2017 H2 Q6

Section: Particles and Waves

Topic: Atomic spectra • Magnetic fields & beams • Photon production

(a) Dark lines in a star’s visible spectrum & hydrogen energy levels

Dark (absorption) lines occur when photons of specific energies are absorbed by atoms in the star’s cooler outer atmosphere. Electrons are promoted to higher energy levels only when the photon energy equals an allowed energy difference, so only those precise wavelengths are removed from the star’s otherwise continuous spectrum.

Using the given hydrogen energy levels (J): E0 = -1.36×10^-19 (n=4), E1 = -2.42×10^-19 (n=3), E2 = -5.42×10^-19 (n=2). Transitions to n=2 give visible Balmer lines:

Transition	ΔE (J)	λ (nm)
$4 \rightarrow 2$	4.06×10^-19	490
$3 \rightarrow 2$	3.00×10^-19	663

These are in the visible range (≈490 nm and ≈660 nm).

(b) Magnetic fields in electron beam guides R and S

(i) Direction in R: use the right-hand rule (or Fleming’s left hand, reversing for negative charge). For electrons

to curve as shown towards the metal target, the magnetic field in R must be into the page (perpendicular to the beam and towards the paper).

(ii) Two differences between fields in R and S (from the diagram): • their direction differs (one into, one out of the page); • their magnitude/uniformity differs (one region is near-uniform; the other is stronger and/or has a gradient for tighter turning/focusing near the target).

(c) Minimum electron speed to produce a 4.16×10^-17 J photon

Assuming a single electron can convert (at least) its kinetic energy into one photon (e.g. X-ray production), set ½mv² = E.

v = √(2E/m) = √(2×4.16×10^-17 / 9.11×10^-31) = 9.56×10^6 m s^-1.

Answer: v_min ≈ 9.6 × 10^6 m s^-1 (≈ 0.032 c, non-relativistic).

Revision tips

- Absorption lines: photons removed at energies matching level gaps; Balmer = transitions to n = 2 (visible).
- Magnetic force on charge q: F = qvB (⊥), direction from left-hand rule; reverse for electrons (negative q).

- For photon production thresholds, equate $\frac{1}{2}mv^2$ to desired photon energy (check if relativistic correction is needed).