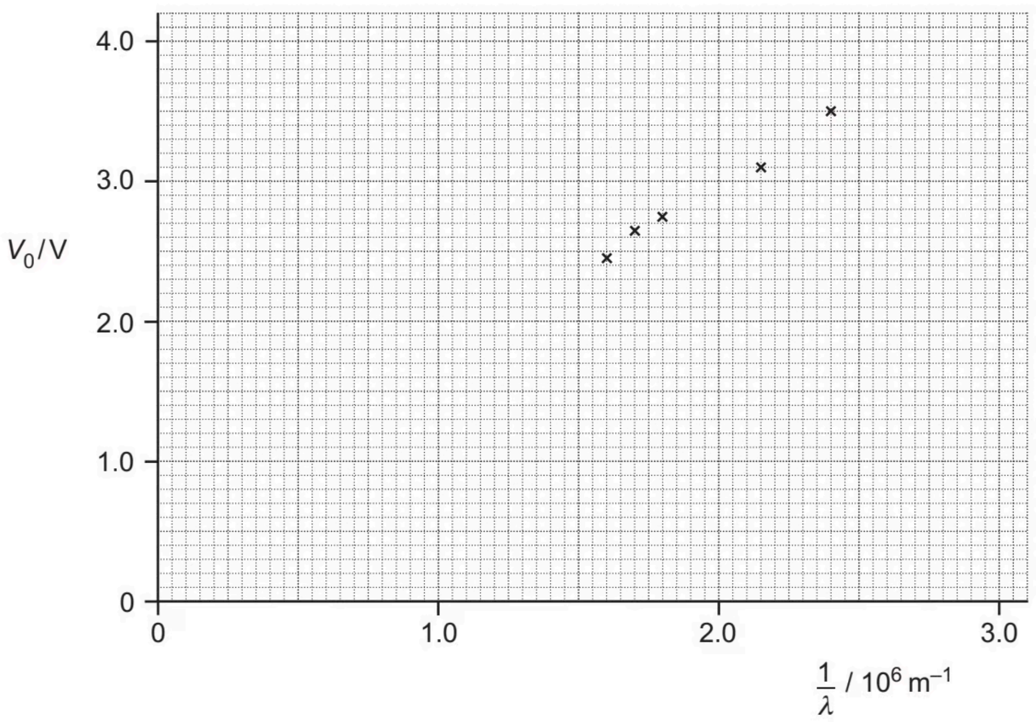
4 (a) An approximate value of the Planck constant h can be determined in the laboratory using light-emitting diodes (LEDs). An LED suddenly starts to conduct and emit monochromatic light when the potential difference across an LED exceeds a minimum value V_0.

The potential difference V_0 and the wavelength λ of the emitted light are related by the equation

$$V_0 = \left(\frac{hc}{e}\right) \times \frac{1}{\lambda}$$

where e is the elementary charge and c is the speed of light in a vacuum.

Fig. 20.1 shows some data points plotted by a student on a V_0 against $\frac{1}{\lambda}$ graph for five different LEDs.



The potential difference across each LED was measured using a digital voltmeter with divisions ±0.01V. The values for the wavelengths are accurate and were provided by the manufacturer of the LEDs.

The value of V_0 was determined by directly observing the state of the LED in the brightly lit laboratory.

i) Draw the straight line of best fit on Fig 20.1 and determine the gradient of the line.

gradient = ... Vm **[2]**

ii) Use your answer in **(i)** and the equation on page 20 to determine a value for h to 2 significant figures. Show your working.

h = ... Js **[3]**

iii) Calculate the percentage difference between your value in **(ii)** and the accepted value of the Planck constant.

difference = ... % **[1]**

iv) Identify the two types of errors shown by the data in Fig. 20.1 and suggest how you could have refined the experiment to reduce or eliminate these errors.

[4]

(10 marks)

(b) Fig. 20.2 shows a gold-leaf electroscope with a clean zinc plate.

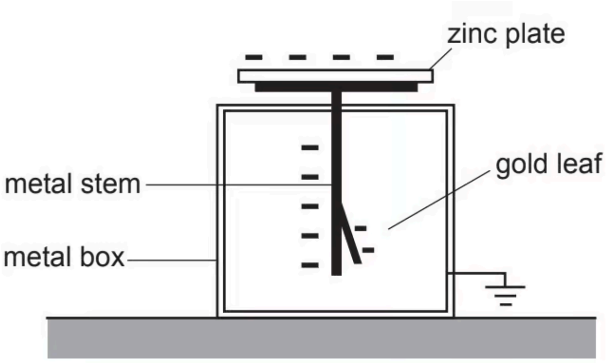


Fig. 20.2

The zinc plate, metal stem and the gold-leaf are given a negative charge by briefly connecting the zinc plate to the negative electrode of a high-voltage supply.

The gold leaf is fully diverged.

The position of the leaf is not affected by intense white light from a table lamp incident on the zinc plate. The gold leaf collapses very quickly when low-intensity ultraviolet radiation from a mercury lamp is incident on the zinc plate.

Explain these observations in terms of photons.

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(4 marks)

Hard Questions

1 (a) Fig. 6.1 shows a single photomultiplier tube and its internal components. The tube can detect gamma photons in high-energy physics experiments.

A single gamma photon incident on the scintillator crystal generates many photons of blue light. These visible light photons travel to the photocathode where they are converted into photoelectrons. The number of electrons is then multiplied in the photomultiplier tube with the help of electrodes called dynodes. A short pulse of electric current is produced at the output end of the photomultiplier tube.

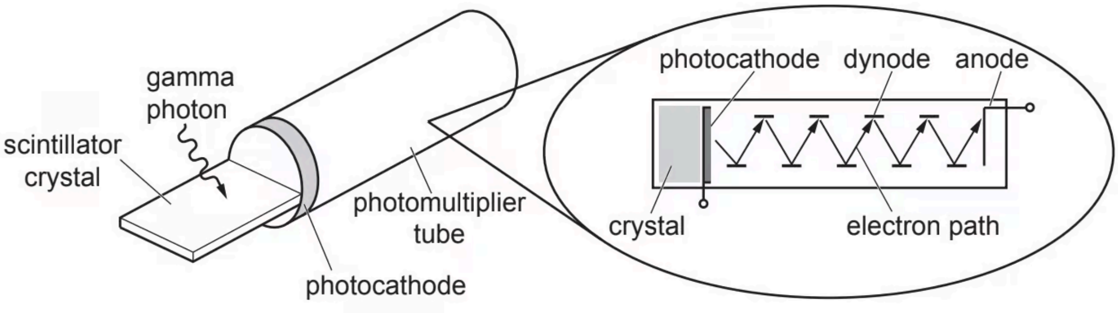

Fig. 6.1

Fig. 6.2 shows a section through the scintillator crystal in air.

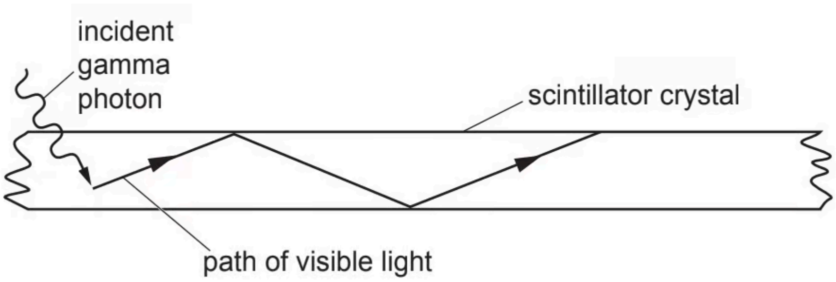

Fig. 6.2

i) The refractive index of the scintillator crystal for visible light is 1.69. The refractive index of air is 1.00. Calculate the critical angle *C* for this crystal.

C = ...° **[2]**

ii) Explain why the visible light inside the scintillator crystal follows the path shown in Fig. 6.2.

[2]

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(4 marks)

(b) A high energy gamma photon passing through the scintillator crystal converts some of its energy into visible light photons of mean wavelength 450 nm.

Show that the energy of a single photon of wavelength 450 nm is less than 3 eV.

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(3 marks)

(c) The photocathode is coated with potassium which has a work function of 2.3 eV. Each emitted photoelectron is accelerated by a potential difference of 100 V between the photocathode and a metal plate, called the first dynode.

i) Show that the maximum kinetic energy of an emitted electron at the photocathode is very small compared to its kinetic energy of 100 eV at the first dynode.

[1]

ii) 2000 photoelectrons are released from the photocathode. Each photoelectron has enough energy to release four electrons from the first dynode at the collision. These four electrons are then accelerated to the next dynode where the process is repeated. There are 9 dynodes in the photomultiplier tube. The total number of electrons collected at the anode for each photoelectron is 4^9.

The pulse of electrons at the anode lasts for a time of 2.5×10^{-9} s.

Calculate the average current due to this pulse.

average current = ... A **[3]**

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(4 marks)