Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Date of birth

Day

Month

Year

Scottish candidate number

Number of seat

1 Answer all the questions.

2 Read every question carefully before you answer.

3 Write your answers in the spaces provided.

4 Do not write in the margins.

5 Do not sketch in ink.

6 All dimensions are given in millimetres.

7 Show all working and units where appropriate.

8 Reference should be made to the Standard Grade and Intermediate 2 Data Booklet (2008 edition) which is provided.

9 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.
1. A manufacturer wants to use a cruise control system to keep a car's speed constant even when it goes up and down hills. The system should allow a driver to take their foot off the accelerator once the desired speed has been set.

(a) Complete the control diagram below for the cruise control system.

(b) State the name of the control diagram symbol X.

(c) This control system makes use of a feedback loop. State the type of control produced by this automatic system.
2. An interior designer wants three lamps to come on when a switch is activated. The lighting circuit is shown below.

(a) State two reasons why it is good practice to have the lamps wired in parallel rather than in series.

(i) 

(ii) 

(b) Calculate, showing all working and units, the total resistance of the lighting circuit shown above.

\[ R_{\text{total}} = \frac{R_1 R_2 R_3}{R_1 + R_2 + R_3} \]

\[ = \frac{100 \, \Omega \times 100 \, \Omega \times 60 \, \Omega}{100 \, \Omega + 100 \, \Omega + 60 \, \Omega} \]

\[ = \frac{6,000,000 \, \Omega^2 \cdot \text{V}^2}{360 \, \text{\Omega}} \]

\[ = 166.67 \, \Omega \]

The designer wants the brightness of the lights to be altered using the following component.

(c) State the name of the component shown above.

(d) State the name of the device that is used to measure current in a circuit.
3. A geothermal power plant uses the heat in the earth to help produce electricity.

(a) Calculate the heat energy absorbed by 100 litres of water which is pumped into the earth at 10°C and comes out as steam at 240°C. (1 litre of water has a mass of 1 kg.)

(b) For every 15 MJ of heat energy that comes from the ground, the power plant produces 5.34 MJ of electricity.

(i) Calculate the efficiency of the power plant.

(ii) Explain why the power plant will not be 100% efficient.
3. (continued)

(c) Geothermal is a source of renewable energy. State two other examples of a renewable energy source.

1
2

(d) State two disadvantages of using fossil fuels, other than cost.

1
2

(e) State two ways that energy can be conserved in the home.

1
2

[Turn over
4. A test rig in a furniture factory is operated by the pneumatic circuit shown below.

(a) Describe, using appropriate terminology, how the pneumatic circuit operates.

When Valve 1 is actuated

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
4. (continued)

(b) State the **full name** of the following components.

Valve 1 ________________________________

Component Y ________________________________

(c) State two ways to vary the length of a pneumatic time delay.

1 ________________________________

2 ________________________________

To reduce damage it was decided to slow the piston movement as it outstrokes. The piston should still instroke quickly.

(d) (i) State the **full name** of a pneumatic component that could be used to slow a piston in one direction.

______________________________

(ii) Mark (X) on the pneumatic circuit where this component should be inserted.

(e) State the name of the following pneumatic actuators.

[Diagram of pneumatic actuators]

______________________________  ________________________________

[Turn over]
5. A prototype circuit for a parking sensor in a car is shown below.

\[ \text{Diagram of parking sensor circuit} \]

(a) (i) State the name of component \( Z \) shown in the circuit above.

(ii) State the type of relay shown in the circuit above.

(b) Describe the operation of the circuit.

As light level drops

(c) Calculate, with reference to the Data Booklet, the value of \( V_{\text{out}} \) when the light level on the LDR is 9 lux.
5. (continued)

(d) State the voltage at which a transistor saturates.

(e) A diode is normally wired in parallel across devices such as relays. State the purpose of the diode.
6. A music venue has a system to cut off the power supply if a band plays too loudly. The system is operated by a microcontroller.

A flowchart for the control system is shown below.
6. (continued)

Input and output connections to the microcontroller are shown in the table below.

<table>
<thead>
<tr>
<th>Input Connection</th>
<th>Pin</th>
<th>Output Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7</td>
<td>Power supply shut off (1 = shut off, 0 = power on)</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Warning light</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sound sensor</td>
<td>0</td>
<td>(1 = loud, 0 = quiet)</td>
</tr>
</tbody>
</table>

Complete, with reference to the flowchart, Data Booklet, and the input/output connections, the PBASIC control program.

init: let dirs = %11110000 ‘set pins 7–4 as outputs, rest inputs
     let pins = 0 ‘all pins off
     symbol counter = b0 ‘define counter address b0

main: if pin0 = 0 then main ‘if sound level is quiet then jump to main
     ‘set for . . . next loop to 10
7. Part of an electronic circuit used to control a central heating system is shown below.

(a) Complete, with reference to the Data Booklet and the wiring diagram, the logic diagram for the central heating system.
7. (continued)

(b) TTL Integrated Circuits (ICs) are used in the prototype but CMOS ICs are chosen for the final product.
State two advantages of CMOS ICs over the TTL ICs.

1 ___________________________________________________________________
2 ___________________________________________________________________

(c) An engineer designed and tested the circuit using a computer simulation.
State two reasons why new circuits are often tested on a computer first.

1 ___________________________________________________________________
2 ___________________________________________________________________

(d) The engineer assembled the circuit on a breadboard and used an LED to show a high output.

(i) State the full name of an LED.
____________________________________________________________________

(ii) Draw the symbol for an LED below.
____________________________________________________________________
8. A simplified diagram of a microcontroller system is shown below.

(a) (i) State the full name of the following microcontroller sub-systems.

I/O PORT

EEPROM

(ii) Describe the difference between RAM and ROM.

(b) (i) State the name of the connections that are used to transfer data from one microcontroller sub-system to another.

(ii) Describe the function of the ALU.

(c) (i) Convert the following binary number to decimal.

%10001011

(ii) Convert the following decimal number to binary.

102 %
9. A model train climbs a steep slope at an amusement park.
A simplified diagram of the train drive system is shown here.

(a) State the names of the labelled parts of the drive system in the diagram above.

Part X _________________________________

Part Y _________________________________

(b) A simplified diagram of the train drive system is shown. Calculate the speed of the 90 tooth gear.

2000 rev/min

_______________ rev/min
9. (continued)

(c) Calculate the linear speed of the train along the track. The pitch of Part Y is 50 mm.

(d) State the names of the mechanisms shown below.

(i) Worm and ______________________

(ii) Worm and ______________________

(iii) State an advantage in the use of a worm in a lifting system.

___________________________________________________________________________

___________________________________________________________________________

[Turn over
10. A microcontroller operates the motors in a robotic dog. To make the dog move in a life-like way the motors must be able to turn at a slower speed.

(a) Describe, with the aid of a sketch, or sketches, how a microcontroller program can be used to make a motor turn at a slower speed.

To reduce damage to the robotic toy the program uses a “soft start” technique when operating the motors. The “soft start” is illustrated in the diagram below. The diagram below shows the output signal to the motor.

(b) Describe, with reference to the diagram, what will happen to a motor when the “soft start” is used.