M1.A

[1]

M2.C

[1]

M3.A

[1]

M4.B

[1]

M5.(a) (i) force acts towards left or in opposite direction to field lines ✓
because ion (or electron) has negative charge
(∴ experiences force in opposite direction to field) ✓

Mark sequentially.
Essential to refer to negative charge (or force on + charge is to right) for 2nd mark.

2

(ii) (use of $W = F s$ gives) force $F = \frac{4.0 \times 10^{-16}}{63 \times 10^{-3}}$ ✓

$= 6.3(5) \times 10^{-15}$ (N) ✓

If mass of ion m is used correctly ***using algebra*** *with F = ma, allow both marks (since m will cancel). If numerical value for m is used, max 1.*

2

(iii) electric field strength $E\left(=\frac{F}{Q}\right)=\frac{6.35\times10^{-15}}{3\times1.6\times10^{-19}}$ = 1.3(2) ✓ 10^{4} (N C^{-1}) ✓

[or $\Delta V\left(=\frac{\Delta W}{Q}\right)=\frac{4.0\times10^{-16}}{3\times1.60\times10^{-19}}$ (833 V)

$E\left(=\frac{\Delta V}{d}\right)=\frac{833}{63\times10^{-3}}$ = 1.3(2) ✓ 10^{4} (V m^{-1}) ✓]

Allow ECF from wrong F value in (ii).

1

(b) (i) (vertically) downwards on diagram ✓

reference to Fleming's LH rule **or** equivalent statement ✓

Mark sequentially.

1st point: allow "into the page".

2

(ii) number of free electrons in wire = $A \times l \times$ number density

= $5.1 \times 10^{-6} \times 95 \times 10^{-3} \times 8.4 \times 10^{28} = 4.1\ (4.07) \times 10^{22}$ ✓

Provided it is shown correctly to at least 2SF, final answer alone is sufficient for the mark. (Otherwise working is mandatory).

1

(iii) $B\left(=\frac{F}{Qv}\right)=\frac{1.4\times10^{-25}}{1.60\times10^{-19}\times5.5\times10^{-6}}$ ✓ = 0.16 (0.159) (T) ✓

[or $B\left(=\frac{F}{Il}\right)=\frac{1.4\times10^{-25}\times4.07\times10^{22}}{0.38\times95\times10^{-3}}$ ✓ = 0.16 (0.158) (T) ✓]

In 2nd method allow ECF from wrong number value in (ii).

2

[10]

M6.(a) (i) *Two examples (any order)*:

- when charged particle is at rest **or** not moving relative to field ✓

• when charged particle moves parallel to magnetic field ✓

2

(ii) $BQv = \frac{mv^2}{r}$ ✓ (gives $BQr = mv$)

Acceptable answers must include correct force equation (1st point).

B and Q are constant so $r \propto$ momentum (*mv*) ✓

Insist on a reference to B and Q constant for 2nd mark.

2

(b) (i) upwards (perpendicular to plane of diagram) ✓

Accept "out of the page" etc.

1

(ii) $v\left(= \frac{BQr}{m}\right) = \frac{0.48 \times 1.60 \times 10^{-19} \times 0.19}{1.67 \times 10^{-27}}$ ✓ $= 8.7(4) \times 10^{6}$ (m s^{-1})

2

(iii) length of path followed (= length of semi-circle) = πr ✓

time taken $t\left(= \frac{\pi r}{v}\right) = \frac{\pi \times 0.19}{8.74 \times 10^{6}} = 6.8(3) \times 10^{-8}$ (s) ✓

Allow ECF from incorrect v from (b)(ii).

[**or** $\frac{v}{r} = \frac{BQ}{m}$ gives $t = \frac{\pi r}{v} = \frac{\pi m}{BQ}$ ✓

$= \frac{\pi \times 1.67 \times 10^{-27}}{0.48 \times 1.60 \times 10^{-19}} = 6.8(3) \times 10^{-8}$ (s) ✓]

Max 1 if path length is taken to be 2πr (gives 1.37 × 10^{-7}s).

2

(iv) $v \propto r$ (and path length $\propto r$) ✓

t = (path length / *v*) **or** (πr / *v*)

so *r* cancels (∴time doesn't depend on *r*) ✓

[**or** $t\left(=\frac{\pi r}{v}\right)=\frac{\pi rm}{BQr}$ ✓ $=\frac{\pi m}{BQ}$ (because r cancels) ✓]

[**or** $BQv = m\omega^2 r$ gives $BQ\omega r = m\omega^2 r$ and $BQ = m\omega = 2\pi fm$ ✓

∴ frequency is independent of r ✓]

2

(c) $v_{max} = 8.74\times10^6\times\left(\frac{0.47}{0.19}\right) = 2.16\times10^7\ (\text{m s}^{-1})$ ✓

1st mark can be achieved by full substitution, as in (b)(ii), or by use of data from (b)(i) and / or (b)(ii).

E_k (= ½ mv_{max}^2) = ½ × 1.67 × 10^{-27} × (2.16 × 10^7)^2 ✓
(= 3.90 × 10^{-13} J)

$$= \frac{3.90\times10^{-13}}{1.60\times10^{-13}} = 2.4(4)\ (\text{MeV})$$ ✓

Allow ECF from incorrect v from (b)(ii), or from incorrect t from (b)(iii).

3
(Total 14 marks)

M7.A

[1]

M8. A

[1]

M9. (a) (magnetic) <u>field</u> is applied perpendicular to path

or direction **or** velocity of charged particles ✓

(magnetic) <u>force</u> acts perpendicular to path

or direction **or** velocity of charged particles ✓

force depends on speed of particle **or** on B [or $F \propto v$ or $F = BQv$ explained] ✓

force provides (centripetal) acceleration towards centre of circle

[**or** (magnetic) force is a centripetal force] ✓

$BQv = \frac{mv^2}{r}$ **or** $r = \frac{mv}{BQ}$ shows that r is constant when B and v are constant ✓

4

(b) (i) radius r of path = $\frac{\text{circumference}}{2\pi} = \frac{27 \times 10^3}{2\pi}$ = 4.30 × 10^3 (m) (allow 4.3km) ✓

centripetal force $\left(= \frac{mv^2}{r}\right) = \frac{1.67 \times 10^{-27} \times (3.00 \times 10^7)^2}{4.30 \times 10^3}$ ✓ = 3.50 × 10^{-16}(N) ✓

3

(ii) magnetic flux density $B \left(= \frac{F}{Qv}\right) = \frac{3.50 \times 10^{-16}}{1.60 \times 10^{-19} \times 3.00 \times 10^7}$ ✓

= 7.29 × 10^{-5} ✓ T ✓

3

(c) magnetic field must be increased ✓

to increase (centripetal) force **or** in order to keep r constant ✓

[**or** otherwise protons would attempt to travel in a path of larger radius]

[**or**, referring to $r = \frac{mv}{BQ}$, B must increase when v increases to keep r constant]

2

[12]

M10. B

[1]

M11. A

[1]

M12. C

[1]