Photoelectric Effect & Wave Particle Duality

Question paper 2

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Quantum Physics
Sub Topic	Photoelectric Effect & Wave Particle Duality
Paper Type	Theory
Booklet	Question paper 2

Time Allowed: **90 minutes**

Score: **/75**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** By reference to the photoelectric effect, explain

(i) what is meant by ***work function energy***,

.....

.....

.....[2]

(ii) why, even when the incident light is monochromatic, the emitted electrons have a range of kinetic energy up to a maximum value.

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.....[2]

(b) Electromagnetic radiation of frequency ***f*** is incident on a metal surface. The variation with frequency ***f*** of the maximum kinetic energy E_{MAX} of electrons emitted from the surface is shown in Fig. 7.1.

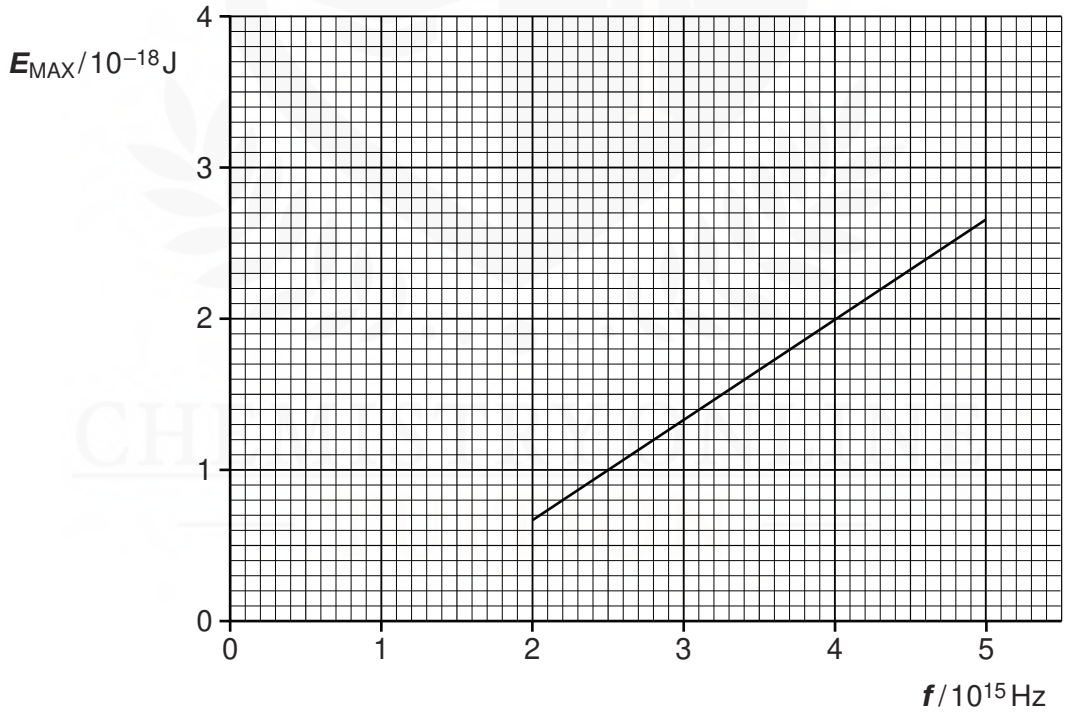

Fig. 7.1

(i) Use Fig. 7.1 to determine the work function energy of the metal surface.

work function energy = ... J [3]

(ii) A second metal has a greater work function energy than that in **(i)**.
On Fig. 7.1, draw a line to show the variation with ***f*** of $\boldsymbol{E}_{MAX}$ for this metal. [2]

(iii) Explain why the graphs in **(i)** and **(ii)** do not depend on the intensity of the incident radiation.

.....

.....

.....[2]

2 Some data for the work function energy Φ and the threshold frequency f_0 of some metal surfaces are given in Fig. 7.1.

metal	$\Phi / 10^{-19}$ J	$f_0 / 10^{14}$ Hz
sodium	3.8	5.8
zinc	5.8	8.8
platinum	9.0	

Fig. 7.1

(a) (i) State what is meant by the ***threshold frequency***.

.....

.....

.....[2]

(ii) Calculate the threshold frequency for platinum.

threshold frequency = ... Hz [2]

(b) Electromagnetic radiation having a continuous spectrum of wavelengths between 300 nm and 600 nm is incident, in turn, on each of the metals listed in Fig. 7.1.
Determine which metals, if any, will give rise to the emission of electrons.

.....

.....

.....

.....[2]

(c) When light of a particular intensity and frequency is incident on a metal surface, electrons are emitted.
State and explain the effect, if any, on the rate of emission of electrons from this surface for light of the same intensity and higher frequency.

.....

.....

.....

.....[3]

3 **(a)** State what is meant by a ***photon***.

.....

.....

.....[2]

(b) It has been observed that, where photoelectric emission of electrons takes place, there is negligible time delay between illumination of the surface and emission of an electron.

State three other pieces of evidence provided by the photoelectric effect for the particulate nature of electromagnetic radiation.

1. .....

.....

2. .....

.....

3. .....

.....

[3]

(c) The work function of a metal surface is 3.5 eV. Light of wavelength 450 nm is incident on the surface.
Determine whether electrons will be emitted, by the photoelectric effect, from the surface.

[3]

4 **(a)** State what is meant by the ***de Broglie wavelength***.

.....

.....

.....[2]

(b) An electron is accelerated from rest in a vacuum through a potential difference of 4.7 kV.

(i) Calculate the de Broglie wavelength of the accelerated electron.

wavelength = ... m [5]

(ii) By reference to your answer in **(i)**, suggest why such electrons may assist with an understanding of crystal structure.

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.....

.....[2]

5 The photoelectric effect may be represented by the equation

photon energy = work function energy + maximum kinetic energy of electron.

(a) State what is meant by ***work function energy***.

.....

.....[1]

(b) The variation with frequency ***f*** of the maximum kinetic energy E_K of photoelectrons emitted from the surface of sodium metal is shown in Fig. 7.1.

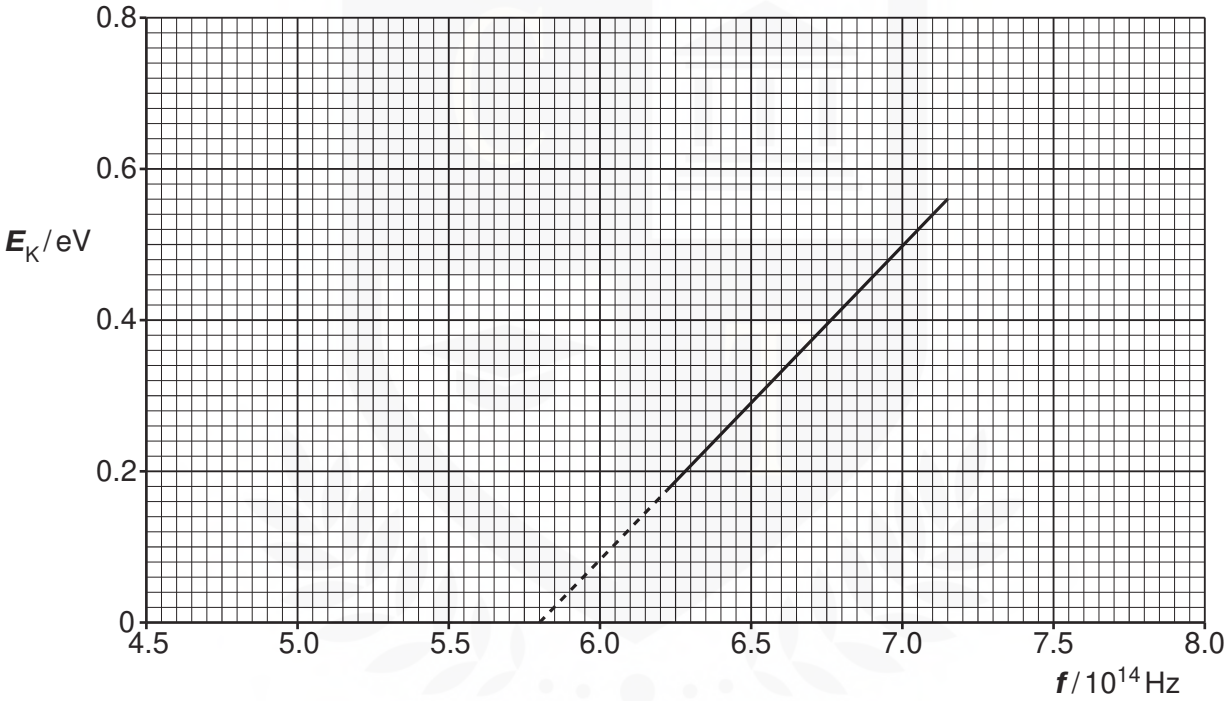

Fig. 7.1

Use the gradient of the graph of Fig. 7.1 to determine a value for the Planck constant ***h***. Show your working.

h = ...J s [2]

(c) The sodium metal in **(b)** has a work function energy of 2.4 eV. The sodium is replaced by calcium which has a work function energy of 2.9 eV.

On Fig. 7.1, draw a line to show the variation with frequency ***f*** of the maximum kinetic energy $\boldsymbol{E}_K$ of photoelectrons emitted from the surface of calcium. [3]

6 An explanation of the photoelectric effect includes the terms photon energy and work function energy.

(a) Explain what is meant by

(i) a ***photon***,

.....

.....

..... [2]

(ii) ***work function energy***.

.....

..... [1]

(b) In an experiment to investigate the photoelectric effect, a student measures the wavelength λ of the light incident on a metal surface and the maximum kinetic energy $\boldsymbol{E}_{max}$ of the emitted electrons. The variation with $\boldsymbol{E}_{max}$ of $\frac{1}{\lambda}$ is shown in Fig. 7.1.

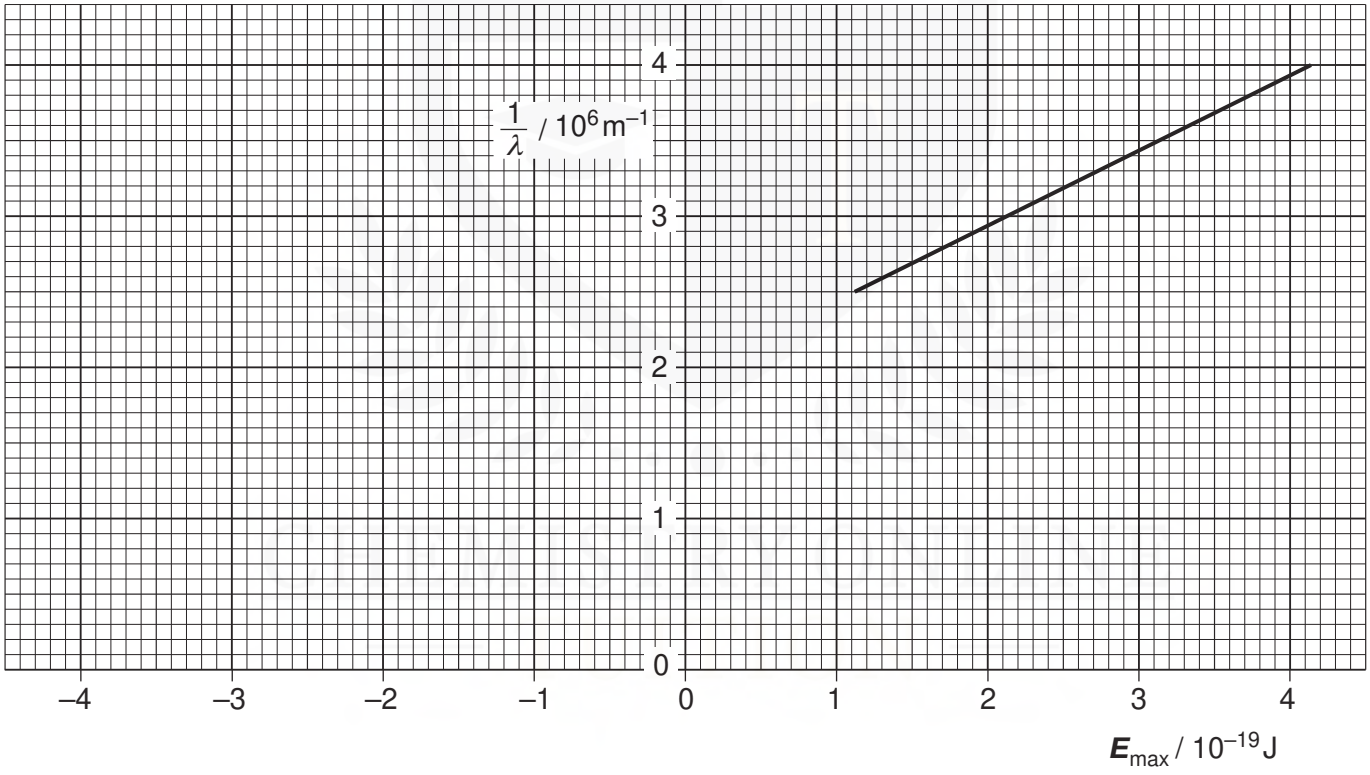

Fig. 7.1

(i) The work function energy of the metal surface is Φ.
State an equation, in terms of λ, Φ and $\boldsymbol{E}_{max}$, to represent conservation of energy for the photoelectric effect. Explain any other symbols you use.

.....

.....

(ii) Use your answer in **(i)** and Fig. 7.1 to determine

1. the work function energy Φ of the metal surface,

Φ = ... J [2]

2. a value for the Planck constant.

Planck constant = ... J s [3]

7 Experiments are conducted to investigate the photoelectric effect.

(a) It is found that, on exposure of a metal surface to light, either electrons are emitted immediately or they are not emitted at all.

Suggest why this observation does not support a wave theory of light.

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.....[3]

(b) Data for the wavelength λ of the radiation incident on the metal surface and the maximum kinetic energy $\boldsymbol{E}_K$ of the emitted electrons are shown in Fig. 7.1.

λ/nm	$\boldsymbol{E}_K/10^{-19}$ J
650	–
240	4.44

Fig. 7.1

(i) Without any calculation, suggest why no value is given for $\boldsymbol{E}_K$ for radiation of wavelength 650 nm.

.....

.....[1]

(ii) Use data from Fig. 7.1 to determine the work function energy of the surface.

work function energy = ... J [3]

(c) Radiation of wavelength 240 nm gives rise to a maximum photoelectric current I.
The intensity of the incident radiation is maintained constant and the wavelength is now reduced.

State and explain the effect of this change on

(i) the maximum kinetic energy of the photoelectrons,

.....

.....

.....[2]

(ii) the maximum photoelectric current I.

.....

.....

.....[2]

8 **(a)** State what is meant by the ***de Broglie wavelength***.

.....

.....

..... [2]

(b) An electron is accelerated in a vacuum from rest through a potential difference of 850 V.

(i) Show that the final momentum of the electron is 1.6×10^{-23} N s.

[2]

(ii) Calculate the de Broglie wavelength of this electron.

wavelength = ... m [2]

(c) Describe an experiment to demonstrate the wave nature of electrons.
You may draw a diagram if you wish.

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..... [5]