OCR
Oxford Cambridge and RSA

# Wednesday 7 June 2023 – Afternoon

## A Level in Design and Technology: Design Engineering

**H404/01** Principles of Design Engineering

**Time allowed: 1 hour 30 minutes**

**You can use:**
- a ruler (cm/mm)
- a scientific calculator
- geometrical instruments

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

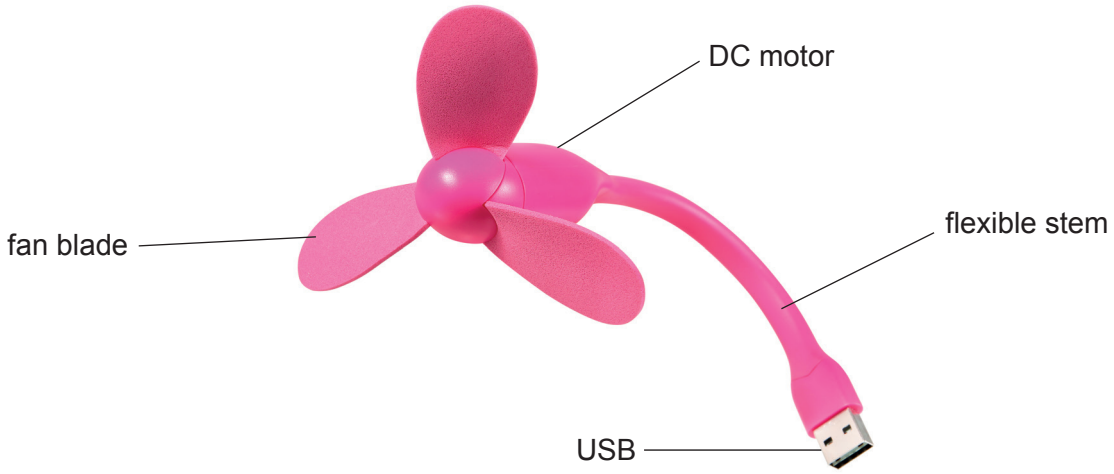
Last name _____

**INSTRUCTIONS**
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. You can use extra paper if you need to, but you must clearly show your candidate number, the centre number and the question numbers.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

**INFORMATION**
- The total mark for this paper is **80**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

**ADVICE**
- Read each question carefully before you start your answer.

**1** This shows a USB-powered personal mini fan.




**(a)** The flexible stem of the personal mini fan is covered with PVC. PVC is a thermo softening polymer.

Identify **two** reasons why a thermo softening polymer is a suitable material for the flexible stem.

1 .....

.....

2 .....

.....

**[2]**

**(b)** Explain why bearings are needed in mechanical systems such as those used in the personal mini fan.

.....

.....

.....

..... **[2]**

**(c)** The personal mini fan is powered by plugging it in to a USB socket.

Explain **one** benefit to the user and **one** benefit to the manufacturer of designing the personal mini fan to be powered from a USB socket.

Benefit to user .....

.....

.....

.....

Benefit to manufacturer .....

.....

.....

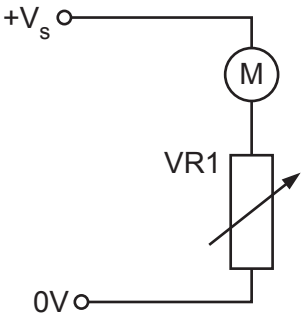
.....

**[4]**

**(d)** The personal mini fan contains a DC motor.

A designer wishes to develop a personal mini fan product by adding a control to adjust the speed of the motor. Different circuits are being considered to achieve this.

This circuit shows how a variable resistor VR1 is used to control the speed of the motor.




**(i)** When variable resistor VR1 is set at 20 Ω, the fan runs at $\frac{1}{2}$ its maximum speed. At this speed, the current flowing through the circuit is 250 mA.

Calculate the power dissipated in variable resistor VR1 when it is set at 20 Ω. Give your answer in W and show your working. **[4]**

Power dissipated in variable resistor VR1 ..... W

**(ii)** Use your result from **part d(i)** to explain why using a variable resistor is not an efficient way of controlling the speed of a DC motor.

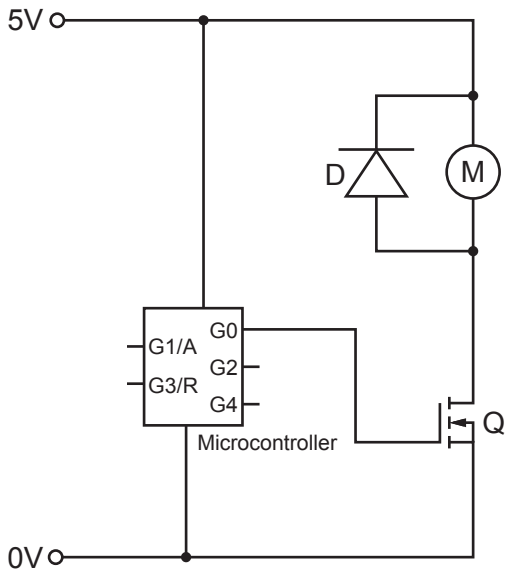
.....

.....

.....

..... **[2]**

**(iii)** This circuit shows the motor being controlled by a microcontroller and other components.




Identify component Q and explain its function in this circuit.

.....

.....

..... **[2]**

**(iv)** Identify **one** reason for including diode D in the circuit.

.....

..... **[1]**

**(v)** Despite the increased complexity, explain **one** reason why a designer might choose to use a microcontroller to achieve motor speed control in products such as a personal mini fan.

.....

.....

.....

..... **[2]**

**(e)** The personal mini fan sells online for less than £4.00. It is classed as a novelty electrical item. It contains no user serviceable parts and product reviews suggest that it has a lifespan of less than one year.

Discuss the role of a designer in ensuring the responsible disposal of products such as the personal mini fan at the end of their product life.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[8]**

**2** **(a)** **Fig. 2.1** shows a conical drill bit.

**Fig. 2.2** shows the cross section of the conical drill bit.

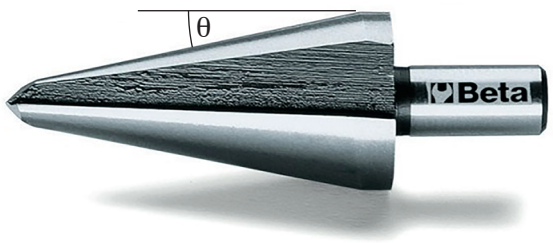



**Fig. 2.1**

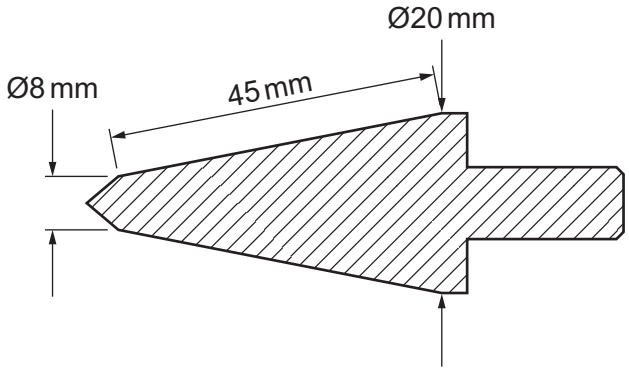


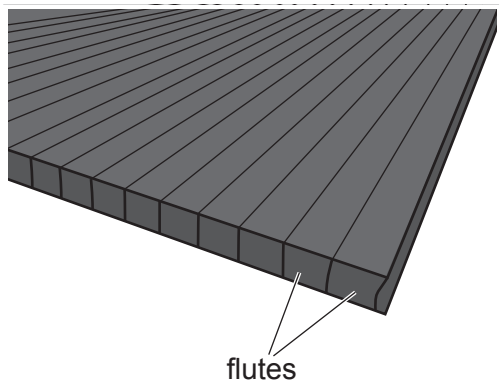

**Fig. 2.2**
(not to scale)

A student needs to calculate taper angle θ.

Calculate the taper angle θ in degrees. Give your answer to **1** decimal place and show your working. **[4]**

θ ..... °

**(b)** This shows part of a corrugated polymer sheet.




The corrugated polymer sheet has hollow flutes which run through the entire length of the sheet. These sheets are sometimes used in solar water heating systems in which the flutes are filled with water and heated by radiant energy from the sun.

The table shows data for the corrugated polymer sheet.

| | |
|---|---|
| Sheet dimensions | 500 mm × 500 mm |
| Sheet thickness | 8.0 mm |
| Internal cross section of flutes | 7.0 mm × 7.0 mm |
| Number of flutes per metre length | 134 |
| Sheet material | Polypropylene |

**(i)** Identify the industrial manufacturing process for corrugated polymer sheets of the type shown above.

..... **[1]**

**(ii)** Use the data in the table to calculate the volume of **one flute** in the corrugated polymer sheet. Give your answer in $cm^3$ and show your working. **[3]**

Volume ..... $cm^3$

**(iii)** Use the data in the table and your answer to **part (b)(ii)** to calculate the total volume of **all** flutes in the corrugated polymer sheet. Give your answer in $cm^3$ and show your working. **[2]**

Total volume ..... $cm^3$

**(iv)** On a sunny day, the corrugated polymer sheet absorbs the sun's energy at a rate of 2.0 kW per $m^2$.

You will need to use the data in the table on **page 8**.

Determine by calculation that the energy absorbed by the corrugated polymer sheet over a period of 15 minutes is 450 000 J. Show your working. **[5]**

**(v)** It is assumed that all heat absorbed is transferred to the water.

Calculate the temperature rise of the water to the nearest °C in the corrugated polymer sheet over a period of 15 minutes.

Use information in **part (iv)** and the formula $Q = mc\Delta T$ where:

Q = heat energy in J
m = mass of water held in corrugated polymer sheet (1.642 kg)
c = specific heat capacity of water (4200 J / kg °C)
$\Delta T$ = temperature change in °C

Show your working. **[3]**

Temperature rise of water ..... °C

**3** **(a)** **(i)** Describe, with an example, a way in which textiles can be used for reinforcement in engineered designs.

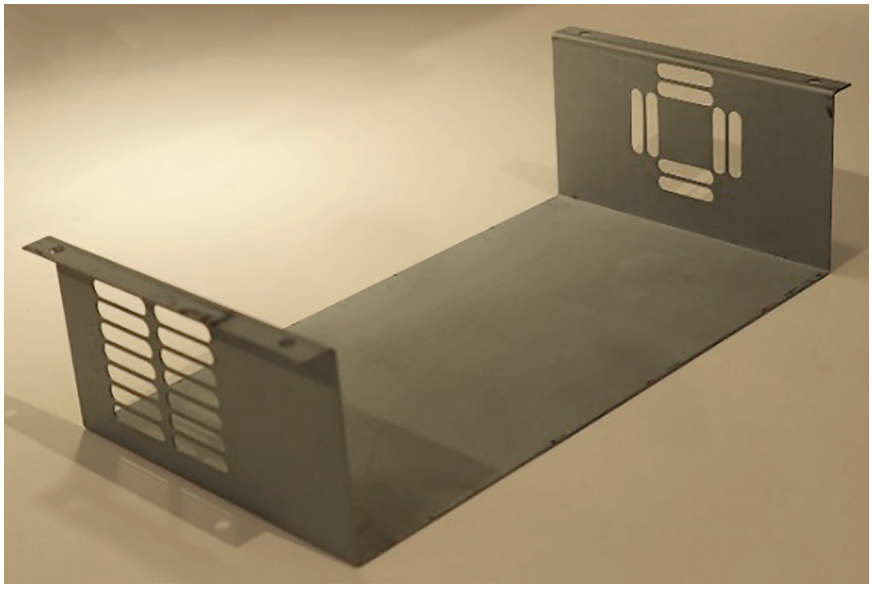
.....

.....

.....

..... **[2]**

**(ii)** This shows a sheet metal part which is manufactured in a batch of 5000.



Describe the industrial manufacturing processes which would have been used to manufacture the sheet metal part.

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

**(b)*** Historically, significant advances in design engineering have often been brought about by a key technical advancement or discovery.

Identify a key historical technical advancement or discovery and the figures associated with it. Discuss how this work has had an influence on future developments in design engineering.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[8]**

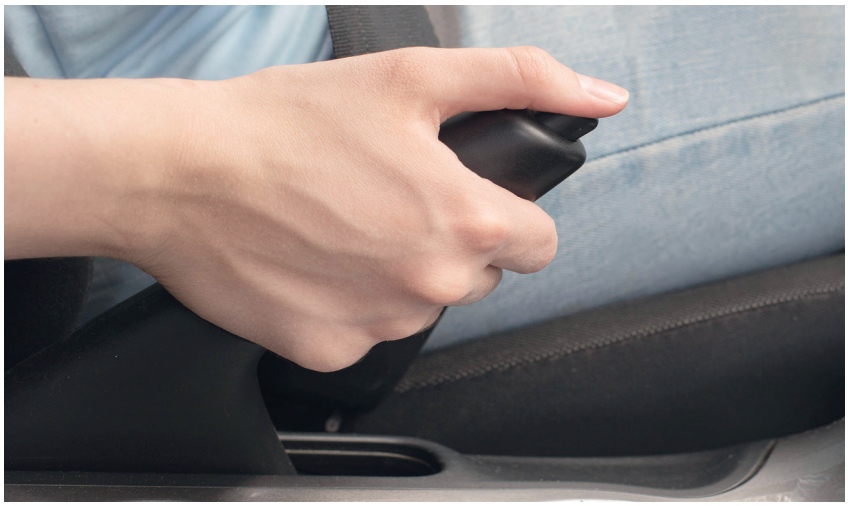
**BLANK PAGE**

**PLEASE DO NOT WRITE ON THIS PAGE**

**4** Cars contain a wide range of control systems.

In many cars, the conventional lever-operated parking brake has been replaced with an electric parking brake which is operated by a switch.

This shows a car driver operating a conventional lever-operated parking brake.



This shows a driver operating an electric parking brake switch.

**(a)** Explain **one** reason why a manufacturer might choose to install an electric parking brake rather than a lever-operated parking brake in a car.

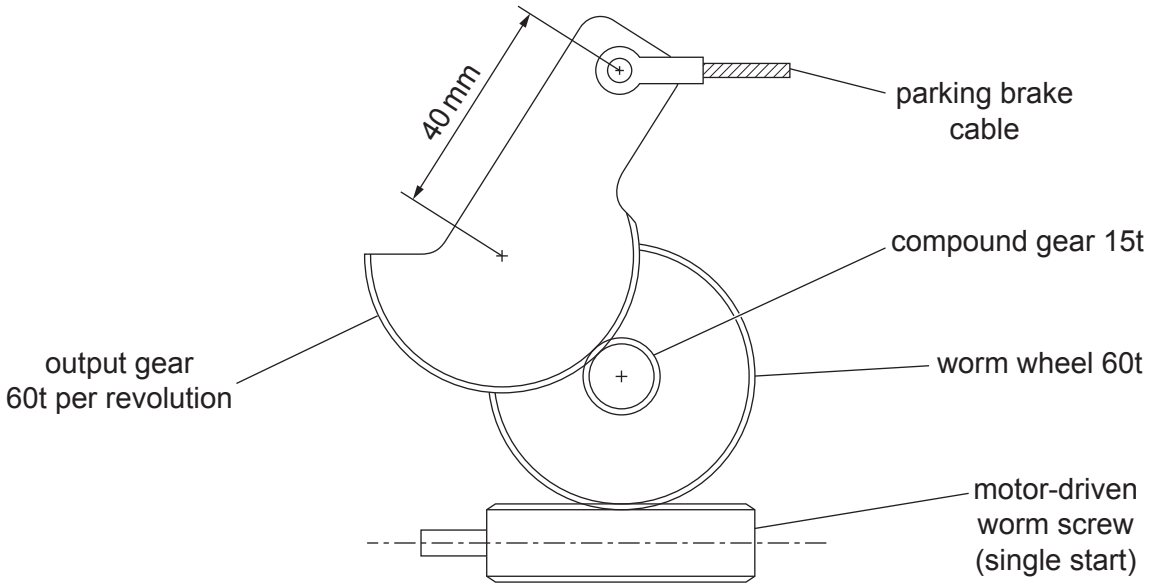
.....

.....

.....

..... **[2]**

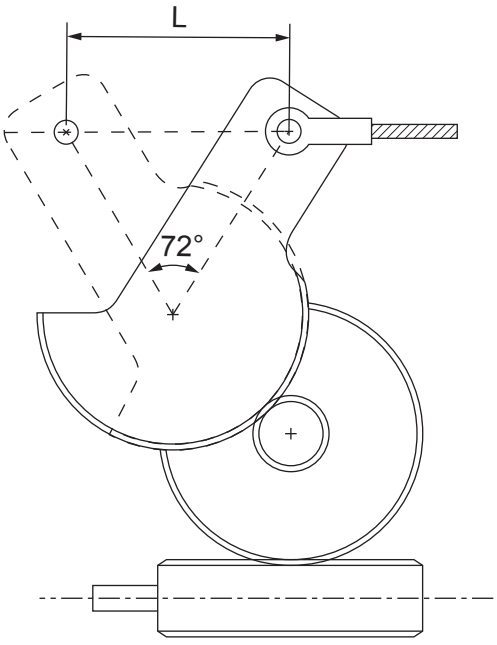
**(b)** This shows the mechanical actuator system for an electric parking brake.




(not to scale)

The actuator uses a motor and gears to pull a cable which applies the parking brake.

During operation, the output gear rotates through 72° into the position shown.




The parking brake cable is pulled through a distance marked L.

**(i)** Use the information on **page 14** to calculate distance L. Give your answer to the nearest mm and show your working. **[4]**

Distance L ..... mm

**(ii)** Use the information on **page 14** to calculate the number of revolutions of the worm wheel that are required to rotate the output gear through an angle of 72°. Show your working. **[3]**

Number of revolutions of worm wheel .....

**BLANK PAGE**

**PLEASE DO NOT WRITE ON THIS PAGE**

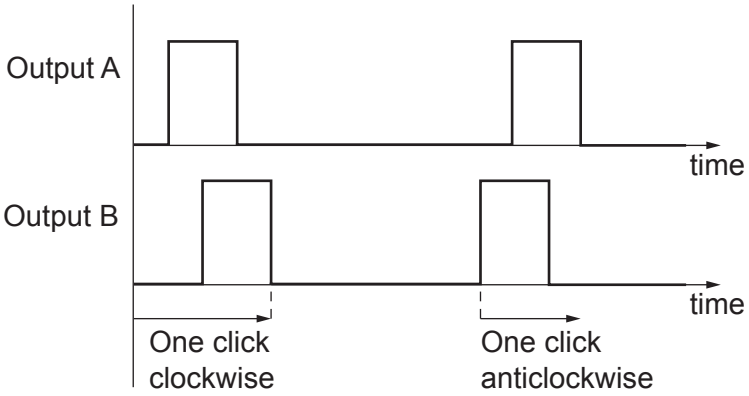
**(c)** This shows the central console control knob in a car.


The control knob clicks as it is rotated and it can be assigned to many different functions.

The control knob is connected to an incremental rotary encoder which produces two output signals, A and B.

Outputs A and B each produce one pulse in sequence when the control knob is turned through one click.

The graph shows the pulses produced by outputs A and B when the control knob is rotated through a single click clockwise and a single click anticlockwise.




**(i)** Describe how incremental rotary encoders can benefit design engineers.

.....

.....

.....

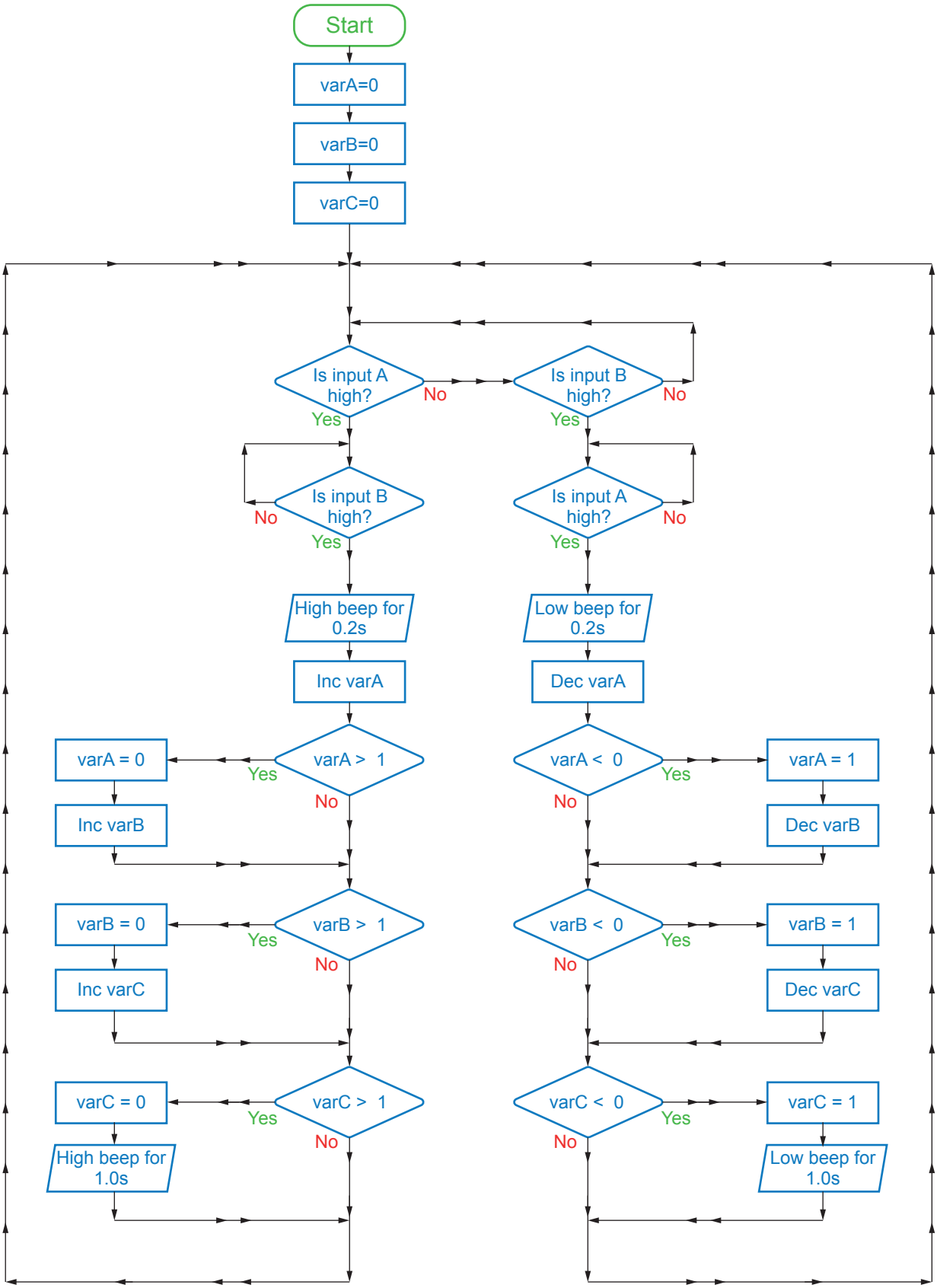
.....

.....

..... **[3]**

**18**

The signals from A and B are monitored by a microcontroller running the following flowchart program.



**(ii)** Use the information on **pages 17 and 18** to describe how the system provides audible feedback to the user when the control knob is rotated **clockwise**.

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

**(iii)** The flowchart program is restarted from the START command and the control knob is rotated **five clicks clockwise**.

Write down the values of variables A, B and C after the fifth click. **[3]**

Variable A .....

Variable B .....

Variable C .....

**(iv)** The control knob is then rotated **two clicks anticlockwise**.

Write down the **new** values of variables A, B and C. **[2]**

Variable A .....

Variable B .....

Variable C .....

**END OF QUESTION PAPER**

**PLEASE DO NOT WRITE ON THIS PAGE**