



X823/76/01

Engineering Science

Marking Instructions

Please note that these marking instructions have not been standardised based on candidate responses. You may therefore need to agree within your centre how to consistently mark an item if a candidate response is not covered by the marking instructions.

General marking principles for 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 specific 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.	(a)	Material will stretch then when the load is removed it will return to its original shape.	1	
	(b)	Material will stretch and when the load is removed it will not return to its original shape.	1	
2.		$V_{IN} = 12 \times (270 / 600)$ $V_{IN} = 5.4 \text{ V}$ $V_{OUT} = - (R_f / R_i) \times V_{IN}$ $V_{OUT} = - (27 / 12) \times 5.4$ $V_{OUT} = -12.15$ $V_{OUT} = -12 \text{ V (2s.f.)}$	3	<p>1 Mark for V_{IN}.</p> <p>1 Mark for identification of correct configuration.</p> <p>1 Mark for V_{OUT} with units.</p>
3.		<p>UDL $0.75 \times 5.7 = 4.275$</p> <p>Moments at A $(6.3 \sin 65 \times 1.5) + (4.275 \times 2.85) = 5.7 \times B$ $B = 3.64$ $B = 3.6 \text{ kN (2s.f.)}$</p> <p>B is vertically upward.</p>	5	<p>1 Mark for UDL.</p> <p>1 Mark for vertical component of 6.3 kN.</p> <p>1 Mark for distance associated with UDL.</p> <p>1 Mark for B with units.</p> <p>1 Mark for stating or drawing direction.</p>
4.		<p>A structural engineer would know</p> <ul style="list-style-type: none"> material properties to help make the correct choice for a particular purpose UDLs and their impact on a structure about the environment the ship would operate in (temperatures, pressures, potential for corrosion, etc) 	2	<p>Must be a descriptive response.</p> <p>1 Mark for each response.</p> <p>Each piece of knowledge must be different and relate to question.</p>

Question		Expected response	Max mark	Additional guidance
5.	(a)	$P = V^2 / R$ $R = V^2 / P$ $R = 12^2 / 4.6$ $R = 31.3043478$ $R = 31 \Omega \text{ (2s.f.)}$	1	1 mark for final answer with units.
	(b)	$R_T = V / I$ $R_T = 12 / 0.38$ $R_T = 31.5789$ $R_{\text{MOSFET}} = R_T - R_{\text{MOTOR}}$ $R_{\text{MOSFET}} = 31.5789 - 31$ $R_{\text{MOSFET}} = 0.5789$ $R_{\text{MOSFET}} = 0.58 \Omega \text{ (2s.f.)}$	2	1 mark for calculating R_T . 1 mark for calculating R_{MOSFET} with units. Use of 31.3043478 acceptable for R_{MOTOR} .
	(c)	$P = I^2 R$ $P = 0.38^2 \times 0.58$ $P = 0.083752$ $P = 0.084 \text{ W (2s.f.)}$	1	1 mark for final answer with units.
6.			4	1 Mark for NOT. 1 Mark for OR. 1 Mark for AND. 1 Mark for simplification indicated.

Section 2

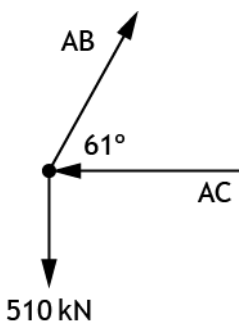
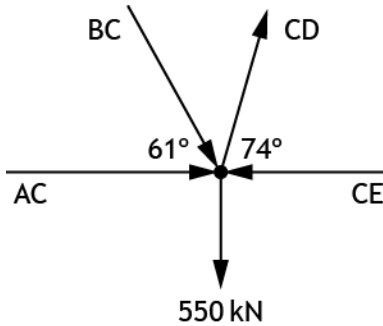
Question		Expected response	Max mark	Additional guidance
7.	(a)	<pre> graph TD Start([START]) --> D0{pin 0 on?} D0 -- N --> P7on[/pin 7 on/] D0 -- Y --> D1{pin 1 on?} D1 -- N --> P7on D1 -- Y --> P7off6on[/pin 7 off, 6 on/] P7off6on --> P10ms1[pause 10ms] P10ms1 --> P6off[/pin 6 off/] P6off --> P10ms2[pause 10ms] P10ms2 --> D2{pin 2 on?} D2 -- N --> P5on[/pin 5 on/] D2 -- Y --> D3{pin 3 on?} D3 -- N --> P5on D3 -- Y --> P5off[/pin 5 off/] P5off --> D2 P5on --> P7on P7on --> D0 </pre>	8	<p>1 mark for 1st decision including loop.</p> <p>1 mark for pin 7 on and decision.</p> <p>1 mark for pin 6 on and off.</p> <p>1 mark for pin 6 suitable delays.</p> <p>1 mark for PWM loop.</p> <p>1 mark for pin 3 on decision.</p> <p>1 mark for pin 5 on and loop.</p> <p>1 mark for pin 5 off and loop.</p> <p>Referencing names in flow chart is also acceptable.</p> <p>Delay/pause times must be equal.</p>
	(b)	<p>When pin 7 is on and pin 6 is off the motor will rotate clockwise.</p> <p>When pin 7 is on and pin 6 is on it will rotate anticlockwise.</p> <p>If pin 7 is off it will stop.</p>	3	<p>1 mark to be given if descriptions of CW and ACW movement are reversed.</p>

Question		Expected response	Max mark	Additional guidance
8.	(a)	<p>When the light level is high the LDR will have a low resistance so the voltage across it will be small.</p> <p>As light level drops the resistance of the LDR will increase and so will the voltage across it.</p> <p>Op-amp 1 will switch positive when the voltage at the non-inverting input rises above the voltage at the inverting input and the LED will switch on.</p>	3	1 mark for each relevant point up to a maximum of 3.
	(b)	$R_{ldr} = 180 \Omega$ $V_{inv} = 5 \times (180/255) = 3.53 \text{ V}$ $V_{non-inv} = 5 \times (750/2750) = 1.36 \text{ V}$ $V_{diff} = 120/60 \times (3.53-1.36)$ $V_{diff} = 4.3315$ $V_{diff} = 4.3 \text{ V (2s.f.)}$	4	<p>1 mark for resistance in the range 180-200Ω.</p> <p>1 mark for each calculation.</p>
	(c)	<p>Voltage reference at 3rd op-amp $= 5 \times (450/940) = 2.393617021$ $= 2.3936$ $= 2.4 \text{ V (2s.f.)}$</p>	2	<p>1 mark for identifying the three op-amps that need to be switched +ve.</p> <p>1 mark for the calculation of voltage.</p>
	(d)	<p>If the resistance is decreased the LEDs will come on at a higher light level.</p> <p>If the resistance is increased it will need to be darker before the LEDs come on.</p> <p>It will adjust the level of light required to switch the LEDs on.</p>	2	
	(e)	$V_{comp} = 8 \times 0.85 = 6.8 \text{ V}$ $R = (6.8-2.3)/0.0052 = 865.3846 \Omega$ $= 870 \Omega (2s.f.)$	3	<p>1 mark for output voltage from op-amp.</p> <p>1 mark for voltage over resistor.</p> <p>1 mark for the resistance.</p>

Question		Expected response	Max mark	Additional guidance
8.	(f)	<p>When the reading is less than 50 the program will jump to the label 'level1' and the m/s ratio will be set so that the LEDs are on all the time (are at full brightness).</p> <p>When the reading is between 50 and 99 the m/s ratio is changed so that the LEDs flash with slightly longer on time. This will keep them bright but not as bright as they were.</p> <p>When the reading is between 100 and 149 the m/s ratio will keep the LEDs off for proportionately longer so they will appear even dimmer.</p> <p>If the reading is 150 or over then the LEDs are off all the time.</p>	4	1 mark for each suitable response.
	(g)	$Z = (A \oplus B) + (\overline{A \cdot D}) + (\overline{C} \cdot D)$	4	<p>1 mark for XOR with A and B.</p> <p>1 mark for NAND with A and D.</p> <p>1 mark for AND with NOT C and D.</p> <p>1 mark for OR between the three expressions.</p> <p>Brackets around NAND and AND functions not required.</p>

Question		Expected response	Max mark	Additional guidance
9.	(a)	$I_b = I_c / h_{FE}$ $= 56 / 27 = 2.1 \text{ mA (2s.f.)}$	1	
	(b)	$V_{res} = I \times R$ $= 0.0021 \times 1500$ $= 3.15 \text{ V}$ $V_{vr} = 3.15 + 0.7$ $= 3.85$ $= 4 \text{ V (1s.f.)}$	2	1 mark for voltage across resistor. 1 mark for voltage over variable resistor. Allow follow through error from (a).
	(c)	$I_{vr} = 4 / 2500 = 1.6 \text{ mA}$ $I_{vr} = 1.6 \text{ mA (2s.f.)}$	1	
	(d)	$I_{therm} = 1.09 + 1.35 = 2.44 \text{ mA}$ $V_{vr} = 1.09 \times 2500 = 2.725 \text{ V}$ $V_{therm} = 6.0 - 2.725 = 3.275 \text{ V}$ $R_{therm} = 3.27 / 0.00244 = 1342.213$ $= 1.3 \text{ k}\Omega \text{ (2s.f.)}$ Temperature = 210-225 °C	5	1 mark for current in thermistor. 1 mark for voltage over variable resistor. 1 mark for voltage over thermistor. 1 mark for resistance of thermistor. 1 mark for temperature from graph.
	(e)	Valve C is actuated by vA or vD+E. C1 outstrokes when vC is actuated and actuates vG. vH is actuated by vG or vD+E. When vH is actuated C2 outstrokes and actuates vK. After a delay vH+vC are actuated. Both cylinders then instroke. vC and vH are also actuated by vI. vK cuts off the air supply to vG and allows C2 to instroke.	6	1 mark for each relevant point.
	(f)	Fewer valves would be required meaning costs would reduce. The system could be reprogrammed to perform other tasks. It would be quicker and easier to make alterations if errors were found in the system.	2	1 mark for each relevant explanation. Each must have a cause and effect.

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	Site surveying/research. Ground soil/core samples. Strata/geology research. Drainage impact assessment. Assessment of impact on traffic. Project management.	2	1 mark for each adequate descriptive response.
		(ii)	Monitoring contamination/pollutant levels for impact on nearby residents/wildlife/fauna. Monitoring air quality for dust levels for impact on nearby residents. Monitoring water quality for impact of pollution from construction work. Monitoring impact on fauna and wildlife. Monitoring waste management and recycling procedure to limit environmental impact. Monitoring noise levels for impact on nearby residents.	1	1 mark for adequate descriptive response.
	(b)	(i)	$T = Fr = (924 \times 3) \times (0.5 \times 12.4)$ $= 17186.4 \text{ Nm}$ $= 17200 \text{ Nm (3s.f.)}$ $= 17.2 \text{ KNm (3s.f.)}$	2	1 mark for 3 cutting blades and correct radius. 1 mark for torque from values used.
		(ii)	$n = 9.93/60 = 0.1655 \text{ revs sec}^{-1}$ $P = 2\pi nT$ $= 2 \times \pi \times 0.1655 \times 17200$ $= 17885.72 \text{ W}$ $= 17900 \text{ W (3s.f.)}$ $= 17.9 \text{ KW (3s.f.)}$	2	1 mark for calculating n. 1 mark for final answer.
	(c)	(i)	To support the load on a shaft as it rotates.	1	
		(ii)	A roller bearing will not wear out as quickly with a large load compared to a ball bearing due to increased surface area contact.	1	
	(d)		$E_p \text{ after lift} =$ $120000 \times 9.8 \times 42.6 =$ 50097600 J $50097600 = 88 \times 910 \times (T - 17)$ $\Rightarrow T - 17 = 625.594$ $\Rightarrow T = 640 \text{ }^\circ\text{C (2s.f.)}$	3	

Question		Expected response	Max mark	Additional guidance
10.	(e)	<p><u>Node A</u></p> <p>$\Sigma F_V = 0$ $\Rightarrow AB_V = 510 \text{ kN}$</p> <p>$AB = 510/\sin 61 = 583.11 \text{ kN}$ $AB = 580 \text{ kN (2s.f.) (1 mark)}$</p> <p>$AB_H = 583\cos 61 = 282.644 \text{ kN}$</p> <p>$\Sigma F_H = 0$ $\Rightarrow AC = 282.644 \text{ kN}$</p> <p>$AC = 280 \text{ kN (2s.f.) (1 mark)}$</p> <p><u>Node C</u></p> <p>$\Sigma F_V = 0$ $\Rightarrow CD_V = 583\sin 61 + 550$ $= 1059.903 \text{ kN}$</p> <p>$CD = 1060/\sin 74 = 1102.6167 \text{ kN}$ $CD = 1100 \text{ kN (2s.f.) (1 mark)}$ TIE (tension) - (1 mark)</p> <p>$CD_H = 1103\cos 74 = 304 \text{ kN}$</p> <p>$\Sigma F_H = 0$ $CE = 283 + 283 + 304$ $= 870 \text{ kN (1 mark)}$ STRUT (compression) - (1 mark)</p>	6	 

Question		Expected response	Max mark	Additional guidance
11.	(a)	Improved journey times due to better traffic flow. Improved access and increased comfort to transport for rail passengers. Improved public access to amenities in city centre.	4	2 marks for each descriptive appropriate impact explained with cause (1 mark) and effect (1 mark).
	(b) (i)		2	1 mark for three forces (including angles). 1 mark for both dimensions.
	(ii)	$W = 650\sin 37 + 776\sin 48$ (1 mark) $= 967.86 \text{ N}$ 970 N (2s.f.) (1 mark)	2	
	(c)	$F_{CH} =$ $530\cos 65 + 776\cos 48 - 650\cos 37 =$ 224.12 N $F_{CV} =$ $650\sin 37 + 776\sin 48 - 530\sin 65 =$ 487.52 N $F_C =$ $\sqrt{224.12^2 + 487.52^2} =$ 536.57 N 540 N (2s.f.) $\tan \theta = 224.12 / 487.52$ $\Rightarrow \theta = 24.69^\circ$ 25° (2s.f.)	6	1 mark for correct substitution. 1 mark for answer. 1 mark for correct substitution. 1 mark for answer. 1 mark for magnitude. 1 mark for angle.
	(d) (i)	$A_{\text{eff}} = (\pi \times 72^2 / 4) - (\pi \times 67^2 / 4)$ $= 545.8517 \text{ mm}^2$ $\sigma = 32700 / 545.8517$ $= 59.9063 \text{ N mm}^{-2}$ $\epsilon = \sigma / E = 59.9063 / 70000 = 8.558 \times 10^{-4}$ $\Delta l = 8.558 \times 10^{-4} \times 2700 = 2.3106$ $= \mathbf{2.3 \text{ mm (2 s.f.)}}$	6	1 mark. 1 mark. 1 mark. 1 mark for E from data booklet, 1 mark for calculation. 1 mark for final answer.
	(ii)	Increase the effective area/tube thickness. Change to a stronger material.	2	

[END OF MARKING INSTRUCTIONS]