



Attempt all questions before checking the answer key.
Use $h = 6.63 \times 10^{-34} \text{ J s}$, $c = 3 \times 10^8 \text{ m/s}$, $e = 1.60 \times 10^{-19} \text{ C}$ and $m_e = 9.11 \times 10^{-31} \text{ kg}$.

A. Very short answers - 1 mark each

1. Define the work function of a metal.
2. What is the threshold frequency in photoelectric emission?
3. Does increasing intensity below threshold frequency cause photoemission in the usual one-photon model?
4. State de Broglie's wavelength relation.
5. What does the stopping potential measure?

B. Short answers / practice - 2 marks each

6. Distinguish the effects of light intensity and frequency on photoelectric emission above threshold.
7. A surface has work function 2 eV. Find threshold frequency.
8. Find the energy in eV of a photon of wavelength 400 nm; use $hc = 1240 \text{ eV nm}$.
9. An electron's momentum doubles. How do its wavelength and non-relativistic kinetic energy change?
10. Why are matter waves not noticeable for a moving cricket ball?
11. Can photoemission occur below threshold in the usual one-photon model by waiting longer?
12. Find stopping potential for maximum electron energy 3.2 eV.
13. Find photon energy at 620 nm using $hc = 1240 \text{ eV nm}$.
14. How does photoelectric saturation current change when intensity doubles above threshold?
15. Find de Broglie wavelength for momentum $6.63 \times 10^{-24} \text{ kg m/s}$.

16. Does changing light intensity change stopping potential at fixed frequency?

17. Compare electron and proton wavelengths at equal speeds.

18. Find maximum kinetic energy when $h\nu = 4.5 \text{ eV}$ and work function is 2.0 eV.

19. Explain why a photon has momentum despite zero rest mass.

20. Sketch maximum kinetic energy versus frequency and label both intercepts.

C. Short answers - 3 marks each

21. Light of photon energy 5 eV falls on a surface of work function 2.2 eV. Find maximum kinetic energy, stopping potential and maximum electron speed.
22. Sketch photocurrent versus collector potential for two light intensities of the same frequency. Label saturation current and stopping potential.
23. Sketch stopping potential versus frequency and show how Planck's constant and work function can be determined.
24. An electron is accelerated from rest through 150 V. Calculate its de Broglie wavelength using $\lambda(\text{nm}) = 1.227/\sqrt{V}$.
25. An electron and a photon each have wavelength 2 nm. Compare their momenta and calculate their energies, treating the electron non-relativistically.

D. Long answers - 5 marks each

26. State the main experimental laws of the photoelectric effect. Explain why classical wave theory fails to account for threshold frequency and instantaneous emission.
27. Derive Einstein's photoelectric equation using photon energy conservation. Explain how it accounts for the observed roles of frequency, intensity and stopping potential.
28. Derive the de Broglie wavelength of an electron accelerated through potential V. Compare wavelengths of an electron and a proton at equal kinetic energy and at equal momentum.
29. Stopping potentials are 0.5 V and 1.5 V for frequencies $6 \times 10^{14} \text{ Hz}$ and $8.5 \times 10^{14} \text{ Hz}$. Determine h/e , threshold frequency and work function in eV from these observations.
30. Describe a photoelectric-effect experiment with a labelled circuit. Explain how saturation current, stopping potential and threshold frequency are measured and interpreted.

ANSWER KEY - Numerical / short answers

- 3) No. 7) $4.83 \times 10^{14} \text{ Hz}$. 8) 3.10 eV. 9) Wavelength halves; kinetic energy quadruples. 11) No. 12) 3.2 V. 13) 2 eV. 14) Approximately doubles, other conditions fixed. 15) $1.0 \times 10^{-10} \text{ m}$. 16) No, in the usual model. 17) $\lambda_e/\lambda_p = m_p/m_e \approx 1836$. 18) 2.5 eV. 21) 2.8 eV; 2.8 V; $9.92 \times 10^5 \text{ m/s}$. 24) 0.1002 nm. 25) Both $p = 3.315 \times 10^{-25} \text{ kg m/s}$; electron $\approx 0.376 \text{ eV}$; photon $\approx 622 \text{ eV}$. 28) At equal K: $\lambda_e/\lambda_p = \sqrt{(m_p/m_e)}$; at equal p: equal wavelengths. 29) $h/e = 4.0 \times 10^{-15} \text{ V s}$; threshold $4.75 \times 10^{14} \text{ Hz}$; work function 1.9 eV.