X036/701

NATIONAL QUALIFICATIONS 2007

FRIDAY, 1 JUNE
1.00 PM – 4.00 PM

TECHNOLOGICAL STUDIES
ADVANCED HIGHER

100 marks are allocated to this paper.

Answer **all** questions in Section A (60 marks).

Answer **two** questions from Section B (20 marks each).

Where appropriate, you may use sketches to illustrate your answer.

Reference should be made to the Advanced Higher Data Booklet (2006 edition) which is provided.

SECTION A

Marks

Attempt all the questions in this Section. (Total 60 marks)

1. The circuit diagram of an astable device is shown in Figure Q1.

(*a*) State the meaning of the term "astable". **1**

Sub-system A shown in Figure Q1 is a Schmitt trigger.

(*b*) Calculate the two possible reference voltages at the non-inverting input.

Assume that the op-amp saturates to the supply rail voltages. **2**

(*c*) Explain the operation of the whole circuit, referring to sub-systems A, B, C and D. **4**

Sub-system D is a resistance-capacitance (RC) circuit with two resistors R_1 and R_2 and capacitor C.

(*d*) For the values shown, calculate:

(i) the "mark" time; **1**

(ii) the "space" time; **1**

(iii) the frequency. **1**

(*e*) State the name of a commercially available integrated circuit that performs the overall function of the three sub-systems A, B and C. **1**

(11)

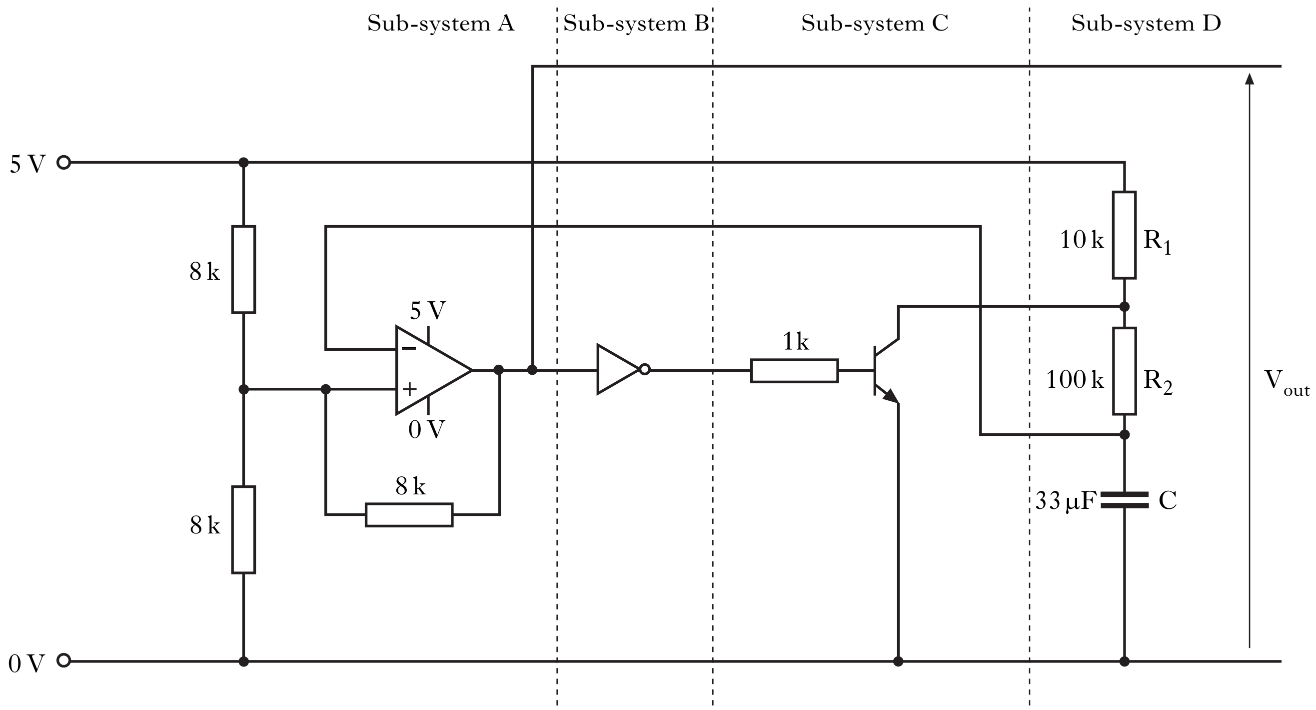

Figure Q1

Marks

2. An astronomical telescope is shown in Figure Q2(*a*).

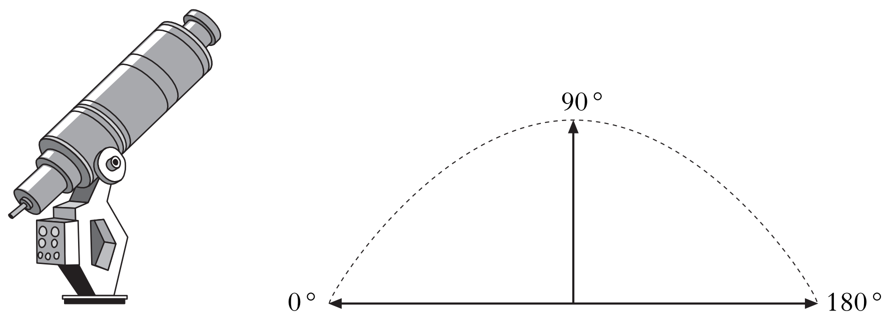

Figure Q2(*a*)

The telescope tracks through 180 degrees of the night sky within a 12 hour period.

The tracking mechanism is driven by a servo-motor with 150 discrete positions within the 180 degrees. Tracking is initiated by a switch-input to a microcontroller and the servo-motor position is determined by a stream of pulses sent from pin 4 of the microcontroller.

Figure Q2(*b*) shows the pulse waveforms output to pin 4 for the 0°, 90° and 180° positions of the servo-motor. Other intermediate positions have proportional waveforms.

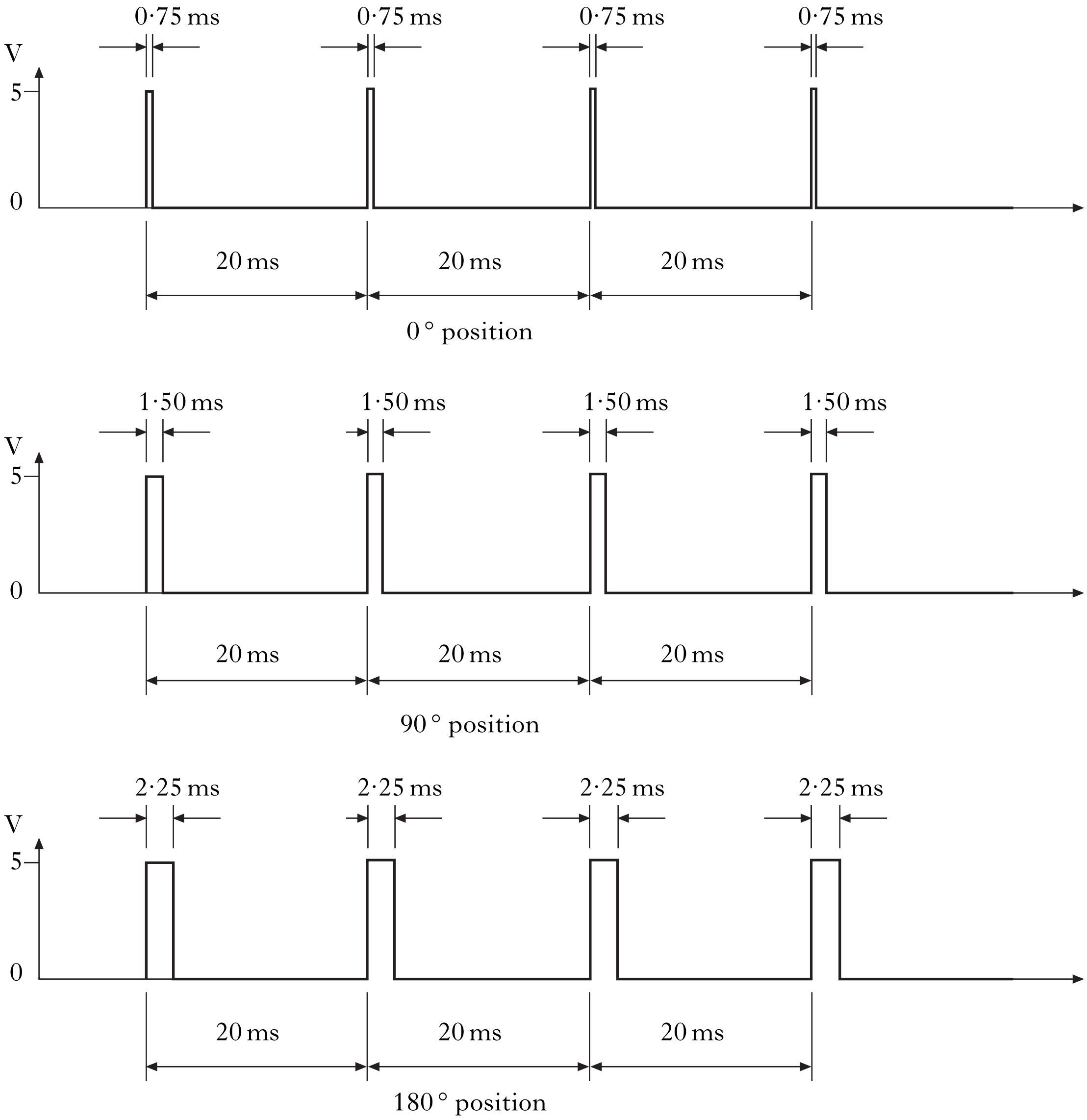

Figure Q2(*b*)

(*a*) Draw the pulse waveform for the 30° position. **2**

Marks

2. (continued)

Figure Q2(*c*) shows the flowcharts for the main program and the sub-procedure "servo".

(*b*) Write the assembler code for the main program. **10**

(12)

TRISB has been initialised.

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

Inputs	PORTB Pins	Outputs
	7	
	6	
	5	
	4	Servo-motor
	3	
	2	
	1	
Start switch (1 = pressed)	0	

2. **(continued)**

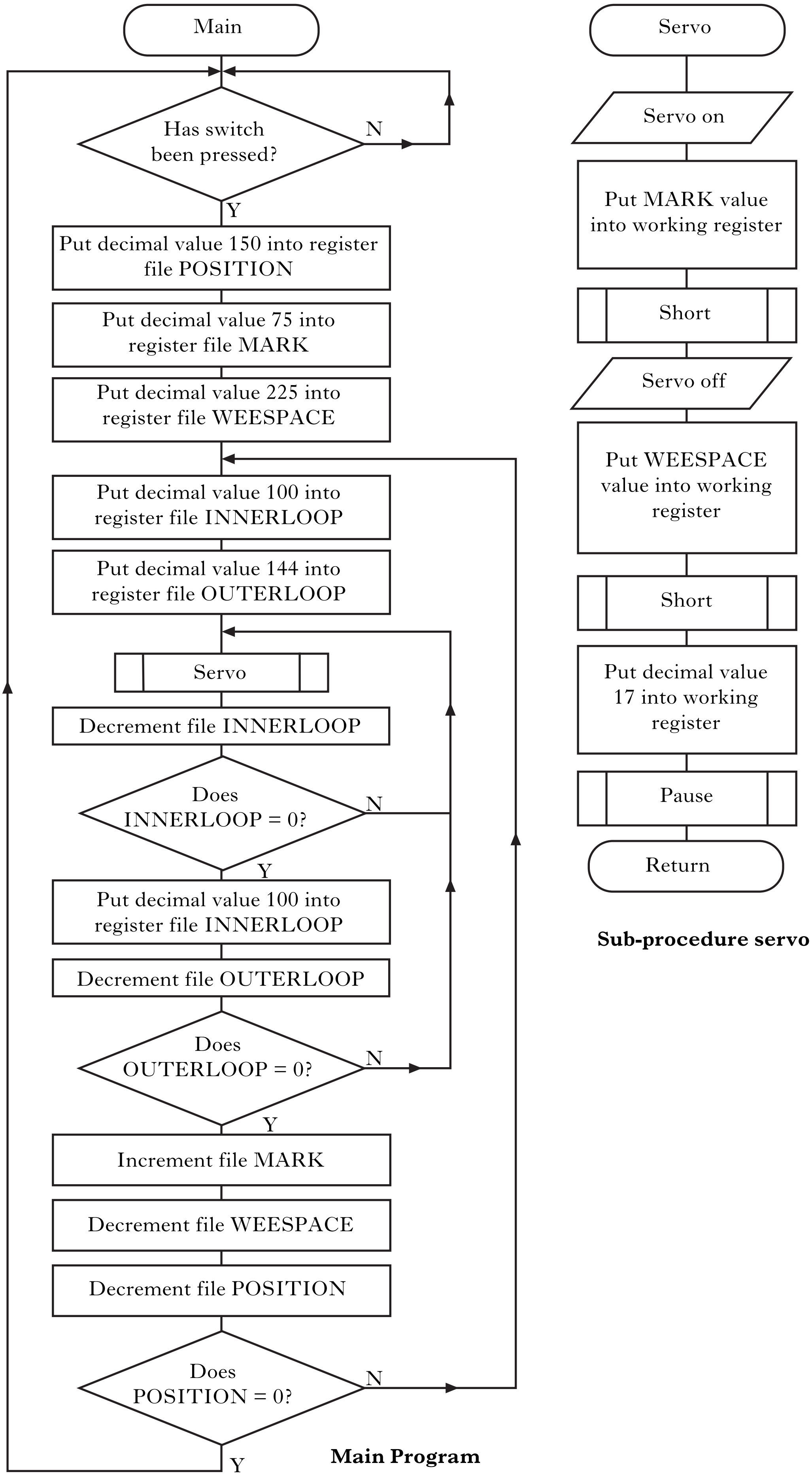

Figure Q2(*c*)

Marks

3. Polypropylene bag clips can be used to seal plastic bags for storage. One such clip is shown in Figure Q3(*a*).

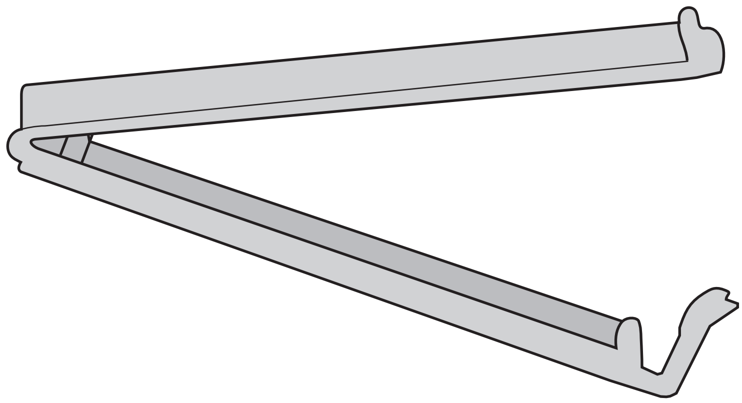

Figure Q3(*a*)

The upper half of the clip has the cross-sectional shape shown in Figure Q3(*b*).

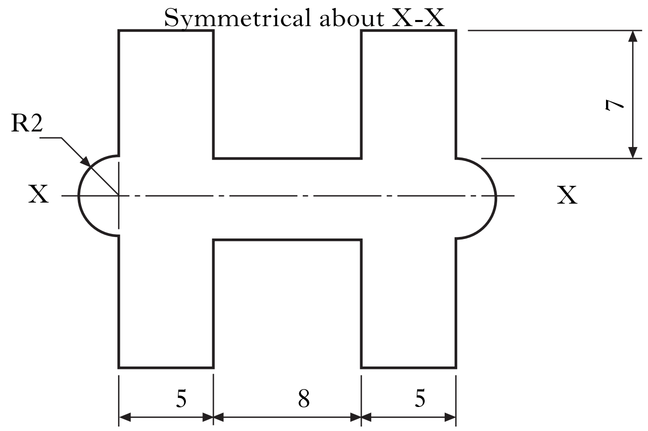

Figure Q3(*b*)

All dimensions are in mm.

(*a*) Calculate the second moment of area (I) of the cross-section about axis X-X. **3**

When clipped onto a bag, the upper half of the clip can be considered to be a beam with a uniformly distributed load.

A free-body diagram of the clip is shown on **Worksheet Q3**. All dimensions are in mm.

(*b*) On **Worksheet Q3,** draw:

(i) the Shear-Force Diagram; **2**

(ii) the Bending-Moment Diagram. **5**

Show all working and complete the table on **Worksheet Q3**. **(10)**

Marks

4. In a stock-control system a sensor detects when an item is removed from stock. The total number of items currently available is displayed on a visual display.

The system is based on a 4-bit counter constructed from J-K bistables, and a 7-segment display.

The counter is set to 9 when the stock is replenished. The counter is then decremented each time an item is removed from stock. When the count reaches 3 a "re-order" signal is sent to the stock control computer. When the count is zero, a red "stock empty" sign illuminates.

(*a*) On **Worksheet Q4** complete the circuit diagram for the counter-display system. **6**

The maximum stock level is to be increased to 14.

(*b*) Describe the modifications required to the counter-display system, in order to implement this new stock level. **1**

(7)

5. A technology student constructed a shift-register to transfer data, using bistables. The incoming data-stream was input into the register at 9600 bits per second. The data was to be transferred out at 1200 bits per second. To achieve this, the student used a frequency divider constructed from positive-edge triggered D-type bistables and an 8-bit 'serial-in parallel-out' (SIPO) shift-register, also constructed from D-type bistables.

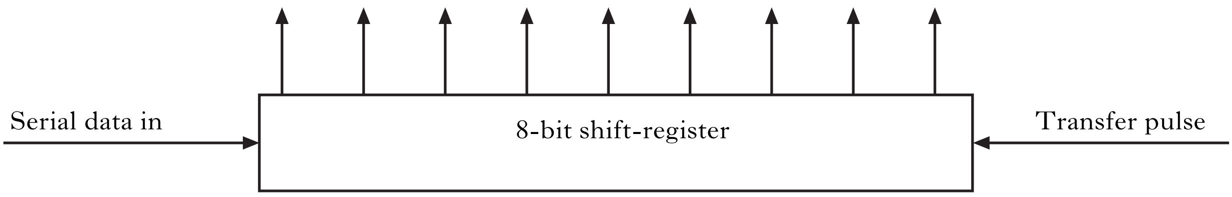

Figure Q5(*a*)

The shift-register represented by Figure Q5(a) is a 'serial-in parallel-out' (SIPO) shift register.

(*a*) (i) State the names of three other types of shift-register.

(ii) Describe the basic function of a shift-register. **2**

When an 8-bit byte of data has been moved into the register serially, a transfer pulse is required to output the byte in parallel form.

(*b*) Using positive-edge triggered D-type bistables:

(i) design a frequency divider with an input frequency of 9600 Hz and an output frequency of 1200 Hz; **3**

(ii) draw the first 4 bits of an 8-bit SIPO shift-register. **3**

(8)

[Turn over

Marks

6. An infusion pump delivers liquid medication to a hospital patient. A microcontroller maintains a constant flow-rate of the medication over a period of time. An engineer investigating the control-system function obtained the following listing of **part** of the microcontroller program.

The actual flow is measured by a sensor connected to an ADC. The decimal value 128 represents the correct flow-rate. If the ADC value is greater than 128 the flow is decreased, if the ADC value is less than 128 the flow is increased.

```
init:      movlw   d'128'         Section A
           movwf   DESIRED

main:      call    adcread
           subwf   DESIRED, W
           btfss   STATUS,C       Section B
           goto    decrease

increase:  movwf   ERROR
           movlw   d'0'
           xorwf   ERROR,W
           btfsc   STATUS,Z
           goto    main
           rlf     ERROR,F
           bsf     PORTB,5        Section C
           movfw   ERROR
           call    pause
           bcf     PORTB,5
           goto    main

decrease:  movwf   ERROR
           comf    ERROR,F
           incf    ERROR,F
           rlf     ERROR,F
           bsf     PORTB,4        Section D
           movfw   ERROR
           call    pause
           bcf     PORTB,4
           goto    main
```

The sub-procedure "adcread" reads the value from the ADC and saves it into the working register W. The sub-procedure "pause" creates a time delay of 1ms multiplied by the value in the working register when the sub-procedure is called.

When pin 5 goes high the motorised valve increases the flow. When pin 4 goes high the motorised valve decreases the flow. When both pins are low the valve is locked in position providing a steady flow.

(*a*) State the purpose of the following registers: STATUS, DESIRED and ERROR. **2**

(*b*) Describe the function of each of the sections of assembler code program listed above:

(i) Section A; **1**

(ii) Section B; **3**

(iii) Section C; **3**

(iv) Section D. **3**

(12)

[END OF SECTION A]

SECTION B

Attempt any TWO questions in this Section.

Each question is worth 20 marks.

7. The free-body diagram of a scale-model prototype frame-bridge is shown in Figure Q7(*a*).

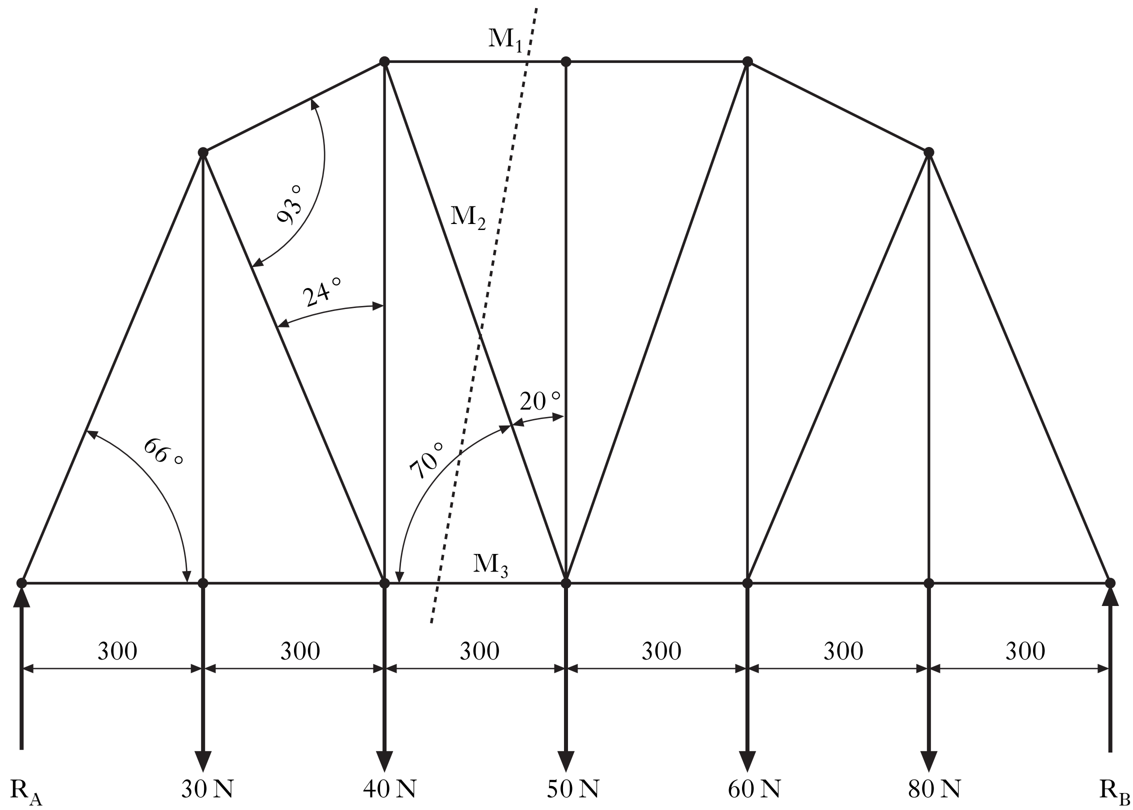

Figure Q7(*a*)

All dimensions in mm.

The model bridge is load-tested and strain-gauges used to verify the theoretical internal forces in the pin-jointed frame members.

(*a*) For the loads shown in Figure Q7(*a*), calculate the reaction forces R_A and R_B. **2**

(*b*) Using the **method of sections**, calculate the magnitude and nature of the forces in members M_1, M_2 and M_3. (Hint: use left-hand section) **10**

An incomplete circuit diagram of the electronic strain-gauge monitoring system is shown in **Worksheet Q7**.

The analogue signals from the strain-gauges are amplified and converted to digital signals for subsequent data-logging by a microcontroller.

(*c*) On **Worksheet Q7** design a 3-bit ADC with a reference voltage of 5V.

Use the library of components shown on **Information Sheet Q7**. Show all calculations and component values. **8**

(20)

[Turn over

Marks

8. An electric window in a car is controlled by an "up" switch and a "down" switch as shown in Figure Q8(*a*).

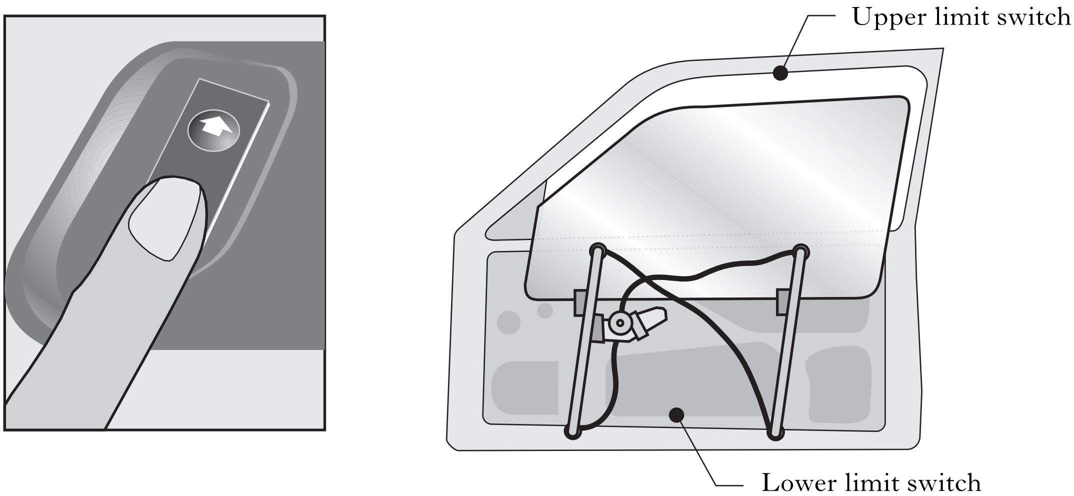

Figure Q8(*a*)

An electronic circuit to control the operation of the window is shown on **Information sheet Q8**.

The window-control system can operate in three modes.

Mode 1 – With each short press of the "down" switch, the electric motor lowers the window for as long as the switch is pressed, until the lower limit switch is actuated.

Mode 2 – If the "down" switch is pressed for a certain minimum time, the electric motor 'latches on', lowering the window automatically until it actuates the lower limit-switch.

Mode 3 – If the "up" switch is pressed, the electric motor raises the window until the switch is released, or until the upper limit switch is actuated.

Sub-system A is an integrator circuit.

(*a*) Calculate the minimum time the "down" switch has to be pressed in order for the electric motor to 'latch on' in mode 2. **3**

Marks

8. (continued)

Sub-system D is an S-R bistable.

(*b*) Draw a circuit diagram showing an S-R bistable constructed from NOR gates. **2**

(*c*) In terms of the sub-systems shown on **Information Sheet Q8,** explain in detail how the electronic circuit achieves modes 1 and 2. **5**

It is decided to replace the electronic circuit with a microcontroller-based system. A diagram of the system is shown in Figure Q8(*c*).

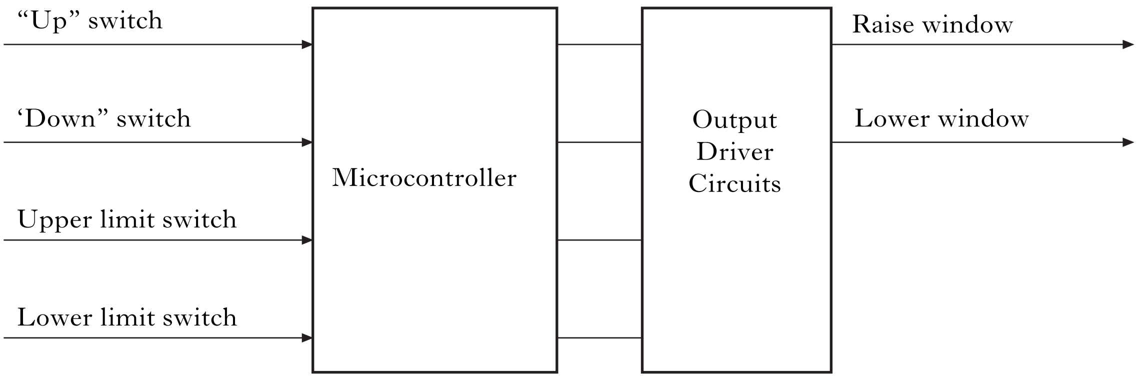

Figure Q8(*c*)

The microcontroller system operates in the **same way** as the electronic system. For mode 2 operation, the status of the "down" switch is checked in a loop every 10 ms in order that latching can take place after 1·5 seconds.

(*d*) Draw a flowchart that would represent the control of the window in modes 1, 2 and 3, as described above. Assume that the window is closed at the start. **10**

(20)

[Turn over

Marks

9. A microcontroller controls a car-park barrier and associated display system. The system consists of a ticket-dispenser machine, an exit-ticket machine, two barriers, a car-park "full" sign and a "spaces" sign, as shown in Figure Q9(a).

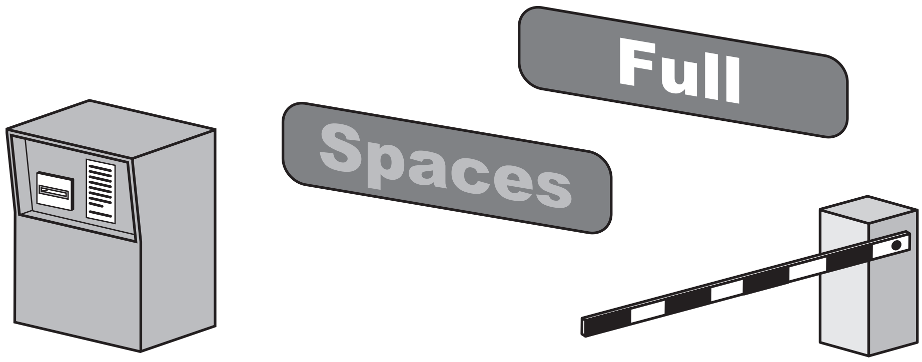

Figure Q9(*a*)

The microcontroller pin connections are shown in the table below.

Input	PORT B	Output
	7	Entry barrier solenoid valve (0 = closed; 1 = open)
	6	"Full" sign
	5	Ticket dispenser
	4	"Spaces" sign
	3	Exit barrier solenoid valve (0 = closed; 1 = open)
Ticket-dispenser button	2	
	1	
Valid-ticket sensor	0	

When a button is pressed on the ticket-dispenser machine, a ticket is dispensed, the entry barrier opens for 10 seconds and then closes. The exit-ticket machine opens the exit barrier for 12 seconds when a valid ticket is sensed.

The running total of vehicles in the car park is monitored and stored. This total starts at zero and is incremented each time a ticket is dispensed. It is decremented each time a valid ticket is sensed at the exit. If the number of vehicles in the car park is less than 100 the "spaces" sign is illuminated. If the number of vehicles is 100 the "spaces" sign goes off, the "full" sign is illuminated and no further tickets are dispensed until the total is less than 100.

(*a*) Write an assembler code program for the sequence described. Use a flowchart or other suitable method to plan your program. **12**

You may assume a pre-written sub-procedure called "wait" that causes a delay of 0·1 seconds multiplied by the number already in the working register. A file-register called COUNTER is already defined and TRISB has been initialized.

9. (continued)

The entry barrier is shown in Figure Q9(*b*). The bar is a 60 mm by 40 mm rectangular hollow box-section with a wall thickness of 3·2 mm.

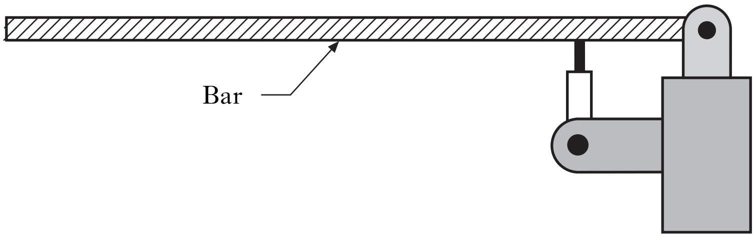

Figure Q9(*b*)

The bar has a uniformly-distributed load of 25 N/m due to its own weight and is supported as shown in Figure Q9(*c*).

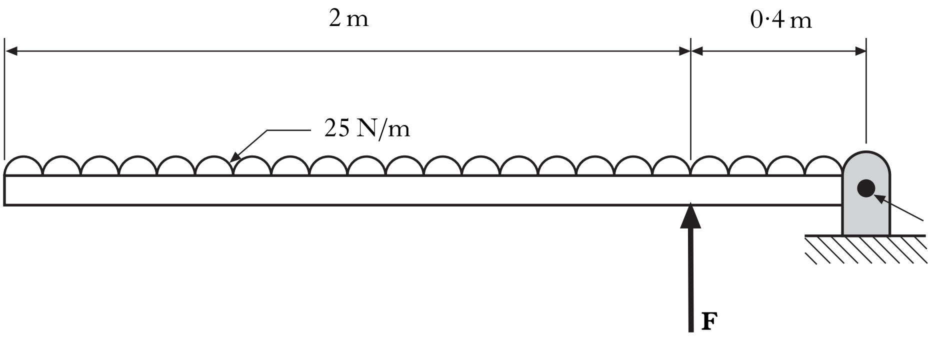

Figure Q9(*c*)

For the loading condition shown in Figure Q9(*c*):

(*b*) calculate the force F exerted by the cylinder and the reaction at the hinge; **2**

(*c*) (i) sketch the shear-force diagram; **2**

(ii) determine the distance of the maximum bending moment from the left-hand end of the beam; **1**

(iii) determine the magnitude of the maximum bending moment. **1**

(*d*) Calculate the maximum bending stress in the bar. **2**

(20)

[END OF SECTION B]

[*END OF QUESTION PAPER*]

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