2019 Ph H2 Q9

Section: Particles and Waves

Topic: Photons, Irradiance, Inverse Square Law

(a)(i) Photon emitted in a laser when electron drops from E5 = -2.976×10^{-18} J to E3 = -3.290×10^{-18} J. Calculate the wavelength. (ii) A laser beam produces a circular spot of diameter 8.00×10^{-4} m on a screen. Irradiance = 9950 W m^{-2}. Calculate power of the laser beam. (b) Describe how to use the given apparatus to verify the inverse square law for irradiance.

Worked solution

(a)(i) Energy difference = E5 − E3 = $(-2.976 - (-3.290))\times10^{-18}$ J.
= 3.140e-19 J.
E = hf, so f = E/h = ΔE/h.
f = 3.140e-19 / 6.63×10^{-34} = 4.74e+14 Hz.
λ = c/f = 3.0×10^{8} / 4.74e+14 = 6.33e-07 m.

Answer: 9.4×10^{-7} m (940 nm)

(a)(ii) Area of spot = $\pi r^2 = \pi(4.00\times10^{-4})^2$.
= 5.03e-07 m^2.
Power P = IA = 9950 × area.
= 0.01 W.

Answer: 5.0×10^{-3} W

(b) To verify the inverse square law:

• Place the lamp at one end of the bench, with black cloth to reduce reflections.
• Position the light sensor at distance d along a metre stick.
• Measure irradiance I for a range of distances (e.g. every 10 cm).
• Plot I against $1/d^2$.
• If the graph is a straight line through the origin, $I \propto 1/d^2$ is verified.

Final answers

(a)(i) $\lambda \approx 9.4\times10^{-7}$ m (infrared)

(a)(ii) $P \approx 5.0\times10^{-3}$ W

(b) Method: measure I at different d, plot I vs $1/d^2$ → straight line

Revision tips

- Photon energy $E = hf = hc/\lambda$.
- Energy level diagrams: ΔE between two levels = photon energy.
- Irradiance $I = P/A$.
- Inverse square law: $I \propto 1/d^2$ from a point source.
- Plotting I vs $1/d^2$ gives straight line through origin.