Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2015

Electronics ELEC4

Unit 4 Programmable Control Systems

Tuesday 9 June 2015 1.30 pm to 3.00 pm

For this paper you must have:
- a pencil and ruler
- a calculator
- a Data Sheet (enclosed).

Time allowed
- 1 hour 30 minutes

A

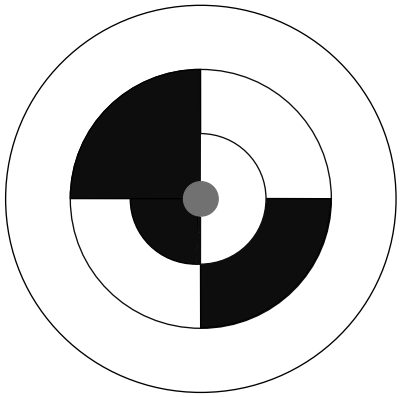
Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Answer **all** questions in the spaces provided.

1 A weathervane is a device which rotates to indicate the direction of the wind.
An electronic version is to be made which will display the wind direction remotely.
The weathervane is attached to a 3-bit binary-coded shaft encoder.
Figure 1 shows a partially completed shaft encoder.

Figure 1



1 (a) Complete the diagram by drawing and shading in the appropriate sections of the outer ring.

[2 marks]

1 (b) Circle the binary value below that represents southwest, if north is represented by 000_2 and east by 010_2.

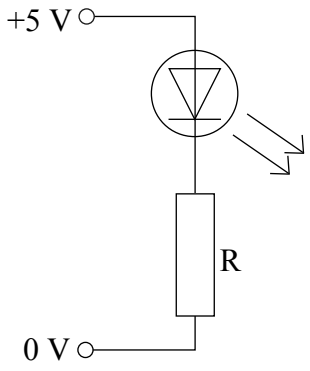
[1 mark]

001_2 100_2 101_2 110_2

1 (c) The binary shaft encoder has an infrared LED placed above each ring and an infrared photodiode below each ring in line with the LED. Infrared radiation from the LED is able to pass through the unshaded sections of the encoder disk but is blocked by the shaded sections.

1 (c) (i) **Figure 2** shows the circuit used to drive each infrared LED.
The infrared LED has a forward voltage of 1.2 V.

Figure 2



The maximum LED current is 15 mA.

Calculate a suitable value for R.

[3 marks]

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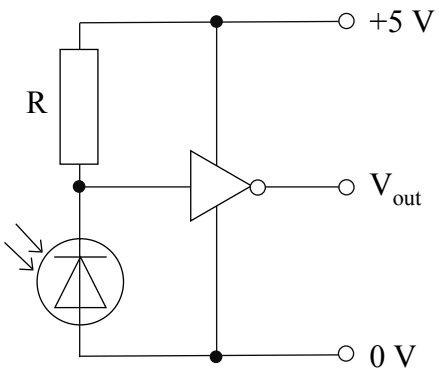
Question 1 continues on the next page

1 (c) (ii) **Figure 3** shows the detector circuit for each photodiode.
The photodiodes have a reverse current of $5\ \mu A$ when illuminated by the LED and $0\ \mu A$ when in the dark.

Figure 3



Calculate a suitable value for R, stating any assumptions made.

[2 marks]

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1 (d) When the direction of the wind changes from northwest to north, the electronic weathervane indicates southwest for a moment before indicating north.

1 (d) (i) Suggest **one** likely reason for this error.

[1 mark]

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1 (d) (ii) State what change could be made to the encoding disk to eliminate this problem.

[1 mark]

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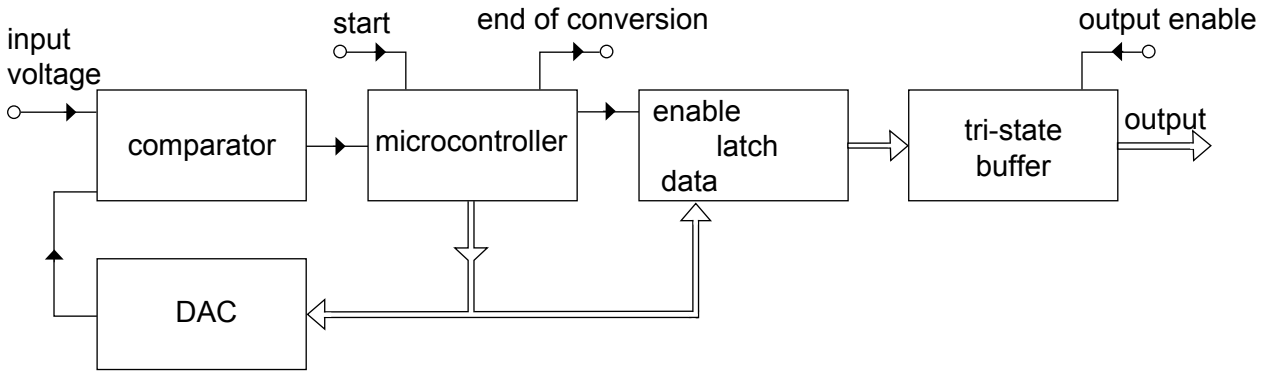
2 **Figure 4** shows the system diagram for one type of analogue to digital converter (ADC).

Figure 4



2 (a) An op-amp is used for the comparator.

Put a tick in the box next to the property of the op-amp which makes it most suitable for use as a comparator.

[1 mark]

Large input resistance. ☐

Large differential voltage gain. ☐

Small output resistance. ☐

A gain bandwidth product of 1 MHz. ☐

2 (b) The DAC (digital to analogue converter) has an 8-bit input and gives an output voltage of +5 V when the input byte has a value of **0x80**.

Show that the output voltage is approximately +7.1 V when the input byte is **0xB6**.

[2 marks]

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Question 2 continues on the next page

2 (c) The output from the comparator is connected to D_0 of **PORTA** of the microcontroller and the enable input of the latch is connected to D_4 of **PORTA**.

State the assembly instructions needed to set **PORTA** bits D_0 to D_3 as inputs and D_4 to D_7 as outputs.

[3 marks]

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2 (d) In operation, the microcontroller sends bytes to the DAC and the comparator compares the input voltage with the output voltage from the DAC.
When the output of the comparator changes, the microcontroller stores the byte in the latch using the enable line.

Explain why the latch is needed.

[2 marks]

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2 (e) The output of the latch is connected to a tri-state buffer to provide the ADC output.

2 (e) (i) State the function of the tri-state buffer.

[1 mark]

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2 (e) (ii) State the possible output states for a bit of the tri-state buffer.

[1 mark]

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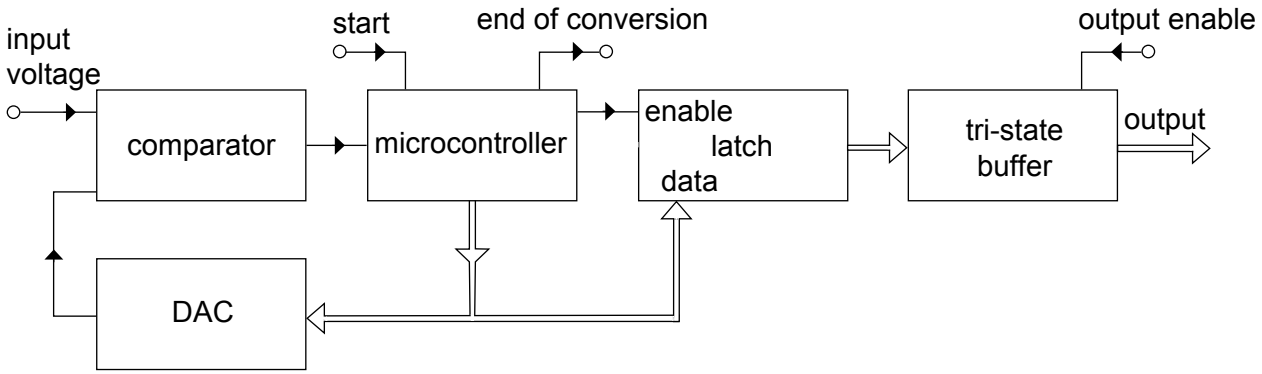
3 You do not need to have attempted **Question 2** before attempting this question.

Figure 5 shows the system diagram for one type of analogue to digital converter (ADC).

Figure 5



In operation, the microcontroller sends bytes to the DAC (digital to analogue converter) and the comparator compares the input voltage with the output voltage from the DAC. When the output of the comparator changes, the microcontroller stores the byte in the latch using the enable line.

The output from the comparator is connected to D_0 of **PORTA** of the microcontroller.

The enable input of the latch is connected to D_4 of **PORTA**.

PORTB is connected to the DAC and latch.

3 (a) To check the output state of the comparator, the microcontroller needs to:

- store the value of **PORTA** in the working register
- isolate bit 0 of the working register
- check if the working register is zero.

Write the assembler instructions for this process.

[3 marks]

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3 (b) To determine the value of the input voltage to the ADC, the microcontroller needs to set each bit of **PORTB** in turn.

Write the assembler instructions to:

- store the value of **PORTB** in the working register
- set bit 3 of the working register without changing the value of any other bit
- store the value of the working register back in **PORTB**.

[3 marks]

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3 (c) When the conversion is complete, the byte stored in **PORTB** needs to be stored in the latch. The enable input of the latch is active low and needs to receive a single pulse to store the data.

3 (c) (i) Explain what is meant by the term **active low**.

[1 mark]

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3 (c) (ii) Draw, in the space below, a diagram of the signal that must be sent by the microcontroller to the enable input of the latch in order to store the value of **PORTB**. Label logic levels on your diagram.

[1 mark]

3 (c) (iii) The assembler code to send this pulse is given below.

```
MOVRW PORTA
ANDW 0xEF
MOVWR PORTA
MOVRW PORTA
ORW 0x10
MOVWR PORTA
```

Calculate the duration of the pulse if the microcontroller clock frequency is 1 MHz.

[2 marks]

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4 To take photographs of stars and galaxies, it is necessary for a telescope to 'track' the stars and galaxies as the earth rotates. This is often achieved by using a stepper motor to rotate the telescope.

4 (a) (i) Compare the rotation of the armature of a stepper motor and of a conventional motor when power is applied.

[2 marks]

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4 (a) (ii) Explain why stepper motors are preferred for this application rather than conventional motors.

[1 mark]

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4 (b) There are two common types of stepper motors: unipolar and bipolar.

Describe the differences between the two types.

[3 marks]

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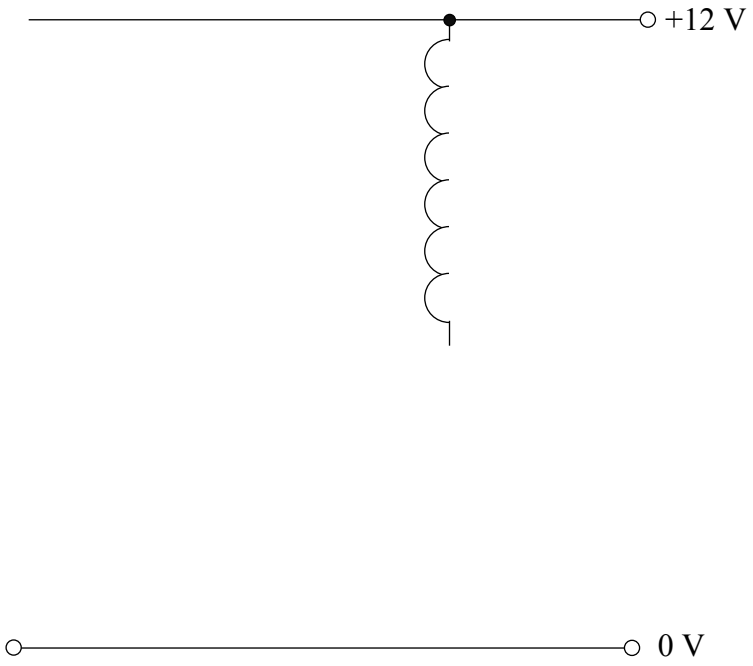
Question 4 continues on the next page

4 (c) A unipolar stepper motor is used to rotate the telescope.
The stepper motor is controlled by a microcontroller which can only provide an output current of $20\ \text{mA}$. Each stepper motor coil requires a current of $1\ \text{A}$ to operate.

Draw on **Figure 6** a suitable driver circuit to interface the coil to the microcontroller.

[4 marks]

Figure 6



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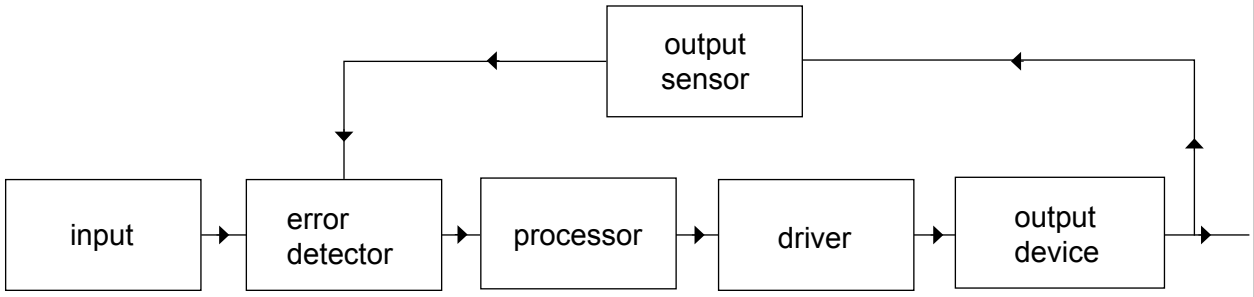
5 **Figure 7** shows the system diagram for a general closed loop control system.

Figure 7



5 (a) Explain the difference between a closed loop system and an open loop system.

[2 marks]

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5 (b) The signal from the output sensor can be either added to or subtracted from the input signal in the error detector.

Describe the effect on the system when:

5 (b) (i) the signal from the output sensor is subtracted from the input

[1 mark]

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5 (b) (ii) the signal from the output sensor is added to the input.

[1 mark]

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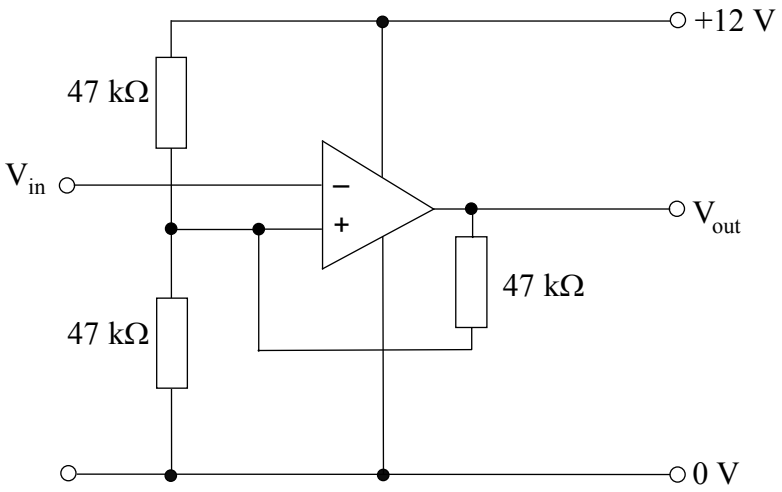
Question 5 continues on the next page

5 (c) **Figure 8** shows an inverting Schmitt trigger. It can be used as a processor in a control system.

Figure 8



Show, using calculations, that the switching levels of the Schmitt trigger are 4 V and 8 V.
You can assume that the op-amp is ideal.

[3 marks]

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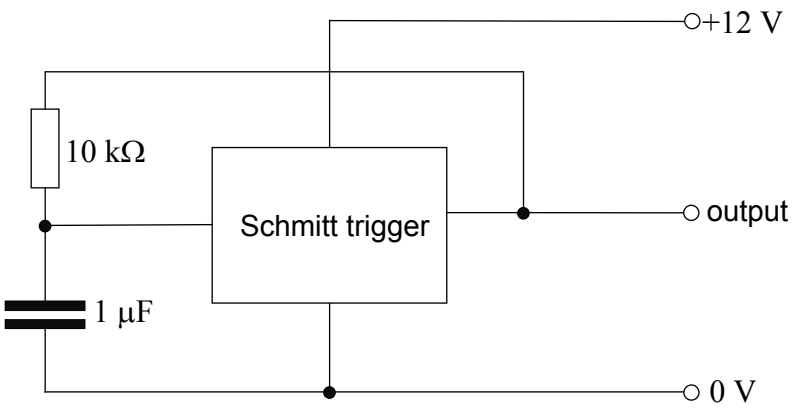
5 (d) The circuit in **Figure 9** makes use of the Schmitt trigger from **Figure 8**.

Figure 9



5 (d) (i) Describe the output signal from this system.

[1 mark]

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5 (d) (ii) Estimate the frequency of the output signal.
(You could compare the switching levels of this circuit to those of a 555 timer IC.)

[2 marks]

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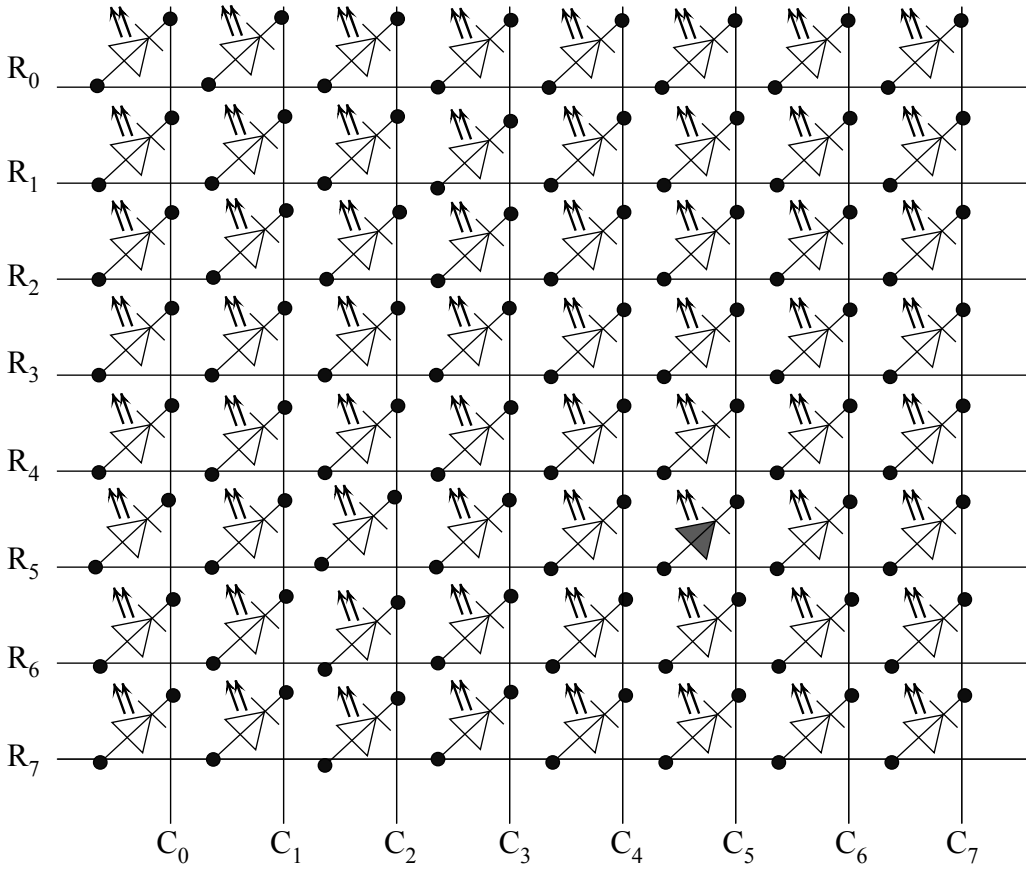
Turn over for the next question

6 **Figure 10** shows the internal layout of an 8 × 8 LED multiplexed dot matrix display, with one of the LEDs lit.
In use, each column is activated in turn.

Figure 10



6 (a) State the signals that must be applied to the rows and columns to light **only** this LED.
[3 marks]

rows .....

.....

columns .....

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6 (b) The LEDs have a forward voltage of 2.1 V and a maximum current of 15 mA.
The system using the display operates from a +5 V power supply and so series resistors are needed to limit the current passing through the LEDs.

State and explain whether these series resistors should be in the row leads or the column leads.

[3 marks]

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6 (c) Calculate the maximum current that each column driver must be able to switch.

[1 mark]

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6 (d) (i) Explain why the eye can perceive a multiplexed display as a continuous image.

[1 mark]

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6 (d) (ii) Estimate, using a calculation, the longest time there should be in switching from column to column for the observer to perceive a continuous image.
State any assumptions that you make.

[2 marks]

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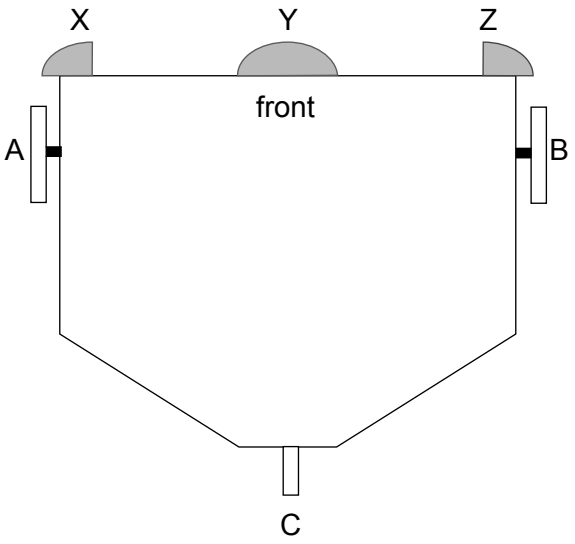
7 The top view of a small robot is shown in **Figure 11**.
A and B are wheels that are driven by motors and can rotate forwards, backwards or stop. C is a small trailing unpowered wheel.

Figure 11



7 (a) If wheels A and B rotate forwards, the robot moves forwards.

Complete each row of **Table 1** by adding a tick in the correct column.
The first row has been completed for you.

[3 marks]

Table 1

Direction of rotation		**Robot function**					
Wheel A	**Wheel B**	**Stops**	**Turns left**	**Turns right**	**Rotates anticlockwise**	**Moves forwards**	**Moves backwards**
Forward	Forward					✓	
Forward	Stop						
Backward	Forward						
Stop	Backward						

7 (b) Attached to the front of the robot are three sensors labelled X, Y and Z.
As the robot moves forwards, sensors X and Y are triggered, indicating an obstacle in front of these sensors. The robot then stops.

Explain the sequence of moves that the robot should make in order for the robot to try to go past the obstacle.

[4 marks]

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7 (c) The robot is powered by a 12 V lead acid battery.

7 (c) (i) State, with reasons, **two** disadvantages of using this type of battery.

[2 marks]

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7 (c) (ii) State, with **one** reason, a more suitable alternative power source.

[1 mark]

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8 You do not need to have attempted **Question 7** before attempting this question.

A robot has digital sensors attached to its front surface to detect obstacles.
The sensors are monitored by a microcontroller. When a sensor detects an obstacle it generates an interrupt request signal for the microcontroller.

8 (a) (i) Describe the sequence of events within a microcontroller when an **interrupt request** signal is received.

[3 marks]

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8 (a) (ii) Describe another method which the microcontroller could use to monitor the state of the sensors.

[2 marks]

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8 (b) Robotic systems need to be able to adapt to their environment and their tasks, and so need to be able to 'learn' from experience.
It is difficult to incorporate 'learning' into traditional control systems and so robotic control systems are increasingly using Artificial Neural Networks.

Compare a traditional control system with a neural network using the headings below.
[5 marks]

Processors .....

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Memory .....

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Speed of operation .....

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10

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED