Mark scheme - Electromagnetism

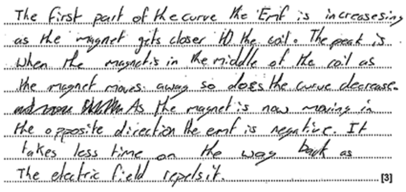
Question			Answer/Indicative content	Marks	Guidance
1			A	1	
			Total	**1**	
2			C	1	
			Total	**1**	
3			**D**	**1**	
			Total	**1**	
4			**D**	1	
			Total	**1**	
5			**D**	**1**	
			Total	**1**	
6			**C**	**1**	
			Total	**1**	
7			B	1	
			Total	**1**	
8			B	1	
			Total	**1**	
9			D	1	
			Total	**1**	
10			C	1	
			Total	**1**	
11			c	1	**Examiner's Comments** This was a well-answered question with most candidates correctly recalling that charge is conserved according to Kirchhoff's first law. A significant number of candidates distracted towards **B**; perhaps because of the unit of charge is the coulomb.
			Total	**1**	
12			D	1	**Examiner's Comments** The correct response is **D**. This question was correctly answered by the

					majority of candidates, although almost all the incorrect responses were **C**, presumably as candidates are aware that it is the e.m.f. that is induced but less familiar with Faraday's law in general.
			Total	**1**	
13			D	1	**Examiner's Comments** The correct response is **D**. Electromagnetism is another challenging set of concepts, resulting in a relatively low number of students obtaining the correct answer. Working showed that many of the candidates appreciated that the field needed to be resolved and were able to select the right trigonometrical function. However, by far the most common mistake was to ignore the turns and to simply calculate the flux through the coil. Whether this is a misconception or simply looking at the 'coil' on the diagram is unknown, however candidate should be reminded of the difference between turns and coils.
			Total	**1**	
14			C	1	
			Total	**1**	
15			C	1	
			Total	**1**	
16			**A**	1	
			Total	**1**	
17			The force is towards the centre of the circle.	B1	
			The force is perpendicular to the motion or no component of force in direction of motion; hence no work is done on the particle.	B1	
			Total	**2**	
18			Flemings left hand rule / the force on the electron is in the plane of the paper, right angles to the velocity and 'downwards'.	B1	
			Circular path within field in a clockwise direction.	B1	**Note**: If drawn on Fig. 22.1, then judge 'circular' path by eye.
			Total	**2**	

19		i	F upwards between poles	B1	
		ii	$F = BIl = 0.032 \times 2.5 \times 0.06$ $= 4.8 \times 10^{-3}$ (N)	B1	
			Total	**2**	
20			$\lambda_1 = d \sin 12.5 = 4.33 \times 10^{-7}$ m giving $1/d = 5 \times 10^5$ or $d = 2 \times 10^{-6}$	C1	or $\lambda_2 = d \sin 14.0 = 4.84 \times 10^{-7}$ (m)
			$\lambda_3 = \sin 19.0/5 \times 10^5 = 6.51 \times 10^{-7}$ (m) **or** $\lambda_1 = d \sin 12.5 = 4.33 \times 10^{-7}$ and $\lambda_3 = d \sin 19.0$ so $\lambda_3 = 4.33 \times 10^{-7} \sin 19.0/\sin 12.5 = 6.51 \times 10^{-7}$ (m)	A1	or use $\lambda_2 = d \sin 14.0 = 4.84 \times 10^{-7}$ m $\sin 19.0/\sin 12.5 = 0.326/0.216 = 1.50$
			Total	**2**	
21			Sinusoidal curve with the same peak e.m.f. Sinusoidal curve with half period	**B1** **B1**	**Note** curve must show at least half a period **Allow** ± 1 small square for e.m.f. **Ignore** phase **Note** graph must show at least half a period **Allow** ± 1 small square for *t* **Examiner's Comments** Most candidates scored a mark for showing that the period of the new e.m.f. trace was halved. Only a small proportional had the peak e.m.f. unchanged; the most frequent incorrect trace showed the peak e.m.f. also being halved. The sinusoidal curves were generally well-sketched.
			Total	**2**	
22			Direction of field shown as clockwise Three field lines shown as concentric circles and distance between adjacent field lines increasing as distance from wire increases	B1 B1	Expect at least one field line with an arrow **Allow** more than three lines, but distance between adjacent field lines increasing distance from wire must increase for all **Examiner's Comments** This question requires the candidates to identify the direction of the field and also to appreciate that the magnitude of the field reduces as the distance from the wire increases. Only around half were able to apply the right hand rule correctly to determine the direction, and only around 10% scored both marks. The increasing separation of the field lines with distance was poorly done for

					the most part. Many candidates kept the same separation, however those that may have attempted to increase this did not do with any clarity, so that parts of the circle would decrease. In general, the quality of the circles meant that it was difficult to be sure what the candidate's intention was. Some candidates were confused by the leader line, thinking it was the wire and attempted to draw a pattern around this. The question is clear that the diagram represents a top-view.
			Total	**2**	
23			Apply a magnetic field at right angles to electric field electric force = magnetic force No resultant vertical force, so only beta-particles with a specific speed will travel horizontally	B1 B1 B1	**Note** this mark is for the idea that E and B are <u>perpendicular</u> even if direction of B is incorrect **Allow** 'apply horizontal magnetic field' **Allow** $Eq = Bqv$ **Allow** $v = E/B$ in this arrangement **<u>Examiner's Comments</u>** This question was quite poorly answered, with many candidates not even mentioning the magnetic field. Few appreciated that the magnetic field needs to be placed perpendicularly to the electric field, although most could state the $EQ = BQv$. However, in a description, there was some confusion about the 'fields' being equal rather than the 'forces'. No candidate gave a suitable description for the last mark but could access it through use of $v = E/B$.
			Total	**3**	
24			Magnetic field (around current-carrying wire) (Fleming's) left-hand rule mentioned (Magnetic) field into page, (current is up the page) **and** force is to the left / towards **X**	B1 B1 B1	**Not** magnetic force **Allow** 'field into page and wires attract' **Note** the field direction and force direction can be shown on the figure
			Total	**3**	
25			centripetal force provided by BQv; hence $\frac{mv^2}{r} = BQv$	C1	
			$B = \frac{mv}{Qr} = \frac{9.11 \times 10^{-31} \times 5.0 \times 10^7}{1.6 \times 10^{-19} \times 0.018}$	C1	
			$B = 1.6 \times 10^{-2}$(T)	A1	
			Total	**3**	
26			$F = BQv$ **and** $F = mv^2/r$ **or** $B = mv/Qr$ (Any subject)	C1 C1	**Allow** e **<u>Examiner's Comments</u>** This question on the circular motion of charged particles in a uniform magnetic

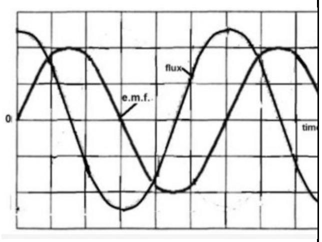
			(B =) $\frac{1.4\times10^{-25}\times4.8\times10^{4}}{1.6\times10^{-19}\times0.18}$ B = 0.23 (T)	A1	field was answered with confidence and flair. Most candidates got the correct answer of 0.23 T for the magnetic flux density. A small number of candidates, mainly at the low-end, were using incorrect equation for the magnetic force experienced by the ions. Some of these equations were hybrids of the **electric** force experienced by charged particles.
			Total	**3**	
27		i	the uncertainty in the measurement of angle is the same for all angles and the bigger the angle measured the smaller the % error	B1	
		ii	n_{max} = d sin 90	C1	
		ii	= 1/(5 × 10^5 × 4.33 × 10^{-7}) = 4.6 but n is an integer so n = 4	A1	
			Total	**3**	
28			○ (Induced) e.m.f. is caused by a change in (magnetic) flux (linkage) / (Induced) e.m.f. is proportional (or equal to) the <u>rate</u> of change of (magnetic) flux (linkage) • The peaks are inverse / e.m.f. changes from positive to negative because: the rate of change of magnetic flux linking the coil changes sign **or** the flux (linkage) increases and then decreases	B1 x 3	**Maximum 3** marks from 4 marking points. **Not** voltage or p.d. or current for e.m.f. **Accept** 'cutting of field lines by coil' for 'change in flux' <u>Answers to any of the last three points must link clearly to the correct graph characteristic</u> **Allow** the North (or South) pole first approaches then recedes **Ignore** magnet approaches then recedes / field increases then decreases **Not** torch is inverted **Allow** no field lines are being cut **Allow** the magnet is accelerating / is travelling faster when it exits the coil **<u>Examiner's Comments</u>** Candidates need to remember to look at the command word in the question. Here it was 'explain'; not 'describe'. The key features to be explained were:

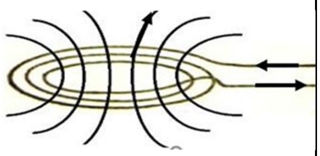
			or description in terms of Lenz's law as seen by coil to conserve energy • The e.m.f.becomes zero because: the (rate of) change of magnetic flux is zero when the magnet is in the middle of the coil • The second peak has a larger negative amplitude because: the **rate** of change of flux linkage is greater (when the magnet leaves the coil compared to when it enters) • The pulses have different widths because: the second Δt is shorter (since magnet accelerates) **or** areas under curves must be the same (because total change of flux linkage is the same on entering and leaving coil) / area under curve = $V\Delta t$ = $N\Delta\varphi$ (so bigger V leads to smaller Δt)		• why is an e.m.f generated? • why does the e.m.f change sign? • why does the e.m.f fall to zero halfway through the fall? • why is the maximum negative e.m.f greater than the maximum positive e.m.f / why is the width of the second peak smaller than that of the first peak? The strongest responses were those where candidates stated at the outset what gave rise to the e.m.f. Some candidates clearly recognised the need to state Faraday's law, but simply quoted the formula without defining any terms and so could not receive credit. Weaker responses were characterised by describing the shape of the graph in terms of the position of the magnet - often incorrectly – rather than in terms of flux linkage. A common misconception was stating that the negative peak was caused by the magnet returning after an inversion, with the zero e.m.f. just after 0.1s being caused by the magnet being temporarily stationary. However, the question clearly states that 'Fig.3.3 shows … the e.m.f. generated … as the magnet falls the distance h'. Exemplar 3 below demonstrates clearly this common misconception. **Exemplar 3**  The first part of the curve the Emf is increasesing as the magnet gets closer tO the coil. The peak is when the magnet is in the middle of the coil as the magnet moves away so does the curve decrease. As the magnet is now moving in the opposite direction the emf is negative. It takes less time on the way back as the electric field repels it. [3]
			Total	**3**	
2 9			F = Bev **and** F = eE E = V / a **or** F = (eE) = eV / a Bev = eV / a giving V = Bva	**B1** **B1** **B1**	**allow** Q or q for e **Examiner's Comments** This was an exercise in writing basic definitions in algebraic form and then using them to derive a given equation. More than half of the candidates managed to gain full marks with less than one third scoring zero. The presentation was sometimes difficult to follow with the inclusion of unnecessary equations and deletions and the substitution of d for a in the last line.
			Total	**3**	

3 0		i	flux = BA = 0.20 × 0.10 × 0.080 = 0.0016 (Wb)	B1	
		i	induced emf = NBA/t = 80 × 0.0016/5 = 0.026 (V)	B1	
		ii	Lenz's law indicates that current must try to maintain the field as it collapses **or** current must produce same field as magnet to try to maintain the field.	M1	
		ii	current is anticlockwise in coil as viewed from S pole.	A1	
			Total	**4**	
3 1		i	I = nAev; $v = 60 \times 10^{-3}/1.2 \times 10^{23} \times 1.6 \times 10^{-19} \times 5.0 \times 0.2 \times 10^{-6}$ v = 3.1 (m s^{-1})	**C1** **C1** **A1**	**allow** any subject
		ii	$V = 80 \times 10^{-3} \times 3.1 \times 5.0 \times 10^{-3}$ $= 1.2 \times 10^{-3}$ (V)	**A1**	**ecf (b)(i); allow** 1.2 mV; 1.3×10^{-3} (V) **Examiner's Comments** This exercise of choosing a formula, substituting values in correct units and evaluating was done well with about three quarters of the candidates gaining full marks.
			Total	**4**	
3 2		i	Two closed loops linking primary coil	B1	lines not touching / crossing, both passing only through iron core
		ii	magnetic flux φ: because the loops of magnetic field (are continuous and) all pass (through the iron core) through each coil	B1	**allow** magnetic flux is the number of lines of the magnetic field if **(i)** is correct
		iii	for magnetic flux density:	B1	Note: (iii) and (iv) can be answered in either order
		iii	3 turn coil as A is smallest OR for magnetic flux linkage: 5 turn coil as largest number of turns	B1	φ is same in each coil, B = φ/A OR φ is same in each coil, m.f.l. = φN
			Total	**4**	
3 3		i	3 downward arrows correctly labelled.	B1	longest being 4.33×10^{-7} (m)

		ii	$\Delta E = hc/\lambda$	C1	
		ii	$\lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 4.8 \times 10^{-20} = 4.1(4) \times 10^{-6}$ (m)	A1	
		ii	region: infra red	B1	**allow** ecf if wavelength calculation incorrect.
			Total	**4**	
3 4		i	The force is right angles to the motion / velocity.	B1	
		i	The particle describes a circle in the plane of the paper.	B1	
		ii	Particle experiences a force perpendicular to motion / velocity.	B1	
		ii	It moves to the right and either comes out or goes into the plane of the paper (in a parabolic path).	B1	
			Total	**4**	
3 5		i	(induced) e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage	B1	**Not** current **Allow** 'rate of cutting' for 'rate of change'
		ii	Connect the primary (coil) to an alternating voltage / current Oscilloscope connected across secondary coil / to measure *E* A graph of *E* against *N* will be a straight line through the origin.	B1 B1 B1	**Allow** AC (can be on the figure) **Not** changing / variable for alternating **Allow** voltmeter (can be on the figure) **Allow** p.d. / voltage for e.m.f. / *E* throughout **Ignore** any component (e.g. lamp or resistor) connected across the secondary coil **Allow** ($E \div N$) = constant
			Total	**4**	
3 6		i	The gradient is maximum / maximum rate of change of *B* / maximum rate of change of flux (linkage)	**B1**	**Allow** slope instead of gradient **<u>Examiner's Comments</u>** Although worth just 1 mark, this question did provide good opportunity for top-end candidates to pick up one mark. Many candidates quoted Faraday's law of electromagnetic induction, without mentioning that the **rate** of change of flux (linkage) was **maximum** at $B = 0$. Low-scoring candidates wrote about the

					orientation of the coil relative to the magnetic field or the *'cutting'* of field lines. None of the explanations led to any marks being credited.
		ii	Tangent drawn to curve at $B = 0$ gradient = 12.5 (maximum e.m.f. = 12.5 × 14 × 10^{-4} × 85) maximum e.m.f. = 1.5 (V)	**C1** **C1** **A1**	**Allow** 11.70 to 13.30; no need to check calculation **Allow** fraction if calculated value is within the range **Allow** ECF from the gradient value if value is outside the range **Alternative:** $E = BAN\omega$ **C1** E = 40 × 10^{-3} × 14 × 10^{-4} × 85 × 2π × 50 **C1** maximum e.m.f. = 1.5 (V) **A1** **Examiner's Comments** Most candidates followed the question and drew decent tangents on Fig. 21.2. Most of the tangents were acceptable, but a few either crossed the curve or had very thick pencil lines. A significant number of candidates quoted the maximum e.m.f. to be equal to the magnitude of the gradient of the tangent. Top-end candidates faced no obstacles here; the gradient was multiplied by [85 × 14 × 10^{-4}] to give an answer around 1.5 V. Once again, a good number of candidates were picking the odd mark through error carried. Converting the cross-sectional area of 14 cm^2 into 14 × 10^{-4} m^2 was a challenge for some of the candidates in the middle and lower quartiles.
			Total	**4**	
37			(force =) 2.2 × 10^{-3} × 9.81 2.2 × 10^{-3} × 9.81 = B × 5.0 × 0.060 (= 0.072 T) (absolute uncertainty =) $\frac{0.2}{6.0}+\frac{0.1}{5.0}$(×0.072 = 0.0038 T) B = 0.072 ± 0.004	C1 C1 C1 A1	**Allow** calculation of percentage uncertainty = 5.3% **Allow** calculation of max B (=0.0759 T) and min B (=0.0683 T) **Note** B must be given to 2 SF and the uncertainty given to 1 SF. **Special case:** allow follow through from incorrect B calculation. **Examiner's Comments** This question is based around a common experiment used to determine the magnetic flux density of a pair of magnets and the experimental design should have been familiar to many candidates, along with the use of $F = BIL\sin\theta$ from the data booklet. The first mark is for identifying the magnitude of the force as being the change in the apparent weight on the balance. Several candidates simply used the reading with the wire, or did not change the mass unit to kg. However, those who managed to get the correct reading for the force generally went on to calculate the magnetic flux density correctly. The uncertainties for two readings were given, and most candidates correctly

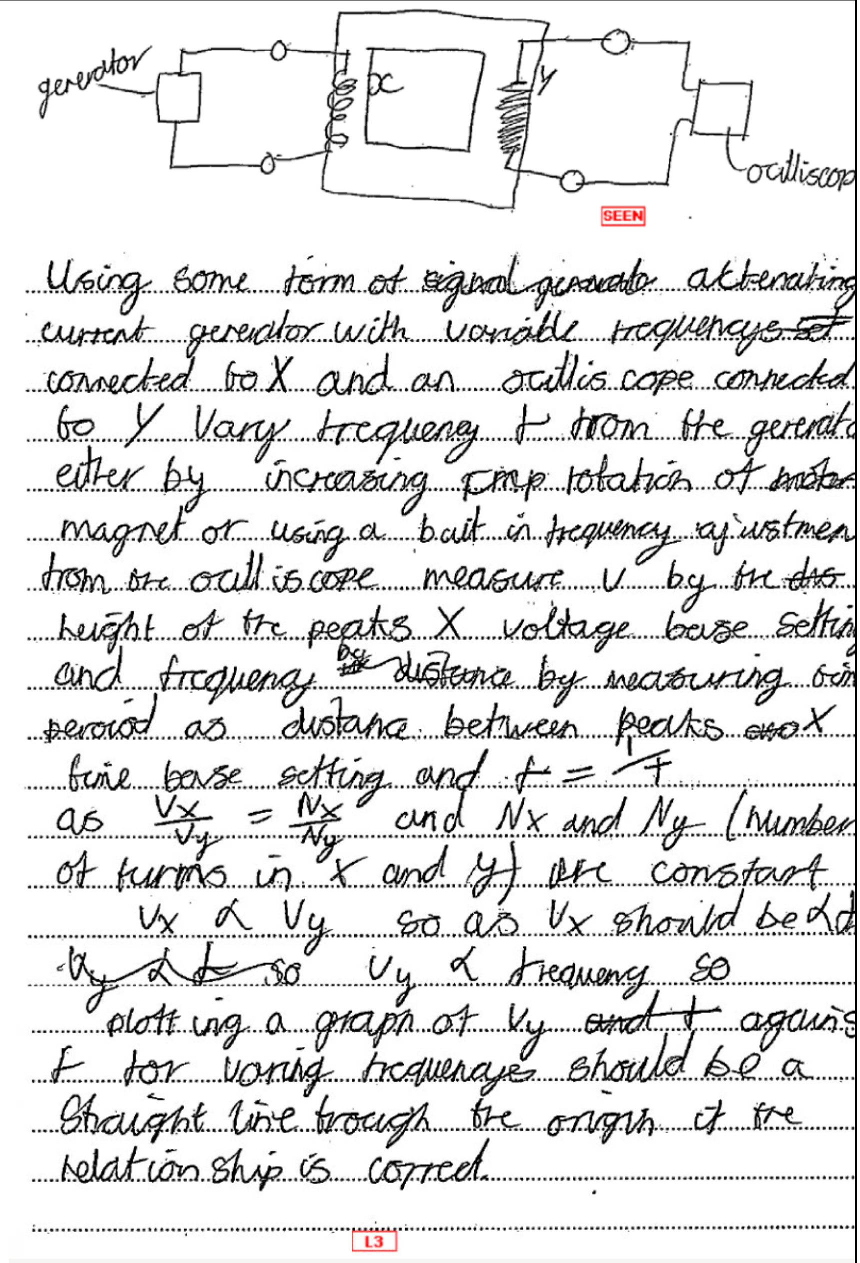
					calculated a percentage uncertainty of 5.3%. The final answer required the correct number of significant figures. Some candidates either did not see this, or ignored it, leaving their final answer in different significant figures. It was noted that several candidates underlined this instruction and in general they tended to follow it. It is good practice to do this.
			Total	**4**	
38		i	the flux in the coil changes/ increases/ decreases/ varies (caused by the spinning/rotating magnet) causing a sinusoidal/alternating e.m.f./AW	B1 B1	**or** e.m.f. is proportional to /equals rate of change of flux linkage/linking the coil **or qualification, e.g.** magnet vertical gives minimum flux through core or maximum rate of change of flux or vice versa with magnet horizontal **or** maximum flux is when emf is zero **or** minimum flux is when emf is maximum **or** vice versa
		ii		B1	**allow** ± cos wave of correct period, constant amplitude at least one cycle **N.B.** quality: curve must look like a reasonable sine wave as one is present on the page to copy **Examiner's Comments** In part (i) many of the candidates described the phase shift that they drew in the sketch graph of part (ii) by stating either the magnitude or the rate of change of the flux linkage when the induced e.m.f. was zero or a maximum. The majority quoted Faraday's law either in words or as a mathematical equation. Some candidates introduced current and Lenz's law not appreciating that an oscilloscope is effectively a voltmeter. Few described the whole picture of a steadily rotating magnetic field sweeping through a coil creating a changing flux linkage.
		iii	$\varphi = BA = V/2\pi fN = 1.2/(2 \times \pi \times 24 \times 150)$ $\varphi = 5.3 \times 10^{-5}$ Wb / T m^2	B1 B1	**allow no other** unit combinations; NOT T m^{-2}
			Total	**5**	
39		i	Hall probe only compares B-fields / AW **or** V will be too small / less than 1 mV so not easy to measure	**B1**	allow any sensible comment, e.g. how do you convert the measured V into a B value
		ii	find B using F = B*Il*; F is measured by weighing magnets (e.g. placed on top pan balance assuming wire is fixed); graph of F against ***I*** to find B*(l)* from gradient / AW;	**B1** **B1** **B1** **B1** **B1**	**max** 4 of the 5 marking points **alt** measure F by adding small masses to wire to return it to zero current position **or** use readings of F at several *I* to find average F/*I*, etc. **or** measurement of small masses in alt. method, etc quantitative suggestion about % error i.e. *l* small (1 mm in 60) leading to large % uncertainty **or** difficulty in determining edge / end of B-field

			greatest uncertainty: measurement of *I* in B-field sensible reason / justification for choosing ***I* or** small masses		**Examiner's Comments** Most candidates did not refer back to (b)(ii), noting that the potential difference across the Hall probe would be very small making the probe an unsuitable instrument for measuring the magnetic flux density, B. However almost all were familiar with the experiment where the magnets are mounted on a top pan balance with a fixed wire carrying the current. Only a small number varied the current and plotted a graph to obtain a more accurate value of B. Also few appreciated that the edges of the field spread out making the length of wire in the field the least reliable measurement.
			Total	**5**	
40		i		B1 B1	One correct line (or dot and cross) drawn Line must go through centre of coil **Allow** an incomplete line or a complete circle round the coil **Ignore** direction of arrow More than one line drawn All lines drawn must go through centre of coil and follow correct shape and <u>direction</u> of field **Ignore** spacing of lines **Ignore** any lines to the right of the coil
		ii	(the magnetic) flux (of the coil) links the <u>base</u> / <u>saucepan</u> (the size/direction of) the flux linkage (constantly) <u>changes/alternates</u> (causing an alternating induced e.m.f.) (induced) <u>current</u> is large because metal/base/ saucepan has low resistance	B1 x 2	2 out of 3 possible marking points **Allow** (the magnetic) field lines cut the (base of the) <u>saucepan</u> **Allow** the (magnetic) field constantly changes/alternates **Allow** a bald statement of Faraday's Law
		iii	The resistance of glass-ceramic/the (cook"s) hand is (very) large So (induced) <u>current</u> (or heating effect of <u>current</u>) is zero/negligible	M1 A1	**Allow** glass-ceramic/hand is an insulator/not a (good) conductor **Do not allow** the induced <u>e.m.f</u>. is (very) small
			Total	**6**	
41	a				Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2ˆ for 3 marks, etc. **Ignore** incorrect references to the terms precision and accuracy

			Level 3 (5-6 marks) Clear evaluation of Fig. 22.1 **and** clear analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Some evaluation of Fig. 22.1 **and** some analysis *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1-2 marks)** Limited evaluation of Fig. 22.1 **or** limited analysis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1×6**	**Indicative scientific points may include:** **Evaluation of Fig. 22.1** • Comment on the line • The straight line misses one error bar / anomalous point ringed or indicated • Too few data points plotted • The triangle used to calculate the gradient is (too) small • Some plots should have been repeated / checked • No error bars for current • 'Not regular intervals' (for current) • No origin shown (AW) **Evaluation of analysis** • The value of B is close to the accepted value • The difference of only 7% • No absolute or percentage uncertainty in B shown (AW) • Worst-fit line or maximum / minimum gradient line could have been used to determine the (absolute or percentage) uncertainty in B • F against I graph should be a straight line or • BL = gradient (any subject) **Examiner's Comment** This was the second level of response (LoR) question in the paper. It required evaluation of a graph drawn by a student and the analysis shown in the box on page 24. Most candidates realised that the graph had few data points, the triangle used for the gradient was too small and the line drawn totally missed one of the error bars. The analysis shown by the candidate did not include an absolute uncertainty in B, which made the statement written by the student lack credibility. Many candidates wrote about drawing doing a line of worst-fit and determining the percentage uncertainty. This was only possible if there were more data points and the error bars for the F values reduced by perhaps repeating the measurements. Once again, there was a good spread of marks amongst the three levels.
	b	i	There is a changing / fluctuating (magnetic) field / flux (linkage) (magnetic) field / flux (linkage) in <u>core</u> and <u>secondary</u> (coil) Statement of Faraday's law: e.m.f. (induced) ∝ <u>*rate*</u> of change of (magnetic) flux <u>linkage</u>	M1 A1 B1	**Note:** This changing flux can be anywhere **Allow** 'the direction of the field oscillates' **Allow** 'the core helps to link the flux to the secondary coil' **Allow** 'equal to / =' **Ignore** 'cutting of flux' **Not** just $E = (-)\Delta(N\phi)/\Delta t$ **Examiner's Comment** The topic electromagnetic induction always challenges candidates. Successful responses often showed correct use of technical terms such as *magnetic flux* or *flux linkage.* Most candidates scored a mark for correctly stating Faraday's law

					of electromagnetic induction. Many realised that an alternating current produced an alternating magnetic flux within the iron core and this change in flux produced an e.m.f. at the secondary coil. One of the popular misconceptions was that there was an alternating current (or induced e.m.f.) within the iron-core. A small number of candidates referred to **electro**magnetic field in their descriptions rather than magnetic field.
		ii	1 (I_S =) 24/12 or 2.0 (A) (I_P =) $\frac{20}{400} \times 2.0$ (current in primary =) 0.10 (A) or (V_P =) 12 × 20 or 240 (V) (I_P =) $\frac{24}{240}$ (current in primary =) 0.10 (A) 2 Idea of changing / increasing (magnetic) field / flux / current (in primary) at the start Eventually current and flux (linkage) are constant, therefore no e.m.f.	C1 A1 C1 A1 B1 B1	**Allow** 1 sf answer **Allow** 1 sf answer **Note:** Any labels used must be clearly defined **Examiner's Comment** This question on current in the primary coil was successfully answered by most candidates. The most favourable method was to calculate the current in the secondary and then the current in the primary coil. The turn-ratio equation and $P = VI$ were effortlessly used to arrive at the correct answer of 0.10 A. Full marks were rarely scored but many top-end candidates did manage to score a mark for suggesting that the lamp was lit for a short period of time at the start because *'there was a changing magnetic flux as the current increased from zero to a steady value'*. Too many answers focussed on the requirement of an alternating supply for an induced e.m.f. in the secondary coil and how a battery is not an alternating supply.
			Total	**13**	
4 2			**Level 3 (5–6 marks)** Clear description, some measurements and full analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description, some	B1 × 6	**Indicative scientific points may include:** **Description** **a.** Signal generator/a.c. supply connected to coil X **b.** Coil Y connected to voltmeter / oscilloscope (can be ondiagram) **c.** Use oscilloscope to determine period / frequency or readoff signal generator **d.** Adjust signal generator / use of rheostat to keep currentconstant in coil X **Measurements**

			measurements and some analysis. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description and/or limited measurements and/or limited analysis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		**1.** Vary f and measure V **2.** Keep <u>current</u> in coil X <u>constant</u> **3.** Detail on how to measure e.m.f. e.g. 'height x y-gain' **4.** Detail on how to measure period on oscilloscopescreen using time base and hence f **Analysis** **1.** Determine f from period measurement, f = 1/T **2.** Plot a graph of V against f **3.** Relationship valid if straight line through the origin <u>**Examiner's Comments**</u> From the proposed arrangements for the investigation, it was apparent that most of the candidates were unfamiliar with the most suitable equipment for this experiment, namely a signal generator. Many improvised by using an ac supply with a variable frequency. A minority of these believed that by increasing the voltage of their power supply it would alter the frequency. Most drew a cell or battery symbol for the ac supply. Others improvised by using the rotating magnet from part (a) but had not realised the significance of the calculation in part (a)(iii) which indicated that at 24 revolutions per second the output voltage was 1.2 V. This made the suggested method of using a stop watch to find the period of rotation impracticable. Few realised that the oscilloscope as a voltmeter could measure both the output voltage and the period of the ac. The instrument was often connected in series in the primary circuit. No one realised that the input current has to be constant to provide a constant flux. Despite all of these difficulties most candidates managed to write sensible statements worthy of credit but rarely full marks. The author of the example shown (exemplar 9) has used the rotating magnet as the ac source and continued with the clues from part (a) to produce an L3 quality answer. **Exemplar 9**

					
			Total	**6**	
4 3			* **Level 3 (5–6 marks)** At least P1 and P2 M1, M2, M4 and M5 At least A2 and A3 At least C1 and C2 *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** At least P1 M1, M4 and M2 or M5 At least A3	B1	**plan P** 1. vary speed of rotation of magnet using motor control 2. expect to see amplitude of signal increase and period of waveform decrease 3. measure (maximum) e.m.f. V and period T for each setting from oscilloscope screen. **measurements M** 1. maximum e.m.f. 2. measured from peak to peak distance on graticule 3. and using V/cm scale setting 4. period of rotation 5. measured along t-axis of graticule 6. and using s/cm time base setting. **analysis A** 1. record table of V, T

			At least C1 *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** At least P1 At least M1 and M4 At least A3 At least C1 *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		2. and (calculate and record) f = 1/T 3. plot graph of V against f **conclusions C** 1. astraight line graph 2. through origin 3. is required to validate Faraday's law.
			Total	**6**	
4 4	a	i	$a = (-)\ 4\pi^2 f^2 x = 4 \times 9.87 \times 4900 \times 0.004$	C1	**allow** 774 (m s^{-2})
		i	a = 770 (m s^{-2})	A1	
		ii	**1** sketch showing one wavelength and 140 (Hz)	B1	both sketch and value required for 1 mark
		ii	**2** driving force is around nodal point / AW;	B1	**max** 3 of the 4 marking points
		ii	points either side of nodal point try to move in opposite directions when force in one direction / AW;	B1	
		ii	move magnet to antinodal point; ¼ of distance between clamps	B1	**not** increase current
	b	i	*f α* $\sqrt{T}$ so $f = 70/\sqrt{2}$ = 49 or 50 Hz	B1	
		ii	**1** μ increases / goes up by 0.4%	B1	**allow** +0.4% NOT 0.4%
		ii	**2** 0.2%,	B1	**or** half of answer to **(ii)1**

		ii	f is lower because μ is bigger and μ is on the bottom of the formula	B1	**or** greater inertia present with same restoring force / other physical argument
			Total	**10**	
4 5			**Level 3 (5–6 marks)** A good plan with discussion of sensitivity and measurements that need taking. Detailed description of analysis needed linked to robust conclusions and consideration of a fair test. extra points from sections may balance omissions from others *The ideas are well structured providing significant clarity in the communication of the science.* **Level 2 (3–4 marks)** A good plan possibly with mention of sensitivity. Measurements that need taking should be described. Analysis linked to conclusions and possibly consideration of a fair test. extra points from sections may balance omissions from others *There is partial structuring of the ideas with communication of the science generally clear.* **Level 1 (1–2 marks)** A plan with discussion of measurements that need taking. Description of analysis needed linked to a conclusion. *extra points from sections may balance omissions from others The ideas are poorly structured and impede the communication of the science.*	B1	**plan P** • investigate one variable with the other fixed • oscilloscope time base can be off • do rough preliminary test over range of variable to check that there is a suitable variation in oscilloscope V • choose and fix f of *I* and value of other variable (M3); • measure e.m.f. V for 5 or 6 settings of variable from oscilloscope screen **sensitivity S** • magnitude of detected signal depends on rate of change of flux linkage / Faraday's law through search coil • so increases with f and B (N and A of search coil are fixed) • for large B use small *L* f changing N **or** large N if changing *L* **measurements M** • measure (maximum) e.m.f. V (using V/cm scale setting) on oscilloscope • measure peak to peak distance on graticule if time base not switched off • keep *L* fixed and adjust croc. clips to change N **or** keep N fixed and alter *L* (use ruler) **analysis A** • record table of V against *N* or *L* • plot graph of V against *N* or 1/ *L* **conclusions C** • straight line graph • through origin is expected • to validate given relationship **fair test F** • ensure that Slinky coils are uniformly spaced and not touching together anywhere • croc. clips make good contact at only one point on coil • plane of coil must be vertical **and** coaxial with Slinky

			Level 0 (0 marks) Insufficient relevant science.		
			Total	**6**	