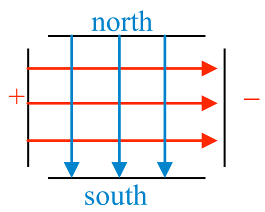
Motion and Forces in Electric and Magnetic Fields: Set 15

Set	Problem	Solution
15	1a 1b 1c 1d	The proton accelerates in a straight line (parallel to the field lines). The proton continues at a constant velocity. The proton curves in a parabolic arc. The proton curves in an arc of a circle. The magnetic field must be oriented from north to south (see diagram). 
	3a	$F_B = F_E$ $vqB = Eq$ $E = vB$ $= (4.5\times10^{6})(24.5\times10^{?3})$ $= 1.10\times10^{5}\ \text{V m}^{-1}$
	3b	Yes. The charges cancel.
	4a	The electrons are forced to follow a curved path (an arc of a circle).
	4b	No effect – the magnetic field only exerts a force on charges moving across the field lines.
	4c	The electrons are decelerated (accelerated in the direction opposite to their motion). $F = Eq$ $ma = Eq$ $a = \frac{Eq}{m}$ $= \frac{(1.00\times10^{3})(1.6\times10^{-19})}{9.11\times10^{-31}}$ $= 1.76\times10^{14}\ \text{m s}^{-2}$ Hence, they accelerate in a straight line at 1.76×10^{14} m s^{-2}
	5a	$E_k = 15\times10^{3}\ \text{eV} = 2.4\times10^{-15}\ \text{J}$ $E_k = \frac{1}{2}mv^2$ $v = \sqrt{\frac{2E_k}{m}}$ $= \sqrt{\frac{2(2.4\times10^{-15})}{9.11\times10^{-31}}}$ $= 7.26\times10^{7}\ \text{m s}^{-1}$
	5b	$F_B = F_c$ $vqB = \frac{mv^2}{r}$ $qB = \frac{mv}{r}$ $r = \frac{mv}{qB}$ $= \frac{(9.11\times10^{-31})(7.26\times10^{7})}{(1.6\times10^{-19})(2.35)}$ $= 1.76\times10^{-4}\ \text{m}$

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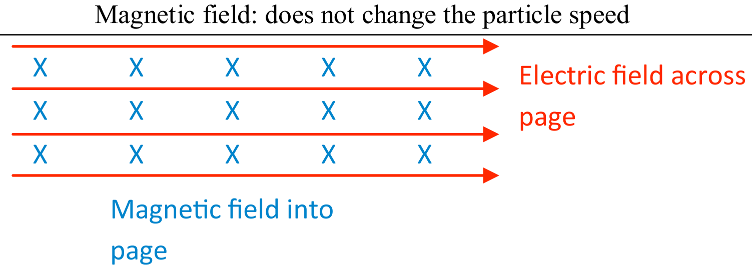
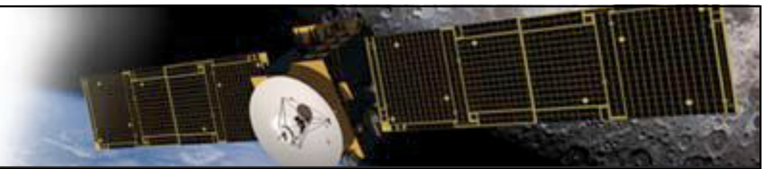
15	5c	$v = \frac{2\pi r}{T}$ $T = \frac{2\pi r}{v}$ $= \frac{2\pi(1.76\times10^{-4})}{7.26\times10^{7}}$ $= 1.52\times10^{-11}\,s$
	6a	$F_B = F_c$ $vqB = \frac{mv^2}{r}$ $qB = \frac{mv}{r}$ $v = \frac{qBr}{m}$ $= \frac{(1.6\times10^{-19})(1.50)(50\times10^{-3})}{1.67\times10^{-27}}$ $= 7.19\times10^{6}\,m\,s^{-1}$
	6b	$v = \frac{2\pi r}{T}$ $T = \frac{2\pi r}{v}$ $= \frac{2\pi(50\times10^{-3})}{7.19\times10^{6}}$ $= 4.37\times10^{-8}\,s$ $f = \frac{1}{T}$ $= \frac{1}{4.37\times10^{-8}}$ $= 2.29\times10^{7}\,Hz$ Hence period is 4.37×10^{-8} s and frequency is 2.29×10^{7} Hz.
	6c	$E_k = \frac{1}{2}mv^2$ $= \frac{1}{2}(1.67\times10^{-27})(7.19\times10^{6})^2$ $= 4.317\times10^{-14}\,J$ $= \frac{4.317\times10^{-14}}{1.6\times10^{-19}}\,eV$ $= 2.698\times10^{5}\,eV$ The required voltage is thus 2.70 kV
	7a	(i) Electric field: deflection is along the field lines; Magnetic field: deflection is at right angles to the field lines (ii) Electric field: changes the particle speed Magnetic field: does not change the particle speed
	7b	



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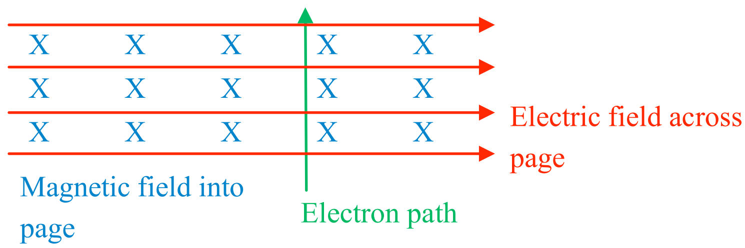
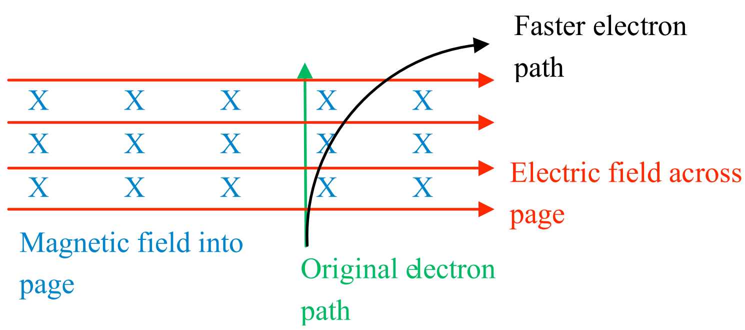
Set	Problem	Solution
15	7b (cont-)	This arrangement will allow a negatively charged particle, such as an electron, to pass undeflected so long as its direction of travel is from the bottom of the page to the top, and its speed is the appropriate value.
	7c	$qvB = Eq$ $vB = E$ $v = \frac{E}{B}$ $= \frac{10^4}{0.1}$ $= 1.00 \times 10^5 \text{ m s}^{-1}$
	8a	$\text{proton energy} = 20 \text{ keV}$ $= 20 \times 10^3 \times 1.6 \times 10^{-19} \text{ J}$ $= 3.2 \times 10^{-15} \text{ J}$ $E_k = \frac{1}{2} mv^2$ $v = \sqrt{\frac{2E_k}{m}}$ $= \sqrt{\frac{2(3.2 \times 10^{-15})}{1.67 \times 10^{-27}}}$ $v = 1.96 \times 10^6 \text{ m s}^{-1}$ $vqB = F = ma$ $a = \frac{vqB}{m}$ $= \frac{(1.96 \times 10^6)(1.6 \times 10^{-19})(0.200)}{1.67 \times 10^{-27}} \text{ m s}^{-2}$ $= 3.75 \times 10^{13} \text{ m s}^{-2}$ at right angles to the field
	8b	The force changes the path of the proton, but always remains the same magnitude and always acts at right angles to the proton's path. This is characteristic of a centripetal force. $qvB = Eq$ $E = vB$ $= (1.96 \times 10^6)(0.200)$ $= 3.92 \times 10^5 \text{ N C}^{-1}$
	9a	$F_B = F_c$ $qvB = \frac{mv^2}{r}$ $qB = \frac{mv}{r}$ $r = \frac{mv}{qB}$ $= \frac{(9.11 \times 10^{-31})(1.6 \times 10^4)}{(1.6 \times 10^{-19})(0.0300)}$ $= 3.04 \times 10^{-6} \text{ m}$

Motion and Forces in Electric and Magnetic Fields: Set 15

Set	Problem	Solution
15	9b	$qvB = Eq$ $E = vB$ $= (1.6\times10^4)(0.0300)$ $= 480\ N\ C^{-1}$
	9c	
	9d	The magnetic force depends on v; the electric force does not. Hence the magnetic force will be bigger for the faster electron but the electric force will not change. This will push the faster electron into a curved path as shown. 
	10a	The alternating electric field between the dees increases the particles' velocities. Since the centripetal force stays constant, an increase in speed gives an increase in path radius.
	10b	$F_B = F_c$ $qvB = \frac{mv^2}{r}$ $qB = \frac{mv}{r}$ $v = \frac{qBr}{m}$ $= \frac{(1.6\times10^{-19})(1.50)(0.200)}{(1.67\times10^{-27})}$ $= 2.87\times10^7\ m\ s^{-1}$ at P $= \frac{(1.6\times10^{-19})(1.50)(0.400)}{(1.67\times10^{-27})}$ $= 5.75\times10^7\ m\ s^{-1}$ at Q