1(a)(i)	(Magnetic) flux linkage **(1)** Weber /Wb (accept T m^2) **(1)**	**2**
1(a)(ii)	The (induced) e.m.f is such as to oppose the change creating it **(1)**	**1**
***1(b)(i)**	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)** There is a changing flux (linkage) **Or** magnetic field lines are cut by the coil **(1)** Inducing an e.m.f .(across the coil) **(1)** There is a current since there is a closed circuit **(1)**	**3**
1(b)(ii)	The rate of change of flux changes **(1)** as speed changes **Or** because flux density at coil changes with distance (MP2 dependent on MP1) **(1)**	**2**
1(b)(iii)	More readings in a short time **Or** increased sampling rate **(1)**	**1**
	Total for question	**9**

Question Number	Answer	Mark
2	Arrow added to diagram downwards on or near the copper rod **(1)** An indication that the field is at right angles to the page or copper rod **(1)** Magnetic field into page **(1)** (Upward arrow for current →magnetic field out of page. If no arrow on rod MP2 &3 can still be scored)	**3**
	Total for question	**3**

Question Number	Answer	Mark
3(a)	The <u>induced</u> <u>e m.f.</u> **(1)** Is equal/proportional to the rate of change of (magnetic) flux (linkage) **Or** $\varepsilon = (-)\, d(N\Phi)/\Delta t$ with symbols defined **(1)**	**2**
***3(b)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) the idea that due to the magnet moving there is a changing field around the ring **(1)** An e.m f. induced (in a closed circuit hence a current flows) **(1)** Change in direction of magnet, changes the direction of e.m.f./current **(1)** Magnitude of e.m f. (and current) depends on the rate of change of flux linkage **Or** magnitude of e m.f. (and current) depends on position/ speed of magnet **(1)**	**4**
3(c)	Use of area $A = \pi r^2$ **(1)** Use of $\varepsilon = BA/t$ **(1)** Use of $I = V/R$ **(1)** I= 4.1 A **(1)** (accept 4.1 – 4.2 A depending on where rounding is done) (candidates who use a circumference instead of an area can only score MP3) <u>Example of calculation</u> Area of coil = $\pi \times (0.05\ m)^2 = 7.9 \times 10^{-3}\ m^2$ $\varepsilon = BA/t = 0.035\ T\ s^{-1} \times 7.9 \times 10^{-3}\ m^2 = 2.8 \times 10^{-4}\ V$ $I = \varepsilon/R = 2.8 \times 10^{-4}\ V / 6.7 \times 10^{-5}\ \Omega$ I= 4.1 A	**4**
	Total for question	**10**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>4(a)(i)</td><td>Max 2
Inconsistent number of significant figures or decimal places
Or results recorded to different precision /resolution (1)
No repeat readings (1)
More readings needed up to <u>1.5</u> cm (1)</td><td>2</td></tr>
<tr><td>4(a)(ii)(1)</td><td>Attempt to use Vr= constant (1)
Correctly finds two values of Vr from values in table and makes comment
Or uses Vr value with another r or V to confirm corresponding value and makes comment (1)

<u>Example of calculation</u>

<table>
<tr><td>r/cm</td><td>V/V</td><td>rV/ cmV</td></tr>
<tr><td>1.0</td><td>0.725</td><td>0.725</td></tr>
<tr><td>1.5</td><td>0.483</td><td>0.725</td></tr>
<tr><td>2.0</td><td>0.363</td><td>0.726</td></tr>
<tr><td>2.5</td><td>0.29</td><td>0.725</td></tr>
<tr><td>3.0</td><td>0.242</td><td>0.726</td></tr>
<tr><td>3.5</td><td>0.21</td><td>0.735</td></tr>
</table></td><td>2</td></tr>
<tr><td>4(a)(ii)(2)</td><td>The graph would be a straight line graph through the origin. (1)
(accept a sketch of a straight line graph going through the origin graph)</td><td>1</td></tr>
<tr><td>4(b)(i)</td><td>An e.m.f. is (induced) when there is a changing (magnetic) field/flux. (1)

Because the <u>current</u> is constant there is a constant magnetic field. Or Because the <u>current</u> is constant there isn’t a changing magnetic field. (1)</td><td>2</td></tr>
<tr><td>4(b)(ii)</td><td>Movement of either the coil or the wire (1)
Use an alternating current/signal/supply/AC (1)
Switch the current on/off Or change current e.g. use of variable resistor (1)</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td>10</td></tr>
</table>

Question Number	Answer		Mark
***5(a**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) A clear statement that an alternating/changing current produces an alternating/changing <u>magnetic</u> field/flux Reference to the iron core becomes magnetised **Or** increases magnetic field the idea that the field produced in the core/wire is linked to the coil (e.m.f. produced) due to EM induction **Or** reference to induced e.m.f. **Or** Faraday's law in words (do not accept induced current/voltage on its own) [be careful not to credit the random use of words/phrases like, there is flux linkage, flux cutting takes place or the field lines are cut by the coil. Also watch out for candidates who think there is a current in the coil creating the flux linkage]	**(1)** **(1)** **(1)** **(1)**	**4**
5(b)	(Constant current means) no change of flux (linkage) **Or** no changing (magnetic) field **Or** flux/ field is constant [do not credit 'flux won't be changing direction' or 'no flux linkage being cut' or alternating]	**(1)**	
5(c)	More than one wire in cable Cable carries current in both directions **Or** <u>Magnetic</u> fields will cancel	**(1)** **(1)**	**2**
5(d)(i)	The larger the current the greater the (magnetic) flux/field (produced) **Or** the larger the change in current the larger the change in the (magnetic) flux/field gives a greater rate of change of flux **Or** bigger change in flux in the same time **Or** a greater (induced) e.m.f./voltage/reading	**(1)** **(1)**	**2**
5(d)(ii)	the idea that frequency changes the value of (induced) e.m.f/voltage/reading **Or** the idea that the frequency changes the rate of change of (magnetic)flux An understanding that there are now two factors (current and frequency) altering (induced) e.m.f/voltage/reading.	**(1)** **(1)**	**2**
	Total for question		**11**

Question Number	Answer	Mark
6(a)(i)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate there is a magnetic field in stator/(iron) core **Or** the core becomes an electromagnet **(1)** This field/flux is changing (due to the AC input) **(1)** *B* field (from the stator) passes through the rotor **(1)** (the changing magnetic flux/field leads to an) induced emf/pd **(1)**	**4**
6(a(ii)	Rotor experiences a force **Or** mention of FLHR **Or** $F = BIl$ **(1)** Due to the current in the **rotor** being in a magnetic field **Or** rotor becomes a magnet **(1)**	**2**
6(a)(iii)	**Max 2** Increase frequency (of current) **(1)** Increase (magnitude of) current **(1)** Add more turns (to either coil) **(1)**	**2**
6(b)(i)	T = 60/33(1,82 s) **Or** f =33/60 (0.55 s^{-1}) **(1)** Use of $\omega = 2\pi/T$ **Or** $w = 2\pi/f$ **(1)** ω= 3.5 rad s^{-1} **(1)** [11.4 rad s^{-1} scores 1; 3.2 x 10^{-3} rad s^{-1} scores 1; 11 π/10 rad s^{-1} scores 2] Example of calculation $\omega = (33 \times 2\pi)/ 60$ s ω= 3.5 rad s^{-1}	**3**
6(b)(ii)	Use of $a = r\omega^2$ **(1)** a = 1.5 ms^{-2} [allow ecf from (b)(i)] **(1)** [11.4 rad s^{-1} gives 16 m s^{-2}] Example of calculation $a = (0.125 \text{ m}) \times (3.5 \text{ rad s}^{-1})^2$ a = 1.5 m s^{-2}	**2**
	Total for question	**13**

Question Number	Answer	Mark
7(a)	(Magnetic) Flux linkage	**(1)** **(1)**
7(b)	QWC (i and iii) – spelling of technical terms must be correct and the answer must be organised in a logical sequence Lenz's law / conservation of energy induced current/emf (direction) Opposes the change (that produced it)	 **(1)** **(1)** **(1)**
	Total for question	**5**