

21.2 Quantum physics (full E.2, HL)

Name: _____ Class: _____ Date: _____

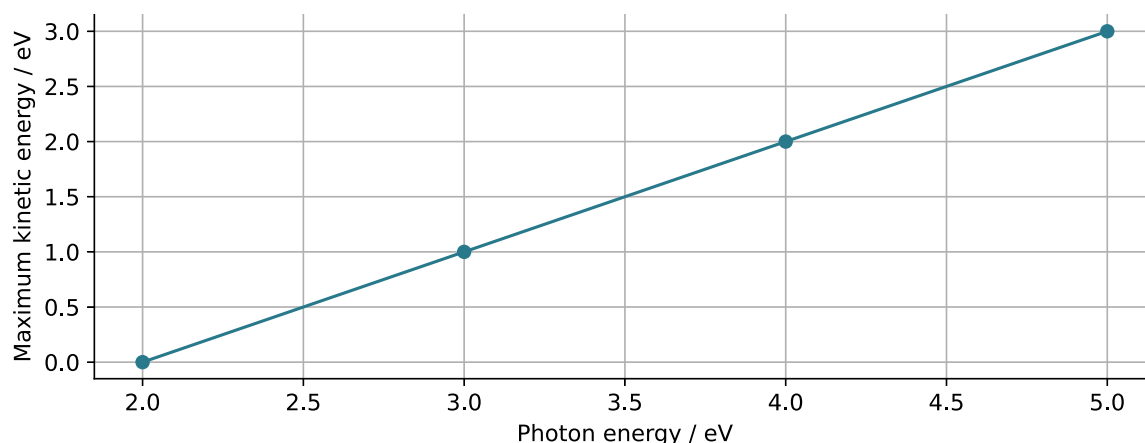
Total: 21 marks

KEY WORDS photoelectric effect • work function
• threshold frequency • de Broglie wavelength
• Compton scattering

Objective

Practise the full guide E.2 toolkit (HL only): the photoelectric effect as evidence for the particle nature of light, threshold frequency, Einstein's relation $E_{max} = hf - \Phi$, the failures of classical wave theory, particle diffraction and the de Broglie wavelength $\lambda = h/p$, and Compton scattering with the wavelength shift $\Delta\lambda = (h/m_e c)(1 - \cos \theta)$. Original practice; not an official IB paper.

1 Key knowledge and worked examples



■ The E.2 equation set (HL)

$$E = hf \quad E_{max} = hf - \Phi \quad f_0 = \frac{\Phi}{h} \quad \lambda = \frac{h}{p} \quad \Delta\lambda = \frac{h}{m_e c}(1 - \cos \theta)$$

Wave theory fails on three counts: emission is instantaneous, there is a threshold frequency below which nothing is emitted however bright the light, and maximum electron energy follows frequency, not intensity.

■ Worked example: one metal, two frequencies

A metal with $\Phi = 2.3$ eV: threshold $f_0 = \Phi/h = (3.7 \times 10^{-19})/(6.6 \times 10^{-34}) = 5.6 \times 10^{14}$ Hz. At 7.0×10^{14} Hz each photon carries 2.9 eV, so $E_{max} = 2.9 - 2.3 = 0.6$ eV. Two habits: convert the work function to joules before dividing by h ; and check any proposed observation against the three wave-theory failures.

2 Practice

2.1 State the photoelectric equation, defining each symbol. [2]

2.2 Give two observations of the photoelectric effect that the classical wave theory of light cannot explain. [2]

2.3 State the de Broglie hypothesis. [1]

2.4 In Compton scattering, state what happens to the wavelength of a photon scattered off an electron at 180° . [1]

3 Exam-style questions

3.1 Light of frequency 6.0×10^{14} Hz strikes a metal of work function 1.9 eV. Calculate the photon energy in eV and the maximum kinetic energy of the photoelectrons. [4]

3.2 An electron beam accelerated through 54 V shows a diffraction maximum from a nickel crystal. Calculate the electron speed from $\frac{1}{2}mv^2 = eV$ and its de Broglie wavelength, and compare with an atomic spacing of about 0.2 nm. [5]

3.3 Explain why Compton scattering is described as evidence for the particle nature of light, and why the shift depends on the scattering angle. [3]

3.4 A metal has work function 2.5 eV. Calculate its threshold frequency, and state what is observed when light of twice that frequency illuminates it. [3]
