Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day

Month

Year

Scottish candidate number

1 Answer all the questions in Section A and any two questions in Section B.
2 Read each question carefully before you answer.
3 Write your answers in the spaces provided.
4 Show all working and units.
5 Do not write in the margins.
6 Do not sketch in ink.
7 Reference should be made to the Standard Grade and Intermediate 2 Data Booklet (2008 edition) which is provided.
8 Before leaving the examination room you must give this book to the Invigilator. If you do not, you may lose all the marks for this paper.

Use blue or black ink. Pencil may be used for graphs and diagrams only.
1. Figure Q1 shows a simplified sub-system diagram of a wind turbine.

(a) State the form of energy at A and B in Figure Q1.

A ________________________________

B ________________________________

Wind is a renewable source of energy.

(b) (i) Describe what is meant by a renewable energy source.

_____________________________________________________________________

_____________________________________________________________________

(ii) State two other sources of renewable energy.

1 ________________________________

2 ________________________________
1. (continued)

(c) Describe one advantage (other than being renewable) and one disadvantage of using wind turbines to generate electricity.

Advantage

Disadvantage

Turn over
2. A control system is used to prevent the water in a bath from overflowing.

Figure Q2

(a) Describe, using appropriate terminology, the operation of the system shown in Figure Q2.

(b) Explain the type of control shown in Figure Q2.

The operation of the system is semi-automatic.

(c) Describe what is meant by semi-automatic.
3. The truth table for a digital electronic circuit is shown below.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Z</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

(a) Complete, with reference to the truth table, the Boolean equation for output Z in terms of inputs A, B and C.

\[ Z = \]

(b) Complete the logic diagram below for the following Boolean equation.

\[ Z = ( \overline{A} \cdot B ) + C \]

(c) State the other name for a NOT gate.

---

Marks

3

3

1

(7)
4. An engineer tested the operation of two lamps connected in series and parallel as shown in Figure Q4(a) and Figure Q4(b).

![Figure Q4(a)](image1)

![Figure Q4(b)](image2)

(a) State two advantages of the lamps being connected in parallel rather than in series.

1. 

2. 

(b) Calculate the total resistance for the circuit shown in:

(i) Figure Q4(a);

(ii) Figure Q4(b).
4. (continued)

The current measured in ammeter $A_1$ is 3 mA and both circuits have the same voltage supply.

(c) Calculate the current reading on:

(i) Ammeter $A_2$;

(ii) Ammeter $A_3$.
5. A pneumatic system to lift components on a production line is shown in Figure Q5.

![Figure Q5](image-url)

(a) State one reason why pneumatic systems are often used in factory production lines.

(b) (i) State the full name of valve 1.

(ii) State the name of the pneumatic symbols below.

- \[\text{Symbol 1}\]
- \[\text{Symbol 2}\]
5. (continued)

(c) Complete the electrical connections to valve 1.

The pneumatic system must be able to lift a maximum load of 250 N. Cylinder A is 25 mm in diameter and air is supplied to the circuit at 0.6 N/mm².

(d) Calculate the outstroking force from cylinder A and state if it is able to lift the maximum load.
6. A microcontroller is used to operate a car wash system.

The sequence for the sub-procedure “Wash” is:
- Turn on the water and soap for 10 seconds
- The car wash moves forward for 20 seconds
- Turn off water, soap and car wash movement
- Turn on the brushes
- The car wash reverses until a limit switch is pressed
- All off
- Return to the main program
6. (continued)

(a) Complete, with reference to the Data Booklet, the flowchart for the sub-procedure “Wash”.

(b) State one reason for the use of a sub-procedure in a control program.
7. Figure Q7 shows an electronic circuit which has been designed to turn on a lamp at a set temperature.

(a) State, with reference to the Data Booklet, which thermistor type has a resistance of 100 kΩ at 10 °C.

For the conditions shown in Figure Q7:

(b) (i) calculate the voltage $V_1$;

(ii) state why the lamp does not light.

(c) Describe the effect that an increasing temperature will have on the resistance of the thermistor and the voltage $V_1$.

(d) Describe how this transistor could be protected.
8. Figure Q8 shows detail of a lighting gantry.

(a) Draw a free body diagram for the lighting gantry shown in Figure Q8.

(b) Calculate:

(i) the reaction force $R_A$ (take moments about $R_B$);

(ii) the reaction force $R_B$. 

[END OF SECTION A]
SECTION B

Attempt any TWO questions (Total 40 marks)

9. Figure Q9(a) shows the circuit diagram to control the motor of a running machine.

![Diagram of a circuit diagram with a 230 V source, 5 V input, 0 V output, a runner sensor, and a start switch connected to a motor M.]

Figure Q9(a)

(a) Describe, using appropriate terminology, the operation of the circuit.

When the runner is in position . . .

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

4 marks
9. (continued)

The relay is rated at 8 W, 5 V.

(b) Calculate, when the transistor is saturated:

(i) the collector current $I_C$;

(ii) the base current $I_B$, if the current gain, $h_{FE} = 50$.

The variable resistor allows analogue control of the motor.

(c) Draw, on the graph below, an example of an analogue signal.

![Graph](V-t)

The operation of the motor was changed to use a microcontroller and Pulse Width Modulation (PWM).

(d) State an advantage of PWM as a method of controlling the speed of a motor.

(e) State where in a microcontroller system:

(i) the program is stored;

(ii) the output driver for the motor is connected.
9. (continued)

The flowchart for the speed control of the motor and the input and output connections are shown in Figure Q9(b).

---

<table>
<thead>
<tr>
<th>Input connection</th>
<th>Pin</th>
<th>Output connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start switch</td>
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<td>Motor</td>
</tr>
<tr>
<td>Runner sensor</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Setspeed</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Motor on</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Wait mark</td>
<td>5</td>
<td></td>
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<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>Runner sensor</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figure Q9(b)
9. (continued)

(f) Complete, with reference to the flowchart, Data Booklet and input/output connections, the PBASIC program to control the speed of the motor.

```plaintext
init:
  symbol mark = b0
  symbol space = b1
  let dirs = %1000000

main:
```

A sub-procedure “Setspeed” is used to control the speed of the motor by adjusting the mark to space ratio as required. For an initial safe slow speed, the mark to space ratio for the motor is set as 1:4.

(g) Complete Figure Q9(c) to show a mark to space ratio of 1:4.

![Figure Q9(c)](chart.png)
10. The winch system shown in Figure Q10(a) is used to haul a fishing net onto a boat.

(a) Calculate the rotational speed of the drum, if the motor rotates at 3000 rev/min.

(b) State the name of gear A connected to the motor.
10. (continued)

An alternative mechanism to A and B in Figure Q10(a), that will prevent the fishing net falling back into the water, is shown in Figure Q10(b).

(c) (i) State the full name of the mechanism shown in Figure Q10(b).

![Figure Q10(b)](image)

X __________________________

Y __________________________

(ii) Indicate on Figure Q10(b) the direction of free rotation.

When fully loaded, the fishing net has a mass of 500 kg.

(d) Calculate:

(i) the work done raising the fishing net 100 m;

(ii) the input electrical energy supplied to the motor if the winch system is 35% efficient;

(iii) the power consumption of the motor during the one minute it takes to raise the fishing net.
10. (continued)

(e)  (i) State one form of energy loss in the winch system when raising the fishing net.

(ii) State one method of reducing this energy loss.

The motor is powered from a diesel generator.

(f) State, other than cost, one advantage and one disadvantage in using diesel as a source of energy.

Advantage

Disadvantage

(20)
11. A pneumatic system is used to transfer packages on a production line as shown in Figure Q11(a).

(a) Describe, using appropriate terminology, the operation of the system.

When a package pushes the plunger on valve 1 . . .

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

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________________________________________________________________________
11. (continued)

Some packages are too light to actuate the plunger.

(b) Describe an alternative pneumatic method of sensing lightweight packages.

The outstroke speed of the cylinders requires to be reduced.

(c) Sketch, on Figure Q11(b), the pneumatic component that would be used to slow only the outstroking of the piston.

![Diagram of pneumatic component]

Figure Q11(b)
11. (continued)

A digital electronic system is used to control the safety system for the production line. The logic diagram for the system is shown in Figure Q11(c).

![Logic Diagram](image)

Figure Q11(c)

(d) Complete the truth table below for the logic circuit.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>P</th>
<th>Q</th>
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</table>
11. (continued)

(e) Complete, with reference to Figure Q11(c), the wiring diagram shown in Figure Q11(d).

![Wiring Diagram]

Figure Q11(d)

The 7400, 7402 and 7404 Integrated Circuits (ICs) are required to construct the circuit.

(f)  (i) State the full name of the following ICs.

7400

7404

(ii) State the name of this IC family.

(iii) State the operating voltage for this IC family.

[END OF SECTION B]

[END OF QUESTION PAPER]
ACKNOWLEDGEMENTS

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Section B Question 9 – Serghei Starus/shutterstock.com