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.

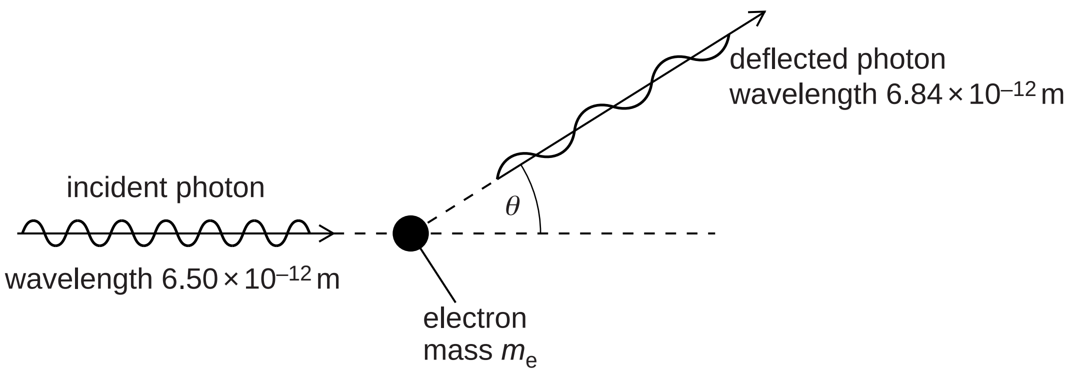

Fig. 8.1

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,

momentum = ... N s [2]

(ii) its energy.

energy = ...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.

θ = ... ° [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*.

....

....

....[2]

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

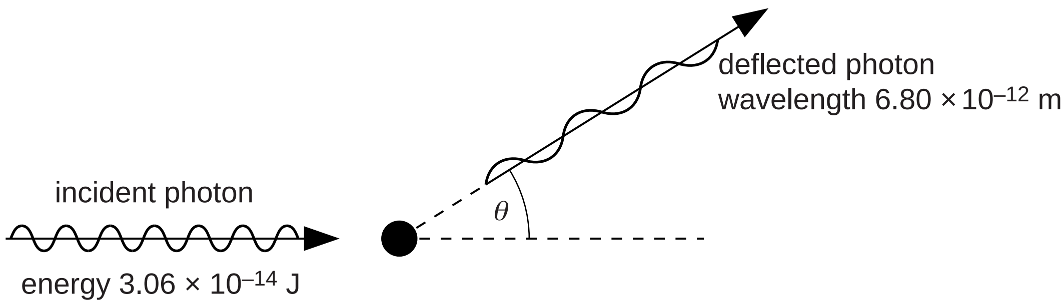

Fig. 6.1

The photon is deflected elastically by the electron through angle θ. The deflected photon has a wavelength of 6.80×10^{-12} 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,

photon energy = ... J [2]

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

speed = ... m s^{-1} [3]

(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.

....

....

.... [2]

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

....

....

.... [2]

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

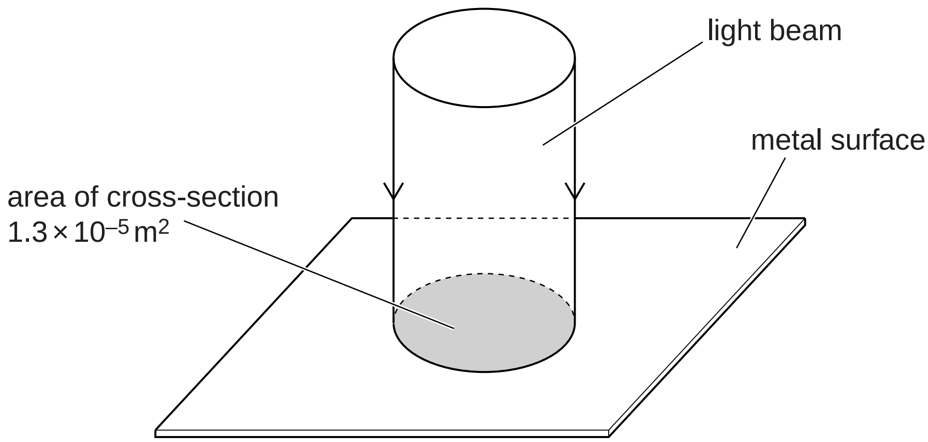

Fig. 8.1

The beam of light has cross-sectional area $1.3 \times 10^{-5}\,m^2$ and power $2.7 \times 10^{-3}\,W$.
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 $3.5 \times 10^{-19}\,J$.

[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.

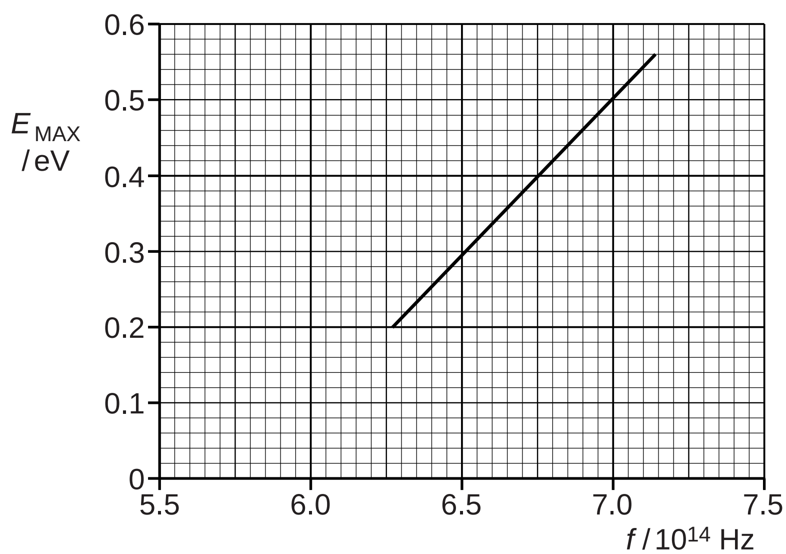

Fig. 9.1

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

....

....

.... [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.

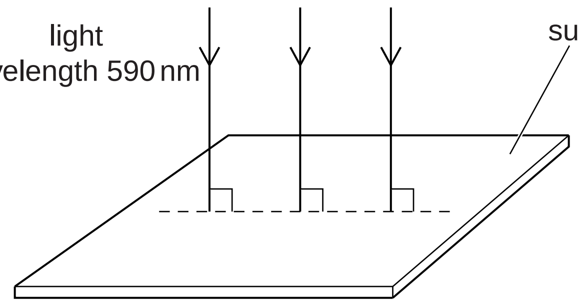

Fig. 8.1

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.

number = ... [3]

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

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

momentum = ... $kg\,m\,s^{-1}$ [3]

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

force = ... N [1]

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

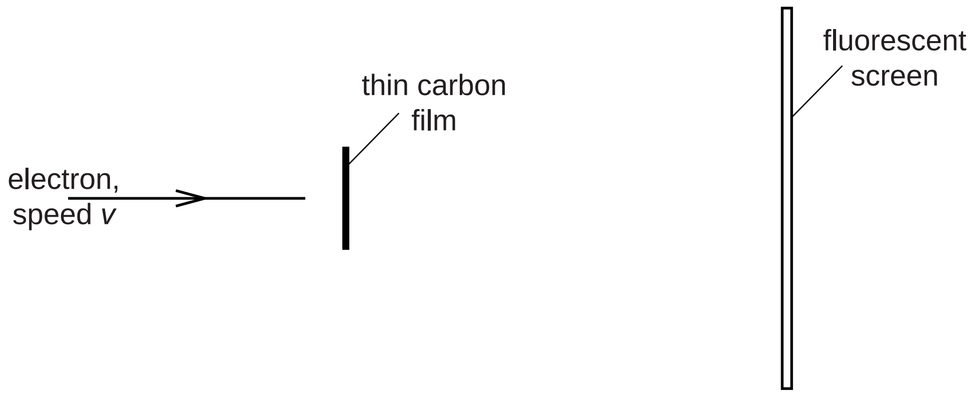

Fig. 7.1

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.

....

....

....

....[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.

....

....

....

....[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]