National
Qualifications
2019

2019 Engineering Science

Advanced Higher

Finalised Marking Instructions

General marking principles for Advanced Higher Engineering Science

Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

(b) If a candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(c) Where a candidate makes an error at an early stage in a multi-stage calculation, award marks for correct follow-on working in subsequent stages. Do not award marks if the error significantly reduces the complexity of the remaining stages. Apply the same principle in questions which require several stages of non-mathematical reasoning.

(d) SQA presents all units of measurement in a consistent way, using negative indices where required (for example ms^{-1}). Candidates can respond using this format, or solidus format (m/s), or words (metres per second), or any combination of these (for example metres/second).

(e) For numerical questions, candidates should round their answers to an appropriate number of significant figures. However, award marks if their answer has up to two figures more or one figure less than the expected answer.

(f) Unless a numerical question specifically requires candidates to show evidence of their working, award full marks for a correct final answer (including unit) on its own.

(g) Award marks where a labelled diagram or sketch conveys clearly and correctly the response required by the question.

(h) Award marks regardless of spelling if the meaning is unambiguous.

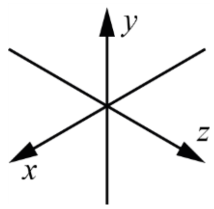
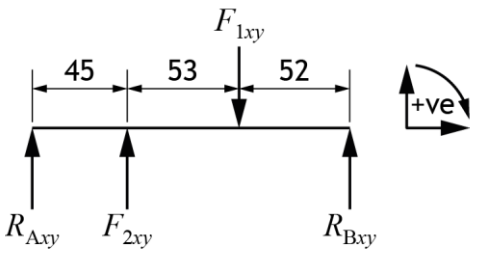
(i) Candidates can answer programming questions in any appropriate programming language. Award marks where the intention of the coding is clear, even where there are minor syntax errors.

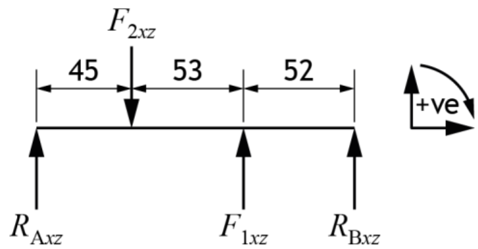
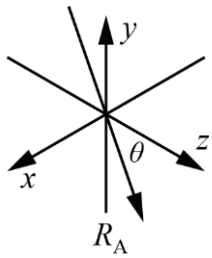
(j) For 'Explain' questions, only award marks where the candidate goes beyond a description, for example by giving a reason, or relating cause to effect, or providing a relationship between two aspects.

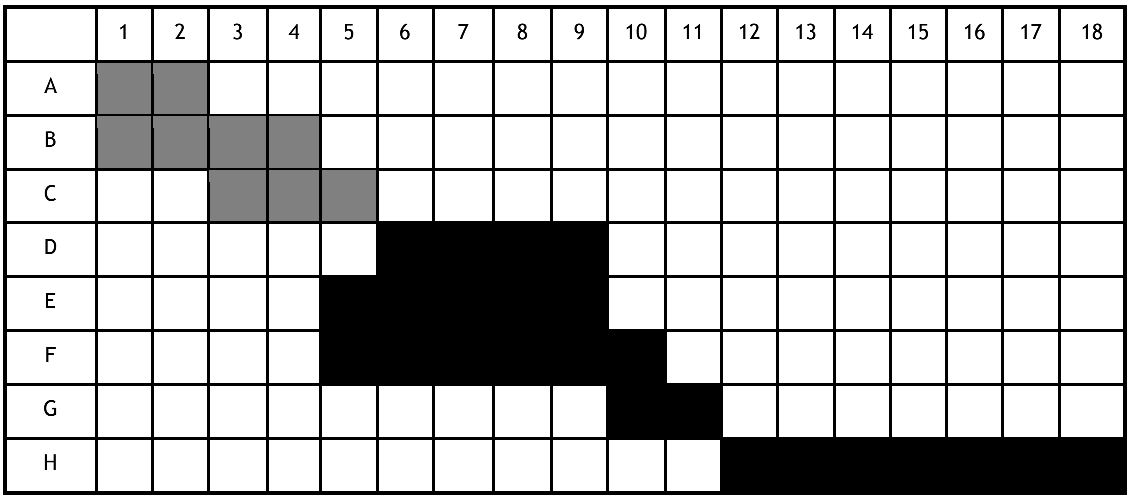
(k) Where separate space is provided for rough working and a final answer, only award marks for the final answer. Ignore all rough working.

Marking instructions for each question

Section 1

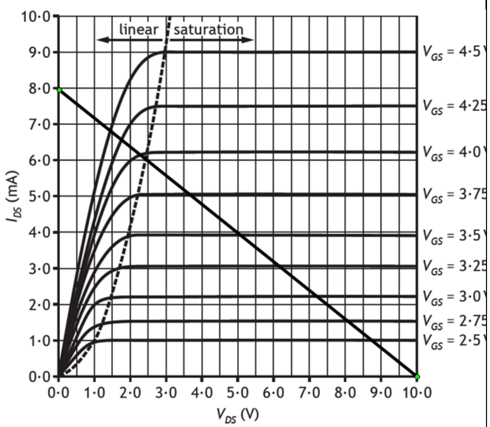
Question			Expected response	Max mark	Additional guidance
1.			Correct decomposition of gear forces in horizontal (*xz*) and vertical (*xy*) planes F_{1xz} = 210 cos20° F_{1xy} = 210 sin20° F_{2xz} = 420 sin20° F_{2xy} = 420 cos20°  Forces in vertical plane (*xy*)  Take moments about end B $\sum M_B = 0$ (R_{Axy} × 0·15) + (420cos20° × 0·105) − (210sin20° × 0·052) = 0 R_{Axy} = −251·37 Forces in horizontal plane (*x*-*z*).	**5**	1 mark Decomposition of 210*N* and 420*N* forces correct in relation to two planes. 1 mark Correct moment equilibrium in *xy* plane derived.

Question			Expected response	Max mark	Additional guidance
1.			**(continued)**  		
			Take moments about end B $\sum M_B = 0$		
			$(R_{Axz} \times 0{\cdot}15) - (420\sin 20° \times 0{\cdot}105) + (210\cos 20° \times 0{\cdot}052) = 0$ $R_{Axz} = 32{\cdot}14$		1 mark Correct moment equilibrium in *xz* plane derived.
			Reaction at A $R_A = \sqrt{R_{Axz}{}^2 + R_{Axy}{}^2}$ $R_A = \sqrt{(32 \cdot 14\cdots)^2 + (-251 \cdot 37\cdots)^2}$ $R_A = 253{\cdot}41$ $\boldsymbol{R_A = 250N}$ **(2*s.f.*)**		1 mark Correct magnitude of the reaction at bearing *A*.
			Angle $\theta = \tan^{-1}\left(\frac{251 \cdot 37\cdots}{32 \cdot 14\cdots}\right) = 82 \cdot 713\cdots$ $\boldsymbol{\theta = 83°}$ **(2*s.f.*)**		1 mark Correct angle of the reaction at bearing *A*. The sense of the angle in relation to the system must be clear, as shown in diagram below. 

Question			Expected response	Max mark	Additional guidance
2.	(a)	(i)		**1**	Chart must be correct
		(ii)	1 week	**1**	Answer must be correct for Gantt chart drawn.
		(iii)	B,E,G,H	**1**	Answer must be correct for Gantt chart drawn.
	(b)		A direct cost can be assigned wholly to a project or a single cost centre within a project. An indirect cost is a cost which may span several projects or cost centres within a single project. In the development of a new drive system for an electric car by a design company, a direct cost would be the cost of manufacturing materials to create the prototype(s). An indirect cost would be the heating and lighting bills for the company's administration building. **OR** In the construction of the AWPR bypass for Aberdeen, a direct cost would be the cost of manufacture and transportation of steel bridge girders. An indirect cost would be the costs to the construction company of their PR/HR departments.	**2**	1 mark Example describing direct cost related to project. 1 mark Example describing indirect cost related to project. Note: 1 mark total for question. Correct general description for each type of cost, not project specific, where the cost types have not been exemplified.

Question			Expected response	Max mark	Additional guidance
3.			Dimensions: Rectangle is 3·9 mm wide by 6·8 mm high Triangles are 6·8/2 = 3·4 mm high and (7·7 - 3·9)/2=1·9 mm wide $I_{xx} = \sum I_{xx}$ $I_{xx} = I_{rectangle} + 4 \times I_{triangle} - I_{circle}$ $I_{xx} = \frac{BD^3}{12} + 4 \times \frac{bh^3}{12} - \frac{\pi D^4}{64}$ $I_{xx} = \frac{3 \cdot 9 \times 6 \cdot 8^3}{12} + 4 \times \frac{1 \cdot 9 \times 3 \cdot 4^3}{12} - \frac{\pi \times 1 \cdot 5^4}{64}$ $I_{xx} = 126 \cdot 8$ $\boldsymbol{I_{xx}}$ **= 130 mm^4 (2*s.f.*)**	**4**	1 mark Interpretation of dimensions of rectangle and triangles. 1 mark Triangles and rectangle added, while circle is subtracted. 1 mark $4 \times I_{triangle}$ calculated. 1 mark Answer and unit.

Question			Expected response	Max mark	Additional guidance
4.	(a)		$\frac{10}{80} \times 6 = 0 \cdot 75V$ $0{\cdot}75 \times n \leq 4{\cdot}6$ $n \leq 6{\cdot}13$ $n = 6$ $\boldsymbol{D_0} = 0$, $\boldsymbol{D_1} = 1$, $\boldsymbol{D_2} = 1$	**3**	1 mark Calculate the number of comparators switched on. *(An ascending list of voltage steps 0.75 V, 1.5 V, 2.25 V......could be used).* 1 mark State logic states of D_1 and D_2. 1 mark State the logic stage of D_0.
	(b)		101 – 5 comparators on. $5 \times 0{\cdot}75 = 3{\cdot}75$ $6 \times 0{\cdot}75 = 4{\cdot}5$ $3{\cdot}75V \leq V_{in} < 4{\cdot}5V$	**2**	1 mark Calculate the minimum and maximum voltages. 1 mark Write range statement correctly.

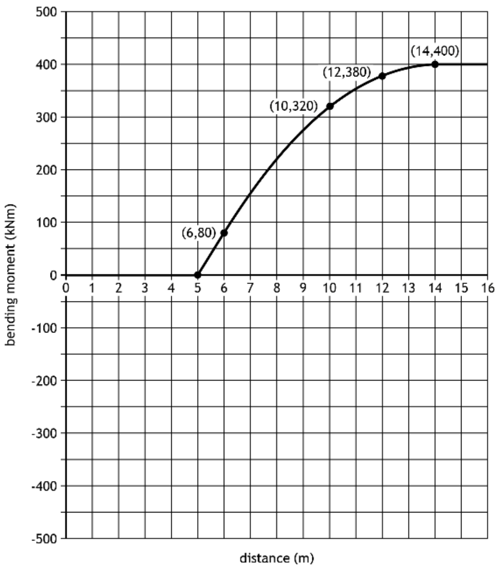
Question			Expected response	Max mark	Additional guidance
5.	(a)		When $V_{DS} = 0$ $$I_{DS} = \frac{10 - 0}{1.25 \times 10^3}$$ $$I_{DS} = 8 \times 10^{-3}$$ $$I_{DS} = 8\ mA$$ 	**2**	1 mark Correct value of 8 mA. 1 mark Straight line drawn to 10V.

Question			Expected response	Max mark	Additional guidance
5.	(b)		$V_{GS} = 3{\cdot}25\ V$ $\frac{R_1}{R_2} = \frac{6\cdot75}{3\cdot25}$ $R_1 = \frac{27}{13}R_2$ $\frac{1}{525} = \frac{1}{\frac{27}{13}R_2} + \frac{1}{R_2}$ $\frac{1}{525} = \frac{13}{27R_2} + \frac{27}{27R_2}$ $\frac{1}{525} = \frac{40}{27R_2}$ $27R_2 = 21000$ $R_2 = 777{\cdot}7\cdots$ **R_2 = 778 kΩ(3*s.f.*)** $R_1 = \frac{27}{13} \times 777\cdot7\cdots\times10^3$ $R_1 = 1{\cdot}615\cdots \times 10^6$ **R_1 = 1·62 MΩ(3*s.f.*)**	**3**	 1 mark Calculate resistor ratio. 1 mark Substitute for one resistance in the equation for parallel resistance. 1 mark Calculate correct values for R_1 and R_2.

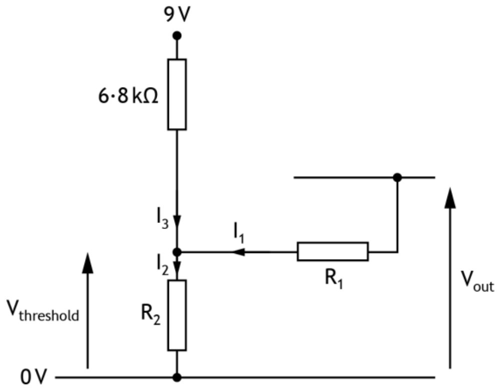
Question			Expected response	Max mark	Additional guidance
6.	(a)		The base load is met by nuclear, biomass and coal which have fairly constant output and capacity. Their outputs are not 100% constant however as mechanical and electrical failure and planned maintenance reduce production at certain times. Wind capacity can be fairly constant at times providing capacity to supply the base load. Coal production can be increased at peak times but it is not nimble enough to compensate for rapid changes in demand. Although the capacity of wind energy is unpredictable, its output can be reduced quickly when responding to dips in demand. This is not true of nuclear or coal production, where reducing output takes time and is often undesirable because of the delay in restarting or increasing output again. CCGT and pumped storage are the most suitable production methods to meet peak demand. The output and duration of production of pumped storage is highly predictable. However once spent, there is a delay before production can begin again. CCGT meets peak demand and compensates for variations in capacity of sources such as wind and solar. CCGT is crucial to meeting UK demand and its capacity must be high enough to compensate for times when there is little or no production from wind and solar.	**3**	Maximum of three marks from: 1 mark Base load is met by production methods which have long-running and inflexible outputs (nuclear, biomass and coal). 1 mark CCGT capacity can meet wide variations in demand and production from sources such as wind and solar. 1 mark Pumped storage helps to meet peak demand but its use is infrequent compared with CCGT as its capacity takes hours to be re-established. Although not mentioned in the data, electricity is imported from the continent at peak times, and to support base load generation if there are significant planned outages of generating capacity. 1 mark Wind energy's capacity can be adjusted down quickly unlike base sources such as coal, nuclear and biomass. This makes it a flexible source during low demand times.

Question			Expected response	Max mark	Additional guidance
6.	(b)		$P_{in} = P_{out} + P_{losses}$ $P_{losses} = (1 - 0{\cdot}981) \times P_{in}$ $= 0{\cdot}019 \times 110 \times 10^3$ $= 2{\cdot}09 \times 10^3 W$ $= 2{\cdot}1\ kW\ (2s.f.)$ $P_{primary\ winding} = I_{\text{in}}^2 \times R_{in}$ $= \left(\frac{110 \times 10^3}{11 \times 10^3}\right)^2 \times 0 \cdot 440 = \mathbf{44} W$ $P_{secondary\ winding}$ $= P_{losses} - P_{core}$ $- P_{primary\ winding}$ $= 2{\cdot}09 \times 10^3 - 1{\cdot}75 \times 10^3 - 44$ $= 296$ $= \mathbf{300\ W\ (2s.f.)}$ **OR** $I_{primary} = \frac{110\,000}{11\,000} = 10A$ $I^2R_{primary} = 102 \quad 0 \cdot 44 = \mathbf{44W}$ $I_{secondary} = \frac{110000}{415} \times 0 \cdot 981 = 260 \cdot 0...$ $I^2R_{secondary} = (260 \cdot 0...)^2 \times 0 \cdot 00438 = 296W$ $= \mathbf{300W\ (2s.f.)}$	3	1 mark Calculate total power loss. 1 mark Calculate power loss in primary winding. 1 mark Calculate power loss in secondary winding. **OR** 1 mark Power loss in primary coil. 1 mark Current in secondary coil. 1 mark Power loss in secondary coil.

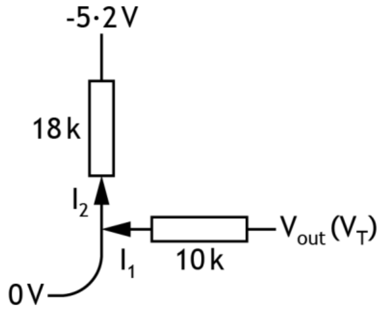
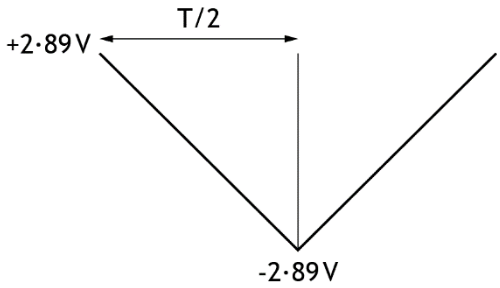
Section 2

Question			Expected response	Max mark	Additional guidance
7.	(a)		BMD for the Forth Road Bridge: $5 \le x \le 6$: $M = 80\,(x - 5)$ $6 \le x \le 14$: $M = 80(x-5) - \frac{10}{2}(x-6)^2$ $14 \le x \le 16$: $M = 80\,(x - 5) - 80\,(x - 10)$ $M = 400$  	**6**	1 mark Linear portion of graph between x=5 and x=6. 1 mark Correct end values (5,0), (6,80). 1 mark Quadratic portion of graph between x=6 and x=14. 1 mark two points indicated on graph from (7,155), (8,220), (9,275), (10, 320), (11,355), (12,380), (13,380). 1 mark Constant portions of graph and positive values of bending moment. 1 mark Max bending moment 400 kNm indicated on graph (graph may be accurately drawn to align with 400 kNm on the scale).

Question			Expected response	Max mark	Additional guidance
7.	(b)		$\sigma_{max} = \frac{M_{max} y}{I}$ The maximum bending moment can be used to calculate a required second moment of area (and depth) of the beam and hence its cross-section. These would be calculated to keep maximum working stresses below a defined safe level, based on the material and required factor of safety. **OR** Where bending moment is lower, second moment of area may be lower for the same level of working stress. Beams can be designed to reduce in cross-section as the bending moment reduces in order to save weight.	**2**	1 mark Relate to calculating safe beam geometry. 1 mark In order to keep maximum stress below a value defined by material and factor of safety. **OR** 1 mark Relate to calculating a changing safe cross-sectional area. 1 mark A reason being to reduce the weight of the beam while operating safely within factor of safety.
	(c)		The Queensferry Bridge. The bending moment distribution produces a "hogging" beam, where tensile stresses would occur above the neutral axis. The neutral axis lies closer to the top edge of the beam so the tensile stress level at the top edge of the beam would be lower than the compressive stress level at the bottom edge of the beam.	**2**	1 mark Selection of correct bridge. 1 mark Explanation must include the fact that the beam hogs and the neutral axis lies closer to the top edge of the beam, reducing the level of stress that occurs where the beam is in tension.

Question			Expected response	Max mark	Additional guidance
7.	(d)		$I_2 = I_1 + I_3$ $\frac{4 \cdot 8}{R_2} = \frac{7 \cdot 7 - 4 \cdot 8}{R_1} + \frac{9 - 4 \cdot 8}{6 \cdot 8}$ $\frac{4 \cdot 8}{R_2} = \frac{2 \cdot 9}{R_1} + \frac{4 \cdot 2}{6 \cdot 8}$ *[eqn 1]* $\frac{2 \cdot 2}{R_2} = \frac{0 - 2 \cdot 2}{R_1} + \frac{9 - 2 \cdot 2}{6 \cdot 8}$ $\frac{2 \cdot 2}{R_2} = -\frac{2 \cdot 2}{R_1} + 1$ *[eqn 2]* Multiply eqn 1 × 2·2 and eqn 2 × 2·9: $\frac{10 \cdot 56}{R_2} = \frac{6 \cdot 38}{R_1} + \frac{9 \cdot 24}{6 \cdot 8}$ *[eqn1]* $\frac{6 \cdot 38}{R_2} = -\frac{6 \cdot 38}{R_1} + 2 \cdot 9$ *[eqn 2]* *[eqn 1] + [eqn 2]* $\frac{10 \cdot 56 + 6 \cdot 38}{R_2} = \frac{9 \cdot 24}{6 \cdot 8} + 2 \cdot 9$ $\frac{16 \cdot 94}{R_2} = 4 \cdot 258$ $R_2 = 3{\cdot}978..\ k\Omega$ Substitute R_2 into eqn 2: $\frac{4 \cdot 8}{3 \cdot 978..} = \frac{2 \cdot 9}{R_1} + \frac{4 \cdot 2}{6 \cdot 8}$ $R_1 = \frac{2 \cdot 9}{0 \cdot 58899}$ $R_1 = 4{\cdot}923..\ k\Omega$ **R_1 = 4.9 kΩ (2 s.f.)** **R_2 = 4.0 kΩ (2 s.f.)**	**5**	 1 mark Kirchhoff's current law and Ohm's law applied for upper threshold. 1 mark Kirchhoff's current law and Ohm's law applied for lower threshold. Note: threshold and output voltages used as incorrect pairs, 1 mark out of 2 at this stage. 1 mark Begin to solve using appropriate strategy. 1 mark Correctly calculating R_2. 1 mark Substitution of R_2 and correctly calculating R_1.

Question			Expected response	Max mark	Additional guidance
8.	(a)		Slip will occur at smallest angle, on the pulley. $135° = \frac{3\pi}{4} radians$ Maximum difference in tensions. $\frac{F_1}{F_2} = e^{\mu\theta}$ $\frac{F_1}{F_2} = e^{0\cdot8\times\frac{3\pi}{4}}$ $F_2 = \frac{F_1}{e^{0\cdot6\times\pi}}$ Maximum power will be transmitted when the difference in belt tension is maximum. $T = (F_1 - F_2)\times\frac{d}{2}$ $T = 470\left(1-\frac{1}{e^{0\cdot6\times\pi}}\right)\times\frac{0\cdot06}{2}$ $T = 11\cdot959\cdots$ Find maximum difference in tensions $P = 2\pi nT$ $P = 2\pi\times\frac{1200}{60}\times11\cdot959\cdots$ P = 1502·8··· ***P* = 1500 *W* (2*s.f.*)**	**4**	1 mark Correctly identify where slip will occur and find angle. Note: if wrong angle used but correct method applied, then no further marks penalty. 1 mark Application of formula to find tension ratio. 1 mark Find torque. 1 mark Find power.

Question			Expected response	Max mark	Additional guidance
8.	(b)		 $I_1 = I_2$ $\frac{V_T - 0}{10\times10^3} = \frac{0-(-5\cdot2)}{18\times10^3}$ $V_T = \frac{5\cdot2}{18\times10^3}\times10\times10^3$ **$+V_T$ = 2·89V** **$-V_T$ = – 2·89V**  Time take for integrator voltage to ramp from +2·89 V to -2·89 V = ½ T Change in voltage is 2(-2·89) = -5·78 V $-5\cdot78 = \frac{1}{1\cdot5\times10^{-6}\times10^3}\int_0^{\frac{T}{2}}5\cdot2dt$ $-5\cdot78 = \frac{10^3}{1\cdot5}\times5\cdot2\times\left(\frac{T}{2}\right)$ **T = 3·3 ms**	5	1 mark Recognition of −5·2 V and 0 V at points on a potential divider. 1 mark Correct use of Kirchhoff's law at node between the two resistors. 1 mark Recognition timespan for ramp +2·89 to -2·89V = T/2. 1 mark Recognition that this represented a ΔV_{out} = -5·78V. 1 mark Correct calculation of T. NOTE: 1 mark total for $\Delta V_{out} = -\frac{1}{1\cdot5\times10^{-6}\times10^3}\int 5.2dt$ 2 mark total for expression and t= T/2.

Question			Expected response	Max mark	Additional guidance
8.	(c)		From the graph: $V_{DS(off)} = 12V$, $I_{DS(on)} = 7 \cdot 0A$, $T_{on} = 30\ ns$, $T_{off} = 25\ ns$ $E_{switching} = \frac{1}{2} \times V_{DS(off)} \times I_{DS(on)} \times (T_{on} + T_{off})$ $E_{switching} = \frac{1}{2} \times 12 \times 7 \cdot 0 \times (30 + 25) \times 10^{-9}$ $E_{switching} = 0 \cdot 00000231J$ $F = \frac{1}{10 \times 10^{-3}} = 100\,Hz$ $P_{switching} = E_{switching} \times 6 \times Frequency$ $P_{switching} = 0 \cdot 00000231 \times 6 \times 100$ $= 0 \cdot 001386\ W$ $=$ **1·4 *mW (2 s.f.)***	**4**	1 mark Interpreting voltage and current graphs and substituting values in formula (order of magnitude may be incorrect on time value). 1 mark Correct calculation of $E_{switching}$. 1 mark Interpretation of six switches per cycle from graph. 1 mark Calculation of Frequency and $P_{switching}$.
	(d)		Ten ADC readings are taken and the mean is calculated ADC reading is subtracted from 1023 as the back-emf voltage reading is relative to 0V when it should be relative to +Vcc	**2**	1 mark Ten readings **and** mean is calculated. 1 mark Explaining why the back-emf reading is subtracted from 1023.

[END OF MARKING INSTRUCTIONS]