



National
Qualifications
2026

2026 Engineering Science

Higher

Question Paper Finalised Marking Instructions

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General marking principles for Higher Engineering Science

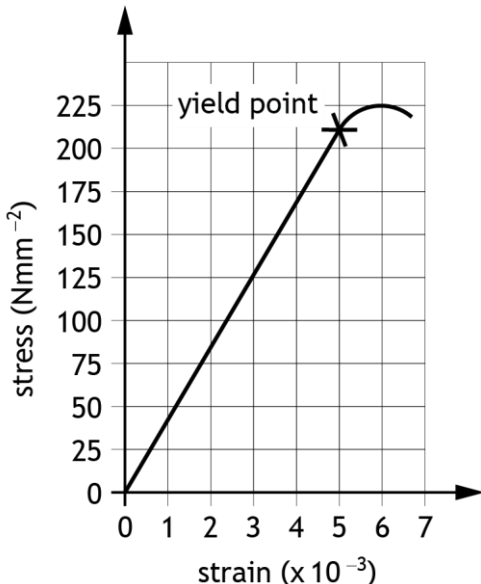
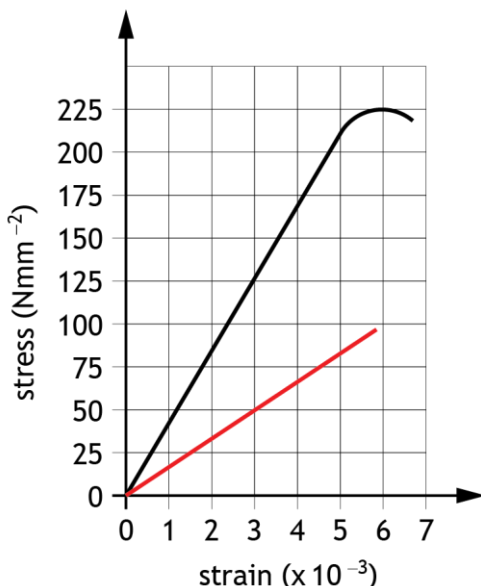
Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

- (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) QUALIFICATIONS SCOTLAND 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. (Note: the use of a recurrence dot, eg $6.\dot{6}$, would imply an infinite number of significant figures and would therefore not be acceptable.)
- (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 'Describe' questions, candidates must provide a statement or structure of characteristics and/ or features, in the context of and appropriate to the question.
- (k) 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.
- (l) Where separate space is provided for rough working and a final answer, only award marks for the final answer. Ignore all rough working.

Detailed marking instructions for each question

Section 1

Question			Expected response			Max mark	Additional guidance																											
1.			<table><tr><td>D</td><td>E</td><td>Z</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td></tr></table>	D	E	Z	1	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	0	1	1	0	1	0	3	1 mark per correct complete column. Column D = NOT B. Apply FTE. Column E = A OR D. Column Z = C NAND E.		
D	E	Z																																
1	1	1																																
1	1	0																																
0	0	1																																
0	0	1																																
1	1	1																																
1	1	0																																
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0	1	0																																
2.	<pre>graph LR RT[required temperature] --> Sum((+/-)) Sum --> CU[control unit] CU --> OD[output driver] OD --> HE[heating element] HE --> AT[actual temperature] AT --> TS[temperature sensor] TS --> Sum</pre>			3	1 mark for error detector to show negative feedback. 1 mark for heating element/heater. 1 mark for desired/required/set temperature and actual temperature. Do not accept “user input” or “heat”.																													

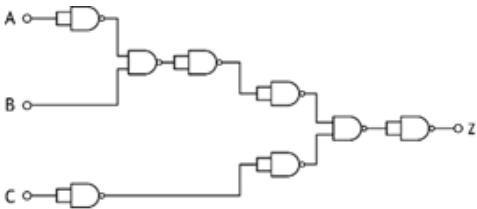
Question			Expected response	Max mark	Additional guidance
3.	(a)		The material will extend under loading and then return to its original length.	1	1 mark for any suitable description of elastic behaviour; must include deformation and return. Do not accept responses that imply compressive testing eg bend.
	(b)			1	1 mark for any annotation that suitably indicates the yield point at the end of the elastic range.
	(c)			1	1 mark for any line drawn from the origin where the elastic region (straight line) section of the graph has a lower gradient than the original graph.
	(d)		$E = \frac{\sigma}{\epsilon}$ $E = \frac{175}{3.64 \times 10^{-3}}$ $E = 48076.92308$ $E = 48 \text{ kNmm}^{-2} (2\text{sf})$	1	1 mark for final answer with unit.

Question			Expected response	Max mark	Additional guidance
4.	(a)		$Av_1 = -\frac{R_{f1}}{R_{i1}}$ $Av_1 = -\frac{40}{10}$ $Av_1 = -4$ $Av_2 = -\frac{R_{f2}}{R_{i2}}$ $Av_2 = -\frac{10}{10}$ $Av_2 = -1$ $Av_{total} = Av_1 \times Av_2$ $Av_{total} = (-4) \times (-1)$ $Av_{total} = 4.0$	2	1 mark for gain of -4. 1 mark for final answer with no unit. Apply FTE.
	(b)		$A_v = 1 + \frac{R_f}{R_i}$ $19 = 1 + \frac{R_f}{10000} a$ $\frac{R_f}{10000} = 19 - 1$ $R_f = (19 - 1) \times 10000$ $R_f = 180000 \Omega$ $R_f = 180k\Omega$	1	1 mark for final answer with unit.

Question			Expected response	Max mark	Additional guidance
5.	(a)		It supports a shaft (while allowing it to rotate). It reduces vibration in the drive shaft. It improves efficiency by reducing vibrations. It reduces wear on the motor/gearbox.	1	1 mark for response, related to context. Do not accept reduce friction/improve efficiency/reduce wear on its own.
	(b)		It is easier to remove and replace the shaft being held by the bearing.	1	1 mark for response. Any suitable response ie ease of maintenance.
	(c)		Clutch.	1	1 mark for response.

Question			Expected response	Max mark	Additional guidance
6.			$R_v = (980 \times \sin 37^\circ) - (420 \times \sin 62^\circ)$ $R_v = 218.9407337 \text{ N}$ $R_h = (980 \times \cos 37^\circ) + (420 \times \cos 62^\circ)$ $R_h = 979.8408562 \text{ N}$ $R = \sqrt{(218.9407337^2 + 979.8408562^2)}$ $R = 1004.00356 \text{ N}$ $R = 1.0 \text{ kN} (2 \text{ sf})$ $\tan \theta = \frac{218.9407337}{979.8408562}$ $\tan \theta = 0.223445198$ $\theta = \tan^{-1} (0.223445198)$ $\theta = 12.59556424^\circ$ $\theta = 13^\circ (2 \text{ sf})$	4	1 mark for calculating R_v (no units required). 1 mark for calculating R_h (no units required). 1 mark for calculating R. Allow FTE from R_h and/or R_v. 1 mark for calculating θ. Allow FTE from R_h and/or R_v. Do not accept 77°.

Section 2

Question			Expected response	Max mark	Additional guidance
7.	(a)		$Z = \overline{(\bar{A}.B)} + \bar{C}$	3	1 mark for NOT A AND B in brackets. 1 mark for NOT C. 1 mark for NOR.
	(b)		 The diagram shows three inputs: A, B, and C. Input A and B are connected to an AND gate. Input C and the output of the first AND gate are connected to a NOR gate. The output of the NOR gate is connected to an AND gate along with the output of the first AND gate. The final output is Z.	3	1 mark for NOT A AND NOT C. 1 mark for AND. 1 mark for NOR.
	(c)		Economic Passengers will not need to pay to replace their luggage if it is handled with care. Airlines/airport would save money as there would be less compensation for damaged luggage. The initial set-up cost for the system is likely to be expensive. Social Passengers will be less frustrated as no damage to their luggage (therefore they will enjoy the travel experience more.) Airline employees will experience fewer customer complaints (therefore reducing work-related stress.)	2	Response must be descriptive. 1 mark for economic impact. 1 mark for social impact. Accept any appropriate response.
	(d)		Using torque calculations to determine forces acting on the belt/motor/gears/shaft/bearings. Calculating the speed of the conveyor belt (in the drive system). Calculating the mechanical power of the drive system (the motor in the drive system). Calculating the efficiency of the drive system. Using simulation software for mathematical modelling/testing mechanical aspects of the system.	2	1 mark for each example. Response must be specific to role of a mechanical engineer and related to the context ie drive system.

Question			Expected response	Max mark	Additional guidance
7.	(e)		<pre> graph TD Start([start]) --> A{A on?} A -- Y --> B{B on?} B -- N --> A B -- Y --> Wait[wait 2 seconds] A -- N --> Wait Wait --> LampOn[/lamp on/] LampOn --> LampOff[/lamp off/] LampOff --> A </pre>	3	1 mark for “A on?” with Y connection to “B on?” and N connection to next stage. 1 mark for “B on?” with N connection back to start and Y connection to next stage. 1 mark for “lamp on” (accept “L on”) in correct symbol. For flow down or to the right, an arrow is not required. For flow upwards or to the left, arrows are added.
	(f)			2	1 mark for digital signal - all shown pulses must be the same voltage. 1 mark for correct mark to space ratio on shown pulses. Response must include a minimum of three marks and two spaces to establish correct ratio. 0 marks for showing only one pulse.
	(g)		Increase mark time, space time stays same. Decrease space time, mark time stays same. Increase mark time, decrease space time. Increase mark:space ratio or duty cycle.	1	1 mark for suitable response - must refer to both mark and space.

Question			Expected response	Max mark	Additional guidance
8.	(a)		$\frac{V_1}{V_2} = \frac{R_1}{R_2}$ $\frac{V_{\text{ref}}}{5} = \frac{220}{(220 + 120)}$ $V_{\text{ref}} = 5 \times \frac{220}{(220 + 120)}$ $V_{\text{ref}} = 3.235294118 \text{ V}$ $V_o = \frac{R_f}{R_i}(V_2 - V_1)$ $-3.2 = \frac{R_f}{10000} \times (2 - 3.235294118)$ $\frac{R_f}{10000} = -3.2 / (2 - 3.235294118)$ $R_f = \frac{-3.2}{(2 - 3.235294118)} \times 10000$ $R_f = 25904.7619 \Omega$ $R_f = 26 \text{ k}\Omega \text{ (2sf)}$	3	1 mark for reference voltage (no units required). 1 mark for correct substitution. Allow FTE from reference voltage. 1 mark for answer with unit.
	(b)		Add an inverting op-amp (after the difference op-amp). Swap the inputs to the op-amp.	2	1 mark for each correct answer.

Question			Expected response	Max mark	Additional guidance
8.	(c)		$V_{\text{sat}} = 12 \times 0.87$ $V_{\text{sat}} = 10.44 \text{ V}$ $V_o = \frac{R_f}{R_i} (V_2 - V_1)$ $10.44 = \frac{33000}{12000} (V_{\text{in}} - 2.7)$ $10.44 \times 12000 = 33000 \times (V_{\text{in}} - 2.7)$ $125280 = 33000V_{\text{in}} - 89100$ $V_{\text{in}} = \frac{125280 + 89100}{33000}$ $V_{\text{in}} = 6.496363636 \text{ V}$ $V_{\text{in}} = 6.5 \text{ V (2sf)}$	2	1 mark for saturation voltage (no units required). 1 mark for correct answer with unit. Allow FTE from saturation voltage.
	(d)		When V_{in} is above 7.5 V, the motors run at full speed (due to the op-amp saturating). When V_{in} drops below 7.5 V, the motors will start to slow down. When V_{in} reaches 2.7 V, the motors will stop.	3	1 mark for describing full speed. 1 mark for describing the speed slowing down. 1 mark for stating that the motor stops. Voltages (7.5 V and 2.7 V) must be referenced in responses to gain the second and third marks.

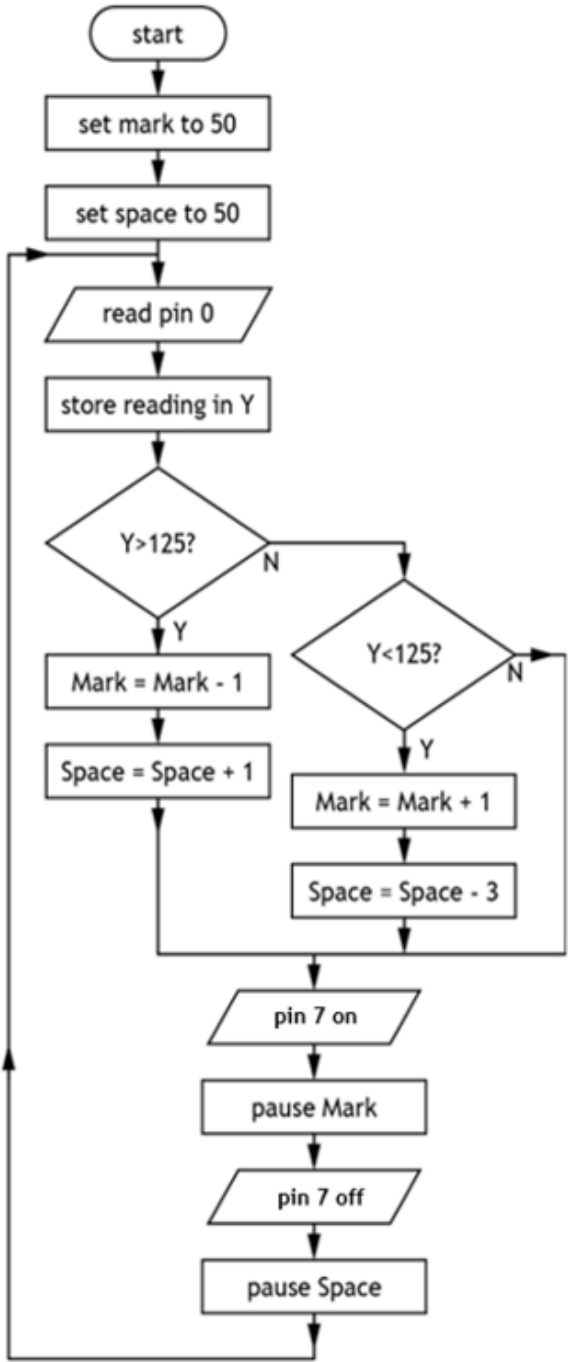
Question			Expected response	Max mark	Additional guidance
8.	(e)		$P = 2\pi nT$ $21000 = 2 \times \pi \times \left(\frac{60}{60}\right) \times T$ $T = \frac{21000}{2 \times \pi \times \left(\frac{60}{60}\right)}$ $T = 3342.253805 \text{ Nm}$ $T = 3.3 \text{ kNm (2 sf)}$	2	1 mark for converting to revs sec⁻¹. 1 mark for final answer with unit. Allow FTE from converting to revs sec⁻¹.
	(f)	(i)	$T = Fr$ $2600 = F \times 2.3$ $F = \frac{2600}{2.3}$ $F = 1130.43478 \text{ N}$ $F = 1.1 \text{ kN (2sf)}$	1	1 mark for final answer with unit.

Question			Expected response	Max mark	Additional guidance
8.	(f)		(continued)		
		(ii)	Method 1 $P = 2\pi nT$ $P = 2 \times \pi \times \left(\frac{65}{60}\right) \times 2600$ $P = 17697.63862 \text{ W}$ $P = Fv$ $v = \frac{P}{F}$ $v = \frac{17697.63862}{1100}$ $v = 16.08876238 \text{ ms}^{-1}$ $v = 16 \text{ ms}^{-1} \text{ (2 sf)}$ Method 2 drum circumference = πd drum circumference = $\pi \times 4.6$ drum circumference = 14.45132621 linear speed = drum circumference $\times$ drum speed $\text{linear speed} = 14.45132621 \times \left(\frac{65}{60}\right)$ $\text{linear speed} = 15.65560339 \text{ ms}^{-1}$ $\text{linear speed} = 16 \text{ ms}^{-1} \text{ (2sf)}$	2	Method 1 1 mark for power (no units required). 1 mark for final answer with unit. Allow FTE from 8f(i). Method 2 1 mark for the drum circumference (no unit required). 1 mark for final answer with unit. Allow FTE from drum circumference.

Question			Expected response	Max mark	Additional guidance
9.			V1 and V2 sends a (pilot) signal to V3. V3 changes state, causing CA to outstroke which actuates V6. When CA outstrokes, V4 unactuates and stops supplying air to V7. V3 also sends (pilot) signal through a time delay. (When V6 is actuated) V7 changes states (actuates) to allow air to flow through to V8. V6 (or time delay) sends a (pilot) signal to V3, changing its state, causing CA to instroke. (When CA instrokes) V4 actuates and sends a (pilot) signal to V8, changing its state, causing CB to outstroke. (When CB outstrokes) V9 is actuated, changing the state of V8, causing CB to instroke. V7 ensures V8 does not receive conflicting air signals.	8	1 mark for each complete descriptive comment. An explanation of the function of V7 must be included for the full 8 marks.

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	$A = \frac{\pi d^2}{4}$ $A = \frac{\pi \times 76^2}{4}$ $A = 4536.459792 \text{ mm}^2$ $\sigma = \frac{F}{A}$ $\sigma = \frac{36900}{4536.459792}$ $\sigma = 8.134096122 \text{ Nmm}^{-2}$ $\text{UCS} = 300 \text{ Nmm}^{-2} \text{ from data booklet}$ $\text{FoS} = \frac{\text{UCS}}{\sigma}$ $\text{FoS} = \frac{300}{8.134096122}$ $\text{FoS} = 36.88178693$ $\text{FoS} = 37(2\text{sf})$	4	1 mark for calculating area (no units required). 1 mark for calculating σ (no units required). Allow FTE from area. 1 mark for UCS (no unit required). 1 mark for final answer with no units. Allow FTE from σ and/or UCS.
		(ii)	A high factor of safety is appropriate due to the risk to life (of possible astronauts). A high factor of safety is appropriate due to the high costs associated with space missions.	1	1 mark for suitable response. Response must refer to the appropriateness of the factor of safety from response in 10a(i). A well justified reason for stating factor of safety too high eg unmanned mission would be acceptable.

Question			Expected response	Max mark	Additional guidance
10.	(b)		UDL = 2.3×0.78 UDL = 1.794 kN @ 1.15 m Take moments around A. $\Sigma CWM = \Sigma ACWM$ $(1.794 \times 1.15) + (6.4 \sin 19^\circ \times 1.8)$ $+ (6.4 \cos 19^\circ \times 2.3) = 1.8 \times B$ $2.0631 + 13.91803343 + 3.750545139 = 1.8B$ $B = \frac{19.73167857}{1.8}$ $B = 10962.04365 \text{ N}$ $B = 11\text{kN}(2 \text{ sf})$	5	1 mark for magnitude of UDL (no units required). 1 mark for horizontal component of 6.4 kN ($6.4 \sin 19$ or $6.4 \cos 71$) multiplied by 1.8 m. 1 mark for vertical component of 6.4 kN ($6.4 \cos 19$ or $6.4 \sin 71$) multiplied by 2.3 m. 1 mark for substitution. Allow FTE from UDL and components of 6.4 kN force. 1 mark for final answer with unit. Apply FTE.

Question		Expected response	Max mark	Additional guidance
11.	(a)	 <pre> graph TD Start([start]) --> SetMark[set mark to 50] SetMark --> SetSpace[set space to 50] SetSpace --> ReadPin[/read pin 0/] ReadPin --> StoreY[store reading in Y] StoreY --> Ygt125{Y > 125?} Ygt125 -- Y --> MarkMinus[Mark = Mark - 1] MarkMinus --> SpacePlus[Space = Space + 1] SpacePlus --> Pin7On[/pin 7 on/] Ygt125 -- N --> Ylt125{Y < 125?} Ylt125 -- Y --> MarkPlus[Mark = Mark + 1] MarkPlus --> SpaceMinus[Space = Space - 3] SpaceMinus --> Pin7On Ylt125 -- N --> Pin7On Pin7On --> PauseMark[pause Mark] PauseMark --> Pin7Off[/pin 7 off/] Pin7Off --> PauseSpace[pause Space] PauseSpace --> ReadPin </pre>	10	1 mark for set mark to 50. 1 mark for set space to 50. 1 mark for $Y > 125$. 1 mark for $Y < 125$. 1 mark for connections relating to the checking of Y. 1 mark for changes to mark and space when $Y > 125$. 1 mark for changes to mark and space when $Y < 125$. 1 mark for Pin 7 (motor) on and off, for each condition of Y. 1 mark for correct two pauses/delays. 1 mark for loop with arrowhead. If a candidate uses the incorrect symbol/ unit then no mark. If they repeat the error, allow FTE. For flow down or to the right, an arrow is not required. For flow upwards or to the left, arrows are added.

Question			Expected response	Max mark	Additional guidance
11.	(c)		(continued)		
			Method 2 $P = VI$ $P_{in} = 48 \times 110$ $P_{in} = 5280 \text{ W}$ $P = \frac{E}{t}$ $P_{losses} = \frac{36 \times 10^6}{(8 \times 60 \times 60)}$ $P_{losses} = 1250 \text{ W}$ $P_{out} = P_{in} - P_{losses}$ $P_{out} = 5280 - 1250$ $P_{out} = 4030 \text{ W}$ $\eta = \frac{P_{out}}{P_{in}}$ $\eta = \frac{4030}{5280}$ $\eta = 0.763257576$ $\eta = 0.76(76\%)(2sf)$		Method 2 1 mark for P_{in} (no units required). 1 mark for P_{out} (no units required). Allow FTE from P_{in}. 1 mark for final answer (unit as appropriate). Allow FTE from P_{in} and/or P_{out}.
	(d)		Fewer waste disposal costs due to increased efficiency. Energy costs lowered due to increased efficiency. Financial benefit from government incentives. Increased sales/investment as products/services are more environmentally friendly. Initial capital costs to make warehouse/equipment more energy efficient such as building methods, sustainable materials costs, etc.	1	1 mark for response. It must be descriptive and not a statement. Simply writing “initial cost” as a negative impact is not enough. The response must give indication of what areas the initial cost will cover eg insulation, water reclamation systems, heat recycling, etc.

Question			Expected response	Max mark	Additional guidance
11.	(e)		Skill Design electronic sub-systems, such as sensing circuits, to detect obstacles. Plan the program logic to structure how the vacuum will operate and respond to inputs. Design interfaces between components to ensure signals are processed correctly. Test programme function to check that inputs are processed and outputs are controlled correctly. Design switching circuits to control outputs. Write code to control movement/sensors/decision-making. Simulate circuits to model/test/find faults before constructing. Calculating values eg, power consumption to ensure the vacuum operates efficiently. Knowledge Understanding of how microcontrollers function to process inputs from sensors and control outputs. Op-amp electronic control systems to amplify and process sensor signals. Digital electronics to ensure correct signal communication between components. Understanding of interfacing so sensors can communicate correctly with the microcontroller.	2	Responses must be descriptive and not a statement, related to context. Accept any appropriate response. 1 mark for skill. 1 mark for knowledge.

Question			Expected response	Max mark	Additional guidance
11.	(e)		(continued)		
			Function of a relay to safely control the motor. Programming knowledge to control how the vacuum responds to sensor inputs and controls movement. Energy audits to ensure efficient operation and minimal energy waste.		

Question			Expected response	Max mark	Additional guidance
12.	(a)		Method 1 $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ $\frac{V_{\text{ref}}}{5} = \frac{56000}{(56000 + 22000)}$ $V_{\text{ref}} = \frac{5 \times 56000}{(56000 + 22000)}$ $V_{\text{ref}} = 3.58974359 \text{ V}$ $\frac{R_{\text{thermistor}}}{5000} = \frac{3.58974359}{5 - 3.58974359}$ $R_{\text{thermistor}} = 1964.28571 \Omega$ Temperature = 72-75 °C (2 sf) Method 2 $\frac{22000}{56000} = \frac{R_{\text{thermistor}}}{5000}$ $R_{\text{thermistor}} \times 56000 = 22000 \times 5000$ $R_{\text{thermistor}} = \frac{22000 \times 5000}{56000}$ $R_{\text{thermistor}} = 1964.28571 \Omega$ Temperature = 72-75 °C (2 sf)	2	Method 1 1 mark for calculating thermistor resistance (no units required). 1 mark for final answer with units. Allow FTE from thermistor resistance. Method 2 1 mark for calculating thermistor resistance (no units required). 1 mark for final answer with units. Allow FTE from thermistor resistance.

Question			Expected response	Max mark	Additional guidance
12.	(b)	(i)	$V_{\text{out}} = 12 \times 0.78$ $V_{\text{out}} = 9.36 \text{ V}$ $V_{\text{Rb}} = I_{\text{b}} \times R_{\text{b}}$ $(9.36 - 0.7) = I_{\text{b}} \times 12000$ $I_{\text{b}} = \frac{9.36 - 0.7}{12000}$ $I_{\text{b}} = 0.000721667 \text{ A}$ $I_{\text{b}} = 0.72 \text{ mA (2 sf)}$	3	1 mark for calculating V_{out} (no units required). 1 mark for voltage across resistor. Allow FTE from V_{out}. 1 mark for final answer with units.
		(ii)	$h_{\text{FE}} = \frac{I_{\text{c}}}{I_{\text{b}}}$ $54 = \frac{I_{\text{c}}}{0.72}$ $I_{\text{c}} = 54 \times 0.72$ $I_{\text{c}} = 38.88 \text{ mA}$ $I_{\text{c}} = 39 \text{ mA (2 sf)}$	1	Apply FTE from 12b(i). 1 mark for answer with units.
		(iii)	Voltage across relay: $V = I_{\text{c}} \times R_{\text{relay}}$ $V = 0.039 \times 85$ $V = 3.315 \text{ V}$ $V_{\text{ce}} = 5 - 3.315$ $V_{\text{ce}} = 1.685 \text{ V}$ $P = VI$ $P = 1.685 \times 0.039$ $P = 0.065715 \text{ W}$ $P = 0.066 \text{ W (2 sf)}$	3	Apply FTE from 12b(ii). 1 mark for calculating the voltage across the relay (no units required). 1 mark for calculating voltage across transistor V_{ce} (no units required). 1 mark for answer with units.
	(c)		Difference	1	1 mark for difference (op-amp).

Question			Expected response	Max mark	Additional guidance																		
13.	(a)		<table><tr><th>Member</th><th>Magnitude</th><th>Nature</th></tr><tr><td>AB</td><td>2.9 MN</td><td>tie</td></tr><tr><td>AE</td><td>1.6 MN</td><td>strut</td></tr><tr><td>BC</td><td>4.7 MN</td><td>tie</td></tr><tr><td>BD</td><td>5.3 MN</td><td>strut</td></tr><tr><td>BE</td><td>1.94 MN</td><td>tie</td></tr></table>	Member	Magnitude	Nature	AB	2.9 MN	tie	AE	1.6 MN	strut	BC	4.7 MN	tie	BD	5.3 MN	strut	BE	1.94 MN	tie	6	If candidate uses alternative method to calculate AB, BC and BD their response may vary slightly from the magnitudes in the table.
			Member	Magnitude	Nature																		
AB	2.9 MN	tie																					
AE	1.6 MN	strut																					
BC	4.7 MN	tie																					
BD	5.3 MN	strut																					
BE	1.94 MN	tie																					
Node A: $\Sigma F_H = 0$ $AB_H = 2.35 \text{ MN}$ $AB = \frac{2.35}{\sin 55^\circ}$ $AB = 2.868820284 \text{ MN}$ $AB = 2.9 \text{ MN (2 sf) tie}$ Node B: $\Sigma F_H = 0$ $BD_H = AB_H + BE$ $BD \cos 35^\circ = 2.9 \cos 35^\circ + 1.94$ $BD \cos 35^\circ = 4.315540929 \text{ MN}$ $BD = \frac{4.315540929}{\cos 35^\circ}$ $BD = 5.268302702 \text{ MN}$ $BD = 5.3 \text{ MN (2 sf) strut}$ $\Sigma F_V = 0$ $BC = AB_V + BD_V$ $BC = AB \cos 55^\circ + BD \sin 35^\circ$ $BC = 2.9 \cos 55^\circ + 5.3 \sin 35^\circ$ $BC = 4.703326778 \text{ MN}$ $BC = 4.7 \text{ MN (2 sf) tie}$	1 mark for AB magnitude with units. 1 mark for AB nature. If candidate uses $AB_H = 2.35 \text{ MN}$ from node A, $BD = 5.2 \text{ MN}$. 1 mark for BD magnitude with units. FTE from AB. 1 mark for BD nature. 1 mark for BC magnitude with units. FTE from AB and BD. 1 mark for BC nature.																						

Question			Expected response	Max mark	Additional guidance
13.	(b)		- designing the foundations for the launch pad to ensure suitable strength/stability - designing the foundations for the road surface for transporting the rocket - designing the traffic management system for site traffic - analysing survey results for ground levels/soil types/water tables, etc - analysing core samples to determine soil types/ground suitability - analysing existing ground works, embankments or structures - designing flood protection systems - designing sewage systems and drainage ponds	2	1 mark for each identified role, related to context. Maximum of 2 marks. Response must be descriptive. Accept any appropriate response linked to development stage.
	(c)		$E_s = \frac{1}{2} Fx$ $0.7645 = \frac{1}{2} F \times 0.000087$ $F = \frac{0.7645}{\left(\frac{1}{2} \times 0.000087\right)}$ $F = 17574.71264 \text{ N}$ $F = 18\text{kN (2 sf)}$	1	1 mark for final answer with units.

Question			Expected response	Max mark	Additional guidance
13.	(d)		$\epsilon = \frac{\Delta l}{l}$ $\epsilon = \frac{0.055}{33000}$ $\epsilon = 1.666666667 \times 10^{-6}$ $E = \frac{\sigma}{\epsilon}$ $216000 = \frac{\sigma}{(1.666666667 \times 10^{-6})}$ $\sigma = 216000 \times (1.666666667 \times 10^{-6})$ $\sigma = 0.36 \text{ Nmm}^{-2}$ $A_{\text{total}} = \frac{F}{\sigma}$ $A_{\text{total}} = \frac{2250}{0.36}$ $A_{\text{total}} = 6250 \text{ mm}^2$ $A_{\text{strand}} = \frac{F}{\sigma}$ $A_{\text{strand}} = \frac{6250}{7}$ $A_{\text{strand}} = 892.8571429 \text{ mm}^2$ $A_{\text{strand}} = 890 \text{ mm}^2 (2 \text{ sf})$	4	1 mark for calculating ϵ. 1 mark for calculating σ (no units required). Allow FTE from ϵ. 1 mark for calculating A_{total} (no units required). Allow FTE from σ. 1 mark for final answer with units. Allow FTE from A_{total}.

[END OF MARKING INSTRUCTIONS]