20. Magnetic Fields

20.3 Force on a moving charge

Paper 4

Marking Scheme

Q1.

(c)(i)	into the page	**B1**
(c)(ii)	forces are in opposite directions	**B1**
	(undeviated) when (magnitudes of) forces are equal	**B1**
(c)(iii)	$Eq = Bqv$	**C1**
	$B = E / v = (6.4 \times 10^3) / (2.6 \times 10^7)$ $= 2.5 \times 10^{-4}$ T	**A1**

Q2.

(b)(i)	into the page	**B1**
(b)(ii)	$F = Bqv$	**C1**
	$= 4.8 \times 10^{-3} \times 1.6 \times 10^{-19} \times 1.7 \times 10^7 = 1.3 \times 10^{-14}$ N	**A1**
(b)(iii)	arrow at point X pointing down the page	**B1**
(b)(iv)	$F = mv^2 / r$	**C1**
	$1.3 \times 10^{-14} = (9.11 \times 10^{-31}) \times (1.7 \times 10^7)^2 / r$	**C1**
	($r = 0.020$ m) $d = 2r$ $d = 0.040$ m	**A1**
(c)	path shows upwards deflection such that the curvature is always anticlockwise within the field	**B1**
	circular path with larger radius	**B1**
	line enters field at X and leaves field at distance $2d$ vertically from X	**B1**

Q3.

(a)(i)	$V_H = BI / ntq$ $= (4.0 \times 10^{-6} \times 5.4) / (1.5 \times 10^{16} \times 1.8 \times 10^{-3} \times 1.60 \times 10^{-19}) = 5.0$ V	**A1**
(a)(ii)	sketch: straight diagonal line from (0, 0) to $t = 0.020$ s **and** straight diagonal line between two non-zero V_H values of same sign from $t = 0.040$ to 0.050 s	**B1**
	horizontal straight line at $V_H = 5.0$ V from $t = 0.020$ to 0.040 s	**B1**
	horizontal straight line at $V_H = 2.5$ V from $t = 0.050$ to 0.080 s	**B1**

Q4.

(a)(i)	(vertically) downwards	**B1**
(a)(ii)	magnetic force (on sphere) is perpendicular to its velocity	**B1**
	magnetic force perpendicular to velocity is the centripetal force **or** magnetic force perpendicular to velocity causes centripetal acceleration **or** acceleration perpendicular to velocity is centripetal (acceleration) **or** magnetic force does not change the speed of the sphere **or** magnetic force has constant magnitude	**B1**
(c)	centripetal force = magnetic force **or** $Bqv = mv^2 / r$	**B1**
	$B = mv / qr$	**C1**
	$= (1.6 \times 10^{-10} \times 0.78) / (0.27 \times 10^{-9} \times 3.4) = 0.14$ T	**A1**

Q5.

(a)(i)	PQRS and WXYZ	**B1**
(a)(ii)	force on charge carriers is perpendicular to both (magnetic) field and current	**B1**
	as charge carriers are deflected to one side, an electric field is set up	**B1**
	(steady V_H when) electric and magnetic forces on charge carriers are equal (and opposite)	**B1**
(b)(i)	n: number density of charge carriers	**B1**
	t: distance PW (or SZ or QX or RY)	**B1**
	q: charge on each charge carrier	**B1**
(b)(ii)	V_H inversely proportional to t	**B1**
	(so t needs to be small for) V_H to be large enough to measure	**B1**

Q6.

(b)(i)	face PSWV shaded	**B1**
(b)(ii)	accumulating electrons cause an electric field (between the faces)	**B1**
	force due to electric field opposes force due to magnetic field	**B1**
	accumulation stops when magnetic force equals electric force	**B1**
(c)(i)	number density of charge carriers	**B1**
(c)(ii)	PV **or** QT **or** SW	**B1**
(d)	(for semiconductor,) n is (much) smaller so V_H (much) larger	**B1**

Q7.

(c)(i)	magnetic force = centripetal force **or** $Bqv = mv^2 / r$	**M1**
	clear substitution of expression for v and correct algebra leading to $q / m = 2V / B^2r^2$	**A1**
(c)(ii)	$q / m = (2 \times 230) / [(0.38 \times 10^{-3})^2 \times 0.14^2]$	**C1**
	$= 1.6 \times 10^{11}$ C kg^{-1}	**A1**
(c)(iii)	(for α-particle,) q / m is (much) smaller	**B1**
	r would be <u>much</u> larger	**B1**

Q8.

(a)	(particle is) stationary/not moving	**B1**
	(particle is) moving parallel to the (magnetic) field	**B1**

Q9.

(a)(i)	force is downwards/down the page **or** current is (right) to left	**B1**
	by left-hand rule, field is into plane of paper	**B1**
(a)(ii)	magnetic force provides the centripetal force	**C1**
	$Bqv = mv^2 / r$	**C1**
	$v = Bqr / m$ $= (8.0 \times 10^{-4} \times 1.60 \times 10^{-19} \times 6.4 \times 10^{-2}) / (9.11 \times 10^{-31})$ $= 9.0 \times 10^{6}$ m s^{-1}	**A1**
(b)(ii)	$Bqv = Eq$ **or** $v = E / B$	**C1**
	$E = 9.0 \times 10^{6} \times 8.0 \times 10^{-4}$ $= 7.2 \times 10^{3}$ N C^{-1}	**A1**
(c)	straight line/undeviated	**B1**
	condition for no deflection depends only on v **or** condition for no deflection does not depend on m or q	**B1**

Q10.

(a)(i)	downwards	**B1**
(a)(ii)	PQRS and JKLM	**B1**
(b)	(as charge separates) an electric field is created (between opposite faces)	**B1**
	(maximum value is reached when) electric force (on electron) is equal and opposite to magnetic force (on electron)	**B1**
(c)	$V_H = BI / ntq$ $= (4.6 \times 10^{-3} \times 6.3 \times 10^{-4}) / (1.3 \times 10^{29} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	**C1**
	$= 1.4 \times 10^{-12}$ V	**A1**
(d)	semiconductors have a (much) smaller value for n	**B1**
	V_H for semiconductors is (much) larger so more easily measured	**B1**

Q11.

(b)	V_H shown as zero before (t_1 – 2 squares) and after (t_2 + 2 squares) and rises to a constant non-zero value between t_1 and t_2	**M1**
	change at t_1 shown as 2 small squares wide and change at t_2 shown as 1 small square wide	**A1**

Q12.

(a)(i)	$v_N = 3.4 \times 10^{7} \times \sin 30°$ $= 1.7 \times 10^{7}$ m s^{-1}	**A1**
(a)(ii)	$mv^2 / r = Bqv$ **or** $r = mv / Bq$	**C1**
	$r = (9.11 \times 10^{-31} \times 1.7 \times 10^{7}) / (3.2 \times 10^{-3} \times 1.60 \times 10^{-19})$	**C1**
	$= 0.030$ m	**A1**
(b)	zero	**B1**
(c)	helix/coil	**B1**

Q13.

(a)	magnitude: (force =) Bqv	**B1**
	direction: P→Q **or** E→F **or** S→R **or** H→G	**B1**
(b)(i)	EHSP and FGRQ	**B1**
(b)(ii)	PE **or** QF **or** RG **or** SH	**B1**
(c)(i)	*any one correct starting point from:* • (mass of 1 atom =) $27 \times 1.66 \times 10^{-27}$ • (amount of substance per unit volume =) 2.7 / 27 • 27 g (of substance) contains 6.02×10^{23} atoms • (2.7 g mass contains) 0.1 mol • (1 cm^3 volume contains) 0.1 mol • (1 m^3 volume contains) 10^5 mol	**C1**
	$n = (2.7 \times 10^3) / (27 \times 1.66 \times 10^{-27}) = 6.0 \times 10^{28}$ **or** $n = (2.7 / 27) \times 10^6 \times 6.02 \times 10^{23} = 6.0 \times 10^{28}$	**A1**
(c)(ii)	$V_H = (0.15 \times 4.6) / (6.0 \times 10^{28} \times 0.090 \times 10^{-3} \times 1.60 \times 10^{-19})$	**C1**
	$= 8.0 \times 10^{-7}$ V	**A1**

Q14.

(a)	electric and magnetic fields at right-angles to one another *(may be shown on a clearly labelled diagram)*	**B1**
	particle enters fields (with velocity) normal to the (two) fields *(may be shown on a clearly labelled diagram)*	**B1**
	no deviation for particles with selected velocity	**B1**
(b)	magnetic force equals/is the centripetal force	**C1**
	$Bqv = mv^2 / r$	**C1**
	$M = Bqr / v$ $= (94 \times 10^{-3} \times 1.6 \times 10^{-19} \times 0.075) / (3.4 \times 10^4)$	**M1**
	division by 1.66×10^{-27} shown, to give m = 20 u	**A1**
(c)	sketch: semicircle clear (in same direction)	**B1**
	with larger radius	**B1**

Q15.

(b)(i)	single path, deflection in 'upward' direction	**B1**
	acceptable circular arc in whole field	**B1**
	no 'kinks' at start or end of curvature, and straight outside region of field	**B1**
(b)(ii)	force (on particle) is normal to velocity/direction of motion/direction of speed	**B1**
(c)	magnetic force provides/is the centripetal force	**B1**
	$Bqv = mv^2 / r$ **or** $r = mv / Bq$	**C1**
	(if q is doubled), new speed = $2v$	**A1**

Q16.

(a)	$0 \rightarrow t_1$ horizontal straight line at non-zero value of V_H **and** $t_3 \rightarrow t_4$ horizontal straight line at different non-zero V_H	**B1**
	$t_1 \rightarrow t_3$ straight diagonal line with negative gradient **and** graph line starts at (0, V_0) and ends at (t_4, $-2V_0$)	**B1**