PRESTON MANOR

A Level Physics Exam Packs

Magnetism

Name:

Form:

Question	Mark

4 **(a)** Define *magnetic flux*.

....

.... **[1]**

(b) Fig. 4.1 shows a generator coil of 500 turns and cross-sectional area $2.5 \times 10^{-3}\,m^2$ placed in a magnetic field of magnetic flux density 0.035T. The plane of the coil is perpendicular to the magnetic field.

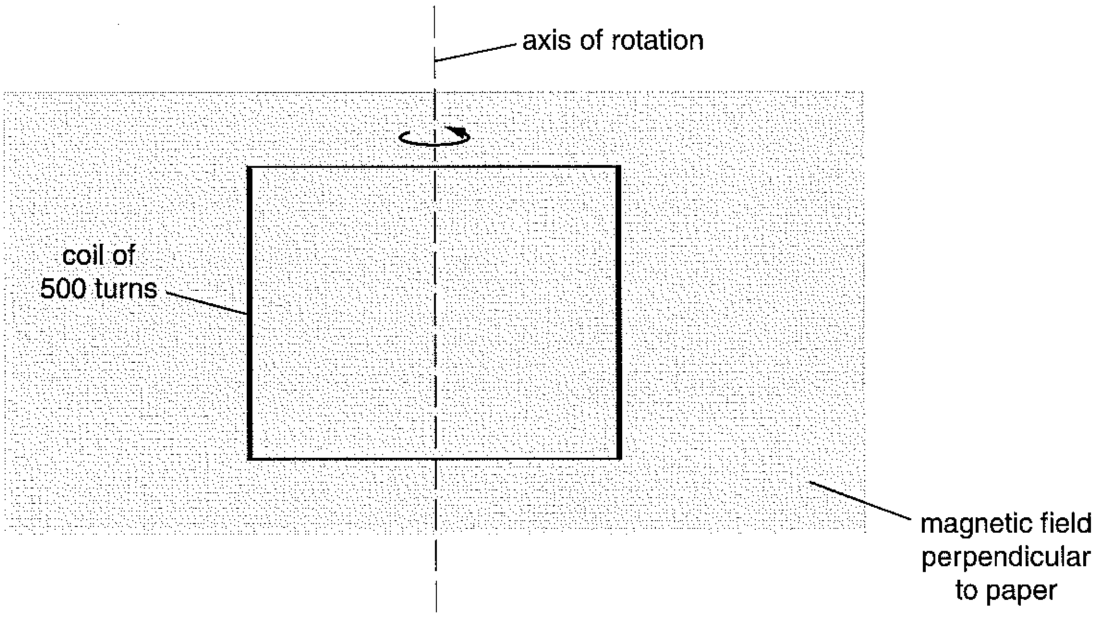

Fig. 4.1

Calculate the magnetic flux linkage for the coil in this position. Give a unit for your answer.

magnetic flux linkage = ... unit .... **[3]**

(c) The coil is rotated about the axis in the direction shown in Fig. 4.1.

Fig. 4.2 shows the variation of the magnetic flux ϕ against time t as the coil is rotated.

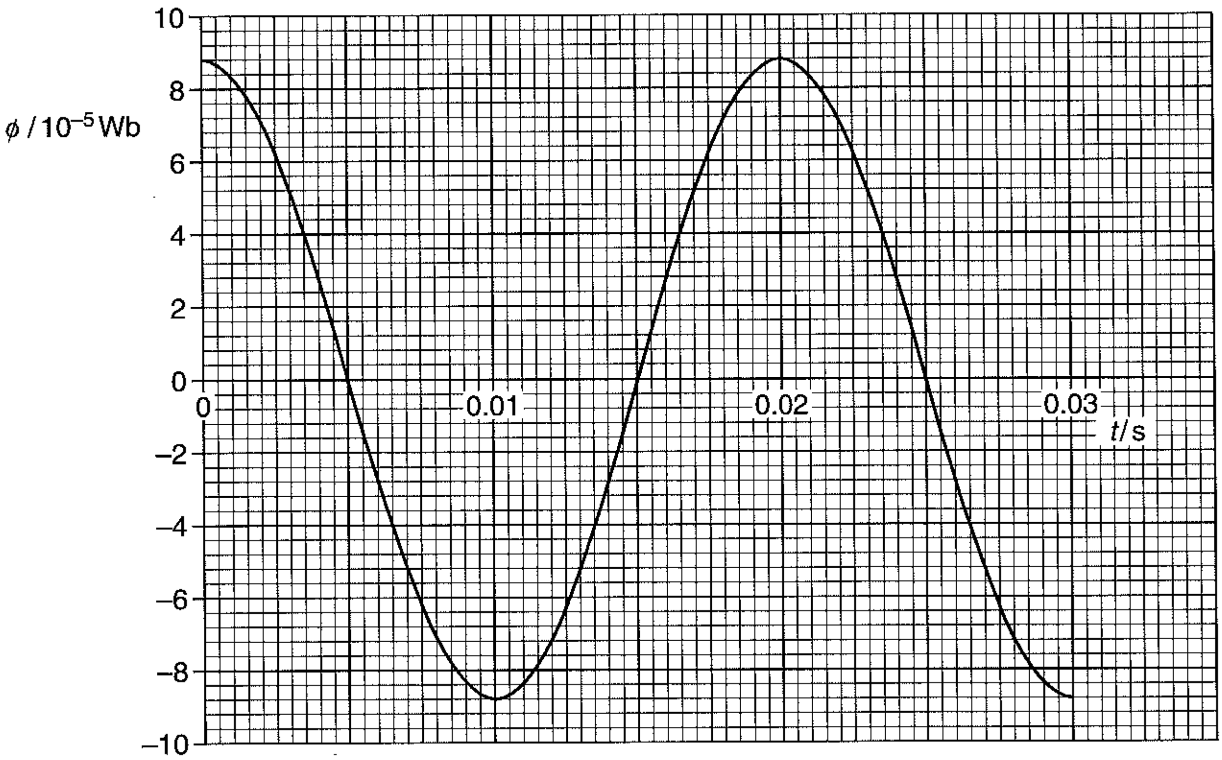

Fig. 4.2

(i) Explain why the magnitude of the magnetic flux through the coil varies as the coil rotates.

....

....

....

.... **[2]**

(ii) State Faraday's law of electromagnetic induction.

....

.... **[1]**

(iii) Use Fig. 4.2 to describe and explain the variation with time of the induced e.m.f. across the ends of the coil.

....

....

....

....

.... **[3]**

(iv) Use Fig. 4.2 to determine the magnitude of the average induced e.m.f. for the coil between the times 0 s and 0.005 s.

average e.m.f. = ... V **[2]**

(v) State and explain the effect on the magnitude of the maximum induced e.m.f. across the ends of the coil when the coil is rotated at twice the frequency.

....

....

.... **[2]**

[Total: 14]

Question			Expected Answers	Marks	Additional Guidance
4	a		magnetic flux = magnetic flux density x area (perpendicular to field direction)	B1	Allow equation with the symbols identified correctly Do not allow magnetic field or magnetic field strength
	b		Φ = NBA = 500 x 0.035 x 2.5 x 10^{-3} = 0.044 (0.04375) unit: Wb	C1 A1 B1	 [allow for one mark 8.75 x 10^{-5} (Wb) i.e. B x A] Allow: Wb turns and T m^2 and V s
	c	(i)	The component of B perpendicular to the area changes / the idea that the area changes relative to the field direction detail of how it varies / depends on cos θ / maximum when field is perpendicular to B / zero when area is parallel to B	B1 B1	Allow the idea that the direction of the field relative to the area of the coil varies with the orientation of the coil Do not allow reference to cutting of the flux by the coil
		(ii)	Induced / e.m.f is proportional / to the rate of change of (magnetic) flux	B1	Allow the emf produced is equal to the rate of change of flux or flux cutting
		(iii)	e.m.f. **max** when ϕ is **zero** or at 0.005 /0.015 /0.025 s e.m.f **zero** when ϕ is a **max** or at 0.0 / 0.01/ 0.02 s e.m.f. and ϕ have the same frequency allow e.m.f and ϕ out of phase by π/2/ emf follows a sin curve emf is the gradient of the graph **MAX 3**	(B1) (B1) (B1) (B1) (B1) B3	

4		(iv)	ε = (change in flux linkage) / time = 0.04375 / 0.005 $(8.8 \times 10^{-5} \times 500) / 0.005$ = 8.75 (V)	 C1 A1	 [if N omitted then give one mark (ε = 0.0175)] [if 10^{-5} omitted then minus 1] [reading error from graph is penalised -1 (should be 8.8 and not 8.4)]
		(v)	Max e.m.f. is twice the original value as the rate of flux change is twice the original	B1 B1	Do not allow just larger Allow: the change in magnetic flux occurs in half the time Allow the max gradient will double
			Total	**[14]**	

9 A proton travelling at a high velocity is fired at a stationary proton. It stops momentarily at a distance of 2.0×10^{-15} m from the stationary proton.

(a) Calculate the electrostatic force acting on each proton when separated by 2.0×10^{-15} m.

force = ... N **[2]**

(b) The two protons fuse together. Explain how the protons are able to remain together.

....

.... **[1]**

(c) Explain why the proton must have a very large velocity for the fusion to occur and the protons to remain together.

....

....

....

.... **[2]**

[Total: 5]

Question			Expected Answers	Marks	Additional Guidance
9	a		$F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$ $= (1.6 \times 10^{-19} \times 1.6 \times 10^{-19}) / 4\pi\varepsilon_0 (2\times 10^{-15})^2$ = 57.5 (N)	C1 A1	Allow use of 9×10^9 instead of $1 / 4\pi\varepsilon_0$ (using this gives 57.6) Allow ≥ 2sf (58) If correct formula quoted and then AE (e.g. not squaring r <u>or</u> not squaring Q) then allow ecf in final answer for 2/3
	b		<u>attractive</u> strong (nuclear force)	B1	Do not it holds them together
	c		as the proton travels towards the stationary proton it experiences a repulsive force that slows it down. (It needs a high velocity) to get close enough (to the proton) / for the (attractive) <u>short range</u> force to have any effect	B1 B1	
			Total	**[5]**	

5 Fig. 5.1 shows a rigid, straight metal rod **XY** placed perpendicular to a magnetic field. The magnetic field is produced by two magnets that are placed on a U-shaped steel core. The steel core sits on a digital balance.

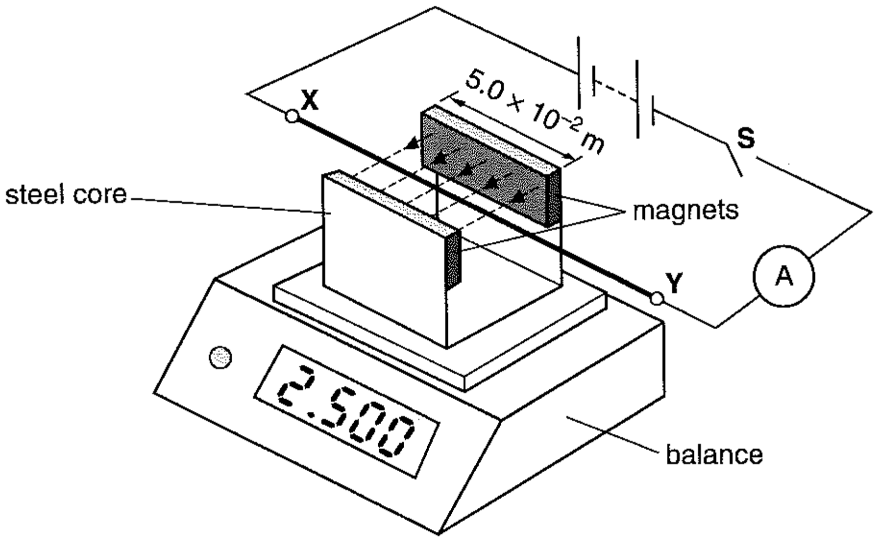

Fig. 5.1

The weight of the steel core and the magnets is 2.500 N. The rod is clamped at points **X** and **Y**. The rod is connected to a battery, switch and ammeter as shown in Fig. 5.1. The direction of the magnetic field is perpendicular to the rod.

Switch **S** is closed.

(a) State the direction of the force that now acts on the rod due to the magnetic field.

.... **[1]**

(b) State how you determined the direction of the force.

....

....

.... **[1]**

(c) The length of the rod in the magnetic field is 5.0×10^{-2} m and the current in the rod is 4.0 A. Assume that the magnets provide a uniform magnetic field of magnetic flux density 0.080 T.

(i) Calculate the force acting on the rod due to the magnetic field.

force = ... N **[1]**

(ii) State and explain the new reading on the balance.

reading on balance = ... N

....

....

....

....

.... **[3]**

(d) The rod is replaced by another rod of the same material having half the diameter of the first wire and the same length. The potential difference across this rod is the same. Calculate the force on this rod due to the magnetic field.

force = ... N **[3]**

[Total: 9]

Turn over

Question			Expected Answers	Marks	Additional guidance
5	(a)		Down(wards)	B1	**Note:** Can be on Fig. 5.1
	(b)		(Fleming's) left-hand rule	B1	**Allow:** Thumb in direction of force, first finger in direction of (magnetic) field and second finger in direction of (conventional) current
	(c)	(i)	force = $BIL = 0.080 \times 4.0 \times 5.0 \times 10^{-2}$ force = 0.016 (N)	B1	
		(ii)	reading = 2.500 – 0.016 reading = 2.484 (N) The force on <u>core/magnets</u> is up(wards) (According to Newton's third law) the forces (on the rod and steel core/magnets) are equal <u>and</u> opposite	B1 B1 B1	Allow: 'up and down' as equivalent to 'opposite'
	(d)		Resistance increases by a factor of 4 Current decreases by a factor of 4 The force decreases by a factor of 4 force = 0.004 (N)	C1 C1 A1	Possible e.c.f. from **(c)(i)** **Note:** force = **(c)(i)**/4 can score full marks **Special case:** Allow 1 mark for (resistance doubles, current is halved, hence) force = 0.008 (N)
			Total	**9**	

3 Fig. 3.1 shows part of an accelerator used to produce high-speed protons. The protons pass through an evacuated tube that is shown in the plane of the paper.

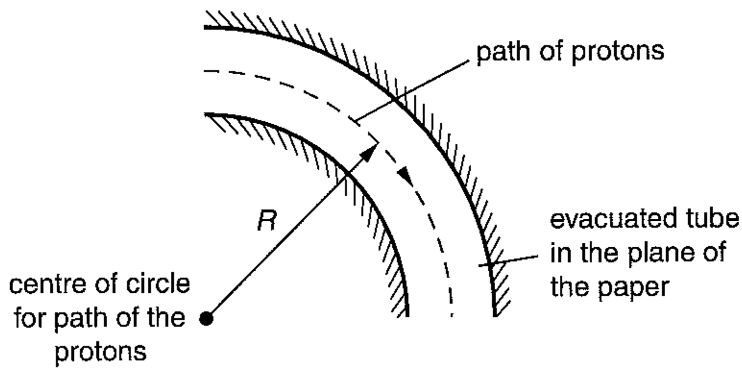

Fig. 3.1

The protons are made to travel in a circle of radius R by a magnetic field of flux density B.

(a) State clearly the direction of the magnetic flux density B that produces the circular motion of the protons.

.... **[1]**

(b) Show that the relationship between the velocity v of the protons and the radius R is given by $v = \dfrac{BQR}{m}$ where Q and m are the charge and mass of a proton respectively.

[1]

(c) Calculate the magnetic flux density B of the magnetic field needed to keep protons in a circular orbit of radius 0.18 m. The time for one complete orbit is 2.0×10^{-8} s.

$B =$ .... T **[3]**

(d) Explain why the magnetic field does not change the speed of the protons.

....

....

....

.... **[2]**

[Total: 7]

Question			Expected Answer	Mark	Additional Guidance
3	(a)		Perpendicular out of plane of paper	B1	**Allow**: 'out of paper' **Not**: 'up the paper'
	(b)		$\frac{mv^2}{R} = BQv$ hence $v = \frac{BQR}{m}$	M1 A0	**Allow**: Use of r instead of R and e instead of Q
	(c)		speed $= \frac{2\pi \times 0.18}{2.0\times10^{-8}}$ or 5.66×10^7 (m s^{-1}) $5.66\times10^7 = \frac{B\times1.60\times10^{-19}\times0.18}{1.67\times10^{-27}}$ (Any subject) B = 3.28 (T)	C1 C1 A1	**Allow** : ecf for incorrect value for speed v Alternative : $t = (\frac{2\pi R}{v} =) \frac{2\pi m}{BQ}$ C1 $B = \frac{2\pi\times1.67\times10^{-27}}{2.0\times10^{-8}\times1.60\times10^{-19}}$ C1 B = 3.28 (T) A1
	(d)		The force / acceleration is perpendicular to the motion / velocity No work is done	B1 B1	**Allow**: 'speed' instead of 'velocity'
			Total	7	

2 **(a)** Define *torque of a couple.*

....

.... **[1]**

(b) Fig. 2.1 shows a current-carrying square coil placed in a uniform magnetic field.

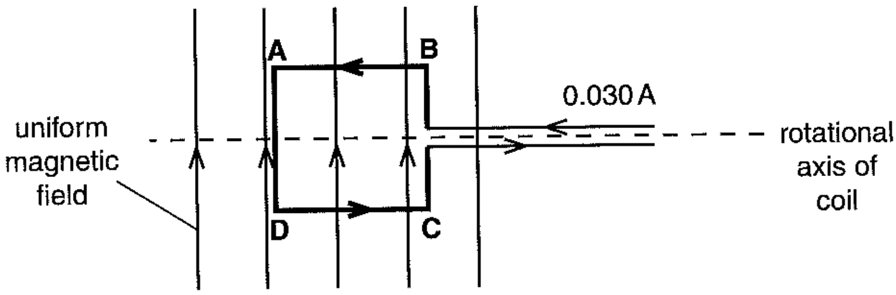

Fig. 2.1

The length of each side of the coil is 0.015 m. The plane of the coil is parallel to the magnetic field. The magnetic field is at right angles to the section **AB** of the coil and has magnetic flux density 0.060 T. The current in the coil is 0.030 A.

(i) Use Fleming's left-hand rule to determine the direction of the force on section **AB** of the coil.

.... **[1]**

(ii) The current-carrying coil will rotate because it experiences a torque. With the coil in the position shown in Fig. 2.1, calculate

1 the force experienced by the length **AB**

force = ... N **[1]**

2 the torque experienced by the coil.

torque = ... N m **[2]**

(c) Fig. 2.2 shows the path of a positive ion of oxygen-16 inside a mass spectrometer.

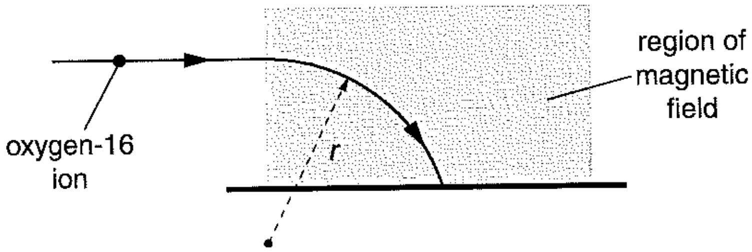

Fig. 2.2

The shaded area in Fig. 2.2 represents a region of uniform magnetic field of flux density 0.14T. The direction of the magnetic field is out of the plane of the paper. The ion has a speed of $4.5 \times 10^6\,\mathrm{m\,s^{-1}}$ and it enters the region at right angles to the magnetic field. While the ion is in the magnetic field, it describes a circular arc of radius *r*. The force experienced by the ion in the magnetic field is $2.0 \times 10^{-13}\,\mathrm{N}$.

(i) Calculate the charge *Q* of the ion.

Q = ... C **[2]**

(ii) The mass of the ion is $2.7 \times 10^{-26}\,\mathrm{kg}$. Calculate the radius *r* of the circular path.

r = ... m **[3]**

(iii) In Fig. 2.2, the oxygen-16 ion is replaced by an oxygen-18 ion. The oxygen-18 ion has the same speed and charge. Explain why this ion describes an arc of greater radius.

....

....

....

.... **[2]**

[Total: 12]

Question			Answers	Marks	Guidance
2	(a)		torque = one of the forces × perpendicular distance (between the forces)	B1	
	(b)	(i)	Into (plane of) paper	B1	**Not**: 'down'
		(ii)1	force = BIL = 0.060 × 0.03 × 0.015 force = 2.7 × 10^{-5} (N)	B1	
		(ii)2	torque = 2.7 × 10^{-5} × 0.015 torque = 4.1 × 10^{-7} (N m) or 4.05 × 10^{-7} (N m)	C1 A1	Possible ecf from **(b)(ii)1** Do not allow 4.0 × 10^{-7} (N m) - rounding error
	(c)	(i)	$F = BQv$ 2.0 × 10^{-13} = 0.14 × Q × 4.5 × 10^{6} charge = 3.2 × 10^{-19} (C) or 3.17 × 10^{-19} (C)	 C1 A1	**Allow**: Any subject
		(ii)	$F = mv^2 / r$ $2.0\times10^{-13} = \dfrac{2.7\times10^{-26}\times(4.5\times10^{6})^2}{r}$ radius = 2.7 (m) or 2.73 (m)	C1 C1 A1	 **Allow**: Any subject
		(iii)	$BQv = mv^2/r$ Hence, radius ∝ mass	B1 B1	 **Allow**: $r \propto m$
			Total	**12**	

3 **(a)** Define *magnetic flux*.

....

.... [2]

(b) Fig. 3.1 shows an experiment to demonstrate electromagnetic induction.

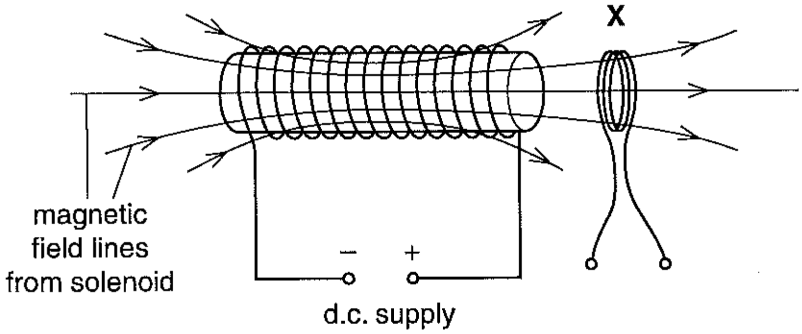

Fig. 3.1

The solenoid is connected to a variable voltage d.c. supply. A coil **X** is placed close to one end of the solenoid. The current in the solenoid is reduced. Fig. 3.2 shows the consequent variation of the magnetic flux density B at right angles to the plane of the coil **X** with time t.

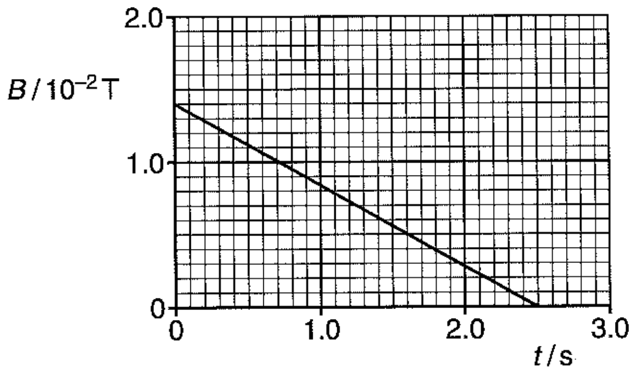

Fig. 3.2

The coil **X** has radius 3.2 cm and 180 turns.

(i) Explain why the induced e.m.f. across the ends of the coil has a constant value from $t = 0$ s to $t = 2.5$ s.

....

....

.... [1]

(ii) Calculate the magnitude of the induced e.m.f. across the ends of coil **X** from $t = 0\,\text{s}$ to $t = 2.5\,\text{s}$.

e.m.f. = ... V **[3]**

(c) Fig. 3.3 shows a transformer circuit.

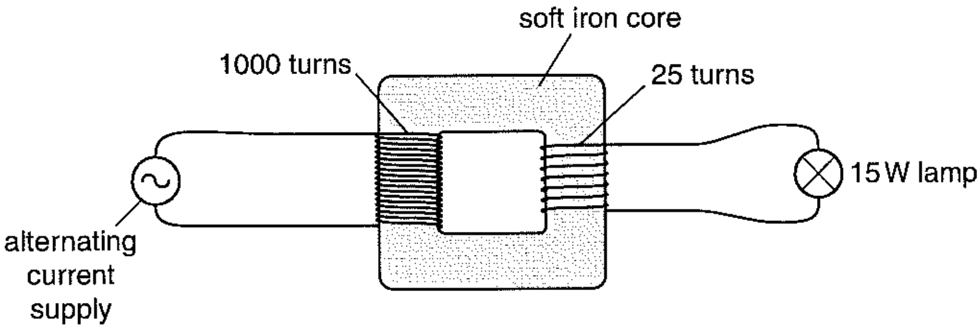

Fig. 3.3

The primary coil has 1000 turns and the secondary coil 25 turns. A lamp is connected to the output of the secondary coil. The potential difference across the lamp is 6.0V and the lamp dissipates 15W. The transformer has an efficiency of 100%.

(i) Calculate the current in the primary coil.

current = ... A **[2]**

(ii) The alternating voltage supply is replaced by a battery. Explain why the p.d. across the lamp is zero some time after the battery is connected.

....

....

....

....

.... **[1]**

[Total: 9]

Question			Answers	Marks	Guidance
3	(a)		magnetic flux = (magnetic) flux density × (cross-sectional) area Idea of (magnetic) field normal to the plane of the area	M1 A1	Allow full credit for magnetic flux = *BA*, where *B* = magnetic flux density normal to area and *A* = (cross-sectional) area
	(b)	(i)	constant rate of change of (magnetic) flux / flux density	B1	**Not**: 'graph has constant gradient'
		(ii)	e.m.f. = rate of change of flux linkage e.m.f. = $\frac{1.4\times10^{-2}\times\pi\times(3.2\times10^{-2})^2\times180}{2.5}$ e.m.f. = 3.2×10^{-3} (V) or 3.24×10^{-3} (V)	C1 C1 A1	**Allow**: $E=\frac{\Delta N\phi}{\Delta t}$ Deduct 1 mark if *B* is misread from the graph and then ecf **Allow**: 2 marks for an answer 3.24×10^{n} (if $n\neq-3$) **Allow**: 2 marks for 1.78×10^{-5} (when 180 has been missed out)
	(c)	(i)	$P = VI$ current in secondary = 15/6 or 2.5 (A) primary voltage = 6.0 × turn ratio = 6.0 × 40 = 240 (V) V_p = 240 (V) or I_s = 2.5 (A) primary current = 2.5/40 or 15/240 input current = 6.3×10^{-2} (A) or 6.25×10^{-2} (A)	C1 A1	The C1 mark is for either of these values
		(ii)	There is no change in flux density / (magnetic) flux / (magnetic) flux linkage	B1	**Not**: 'There is no change in the magnetic field'
			Total	**9**	

2 Fig. 2.1 shows the circular track of an electron moving in a uniform magnetic field.

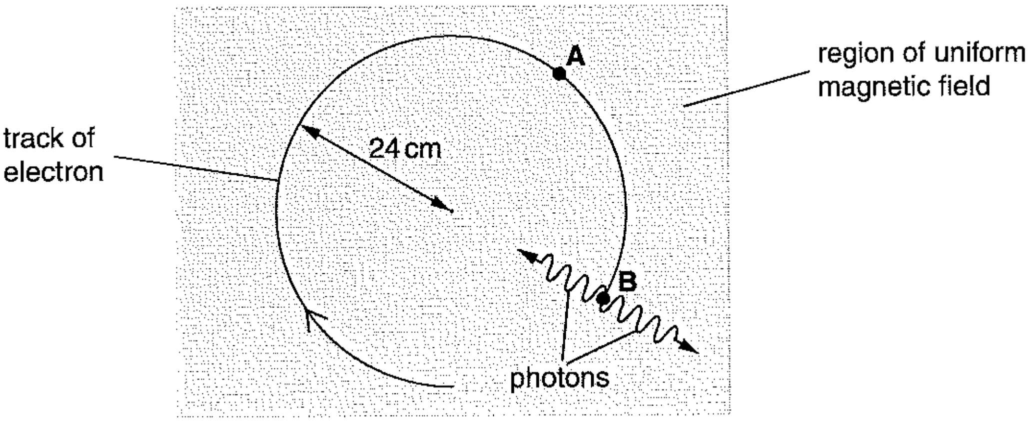

Fig. 2.1

The magnetic field is perpendicular to the plane of Fig. 2.1. The speed of the electron is $6.0 \times 10^{7}\,\text{m s}^{-1}$ and the radius of the track is 24 cm. At point **B** the electron interacts with a stationary positron.

(a) **(i)** On Fig. 2.1, draw an arrow to show the force acting on the electron when at point **A**. Label this arrow **F**. **[1]**

(ii) Explain why this force does not change the speed of the electron.

....

....

.... **[1]**

(b) Calculate the magnitude of the force F acting on the electron due to the magnetic field when it is at **A**.

F = ... N **[2]**

(c) Calculate the magnetic flux density of the magnetic field.

magnetic flux density = ... T **[2]**

(d) At point **B**, the electron and the positron annihilate each other. A positron has a positive charge and the same mass as the electron. The particles create two gamma ray photons. Calculate the wavelength of the gamma rays assuming the kinetic energy of the electron is negligible.

In your answer, you should make your reasoning clear.

wavelength = ... m **[3]**

[Total: 9]

Question			Answer	Marks	Guidance
2	(a)	(i)	Correct direction of force at **A** (and marked **F**)	B1	
		(ii)	The force is perpendicular to velocity / motion (hence no work done on the electron) or No (component of) acceleration / force in direction of velocity / motion (hence no work done on electron) or No distance moved in the direction of the force	B1	
	(b)		$F = \dfrac{mv^2}{r}$ force = $\dfrac{9.11\times10^{-31}\times(6.0\times10^7)^2}{0.24}$ force = 1.4×10^{-14} (N)	C1 A1	**Note**: Answer to 3sf is 1.37×10^{-14} (N) **Allow**: 1 mark for 1.4×10^n; $n \neq -14$ (POT error)
	(c)		$F = BQv$ $1.37\times10^{-14} = B\times1.60\times10^{-19}\times6.0\times10^7$ $B = 1.4 \times 10^{-3}$ (T)	C1 A1	Possible ecf from **(b)** **Note**: Answer to 3 sf is 1.43×10^{-3} (T) for 1.37×10^{-14} (N) **Note**: Using 1.4×10^{-14} (N) gives 1.46×10^{-3} (T) **Note**: Using $B = mv/Qr$ gives 1.42×10^{-3} (T)
	(d)		Using $(E=)mc^2$ and $(E=)\dfrac{hc}{\lambda}$ **(QWC)** $2\times mc^2 = 2\times\dfrac{hc}{\lambda}$ or $mc^2 = \dfrac{hc}{\lambda}$ or $mc = \dfrac{h}{\lambda}$ Correct substitution (any subject) $\lambda = 2.4 \times 10^{-12}$ (m)	B1 C1 A1	Eg: $2\times9.11\times10^{-31}\times(3.0\times10^8)^2 = 2\times\dfrac{6.63\times10^{-34}\times3.0\times10^8}{\lambda}$ Answer to 3 sf is 2.43×10^{-12} (m) **Allow**: 1 mark for 1.21×10^{-12} (m) or 4.86×10^{-12} (m) for the C1A1 marks
			Total	**9**	

3 Fig. 3.1 shows an arrangement used to accelerate electrons.

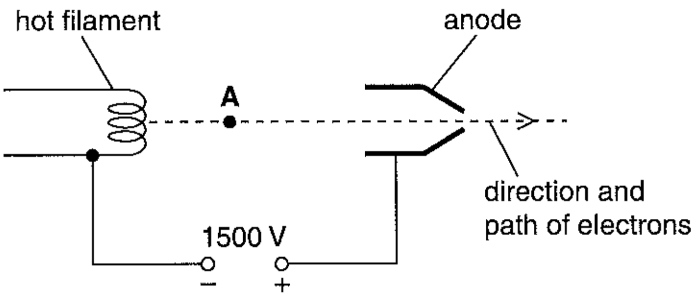

Fig. 3.1

(a) Draw an arrow on Fig. 3.1 to show the direction of the electric field at point **A**. **[1]**

(b) The potential difference between the filament and the anode is 1500V. The speed of an electron at the filament is negligible.

(i) Determine the kinetic energy in electronvolts (eV) of an electron at the anode.

kinetic energy = ... eV **[1]**

(ii) Calculate the speed v of an electron at the anode.

v = ... m s^{-1} **[3]**

(c) The electrons from the arrangement shown in Fig. 3.1 enter a region of space occupied by both uniform electric and magnetic fields, as shown in Fig. 3.2.

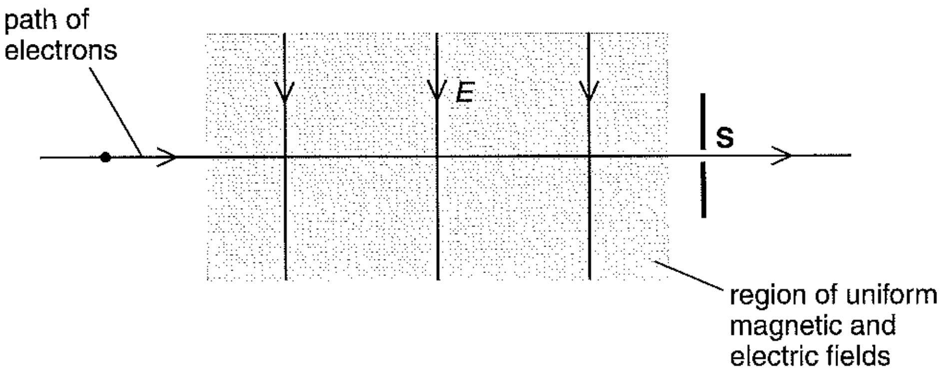

Fig. 3.2

The electric field strength of the electric field is E and its direction is shown in Fig. 3.2. The magnetic flux density of the magnetic field is B. The direction of the magnetic field is perpendicular to E and directed into the plane of the paper. B is increased until all the electrons pass through the slit **S** at a particular speed v. The path of the electrons is now horizontal as shown.

(i) Derive an expression for v in terms of E and B.

[2]

(ii) The magnetic flux density is increased further. The electric field strength is unchanged. Describe and explain what happens to the path of the electrons.

....

....

....

.... **[2]**

[Total: 9]

Question			Answer	Marks	Guidance
3	(a)		Arrow to the left	B1	
	(b)	(i)	1500 (eV)	B1	**Note**: 2.4×10^{-16} (J) on the answer line scores zero
		(ii)	(KE =) $1500 \times 1.6 \times 10^{-19}$ ($= 2.4 \times 10^{-16}$ J)	C1	Possible ecf from **(b)(i)**
			$2.4 \times 10^{-16} = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$ (Allow any subject)	C1	
			$v = 2.3 \times 10^7$ (m s^{-1})	A1	**Allow**: 2 marks for 5.3×10^{14} (answer not square-rooted) **Note**: $v = \sqrt{\frac{2 \times 1500}{9.11 \times 10^{-31}}} = 5.74 \times 10^{16}$ (m s^{-1}) does not score
	(c)	(i)	$F_{(E)} = Eq$ and $F_{(M)} = Bqv$		
			$Eq = Bqv$ (This mark is for equating the two equations)	M1	**Allow** an equivalent approach
			(Hence) $v = \frac{E}{B}$	A1	**Allow** any subject
		(ii)	Force due to magnetic field > force due to electric field	B1	**Allow**: magnetic force > electric force or $F_M > F_E$ or $Bqv > Eq$ or magnetic force is bigger <u>and</u> electric force is the same
			Electrons drift 'downwards'	B1	**Note**: This mark can be scored on Fig. 3.2
			Total	**9**	

3 Fig. 3.1 shows a section through a mass spectrometer.

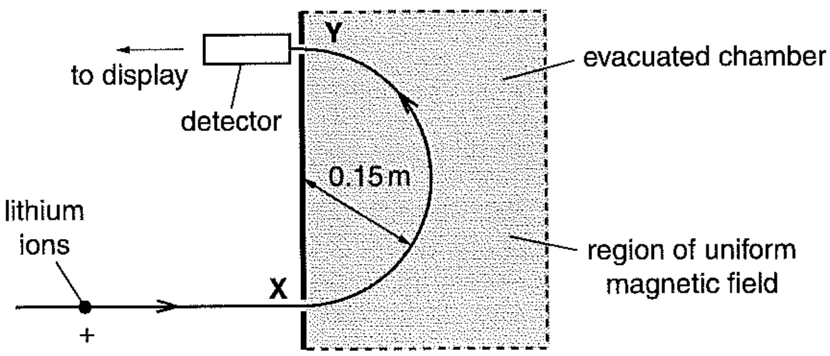

Fig. 3.1

A beam of positive lithium ions enter the evacuated chamber through the hole at **X**. The ions travel through a region of uniform magnetic field. The magnetic field is directed vertically into the plane of the diagram. The ions exit and are detected at **Y**.

(a) Name the rule that may be used to determine the direction of the force acting on the ions.

.... [1]

(b) Explain why the speed of the ions travelling from **X** to **Y** in the magnetic field does not change despite the force acting on the ions.

....

....

.... [1]

(c) The lithium-7 ions are detected at **Y**. All the ions have the same speed, $4.0 \times 10^5\,\mathrm{m\,s^{-1}}$ and charge, $+1.6 \times 10^{-19}\,\mathrm{C}$. The radius of the semi-circular path of the ions in the magnetic field is 0.15 m. The mass of a lithium-7 ion is $1.2 \times 10^{-26}\,\mathrm{kg}$.

(i) Calculate the force acting on a lithium ion as it moves in the semi-circle.

force = ... N **[2]**

(ii) Calculate the magnitude of the magnetic flux density B.

B = ... T **[2]**

(iii) The current recorded by the detector at **Y** is 4.8×10^{-9} A. Calculate the number of lithium-7 ions reaching the detector per second.

number per second = ... s^{-1} **[2]**

(d) Fig. 3.2 shows the variation of current I in the detector with magnetic flux density B.

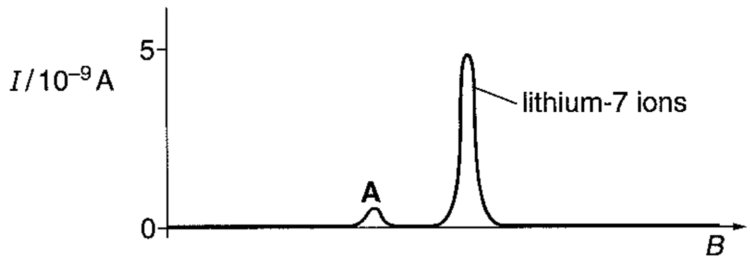

Fig. 3.2

The peak **A** is due to ions of another isotope of lithium. These ions have the same speed and charge as the lithium-7 ions. Explain the significance of the 'height' and position of peak **A**.

....

....

....

....

.... **[2]**

[Total: 10]

Question			Answer	Marks	Guidance
3	(a)		(Fleming's) left-hand rule	B1	
	(b)		The force is at right angles to the velocity (hence no work is done on the ions) / no (component of) force in the direction of motion / no (component of) acceleration in the direction of motion (AW)	B1	**Allow**: 'force is right angles to the motion'
	(c)	(i)	$F = \frac{mv^2}{r}$ force = $\frac{1.2\times10^{-26}\times(4.0\times10^5)^2}{0.15}$ force = 1.3×10^{-14} (N)	 C1 A1	 **Note**: Answer to 3 sf is 1.28×10^{-14} (N)
		(ii)	$F = BQv$ $1.28\times10^{-14} = B\times1.6\times10^{-19}\times4.0\times10^5$ B = 0.20 (T)	 C1 A1	 Possible ecf from **(c)(i)** **Allow**: 1 sf answer of 0.2 (T)
		(iii)	number per second = $\frac{4.8\times10^{-9}}{1.6\times10^{-19}}$ number per second = 3.0×10^{10} (s^{-1})	C1 A1	 **Allow**: 1 sf answer of 3×10^{10} (s^{-1})
	(d)		(height is smaller) hence less abundance (than lithium-7) position suggests that the ions are less massive / lighter fewer neutrons (than lithium-7)	B1 B1	**Allow**: fewer / less (than lithium-7)
			Total	**10**	

2 Fig. 2.1 shows the circular path described by a helium nucleus in a region of uniform magnetic field in a vacuum.

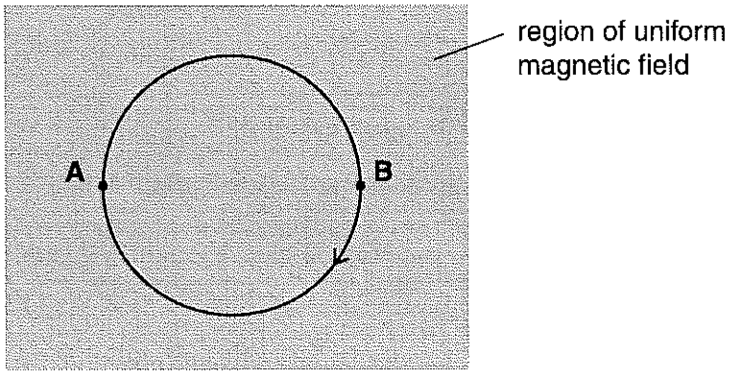

Fig. 2.1

The direction of the magnetic field is perpendicular to the plane of the paper. The magnetic flux density of the magnetic field is 0.20 mT. The radius of the circular path is 15 cm. The helium nucleus has charge $+3.2 \times 10^{-19}$ C and mass 6.6×10^{-27} kg.

(a) Explain why the helium nucleus

(i) travels in a circular path

....

.... **[1]**

(ii) has the same kinetic energy at **A** and **B**.

....

....

.... **[1]**

(b) Calculate the magnitude of the momentum of the helium nucleus.

momentum = ... $kg\,m\,s^{-1}$ **[3]**

(c) Calculate the kinetic energy of the helium nucleus.

kinetic energy = ... J **[2]**

(d) A uniform electric field is now also applied in the region shaded in Fig. 2.1. The direction of this electric field is from **left** to **right**. Describe the path now followed by the helium nucleus in the electric and magnetic fields.

....

....

....

.... **[2]**

[Total: 9]

Question			Answers	Marks	Guidance
2	(a)	(i)	A (constant) force acts at right angles to the velocity / motion (of the helium nucleus).	B1	**Note:** The answer must be in terms of force and not acceleration. **Allow** 'force is towards the centre of the circle'. **Not** 'there is a *centripetal* force' - unless explained. **Not** 'force is right angles to speed'.
	(a)	(ii)	No work done (by the force) / no acceleration in the direction of motion / no force in direction of motion	B1	**Allow** force / acceleration is at right angles to velocity / motion.
	(b)		$BQv = \frac{mv^2}{r}$ or $mv = BQr$ momentum = $0.20 \times 10^{-3} \times 3.2 \times 10^{-19} \times 0.15$ momentum = 9.6×10^{-24} (kg m s^{-1})	C1 C1 A1	**Allow** $v = 1.45.. \times 10^3$ (m s^{-1}); $p = 1.45.. \times 10^3 \times 6.6 \times 10^{-27}$
	(c)		$v = 9.6 \times 10^{-24}/6.6 \times 10^{-27}$ or $v = 1.45... \times 10^3$ (m s^{-1}) KE = $\frac{1}{2} \times 6.6 \times 10^{-27} \times (1.45... \times 10^3)^2$ KE = 7.0×10^{-21} (J)	C1 A1	Possible ecf from **(b)** **Allow** 1 sf answer **Alternative**: ($E = p^2/2m$); KE = $\frac{(9.6 \times 10^{-24})^2}{2 \times 6.6 \times 10^{-27}}$ C1 KE = 7.0×10^{-21} (J) A1
	(d)		The helium nucleus moves to the right. The path is a clockwise curve / looped (in the plane of the paper).	B1 B1	**Not** if the path is shown as a straight line. **Allow** 2 marks for clockwise curve / loop to the right. **Allow** 1 mark for a sketch showing an 'upward curve to the right'
			Total	9	