



National
Qualifications
2022

2022 Engineering Science
Advanced Higher
Finalised Marking Instructions

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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

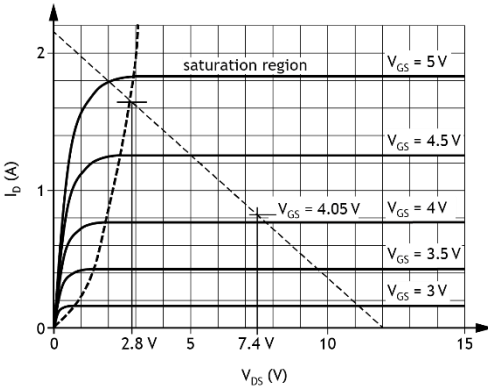
Question	Expected response	Max mark	Additional guidance
1.	$I_{xx} = I_{xx \text{ rectangle}} - 4 \times I_{xx \text{ triangle}}$ $I_{xx} = \left(\frac{b d^3}{12} \right)_r - 4 \times \left(\frac{b h^3}{12} \right)_t$ $I_{xx} = \frac{30.0 \times 40.0^3}{12}$ $- 4 \times \left(\frac{10.0 \times 10.0^3}{12} \right)$ $I_{xx} = 160.0 \times 10^3 - 4 \times 833.3$ $= 156.6 \times 10^3$ $I_{xx} = 157 \times 10^3 \text{ mm}^4 \text{ (3 s.f.)}$	3	<p>1 mark Calculate second moment of area of a triangle.</p> <p>1 mark Subtract 4 triangles from a rectangle.</p> <p>1 mark Final answer and units.</p>

Question		Expected response	Max mark	Additional guidance
2.	(a)	<p>Many forms of electrical generation have to run under constant conditions for best efficiency. They also require time to ‘heat up’ and cannot be turned on or off rapidly. Electricity from renewable sources can be intermittent and unreliable. It is important to have an electrical supply that can react quickly to changes in demand and smooth out peaks in demand.</p> <p>Hydro-electric power stations store water at height and generate electricity by allowing the water to flow through turbines connected to generators. Hydro plants can run to full power production very quickly. Pumps storage schemes use excess electricity in the grid to pump water up the hill to a reservoir to be utilised when needed.</p> <p>OR</p> <p>Within an electricity supply system, it is important to have a method of generation that can respond rapidly to changes in supply from other forms of generation, which may be intermittent.</p> <p>OR</p> <p>It is important to have an electricity supply system that can respond rapidly to changes in demand from customers, which some forms of energy generation cannot do.</p> <p>Pumped storage can pump water to a reservoir to store energy when there is surplus energy generation on the grid and release the water to generate electricity rapidly when there is insufficient energy generation on the network.</p>	2	<p>1 mark Identify that it is a limited means of reacting to changes in demand or smoothing of intermittency of supply.</p> <p>1 mark Describe how pump storage systems work to mitigate either of the above by storing excess generated energy and releasing the energy when required.</p>

Question		Expected response	Max mark	Additional guidance
2.	(b)	$\eta = 0.96 \times 0.97 \times 0.97 \times 0.94$ $\eta = 0.849 \dots$ $\eta = 0.85$ (2 s.f.) Therefore, for every 1 unit of electricity in, you can return 0.85 units from this arrangement.	2	<p>The overall system efficiency is the product of the efficiency chain.</p> <p>Motor loss \Rightarrow mechanical losses \Rightarrow mechanical losses \Rightarrow generator loss</p> <p>1 mark Take account of the fact that mechanical losses occur in both the raising and the lowering operation.</p> <p>1 mark Correct numerical answer.</p> <p>There is follow-through if the mechanical loss is accounted for only once or if it is accounted for twice, but its value is incorrectly stated.</p> <p>An answer of 0.875... units (one mechanical loss) will gain 1 mark.</p> <p>Note: $1 - (0.04 + 0.03 + 0.03 + 0.06)$ is not correct.</p>

Question		Expected response	Max mark	Additional guidance																																																																																																																																																																																																		
3.	(a)	<p>Capital costs - money spent on purchasing/installing/decommissioning equipment - for example turbines, moorings, installation - which is expected to be in use for a reasonable length of time (usually more than one year).</p> <p>The money is generally, although not exclusively investment (for example decommissioning would occur after commercial benefit has accrued) - it must be spent before any commercial benefit is possible and is a one-time cost.</p> <p>Economies of scale - as the scale of production increases, the overall capital cost of components will decrease.</p> <p>Learning from prototypes testing will provide focus for research and development which could lead to more cost-effective components and production methods.</p>	3	<p>1 mark Describe engineering-related categories of spending AND note that goods will be in use for the medium to long term.</p> <p>1 mark Explain that money is investment, the return will not be immediate.</p> <p>1 mark Give valid engineering reason for downward trend in costs from prototype to commercial production.</p>																																																																																																																																																																																																		
	(b) (i)		1	<p>1 mark Add bars for G and H, including float for G.</p>																																																																																																																																																																																																		
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Question			Expected response	Max mark	Additional guidance
3.	(b)	(ii)	B, C, E, F, H	1	1 mark Determine the Critical Path.
	(c)		<p>Management of human resources (or material resources) required for stages on the critical path must be close and careful to ensure delays do not arise.</p> <p>Any materials (or equipment or contracted labour) supplied on the critical path could have fixed penalties for delays written into the delivery contract.</p> <p>Resources could be switched from stage D if stage C, E or F (or all) if either begins to lag and the skills base existed in the workforce. Resources could be switched from G to E or F or both if either begins to lag and the skills base existed in the workforce.</p> <p>Authorisation of overtime necessary for staff assigned to this critical path if necessary to avoid delay.</p>	2	<p>1 mark Recognise that resources must be most closely managed on the critical path.</p> <p>1 mark Suggest a management technique that might be used to control the critical path.</p>

Question	Expected response	Max mark	Additional guidance
4. (a)	 <p> $V_{DS} = \frac{12 + 2.8}{2} = 7.4 \text{ V}$ From the graph, $V_{GS} = 4.05 \text{ V}$ (Accept 4.0 V – 4.1 V) </p>	3	<p>1 mark Correct values of 12 V for V_{DS} and 2.14 A for I_{DS}</p> <p>1 mark Midpoint of saturation region of operation identified correctly.</p> <p>1 mark Determine suitable value for V_{GS} from graph.</p>
	<p>(b)</p> $\frac{R_1}{R_2} = \frac{12 - 4.05}{4.05}$ $R_1 = 1.963 \dots \times R_2$ $\frac{1}{100} = \frac{1}{1.963R_2} + \frac{1}{R_2}$ $\frac{1}{100} = \frac{2.963}{1.963R_2}$ $R_2 = 150 \text{ k}\Omega \text{ (2 s.f.)}$ $R_1 = 1.963 \times R_2$ $R_1 = 290 \text{ k}\Omega \text{ (2 s.f.)}$	2	<p>1 mark Calculate resistor ratio for the selected value of V_{GS}.</p> <p>1 mark Calculate correct values for R_1 and R_2.</p> <p>These marks are available for an incorrect choice of V_{GS} in part(a) of the question.</p>

Question	Expected response	Max mark	Additional guidance
5.	<p>From the graph:</p> <p>$V_{DS(on)} = 12V$, $I_{DS(on)} = 3.0A$ $T_{on} = 28 \text{ ns}$, $T_{off} = 24 \text{ ns}$</p> $E_{\text{Switching}} = \frac{1}{2} V_{DS(off)}(T_{on}I_{DS(on)} + T_{off}I_{DS(on)})$ $E_{\text{Switching}} = \frac{1}{2} \times 12 \times (28 \times 10^{-9} \times 3.0 + 24 \times 10^{-9} \times 3.0)$ $E_{\text{Switching}} = 936 \text{ nJ}$ <p>$T = 5.0 \times 10^{-3} \text{ s}$, $n = 6$ $T = 10.0 \times 10^{-3} \text{ s}$, $n = 12$</p> $\text{frequency} = \frac{6}{5.0 \times 10^{-3}} = 1.2 \text{ kHz}$ <p>$P_{\text{Switching}} = E_{\text{Switching}} \times \text{frequency}$ $P_{\text{Switching}} = 936 \times 10^{-9} \times 1.2 \times 10^3$ $P_{\text{Switching}} = 1.1 \text{ mW (2 s.f.)}$</p>	4	<p>1 mark Interpret voltage and current graphs, substituting values in formula and correct calculation of $E_{\text{switching}}$</p> <p>If magnitude of answer is incorrect then award this mark, but penalise fourth mark when power is calculated</p> <p>1 mark interpret period and switching events within the period from the graph</p> <p>1 mark Calculation of frequency</p> <p>If frequency is 600 Hz, then award this mark, but not the second mark, because the number of switching events within the period has not been identified.</p> <p>1 mark Calculation of $P_{\text{switching}}$. Answer and units.</p>

Question		Expected response	Max mark	Additional guidance
6.	(a)	$V_2 = -\frac{1}{5.6 \times 10^3 \times C} \times \int 5dt$ $V_2 = -\frac{1}{5.6 \times 10^3 \times C} \times 5t + k$ <p>From the graph, When $t=0$, $V_2=0$, so $k=0$ When $t=0.2$, $V_2=-9$</p> $-9 = -\frac{1}{5.6 \times 10^3 \times C} \times 5(0.2)$ $C = 19.8... \times 10^{-6}$ $C = 20 \mu\text{F} \text{ (2 s.f.)}$	2	<p>1 mark Use the expression for the integrator from the data booklet and the graph to find an expression for the unknown, C.</p> <p>1 mark Calculation of C. Answer and units.</p>
	(b)	Increasing the capacitance will increase the time to saturate.	1	<p>1 mark For correct change to time.</p> <p>If capacitance in part (a) is calculated to be greater than $33\mu\text{F}$, the change in part (b) will cause a decrease in time to saturate.</p>
	(c)	$V_{in} = 5.0 \text{ V}$ $V_2 = -\frac{5.0t}{5.6 \times 10^3 \times 33 \times 10^{-6}}$ $V_2 = -27.056t$ $V_{out} = -\frac{1}{9.1 \times 10^3 \times 100 \times 10^{-9}} \times \int -27.056t dt$ $V_{out} = \frac{27.056t^2}{910 \times 10^{-6}}$ $V_{out} = 14.9 \times 10^3 t^2$ $V_{out} = 15 \times 10^3 t^2 \text{ (2 s.f.)}$	3	<p>1 mark Substitute values and calculate V_2.</p> <p>1 mark Substitute V_2 and other values into V_{out} calculation.</p> <p>1 mark Final expression for V_{out}.</p>

Question		Expected response	Max mark	Additional guidance
7.	(a)	$E = 200 \times 10^3 \text{ Nmm}^{-2}$ $P = 95 \times 9.8 \text{ N}$ $L = 1.5 \times 10^3 \text{ mm}$ $a = 0.50 \text{ m} = 500 \text{ mm}$ $\delta_{\max} = \frac{Pa}{24EI} (3L^2 - 4a^2)$ $\delta_{\max} = \frac{95 \times 9.8 \times 500}{24(200 \times 10^3)(21 \times 10^3)}$ $\times (3(1.5 \times 10^3)^2 - 4(500)^2)$ $\delta_{\max} = 26.55 \dots$ $\delta_{\max} = 27 \text{ mm (2 s.f.)}$	3	<p>1 mark Establish value of P and select lowest value of E.</p> <p>Note: This mark is not awarded for any combination of;</p> <ul style="list-style-type: none"> • g not applied, • mass not halved, • E not the minimum value in the range given in the data booklet. <p>1 mark Substitute parameters with consistent units (as shown, or L = 1.5 m, a = 0.5 m, E = 200 × 10⁹ Nm⁻², I = 21 × 10⁻⁹ m⁴.)</p> <p>1 mark Answer and units.</p>
	(b)	$M_{\max} = P \times a$ $= (95 \times 9.8) \times 500$ $= 465.5 \times 10^3 \text{ Nmm}$ $y_{\max} = \frac{D}{2} = 14.5 \text{ mm}$ $\sigma_{\max} = \frac{M_{\max} \times y_{\max}}{I}$ $\sigma_{\max} = \frac{465.5 \times 10^3 \times 14.5}{21 \times 10^3}$ $= 321.41\dot{6}$ $\sigma_{\max} = 320 \text{ Nmm}^{-2} \text{ (2 s.f.)}$	2	<p>1 mark Determine bending moment.</p> <p>1 mark Determine stress. Answer and units.</p>

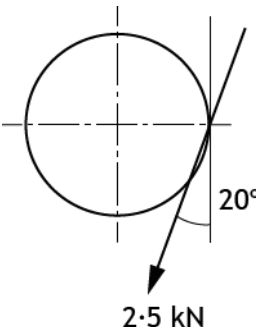
Question		Expected response	Max mark	Additional guidance
7.	(c)	<p>$680 < UTS / UCS < 2400$.</p> <p>Factor of safety may be as low as 2.1. This is not high enough for a weight lifted over a person.</p> <p>OR</p> <p>Choose a low-alloy steel with a high UTS so the factor of safety is 6-7 when the weight is lifted over a person.</p>	1	<p>1 mark</p> <p>A UTS/UCS value must be referenced, and a reasonable comment made on the FOS, based on calculated value of maximum stress and scenario.</p> <p>FoS need not be referenced explicitly. Responses may refer to stresses becoming greater than calculated during lifting motion or lifting heavier weights which would make the lower end of UTS/UCS range dangerous.</p>

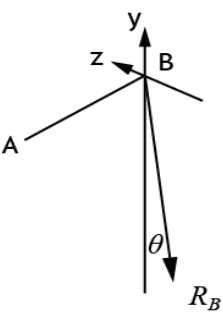
Section 2

Question		Expected response	Max mark	Additional guidance
8.	(a)	<p>A- Rectifier or AC-DC converter B- Inverter or DC-AC converter</p> <p>The AC electricity supply is at constant frequency. The rectifier converts an AC signal to the DC required to supply an inverter, irrespective of the supply frequency. The inverter converts DC to AC, but at a controlled frequency, which is variable.</p> <p>This enables 3-phase motors to be run at a range of speeds, speed being linked to the frequency of electricity that is supplied.</p>	3	<p>1 mark Name the two sub-systems.</p> <p>1 mark Describe the function of each.</p> <p>or</p> <p>1 mark for each name and function.</p> <p>1 mark Identify the need for the combination of functions in the application, producing a variable frequency power supply from a constant frequency power supply.</p>

Question		Expected response	Max mark	Additional guidance
8.	(b)	$P_{in} = P_{out} + P_{losses}$ <p>pr = primary, se = secondary</p> $P_{pr} = V_{se} \times I_{se} + \left[\left(\frac{P_{pr}}{V_{pr}} \right)^2 R_{pr} + P_{core} + I_{se}^2 R_{se} \right]$ $5.2 \times 10^6 = 1.5 \times 10^3 \times I_{se}$ $+ \left[\left(\frac{5.2 \times 10^6}{25 \times 10^3} \right)^2 \times 482 \times 10^{-3} \right]$ $+ 2.5 \times 10^3 + 1.74 \times 10^{-3} \times I_{se}^2$ $I_{se}^2 + 862.069 \times 10^3 \times I_{se} - 2.97508 \times 10^9 = 0$ $I_{se} = 3437 \text{ A}$ $P_{loss(se)} = I_{se}^2 R_{se}$ $P_{loss(se)} = 3437^2 \times 1.74 \times 10^{-3}$ $P_{loss(se)} = 20.6 \text{ kW}$ $P_{loss(se)} = 21 \text{ kW (2 s.f.)}$	4	<p>1 mark State conservation of power: input power supplies output power and power 'losses'.</p> <p>1 mark Recognise secondary winding current as unknown parameter and correct statement of three losses.</p> <p>1 mark Solve for unknown current in secondary winding.</p> <p>1 mark Calculate resistive power loss in secondary winding. Answer and units.</p> <p>Additional notes</p> $I_{se} = I_{pr} = \frac{P_{pr}}{V_{pr}} = \frac{5.2 \times 10^6}{25 \times 10^3} = 208 \text{ A}$ <p>Using this current as the secondary winding current takes no account of the effect of the transformer on current in the secondary winding or of the transformer power losses in the primary winding and the core. A calculation of I^2R loss using this value and the secondary winding resistance gives 75.3 W. This would be worth 1 mark (the fourth mark).</p> $I_{se} = I_{pr} \times \frac{V_{pr}}{V_{se}} = 208 \times \frac{25 \times 10^3}{1.5 \times 10^3} = 3467 \text{ A}$ <p>A calculation of I^2R loss using this value and the secondary winding resistance gives 20.9 kW. The step-down ratio has been applied assuming no losses and a power loss is what is being calculated. This would be worth 2 marks (the third and fourth mark).</p>

Question		Expected response	Max mark	Additional guidance
8.	(c)	<p>The period of the signal depends on length of the main delay value (pauseus 140)/delayMicroseconds (1400)).</p> <p>Adjusting this value would allow the period to be changed: increase the delay value and the period would increase; decrease it and the period would decrease.</p>	2	<p>1 mark State what the period depends upon - the interval in the time delay within the loop.</p> <p>1 mark Explain how it can be adjusted - increasing the delay interval increases the period of the sine wave and vice versa.</p> <p>If frequency is mentioned rather than period, then</p> <p>increasing the delay interval reduces the frequency and vice versa.</p>
	(d)	<p>Calculating the values as the program runs could introduce some unacceptable processing delays within each iteration which could affect the phase and timing of the output PWM waveform.</p> <p>Reading pre-calculated values from memory is likely to be faster and so should ensure a more accurate output waveform.</p>	2	<p>1 mark Recognition of the likelihood of the delay lengthening when calculating values.</p> <p>1 mark This could affect the length of the period, thus affecting the frequency of the waveform.</p> <p>If calculation takes too long, then an output value, or output values, would be delayed. This would distort the shape of the sine wave as well as change its period. The call time from memory will be fixed and is likely to be less than a calculation duration.</p>

Question		Expected response	Max mark	Additional guidance
8.	(e)	$P = 2 \pi n T$ $80 \times 10^3 = \frac{2\pi \times 1800 \times T}{60}$ $T = \frac{80 \times 10^3 \times 60}{2\pi \times 1800} = 424.41 \text{ Nm}$ $F_{\text{tangential}} = \frac{T}{r} = \frac{424.41}{\frac{0.48}{2} \times \frac{45}{60}}$ $= 2357.85 \dots \text{N}$ $F_{\text{gear}} = \frac{F_{\text{tangential}}}{\cos 20^\circ}$ $F_{\text{gear}} = \frac{2357.85}{\cos 20^\circ}$ $F_{\text{gear}} = 2509.17 \dots$ $F_{\text{gear}} = 2.5 \text{ kN (2 s.f.)}$ <p>If the wheel is turning anticlockwise, so is the motor.</p> <p>The motor gear is driving the middle gear (idler) so the reaction on the motor gear must be as shown</p> 	4	<p>1 mark Calculate the torque on the motor gear.</p> <p>1 mark Calculate the tangential force.</p> <p>The radius of the motor gear will be smaller than the radius of the gear on the bogie by the tooth ratio 45:60</p> <p>1 mark Calculate the contact force on the motor gear.</p> <p>1 mark Clearly indicate the line of action and direction of the contact force (or indicate the tangential and radial components and their directions).</p>

Question		Expected response	Max mark	Additional guidance
8.	(f)	<p>Vertical component of 48.6 kN gear force</p> $F_y = 48.6 \cos 20^\circ = 45.669 \text{ kN}$ <p>Horizontal component of 48.6 kN gear force</p> $F_z = 48.6 \sin 20^\circ = 16.622 \dots \text{ kN}$ <p>Take moments about bearing A. Clockwise moments are taken as positive,</p> $-(122 \times 0.11) + (45.669 \times 1.22) - (122 \times 1.33) - (R_{By} \times 1.44) = 0$ $R_{By} = \frac{-119.96\dots}{1.44} = -83.308\dots \text{ kN}$ <p>Take moments about bearing A. Clockwise moments are taken as positive,</p> $-(14.4 \times 0.11) + (16.622 \times 1.22) - (14.4 \times 1.33) - (R_{Bz} \times 1.44) = 0$ $R_{Bz} = \frac{-0.45716}{-1.44} = -0.31747\dots \text{ N}$ <p>Magnitude of reaction force</p> $R_B = \sqrt{R_{By}^2 + R_{Bz}^2}$ $= \sqrt{(-83.308)^2 + (-0.31747)^2}$ $= 83 \text{ kN (2 s.f.)}$ <p>Angle of reaction, from vertical,</p> $\theta = \tan^{-1} \left(\frac{R_{Bz}}{R_{By}} \right)$ $\theta = \tan^{-1} \left(\frac{-0.317}{-83.3} \right)$ $\theta = 0.2^\circ$ 	5	<p>1 mark Determine components of gear force correctly for each plane in relation to known forces at wheels.</p> <p>1 mark Equation of equilibrium in xy plane.</p> <p>1 mark Equation of equilibrium in yz plane.</p> <p>1 mark Magnitude of force at bearing B.</p> <p>1 mark Direction of force at bearing B, with clear indication of where stated angular value lies in relation to existing forces and axle geometry.</p> <p>Note: vertically downwards would be acceptable when angle is this small.</p>

Question		Expected response	Max mark	Additional guidance
9.	(a)	<p>Find Reactions at points A and B, use convention that forces acting to the right, and forces acting vertically up, are positive.</p> $\Sigma F_x = 0$ $\Sigma F_y = 0$ $F_{yA} - 25 - 750 - 50 + F_{yB} = 0$ $F_{yA} + F_{yB} = 825 \text{ kN}$ <p>To find F_{yB}, take moments about A. Clockwise moments are positive.</p> $\Sigma M_A = 0$ $(25 \times 2) + (750 \times 3) + (50 \times 4) - (F_{yB} \times 6) = 0$ $F_{yB} = \frac{2500}{6} = 416.6 \text{ kN}$ <p>Thus,</p> $F_{yA} = 825 - 416.6 = 408.3 \text{ kN}$	4	<p>In the calculation of Reactions at points A and B, the UDL force is represented by a single force of magnitude 750 kN acting at the middle of the beam (5 m from left hand end).</p> <p>1 mark Calculate Reactions.</p> <p>On shear force diagram</p> <p>1 mark Indicate Reactions correctly.</p> <p>1 mark Indicate point loads correctly.</p> <p>1 mark Indicate UDL as piecewise continuous slope of unchanging gradient between all point loads and Reactions.</p>

Question			Expected response	Max mark	Additional guidance
9.	(b)	(i)	For $4 < x < 6$ $M = -\frac{75x^2}{2} + 408.3[x - 2] - 25[x - 4]$ OR $M = -\frac{75x^2}{2} + 383.3x - 716.6$	3	1 mark Correct term for distributed load. 1 mark Correct term for Reaction A. 1 mark Correct term for point load at $x = 4\text{m}$ The expression does not have to be simplified to the second form given to gain full marks.
		(ii)	$\frac{dM}{dx} = -\frac{(2 \times 75)x}{2} + 408.3 - 25$ $\frac{dM}{dx} = 0$ $x = 5.1 \text{ m (2 s.f.)}$	2	1 mark Differentiates bending moment equation correctly. 1 mark Set derivative to zero for maximum/minimum value and finds value for position of maximum bending moment.

Question		Expected response	Max mark	Additional guidance
9.	(c)	<p>Upper Threshold = 4.25 V Low Threshold = 1.4 V</p> <p>KCL Statements</p> <p>@ Upper threshold $V_+ = 4.25$ V $V_{out} = 5.20$V</p> $I_3 - I_2 - I_1 = 0$ $\frac{5.2 - 4.25}{10 \times 10^3} - \frac{4.25 - 0}{R_2} + \frac{6.0 - 4.25}{R_1} = 0$ $\frac{0.95}{10 \times 10^3} - \frac{4.25}{R_2} + \frac{1.75}{R_1} = 0 \dots \dots \text{Eqn 1}$ <p>@ Lower threshold $V_+ = 1.40$ V $V_{out} = 0.00$V</p> $I_1 - I_3 - I_2 = 0$ $\frac{6.0 - 1.4}{R_1} - \frac{1.4}{10 \times 10^3} - \frac{1.4}{R_2} = 0$ $\frac{4.6}{R_1} - \frac{1.4}{10 \times 10^3} - \frac{1.4}{R_2} = 0 \dots \dots \text{Eqn 2}$ <p>Add: Eqn 1 \times 4.6, Eqn 2 \times -1.75</p> $-\frac{(-1.75) \times 1.4}{10 \times 10^3} - \frac{(-1.75) \times 1.4}{R_2}$ $+ \frac{4.6 \times 0.95}{10 \times 10^3} - \frac{4.6 \times 4.25}{R_2} = 0$ $\frac{6.82}{10 \times 10^3} - \frac{17.1}{R_2} = 0$ <p>$R_2 = 25.073 \dots \times 10^3 \Omega$ $R_1 = 23.488 \dots \times 10^3 \Omega$</p> <p>$R_2 = 25 \text{ k}\Omega$ $R_1 = 23 \text{ k}\Omega$ (2 s.f.)</p>	5	<p>1 mark Kirchhoff's current law and Ohm's law used for unknown currents producing eqn 1.</p> <p>1 mark Kirchhoff's current law and Ohm's law used for unknown currents producing eqn 2.</p> <p>1 mark Eliminating R_1 (or R_2).</p> <p>1 mark Correctly calculating R_2.</p> <p>1 mark Substitution of R_2 and correctly calculating R_1.</p>

Question		Expected response	Max mark	Additional guidance
9.	(d)	<p>For 10 revs min⁻¹, the minimum number of pulses detected would be 9.</p> <p>This is a percentage error of 10 %</p>	2	<p>1 mark Interpreting information from the example graphs as a possible error of one pulse in the count.</p> <p>1 mark Calculation of the error as a percentage of running speed.</p>
	(e)	<p>5% tolerance produces a minimum speed of 4.75 revs min⁻¹ for a true speed of 5 revs min⁻¹ Delay must be increased to reduce error.</p> <p>3 s delay - error of $(1 - 4/5) \times 100 = 20 \%$ 6 s delay - error = $(1 - 9/10) \times 100 = 10 \%$ 12 s delay - error = $(1 - 19/20) \times 100 = 5 \%$</p> <p>count b.0,12000,counter</p> <p>counter = counter * 100</p> <p>rpm = counter/4</p>	4	<p>1 mark Calculating the change in the delay.</p> <p>1 mark Describing in the program.</p> <p>1 mark Recognising that the counter value must be multiplied by 100.</p> <p>1 mark Final calculation of rpm.</p>

[END OF MARKING INSTRUCTIONS]