| Question | Answer | Marks |
|---|---|---|
| 1 | **Defining the problem** | |
| | *x* is the independent variable and *V* is the dependent variable **or** vary *x* and measure *V* | **1** |
| | keep <u>current</u> (in the coil P) <u>constant</u> | **1** |
| | **Methods of data collection** | |
| | labelled diagram showing both coils supported | **1** |
| | two correct circuit diagrams for coil P <u>and</u> coil Q:<br>power supply connected to one coil <u>and</u> voltmeter/c.r.o. connected to other coil | **1** |
| | method to determine *x*, e.g. use a ruler or drawn labelled horizontal ruler adjacent to coils <u>with *x* indicated</u> | **1** |
| | method to measure *x* from centre of coil P to centre of coil Q, e.g. measure width of (each) coil and divide by 2 and add to separation of coils | **1** |
| | **Method of analysis** | |
| | plots a graph of ln *V* against *x* [or log *V* against *x* etc.] | **1** |
| | relationship valid if a straight line produced | **1** |
| | *k* = –gradient | **1** |

| Question | Answer | Marks |
|---|---|---|
| | **Additional detail including safety considerations** | **Max. 6** |
| | D1 do not touch hot coil/use gloves to position hot coil/heat-proof gloves to position coil | |
| | D2 use large current/number of turns/iron core (to produce large magnetic field/induced e.m.f.) | |
| | D3 use high frequency (to produce larger induced e.m.f.) | |
| | D4 use an a.c. power supply or signal generator (connected to coil P) | |
| | D5 keep the number of turns (on each coil) constant/frequency constant | |
| | D6 method described to check that current is constant, e.g. use an ammeter and variable resistor/variable power supply | |
| | D7 repeat measurements of *x* for different parts of the coil and average | |
| | D8 method to position ruler horizontally to measure *x* described e.g. use a spirit level or same height from bench at both ends | |
| | D9 method to keep coils parallel/co-axial e.g. adjust coil Q until maximum reading or use set square to ensure that coils are at right angles to the axis | |
| | D10 $\ln V = -kx + \ln V_0$ | |

**2 Planning (15 marks)**

**Defining the problem (3 marks)**

P1 *f* is the independent variable and *V* is the dependent variable or vary *f* and measure *V* [1]
P2 Keep the current in coil X constant [1]
P3 Keep the number of turns on coil (Y)/area of coil Y constant
Do not credit reference to coil X only. [1]

**Methods of data collection (5 marks)**

M1 Two independent coils labelled X and Y. [1]
M2 Alternating power supply/signal generator connected to coil X in a workable circuit. [1]
M3 Coil Y connected to voltmeter/c.r.o. in a workable circuit. [1]
M4 Use c.r.o. to determine period/frequency or read off signal generator. [1]
M5 Method to keep current constant in coil X: adjust signal generator/use of rheostat. [1]

**Method of analysis (2 marks)**

A1 Plot a graph of *V* against *f*. [1]
A2 Relationship valid if straight line through origin [1]

**Safety considerations (1 mark)**

S1 Reference to hot coils – switch off when not in use/use gloves/do not touch coils. Must refer to hot coils. [1]

**Additional detail (4 marks)**

D1/2/3/4 Relevant points might include [4]

1. Use large current in coil X/large number of coils on coil Y (to increase emf).
2. Use iron core (to increase emf).
3. Detail on measuring emf e.g. height × *y*-gain.
4. Avoid other alternating magnetic fields.
5. Detail on measuring frequency from c.r.o. to determine period and hence *f*.
6. Use of ammeter/c.r.o. and resistor to check current is constant
7. Use insulated wire for coils.
8. Keep coil Y and coil X in the same relative positions.

Do not allow vague computer methods.

**[Total: 15]**

**3 Planning (15 marks)**

**Defining the problem (3 marks)**

P *v* is the independent variable or vary *v.* [1]

P *E* is the dependent variable or measure *E.* [1]

P Keep the number of turns on the coil constant. [1]

**Methods of data collection (5 marks)**

M1 Labelled diagram showing magnet falling vertically through coil. [1]

M2 Voltmeter or c.r.o. connected to the coil. Allow voltage sensor connected to datalogger. [1]

M3 Method to change speed e.g. change height. [1]

M4 Measurements to determine *v*. Use metre rule to measure distance magnet falls to the bottom of the coil or metre rule/ruler to measure length of coil or ruler to measure length of the magnet. [Allow timing instrument to measure the time of the fall from the start to the bottom of the coil.] [1]

M5 Method of determining *v* corresponding to appropriate distance e.g. $v = \sqrt{2gh}$ or $v=2h/t$ (for height method) or $v = L/t$ for length of magnet or coil and by stopwatch, timer or lightgate(s) connected to datalogger. [Allow $v = gt$ for timing fall to bottom of coil.] [1]

**Method of analysis (2 marks)**
A Plot a graph of *E* against *v*. [Allow lg *E* against lg *v*] [1]

A Relationship valid if straight line through origin. [1]
[If lg-lg then straight line with gradient = (+)1 (ignore reference to *y*-intercept)]

**Safety considerations (1 mark)**
S Keep away from falling magnet/use sand tray/cushion to catch magnet. [1]

**Additional detail (4 marks)**
D1/2/3/4 Relevant points might include [4]
Use coil with large number of turns/drop magnet from large heights/strong magnet
1 Detailed use of datalogger/storage oscilloscope to determine maximum *E*; allow video camera including slow motion play back
2 Use same magnet or magnet of same strength.
3 Use of short magnet so that *v* is (nearly) constant
4 Use short/thin coil so that *v* is (nearly) constant
5 Use a non-metallic vertical guide/tube
6 Method to support vertical coil or guide/tube
7 Repeat experiment for each *v* and average

Do not allow vague computer methods.

**[Total: 15]**

**4 Planning (15 marks)**

**Defining the problem (3 marks)**

P *t* is the independent variable or vary *t*. [1]

P *V* is the dependent variable or measure *V*. [1]

P Keep the current (in the primary coil) constant. [1]

**Methods of data collection (5 marks)**

M Diagram showing two independent labelled coils wound on iron cores. [1]

M AC power supply / signal generator connected to one coil. [1]

M Voltmeter / oscilloscope connected to other coil in a workable circuit. [1]

M Measure thickness of card using micrometer / vernier calipers / digital calipers. [1]

M Method to keep current constant – rheostat (or variable power supply) and ammeter correctly positioned in primary circuit and explained. Diagram and text required. [1]

**Method of analysis (2 marks)**

M Plot a graph of ln *V* against *t* (allow lg *V* against *t*) or ln $V/V_0$ against *t* [1]

M $\sigma = -$gradient [1]

**Safety considerations (1 mark)**

S Precaution linked to hot coil(s) e.g. switch off when not in use / do not touch / wear gloves. [1]

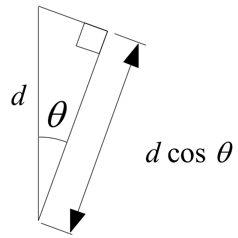
**Additional detail (4 marks)**

D Relevant points might include [4]

1 Use large current (in primary coil)/large number of turns on the secondary to achieve measurable *V* (allow more turns on secondary than primary).
2 Keep frequency of power supply constant or keep the number of turns on each coil constant.
3 Use laminated cores or use insulated wire for turns.
4 Repeat measurements of *t* and average.
5 Measurement of $V_0$ stating that no card is present.
6 Logarithmic equation: $\ln V = \ln V_0 - \sigma t$
7 Relationship is valid if the graph is a straight line with *y*–intercept = $\ln V_0$
8 Discussion of compression of card / measure *t* when secured.

Do not allow vague computer methods.

**[Total: 15]**

<table>
<tr><th>Question</th><th>Answers</th><th>Additional Comments/Guidance</th><th>Mark</th></tr>
<tr><td>01.1</td><td>period determined from at least 4 cycles, in range 3.8(0) to 5.0(0) × $10^{-4}$ s ✓<br>frequency $= \frac{1}{\text{period}}$ in range 2300 ± 300 Hz ✓</td><td>accept 2 sf period, 2.3 × $10^3$ Hz</td><td>2</td></tr>
<tr><td>01.2</td><td>peak to peak voltage = 6.8 divisions seen ✓<br>rms voltage = 24 mV ✓</td><td>accept 24.0 or 24.1 mV</td><td>2</td></tr>
<tr><td>01.3</td><td>flux linked with the search coil depends on the <u>area</u> of coil presented $_1$✓<br>area is proportional to $d \cos\theta$ $_2$✓<br><br>[flux linked with the search coil depends on component of B perpendicular to the plane of the coil $_1$✓<br>component is prop $B \cos\theta$, or suitable sketch] $_2$✓</td><td>for $_1$✓ accept $N\phi = BA$<br>for $_2$✓ accept evidence in sketch, eg<br>
</td><td>2</td></tr>
<tr><td>01.4</td><td>six correctly calculated values of cos $\theta$; accept all to 3 sf or all to 4 sf $_1$✓<br>axes labelled, correct separator and unit with $l$, suitable scales $_2$✓<br>plots correct to half a square (check at least one) $_3$✓<br>ruled straight line extrapolated to meet either or both axes $_4$✓<br>[for false plot allow $_2$✓ and $_4$✓ = 2 MAX]</td><td><table><tr><th>$\theta$/°</th><th>$l$/cm</th><th>cos □</th></tr><tr><td>10</td><td>6.7</td><td>0.985</td></tr><tr><td>34</td><td>5.6</td><td>0.829</td></tr><tr><td>50</td><td>4.4</td><td>0.643</td></tr><tr><td>60</td><td>3.4</td><td>0.500</td></tr><tr><td>72</td><td>2.1</td><td>0.309</td></tr><tr><td>81</td><td>1.1</td><td>0.156</td></tr></table></td><td>4</td></tr>
</table>

| | | | |
|---|---|---|---|
| 01.5 | direct proportionality is confirmed since graph is a straight line with zero [negligible] intercept ✓<br>[allow ecf for false plot] | must refer to intercept | 1 |
| 01.6 | idea of repositioning trace $_1$✓<br>(to reposition the trace) so that an end of the line is aligned with [close to] a (horizontal) graduation $_2$✓<br>(to reposition the trace) so that the line is aligned with the <u>central</u> (vertical) graduation on the screen $_3$✓<br>associates *y*-shift and *x*-shift correctly with trace change $_4$✓ | accept clear marks on Fig 7 for all except 4th point<br><br>allow alignment with graduation (can be major or minor) of either end of the line for $_2$✓ | 4 |
| 01.7 | adjust *y*-voltage gain to a less sensitive [precise] setting [20 mV $cm^{-1}$] ✓<br>since *I* is increased beyond the range of the screen [vertical length of trace is too great] ✓<br>because induced emf is proportional to rate of change of flux linkage [or quotes Faraday's Law] ✓<br>and rate of change of flux linkage is doubled [same flux change in half the time] ✓ | accept 'reduce Y gain' but reject 'use lower Y gain setting'<br><br>no credit for suggestions that time-base setting should be changed<br><br>answer without quantitative detail 2 MAX | 3 MAX |
| 01.8 | evidence of suitable test employed to test whether curve shows exponential decrease, eg valid measurement of half life over more than one region $_1$✓<br>states that trend is not exponential $_2$✓ | cannot earn $_2$✓ without valid $_1$✓ | 2 |

Q2.

| Question Number | Acceptable answers | | Additional guidance | Mark |
|---|---|---|---|---|
| | • The relationship between $\omega$ and turning effect is (approximately) proportional | **(1)** | Accept attempt to find a constant ratio and relevant conclusion | **4** |
| | • As speed increases rate of change/cut of magnetic flux increases | **(1)** | Accept alternatives to flux | |
| | • this increases the induced current in the copper disc | **(1)** | accept ref. to emf rather than current | |
| | • this will lead to an increase in force (on the copper disc as it is within a magnetic field/flux) | **(1)** | Dependent on MP2 or 3 | |

Q3.

| Question Number | Acceptable answers | | Additional guidance | Mark |
|---|---|---|---|---|
| **(i)** | • change in magnetic flux (linkage as motor rotates) **Or** (copper disc is) cutting magnetic flux/field<br>• therefore there is an <u>induced</u> <u>e.m.f.</u> (according to Faraday's law) | **(1)**<br>**(1)** | Accept flux linkage for magnetic flux | **2** |
| **(ii)** | • copper disc rotates in the same direction<br>• because it reduces the rate of magnetic flux change<br>• so as to oppose the change that produces it | **(1)**<br>**(1)**<br>**(1)** | Accept induced current produces magnetic fields **Or** force on current in a magnetic field for MP2<br>Accept alternatives to flux as in (i) | **3** |

Q4.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.<br><br>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br><br>The following table shows how the marks should be awarded for indicative content.<br><br>Indicative content:<ul><li>(Maximum/Initial) current is equal to battery emf divided by R<br>Or current as switch closed<br>Or current as complete circuit<br>Or current due to battery</li><li>Coil rotates</li><li>(movement of) coil "cuts/changes" (magnetic) flux (linkage) / field</li><li>Which induces an emf (according to Faraday's law)</li><li>Opposes original emf/current according to Lenz's law<br>Or current reduced as effect opposes change</li><li>The faster the coil rotates the larger this (back) emf/effect the smaller the current</li></ul></td><td><table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table><br><br>ic3 needs a link to coil moving<br>ic4 depends on ic3</td><td>6</td></tr>
</table>

Q5.

| Question Number | Acceptable Answer | Additional Guidance | Mark |
|---|---|---|---|
| (i) | • Use of $F = BQv$ and $F = EQ$ (1)<br>• Algebra to show $v = \frac{E}{B}$ (1) | | 2 |
| (ii) | • Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ (1)<br>• Use of $v = \frac{E}{B}$ (1)<br>• $\frac{e}{m}$=1.7×10$^{11}$C kg$^{-1}$ (1) | Example of calculation:<br>$v = \frac{E}{B} = \frac{1.4 \times 10^4 \text{ V m}^{-1}}{1.5 \times 10^{-3} \text{ T}}$   $\frac{e}{m} = \frac{v^2}{2V}$<br>$\frac{e}{m} = \frac{(9.33 \times 10^6 \text{ m s}^{-1})^2}{2 \times 250 \text{ V}} = 1.74 \times 10^{11} \text{ C kg}^{-1}$ | 3 |

Q6.

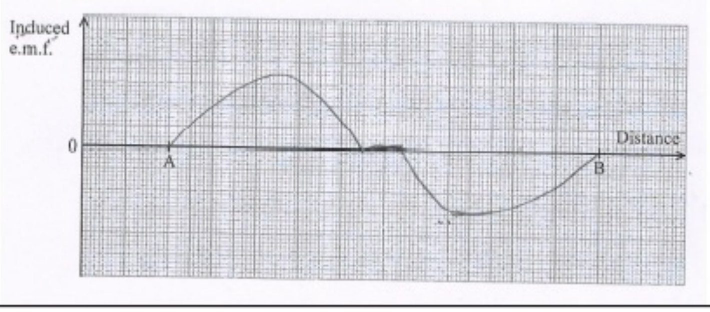
| Question Number | Acceptable answers | Additional guidance | Mark |
|---|---|---|---|
| * | This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.<br><br>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br><br>The following table shows how the marks should be awarded for indicative content.<br><br>Indicative content:<br>Generator:<br>• coil has to be rotated<br>• cuts magnetic flux **Or** rate of change of flux linkage<br>• induces an emf<br><br>Motor:<br>• current provided to coil<br>• Force on sides of coil that are perpendicular to magnetic field<br>• rotate coil as forces provide a moment | (see table below) | 6 |

| IC points | IC mark | Max linkage mark available | Max final mark |
|---|---|---|---|
| **6** | 4 | 2 | **6** |
| **5** | 3 | 2 | **5** |
| **4** | 3 | 1 | **4** |
| **3** | 2 | 1 | **3** |
| **2** | 2 | 0 | **2** |
| **1** | 1 | 0 | **1** |
| **0** | 0 | 0 | **0** |

Q7.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.<br>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.<br>The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content:
<ul>
<li>As magnet A moves, its coil experiences a change of magnetic <u>flux</u> (linkage)</li>
<li>The change in magnetic flux linkage <u>induces an emf</u> in the coil</li>
<li>The (induced) emf causes a current in both coils</li>
<li>The current in the second coil causes a force to act on magnet B,<br>driving magnet B into oscillation</li>
<li>Because both mass-spring systems have the same period/frequency</li>
<li>Resonance occurs (and magnet B oscillates with increasing amplitude)</li>
</ul>
</td>
<td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
Linkage Marks<br><br>IC points 1 – 4<br>Three of these points could score one linkage mark<br><br>IC points 5 & 6 could score one linkage mark</td>
<td>6</td>
</tr>
</table>

Q8.

| Question Number | Answer | | Mark |
|---|---|---|---|
| *(a) | (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)<br>**Max 6 from**<br>Reference to changing/cutting of field/flux | (1) | |
| | Induced e.m.f. proportional to rate of change/cutting of flux (linkage)<br>(accept equation) | (1) | |
| | Initial increase in e.m.f. as the magnet gets closer to the coil | (1) | |
| | Identifies region of negative gradient with magnet going through the coil | (1) | |
| | Indication that magnet's speed increases as it falls | (1) | |
| | Negative (max) value › positive (max) value<br>(this mark is dependent on awarding marking point 5) | (1) | |
| | Time for second pulse shorter<br>(this mark is dependent on awarding marking point 5) | (1) | |
| | The areas of the two parts of the graph will be the same (since Nφ constant) | (1) | 6 |
| (b) | Two sequential pulses<br>(if **not** two sequential pulses, scores zero)<br>Pulses same height (+/- 3 mm squares) and width (by eye)<br>Pulses in opposite directions<br>Region of zero e.m.f. in the middle | (1)<br><br>(1)<br>(1)<br>(1) | 4 |
| | <u>Example</u> (peaks could be in opposite directions)<br> | | |

Q9.

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>Max 2<br>Inconsistent number of significant figures or decimal places<br>Or results recorded to different precision /resolution<br>No repeat readings<br>More readings needed up to 1.5 cm</td><td><br><br>(1)<br>(1)<br>(1)</td><td>2</td></tr>
<tr><td>(a)(ii)(1)</td><td>Attempt to use $Vr$= constant<br>Correctly finds two values of $Vr$ from values in table and makes comment<br>Or uses $Vr$ value with another $r$ or $V$ to confirm corresponding value and makes comment<br><br>Example of calculation<br>
<table>
<tr><th>$r$/cm</th><th>$V$/V</th><th>$rV$/ cmV</th></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>(1)<br><br><br>(1)</td><td>2</td></tr>
<tr><td>(a)(ii)(2)</td><td>The graph would be a straight line graph through the origin.<br>(accept a sketch of a straight line graph going through the origin graph)</td><td>(1)</td><td>1</td></tr>
<tr><td>(b)(i)</td><td>An e.m.f. is (induced) when there is a changing (magnetic) field/flux.<br><br>Because the current is constant there is a constant magnetic field. Or Because the current is constant there isn't a changing magnetic field.</td><td>(1)<br><br><br>(1)</td><td>2</td></tr>
<tr><td>(b)(ii)</td><td>Movement of either the coil or the wire<br>Use an alternating current/signal/supply/AC<br>Switch the current on/off Or change current e.g. use of variable resistor</td><td>(1)<br>(1)<br>(1)</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td></td><td>10</td></tr>
</table>