National
Qualifications
2022

2022 Engineering Science

Higher

Finalised 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.

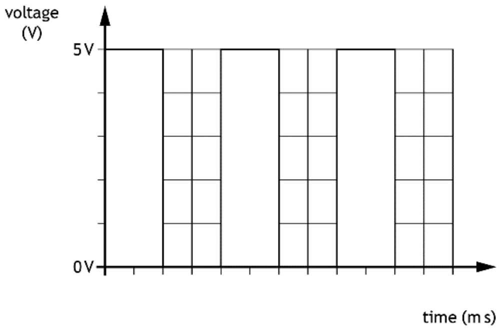
(j) For 'Explain' questions, only award marks where the candidate goes beyond a description, for example by giving a reason, or relating cause to effect, or providing a relationship between two aspects.

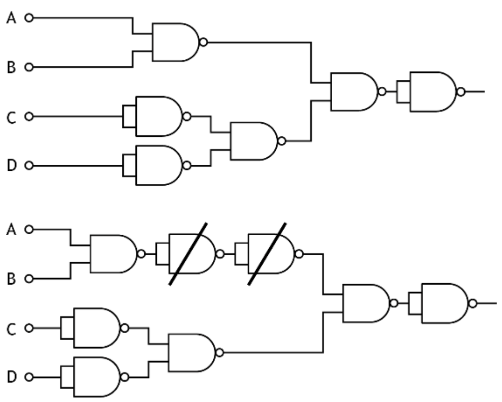
(k) Where separate space is provided for rough working and a final answer, only award marks for the final answer. Ignore all rough working.

Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)	Elastic	**1**	
		(ii)	Plastic	**1**	
	(b)	(i)	E = 200/0.001 = 200,000 Nmm^{-2} **= 200 $kNmm^{-2}$ (1 sf)**	**1**	Any appropriate value of stress and strain from graph can be used
		(ii)	Ultimate Tensile Stress	**1**	Accept UTS
2.	(a)		$V_{in} = V_t \times R_1/R_t$ $= 5 \times 2/10$ $= 1$ V $V_{out} = (-R_f/R_i) \times V_{in}$ $= (-10/50) \times 1.0$ **= -0.20 V (2 sf)**	**2**	1 mark for calculating V_{in} (units not required) 1 mark for calculating V_{out} (with units)
	(b)		By decreasing the value of R_f (feedback resistance) By increasing the value of R_i (input resistance) Decreasing the ratio of R_f to R_i	**1**	1 mark for correct description of R_f or R_i Do not accept 'change the value of......'
	(c)		Inverting	**1**	
3.			Uniformly distributed load: = 4.5 × 1.4 = 6.3 kN @ 0.7m from A Moments about B: $(1.1 \times 0.3) + (R_A \times 1.4) = 6.3 \times 0.7$ $R_A \times 1.4 = (6.3 \times 0.7) - (1.1 \times 0.3)$ $R_A = 4.08/1.4$ = 2.914285714 **= 2.9 kN (2 sf)**	**3**	1 mark for value 6.3kN (unit not required) 1 mark for substitution 1 mark for final answer with unit

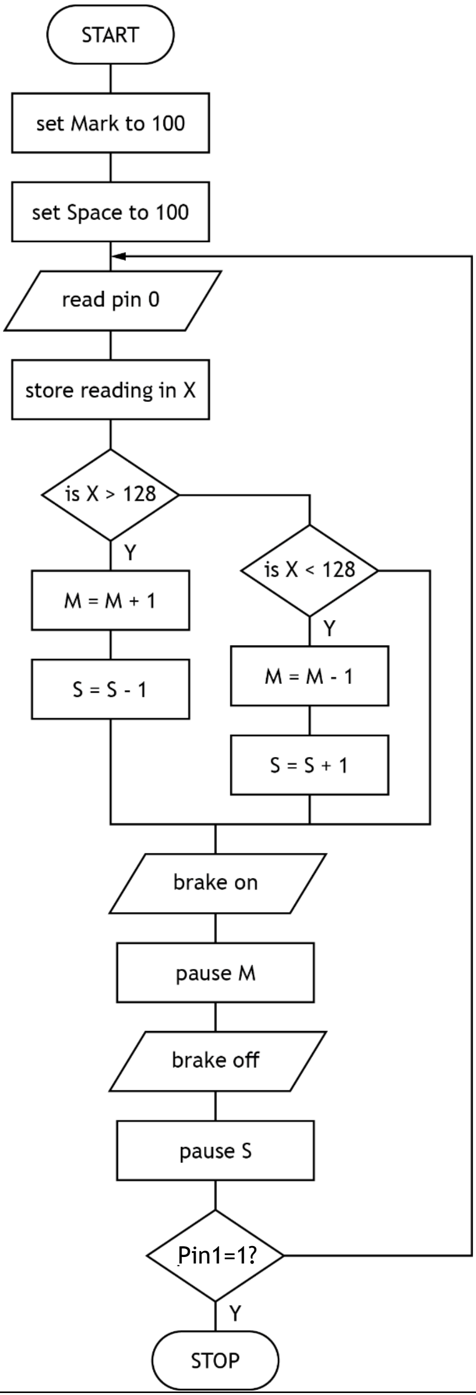
Question			Expected response	Max mark	Additional guidance
4.	(a)			**2**	1 mark for correct ratio - on for the same length of time as off 1 mark for digital signal – all pulses must be the same height
	(b)		Decrease mark time, space time stays same Increase space time, mark time stays same Decrease mark time, increase space time Decrease of mark:space ratio or duty cycle	**1**	1 mark for suitable response – must refer to both mark and space
	(c)		Torque remains the same at all speeds	**1**	1 mark for suitable response
5.			Use knowledge of material values (Young's Modulus, UTS) in structural calculations Use knowledge of factor of safety to determine suitable cross-sectional area of materials Use knowledge of materials costs to ensure costs are controlled Use knowledge of available material sections to provide required strength and stability Use knowledge of computer simulation software to analyse current structure Use knowledge of materials relating to reduction of material integrity.	**2**	1 mark for each suitable response

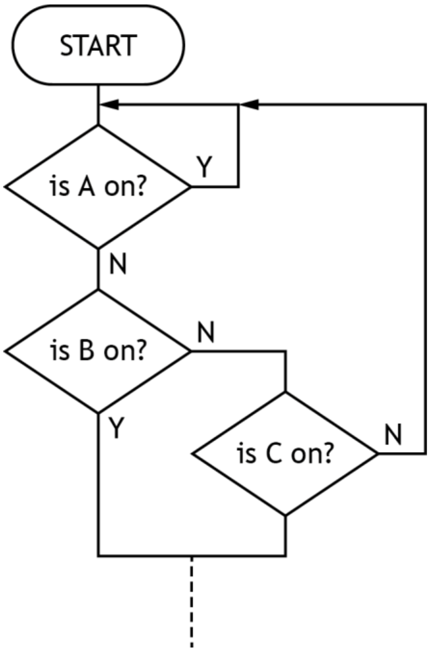
Question			Expected response	Max mark	Additional guidance
6.				**3**	1 mark for NAND 1 mark for OR 1 mark for AND

Section 2

Question			Expected response	Max mark	Additional guidance
7.	(a)		E_{out} = 10000 × 9.8 × 32 = 3136000 J E_{in} = 3136000/0.92 = 3408695.65 = **3.4 MJ (2 sf)**	**2**	1 mark for correct energy out (unit not required) 1 mark for correct energy in with unit
	(b)		E_{in} = 80000 × 15 E_{in} = 1200000 J P_{in} = 1200000 /11 = 109.090909 kW P_{out} = 109.090909 × 0.87 = 94909.0909 = **95 kW (2 sf)** **Alternative method** E_{in} = 80000 x 15 E_{in} = 1200000 J E_{out} = 1200000 x 0.87 = 1044000 J P_{out} = E_{out} / t = 1044000 / 11 = 94909.09 = **95kW (2 sf)**	**3**	1 mark for correct energy in (units not required) 1 mark for correct power in (unit not required) 1 mark for correct power out (with unit) 1 mark for correct energy in (units not required) 1 mark for correct energy out (units not required) 1 mark for correct power out (with unit)

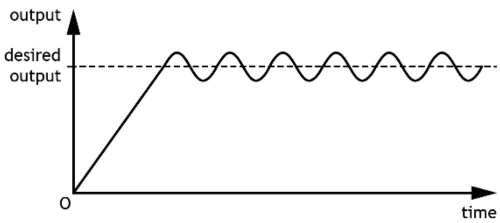
Question			Expected response	Max mark	Additional guidance
	(c)		Area = $(\pi \times 48^2)/4$ = 1809.557368 mm^2 Stress = 80000/1809.557368 = 44.20970641 Nmm^{-2} UTS = 430 FoS = 430/44.20970641 = 9.726370856 = **9.7 (2 sf)**	**4**	1 mark for correct area (units not required) 1 mark for correct stress (units not required) 1 mark for UTS from data booklet (units not required) 1 mark for correct FoS (no units)
	(d)		Economic - • It would make renewable sources of energy more economically viable. • The towers could be located anywhere so they could be built on less expensive land where there is no desire for other developments. Environmental – • It would reduce the need to use fossil fuels to create electricity. • Manufacturing the concrete blocks will generate a lot of carbon emissions. • It would provide a reliable, predictable energy source for the national grid. • The large construction would disrupt wildlife habitats and therefore the ecosystem	**4**	1 mark for each **economic** response to a maximum of 2 marks. 1 mark for each **environmental** response to a maximum of 2 marks. Response must be suitably descriptive for Higher level.
	(e)		It would not require the mining of materials to create batteries. There would be no need to replace the batteries after they wear out. Disposing of battery chemicals after they have been used is expensive. Used batteries can harm the environment if they are not disposed of properly.	**2**	1 mark for each suitable answer.

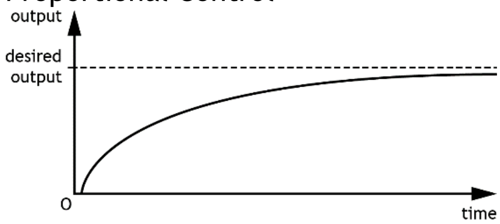
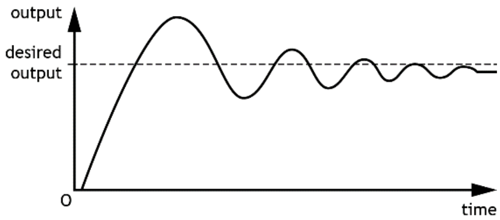
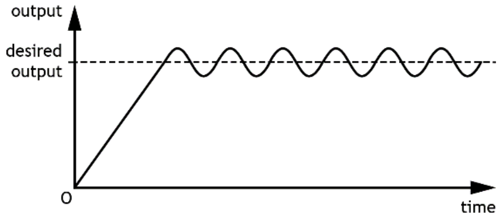
Question			Expected response	Max mark	Additional guidance
8.	(a)			**8**	a. 1 mark for X >128 b. 1 mark for X < 128 c. 1 mark for connections relating to the checking of X d. 1 mark for changes to Mark and Space when X>128 e. 1 mark for changes to Mark and Space when X<128 f. 1 mark for brake on and off, for each condition of X g. 1 mark for correct two pauses/delays h. 1 mark for pin 1 decision and loop Flow chart can finish with a Stop box or a loop to the start. No marks awarded. NB If a candidate uses the wrong symbol type then no mark, if they repeat the error for the same symbol allow FTE.

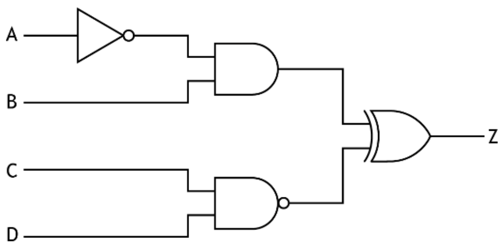
Question			Expected response	Max mark	Additional guidance
8.	(b)			**3**	a) 1 mark for correct feedback loops from A and C b) 1 mark for the use of both B and C in decision boxes c) 1 mark for correct OR arrangement for B and C
	(c)	(i)	$V_{out} = R_f/R_i\ (V_2-V_1)$ $4.5 = 56/22\ (2.3 - V_1)$ $V_1 = 0.5321428571$ V $V_1\ /\ V_2 = R_1\ /\ R_2$ $(6 - 0.5321428571)\ /\ 0.5321428571 = 1500\ /\ R_{VR}$ $R_{VR} = 145.9830176$ **R_{VR} = 150 Ω (2 sf)** Alternative Solution $V_+ - V_- = 4.5/(56/22)$ $= 1.767857143$ V $V_+ = 2.3 - 1.7678757143$ $= 0.5321428571$ V $R_{VR}/1500 = 0.5321428571/(6 - 0.5321428571)$ $R_{VR} = 145.9831702$ Ω **R_{VR} = 150 Ω (2 sf)**	**4**	 1 mark for correct substitution 1 mark for V_1 (units not required) 1 mark for correct substitution 1 mark for final answer with units 1 mark for difference between input voltages 1 mark for V_{VR} (units not required) 1 mark for voltage over 1500Ω resistor 1 mark for R_{VR} (with units)

Question			Expected response	Max mark	Additional guidance
	(c)	(ii)	The resistance of the variable resistor could be increased. The resistance of the 1.5 kΩ resistor could be descreased.	**1**	1 mark for either description

Question			Expected response	Max mark	Additional guidance
9.	(a)		LDR resistance = 5 kΩ V_A = $(V_s \times R_2) / (R_1 + R_2)$ V_A = (6 x 5) / (1.5 + 5) = 4.615384615 = **4.6 V (2 sf)**	**2**	1 mark for correct value of resistance (5 to 5.3 kΩ) 1 mark for calculation of V_A
	(b)	(i)	V_{outmax} = 9 × 0.75 = 6.75 V I = (6.75-0.7)/4700 = 0.001287234 A = **1.3 mA (2 sf)**	**3**	1 mark for calculating Vout max (units not required) 1 mark for correct voltage across base resistor (units not required) 1 mark for current (with units)
		(ii)	I = V / R I_c max = 6/5 = 1.2 A $H_{fe} = I_c / I_b$ h_{fe} = 1.2/0.0013 = 923.0769231 = **920 (2 sf)**	**2**	1 mark for collector current (units not required) 1 mark for gain (no units)

Question			Expected response	Max mark	Additional guidance
9.	(c)		**Input voltage dividers** 1. Resistance of LDR_A will increase 2. V_A will increase (and V_B will decrease). **Op-amp and transistor** 3. When V_A is greater than V_B the op-amp saturates negatively. 4. When the output saturates negatively the transistor will switch off. **Relay and motor** 5. When the transistor switches off the relay will reset. 6. When the relay has reset, current will be forced through the motor in the opposite direction and it will turn in reverse.	**6**	1 mark for each correctly described point. At least one mark must come from each of the three areas to achieve full marks. Max of 4 marks for describing any one section.
	(d)	(i)		**2**	1 mark for trace rising towards desired output. (must be straight line) 1 mark for showing 'hunting' effect.
		(ii)	The motor would constantly be in motion meaning it would have increased power consumption. The system would not settle in position so would increase wear on the moving parts.	**1**	

Question			Expected response	Max mark	Additional guidance
9.	(e)	(i)	Proportional	1	
		(ii)	The output of the control system is proportional to the difference between a feedback signal from the ouput of the system and the desired/reference value. With a two state system the output is either off or on (back/forward, positive/negative) Proportional Control   Two state control 	3	a. 1 mark for identifying that the output can vary between more than two states. b. 1 mark for highlighting how this is different from the two-state option by description or graphically c. 1 mark for identifying what the output is proportional to. OR a. 1 mark for graph showing evidence of curved line from starting point (proportional graph). b. 1 mark for the output settling over time towards desired value (proportional graph) c. 1 mark for a correct two state graph or description to show difference between two. NB Graphs should be fully labelled

Question			Expected response	Max mark	Additional guidance
10.	(a)		$(\overline{A}\cdot\overline{B}\cdot C\cdot\overline{D}) + (A\cdot\overline{B}\cdot C\cdot\overline{D}) + (A\cdot B\cdot C\cdot\overline{D})$ $+ (A\cdot B\cdot C\cdot D)$ **OR** $(A\cdot B\cdot C) + (\overline{B}\cdot C\cdot\overline{D})$	**2**	1 mark for 2 functions correctly described 1 mark for complete equation **OR** 1 mark for each correct function Brackets not required.
	(b)			**4**	1 mark for each correctly connected gate If NAND equivalent or other option is produced then give credit as appropriate.
	(c)	(i)	1. VA must be released. 2. If VB **or** VC is then actuated a signal is sent to change the state of VF. 3. When VF is actuated C1 will outstroke and VE will be actuated. 4. After a delay, C2 will outstroke. 5. When VH is actuated a pilot signal will be sent to VG and VF causing both cylinders to instroke. 6. When VF has been actuated VE will return to its orignal state. 7. VEs function is to prevent both sides of VF being actuated at the same time.	**6**	1 mark for each relevant point up to a maximum of 5 marks. For point 2 to be given there must be mention of OR control. For point 3 to be given VE being actuated in addition to C1 being outstroked must be mentioned. Final mark to be reserved for mentioning the function of VE (point 7).
		(ii)	Significantly fewer components would be required so the system would be smaller/cheaper/quicker to manufacture. Would allow for changes to be made to the function of the system as it can be reprogrammed more easily than constructing a replacement pneumatic circuit.	**2**	

Question			Expected response	Max mark	Additional guidance
10.	(d)	(i)	$R = V^2/P$ $R = 6^2/12$ $=$ **3.0 Ω (2 sf)**	**1**	1 mark for final answer with unit
		(ii)	$I = V / R_T$ $I = 6/(3 + 0.7)$ $= 1.621621622$ **= 1.6 A (2 sf)**	**1**	1 mark for final answer with unit

Question			Expected response	Max mark	Additional guidance
11.	(a)		$A = (\pi 36^2/4) - (\pi 31^2/4)$ $= 263.1083847\ mm^2$ $E = 196\ kNmm^{-2}$ $\sigma = E\epsilon$ $= 196 \times 10^3 \times 4.6 \times 10^{-5}$ $\sigma = 9.016\ Nmm^{-2}$ $F = \sigma A$ $= 9.016 \times 263.1083847$ $F = 2372.185196$ **= 2400 N (2 sf)**	**4**	1 mark for effective area (units not required) 1 mark for Youngs Modulus (from data booklet) (units not required) 1 mark for stress (units not required) 1 mark final answer (with unit)
	(b)		$F = 12000 \times 9.8$ $= 117600\ N$ $r = 0.320/2$ $= 0.160\ m$ $T = 117600 \times 0.16$ $= 18816\ Nm$ $n = 12/60$ $= 0.2\ revs\ sec^{-1}$ $P = 2\pi n T$ $= 2\pi \times 0.2 \times 18816$ $P = 23644.88295$ **P = 24 kW (2 sf)**	**5**	1 mark for calculating force (units not required) 1 mark for calculating radius (units not required) 1 mark for calculating Torque (units not required) 1 mark for calculating n 1 mark for final answer with units
	(c)		$\Sigma F_V = 0$ $F_V + 9.2 \sin 71^\circ - 5.4 \sin 35^\circ - 6.7 \cos 22^\circ = 0$ $F_V = 0.61067369\ kN$ $\Sigma F_H = 0$ $F_H + 5.4 \cos 35^\circ - 9.2 \cos 71^\circ - 6.7 \sin 22^\circ = 0$ $F_H = 1.081670158\ kN$ $F = \sqrt{(0.61067369^2 + 1.081670158^2)}$ $F = 1.242148416$ **F = 1.2 kN (2 sf)** $\tan\theta^\circ = 0.61067369/1.081670158$ $\theta = 29.44757529$ **θ = 29° (2 sf)**	**6**	1 mark for substitution 1 mark for F_V (units not required) 1 mark for substitution 1 mark for F_H (units not required) 1 mark for F 1 mark for θ

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>12.</td><td></td><td></td><td>
<table>
<tr><th>Member</th><th>Magnitude</th><th>Nature</th></tr>
<tr><td>AB</td><td>48 kN</td><td>Strut</td></tr>
<tr><td>AC</td><td>37 kN</td><td>Tie</td></tr>
<tr><td>BC</td><td>6.9 kN</td><td>Tie</td></tr>
<tr><td>BD</td><td>37 kN</td><td>Strut</td></tr>
<tr><td>CD</td><td>14 kN</td><td>Strut</td></tr>
</table>

Node A

$\Sigma F_V = 0$
$AB_V = 31$ kN
AB sin 40° = 31
AB = 31/sin 40°
AB = 48.22743863
AB = 48 kN (2 s.f.)

$\Sigma F_H = 0$
AC = AB cos 40°
= 48 cos 40°
= 36.77013327
= 37 kN (2 sf)

Node B

$\Sigma F_V = 0$
AB_V = 24 + BC
AB sin 40° = 24 + BC
48 sin 40° = 24 + BC

BC = 30.85380526 − 24
= 6.853805265
= 6.9 kN (2 s.f.) (tie)

$\Sigma F_H = 0$
AB cos 40° = BD
48 cos 40° = BD
BD = 36.77013327
= 37kN (2 sf) (strut)

Node C

$\Sigma F_V = 0$
CD_V = 6.9 kN
CD = 6.9 /sin 29°
= 14.23239084
= 14 kN (2 sf) (strut)
</td><td>8</td><td>
1 mark for force AB (with units in table or working)

1 mark for force AC (with units in table or working)

1 mark for force BC (with units in table or working)
1 mark for nature

1 mark for force BD (with units in table or working)
1 mark for nature

1 mark for force CD (with units in table or working)
1 mark for nature
</td></tr>
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[END OF MARKING INSTRUCTIONS]