

Dual Nature of Radiation and Matter — Assignment 2

Class 12 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
 (2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
 (3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Photoelectric Effect

1. State the laws of photoelectric emission.
2. The threshold wavelength of a metal is 500 nm. Find its work function.
3. Explain how the photoelectric effect shows the particle nature of light.

Einstein's Photoelectric Equation

1. Write Einstein's photoelectric equation and explain each term.
2. Light of wavelength 400 nm falls on a metal of work function 2 eV. Find the maximum kinetic energy.
3. Use Einstein's equation to explain the laws of photoelectric emission.

Stopping Potential and Graphs

1. What is stopping potential and how is it related to K_{max} ?
2. Draw and explain the graph of photocurrent versus collector potential.
3. Draw and explain the graph of K_{max} versus frequency.

Wave Nature of Matter — de Broglie

1. State the de Broglie hypothesis.
2. Derive the de Broglie wavelength of an electron accelerated through a potential V .
3. Calculate the de Broglie wavelength of an electron accelerated through 100 V.

Davisson-Germer Experiment

1. What did the Davisson-Germer experiment demonstrate?
2. Describe the Davisson-Germer experiment.
3. How does it verify de Broglie's hypothesis?

Part B — Integrated problems (multi-topic)

1. The threshold frequency of a metal is $6 \times 10^{14} \text{ Hz}$. Find its work function in eV and the maximum kinetic energy of photoelectrons when light of frequency $8 \times 10^{14} \text{ Hz}$ is incident.
2. Light of wavelength 300 nm is incident on a metal of work function 2.2 eV. Find the stopping potential. (Take $hc = 1240 \text{ eV}\cdot\text{nm}$)
3. An electron is accelerated through a potential difference of 500 V. Find its de Broglie wavelength and its momentum.

4. The maximum kinetic energy of a photoelectron is 1.5 eV. Find the stopping potential and the corresponding frequency of the incident light if the work function is 1.5 eV.
5. Find the de Broglie wavelength of a proton moving with a speed of 10^5 m/s. How does it compare with that of an electron of the same speed?

Answer Key

Photoelectric Effect

Laws: emission is instantaneous; K_{max} depends only on frequency; photocurrent depends on intensity; below threshold no emission. Work function $= hc/\lambda_0 = 1240/500 \approx 2.48$ eV.

Einstein's Photoelectric Equation

$h\nu = \phi_0 + K_{\text{max}}$, where $h\nu$ is the photon energy, ϕ_0 the work function and K_{max} the maximum kinetic energy. For $\lambda = 400$ nm on $\phi_0 = 2$ eV: $K_{\text{max}} = 3.1 - 2 = 1.1$ eV.

Stopping Potential and Graphs

$K_{\text{max}} = eV_0$. $K_{\text{max}}-\nu$ graph is a straight line of slope h with intercept $-\phi_0$; the intercept on the ν -axis is the threshold frequency. Saturation current is proportional to intensity.

Wave Nature of Matter — de Broglie

$\lambda = h/mv$; for an accelerated electron $\lambda = h/\sqrt{2meV} = 12.27/\sqrt{V}$ Å. For $V = 100$ V, $\lambda \approx 1.23 \times 10^{-10}$ m.

Davisson-Germer Experiment

Electrons diffracted by a nickel crystal; the diffraction pattern verified de Broglie's hypothesis, confirming the wave nature of electrons.

Integrated problems

1: $\phi_0 = h\nu_0 = 2.48$ eV; $K_{\text{max}} = h(\nu - \nu_0) = (8-6) \times 10^{14} \times h/e \approx 0.83$ eV. 2: $E = 1240/300 \approx 4.13$ eV; $V_0 = (4.13 - 2.2) = 1.93$ V. 3: $\lambda = 12.27/\sqrt{500}$ Å ≈ 0.55 Å; $p = h/\lambda \approx 1.2 \times 10^{-24}$ kg·m/s. 4: $V_0 = 1.5$ V; $\nu = (\phi_0 + K_{\text{max}})/h \approx 7.25 \times 10^{14}$ Hz. 5: $\lambda_p = h/(m_p v) \approx 4 \times 10^{-12}$ m; the electron (smaller mass) has a much larger de Broglie wavelength for the same speed.