Solutions

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

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

2.4 Attraction.

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

3.2 $v = E/B = 1.5 \times 10^4/0.050 = 3.0 \times 10^5$ 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 $r = mv/qB = (6.6 \times 10^{-27} \times 1.0 \times 10^6)/(3.2 \times 10^{-19} \times 0.40) = 6.6 \times 10^{-21}/1.28 \times 10^{-19} = 5.2 \times 10^{-2}$ m; $q/m = v/(rB) = 1.0 \times 10^6/(5.2 \times 10^{-2} \times 0.40) = 4.8 \times 10^7$ C/kg; a proton's charge-to-mass ratio (9.6×10^7 C/kg) is twice the alpha's, so its radius is half: $r_p \approx 2.6 \times 10^{-2}$ m.

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