National
Qualifications
2024

2024 Engineering Science

National 5

Question Paper Finalised Marking Instructions

These marking instructions have been prepared by examination teams for use by SQA appointed markers when marking external course assessments.

General marking principles for National 5 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.

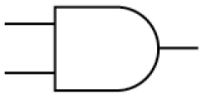
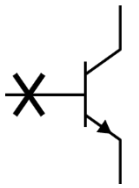
(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

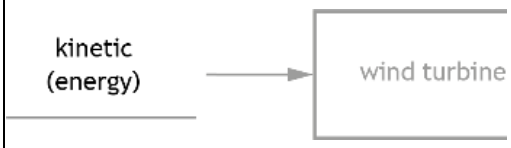
(b) Where a candidate makes an error at an early stage in a multi-stage calculation, credit should normally be given for correct follow-on working in subsequent stages, unless the error significantly reduces the complexity of the remaining stages. The same principle should be applied in questions which require several stages of nonmathematical reasoning.

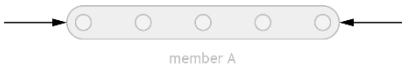
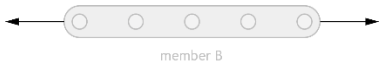
(c) All units of measurement will be presented in a consistent way, using negative indices where required (eg ms^{-1}). Candidates may respond using this format, or solidus format (m/s) or words (metres per second), or any combination of these (eg metres/second).

Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1.	(a)		NOT (gate)/Inverter	**1**	Do not accept symbol.
	(b)			**1**	Inputs and output must be shown. Accept more than two inputs.
2.	(a)		(NPN) transistor	**1**	
	(b)			**1**	Accept X close to the base connection or anywhere on the horizontal line.
3.	(a)		Connection of the main air/exhaust is on the incorrect port. (Pilot air) line type to the cylinder should be solid. The piston should be outstroked.	**2**	1 mark for each error described. 1 mark maximum for main air/ exhaust error. Accept amendments to diagram.
	(b)		Mechanical (engineer)	**1**	

Question			Expected response	Max mark	Additional guidance
4.	(a)		$\text{velocity ratio} = \frac{\text{speed of input}}{\text{speed of output}}$ $\text{velocity ratio} = \frac{120}{820}$ $\text{velocity ratio} = \frac{6}{41}$ **VR = 6 : 41 (2 sf)**	**2**	1 mark for substitution. 1 mark for correct answer from given working. Ignore any unit. Accept 1 : 6.8 Accept 0.15 : 1 Accept 0.146 (3 sf) Ratio must be simplified.
	(b)		No effect. The velocity of gear C will not change.	**1**	
5.	(a)	(i)	Civil (engineer)	**1**	
		(ii)	Environmental (engineer)	**1**	
	(b)			**1**	Do not accept ‘wind’.
	(c)		Closed loop (control)	**1**	Do not accept ‘closed’ on its own.

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)		**1**	Accept pairs of forces drawn vertically opposite and facing.
		(ii)		**1**	Accept pairs of forces drawn vertically opposite and opposing. Do not accept FTE.
	(b)		$\sigma = \frac{F}{A}$ $\sigma = \frac{1152}{36}$ **σ = 32 Nmm^{-2} (2 sf)**	**2**	1 mark for substitution. 1 mark for correct answer from given working with unit.
7.	(a)		Regular maintenance. Avoid overloading/revving. Lubricate/oil/grease the parts.	**1**	Descriptive answer. Do not accept single words. Accept use of bearings/use a slippery material.
	(b)		Heat/sound (energy)	**1**	

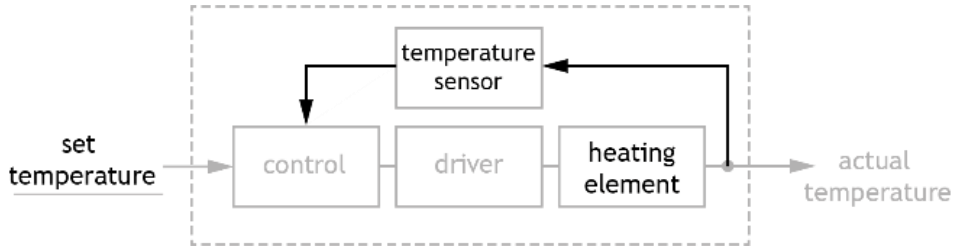
Question			Expected response	Max mark	Additional guidance
8.	(a)	(i)	$Rt = \frac{R1 \times R2}{R1 + R2}$ $Rt = \frac{390 \times 270}{390 + 270}$ R_t = 159.5455 **R_t = 160 Ω (2 sf)** **Alternative method** $\frac{1}{Rt} = \frac{1}{R1} + \frac{1}{R2}$ $\frac{1}{Rt} = \frac{1}{390} + \frac{1}{270}$ $Rt = \frac{1}{0.0062678}$ R_t = 159.5455 **R_t = 160 Ω (2 sf)**	**2**	1 mark for substitution. 1 mark for correct answer from given working with unit. 1 mark for substitution. 1 mark for correct answer from given working with unit.
		(ii)	R_t = 780 + 1200 + 160 R_t = 2140 **R_t = 2100 Ω (2 sf)**	**2**	1 mark for substitution. Apply FTE from (a)(i). 1 mark for correct answer from given working with unit.
	(b)		V = I R 1.2 = I x 390 I = $\frac{1.2}{390}$ I = 0.00308 **I = 0.0031 A (2 sf)**	**3**	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

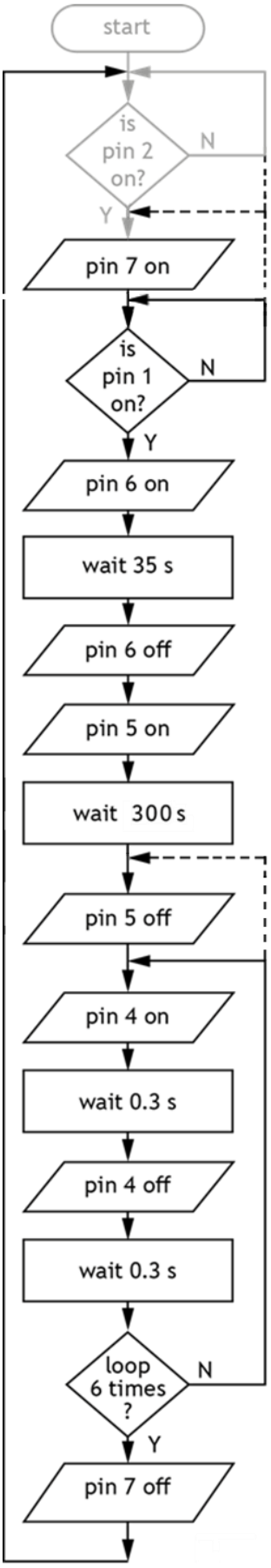
Question			Expected response	Max mark	Additional guidance
8.	(c)	(i)	Voltage V_1 – decrease	**1**	
		(ii)	Current A_1 – decrease	**1**	Apply FTE from part (c)(i).
	(d)		Components are not destroyed ...making it cheaper to test. A range of components are readily available ...making it quicker to change/test. Software can highlight issues in the circuit ...making it easier to correct faults. It is safer to the user ...because fault/failure is simulated.	**2**	Descriptive answer. 1 mark for cause. 1 mark for effect.

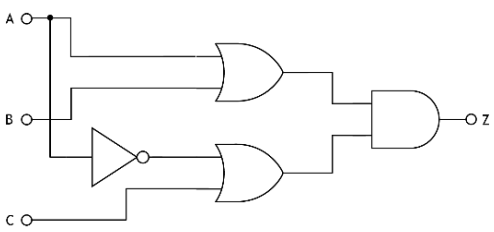
Question			Expected response	Max mark	Additional guidance
9.	(a)		$120 \times 64 = \text{input speed} \times 16$ $\text{input speed} = \frac{7680}{16}$ $\text{input speed} = 480 \text{ (revs min}^{-1}\text{)}$ $480 \times 48 = \text{input speed} \times 16$ $\text{input speed} = \frac{23040}{16}$ $\text{input speed} = 1440$ **1400 revs min^{-1} (2 sf)** **Alternative method** $\frac{\text{speed of output}}{\text{speed of input}} = \frac{A}{B} \times \frac{C}{D}$ $\frac{120}{\text{input speed}} = \frac{16}{48} \times \frac{16}{64}$ $\frac{120}{\text{input speed}} = \frac{1}{12}$ $\text{input speed} = 120 \times \frac{12}{1}$ $\text{input speed} = 1440$ **1400 revs min^{-1} (2 sf)**	**4**	1 mark for substitution. 1 mark for correct answer from given working (unit not required). 1 mark for substitution. Apply FTE. 1 mark for correct answer from given working with unit. Do not accept 'RPM'. 1 mark for first ratio. 1 mark for second ratio. 1 mark for transposition. 1 mark for correct answer from given working with unit.

Question			Expected response	Max mark	Additional guidance
9.	(b)		P = VI 250 = 36 × I $I = \frac{250}{36}$ I = 6.944444444 **I = 6.9 A (2 sf)**	**3**	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
	(c)		Lubricate/oil the gears ...to reduce friction/energy loss.	**2**	Descriptive answer. 1 mark for cause with reference to the gear train. 1 mark for effect.
	(d)		No CO_2 emissions/pollution (when cycling). Fewer car journeys so less noise/ pollution.	**1**	Descriptive answer relating to use with a positive environmental aspect.
	(e)		Easier/less effort, so encourages more people to cycle. Improves fitness/lifestyle/ wellbeing. Journey times reduced. Reduces the number of cars on the road, making it safer to travel. Reduction in noise for residents living next to a road.	**1**	Descriptive answer relating to use with an improvement to life aspect.
	(f)		Expensive to maintain/ repair/hire the electric bike. Maintenance of charging stations is expensive. Expensive to charge. Reduction in car sales.	**1**	Descriptive answer relating to use with a negative monetary aspect. Responses can refer to renting versus owning an electric bike.

Question			Expected response	Max mark	Additional guidance
10.	(a)		800 Ω	**1**	1 mark for correct answer with unit.
	(b)		Voltage divider.	**1**	Accept potential divider.
	(c)		$V_{therm} = 5 - 1.4$ $V_{therm} = 3.6$ V $\frac{R_1}{R_2} = \frac{V_1}{V_2}$ $\frac{R_1}{4.8k} = \frac{1.4V}{3.6V}$ $R_1 = \frac{1.4V}{3.6V} \times 4.8k$ $R_1 = 1.8666666667$ **R_1 = 1.9 kΩ (2 sf)**	**4**	1 mark V_{therm} unit not required. 1 mark for substitution. Apply FTE for V_{therm}. If V_{therm} not calculated, accept 5V for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit. Accept alternative method.
	(d)		*As the water temperature increases…* The resistance of the thermistor will decrease. This will cause V_{in} to increase. The transistor will then switch on/ the relay will activate. The blue LED will turn off and the red LED will switch on.	**5**	Descriptive answer. Apply FTE from previous description. 1 mark thermistor resistance decrease. 1 mark V_{in} increase. 1 mark transistor/relay switching on. 1 mark blue LED off. 1 mark red LED on. Award a maximum of 1 mark for both LEDs (red & blue) switch on/ both LEDs swich off.

Question			Expected response	Max mark	Additional guidance
10.	(e)		Ammonia fuelled engines are new and untried … so they may be unreliable. Nuclear battery charge lasts up to 50 years … so portable product will never need recharged in their lifetime.	**2**	Descriptive answer. 1 mark for cause. 1 mark for effect. If an established or developing technology is named, such as AI or self-driving cars, 1 mark maximum for cause **and** effect. No mark for only stating an emerging technology.
11.	(a)			**4**	1 mark – set temperature Accept user input. 1 mark – temperature sensor. Accept heat sensor/thermostat. Do not accept thermometer/ thermistor. 1 mark – feedback loop with both arrows starting after heating element. 1 mark – heating element/heater. Do not accept heat.
					

Question			Expected response	Max mark	Additional guidance
11.	(b)			11	Pin 7 on and off in correct position – 1 mark. Pin 1 on? with y/n - 1 mark. Pin 1 loop back with arrow before decision – 1 mark. Pin 6 on and off in correct position – 1 mark. Pin 5 on and off in correct position – 1 mark. Pin 4 on and off in correct position – 1 mark. All four delay times with correct units - 1 mark. Accept 5 minutes rather than 300 s. Loop x 6? with y/n – 1 mark. Feedback loop and arrow to before pin 4 on – 1 mark. Continuous loop and arrow to start of program – 1 mark. All symbols correct – 1 mark. Ignore any additional steps including their symbols.

Question			Expected response	Max mark	Additional guidance
12.	(a)		Using solar panels, generate energy/ do not use fossil fuels ...so no greenhouse gases will be released.	**2**	Descriptive response. 1 mark for cause (generate energy from sun/reduced use of fossil fuels). 1 mark for effect (no release of greenhouse gasses). Do not accept pollution. Accept carbon emissions. Gases/emission must be specific to greenhouse or CO_2/dN_2O.
	(b)		7.5 x 60 × 60 = 27000 (s) $E_e = VIt$ $E_e = 24 \times 0.42 \times 27000$ $E_e = 272160$ **E_e = 270000 J (2 sf)**	**3**	1 mark for time, units not required. 1 mark for substitution. Apply FTE from time calculation. If time in seconds not calculated, accept 7.5 hrs for substitution. 1 mark for correct answer from given working with unit.
	(c)			**4**	1 mark for input A connected to a NOT gate. 1 mark for both input A and input B directly connected to an OR gate. 1 mark for both input (NOT) A and input C connected to an OR gate. 1 mark for AND gate output directly wired to Z with input connections.

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	Design the propeller. Calculate the output speed of the propeller. Test the drive system of the propeller. Simulate the water flow over the wing.	**1**	Descriptive answer. Activity and mechanical aspect.
		(ii)	Calculate the forces acting on the mast/board/wing. Selecting materials for the board. Design the shape of the wing/mast. Simulate the forces acting on the mast/board/wing.	**1**	Descriptive answer. Activity and structural aspect.
		(iii)	Design the controller's wireless/ control circuit. Simulate the control circuit. Write the control program for the wireless controller. Select sensors for the wireless controller.	**1**	Descriptive answer. Activity and electronics aspect. Do not accept 'design the controller' on its own.
	(b)		$E_k = ½ mv^2$ $13000 = ½ \times 115 \times v^2$ $v = \sqrt{\frac{2 \times 13000}{115}}$ $v = 15.0362$ **$v = 15\ ms^{-1}$ (2 sf)**	**3**	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
	(c)		C It is corrosion resistant (against the water) and high strength (resisting the range of forces acting on it).	**2**	1 mark for selecting material C. 1 mark for justification that includes reference to corrosion resistant and high strength. Do not accept strong.

Question			Expected response	Max mark	Additional guidance
14.	(a)	(i)	$\Sigma_{moments} = 0$ $\Sigma CWM = \Sigma ACWM$ $(46k \times 4.5) = (3.9k \times 10) + (R_1 \times 11.2)$ $207 = 39 + 11.2R_1$ $R1 = \frac{207 - 39}{11.2}$ **R_1 = 15 kN (2 sf)**	**3**	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	$\Sigma F_{vertical} = 0$ $\Sigma F_{up} = \Sigma F_{down}$ $15k + 3.9k + R_2 = 46k$ $R_2 = 46k - 18.9k$ $R_2 = 27.1$ **R_2 = 27 kN (2 sf)**	**2**	1 mark for substitution Apply FTE from (a)(i). 1 mark for correct answer from given working with unit.
	(b)		$\in = \frac{\Delta l}{l}$ $0.00038 = \frac{0.46}{l}$ $l = \frac{0.46}{0.00038}$ $l = 1210.526316$ **l = 1200 mm (2 sf)**	**3**	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>14.</td><td>(c)</td><td></td><td>
<table>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td>Z</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td></tr>
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</table>
</td><td>3</td><td>1 mark for each correct column.

1 mark for column E = NOT B.

1 mark for column F = D OR E.

1 mark for column Z = F AND C.

Apply FTE.</td></tr>
<tr><td>15.</td><td>(a)</td><td></td><td>When the air bleed is covered valve 1 is actuated …

Pilot air changes the state of valve 2 which will cause piston B to outstroke.

Piston B will actuate valve 3 (sending air to cylinder A) which will cause piston A to outstroke.

When valve 3 is actuated a time delay will occur/a time delay will occur before changing the state of valve 2.

(Pilot air) changes the state of valve 2 which will cause piston B to instroke.

When plunger on valve 3 is unactauted, piston A will instroke.</td><td>5</td><td>Descriptive response.

1 mark for changes the state of valve 2 and B outstroking.

1 mark for actuating valve 3 and outstroking A.

1 mark for time delay (stated or inferred) after valve 3 actuates/ after A outstrokes/before valve 2 resets.

1 mark for changes the state of valve 2 and instroking B.

1 mark for A instroking including condition stated or inferred.

Accept actuate as change of state for valve 2.</td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
15.	(b)		$A = \frac{\pi d^2}{4}$ $A = \frac{\pi 12^2}{4}$ A = 113.0973355 (mm^2) (36π) $P = \frac{F}{A}$ $P = \frac{18\ N}{113.0973355}$ P = 0.1591549431 **P = 0.16 Nmm^{-2} (2 sf)**	**3**	1 mark for area (unit not required) Accept 36π. 1 mark for substitution (apply FTE from area). Accept use of diameter (12 mm) for substitution if area not calculated. 1 mark for correct answer from given working with unit.
	(c)		Slow the air …on the 5/2 valve's exhaust port. Add a uni-directional restrictor …air in the instroking pipe of the double acting cylinder.	**2**	Descriptive response. 1 mark for restricting the air flow. 1 mark for exhaust air location. Accept responses shown on the circuit diagram. Do not accept 'UDR' on its own.
	(d)		Reciprocating	**1**	Accept reciprocal.

[END OF MARKING INSTRUCTIONS]

