

Photons, work functions and matter waves

AP Physics 2 (algebra-based) · Test answers (mark scheme)

Marks are shown for each step. Method marks are given for a correct relationship even if the arithmetic slips, but final answers need units.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 15

Question 1 Photon energy (2 marks)

a. $E = 1240 / 480 = \mathbf{2.58 \text{ eV}}$.

b. $f = c / \lambda = 3.00 \times 10^8 / 4.80 \times 10^{-7} = \mathbf{6.25 \times 10^{14} \text{ Hz}}$.

Marking: one mark each part.

Question 2 Photoelectric calculation (3 marks)

a. $E = 1240 / 450 = 2.76 \text{ eV}$, so $K_{\text{max}} = 2.76 - 2.10 = \mathbf{0.66 \text{ eV}}$.

b. $\lambda_0 = 1240 / 2.10 = \mathbf{590 \text{ nm}}$.

Marking: photon energy (1); subtraction (1); threshold (1).

Question 3 Failure of the wave model (2 marks)

a. A wave of high intensity should give any electron enough energy after a short time, whatever the frequency, but no emission is seen.

b. Each photon has energy hf ; a red photon has less than the work function, so no electron is freed, however many photons arrive.

Marking: one mark each part.

Question 4 Reading a current graph (3 marks)

a. The upper curve is brighter light, because more photons release more electrons per second, giving a larger saturation current.

b. The current drops to zero at about -1.5 V , so $V_s = 1.5 \text{ V}$ and $K_{\text{max}} = \mathbf{1.5 \text{ eV}}$.

c. Both curves use light of the same frequency, so each photon has the same energy and the electrons have the same maximum kinetic energy.

Marking: one mark each part.

Question 5 de Broglie wavelength of an electron (3 marks)

a. $p = mv = 9.11 \times 10^{-31} \times 2.0 \times 10^6 = \mathbf{1.82 \times 10^{-24} \text{ kg}\cdot\text{m/s}}$.

b. $\lambda = h / p = 6.63 \times 10^{-34} / 1.82 \times 10^{-24} = \mathbf{3.6 \times 10^{-10} \text{ m}}$.

c. Its wavelength, about 4×10^{-35} m, is far too small to meet any gap of comparable size.

Marking: one mark each part.

Question 6 Evidence for the models (2 marks)

a. The **photoelectric effect** supports the particle nature of light.

b. **Electron diffraction** supports the wave nature of matter.

Marking: one mark each part.

Question 7 Photons per second (3 marks)

a. $E = hc / \lambda = 6.63 \times 10^{-34} \times 3.00 \times 10^8 / 6.00 \times 10^{-7} = \mathbf{3.3 \times 10^{-19} \text{ J}}$.

b. $N = P / E = 2.0 \times 10^{-3} / 3.3 \times 10^{-19} = \mathbf{6.0 \times 10^{15} \text{ per second}}$.

Marking: energy (1); division (1); answer with unit (1).

Question 8 LED colours (2 marks)

a. A blue photon has a higher frequency and so a higher energy, $E = hf$, than a red photon. The electrons crossing the LED must gain that energy from the supply, $eV = hf$, so a larger voltage is needed to emit blue light.

Marking: relation between colour and photon energy (1); link to voltage (1).