2023 Engineering Science

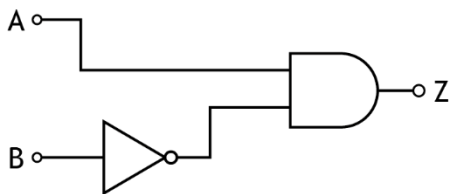# National 5

Finalised Marking Instructions

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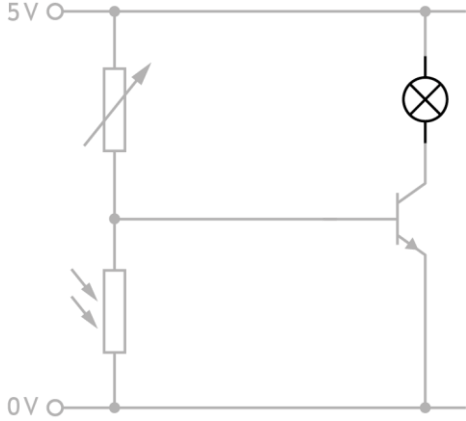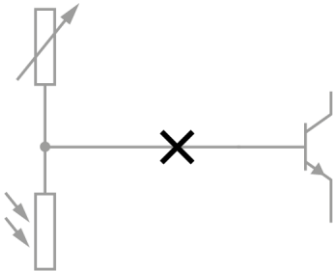
(a)   Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

(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).

(d)   For numerical questions, candidates should round their final 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.
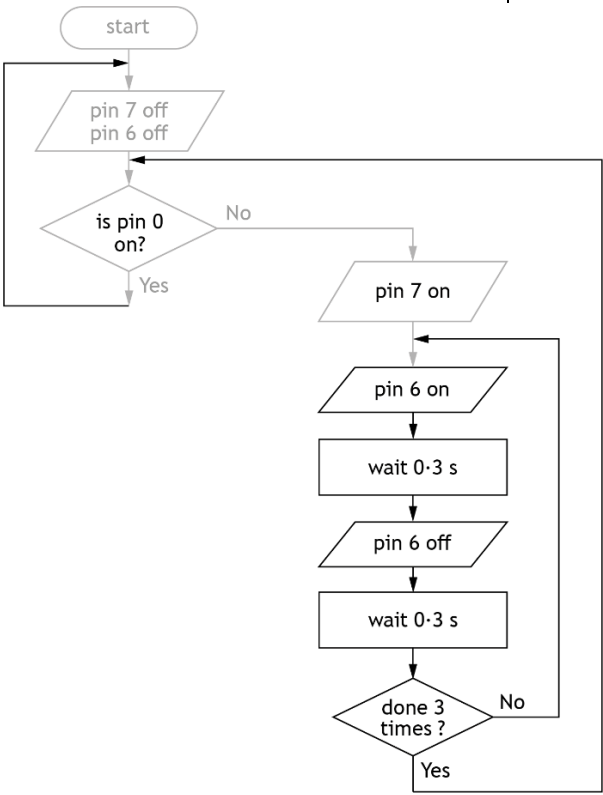
Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1.	(a)		user input → doorbell → sound	1	1 mark for sound at output. Accept noise/light.
	(b)		Closed loop (control)	1	Do not accept closed on its own.
2.			Velocity Ratio = $\dfrac{\text{Speed of Input}}{\text{Speed of Output}}$ Velocity Ratio = $\dfrac{360}{12}$ VR = **30 : 1**	2	1 mark for substitution. 1 mark for correct answer from given working. Ignore any units. Ratio must be simplified. Accept 30.
3.				2	1 mark for B wired to NOT gate. 1 mark for AND gate with inputs and output connections.
4.	(a)		Size/direction/position of force(s).	1	Descriptive response. Do not accept: size/direction/ forces/position on its own. Accept distance between cables.
	(b)		$\varepsilon = \dfrac{\Delta l}{l}$ $\varepsilon = \dfrac{0.0013}{4.5}$ $\varepsilon = 0.000288889$ $\varepsilon = \mathbf{0.00029}$ **(2 sf)**	2	1 mark for substitution. 1 mark for correct answer from given working. Ignore any units.
	(c)		Tensile	1	Accept tension/tie. Do not accept pulling force/gravity.

Question			Expected response	Max mark	Additional guidance
5.	(a)		$V = IR$ $V = 0.0025 \times 120$ $V = \textbf{0.30 V (2 sf)}$	**2**	1 mark for substitution. 1 mark for answer from given working with unit.
	(b)		Decrease (in the current).	**1**	
6.	(a)		$E_e = ItV$ $E_e = 1.5 \times 160 \times 18$ $E_e = 4320$ $E_e = \textbf{4.3 kJ (2 sf)}$	**2**	1 mark for substitution. 1 mark for correct answer from given working with unit. Alternative method using power: 1 mark for 27(W). 1 mark for energy (E = P × t) final answer with unit. Apply FTE.
	(b)		Reduce wear (on the gear system). Gears run smoother/quieter. Improve efficiency/battery life. Less heat/sound/energy losses.	**1**	Descriptive response. Accept reduces friction (stated or implied). Accept stops the gears rusting/ prevents losing torque.
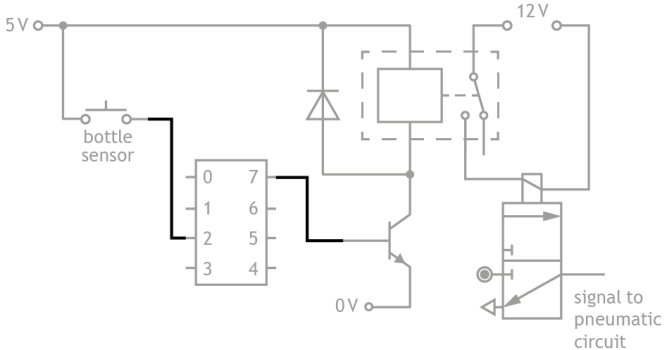
	Question		Expected response	Max mark	Additional guidance
7.	(a)			1	1 mark for lamp symbol and correct connections.
	(b)		Light Dependant Resistor	1	Do not accept LDR.
	(c)			1	1 mark for position of ammeter, indicated on the wire, to measure the base current. Accept ammeter symbol in correct position.
	(d)		(Fixed) Resistor	1	Accept variable resistor.

Section 2

Question			Expected response	Max mark	Additional guidance
8.	(a)			**10**	Pin 0 on ? decision – 1 mark.

Yes loop to start (arrow provided) – 1 mark.

Pin 7 on in correct position – 1 mark.

Pin 6 on **and** off in correct position – 1 mark.

Both delays in correct position – 1 mark.

Total delay time with unit = 0.6 s - 1 mark.

x3 ? decision with Y/N – 1 mark.

Correct repeat sequence loop with arrow back to before pin 6 on – 1 mark.

Loop after sequence with arrow back to before pin 0 – 1 mark

Accept (on, off, delay) sequence repeated three times – 2 marks.

All symbols correct – 1 mark.

Ignore any additional steps. |

Question			Expected response	Max mark	Additional guidance
8.	(b)		$\sigma = \dfrac{F}{A}$ $15 = \dfrac{F}{48}$ $F = 15 \times 48$ $F = \textbf{720 N (2 sf)}$	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
9.	(a)		*When a signal is received from the microcontroller …*	5	Descriptive response.
			valve 1 actuates and pilot air switches valve 2 and piston A outstrokes.		1 mark for valve 1/2 causing piston A to outstroke.
			..piston A actuates valve 4 which sends pilot air to reset valve 2 causing piston A to instroke.		1 mark for valve 4 and 2 to cause piston A to instroke.
			valve 1 actuates and pilot air switches valve 3 and piston B outstrokes.		1 mark for valve 1/3 causing piston B to outstroke.
			..piston B actuates valve 5 which sends pilot air to reset valve 3 causing pistion B to instroke.		1 mark for valve 5 and 3 causing piston B to instroke.
			Piston A outstrokes slowly and piston B instrokes slowly.		1 mark for piston A outstroking slowly **and** piston B instroking slowly. If response describes valve 1 (or both 5/2 valves) causing both pistons to outstroke then 2 marks can be awarded. Instroking conditions must clearly link both named valves to the correct cylinder.
	(b)	(i)	$P = \dfrac{F}{A}$ $0.32 = \dfrac{620}{A}$ $A = \dfrac{620}{0.32}$ $A = 1937.5$ $A = \textbf{1900 mm}^2 \textbf{ (2 sf)}$	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
9.	(b)	(ii)	$A = \dfrac{\pi d^2}{4}$ $1900 = \dfrac{\pi d^2}{4}$ $d = \sqrt{\dfrac{1900 \times 4}{\pi}}$ $d = 49.1849$ $d = $ **49 mm (2 sf)**	3	1 mark for substitution. Allow FTE from (b)(i). 1 mark for transposition. 1 mark for correct answer from given working with unit. If radius is given as the final answer then max 2 marks.
	(c)		(Line) 7	1	
	(d)			2	Bottle sensor correctly wired to pin 2 – 1 mark. Pin 7 correctly wired to base of transistor – 1 mark. Do not accept any additional pins wired to bottle sensor/transistor.

	Question		Expected response	Max mark	Additional guidance
10.	(a)		Design the LED/charging/sensing circuit. Write the control program. Simulate/test/prototype the LEDs circuit. Calculate the voltage/current/power required for all LEDs. Selecting components to be used to drive/protect the LEDs.	1	Descriptive electronic based response relating to the design phase. 1 mark for any appropriate response of an engineer's activity and specific electronic aspect. Building must relate to prototype. Do not accept circuit/circuit diagram/warning sign on its own as an electronic aspect.
	(b)		Reduction in running costs. Longer lasting so repair/replacement costs less.	1	Descriptive response relating to financial impact (positive/negative) using LEDs. 1 mark for an economic impact (positive/negative). Do not accept LEDs are cheaper on its own.
	(c)		LEDs are long lasting … resulting in less materials going to landfill. It is a renewable source/does not use fossil fuel …so it does not pollute/damage the environment. Solar does not produce CO_2 …reducing climate change/global warming. Solar powered LEDs do not need mains electricity …so no need to dig up the ground to lay cabling.	2	Explanation based on environmental impact (positive/negative) of using solar powered LEDs. 1 mark for cause. 1 mark for effect.

Question			Expected response	Max mark	Additional guidance
10.	(d)	(i)	$\dfrac{1}{RT} = \dfrac{1}{R1} + \dfrac{1}{R2} + \dfrac{1}{R3}$ $\dfrac{1}{RT} = \dfrac{1}{82} + \dfrac{1}{78} + \dfrac{1}{86}$ $RT = \dfrac{1}{0.03664354175}$ $R_T = 27.28994$ $R_T = \mathbf{27\ \Omega\ (2\ sf)}$	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	$R_T = 27 + 390$ $R_T = 417\ \Omega$ $R_T = \mathbf{420\ \Omega\ (2\ sf)}$	1	Allow FTE from part (i). 1 mark for correct answer with unit.
	(e)		$P = VI$ $1.8 = 12 \times I$ $I = \dfrac{1.8}{12}$ $I = \mathbf{0.15\ A\ (2\ sf)}$	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
11.	(a)	(i)	Design the brake lever. Design the wheels to spin freely. Simulate the brake mechanism. Select an appropriate material for the wheel axle. Calculate the braking force.	1	Descriptive mechanical response relating to the design phase and carriage. 1 mark for any appropriate response of an engineer's activity and specific mechanical aspect of the carriage. Do not accept design the wheel/ gears/mechanism on its own. Building must relate to prototype.
		(ii)	Survey/test the ground on the hillside. Plan the route/site of the mountain coaster track. Design the position of the access roads to the coaster track.	1	Descriptive civil response relating to the design phase and mountain coaster. 1 mark for any appropriate response of an engineer's activity and specific civil aspect.
		(iii)	Monitor the (impact on) local wildlife/area. Measure the noise/pollution level.	1	Descriptive environmental response relating to the construction phase. 1 mark for any appropriate response of an engineer's activity and specific environmental aspect of the construction. Must be a monitoring based activity.
	(b)	(i)	E_p = mgh $13 \times 10^3 = m \times 9.8 \times 6.2$ $m = \dfrac{13000}{9.8 \times 6.2}$ m = 213.9566 m = **210 kg (2 sf)**	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

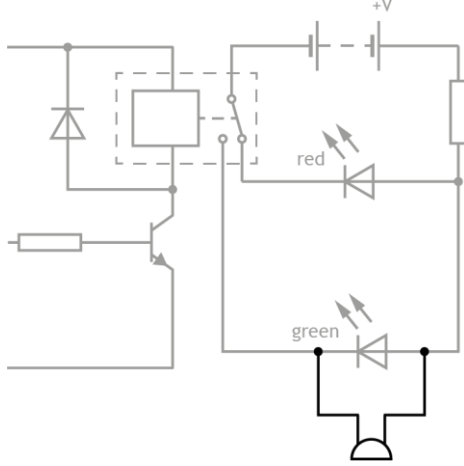| Question			Expected response	Max mark	Additional guidance
11.	(b)	(ii)	$E_k = \frac{1}{2}\, mv^2$ $E_k = \frac{1}{2} \times 210 \times 2.7^2$ $E_k = 765.45$ $E_k = \textbf{770 J (2 sf)}$	2	1 mark for substitution. Allow FTE from (b)(i). 1 mark for correct answer from given working with unit.
	(c)		2000 – 2100 (N)	1	Unit not required.
	(d)		B Metal B is corrosion resistant and is (more) durable. Metal B because the structure will be used outside and it is corrosion resistant. Metal B because it is durable and so parts will not need to be replaced often.	2	1 mark for metal B. 1 mark for corrosion resistant **and** durable. **OR** 1 mark for a property with valid rationale based on selection. Apply FTE from metal selection.

Question			Expected response	Max mark	Additional guidance
12.	(a)		To separate an (external) input/ output from a sub-systems/ process. To contain all the sub-systems that are in a system. To show what goes in/out of a system. To separate the outside environment from a system.	**1**	Response describing containment/ separation of system and external influences.
	(b)		*The water temperature is set …* The temperature sensor (detects the actual temperature and) sends a signal to the control. The control will compare the set temperature with the actual temperature. If the water is too cold the heater will switch on. **OR** If the water is at/above the set temperature the heater will switch off.	**3**	1 mark for feedback description. 1 mark for control comparison description. 1 mark for description of the heating element switching on when too cold/switching off when correct temperature.
	(c)		(Type) 1	**1**	
	(d)		Less energy will be needed to heat the water … so there will be fewer greenhouse gasses given off/reducing climate change/carbon footprint.	**2**	Explanation must relate to climate change. 1 mark for cause (energy reduced). 1 mark for effect (greenhouse gas emission). Apply FTE.

	Question		Expected response	Max mark	Additional guidance
12.	(e)		$E_h = cm\Delta T$ $E_h = 4180 \times 8.6 \times 15$ $E_h = 539220$ $E_h =$ **540 kJ (2 sf)**	2	1 mark for substitution. 1 mark for correct answer from given working with unit.
	(f)		<table><tr><td>A</td><td>B</td><td>C</td><td>D</td><td>Z</td></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td></tr></table>	3	1 mark for column C (NOT A). 1 mark for column D (C OR B). Allow FTE. 1 mark for column Z (D AND B). Allow FTE.
	(g)		$Y = (F \bullet \overline{G} \bullet H) + (F \bullet G \bullet \overline{H})$ Alternative $Y = F \bullet ((\overline{G} \bullet H) + (G \bullet \overline{H}))$ $Y = F \bullet (G \oplus H)$	3	1 mark for $(F \bullet \overline{G} \bullet H)$. 1 mark for $(F \bullet G \bullet \overline{H})$. If only one statement is given then bracket is not required. 1 mark for OR-ing all statements. Do not accept F/G/H on its own as a statement. Alternative 1 mark for F AND 1 mark for both $(\overline{G} \bullet H)$ and $(G \bullet \overline{H})$ with brackets. 1 mark for OR-ing G/H statements. If Exclusive OR used then 2 marks for (G EOR H) with bracket.

	Question		Expected response	Max mark	Additional guidance
13.	(a)		reel: rotary cutter bar: reciprocating	2	1 mark for reel motion. Accept rotational/rotating. 1 mark for cutter bar motion. Accept reciprocal.
	(b)	(i)	$\Sigma CWM = \Sigma ACWM$ $(R_A \times 4.4) = (82 \times 2.6) + (32 \times 6.8)$ $R_A = \dfrac{430.8}{4.4}$ $R_A = 97.909$ $R_A = $ **98 kN (2 sf)**	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	$\Sigma F_{vertical} = 0 \qquad \Sigma F_{up} = \Sigma F_{down}$ $R_B + 98 = 32 + 82$ $R_B = $ **16 kN (2 sf)**	2	1 mark for substitution. Allow FTE from part(b)(i). 1 mark for correct answer from given working with unit.

Question			Expected response	Max mark	Additional guidance
13.	(c)		$3750 \times 10 = $ Output speed $\times 50$	**4**	1 mark for substitution.
			$Output speed = \dfrac{37500}{50}$		
			Output speed = 750 (revs min^{-1})		1 mark for correct answer from given working (unit not required).
			$750 \times 12 = 250 \times$ gear D		1 mark for substitution. Allow FTE.
			$gear D = \dfrac{9000}{250}$		
			gear D = **36** (teeth)		1 mark for correct answer from working (ignore any units).
			Alternative method		**Alternative method**
			$VR = \dfrac{3750}{250}$		1 mark for velocity ratio (does not need to be simplified).
			$VR = 15{:}1$		
			$\dfrac{15}{1} = \dfrac{50}{10} \times \dfrac{D}{12}$		1 mark 50:10 gear ratio (ratios could be inverted).
			$D = \dfrac{15 \times 12 \times 10}{50}$		1 mark for transposition.
			gear D = **36** (teeth)		1 mark for correct answer from working (ignore any units).
	(d)		Graphene.	**2**	Accept impact for any emerging technology.
			Conducts electricity quickly.		
			…this would result in batteries charging quicker/circuits working quicker.		1 mark for cause.
			Fully autonomous car.		1 mark for effect.
			Will not be fully tested.		If no technology named or the given example is clearly established/ developing; 1 mark maximum for having both cause and effect.
			…so, there could be faults/could cause an accident.		

Question			Expected response	Max mark	Additional guidance
14.	(a)		*As the temperature increases …* The (thermistor) resistance will decrease. The voltage (V_{in}) will increase.	2	Descriptive response. 1 mark for thermistor resistance decreasing. 1 mark for V_{in} based on resistance response. If V_{in} increasing stated without reference to thermistor resistance – 1 mark only.
	(b)		$5 – 1.9 = 3.1$ (V) $\dfrac{3.1}{1.9} = \dfrac{R}{1.7}$ $R = \dfrac{3.1 \times 1.7}{1.9}$ $R = 2.77368$ $R =$ **2.8 kΩ (2 sf)** **Alternative method** $5 – 1.9 = 3.1$ (V) $V_R = IR$ $1.9 = I \times 1.7$ $I = 1.1176$ (mA) $V = IR$ $3.1 = 1.1176 \times R$ $R = \dfrac{3.1}{1.1176}$ $R = 2.7738$ $R =$ **2.8 kΩ (2 sf)**	4	1 mark for voltage across variable resistor. Units not required. 1 mark for substitution. Apply FTE and accept 5.0 V if V_1 is not calculated. 1 mark for transposition. 1 mark for correct answer from given working with unit. **Alternative method** 1 mark for voltage across variable resistor. Units not required. 1 mark for calculating current. Units not required. Apply FTE and accept 5.0 V if V_1 is not calculated. 1 mark for transposition. Allow FTE. 1 mark for correct answer from given working with unit.

Question			Expected response	Max mark	Additional guidance
14.	(c)		*When the transistor activates the relay …* the red LED will switch off and the green LED will switch on.	**2**	Descriptive response relating to LEDs individually. LED colour needs to be stated/implied by position. 1 mark for red LED switching off. 1 mark for green LED switching on. Apply FTE for second description.
	(d)			**2**	1 mark for correct symbol of the buzzer. 1 mark for wiring connected anywhere in parallel with green LED.
	(e)		Quicker to develop solution. Saves money as no replacement components needed. Components will not be destroyed/ wasted. Easier to change circuit during testing. No risk to the user due to fault/failure.	**1**	Descriptive response relating to an advantage of simulation testing. 1 mark for a relevant description. Not faster, cheaper, easier or safer to simulate on its own. Component cost must relate to replacement of parts.
	(f)		A compound gear train will use smaller gears …which makes it able to fit inside the small space/laminator.	**2**	1 mark for cause (smaller gears/ train). Do not accept high velocity ratio as a cause or effect. 1 mark for effect (compact space). Accept responses explaining the disadvantage of a simple gear train.

[END OF MARKING INSTRUCTIONS]