Higher coursework assessment task

Higher Engineering Science

Assignment

Assessment task: manufacturing factory

Specimen — valid from session 2024-25 and until further notice

This edition: September 2024 (version 2.0)

Contents

Introduction

This document contains instructions for teachers, lecturers, and candidates for the Higher Engineering Science assignment. It must be read in conjunction with the course specification.

There is an additional document that contains the worksheets for this assignment.

This assignment has 50 marks out of a total of 160 marks available for the course assessment.

This is one of two course assessment components. The other component is a question paper.

Whilst this document contains ‘instruction for teachers and lecturers’ and ‘instructions for candidates’, everything in the document can be given to candidates.

Instructions for teachers and lecturers

This assignment is valid for the current session only.

Assessment conditions

You must conduct the assignment under a high degree of supervision and control. This means:

- all candidates must be within your direct sight
- candidates must not interact with each other
- candidates must not have access to email, the internet or mobile phones
- candidates must complete their work independently — no group work is permitted
- classroom display materials that might provide assistance must be removed or covered
- there must be no interruption for learning and teaching
- candidates must be in a classroom environment

Duration

Candidates have 8 hours to complete the assignment, starting at an appropriate point in the course after all content has been delivered. Once candidates begin their assignment, they must continue in each subsequent class period until the permitted time allocation has been used up.

You have a responsibility to manage candidates' work, distributing it at the beginning and collecting it at the end of each class period, and storing it securely in-between. This activity does not count towards the total time permitted for candidates to complete the assignment.

Resources

This is a closed-book assessment. Candidates must not have access to learning and teaching materials, the internet, notes, exemplar materials, resources on classroom walls or anything similar.

A data booklet containing relevant data and formulae is available on the Higher Engineering Science subject page on SQA's website. This can be used for the assignment.

Each assessment task includes instructions and details of any equipment or materials required for the assignment. Candidates can also use normal classroom equipment, software and hardware (such as drawing instruments, pneumatics, mechanisms and electronics kit, simulation software, and PCs to run the software) to complete the tasks.

There may be instances where restriction of internet and/or network use is not practical or feasible (for example, a local authority-managed IT network with specific limitations, software that is web-based, or something similar), however, it remains your professional responsibility to make every effort to meet the assessment conditions.

Alteration or adaptation

You must not alter, adapt or modify the assignment in any way — this includes moving the content into a different format. All candidates must undertake the assignment exactly as it has been provided by SQA.

Reasonable assistance

Candidates must progress through each stage of the assignment without your intervention or guidance, having acquired the skills needed earlier in the course.

Once candidates complete the assignment, you must not return it to them for further work. You must not provide feedback to candidates or offer your opinion on the perceived quality or completeness of the assignment response at any stage.

You can provide reasonable assistance to support candidates with the following aspects of their assignment:

- printing, collating and labelling their evidence to ensure it is in the format specified by SQA
- ensuring candidates have all the materials and equipment required to complete the assignment
- understanding the information outlined in these instructions

Artificial Intelligence

This is not permitted. Please see SQA's website for more information, if needed.

Evidence

This assignment will be electronically marked from image (MFI), which means the following instructions must be followed.

It is your responsibility to ensure that all candidate evidence (whether created manually or electronically) is:

- clear and easy to read (anything handwritten or drawn must be in blue or black permanent ink only)
- without anything else fixed to the pages (for example,photographs are glued in place)
- labelled at the top to show the task that it refers to
- labelled at the bottom to show the candidate's Scottish Candidate Number (SCN)
- compiled in task order with our flyleaf as the front cover
- printed or presented on A4 paper and secured with a single staple in the top left corner (prints can be single-sided or double-sided, however we prefer double-sided)

Assignment

This assignment contains a number of tasks. Each task details:

- what the candidate must do (including any specific instructions on how the task must be carried out)
- how many pages of evidence are expected
- an anticipated duration

This ensures that candidates do not produce too much or spend too long on a single task (whilst there is a time limit for the assignment, there is no page limit or page count).

Candidates can complete the tasks in the order presented or in an order that helps you manage classroom equipment and resources.

You must ensure that candidates are aware of the assessment conditions for the assignment, and that they understand what they should do for each task.

Instructions for candidates

This assignment has 50 marks out of a total of 160 marks available for the course assessment.

This is a closed-book assessment. Your teacher or lecturer lets you know how to carry out the assignment and they will go over the assessment conditions.

The assignment has a number of tasks and for each task, you are provided with an engineering science context or situation.

In this assignment, you have to: :

- analyse a problem
- design a solution to the problem
- build (simulate or construct) your solution
- test your solution
- evaluate your work

Unless otherwise instructed, you should complete all of the tasks in the order presented.

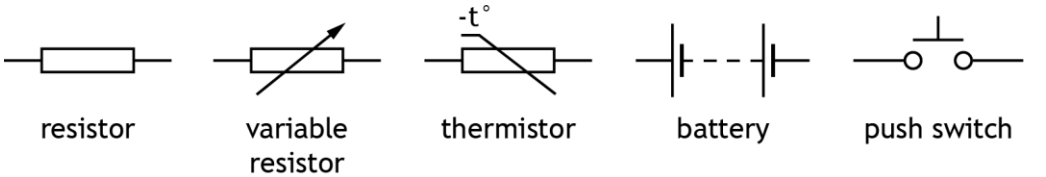
Each page of your response must note the task number at the top of the page and your Scottish Candidate Number (SCN) at the bottom of the page.

You have 8 hours to complete the assignment. The time to set up and clear away any equipment you need, and for any printing that is necessary, does not count towards the 8 hours.

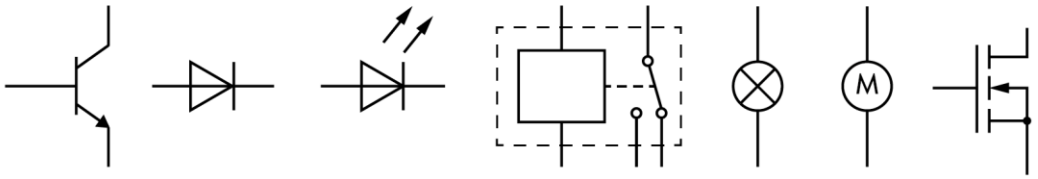
Data sheets — Manufacturing factory

You can use these data sheets and SQA's Higher Engineering Science data booklet when completing this assignment. **No other resource material is permitted.**

Electronic components

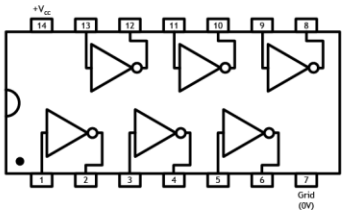


resistor | variable resistor | thermistor | battery | push switch

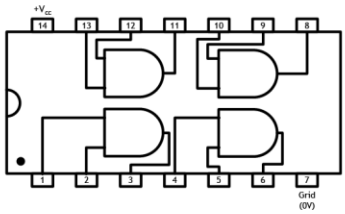


NPN transistor | diode | LED | SPDT relay | lamp | motor | MOSFET

IC pinout diagrams



7404



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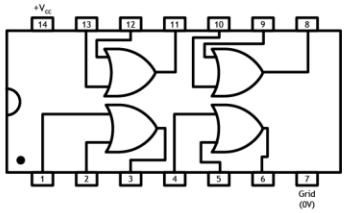

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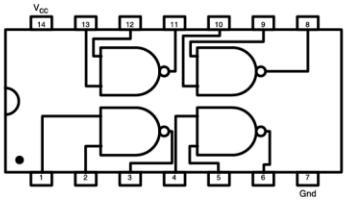

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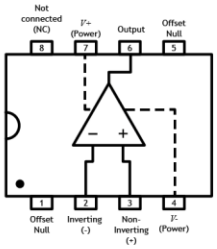
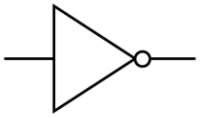
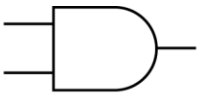


741

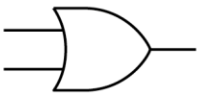
Logic gates



NOT gate

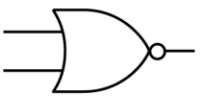


AND gate

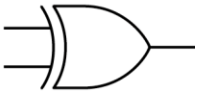


OR gate

NAND gate



NOR gate



XOR gate

Pneumatic components

Actuators

solenoid

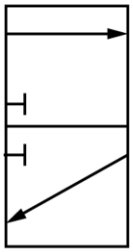
plunger

diaphragm

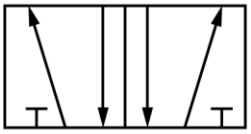
spring return

pilot air

Valves



3/2 valve

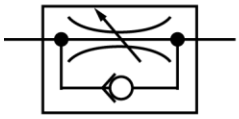


5/2 valve

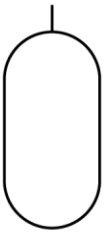
main air

exhaust

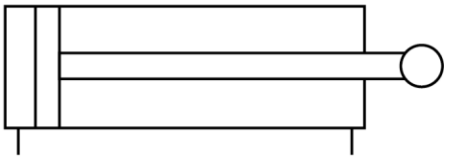
Components and cylinders



unidirectional restrictor

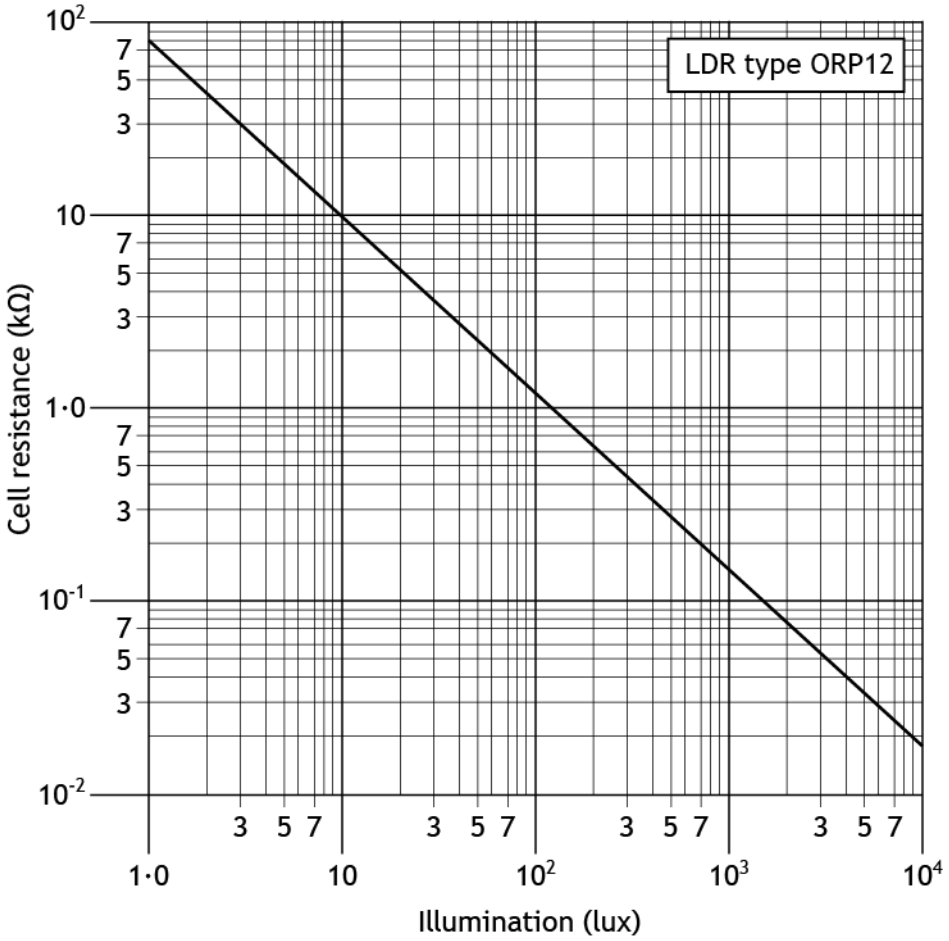


reservoir

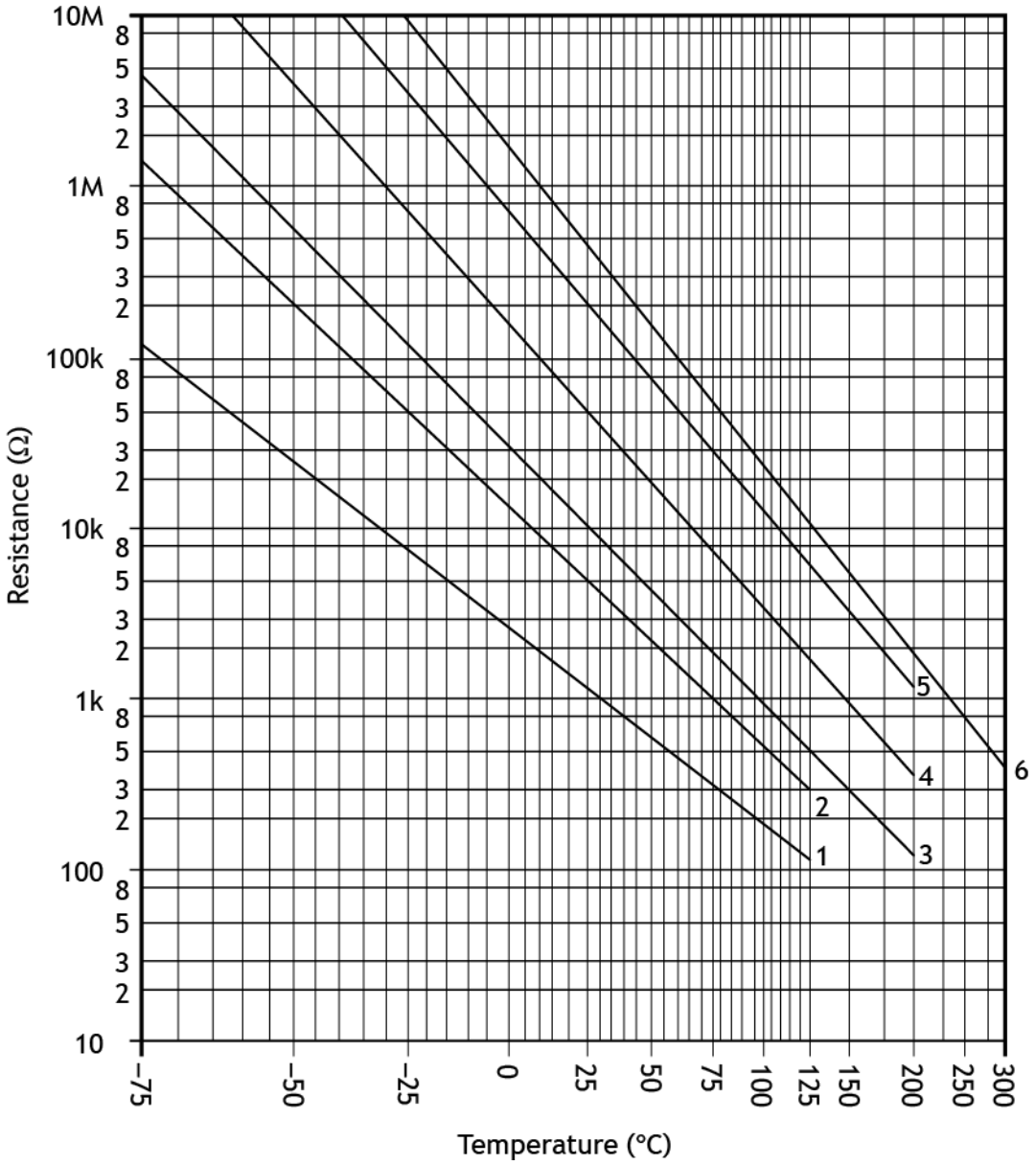


double acting cylinder

Light Dependent Resistor (LDR) graph for an ORP12 LDR



Thermistor graph



Manufacturing factory

A team of engineers is involved in several tasks during the planning of a new factory.

The tasks include developing proposals for the following:

- Task 1 — heating system
- Task 2 — package distribution system
- Task 3 — security system

Task 1 — heating system

- Notional time: 3 hours
- Volume: completed on up to five single-sided A4 pages
- Worksheet: provided for task 1c

The proposed factory heating system is a pumped hot-water and radiator system.

An electronic control system is required to control the heating system within the factory. The system should meet the following specification:

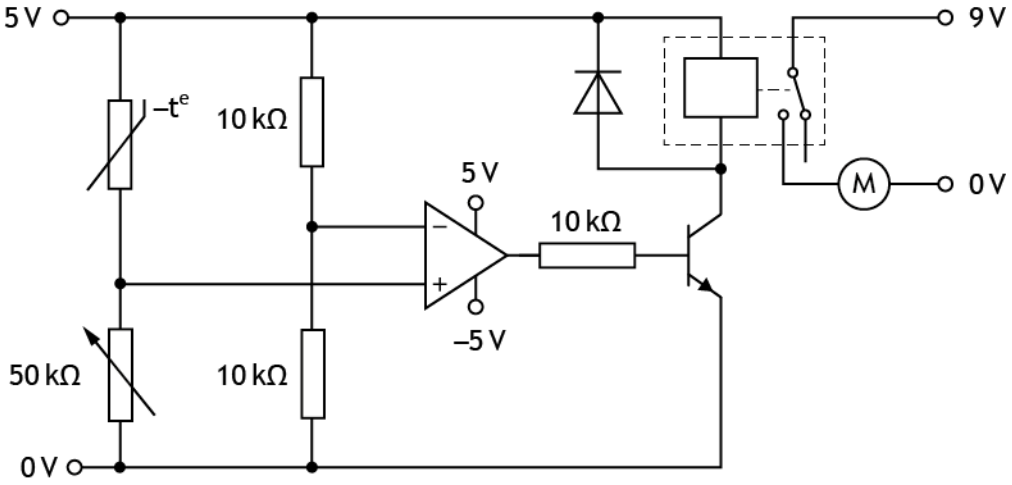
i A user sets the desired temperature within the factory.

ii Whenever the actual temperature of the factory drops below the desired temperature, a motorised pump switches on.

iii Whenever the actual temperature of the factory rises above the desired temperature, the motorised pump switches off.

1a Analyse the above specification by designing a control diagram for the electronic control and pump motor. **(6 marks)**

The circuit diagram below shows a proposal for the electronic control system of the heating system.



1b Simulate or construct this circuit. **(3 marks)**

1c Complete the testing table in **worksheet 1c** by carrying out the planned tests given in the table. You should make amendments, as necessary, **before** moving on to the next test.

You must write descriptions of the actual results you observed during testing and any appropriate amendments you made to enable the system to satisfy the specification. **(4 marks)**

1d Using your results from **task 1c**, simulate or construct your amended circuit. **(1 mark)**

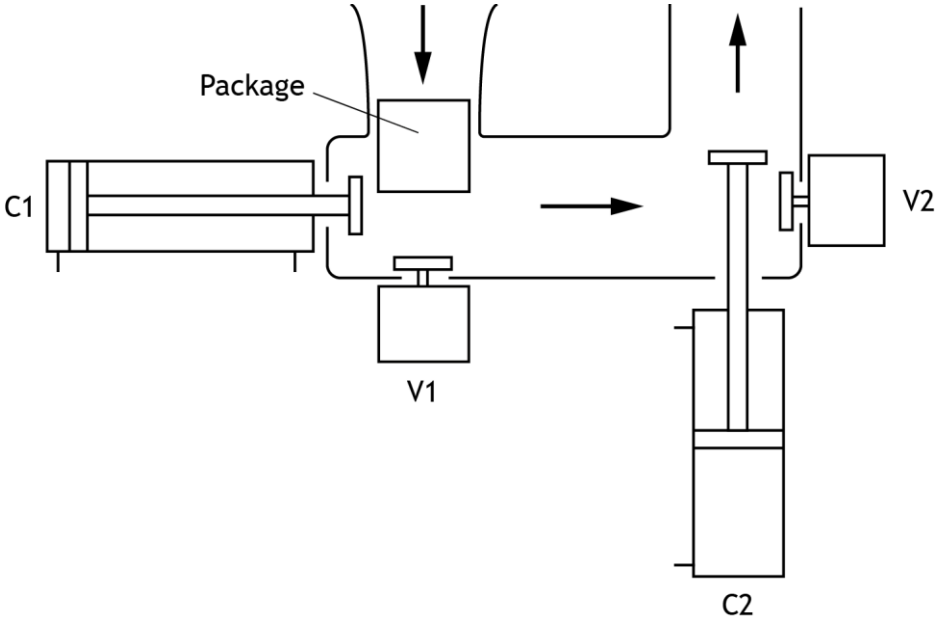
1e Evaluate the performance of your amended circuit from **task 1d** against the system specification, by:

- describing how your amended solution meets specification points ii and iii — you should do this by referring to testing and any amendments you may have made
- describing the overall effectiveness of your amended solution in controlling the heating system
- suggesting an improvement to the system **(4 marks)**

Task 2 — package distribution system

- Notional time: 3 hours 45 minutes
- Volume: completed on up to six single-sided A4 pages
- Worksheet: provided for task 2d

A plan view of part of the factory's pneumatically operated package distribution system is shown below.



The system must meet the following specification:

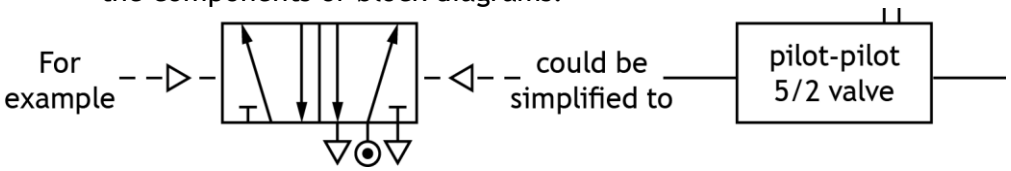
i A package is loaded manually and pushed into position to activate valve V1.

ii Cylinder C2 instrokes and, after an adjustable delay, cylinder C1 outstrokes.

iii The package then slides down a slope and actuates valve V2. This causes cylinder C1 to instroke and, at the same time, causes cylinder C2 to outstroke.

Description of part	Number supplied
5/2 Pilot-pilot valve	2
3/2 Plunger, spring return valve	2
Unidirectional flow restrictor	1
Reservoir	1
Double acting cylinder	2

2a Design a pneumatic circuit to meet the specification, using the correct symbols for the components or block diagrams.

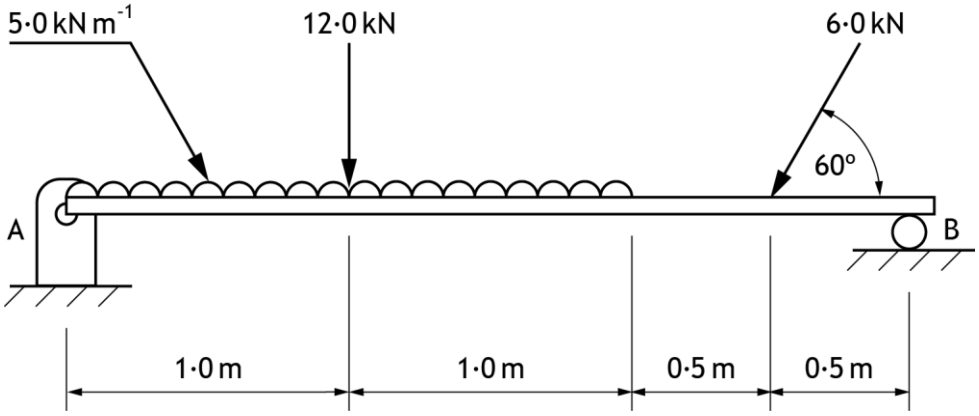


You must label V1, V2, C1 and C2, and the direction of the piston outstroke on cylinders C1 and C2. Show all required pipe connections between the components.

If using block diagrams, label all pneumatic components. **(6 marks)**

The package distribution system for the factory needs load-bearing supports.

A diagram of a support is shown below.

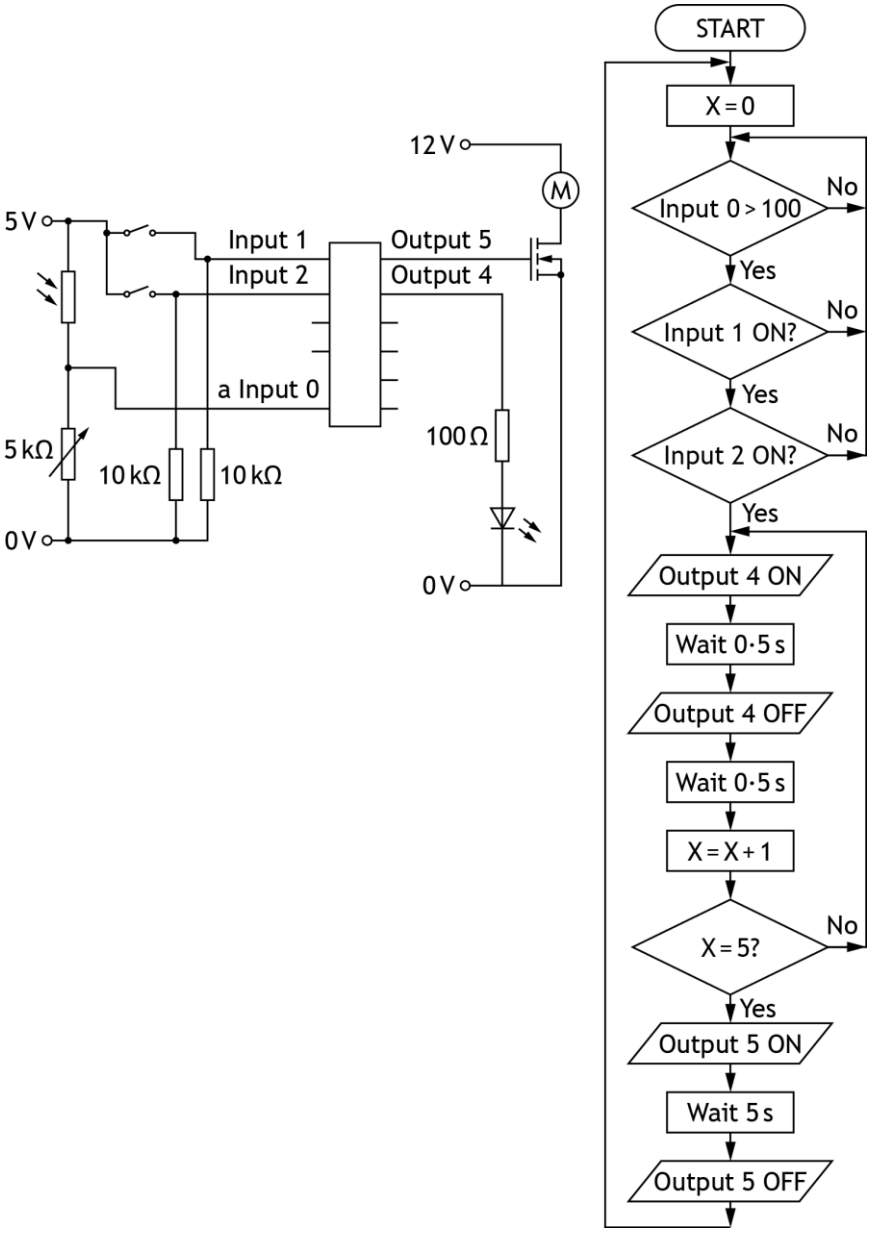


2b Simulate this structure to determine the horizontal and vertical reactions at A and at B. **(2 marks)**

A section of the package distribution system will use a microcontroller to operate a motorised packaging machine and warning system.

As a possible solution, an electronic engineer has designed the flowchart and circuit shown below.

Note: the voltage divider is connected to an analogue input.



2c Simulate or construct the flowchart and electronic circuit **integrated together** as shown above. **(4 marks)**

The packaging distribution system is operated by a microcontroller, using the following specification:

i When the light level drops below a set level (100), the system must be ready to activate the motor and LED.

ii If either switch is pressed when the light level is below the set level then the LED will flash.

iii The LED must flash five times before the motor is activated.

Errors were found with the flowchart during testing.

2d Complete the testing table in **worksheet 2d** by carrying out the planned tests given. You should make amendments, as necessary, **before** moving on to the next test.

You must write descriptions of the actual results you observed during testing and any appropriate amendments you made to enable the system to satisfy the specification. **(5 marks)**

2e Draw or simulate your **amended flowchart** from task 2d. **(2 marks)**

2f Evaluate the performance of your circuit and amended flowchart from **task 2e** against the system specification by describing:

- how your amended flowchart meets each of the specification points
- two observations on its overall suitability as a packaging distribution system

(5 marks)

Task 3 — security system

- Notional time: 1 hour 15 minutes
- Volume: completed on up to four single-sided A4 pages
- Worksheet: provided for task 3c

Note: you must not use simulation software to complete task 3a

A combinational logic circuit is required to control part of the factory's security system.

An electronic engineer has developed the following Boolean equation:

$$Z = (\overline{A \cdot B}) + (C \cdot D)$$

3a Draw a circuit diagram to perform this function.
You must not use simulation software to complete this task. **(3 marks)**

3b Simulate or construct your logic circuit from **task 3a**. **(2 marks)**

3c Test your logic circuit and complete the truth table on **worksheet 3c** showing the actual results. **(1 mark)**

3d Evaluate the performance of your logic circuit against the expected results in **worksheet 3c**. **(1 mark)**

The electronic engineer considered using a NAND equivalent circuit as an alternative to a circuit made up of different logic gates.

3e Describe the impact this would have on the circuit. **(1 mark)**

[END OF ASSIGNMENT]

Marking instructions

The following marking instructions are for the Higher Engineering Science specimen assignment. In line with SQA's normal practice, they are addressed to the marker. They will also be helpful if you are preparing candidates for course assessment.

Marking instructions are not provided for annual assessment tasks. Candidates' evidence is submitted to SQA for external marking.

General marking principles

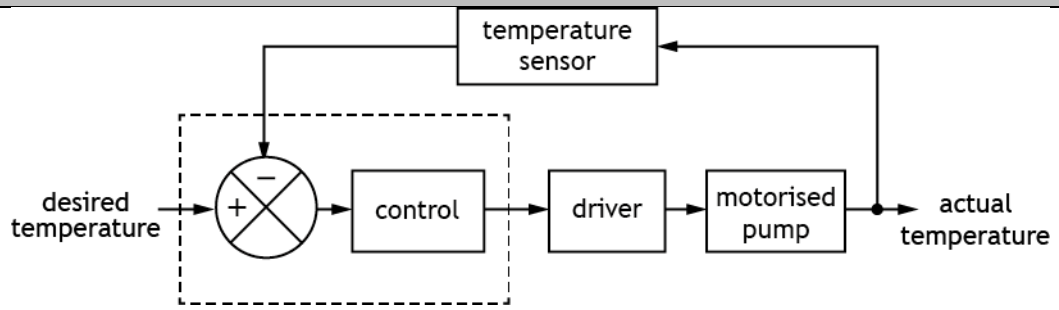
Always apply these general principles. Use them in conjunction with the specific marking instructions, which identify the key features required in candidates' responses.

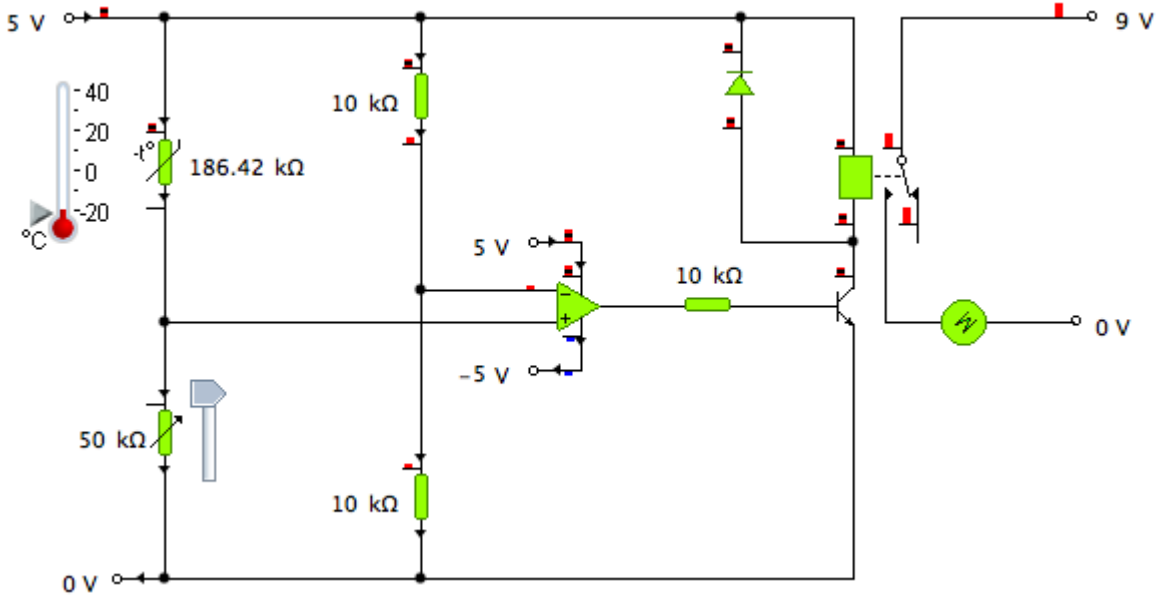
a Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

b If a candidate response does not seem to be covered by either the principles or specific marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

Specific marking instructions

Task 1 — heating system

Task	Expected response	Max mark	Additional guidance
1a		6	Control diagram: ♦ error detector **(1 mark)** ♦ control box, correct order **(1 mark)** ♦ driver box, correct order **(1 mark)** ♦ motor box, correct order **(1 mark)** ♦ temperature sensor, feedback loop, from correct place and direction **(1 mark)** ♦ both input and output **(1 mark)**

Task	Expected response	Max mark	Additional guidance
1b		3	Input – voltage dividers **(1 mark)** Process – op-amp and transistor **(1 mark)** Output – relay, motor, power supply, diode and orientation **(1 mark)**

<table>
<tr><th>Task</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>1c</td><td>
<table>
<tr><th>Planned test</th><th>Expected result</th><th>Actual result</th><th>Amendment made</th></tr>
<tr><td>Starting with the lowest temperature setting, increase the temperature to the thermistor to its highest setting</td><td>Motor will switch off</td><td>Motor switches on</td><td>Rewire the relay or flip voltage divider or flip op-amp</td></tr>
<tr><td>Lower the temperature to the thermistor to its lowest setting</td><td>Motor will switch on</td><td>Motor does switch on</td><td>None required</td></tr>
<tr><td>Adjust the variable resistor, and then raise and lower the temperature</td><td>Motor will switch off or on at different temperatures</td><td>Motor does switch off or on at different temperatures</td><td>None required</td></tr>
</table>
</td><td>4</td><td>Actual result:
motor remains on
(1 mark)

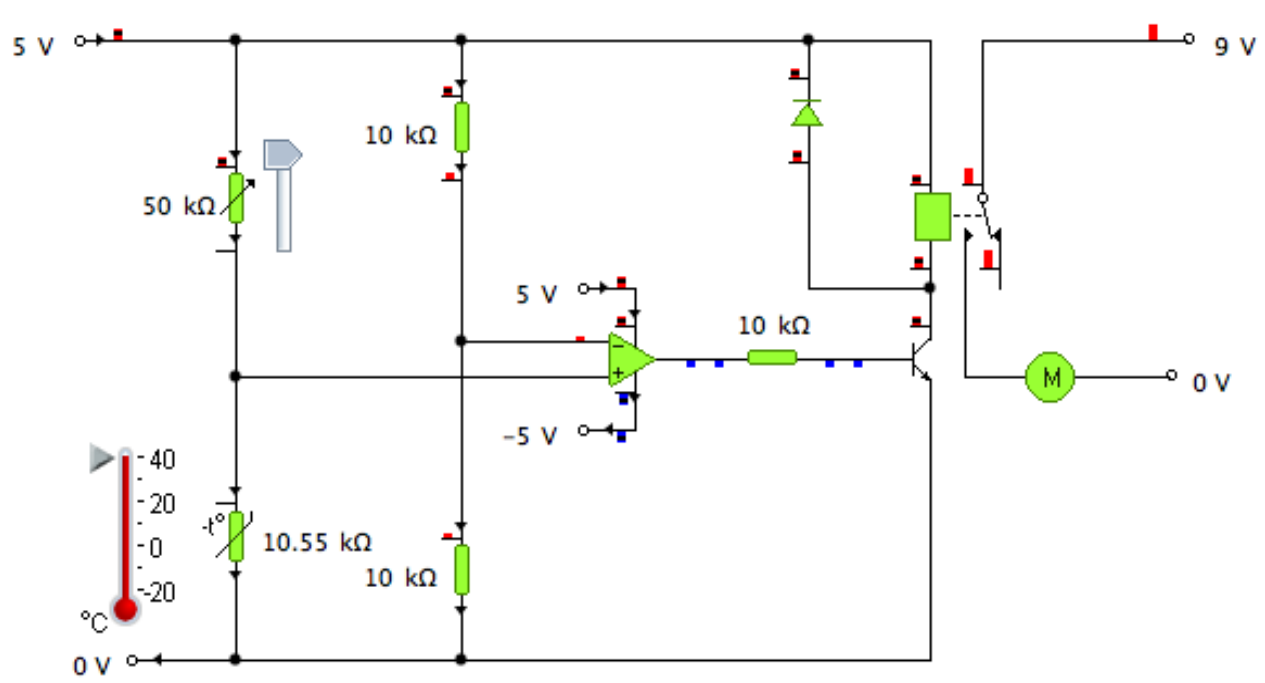
Amendment made:
rewire the relay or flip voltage divider or flip op-amp
(1 mark)

Actual result:
motor will switch on
(1 mark)

Amendment made:
none required

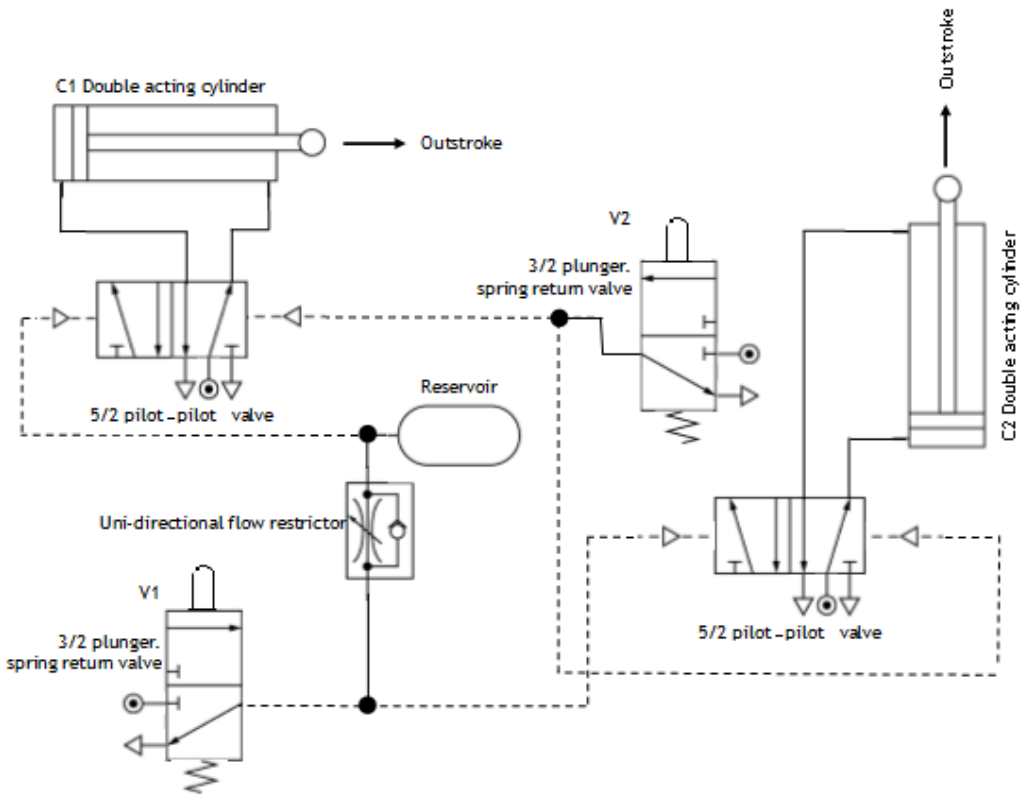
Actual result:
motor will switch off or on at different temperatures
(1 mark)

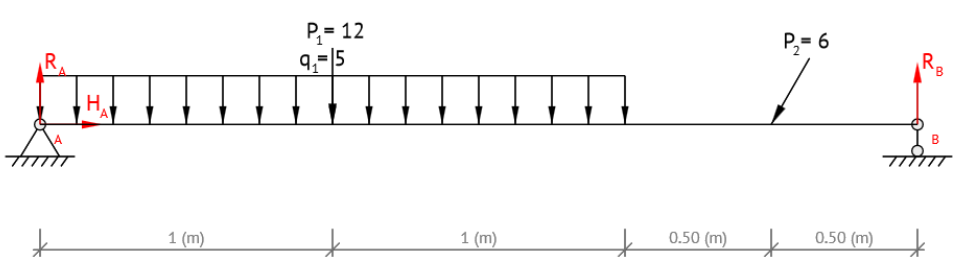
Amendment made:
none required</td></tr>
</table>

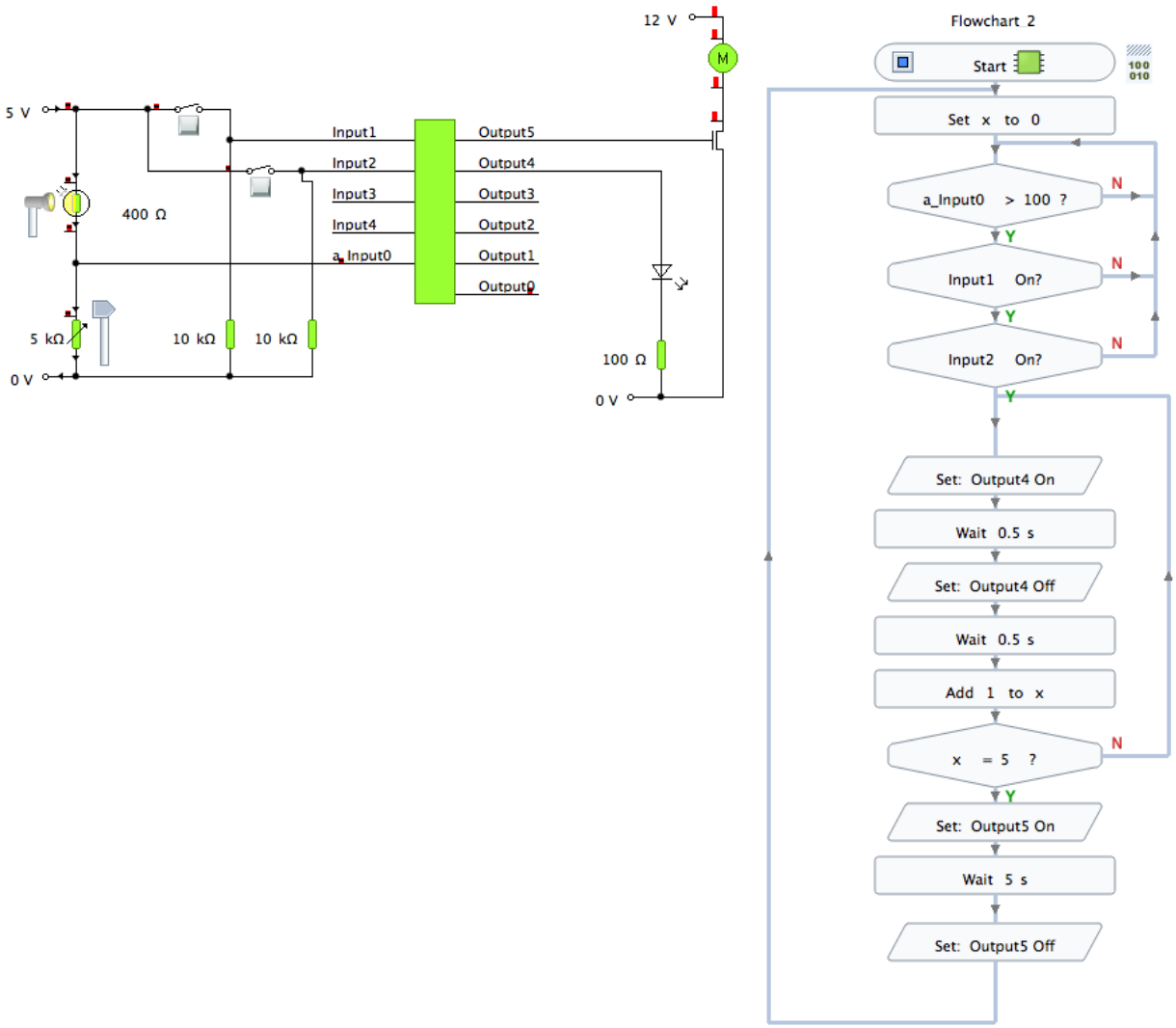
Task	Expected response	Max mark	Additional guidance
1d		**1**	Correct positive amendment made to the circuit shown on simulation **(1 mark)** Allow follow-through error based on candidate's response in testing table 1c

Task	Expected response	Max mark	Additional guidance
1e	Specification point ii met — when I lower the input temperature, the motor switches on. Specification point iii met — when I raise the input temperature, the motor switches off. After switching off, the motor took a considerable time to slow down and stop. This may cause some issues, as heat would still be supplied during this phase, raising the temperature even further. The sensitivity of the temperature sensor was successfully altered using the variable resistor, so the user could set the system to trigger at different levels. The solution performs as expected, however, it would only provide very basic control for what is a quite complex environment. Introducing independent controls for different areas would be a much better option.	**4**	Evaluative comment about each specification point, maximum 2 marks **(1 mark each point)** Evaluative comment about the overall system **(1 mark)** Improvement comment about system **(1 mark)** Evaluative comments should be descriptive and detail how well the specification points were met, and the changes that were made You can award the mark for the evaluative comment about the overall system for possible improvements Allow follow-through error based on candidate's response in testing table 1c

Task 2 — package distribution system

Task	Expected response	Max mark	Additional guidance
2a		**6**	Both 5/2 valves connected to each cylinder **(1 mark)** V1 3/2 valve connected to 5/2 to produce C2- (**1 mark**) V1 3/2 valve connected to 5/2 to produce C1+ (**1 mark**) V2 connected to produce C1- and C2+ (**1 mark**) V2 connected to produce C2+ (**1 mark**) UDR and reservoir positioned to form delay (**1 mark**)

Task	Expected response	Max mark	Additional guidance
2b	 **Calculate the reactions at the supports of a beam** 1. A beam is in equilibrium when it is stationary relative to an inertial reference frame. The following conditions are satisfied when a beam, acted upon by a system of forces and moments, is in equilibrium: **$\Sigma F_x = 0$:** $H_A - P_2*\cos(60) = 0$ **$\Sigma M_A = 0$:** The sum of the moments about a point A is zero: $- q_1*2*(2/2) - P_1*1 - P_2*\sin(60)*2.5 + R_B*3 = 0$ **$\Sigma M_B = 0$:** The sum of the moments about a point B is zero: $- R_A*3 + q_1*2*(3 - 2/2) + P_1*2 + P_2*\sin(60)*0.5 = 0$ 2. Solve this system of equations: $H_A = P_2*\cos(60) = 6*0.5000 = 3.00$ (kN) Calculate reaction of roller support about point B: $R_B = (\ q_1*2*(2/2) + P_1*1 + P_2*\sin(60)*2.5) / 3 = (\ 5*2*(2/2) + 12*1 + 6*\sin(60)*2.5) / 3 = 11.66$ (kN) Calculate reaction of pin support about point A: $R_A = (\ q_1*2*(3 - 2/2) + P_1*2 + P_2*\sin(60)*0.5) / 3 = (\ 5*2*(3 - 2/2) + 12*2 + 6*\sin(60)*0.5) / 3 = 15.53$ (kN) 3. The sum of the forces is zero: **$\Sigma F_y = 0$:** $R_A - q_1*2 - P_1 - P_2*\sin(60) + R_B = 15.53 - 5*2 - 12 - 6*\sin(60) + 11.66 = 0$ Vertical: R_A = 15·53 kN R_B = 11·66 kN Horizontal: R_A = 3 kN R_B = 0 N	**2**	Reaction at R_A, horizontal and vertical **(1 mark)** Reaction at R_B, horizontal and vertical **(1 mark)** Allow follow-through error for incorrect values simulated/constructed

Task	Expected response	Max mark	Additional guidance
2c		**4**	Digital inputs (**1 mark**) Using analogue input on microcontroller and voltage divider (**1 mark**) Outputs, including MOSFET (**1 mark**) Flow chart (**1 mark**)

<table>
<tr><th>Task</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>2d</td><td>
<table>
<tr><th>Actual result</th><th>Amendments made</th></tr>
<tr><td>Flow chart moved on when light level increased above 100</td><td>Change decision box so that > becomes <</td></tr>
<tr><td>LED started flashing only when both switches were pressed

By testing that only one switch is pressed, the result is the LED does not flash</td><td>Moved decision boxes to form OR arrangement</td></tr>
<tr><td>LED flashed five times before the motor spun</td><td>No amendments</td></tr>
</table>
</td><td>5</td><td>Actual result for light sensor (1 mark)

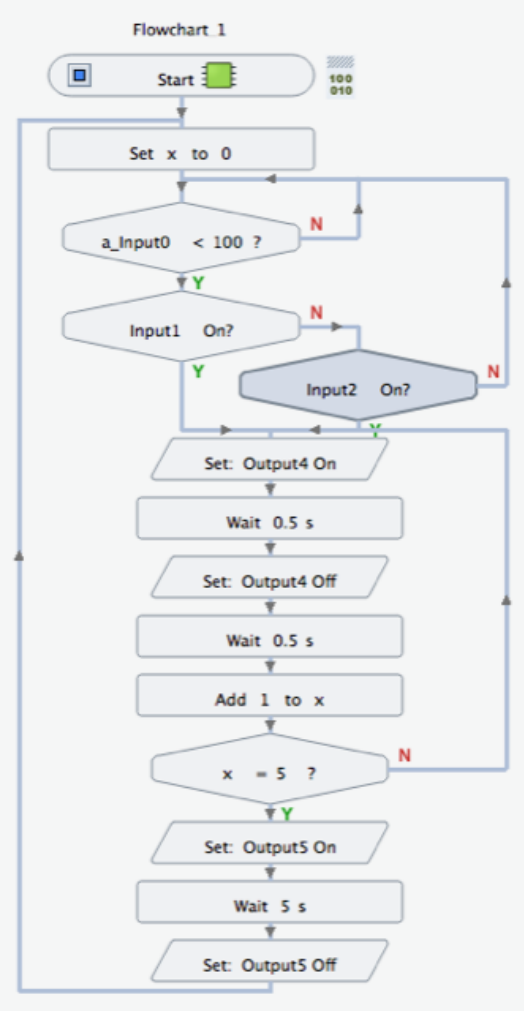
Actual result for AND/OR (1 mark)

Actual result for fixed loop (1 mark)

Amendment for light sensor (1 mark)

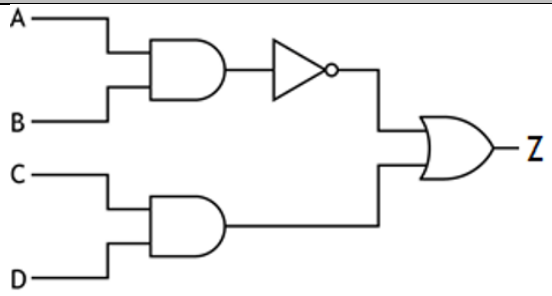
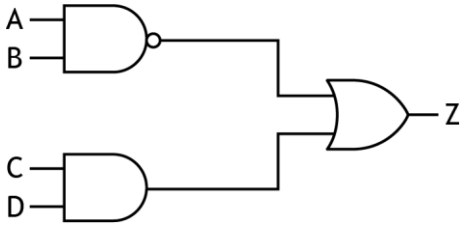
Amendment for AND/OR (1 mark)

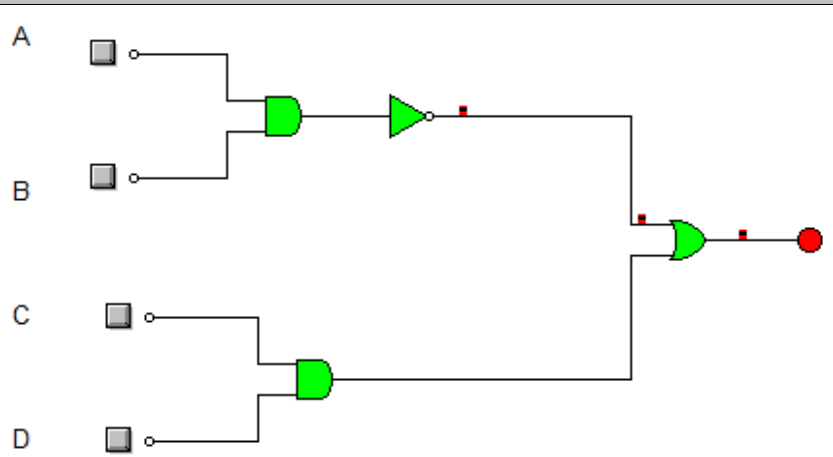
Follow through: award marks if candidates make mistakes completing the simulation, but rectify them in the testing section</td></tr>
</table>

Task	Expected response	Max mark	Additional guidance
2e		**2**	Flowchart must cover both amendments Light level amendment **(1 mark)** OR control amendment **(1 mark)**

Task	Expected response	Max mark	Additional guidance
2f	Specification point i met — the system now requires the light level to be below 100 before anything else can happen and works effectively. Specification point ii met — initially the system operated an AND function with the switches, but has now been changed to the required OR function and operates correctly. Specification point iii met — the LED successfully flashed five times before the motor began. The use of the microcontroller means that the system can easily be adapted or upgraded if additional functions are required. Using push-to-make switches would mean the system would not just keep repeating without further user input.	**5**	Award 1 mark for referencing each specification point and stating if the specification point is met (**3 marks**) Award 1 mark for each observation on broader aspects of the solution **(2 marks)** Allow follow-through error based on final flowchart/circuit

Task 3 — security system

Task	Expected response	Max mark	Additional guidance
3a	 	**3**	Award 1 mark for each correct gate with connections (**3 marks**) AND and NOT in series could be replaced with NAND as shown in the second diagram

Task	Expected response	Max mark	Additional guidance
3b		**2**	Correct gates, as per candidate's design, follow through **(1 mark)** Inputs/outputs **(1 mark)** AND and NOT could be replaced with NAND

<table>
<tr><th>Task</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
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</table>
</td><td>1</td><td>Actual results in truth table (1 mark)

Award no marks if there is no evidence of simulation in 3b

Allow follow-through error, based on final flowchart/circuit</td></tr>
</table>

Task	Expected response	Max mark	Additional guidance
3d	The actual results were significantly different from the expected results because the combinational logic circuit behaves exactly as the Boolean expression requires. The expected results in the table are therefore incorrect.	**1**	Evaluative comment based on the result **(1 mark)** Evaluative comments must be descriptive
3e	Producing the control system with a NAND equivalent circuit would be easier to construct and cheaper, as it would use fewer chips.	**1**	Description of the impact of using a NAND alternative **(1 mark)** You can award the mark for describing a possible improvement to the overall system

Copyright acknowledgements

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Administrative information

Published: September 2024 (version 2.0)

History of changes

Version	Description of change	Date
2.0	Content of assessment instrument unchanged. Surround and format changed to support Marking from Image. Amendments made throughout for accessibility.	September 2024

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