<table>
<thead>
<tr>
<th>Question Number</th>
<th>Answer</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)(i)</td>
<td>(Magnetic) flux linkage&lt;br&gt;Weber /Wb (accept T m² )</td>
<td>2</td>
</tr>
<tr>
<td>1(a)(ii)</td>
<td>The (induced) e.m.f is such as to oppose the change creating it</td>
<td></td>
</tr>
<tr>
<td>*1(b)(i)</td>
<td><strong>QWC – work must be clear and organised in a logical manner using</strong>&lt;br&gt;<strong>technical terminology where appropriate</strong>&lt;br&gt;There is a changing flux (linkage) Or magnetic field lines are cut by the coil Inducing an e.m.f. (across the coil) There is a current since there is a closed circuit</td>
<td>3</td>
</tr>
<tr>
<td>1(b)(ii)</td>
<td>The rate of change of flux changes&lt;br&gt;as speed changes Or because flux density at coil changes with distance (MP2 dependent on MP1)</td>
<td>2</td>
</tr>
<tr>
<td>1(b)(iii)</td>
<td>More readings in a short time Or increased sampling rate</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total for question</strong></td>
<td></td>
<td>9</td>
</tr>
</tbody>
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<tr>
<td>2</td>
<td>Arrow added to diagram downwards on or near the copper rod&lt;br&gt;An indication that the field is at right angles to the page or copper rod Magnetic field into page (Upward arrow for current →magnetic field out of page. If no arrow on rod MP2 &amp;3 can still be scored)</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total for question</strong></td>
<td></td>
<td>3</td>
</tr>
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<tr>
<td>3(a)</td>
<td>The induced e.m.f. is equal/proportional to the rate of change of (magnetic) flux (linkage). Or $\varepsilon = (-) \frac{d(N\Phi)}{\Delta t}$ with symbols defined.</td>
<td>1</td>
</tr>
<tr>
<td>3(b)</td>
<td>(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. An e.m.f. induced (in a closed circuit hence a current flows). Change in direction of magnet, changes the direction of e.m.f./current. 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.</td>
<td>1</td>
</tr>
<tr>
<td>3(c)</td>
<td>Use of area $A = \pi r^2$. Use of $\varepsilon = BA/t$. Use of $I = V/R$. $I= 4.1$ A (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) Example of calculation: Area of coil $= \pi \times (0.05 \text{ m})^2 = 7.9 \times 10^{-3} \text{ m}^2$ $\varepsilon = BA/t = 0.035 \text{ T s}^{-1} \times 7.9 \times 10^{-3} \text{ m}^2 = 2.8 \times 10^{-4} \text{ V}$ $I = \varepsilon/R = 2.8 \times 10^{-4} \text{ V} / 6.7 \times 10^{-5} \Omega$ $I= 4.1$ A</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total for question**: 10
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</table>
| **4(a)(i)**     | **Max 2**  
Inconsistent number of significant figures or decimal places  
Or results recorded to different precision /resolution  
No repeat readings  
More readings needed up to 1.5 cm | (1)  
(1)  
(1)  
2 |
| **4(a)(ii)(1)** | Attempt to use \(Vr=\text{constant}\)  
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)  
2 |

**Example of calculation**

<table>
<thead>
<tr>
<th>(r/\text{cm})</th>
<th>(V/\text{V})</th>
<th>(rV/\text{cmV})</th>
</tr>
</thead>
<tbody>
<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>
<tr>
<td>4(a)(ii)(2)</td>
<td>The graph would be a straight line graph through the origin. (accept a sketch of a straight line graph going through the origin graph)</td>
<td>(1) 1</td>
</tr>
</tbody>
</table>
| **4(b)(i)**     | An e.m.f. is (induced) when there is a changing (magnetic) field/flux.  
Because the \(\text{current}\) is constant there is a constant magnetic field. Or Because the \(\text{current}\) is constant there isn’t a changing magnetic field. | (1)  
2 |
| **4(b)(ii)**    | Movement of either the coil or the wire  
Use an alternating current/signal/supply/AC  
Switch the current on/off Or change current e.g. use of variable resistor | (1)  
(1)  
(1) 3 |

**Total for question** 10
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<tr>
<td>*5(a)</td>
<td><em>(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)</em>  &lt;br&gt; A clear statement that an alternating/changing current produces an alternating/changing magnetic field/flux  &lt;br&gt; Reference to the iron core becomes magnetised <em>Or</em> increases magnetic field  &lt;br&gt; the idea that the field produced in the core/wire is linked to the coil  &lt;br&gt; *(e.m.f. produced) due to EM induction <em>Or</em> reference to induced e.m.f. <em>Or</em> Faraday's law in words (do not accept induced current/voltage on its own)  &lt;br&gt; <em>[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]</em></td>
<td>4</td>
</tr>
<tr>
<td>5(b)</td>
<td><em>(Constant current means) no change of flux (linkage) <em>Or</em> no changing (magnetic) field <em>Or</em> flux/field is constant [do not credit 'flux won't be changing direction' or 'no flux linkage being cut' or alternating]</em></td>
<td>1</td>
</tr>
<tr>
<td>5(c)</td>
<td>More than one wire in cable  &lt;br&gt; cable carries current in both directions <em>Or</em> Magnetic fields will cancel</td>
<td>2</td>
</tr>
<tr>
<td>5(d)(i)</td>
<td>The larger the current the greater the (magnetic) flux/field (produced) <em>Or</em> the larger the change in current the larger the change in the (magnetic) flux/field  &lt;br&gt; gives a greater rate of change of flux <em>Or</em> bigger change in flux in the same time <em>Or</em> a greater (induced) e.m.f./voltage/reading</td>
<td>2</td>
</tr>
<tr>
<td>5(d)(ii)</td>
<td>the idea that frequency changes the value of (induced) e.m.f/voltage/reading <em>Or</em> the idea that the frequency changes the rate of change of (magnetic) flux  &lt;br&gt; An understanding that there are now two factors (current and frequency) altering (induced) e.m.f/voltage/reading.</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total for question</strong></td>
<td></td>
<td><strong>11</strong></td>
</tr>
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| 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  
This field/flux is changing (due to the AC input)  
*B* field (from the stator) passes through the rotor  
(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* = *B*Il  
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)  
Increase (magnitude of) current  
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))  
Use of *ω* = 2π/T Or *w* = 2π/*f*  
*ω* = 3.5 rad s⁻¹ Or use of *ω* = 3.5 rad s⁻¹ | (1) 3 |
|                 | [11.4 rad s⁻¹ scores 1; 3.2 x 10⁻³ rad s⁻¹ scores 1; 11π/10 rad s⁻¹ scores 2]  
Example of calculation  
*ω* = (33 × 2π)/ 60 s  
*ω* = 3.5 rad s⁻¹ | |
| 6(b)(ii)        | Use of *a* = *ro*²  
*a* = 1.5 ms⁻² [allow ecf from (b)(i)]  
[11.4 rad s⁻¹ gives 16 m s⁻²]  
Example of calculation  
*a* = (0.125 m) × (3.5 rad s⁻¹)²  
*a* = 1.5 m s⁻² | (1) 2 |
<p>| <strong>Total for question</strong> | | 13 |</p>
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<tr>
<td>7(a)</td>
<td>(Magnetic) Flux linkage</td>
<td>(1)</td>
</tr>
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| 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)  |

**Total for question** 5