3	**C is the correct answer,** as $F = Bqv\ \sin\theta$ and $\sin\theta = 1$	1

9	**A is the only correct answer** because the kinetic energy of the particle decreases by synchrotron radiation and, if not in a vacuum, ionisation and the path therefore decreases in radius because decreasing ke decreases momentum and r = p/BQ B is not correct because this would increase the radius C is not correct because this would increase the radius D is not correct because this would increase the radius	1

4	**C is the only correct answer** because using $F = BIl$ gives $I = F / Bl$ A is not correct because it is not $I = F / Bl$ B is not correct because it is not $I = F / Bl$ D is not correct because it is not $I = F / Bl$	1

7	**B is the correct answer because** $r = \frac{mv}{BQ}$	1

6	**The only correct answer is C** (more turns in coil Q, closer together) A is not correct because fewer turns in Q will reduce e.m.f. B is not correct because the two coils further apart and fewer turns in Q will reduce e.m.f. D is not correct because two coils further apart will reduce e.m.f.	1

6	**D is the correct answer** A is not correct because we do not know the sign of the charge on each particle B is not correct because we do not know the direction of the magnetic field C is not correct because we do not know the direction of the magnetic field	1

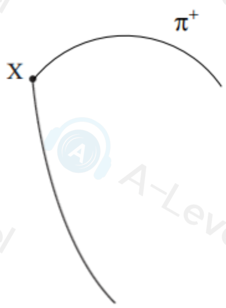
8	**B is the correct answer** A is not correct because the poles at X and Y must be opposite C is not correct because this would not oppose the change in flux linkage D is not correct because the poles at X and Y must be opposite	1

10	**B is the only correct answer** because $r = p/Bq = mv/Bq$ and mass is 4 times mass of a proton and charge is twice the charge of a proton while B and v remain the same, so the multiplying factor is 4/2 = 2 and the initial radius is $2r$ A is not correct because the initial radius is $2r$ C is not correct because the initial radius is $2r$ D is not correct because the initial radius is $2r$	1

4	**A is the correct answer** because $\phi = B.A$	1

5	**The only correct answer is D** ($\frac{F}{B \times e \times \sin 66°}$, from Y to X) A is not correct because the angle between the direction of motion and the magnetic field is 66° and the direction of v is from Y to X B is not correct because the angle between the direction of motion and the magnetic field is 66° C is not correct because the direction of v is from Y to X	1

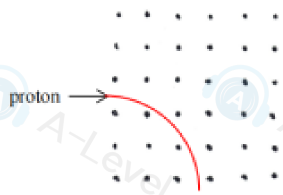
3	**A is the only correct answer** because the force is down the page using FLHR B is not correct because it does not show the force down the page C is not correct because it does not show the force down the page D is not correct because it does not show the force down the page		1
10	The only correct answer is **A** **B** is not correct because the length of the magnet is the length of wire perpendicular to the field **C** is not correct because the force is into the page **D** is not correct because the force is into the page		1
18(a)	Use of $r = \frac{p}{BQ}$ B = 1.15 T Example of calculation $1.99 \text{ m} = \frac{3.67 \times 10^{-19} \text{ kg m s}^{-1}}{B \times 1.60 \times 10^{-19} \text{ C}}$ B = 1.15 T	(1) (1)	2
18(b)(i)	Baryon	(1)	1
18(b)(ii)	**Conservation of charge** Show charge for all particles: Σ^+ is (+)1, π^+ is (+)1, n is 0 Show total charge before = total charge after, with conclusion that charge is conserved Dependent on MP1 **Conservation of lepton number** Show lepton number for all particles: Σ^+ is 0, π^+ is 0, n is 0 Show total lepton number before = total lepton number after, with conclusion that lepton number is conserved Dependent on MP3 Example of deduction Charge before = +1, charge after = +1 + 0 = +1 Charge before = charge after, so conservation of charge applies Lepton number before = 0, charge after = 0 + 0 = 0 Lepton number before = lepton number after, so conservation of lepton applies	(1) (1) (1) (1)	4

18(b)(iii)	Use of trigonometrical function for x component of π momentum **Or** Use of trigonometrical function for y component of π momentum Applies conservation of momentum Applies trigonometry to calculate final angle for neutron Applies trigonometry or Pythagoras to calculate magnitude Angle = 16.8° Magnitude = 3.36×10^{-19} kg m s^{-1} <u>Example of calculation</u> x component π = 1.07×10^{-19} kg m s^{-1} × sin 65° = 9.70×10^{-20} kg m s^{-1} y component of π = 1.07×10^{-19} kg m s^{-1} × cos 65° = 4.52×10^{-20} kg m s^{-1} y component of neutron = 3.67×10^{-19} kg m s^{-1} – 4.52×10^{-20} kg m s^{-1} = 3.22×10^{-19} kg m s^{-1} x component of neutron = 9.70×10^{-20} kg m s^{-1} tan θ = 9.70×10^{-20} kg m s^{-1} ÷ 3.22×10^{-19} kg m s^{-1} = 0.301 θ = 16.8° $p^2 = (3.22 \times 10^{-19}\text{ kg m s}^{-1})^2 + (9.70 \times 10^{-20}\text{ kg m s}^{-1})^2$ $p = 3.36 \times 10^{-19}$ kg m s^{-1}	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
18(b)(iv)	Curving to the right (clockwise) Correct initial direction Smaller radius of curvature than sigma No line for neutron (stated or dependent on seeing line definitively for pion)  	**(1)** **(1)** **(1)** **(1)**	**4**
22(a)	There is a (resultant) force on the electrons in the vertical direction So the electrons are accelerated vertically But in the horizontal direction the electrons have a constant speed	**(1)** **(1)** **(1)**	**3**

22(b)(i)	Use of $W = QV$ Use of $E_K = \frac{1}{2}mv^2$ $v = 1.73 \times 10^7$ (m s^{-1})(minimum 3 sf required) <u>Example of calculation</u> $E_K = 1.6 \times 10^{-19}\ \text{C} \times 850\ \text{V} = 1.36 \times 10^{-16}\ \text{J}$ $v = \sqrt{\frac{2 \times 1.6 \times 10^{-19}\ \text{C} \times 850\ \text{V}}{9.11 \times 10^{-31}\ \text{kg}}} = 1.73 \times 10^7\ \text{m s}^{-1}$	(1) (1) (1)	3
22(b)(ii)	Use of $s = ut$ Use of $F = EQ$ Use of $F = ma$ Use of $s = ut + \frac{1}{2}at^2$ $s = 0.028$ m (Allow ecf from (b)(i)) <u>Example of calculation</u> $t = \frac{7.5 \times 10^{-2}\ \text{m}}{1.73 \times 10^7\ \text{m s}^{-1}} = 4.34 \times 10^{-9}\ \text{s}$ $F = 1.7 \times 10^4\ \text{V m}^{-1} \times 1.6 \times 10^{-19}\ \text{C} = 2.72 \times 10^{-15}\ \text{N}$ $a = \frac{2.72 \times 10^{-15}\ \text{N}}{9.11 \times 10^{-31}\ \text{kg}} = 2.99 \times 10^{15}\ \text{m s}^{-2}$ $s = \frac{1}{2} \times 2.99 \times 10^{15}\ \text{m s}^{-2}\ (4.34 \times 10^{-9}\ \text{s})^2 = 0.028\ \text{m}$	(1) (1) (1) (1) (1)	5
22(b)(iii)	Use of $F = BQv \sin\theta$ with $F = \frac{mv^2}{r}$ to obtain $\frac{e}{m} = \frac{v}{Br}$ **Or** Use of $p = mv$ with $r = \frac{p}{BQ}$ to obtain $\frac{e}{m} = \frac{v}{Br}$ $\frac{e}{m} = 1.65 \times 10^{11}$ C kg^{-1} (ecf from (b)(i)) Substitutes standard values into $\frac{e}{m}$ Standard value of $\frac{e}{m} = 1.76 \times 10^{11}$ C kg^{-1} calculated **and** comparison with experimental value **and** clear conclusion <u>Example of calculation</u> $\frac{e}{m} = \frac{1.73 \times 10^7\ \text{m s}^{-1}}{3.0 \times 10^{-3}\ \text{T} \times 3.5 \times 10^{-2}\ \text{m}} = 1.65 \times 10^{11}\ \text{C kg}^{-1}$ $\frac{e}{m} = \frac{1.6 \times 10^{-19}\ \text{C}}{9.11 \times 10^{-31}\ \text{kg}} = 1.76 \times 10^{11}\ \text{C kg}^{-1}$	(1) (1) (1) (1)	4

18(a)	The magnets/poles are moved relative to the coil/reader This causes a change in flux linkage with the coil **Or** This causes the coil to cut lines of flux An <u>e.m.f.</u> is <u>induced</u> across the coil The (north/south) pole affects the direction of the e.m.f. **Or** the sensor will register positive and negative p.d. as the polarity of the magnetic field changes.	(1) (1) (1) (1)	**4**

18(b)	Use of $\frac{dA}{dt} = Lv$ Use of flux linked with one turn of coil $\phi = BA$ Use of $\mathcal{E} = -\frac{\delta(N\phi)}{\delta t}$ $\varepsilon = 1.65 \times 10^{-6}$ (V) 1.65×10^{-6} (V) $> 1.5 \times 10^{-6}$ (V) so can detect the direction of the emf Or Comparison of their calculated value with 1.5×10^{-6} (V) and conclusion consistent with comparison <u>Example of calculation</u> $\varepsilon = -\frac{d(N\phi)}{dt} = \frac{d(NBA)}{dt}$ $\varepsilon = \frac{25 \times 24 \times 10^{-6}\, T \times 0.090\, m \times 0.98 \times 10^{-3}\, m}{0.032\, s} = 1.65 \times 10^{-6}\, V$ 1.65×10^{-6} (V) $> 1.5 \times 10^{-6}$ (V) so can detect the direction of the emf	(1) (1) (1) (1) (1)	**5**

11(a)	Use of $F = Bqv \sin\theta$ $v = 7.8 \times 10^{6}$ m s^{-1}	(1) (1)	<u>Example of calculation</u> $6.5 \times 10^{-13}\, N = 0.52\, T \times 1.6 \times 10^{-19}\, C \times v$ $v = \frac{6.5 \times 10^{-13}\, N}{0.52\, T \times 1.6 \times 10^{-19}\, C} = 7.81 \times 10^{6}\, m\, s^{-1}$	2
11(b)	Path curves Clockwise curve towards bottom of the page	(1) (1)	<u>Example of diagram</u> 	2

15(a)(i)	By (Fleming's) left hand rule ((F)LHR) **Or** magnetic field perpendicular to current, so (magnetic force) Force is up on left/AC/A **and** down on right/BD/D (dependent on MP1)	(1) (1)	**2**

15(a)(ii)	Use of $F = BIl$	**(1)**	
	Use of moment = force × perpendicular distance	**(1)**	
	Resultant moment = 9.1×10^{-3} N m	**(1)**	**3**
	<u>Example of calculation</u> $F = 0.68 \text{ T} \times 0.24 \text{ A} \times 0.05 \text{ m} \times 32$ $= 0.26 \text{ N}$ Moment = $(0.26 \text{ N} \times \frac{0.035 \text{ m}}{2}) \times 2$ $= 9.1 \times 10^{-3}$ N m		

15(b)(i)	Change in flux <u>linkage</u> (with coil) **Or** (Wires) cut lines of (magnetic) flux	**(1)**	
	<u>Induces</u> <u>emf</u>	**(1)**	**2**

15(b)(i)	Change in flux <u>linkage</u> (with coil) **Or** (Wires) cut lines of (magnetic) flux	**(1)**	
	<u>Induces</u> <u>emf</u>	**(1)**	**2**