

Photon energy, work function and matter waves

Physics grades 11-12 (A Level · IB · Class 11-12) · Test answers (mark scheme)

Award marks for method as well as for the final answer. Accept answers within rounding and follow through an earlier slip. Do not penalise a missing unit more than once in each question.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB E.2

Question 1 Photon energy (2 marks)

$$E = hf = 6.63 \times 10^{-34} \times 7.5 \times 10^{14} = \mathbf{4.97 \times 10^{-19} \text{ J}} \text{ (3.11 eV).}$$

Marking: 1 mark for the formula and substitution, 1 mark for the answer with unit.

Question 2 Work function (2 marks)

The work function is the **minimum energy needed to remove an electron from the metal surface**. The threshold frequency is the **lowest frequency of light that can eject electrons**, and $\phi = hf_0$.

Marking: 1 mark for each definition (the relationship may be given in either).

Question 3 Einstein's equation (3 marks)

$$E = hc/\lambda = 4.42 \times 10^{-19} \text{ J} = 2.763 \text{ eV}. K_{\max} = 2.763 - 2.1 = \mathbf{0.66 \text{ eV}}, \text{ so } V_s = \mathbf{0.66 \text{ V}}.$$

Marking: 1 mark for photon energy, 1 mark for $K_{\max}$, 1 mark for stopping potential.

Question 4 Wave model failure (3 marks)

The wave model predicts that energy is spread over the surface and can build up in each electron over time, so **any frequency should work if bright enough**, after a delay. In the photon model each electron absorbs a **single photon**; if hf is less than ϕ , no photon has enough energy, however many arrive.

Marking: 1 mark for the wave prediction, 1 mark for one photon per electron, 1 mark for hf being less than ϕ .

Question 5 Intensity (2 marks)

The photocurrent is **halved**, because half as many photons arrive per second. $K_{\max}$ is **unchanged**, because each photon still has energy hf .

Marking: 1 mark each.

Question 6 Graph analysis (3 marks)

a) $f_0 = 5.0 \times 10^{14} \text{ Hz}$.

b) $\phi = hf_0 = 6.63 \times 10^{-34} \times 5.0 \times 10^{14} = 3.31 \times 10^{-19} \text{ J} = 2.07 \text{ eV}$.

Marking: a) 1 mark. b) 1 mark for substitution, 1 mark for the answer.

Question 7 de Broglie (3 marks)

$$\lambda = h/(mv) = 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.0 \times 10^6) = 1.8 \times 10^{-10} \text{ m} \text{ (0.18 nm)}.$$

Marking: 1 mark for the formula, 1 mark for the momentum, 1 mark for the answer.

Question 8 Duality evidence (2 marks)

The **photoelectric effect** shows the particle nature of light. **Electron diffraction** by a crystal or thin film shows the wave nature of electrons.

Marking: 1 mark each.