

Photoelectric Effect & Wave Particle Duality

Question paper 1

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 1

Time Allowed: 65 minutes

Score: /54

Percentage: /100

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

- 1 A photon of wavelength 6.50×10^{-12} m is incident on an isolated stationary electron, as illustrated in Fig. 8.1.

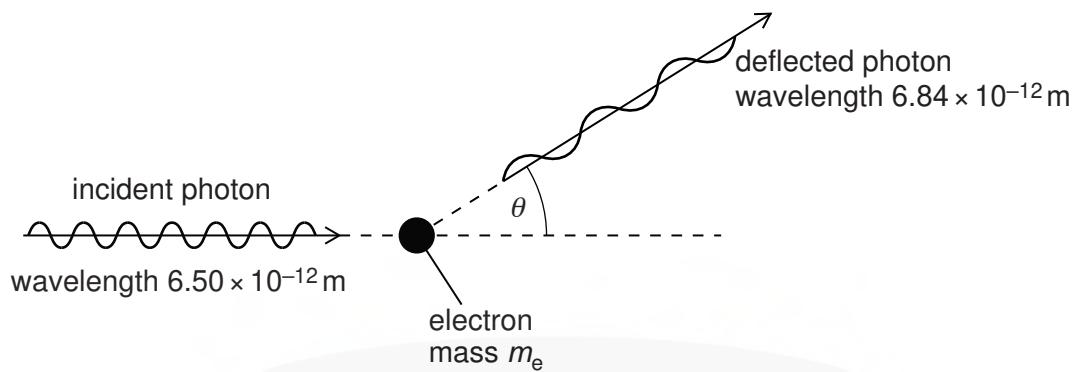


Fig. 8.1

The photon is deflected elastically by the electron of mass m_e . The wavelength of the deflected photon is 6.84×10^{-12} m.

(a) Calculate, for the incident photon,

(i) its momentum,

$$\text{momentum} = \dots \text{Ns} [2]$$

(ii) its energy.

$$\text{energy} = \dots \text{J} [2]$$

(b) The angle θ through which the photon is deflected is given by the expression

$$\Delta\lambda = \frac{h}{m_e c} (1 - \cos \theta)$$

where $\Delta\lambda$ is the change in wavelength of the photon, h is the Planck constant and c is the speed of light in free space.

(i) Calculate the angle θ .

$\theta = \dots \text{ } ^\circ$ [2]

(ii) Use energy considerations to suggest why $\Delta\lambda$ must always be positive.

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[3]

- 2 (a) Explain what is meant by a *photon*.

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[2]

- (b) An X-ray photon of energy $3.06 \times 10^{-14} \text{ J}$ is incident on an isolated stationary electron, as illustrated in Fig. 6.1.

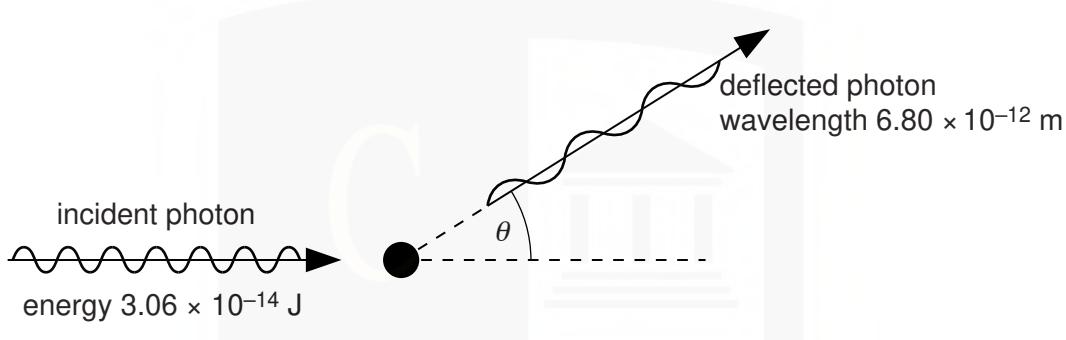


Fig. 6.1

The photon is deflected elastically by the electron through angle θ . The deflected photon has a wavelength of $6.80 \times 10^{-12} \text{ m}$.

- (i) On Fig. 6.1, draw an arrow to indicate a possible initial direction of motion of the electron after the photon has been deflected. [1]

- (ii) Calculate

1. the energy of the deflected photon,

$$\text{photon energy} = \dots \text{ J} [2]$$

2. the speed of the electron after the photon has been deflected.

- (c) Explain why the magnitude of the final momentum of the electron is not equal to the change in magnitude of the momentum of the photon.
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[2]

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

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[2]

- (b) A beam of light is incident normally on a metal surface, as illustrated in Fig. 8.1.

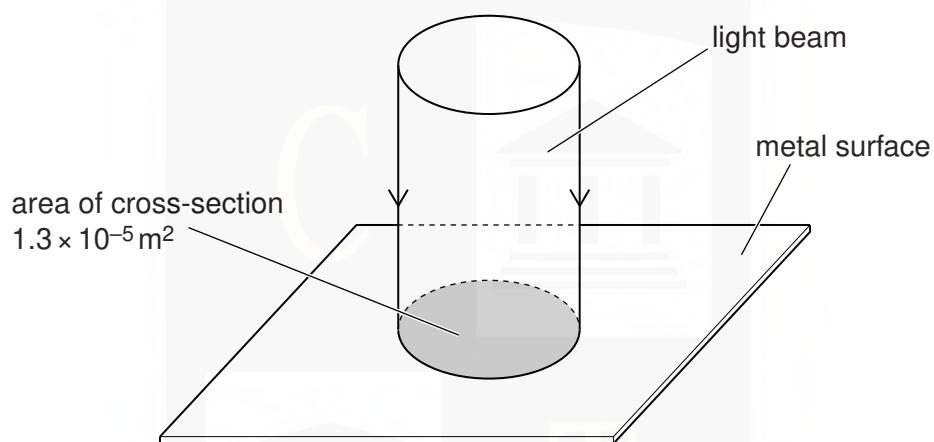


Fig. 8.1

The beam of light has cross-sectional area $1.3 \times 10^{-5} \text{ m}^2$ and power $2.7 \times 10^{-3} \text{ W}$.
The light has wavelength 570 nm.

The light energy is absorbed by the metal and no light is reflected.

- (i) Show that a photon of this light has an energy of $3.5 \times 10^{-19} \text{ J}$.

[1]

(ii) Calculate, for a time of 1.0 s,

1. the number of photons incident on the surface,

number = [2]

2. the change in momentum of the photons.

change in momentum = kg m s^{-1} [3]

(c) Use your answer in (b)(ii) to calculate the pressure that the light exerts on the metal surface.

pressure = Pa [2]

- 4 For a particular metal surface, it is observed that there is a minimum frequency of light below which photoelectric emission does not occur. This observation provides evidence for a particulate nature of electromagnetic radiation.

- (a) State three further observations from photoelectric emission that provide evidence for a particulate nature of electromagnetic radiation.

1.

2.

3.

[3]

- (b) Some data for the variation with frequency f of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface are shown in Fig. 9.1.

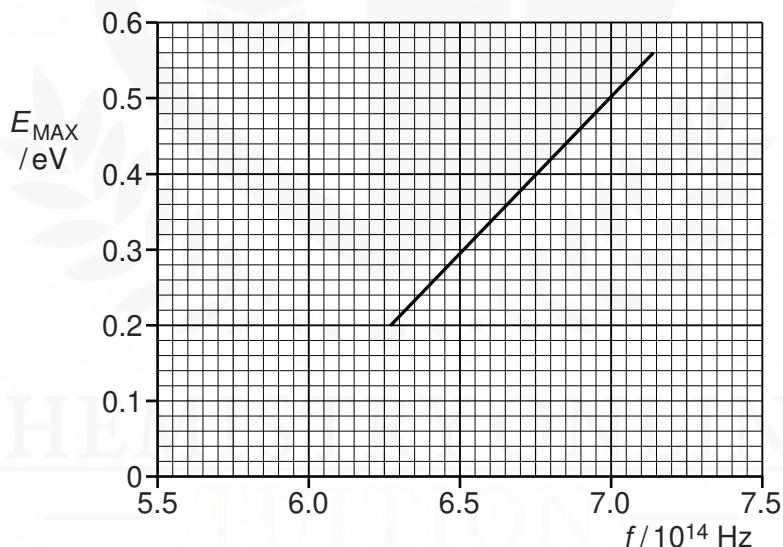


Fig. 9.1

- (i) Explain why emitted electrons may have kinetic energy less than the maximum at any particular frequency.

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[2]

(ii) Use Fig.9.1 to determine

1. the threshold frequency,

threshold frequency = Hz [1]

2. the work function energy, in eV, of the metal surface.

work function energy = eV [3]

- 5 Light of wavelength 590 nm is incident normally on a surface, as illustrated in Fig. 8.1.

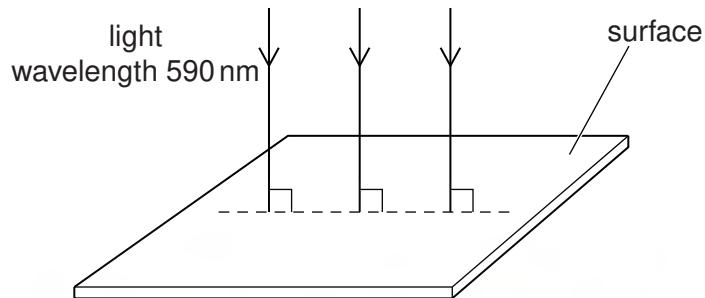


Fig. 8.1

The power of the light is 3.2 mW. The light is completely absorbed by the surface.

- (a) Calculate the number of photons incident on the surface in 1.0 s.

$$\text{number} = \dots \quad [3]$$

- (b) Use your answer in (a) to determine

- (i) the total momentum of the photons arriving at the surface in 1.0 s,

$$\text{momentum} = \dots \text{ kg m s}^{-1} \quad [3]$$

- (ii) the force exerted on the surface by the light.

$$\text{force} = \dots \text{ N} \quad [1]$$

- 6 Electrons, travelling at speed v in a vacuum, are incident on a very thin carbon film, as illustrated in Fig. 7.1.

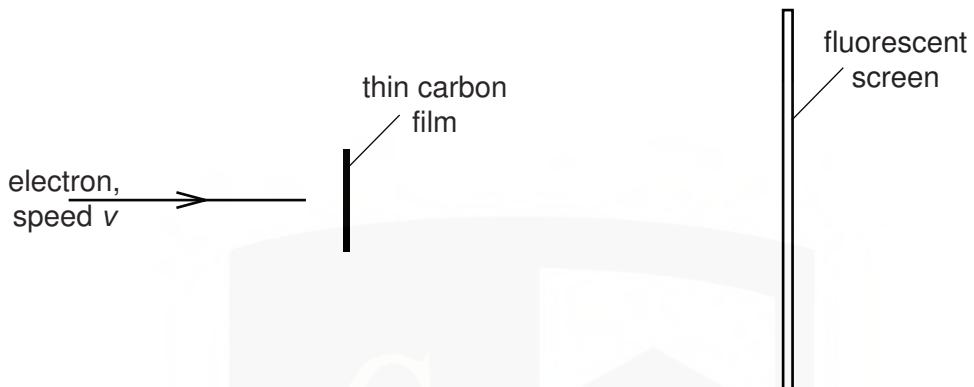


Fig. 7.1

The emergent electrons are incident on a fluorescent screen.
A series of concentric rings is observed on the screen.

- (a) Suggest why the observed rings provide evidence for the wave nature of particles.

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..... [2]

- (b) The initial speed of the electrons is increased. State and explain the effect, if any, on the radii of the rings observed on the screen.

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..... [3]

- (c) A proton and an electron are each accelerated from rest through the same potential difference.

Determine the ratio

$$\frac{\text{de Broglie wavelength of the proton}}{\text{de Broglie wavelength of the electron}}$$

ratio = [4]