Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

General Certificate of Education
June 2003
Advanced Level Examination

AQA

ASSESSMENT and
QUALIFICATIONS
ALLIANCE

ELECTRONICS ELE4
Unit 4   Electronic Control Systems

Thursday 26 June 2003   Afternoon Session

In addition to this paper you will require:
- a calculator.
- a pencil and a ruler.

Time allowed: 1 hour 30 minutes

Instructions
- Use blue or black ink or a ball-point pen. Use a pencil for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.
- A *Data Sheet* is provided on pages 3 and 4. Detach this perforated sheet at the start of the examination.

Information
- The maximum mark for this paper is 72.
- Mark allocations are shown in brackets.
- Any correct electronics solution will gain credit.
- The paper carries 15% of the total marks for Electronics Advanced award.
- You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
7			
Total (Column 1)			
Total (Column 2)			
TOTAL			
Examiner's Initials			

Data Sheet

Resistors	Preferred values for resistors (E24) series: 1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1 ohms and multiples that are ten times greater.
Resistor Printed Code **(BS 1852)**	This code consists of letters and numbers: R means $\times 1$ K means $\times 1000$ (i.e. 10^3) M means $\times 1\,000\,000$ (i.e. 10^6) Position of the letter gives the decimal point Tolerances are given by the letter at the end of the code, F = ± 1%, G = ± 2%, J = ± 5%, K = ± 10%, M = ± 20%.

Resistor Colour Code

Number	Colour
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White
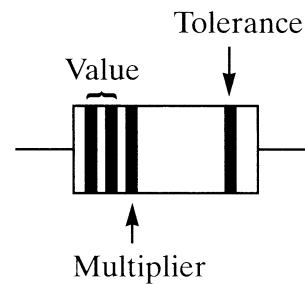
Tolerance, gold = ± 5%, silver = ± 10%, no band ± 20%.

Silicon diode	$V_F = 0.7\,\text{V}$
Silicon transistor	$V_{be} \approx 0.7\,\text{V}$ in the on state $V_{ce} \approx 0.2\,\text{V}$ when saturated

Resistance

$$R_T = R_1 + R_2 + R_3 \qquad \text{series}$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \text{parallel}$$

Capacitance

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \qquad \text{series}$$

$$C_T = C_1 + C_2 + C_3 \qquad \text{parallel}$$

Time constant

$$T = CR$$

ac theory

$$I_{rms} = \frac{I_o}{\sqrt{2}}$$

$$V_{rms} = \frac{V_o}{\sqrt{2}}$$

$$X_C = \frac{1}{2\pi f C} \qquad \text{reactance}$$

$$X_L = 2\pi f L \qquad \text{reactance}$$

$$f = \frac{1}{T} \qquad \text{frequency, period}$$

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad \text{resonant frequency}$$

Turn over ▶

Operational amplifier	$G_V = \dfrac{V_{out}}{V_{in}}$	voltage gain
	$G_V = -\dfrac{R_f}{R_1}$	inverting
	$G_V = 1 + \dfrac{R_f}{R_1}$	non-inverting
	$V_{out} = -R_f \left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3} \right)$	summing
Astable and Monostable using NAND Gates	$f \approx \dfrac{1}{2RC}$	astable
	$T \approx RC$	monostable
555 Astable and Monostable	$T = 1.1RC$	monostable
	$\left. \begin{array}{l} t_H = 0.7(R_A + R_B)C \\ t_L = 0.7R_BC \end{array} \right]$	astable
	$f = \dfrac{1.44}{(R_A + 2R_B)C}$	two resistor circuit
Electromagnetic Waves	$c = 3 \times 10^8 \,\mathrm{m\,s^{-1}}$	speed in vacuo

List of BASIC Commands

DIM variable [(subscripts)]

DO [{**WHILE** | **UNTIL**} condition]
    [statement block]
LOOP

DO
    [statement block]
LOOP [{**WHILE** | **UNTIL**} condition]

FOR counter = start **TO** end [**STEP** increment]
    [statement block]
NEXT counter

GOSUB [label | line number]
    [statement block]
RETURN

IF condition **THEN**
    [statement block 1]
ELSE
    [statement block 2]

INKEY$

INP (port %)

INPUT [;] ["prompt" {;1, }] variable list (comma separated)

LPRINT [expression list] [{ ;1, }]

OUT port%, data%

PRINT [expression list] [{;1,}]

REM remark

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

1 All of the questions below refer to this system diagram for a generalised microprocessor control system.
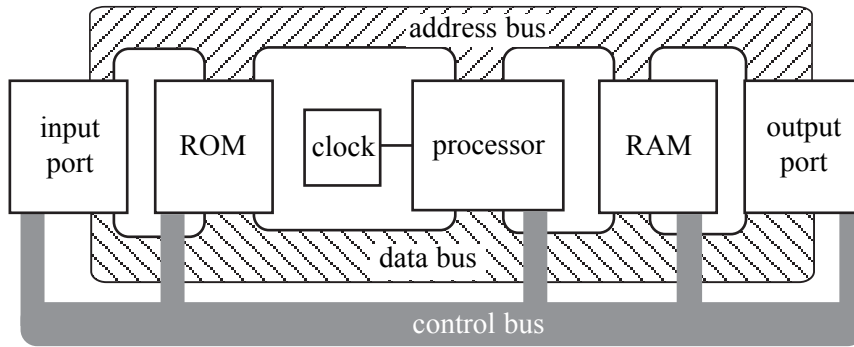
(a) (i) State a difference between RAM and ROM.

....

(ii) State **two** types of instructions that are likely to be stored in the ROM.

....

....

(3 marks)

(b) (i) Explain what is meant by the term *bus*.

....

....

(ii) Why are buses used in computer systems?

....

....

(iii) Explain why the data bus needs to be bi-directional.

....

....

(3 marks)

(c) (i) Input and output ports can be memory mapped. Explain what is meant by the term *memory mapping*.

....

....

(ii) Explain how memory mapping differs from I/O mapping.

....

....

(3 marks)

9

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

2   A computer operates a large seven segment display from its parallel port. A plan of the display is shown
below together with a table matching the segments of the display to the parallel port outputs.
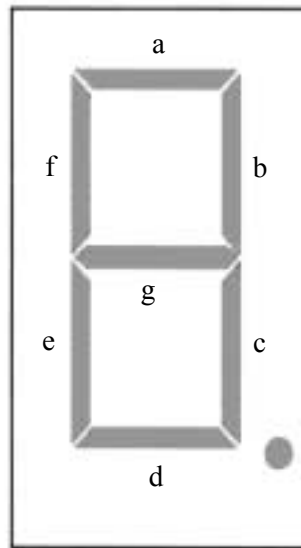
Port output	Display segment
D_0	a
D_1	b
D_2	c
D_3	d
D_4	e
D_5	f
D_6	g
D_7	decimal point

(a)   (i)   Which segments must be lit to display the number 3?

....

(ii)   If a logic 1 output is required to light a segment, state, in hexadecimal, the number which
must be written to the output port to display the number 3. Show your reasoning.

....

....

....

....
(4 marks)

(b) Each segment of the display consists of 10 LEDs, each with a maximum forward voltage of 1.9 V and a maximum current of 30 mA. The circuit diagram for a segment, together with its driver, is shown below.
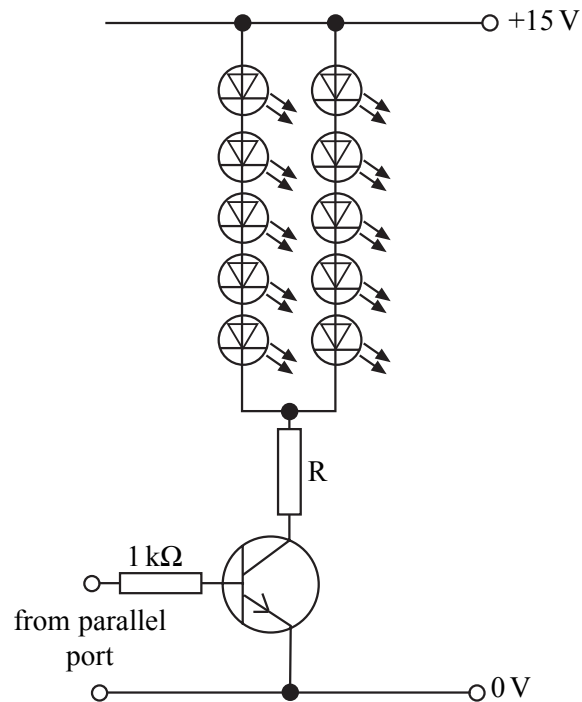
(i) State the maximum current that has to be switched by the transistor.

....

(ii) Estimate, showing your working, a suitable value for the resistor R.

....

....

(iii) Estimate, showing your working, a suitable power rating for the resistor R.

....

....

(5 marks)

Turn over ▶

3   The eight data outputs of the parallel port of a computer are connected to the eight inputs of a summing amplifier. A graph of the output voltage from the summing amplifier against the decimal number sent to the parallel port by the computer is shown below.
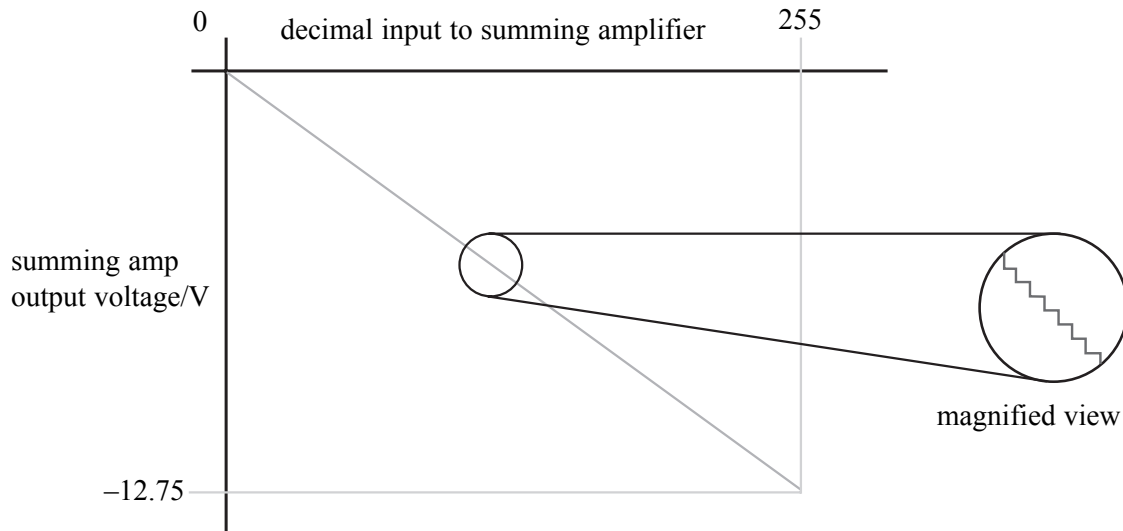
(a)   (i)   Name the process being performed by the summing amplifier.

....

(ii) Estimate, showing your working, the change in the output voltage which corresponds to a change of 1 in the input number.

....

....

(iii) Draw the diagram of a circuit that could be used to change the negative output voltage of the summing amplifier into a positive voltage of the same value. Include suitable component values.

(5 marks)

Part of the QBasic program used to produce the number/voltage graph is shown below.

```
start:
INPUT "ENTER THE INPUT NUMBER FOR THE SUMMING AMPLIFIER"; X
IF X > 255 THEN END
IF X < 0 THEN END
N% = INT(X)
OUT(&H378), N%
GOTO start
```

(b) Explain the purpose of the following statements.

   (i) **start:**

   ....

   (ii) **OUT(&H378), N%**

   ....

(2 marks)

(c) State **two** ways in which it is possible to exit from the program.

   ....

   ....

(2 marks)

9

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

4 A brewery is controlled by a PC which needs to read bytes of data from the various sensors which monitor the brewing process and then accurately process the information. Part of the system diagram is shown below.
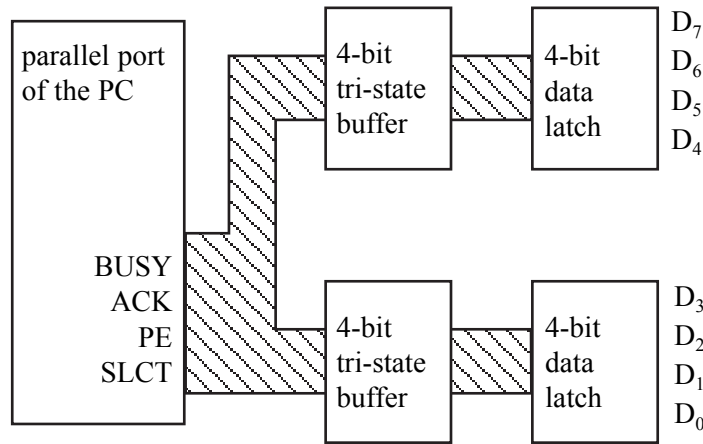
(a) The 4-bit data latches are each made from four D-type flip-flops.

(i) Draw the symbol for a D-type flip-flop.

(ii) By describing the function of a D-type flip-flop, explain how it can be used as a 1-bit data latch.

....

....

....

(3 marks)

(b) (i) Explain what is meant by the term *tristate*.

....

....

(ii) Explain why tristate buffers are needed in this system.

....

....

(3 marks)

(c) The Managing Director of the brewing company has read that the latest form of computer control systems are Neural Networks and wants to investigate whether the brewing process would be more efficient if it was controlled by one.

    (i) State **two** differences between a Neural Network and a PC.

....

....

....

....

    (ii) State, with a reason, whether you would advise this change.

....

....

....

....

(3 marks)

$\frac{}{9}$

TURN OVER FOR THE NEXT QUESTION

5 PIC/AVR devices are now used to provide all of the timing and control systems for most domestic electronic and electrical goods, e.g. dishwashers, washing machines etc.

(a) (i) State **one** way in which the architecture of a PIC/AVR differs from a conventional computer system.

....

....

(ii) Why are PICs/AVRs now commonly used for providing the control functions for domestic goods, e.g. washing machines?

....

....

....

....

(2 marks)

(b) The control functions processed by the PICs/AVRs on a washing machine can be classified as either open or closed loop.
Explain why the functions of filling with water and heating it to the required temperature are classified as closed loop.

....

....

....

....

(2 marks)

(c) In a washing machine, when carrying out the function of a 'slow spin', the drum has to rotate at a steady speed of 200 revolutions per minute. To maintain this speed, negative feedback is provided to the PIC/AVR from a rotation sensor attached to the drum.

(i) Explain what is meant by the term *negative feedback*.

....

....

(ii) Explain how the negative feedback controls the rotation speed of the drum.

....

....

(2 marks)

(d) The circuit diagram for the temperature sensor is shown below. The PIC/AVR produces a temperature control voltage dependent upon the temperature of the wash selected.
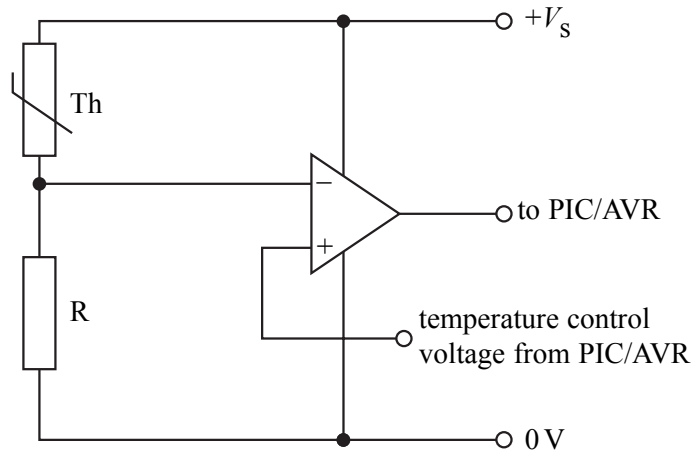
(i) Name the temperature sensing element in the circuit.

....

(ii) Explain how the temperature sensing circuit functions.

....

....

....

....

....

(3 marks)

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

6 Attached to the fly-wheel of a petrol engine is an optical shaft encoder which provides information to the Engine Management Unit (EMU) about the speed of rotation of the engine. The optical shaft encoder consists of a metal disk with 12 evenly spaced slots around the disk. An opto-switch produces a pulse every time a slot passes by. A graph of two such pulses is shown below.
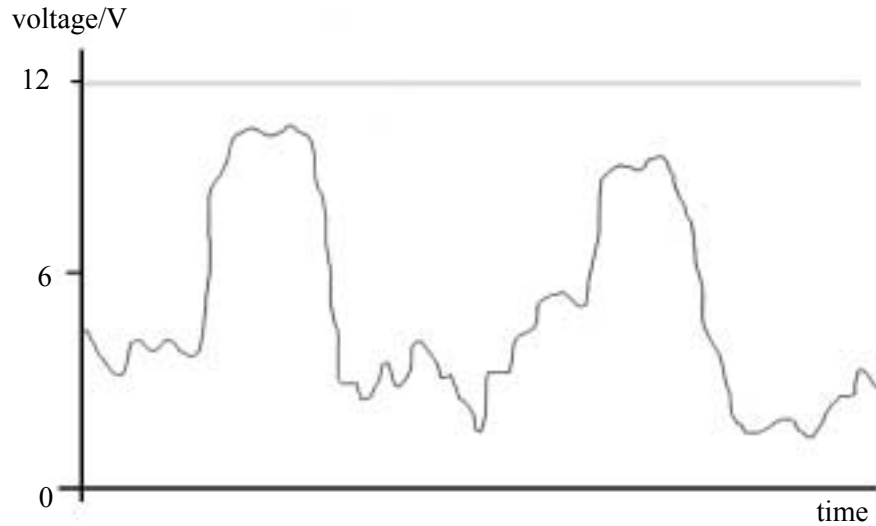
The pulses are passed through the Schmitt Trigger circuit below.
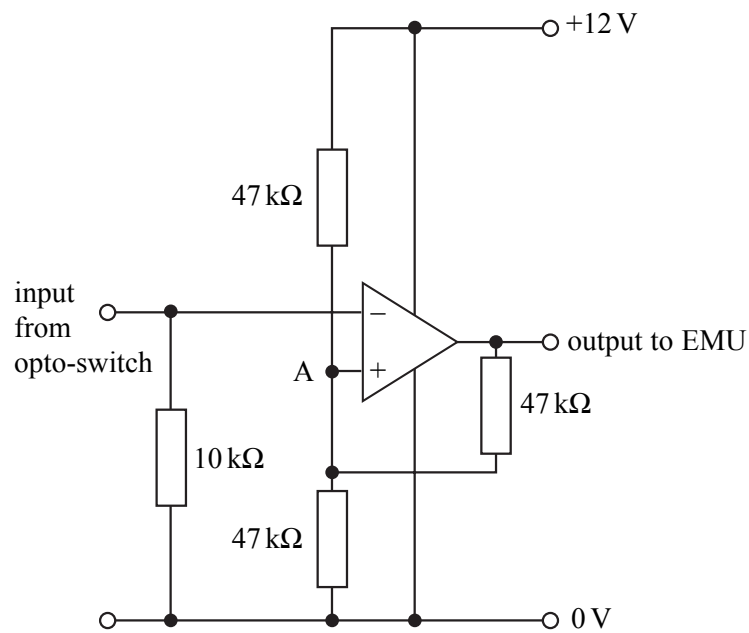
(a) Suggest a reason why a Schmitt trigger is needed in this application.

....

....

(1 mark)

(b) Assume that the op-amp output is either +12 V or 0 V.

(i) Show that the voltage at point A in the Schmitt trigger circuit is 4 V when the output of the op-amp is at 0 V.

....

....

....

(ii) Calculate the voltage at point A in the Schmitt trigger circuit when the output of the op-amp is 12 V.

....

....

....

(iii) In terms of the general properties of an op-amp explain why the switching levels of the Schmitt trigger are the same as the values in parts (i) and (ii) above.

....

....

....

(8 marks)

$\dfrac{}{9}$

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

7 In a hospital pathology laboratory, a circular rack of 12 test tubes has to be rotated accurately so that each test tube can be positioned under a pipe in order that a precise amount of liquid can be added to each test tube.

The arrangement is shown below.
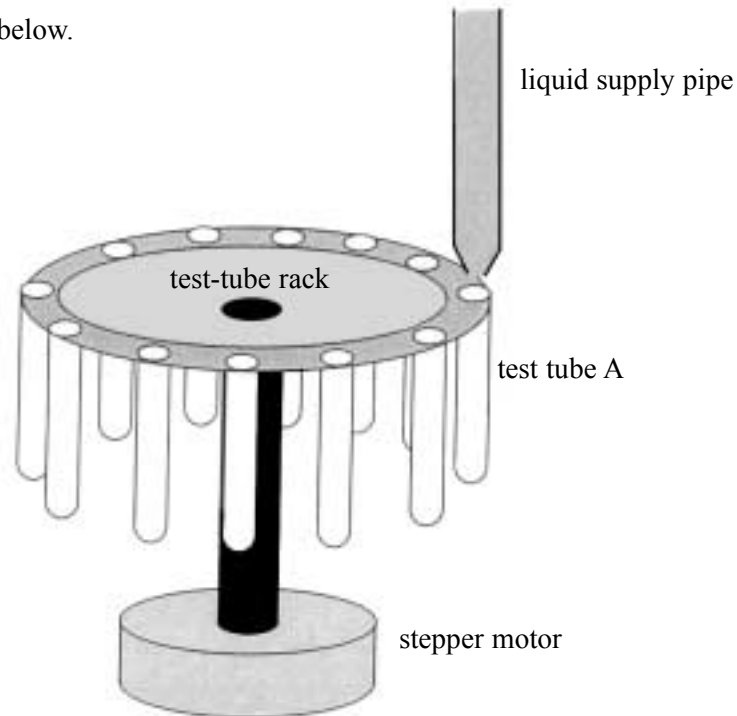
(a) The test-tube rack is rotated by a stepper motor. The stepper motor is 4 pole, operates from a 48 V supply and is controlled by a computer. The circuit diagram of the stepper motor is shown below.

Draw on the diagram a suitable driver circuit to interface **one** of the stepper motor coils to the parallel port of the computer.
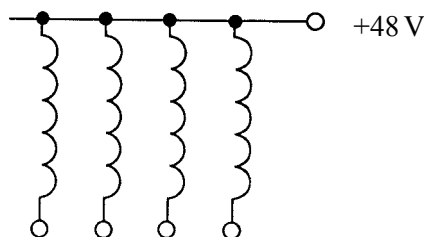
(3 marks)

(b) The coils are operated by D_0, D_1, D_2, D_3 of the parallel port. The flow diagram below makes the test-tube rack rotate clockwise to the next test-tube i.e. $30°$.

Step 1 — start

Step 2 — set only $D_0 = 1$

Step 3 — pause 100 ms

Step 4 — set only $D_1 = 1$

Step 5 — pause 100 ms

Step 6 — set only $D_2 = 1$

Step 7 — pause 100 ms

Step 8 — set only $D_3 = 1$

Step 9 — stop

(i) Explain why the test-tube holder rotates $30°$.

....

....
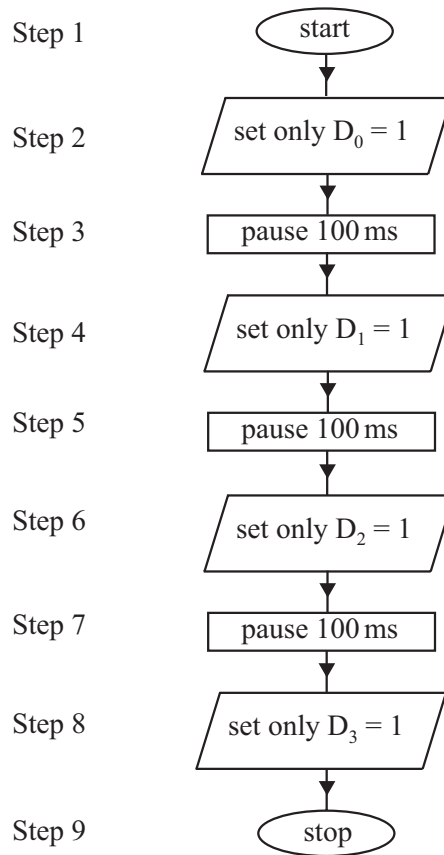
(ii) Explain how you would change the flow diagram to make the stepper motor rotate the test-tube holder $30°$ anticlockwise.

....

....

....

....

(iii) Explain how the speed of rotation of the motor can be changed.

....

....

(4 marks)

QUESTION 7 CONTINUES ON THE NEXT PAGE

Turn over ▶

(c) (i) Explain why the QBasic statement for step 6 of the flow diagram is

OUT(&H378),4

....

....

(ii) The pause process of the flow diagram is handled by a subroutine called

waitabit

Convert the flow diagram, which makes the test-tube rack rotate 30°, into a QBasic program.

....

....

....

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....

....

....

....

(5 marks)

(d) To provide a reference point for the system, an optical switch provides a logic 1 to bit 5 (D_5) of the parallel input port addressed at &H379 when test tube A is in line with the liquid supply pipe. This input is *polled* by a subroutine called **ref**.

(i) Explain what is meant by the term *polled*.

....

....

(ii) Explain how polling differs from an *interrupt*.

....

....

(iii) Explain how you would make the system ensure that the test-tubes align with the liquid supply pipe when the system is first switched on.

....

....

....

....

....

(5 marks)

(e) Why is the stepper motor the most suitable type of motor for this application?

....

....

(1 mark)

$\overline{18}$

END OF QUESTIONS