



National
Qualifications
2022

2022 Engineering Science

National 5

Finalised Marking Instructions

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General marking principles for National 5 Engineering Science

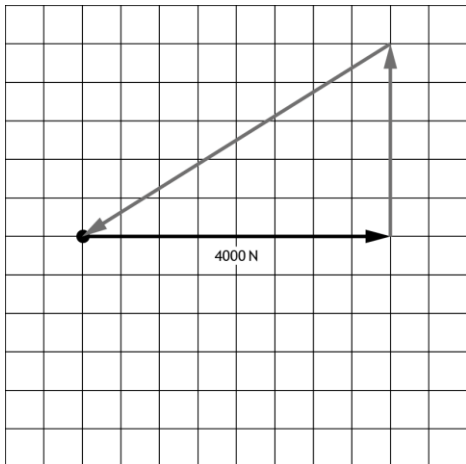
Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

- (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) | | Simple | 1 | |
| | (b) | | Idler | 1 | |
| 2. | (a) | | Sound/movement (air) | 1 | Accept noise/kinetic. Ignore any additional words. Do not accept wind. |
| | (b) | | Open loop (control) | 1 | Do not accept open on its own |
| 3. | | | Work done = Force \times Distance Work done = 2200×12 Work done = 26400 Work done = 26000 J (2 sf) | 2 | 1 mark for substitution. 1 mark for correct answer from given working with unit. Accept Nm as unit. |
| 4. | (a) | | Acts as a (electronic) switch | 1 | Descriptive response of function. Accept amplifies current/signal. |
| | (b) | | Emitter | 1 | |
| 5. | (a) | | $\epsilon = \frac{\Delta l}{l}$ $\epsilon = \frac{0.012}{25}$ $\epsilon = \mathbf{0.00048 (2 sf)}$ | 2 | 1 mark for substitution. 1 mark for correct answer from given working. Ignore any unit. |
| | (b) | | (material) C it is corrosion resistant and it is ductile/not brittle it is resistant to corrosion because it will be used outside it is ductile and so it will not snap | 2 | 1 mark for material C. 1 mark for identification of both properties or justification of one. Do not accept strong. Allow FTE from chosen material. |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|-------|--|----------|---|
| 6. | (a) | (i) | Electronic | 1 | Do not accept electrical. |
| | | (ii) | Structural | 1 | |
| | | (iii) | Mechanical | 1 | |
| | (b) | | Monitoring the sea life Monitoring the impact on the sea bed Check that the contractors are meeting legislation | 1 | Descriptive response during construction phase. 1 mark for any appropriate response of an engineer's activity and an environmental aspect. Accept land-based descriptions. |
| 7. | | |  | 2 | 1 mark for vertical line (2500N - 5 squares) upward joined nose to tail to 4000N. 1 mark for the inclined (4700N) force drawn to scale with arrow (sloping down to left) onto the end of the 4000N line. Allow FTE from incorrect vertical force. 1 mark for completing the triangle with an arrow (any direction). |
| 8. | | | It does not produce greenhouse gases It does not pollute (when in use) Solar reduces the need to burn fossil fuels/extracting resources/fewer greenhouse gases Reduced effect on climate change/ carbon footprint (when in use) Spoils/disrupts the natural landscape Wildlife disrupted/habitats destroyed | 2 | Descriptive response. 1 mark for each environmental impact. Can be an advantage or disadvantage. Accept solar used in other contexts. Do not accept renewable/does not use fossil fuel/uses lots of land, on its own. Accept disruption/resources used during construction. |

Section 2

| Question | | Expected response | Max mark | Additional guidance |
|----------|-----|---|----------|--|
| 9. | (a) | <pre> graph TD Start([start]) --> Pin0{pin 0 on?} Pin0 -- No --> Pin0 Pin0 -- Yes --> Pin7On[/pin 7 on/] Pin7On --> Wait03[wait 0.3 s] Wait03 --> Pin7Off[/pin 7 off/] Pin7Off --> Wait02[wait 0.2 s] Wait02 --> Done3{done 3 times?} Done3 -- No --> Pin7On Done3 -- Yes --> Pin6On[/pin 6 on/] Pin6On --> Pin1{pin 1 on?} Pin1 -- No --> Pin6On Pin1 -- Yes --> Pin6Off[/pin 6 off/] Pin6Off --> Pin0 </pre> | 10 | <p>Pin 0 on ? with Y/N, loop and arrow in correct position - 1 mark.</p> <p>Pin 7 on and off in correct position - 1 mark.</p> <p>Both delays in correct position (ignore incorrect values and unit) - 1 mark.</p> <p>Total delay time(s) with unit = 0.5 s per cycle - 1 mark.</p> <p>X3 decision with Y/N in correct position - 1 mark.</p> <p>Loop and arrow (x3 decision) back to before pin 7 on - 1 mark.</p> <p>Pin 6 on and off in correct position - 1 mark.</p> <p>Pin 1 on? with Y/N, loop and arrow in correct position - 1 mark.</p> <p>Accept decision feedback loop to before pin 6 on.</p> <p>Continuous loop to start with arrow - 1 mark.</p> <p>All marked symbols correct - 1 mark.</p> <p>Ignore any additional steps.</p> <p>accept on/off repeated 3 times max 2 marks.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|---|----------|---|
| 9. | (b) | | To go back to line 1/main/restart the program To create a continuous loop. | 1 | Descriptive response. 1 mark for looping program back to start. Accept reset the program. Do not accept go to main on its own. |
| | (c) | | The program loops back to line 1/main/"let count = 0"/wrong line ...therefore it will reset the count/ the count will not pass 1/count will not reach 20. | 2 | 1 mark for program looping back to the line 1 (cause). 1 mark for resetting the count (effect). |
| 10. | (a) | | <i>When the temperature decreases to a low temperature ...</i> The resistance (of the thermistor) will increase. This will cause the voltage (V_1) to increase. When the voltage V_1 increases the transistor/relay will switch on. ... turning on the LEDs and buzzer. | 4 | Descriptive response. 1 mark for resistance of thermistor increase. 1 mark for voltage V_1 increase. 1 mark for transistor switching on/ saturate or relay energising/switch on. 1 mark for both LEDs and the buzzer turning on. Apply FTE between each statement. |
| | (b) | | The resistance of the variable resistor can be altered ...which will change the temperature that will give a warning. | 2 | 1 mark for resistance can be adjusted (cause). Do not accept the resistance is different. 1 mark for a different temperature(s) to activate the circuit (effect). |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|--|----------|--|
| 10. | (c) | | $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ $\frac{0.84}{5.2} = \frac{R}{190}$ $R = 0.16154 \times 190$ $R = 30.6926$ $R = 31 \text{ k}\Omega \text{ (2 sf)}$ <p>OR</p> $V_R = IR$ $5.2 = I \times 190$ $I = 0.027368 \text{ (mA)}$ $V = IR$ $0.84 = 0.027368 \times R$ $R = \frac{0.84}{0.027368}$ $R = 30.6928$ $R = 31 \text{ k}\Omega \text{ (2 sf)}$ | 3 | <p>1 mark for substitution.</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working with unit.</p> <p>1 mark for calculating current.</p> <p>1 mark for transposition (allow FTE.)</p> <p>1 mark for correct answer from given working with unit.</p> |
| | (d) | | 20 kΩ | 1 | <p>1 mark for correct answer with unit.</p> <p>Accept 20 000 Ω.</p> |

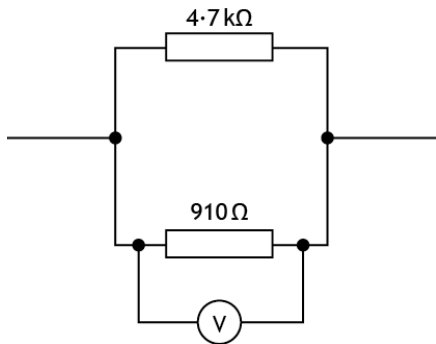
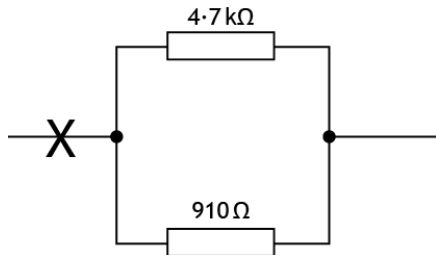
| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|--|----------|--|
| 10. | (e) | | <p>Input_{speed} × in_{size} = output_{speed} × out_{size}</p> <p>$12 \times 96 = \text{output speed} \times 16$</p> <p>$\text{output speed} = \frac{1152}{16}$</p> <p>output speed = 72 (revs min⁻¹)</p> <p>$12 \times \text{input speed} = 72 \times 120$</p> <p>$\text{input speed} = \frac{8640}{12}$</p> <p>Input speed = 720 revs min⁻¹ (2 sf)</p> <p>OR</p> <p>$\frac{\text{output speed}}{\text{input speed}} = \frac{A}{B} \times \frac{C}{D}$</p> <p>$\frac{12}{\text{input speed}} = \frac{12}{120} \times \frac{16}{96}$</p> <p>$\text{input speed} = \frac{12}{\left(\frac{12}{120} \times \frac{16}{96}\right)}$</p> <p>$\text{input speed} = \frac{12}{\left(\frac{1}{60}\right)}$</p> <p>input speed = 720 revs min⁻¹ (2 sf)</p> | 4 | <p>1 mark for substitution.</p> <p>1 mark for correct answer from given working (unit not required).</p> <p>1 mark for substitution.</p> <p>1 mark for correct answer from given working with unit.</p> <p>Allow FTE.</p> <p>Do not accept RPM.</p> <p>1 mark for first ratio (could be inverted).</p> <p>1 mark for second ratio (same order as first ratio).</p> <p>Accept simplified ratios.</p> <p>1 mark for transposition (12 × 60 if ratios inverted).</p> <p>1 mark for correct answer from given working with unit.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|-------|---|----------|---|
| 11. | (a) | (i) | $\Sigma CWM = \Sigma ACWM$ $(3.5 \times 5) + (F \times 7.5) = (2.1 \times 10)$ $17.5 + (F \times 7.5) = 21$ $F = \frac{3.5}{7.5}$ $F = 0.4666666667$ $F = \mathbf{0.47 \text{ kN (2 sf)}}$ | 3 | <p>1 mark for substitution.</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working with unit.</p> |
| | | (ii) | $\Sigma F_{\text{vertical}} = 0$ $3.5 + 0.47 = R_A + 2.1$ $R_A = 3.97 - 2.1$ $R_A = 1.87$ $R_A = \mathbf{1.9 \text{ kN (2 sf)}}$ | 2 | <p>1 mark for substitution.</p> <p>Allow FTE from part a(i).</p> <p>1 mark for correct answer from given working with unit.</p> |
| | (b) | (i) | <p>More people will be able to use the station.</p> <p>Easier access/less effort for travellers to reach the platform/walkway.</p> <p>Jobs created during installation/maintenance.</p> | 1 | <p>Descriptive positive social response.</p> <p>Benefit must relate to the person/people - stated/implied and the context.</p> <p>Do not accept save people time/jobs on its own.</p> |
| | | (ii) | <p>Increase in profits by installing lifts.</p> <p>(Maintenance) jobs created giving income.</p> <p>(Easier access for everyone) so increased profit/customers in platform shops.</p> | 1 | <p>Descriptive positive economic response.</p> <p>Response must include cost/money benefit stated/inferred.</p> <p>Do not accept employment/increase in profit on its own.</p> |
| | | (iii) | <p>The (lift) would be expensive to install/maintain.</p> <p>Increase in running costs.</p> | 1 | <p>Descriptive negative economic response.</p> <p>Response must include cost/money drawback stated/inferred.</p> <p>Do not accept employment/cost/losses on its own.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|--|----------|---|
| 11. | (c) | | <div> <div>energy in</div> <div>electrical</div> <div>44 kJ</div> <div>→</div> <div>lift</div> <div>→</div> <div>32 kJ</div> <div>energy out</div> <div>potential</div> <div>energy losses</div> <div>heat/sound</div> <div>12 kJ</div> </div> | 3 | <p>1 mark for input electrical energy and 44 (kJ).</p> <p>1 mark for output potential energy and 32 (kJ).</p> <p>1 mark for lost heat/sound energy and 12 (kJ).</p> <p>Allow FTE for energy losses value.</p> |

| Question | | | Expected response | Max mark | Additional guidance | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------|-----|---|--|----------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12. | (a) | | <table><tr><th>D</th><th>E</th><th>Z</th></tr><tr><td>1</td><td>1</td><td>0</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>1</td><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr></table> | D | E | Z | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 | 1 mark per correct complete column. Column D = NOT A Allow for FTE Column E = B OR D Column Z = C AND E |
| D | E | Z | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | (b) | | <pre>graph LR; L((L)) --- AND1[AND]; M((M)) --- AND1; AND1 --- OR1[OR]; N((N)) --- NOT1[NOT]; NOT1 --- OR1; OR1 --- Y((Y))</pre> | 3 | 1 mark for L and M wired individually to AND gate. 1 mark for N wired to NOT gate. 1 mark for OR gate output wired to Y and inputs to NOT and AND. FTE - 1 mark OR gate wired to N and/or L and M if a previous gate(s) omitted. | | | | | | | | | | | | | | | | | | | | | | | | | | | |

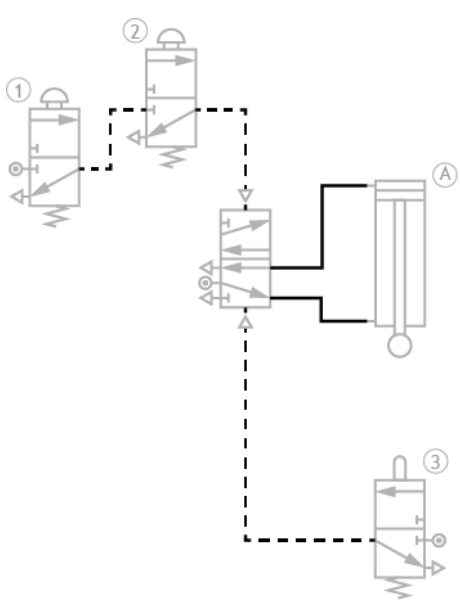
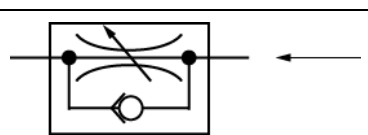
| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|------|--|----------|---|
| 12. | (c) | | <p>Quicker to assemble the circuit</p> <p>Quicker to change the circuit</p> <p>Easier to see faults/issues with circuit</p> <p>Reduces cost as components will not be destroyed</p> <p>No risk of damage to actual components/user</p> | 2 | <p>Descriptive advantage.</p> <p>1 mark for each relevant statement.</p> <p>Not speed, cost, safety, ease, on its own.</p> <p>Cost must relate to speed or no damaged components.</p> |
| | (d) | (i) | $\sigma = \frac{F}{A}$ $0.84 = \frac{F}{190}$ $F = 0.84 \times 190$ $F = 159.6$ $F = 160 \text{ N (2 sf)}$ | 3 | <p>1 mark for substitution.</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working with unit.</p> |
| | | (ii) | Tensile/Tension | 1 | <p>Accept Tie.</p> <p>Do not accept pulling force/gravity.</p> |
| | (e) | | The stress will decrease | 1 | |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|-------|---|----------|---|
| 13. | (a) | (i) | $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$ $R_T = \frac{4700 \times 910}{4700 + 910}$ $R_T = 762.3885918 \, \Omega$ $R_T = \mathbf{760 \, \Omega \, (2 \, sf)}$ $\frac{1}{R_t} = \frac{1}{4700} + \frac{1}{910}$ $R_t = 762.3885918 \, \Omega$ $R_t = \mathbf{760 \, \Omega \, (2 \, sf)}$ | 2 | <p>1 mark for substitution with the same unit.</p> <p>1 mark for correct answer from given working with unit.</p> <p>1 mark for substitution with the same unit.</p> <p>1 mark for correct answer from given working with unit.</p> |
| | | (ii) |  | 2 | <p>1 mark for correct symbol.</p> <p>1 mark for correct wiring across the 910 Ω resistor branch.</p> |
| | | (iii) |  | 1 | <p>1 mark for X (ammeter) in correct series position.</p> <p>Accept X on the wire at either side.</p> <p>Do not accept X on a node.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|---|----------|--|
| 13. | (b) | | $V = IR_T$ $36 = 2 \times R_T$ $R_T = \frac{36}{2}$ $R_T = 18 (\Omega)$ $R = 18 - 5.6$ $R = 12.4$ $R = 12 \Omega (2 \text{ sf})$ OR $V = IR$ $V = 2 \times 5.6$ $V = 11.2 (V)$ $V_R = V_S - V$ $V_R = 36 - 11.2$ $V_R = 24.8 (V)$ $V = IR$ $R = \frac{24.8}{2}$ $R = 12.4$ $R = 12 \Omega (2 \text{ sf})$ | 4 | <p>1 mark for substitution.</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working (units not required).</p> <p>1 mark for correct answer from given working with unit.</p> <p>Allow FTE.</p> <p>1 mark for voltage over 5.6 Ω resistor (units not required).</p> <p>1 mark for voltage over R (units not required).</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working with unit.</p> <p>Allow FTE.</p> <p>If voltage divider ratio used mark as second guidance.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|---|----------|---|
| 13. | (c) | | $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2}64 \times 3.4^2$ $E_k = 369.92$ $E_k = \mathbf{370\ J\ (2\ sf)}$ | 2 | <p>1 mark for substitution.</p> <p>1 mark for correct answer from given working with unit.</p> |
| | (d) | | <p>Driverless cars have no human error ...therefore safer</p> <p>Driverless cars may not be fully tested ...which could cause an accident</p> <p>Cars can travel at an appropriate speed/distance between cars ...resulting improved road safety</p> | 2 | <p>Explanation relating to road safety.</p> <p>1 mark for cause.</p> <p>1 mark for effect.</p> <p>Do not accept no driver as a cause on its own.</p> |
| 14. | (a) | | <p>The water flow rate is set (by the user)</p> <p>The sensor detects the (actual water) flow rate.</p> <p>The control unit compares both flow rate (values).</p> <p>OR</p> <p>The control unit decides if the rate is too low/high/correct.</p> <p>The motor activates/the gear mechanism turns/the gate moves</p> <p>The gate moves up/opens when the rate is too low</p> <p>OR</p> <p>The gate lowers/closes when the rate is too high</p> <p>OR</p> <p>The gate will not move when the rate is correct</p> | 5 | <p>Descriptive responses.</p> <p>1 mark for the external signal inputted/user setting of level.</p> <p>1 mark for description of the sensing action/feedback from sensor.</p> <p>1 mark for description of the control (comparison/decision making).</p> <p>1 mark for description of the control of the motor/gear/gate.</p> <p>1 mark for description of the correct gate movement for the condition described.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|---|----------|--|
| 14. | (b) | | $\text{Velocity Ratio} = \frac{\text{Speed of Input}}{\text{Speed of Output}}$ $14 = \frac{870}{\text{speed of output}}$ $\text{speed of output} = \frac{870}{14}$ $\text{speed of output} = 62.14285$ $\text{speed of output} = \mathbf{62 \text{ revs min}^{-1}}$ $\mathbf{(2 \text{ sf})}$ | 3 | <p>1 mark for substitution.</p> <p>Accept 14:1 for VR in substitution.</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working with unit.</p> <p>Do not accept RPM.</p> |
| | (c) | | <p>The program can be easily modified/corrected</p> <p>It is reprogrammable</p> <p>Its more reliable because there are less components</p> | 1 | <p>Descriptive response relating to when in use.</p> <p>Do not accept cheaper/fewer components/reliable/quicker on its own.</p> <p>Do not accept easier/quicker to replace component.</p> |
| | (d) | | $\eta = \frac{\text{Power out}}{\text{Power in}}$ $0.85 = \frac{15}{\text{Power in}}$ $\text{Power in} = \frac{15}{0.85}$ $\text{Power in} = 17.647$ $\text{Power in} = \mathbf{18 \text{ MW (2 sf)}}$ | 3 | <p>1 mark for substitution.</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working with unit.</p> |
| | (e) | | <p>Once in use Hydro power does not emit any greenhouse gases ...therefore does not contribute to global warming</p> <p>When in use Hydro power reduces the need to use fossil fuels ...therefore reducing greenhouse gases/carbon footprint/impact on climate change.</p> | 2 | <p>Explanation must relate to climate change and the use of Hydro.</p> <p>Do not accept pollution related responses.</p> <p>Do not accept construction based responses.</p> <p>1 mark for cause.</p> <p>1 mark for effect.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|--|----------|--|
| 15. | (a) | |  | 5 | <p>Pipe connections must be port to port.</p> <p>1 mark for ANDing valve ① to valve ② and piping pilot actuator on top of the 5/2 valve.</p> <p>1 mark for piping up valve ③ to pilot actuator on the bottom of 5/2 valve.</p> <p>1 mark for a pilot air line type for given piping into the 5/2.</p> <p>1 mark for top pipe to DAC from 5/2 valve.</p> <p>1 mark for bottom pipe to DAC from 5/2 valve.</p> <p>Allow FTE if incorrect 5/2 state outputs port are used. 1 mark max for DAC piping.</p> |
| | (b) | |  | 2 | <p>1 mark for correct symbol of a uni-directional restrictor.</p> <p>1 mark for correct orientation of by-pass route.</p> <p>Symbol need not be drawn on the given pipe.</p> |
| | (c) | | $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$ $1.4 = \frac{490}{\text{Area}}$ $A = \frac{490}{1.4}$ $A = 350 \text{ mm}^2 \text{ (2 sf)}$ | 3 | <p>1 mark for substitution.</p> <p>1 mark for transposition.</p> <p>1 mark for correct answer from given working with unit.</p> |

| Question | | | Expected response | Max mark | Additional guidance |
|----------|-----|--|---|----------|---|
| 15. | (d) | | <p>The area on the instroke is smaller (due to the piston rod), ...resulting in the instroking force being smaller</p> <p>The area on the outstroke is larger (due to no piston rod), ...resulting in the outstroking force being larger</p> <p>The two areas are different ... therefore the outstroke force is larger</p> | 2 | <p>1 mark for cause (difference in area - stated or inferred).</p> <p>1 mark for effect (specific effect on difference in force in/outstroke).</p> <p>Do not accept size in place of area.</p> <p>Do not accept forces will be different.</p> <p>Allow FTE.</p> |

[END OF MARKING INSTRUCTIONS]