

## Solutions

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Original-task marking: M1 method, A1 accuracy, B1 reasoning.

**2.1** The magnetic force always acts perpendicular to the velocity; a perpendicular force does no work, so the speed and hence kinetic energy stay constant.

**2.2**  $r = m_e v / qB = (9.1 \times 10^{-31} \times 1.0 \times 10^6) / (1.6 \times 10^{-19} \times 0.20) = 9.1 \times 10^{-25} / 3.2 \times 10^{-20} = 2.8 \times 10^{-5} \text{ m}.$

**2.3** The electric and magnetic forces must balance:  $qE = qvB$ , so only  $v = E/B$  passes undeflected.

**2.4** Attraction.

**3.1**  $F = BIL \sin \theta = 0.20 \times 5.0 \times 0.30 \times 1 = 0.30 \text{ N}$ ; parallel to the field,  $\theta = 0$  so  $\sin \theta = 0$  – the force falls to zero.

**3.2**  $v = E/B = 1.5 \times 10^4 / 0.050 = 3.0 \times 10^5 \text{ m/s}$ ; for a faster particle the magnetic force  $qvB$  exceeds the electric force  $qE$ , so it deflects along the magnetic-force direction (the same side regardless of sign, since both forces flip with charge).

**3.3**  $r = mv/qB = (6.6 \times 10^{-27} \times 1.0 \times 10^6) / (3.2 \times 10^{-19} \times 0.40) = 6.6 \times 10^{-21} / 1.28 \times 10^{-19} = 5.2 \times 10^{-2} \text{ m}$ ;  $q/m = v/(rB) = 1.0 \times 10^6 / (5.2 \times 10^{-2} \times 0.40) = 4.8 \times 10^7 \text{ C/kg}$ ; a proton's charge-to-mass ratio ( $9.6 \times 10^7 \text{ C/kg}$ ) is twice the alpha's, so its radius is half:  $r_p \approx 2.6 \times 10^{-2} \text{ m}.$

**3.4**  $F/L = \mu_0 I_1 I_2 / 2\pi r = (4\pi \times 10^{-7} \times 10 \times 10) / (2\pi \times 0.050) = 4.0 \times 10^{-4} \text{ N/m}$ ; same-direction currents attract, so reversing one current turns it into repulsion.