7(a)	(induced) e.m.f. is (directly) proportional to rate
	of change of (magnetic) flux (linkage)
7(b)(i)	flux = e.m.f. × time
	flux = 0.54 × 15 = 8.1 Wb
7(b)(ii)	$\Phi = BA$
	area = 8.1 / (38 × 10^{-6}) = 2.1 × 10^{5} m^{2}
7(b)(iii)	area = speed × time × width
	v = (2.1 × 10^{5}) / (15 × 68) = 210 m s^{-1}
7(b)(iv)	opposing force (due to current in wings) must be backwards
	from Fleming's left-hand rule, current (in wings) must be from Q to P
	current is from – to + inside an e.m.f. source so P is at higher potential

6(a)(i)	$F = BIL$
	force on QR = 5.2 × 10^{-3} × 1.2 × 0.054 × 190
	= 0.064 N
6(a)(ii)	torque = force × perpendicular distance between forces
	= 0.064 × 0.025 cos θ = (1.6 × 10^{-3}) cos θ N m
6(a)(iii)	one complete cycle of a sinusoidal curve between 0 and 360°
	τ axis labelled to show maximum and minimum torques at ± 1.6 × 10^{-3} N m
	maximum at 0 and 360° and minimum at 180° (or vice versa), with torque shown as zero at 90° and 270°
6(b)	(ferrous core) increases magnetic flux density
	amplitude of torque increases

1	**Defining the problem**
	vary f and measure V **or** f is the independent variable and V is the dependent variable
	keep E <u>constant</u>
	Methods of data collection
	labelled diagram of workable experiment including: • circuit with a.c. supply • oscilloscope connected in parallel with the resistor • workable circuit • oscilloscope and a.c. supply labelled
	labelled signal generator or <u>variable frequency</u> power supply connected across the terminals
	method to determine V or E from oscilloscope, e.g. multiply amplitude / height of wave by y-gain on oscilloscope
	method to determine f from oscilloscope, e.g. determine period T by multiplying number of divisions in 1 cycle or horizontal distance in 1 cycle by the time base **and** $f = 1/T$
	Method of Analysis
	plot a graph of $\frac{1}{V}$ against f or equivalent, e.g. f against $\frac{1}{V}$ Allow logarithms e.g. lg V against lg f.
	relationship valid <u>if</u> a straight line is produced <u>passing through the origin</u> (for lg V against lg f: relationship valid <u>if</u> a straight line is produced with <u>gradient = −1</u>)

1

$\frac{1}{V}$ against f	f against $\frac{1}{V}$
$K = \frac{lES}{AN^2} \times \text{gradient}$	$K = \frac{lES}{AN^2} \times \frac{1}{\text{gradient}}$

(for lg V against lg f: $K = \frac{ElS}{AN^2} \times 10^{-y\text{-intercept}}$).

	Additional detail including safety considerations
	D1 precaution linked to <u>hot coil</u> or <u>hot resistor</u> or prevention of <u>burns</u> from <u>coil</u> or <u>resistor</u>, e.g. use gloves / switch off power supply when not measuring V to prevent burns from coil / resistor
	D2 keep N **and** A **and** l **and** S <u>constant</u>
	D3 method to keep S constant, e.g. switch off power supply between readings to prevent heating of resistor or to allow resistor to cool
	D4 method to determine A, e.g. use calipers / micrometer to measure diameter (of coil) / d **and** $A = \frac{\pi d^2}{4}$
	D5 repeat measurements of diameter d along the length of the coil / in different directions **and** determine the average value of d
	D6 method to determine the value of S, e.g. separate circuit diagram showing resistor connected to ohmmeter, or circuit diagram showing resistor connected to a power supply with an ammeter and voltmeter **and** $S = V / I$
	D7 measure l with a ruler / calipers
	D8 oscilloscope drawn connected across terminals / across signal generator **and** description to determine E
	D9 adjust y-gain for maximum amplitude **or** adjust time base for length of one wave or measure n waves and divide measured time by n
1	D10 method to keep E constant, e.g. check p.d. and alter supply **or** method to keep l constant, e.g. tape coil **or** method to keep A constant, e.g. wind wire on a cylinder

1	**Defining the problem**
	Vary p and measure B OR p is the independent variable and B is the dependent variable.
	Keep V <u>constant</u> or potential difference between the ends of each conductor <u>constant</u>.
	Methods of data collection
	Labelled diagram of workable experiment including: • conductors in parallel connected in series to power supply and resistor • circuit symbols for (variable) resistor and power supply • X labelled and one other label from L, P, Q, p and q.
	Voltmeter connected in parallel with conductors (to measure V) and conductors in parallel connected to a power supply.
	Method to measure L **and** p **and** q e.g. use a rule / ruler / calipers.
	Method to measure B, e.g. use a (calibrated) Hall probe **and** adjust / rotate probe until <u>maximum</u> value.
	Method of Analysis
	Plots a graph of B against $\frac{1}{p}$ or equivalent. Do not accept logarithms.
	<table><tr><td>B against $\frac{1}{p}$</td><td>$\frac{1}{p}$ against B</td></tr><tr><td>$Y = \frac{L \times \text{gradient}}{AV}$</td><td>$Y = \frac{L}{AV \times \text{gradient}}$</td></tr></table>
1	<table><tr><td>B against $\frac{1}{p}$</td><td>$\frac{1}{p}$ against B</td></tr><tr><td>$Z = \frac{q \times y\text{-intercept}}{\text{gradient}}$ OR $Z = \frac{Lq \times y\text{-intercept}}{YAV}$</td><td>$Z = -q \times y\text{-intercept}$</td></tr></table>
	Additional detail including safety considerations Any **six** from:
	D1 precaution linked to <u>high current</u> / <u>hot conductors</u>, e.g. use gloves / switch off power supply when not measuring B / between measurements / allow conductors to cool
	D2 keep A **and** L **and** q constant
	D3 use calipers / micrometer to measure diameter / d of conductor **and** $A = \frac{\pi d^2}{4}$
	D4 repeat measurements of d <u>in different positions</u> **and** <u>average</u> d
	D5 method to determine the position of X in relation to the conductors, e.g. divide L by two to find the midpoint of P / Q **and** use a set square / protractor / plumb line to mark X OR divide L by two to find the midpoint of P / Q **and** use a grid to mark X
	D6 measure B (using Hall probe) first in one direction and then in the opposite direction and average B OR Measure B with current / p.d. in one direction and then in the opposite direction and average B
	D7 additional detail on measuring p and / or q, e.g. measure to the conductor and add on the radius

1	D8 description of method to keep q constant, e.g. tape / adhesive putty to fix conductor Q to the bench OR for vertical methods fix conductor Q in clamp(s) attached to stand(s) to keep q constant
	D9 method to keep P and Q parallel, e.g. measure the separation (between the conductors) at different points
	D10 relationship valid <u>if</u> a straight line is produced (with a y-intercept = $\frac{YZAV}{Lq}$). Do not accept passing through the origin.
	D11 method to keep V constant, e.g. adjust / change variable resistor / power supply to keep voltmeter reading constant.