# Photoelectric Effect & Wave Particle Duality

## Question paper 3

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|---|---|
| **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 3 |

**Time Allowed:** **62 minutes**

**Score:** **/51**

**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, state what is meant by the *threshold frequency*.

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..... [2]

**(b)** The surface of a zinc plate has a work function of $5.8 \times 10^{-19}$ J.
In a particular laboratory experiment, ultraviolet light of wavelength 120 nm is incident on the zinc plate. A photoelectric current $I$ is detected.
In order to view the apparatus more clearly, a second lamp emitting light of wavelength 450 nm is switched on. No change is made to the ultraviolet lamp.

Using appropriate calculations, state and explain the effect on the photoelectric current of switching on this second lamp.

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..... [4]

**2** **(a)** Explain why, for the photoelectric effect, the existence of a threshold frequency and a very short emission time provide evidence for the particulate nature of electromagnetic radiation, as opposed to a wave theory.

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..... [4]

**(b)** State and explain two relations in which the Planck constant *h* is the constant of proportionality.

1. .....

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2. .....

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[6]

**3** **(a)** **(i)** Explain what is meant by a *photon*.

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..... [1]

**(ii)** Show that the photon energy of light of wavelength 350 nm is $5.68 \times 10^{-19}$ J. [1]

**(iii)** State the value of the ratio

$$\frac{\text{energy of photon of light of wavelength 700 nm}}{\text{energy of photon of light of wavelength 350 nm}}.$$

ratio = …….. [1]

**(b)** Two beams of monochromatic light have similar intensities. The light in one beam has wavelength 350 nm and the light in the other beam has wavelength 700 nm.

The two beams are incident separately on three different metal surfaces. The work function of each of these surfaces is shown in Fig. 5.1.

| metal | work function / eV |
|---|---|
| tungsten | 4.49 |
| magnesium | 3.68 |
| potassium | 2.26 |

**Fig. 5.1**

**(i)** Explain what is meant by the *work function* of the surface.

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..... [2]

**(ii)** State which combination, if any, of monochromatic light and metal surface could give rise to photo-electric emission. Give a quantitative explanation of your answer.

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..... [3]

**4** The photoelectric effect may be summarised in terms of the word equation

photon energy = work function energy + maximum kinetic energy of emitted electrons.

**(a)** Explain

**(i)** what is meant by a *photon*,

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..... [2]

**(ii)** why most electrons are emitted with kinetic energy less than the maximum.

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..... [2]

**(b)** Light of constant intensity is incident on a metal surface, causing electrons to be emitted.

State and explain why the rate of emission of electrons changes as the frequency of the incident light is increased.

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..... [2]

**5** A parallel beam of electrons, all travelling at the same speed, is incident normally on a carbon film. The scattering of the electrons by the film is observed on a fluorescent screen, as illustrated in Fig. 7.1.

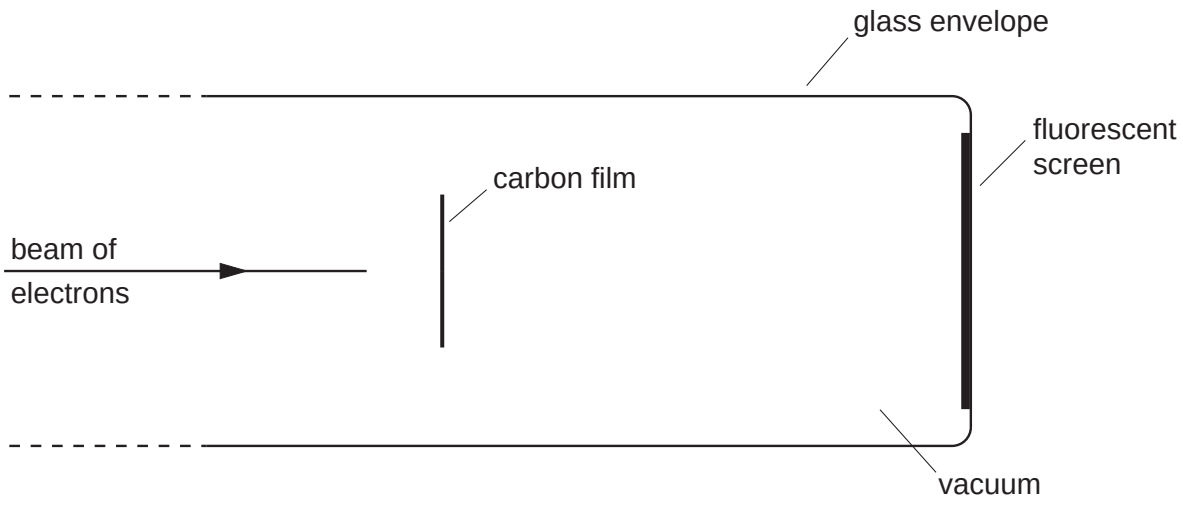


**Fig. 7.1**

**(a)** Assuming that the electrons behave as **particles**, predict what would be seen on the screen.

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..... [1]

**(b)** In this experiment, the electrons do **not** behave as particles.

Describe briefly the pattern that is actually observed on the screen. You may draw a sketch if you wish.

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..... [1]

**(c)** The speed of the electrons is gradually increased.

State and explain what change, if any, is observed in the pattern on the screen.

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..... [3]

**6** **(a)** State the de Broglie relation, explaining any symbols you use.

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..... [2]

**(b)** An electron of mass $m$ has kinetic energy $E$. Show that the de Broglie wavelength $\lambda$ of this electron is given by

$$\lambda = \frac{h}{\sqrt{2mE}}.$$

[2]

**(c)** Calculate the potential difference through which an electron, initially at rest, must be accelerated so that its de Broglie wavelength is equal to 0.40 nm (the diameter of an atom).

potential difference = ..... V [3]

**7** **(a)** Explain what is meant by a *photon* of electromagnetic radiation.

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..... [2]

**(b)** The photoelectric effect provides evidence for the particulate nature of electromagnetic radiation. State three experimental observations that support this conclusion.

1. .....

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2. .....

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3. .....

..... [3]

**(c)** Electromagnetic radiation of wavelength $\lambda$ and intensity $I$, when incident on a metal surface, causes $n$ electrons to be ejected per unit time. The maximum kinetic energy of the electrons is $E_{max}$.

State and explain the effect, if any, on $n$ and $E_{max}$ when

**(i)** the intensity is reduced to $\frac{1}{2}\ I$ but the wavelength $\lambda$ is unchanged,

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**(ii)** the wavelength $\lambda$ is reduced but the intensity $I$ is not changed.

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[4]