InkPhysics

QUESTION WORKBOOK

Quanta and wave-particle duality

Turning points · Year 13

AQA 3.12.2.4, 3.12.2.5, 3.12.2.6 · CIE 22.1.1, 22.1.2, 22.3.1, 22.3.2, 22.3.3, 22.3.4
OCR A 4.5.1(a), 4.5.1(b), 4.5.2(b), 4.5.2(e), 4.5.3(a), 4.5.3(c)

18 questions · 52 marks

NAVY SCREEN EDITION

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SECTION A · Warm-up

A1 State what is meant by the ultraviolet catastrophe. [2]

A2 State Planck's interpretation of black-body radiation, and how it removes the catastrophe. [2]

A3 Give two observations about photoelectricity that classical wave theory cannot explain. [2]

A4 Write down the de Broglie relation between the momentum of a particle and its wavelength. [1]

A5 Using the photon model, explain why increasing the intensity of the light falling on a photoemissive surface increases the number of electrons emitted each second but not their maximum kinetic energy. [2]

SECTION B · Standard

B1 Calculate the de Broglie wavelength of electrons accelerated from rest through 150 V. [3]

B2 Calculate the de Broglie wavelength for an accelerating pd of 5.0 kV. [2]

B3 In a low-energy electron diffraction experiment the accelerating pd is made nine times larger. State and explain the effect on the ring pattern. [3]

B4 Explain the significance of Einstein's explanation of the photoelectric effect for the nature of electromagnetic radiation. [3]

B5 An ultraviolet lamp emits radiation of frequency 1.5×10^{15} Hz. Calculate the energy of one quantum of this radiation. $h = 6.63 \times 10^{-34}$ J s. [2]

B6 In an electron microscope column an electron travels at 4.0×10^{6} m s^{-1}. Calculate its de Broglie wavelength. $h = 6.63 \times 10^{-34}$ J s; $m_e = 9.11 \times 10^{-31}$ kg. [3]

B7 Electrons are accelerated from rest through 48 V towards a thin metal crystal in which the atomic planes are about 2×10^{-10} m apart. Show that the de Broglie wavelength of the electrons is about 1.8×10^{-10} m, and explain why a diffraction pattern is observed. $h = 6.63 \times 10^{-34}$ J s; $m_e = 9.11 \times 10^{-31}$ kg; $e = 1.60 \times 10^{-19}$ C. [4]

SECTION C · Stretch

C1 Calculate the anode voltage that gives electrons a de Broglie wavelength of 5.0×10^{-11} m, half the size of a typical atom. [4]

C2 Describe the principle of operation of the transmission electron microscope. [3]

C3 Describe the principle of operation of the scanning tunnelling microscope. [3]

C4 A virus particle 90 nm across is to be imaged. The laboratory has an optical microscope using light of wavelength 500 nm and a simple electron microscope with an anode pd of 1.2 kV. A microscope cannot resolve detail much smaller than the wavelength it uses. Deduce which instrument can resolve the virus. $h = 6.63 \times 10^{-34}$ J s; $m_e = 9.11 \times 10^{-31}$ kg; $e = 1.60 \times 10^{-19}$ C. [4]

C5 Estimate the de Broglie wavelength of a 60 kg sprinter running at 10 m s^{-1}, and hence explain why the wave nature of matter is never noticed for everyday objects. $h = 6.63 \times 10^{-34}$ J s. [3]

C6 The photoelectric effect could not be explained by the classical wave theory of light. Explain fully how the observations contradict the wave theory, and how Einstein's photon model accounts for them. [6]