2023 Ph H2 Q14

Section: Particles and Waves

Topic: The Photoelectric Effect / Planck's Constant

Summary of Question:

A student uses LEDs of known frequency to measure switch-on voltages. From the relation $eV = hf$, they plot V against f, find the gradient, and use it to calculate Planck's constant h.

(a) Graph of V against f

Plot the given data (straight line expected). Frequency on x-axis, voltage on y-axis. Line of best fit is approximately straight.

(b) Gradient of graph

Take two points: (6.4, 2.32), (4.5, 1.38).

$m = (2.32 - 1.38) / (6.4 - 4.5) = 0.94 / 1.9 = 0.495$ V per 10^{14} Hz

Convert: $0.495 / 1 \times 10^{14} = 4.95 \times 10^{-15}$ V·s

(c) Planck's constant

Gradient = h/e. So $h =$ gradient $\times e$.

$h = (4.95 \times 10^{-15})(1.60 \times 10^{-19}) = 7.92 \times 10^{-34}$ J·s

$\approx 8.0 \times 10^{-34}$ J·s

(d) Improvement

Use a more sensitive method of detecting when the LED just begins to emit light (e.g. light sensor rather than human eye). This reduces uncertainty in threshold voltage reading.

Final Answers

(b) Gradient $\approx 4.95 \times 10^{-15}$ V·s

(c) Planck's constant $\approx 8.0 \times 10^{-34}$ J·s

(d) Improvement: use light sensor instead of eye

Revision Tips

• Graph of V vs f has gradient h/e.

• Threshold frequency = intercept on frequency axis.

• Human detection of faint light is unreliable → use objective detector.