X036/13/01

NATIONAL QUALIFICATIONS 2012

FRIDAY, 18 MAY
1.00 PM – 4.00 PM

TECHNOLOGICAL STUDIES
ADVANCED HIGHER

200 marks are allocated to this paper.

Answer **all** questions in Section A (120 marks).

Answer **two** questions from Section B (40 marks each).

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

You should plan assembler code programs using a flowchart or other suitable method.

Reference should be made to the Advanced Higher Data Booklet (2008 edition) which is provided.

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©

Marks

SECTION A

Attempt ALL the questions in this Section. (Total 120 marks)

1. The frying pan shown in Figure Q1(*a*) has a temperature indicator which displays a range of values between 0 and 9, representing temperatures from "cold" to "very hot".

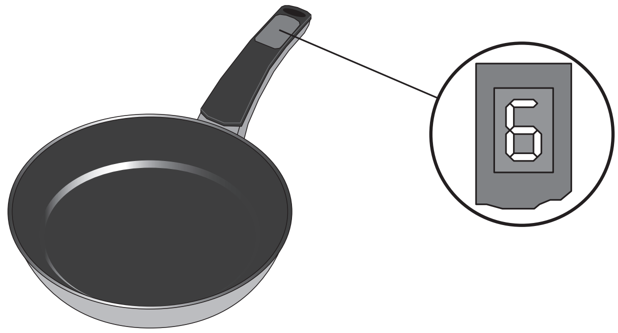


Figure Q1(*a*)

The system uses an analogue-to-digital converter (ADC), as shown in Figure Q1(*b*).

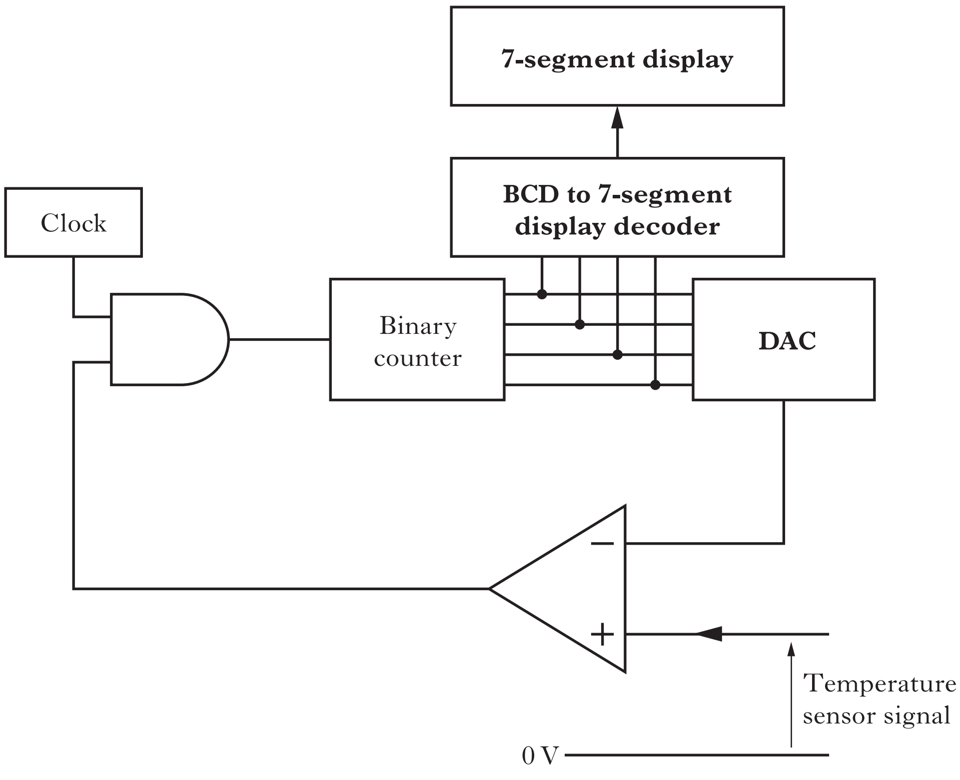


Figure Q1(*b*)

(*a*) Explain the operation of the ADC system shown in Figure Q1(*b*). **7**

The digital-to-analogue converter (DAC) sub-system shown in Figure Q1(*b*) is a 4-bit device which has a maximum output voltage of 6 V and a feedback resistor (R_f) of 47 kΩ. The DAC input voltages are 0 V or 5 V.

(*b*) Design an appropriate 4-bit DAC, showing all component values. **8**

(15)

Marks

2. A kayaker uses the type of paddle shown in Figure Q2(*a*).

Figure Q2(*a*)

The shaft is a hollow circular section, as shown in Figure Q2(*b*).

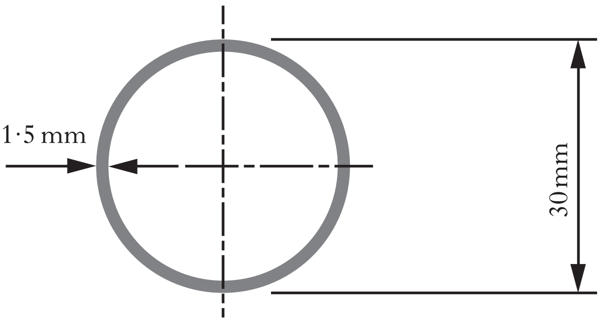


Figure Q2(*b*)

(*a*) Calculate the Second Moment of Area for this cross-section. **4**

For testing purposes, the shaft is considered to be a simply-supported beam with a central point load, as shown in Figure Q2(*c*).

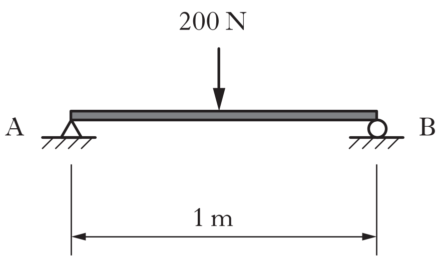


Figure Q2(*c*)

(*b*) Calculate the maximum stress due to bending. **5**

The shaft material is a composite with a Modulus of Elasticity of 150 kN/mm^2.

(*c*) Calculate the maximum deflection of the shaft. **3**

(12)

[Turn over

Marks

3. A development team are writing documentation for the interface shown in Figure Q3 which allows an on-board flash-memory microcontroller to be programmed by a PIC programmer.

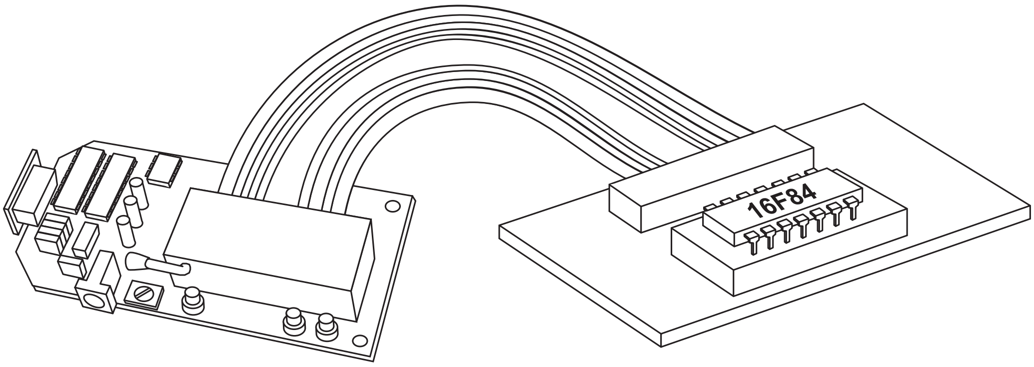


Figure Q3

A "help" document is required, containing a step-by-step guide to developing a PIC assembler program and uploading to the microcontroller, using standard hardware and software.

Describe the required steps, identifying any software or hardware used. **8**

(8)

Marks

4. The washing machine shown in Figure Q4 is controlled by a sequential-control system.

Figure Q4

The truth table for the sequential control of the washing machine is shown below.

Clock pulse	Water valve (V)	Drum motor (D)	Water heater (H)	Pump motor (P)
0	1	0	0	0
1	0	1	0	0
2	0	1	0	0
3	0	1	1	0
4	0	1	1	0
5	0	1	1	0
6	0	1	0	0
7	0	1	0	0
8	0	1	0	1
9	0	1	0	1
reset				

(*a*) Write the Boolean expression for the water heater, (H). **2**

(*b*) Complete, on **Worksheet Q4**, the reset function for the counter, and the logic array for outputs D, H, and P. **6**

(*c*) Explain the operation of the sequential-control system shown on **Worksheet Q4**, in terms of sub-systems A, B, C and D. **8**

(16)

Marks

5. One of the most common causes of vehicle accidents is the driver dozing at the wheel. A microcontroller-based sleep sensor, as shown in Figure Q5, fits over a driver's ear, and monitors the head angle. If the head angle changes, indicating that the driver may be starting to fall asleep, an alarm tone sounds.

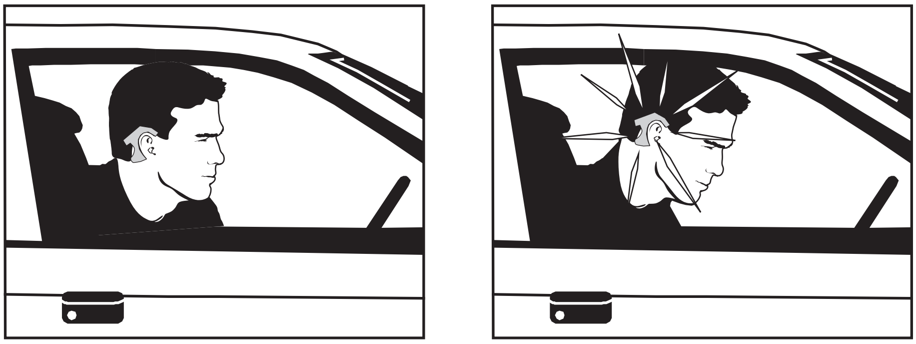


Figure Q5

Before use, the "natural head angle" is stored by a sub-procedure *calibrate*, which is called from the main program. The procedure sequence is as follows:

A sub-procedure *adcread* is called which saves the head-angle value in the register file DATA. The contents of DATA are then moved to the register file ANGLE. The value in ANGLE is doubled, 15 is subtracted, and the final value is retained in ANGLE. A buzzer beeps for half a second to indicate that calibration is complete.

The relevant input/output connections are shown in the table below.

Inputs	PORT B pins	Outputs
	7	buzzer
Calibrate switch	1	

(*a*) Write, in assembler code, the sub-procedure *calibrate*. **8**

Note: The sub-procedure *wait* creates a delay of 100 ms multiplied by the value in the Working Register W before the procedure is called. The register files ANGLE and DATA have been set up.

The main program sequence, which detects a dangerous head angle, is as follows:

The calibrate switch is checked in a loop every 100 ms for up to 5 s; if the switch is pressed within this time, then the sub-procedure *calibrate* is called and the switch is no longer checked.

The head angle is then checked by calling the sub-procedure *adcread*, which saves the head-angle value in the register file DATA.

- If the value in DATA is greater than the value in ANGLE then a buzzer is switched on for 50 ms and off for 250 ms; the head-angle value is then checked again.
- If the values in DATA and ANGLE are equal, the head-angle value is checked again.
- If the value in DATA is less than the value in ANGLE, indicating that the driver is awake, then the program repeats from the start.

(*b*) Write, in assembler code, a program to carry out the sequence described above. **18**

(26)

Note: The sub-procedure *pause* creates a delay of 1 ms multiplied by the value in the Working Register, W, before the procedure is called. The register files COUNTER, ANGLE and DATA have been set up. TRISB has been initialised.

6. The timing display for a ski-slalom race competition is shown in Figure Q6(*a*).

Figure Q6(*a*)

The counting circuit for the timing system is constructed from bistables.

(*a*) Draw a circuit diagram for a 4-bit up-counter, constructed from positive-edge D-type bistables. **3**

When a competitor misses a slalom gate, a penalty switch is pressed. This increases by 3 seconds the penalty count on the display shown in Figure Q6(*b*).

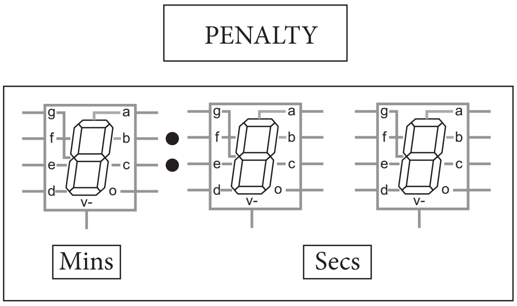
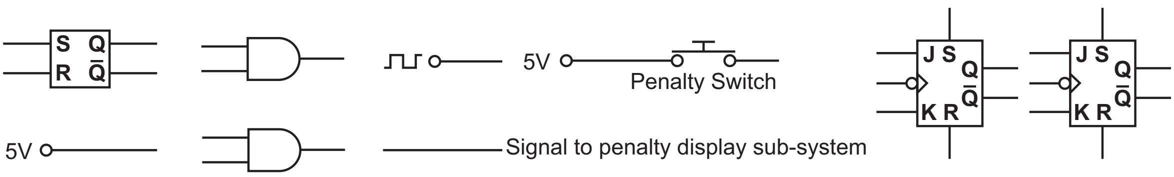


Figure Q6(*b*)

The penalty-switch signal is debounced using an SR-bistable.

When the penalty switch is pressed, the SR-bistable is set, pulses are sent to the penalty display and a 2-bit counter is clocked. After three pulses the SR-bistable and the 2-bit counter are reset.

(*b*) Draw a circuit diagram for the penalty system, using the components shown below. **9**



An SR-bistable may be constructed using NOR gates.

(*c*) Draw an SR-bistable constructed from NOR gates. Label the inputs and outputs. **3**

(15)

[Turn over

7. A schematic diagram representing a hydro-electric power scheme is shown in Figure Q7(*a*).

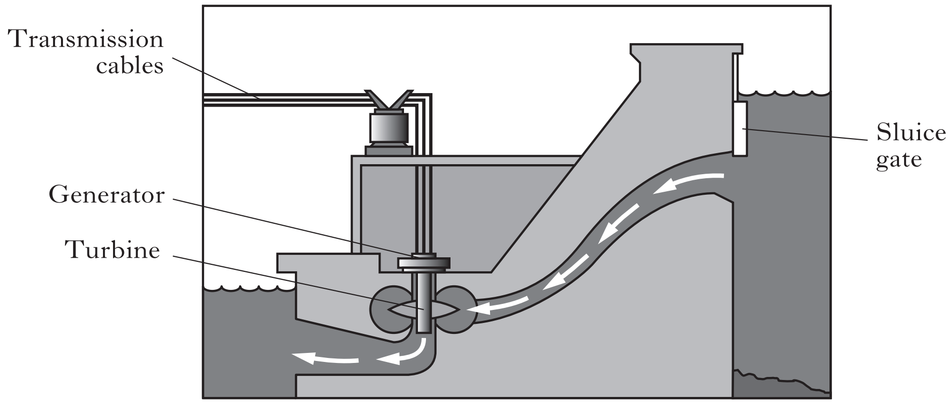


Figure Q7(*a*)

The flow of water into the turbine is controlled in order to regulate the speed of the turbine. This is achieved by a motor-driven sluice gate controlled by a microcontroller. A simplified system-diagram for this is shown in Figure Q7(*b*).

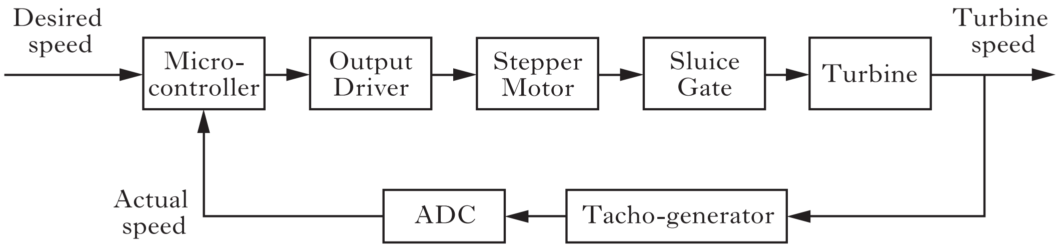


Figure Q7(*b*)

The microcontroller control program is split into three functions:

Main program: A pre-written sub-procedure *adcread* is called which stores the actual tacho-generator speed in a register file called DATA. DATA is subtracted from the desired speed of 128 and saved in a register file called ERROR.

If ERROR is zero then no output action is required. If ERROR is positive, a sub-procedure *sluiceup* is called. If ERROR is negative, a sub-procedure *sluicedown* is called. The program repeats continuously.

Sluicedown: Rotates a stepper motor clockwise 4 steps, in a loop. The value held in ERROR determines the number of loops. The time delay between steps is 10 seconds.

Sluiceup: Corrects the corruption in ERROR and then rotates the stepper motor anti-clockwise.

Marks

7. (continued)

The PORTB pins for the clockwise sequence of the four-coil stepper motor are shown below.

Coil No	1	2	3	4
PORTB pin	7	6	5	4
Step 1	1	1	0	0
Step 2	0	1	1	0
Step 3	0	0	1	1
Step 4	1	0	0	1

(*a*) Write, in assembler code, the main program. **10**

(*b*) Write, in assembler code, the sub-procedure *sluiceup*. **6**

(16)

Note: The sub-procedure *wait* creates a delay of 100 ms multiplied by the value held in the Working Register, W, before the sub-procedure is called. The register files DATA and ERROR have been set up. TRISB has been initialised.

[Turn over

Marks

8. A structural engineer is investigating the maximum Bending Moment in the beam shown in Figure Q8(*a*).

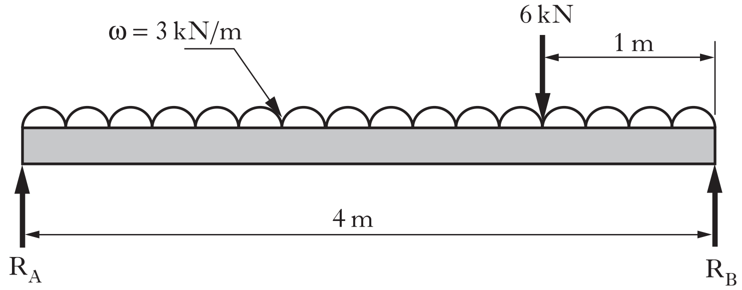


Figure Q8(*a*)

(*a*) Calculate the reaction at R_A. **3**

To calculate the position and value of the maximum Bending Moment, the engineer considers the section of beam shown in Figure Q8(*b*), between the limits of 0 m and 3 m, measured from the left-hand end.

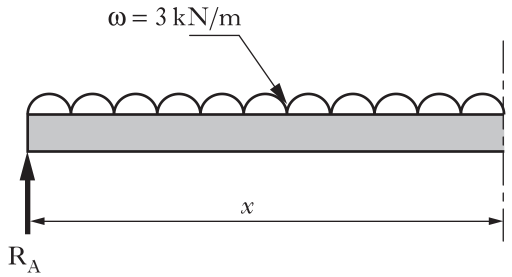


Figure Q8(*b*)

(*b*) Determine the **equation** for the Bending Moment in terms of variable x, $(0 \leq x \leq 3)$. Substitute all known values. **3**

(*c*) Using the equation developed in part (*b*), determine the distance, x, indicating the position of the maximum Bending Moment. Show all working. **3**

(*d*) Determine the value of the maximum Bending Moment. **3**

(12)

[*END OF SECTION A*]

SECTION B

Attempt any TWO questions in this Section.

Each question is worth 40 marks

9. The frequency of the electricity being generated by the wind turbines shown in Figure Q9(*a*) is monitored by an electronic system.

Figure Q9(*a*)

The wind turbines should generate an alternating current at a frequency of exactly 50 Hz. The actual frequency is compared with a 50 Hz sine wave produced by a test oscillator, and the result of the comparison displayed to an operator.

(*a*) State the name of a suitable oscillator circuit. **1**

The test oscillator uses a capacitor, C, of 4·7 μF, and a resistor, R.

(*b*) Calculate the required value of R. **3**

Information sheet Q9 shows the circuit diagram for the electronic monitoring system.

(*c*) Explain in detail the operation of this circuit, in terms of sub-systems A, B, C, and D. **7**

The switch-off threshold level of sub-system A, shown in Figure Q9(*b*), is 6 V.

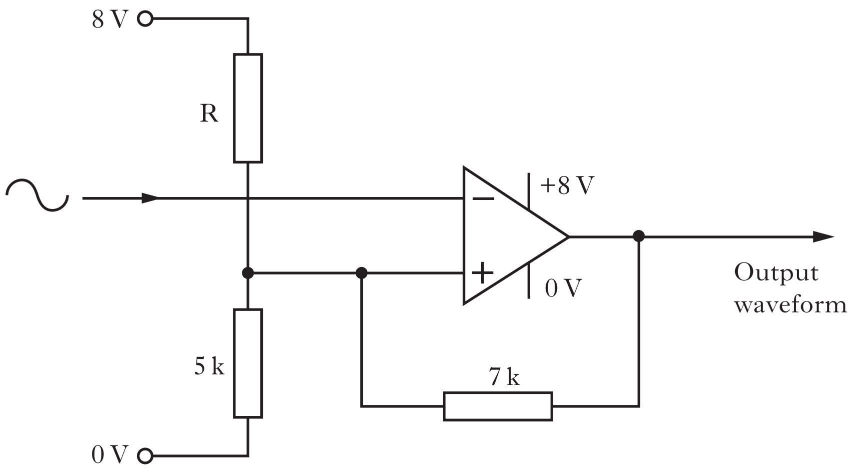


Figure Q9(*b*)

(*d*) (i) Sketch the output waveform. **1**

(ii) Calculate the value of resistor R. **5**

(iii) Calculate the switch-on threshold voltage. **2**

9. (continued)

The system is redesigned using a microcontroller, to compare the output from sub-system A with the value 50, and to control the display. The control sequence is represented by the flowchart in Figure Q9(*c*). The register file EDGE is used to detect a rising edge in the output signal from sub-system A. Each time a rising edge is detected, the register file COUNT is incremented. When an external timer goes high the value in COUNT is compared with 50 and the appropriate output indicator is activated.

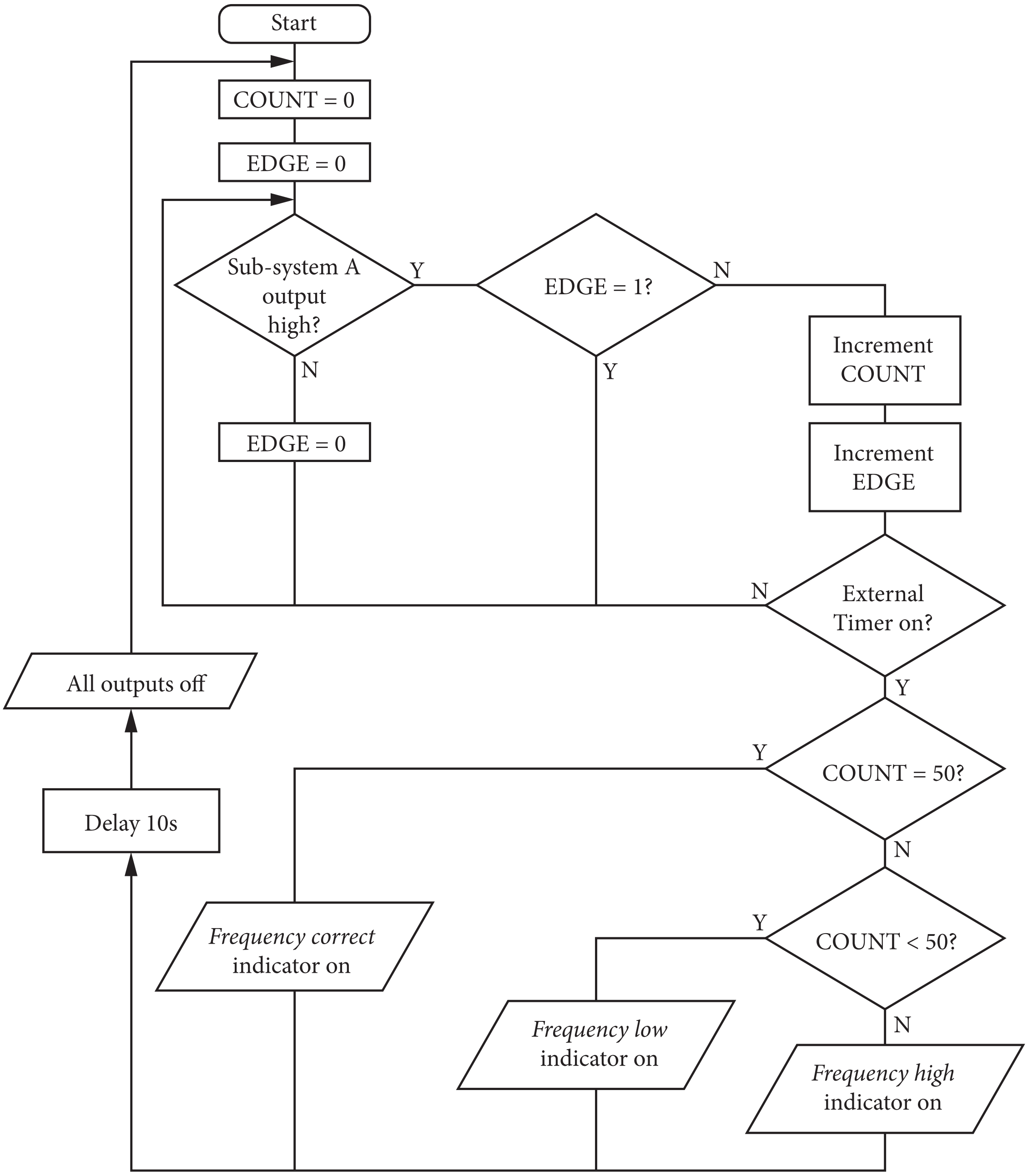


Figure Q9(*c*)

9. (continued) *Marks*

Inputs	PORT B pins	Outputs
	7	Frequency low indicator
	6	Frequency high indicator
	5	Frequency correct indicator
Signal from sub-system A	1	
External Timer	0	

(*e*) Write, in assembler code, the program represented by the flowchart. **21**

(40)

Note: The sub-procedure *wait* creates a delay of 100 ms multiplied by the value in the Working Register, W, before the procedure is called. The register files COUNT and EDGE have been set up. TRISB has been initialised.

[Turn over

10. The electric golf cart shown in Figure Q10(*a*) is controlled by a microcontroller. One of the trolley features is an adjustable distance control which allows the cart to be sent on a solo-run of 10 m or 20 m. *Marks*

Figure Q10(*a*)

The solo-run feature is initiated by pressing the solo-run button for a short time or a longer time. Sub-procedure *Mode1* sets the trolley moving for 12·6 seconds at one-third speed, and sub-procedure *Mode2* sets the trolley moving for 16·2 seconds at half speed.

The motor speed is controlled by pulse-width modulation (PWM), with a cycle time of 90 ms.

(*a*) Calculate the MARK and SPACE times and the required number of PWM cycles for the following modes of operation:

(i) one-third speed for 12·6 seconds (Mode 1); **2**

(ii) half speed for 16·2 seconds (Mode 2). **1**

The program operates as follows:

The register file SOLO is cleared. In a loop, the solo-run button is checked and if it has been pressed, SOLO is incremented. After 200 ms the solo-run button is checked again, and if it is still pressed, SOLO is incremented again. If SOLO is equal to zero the loop is repeated.

If SOLO is equal to 1 then call *Mode1*. If SOLO is equal to 2 then call *Mode2*. The program then restarts from the beginning.

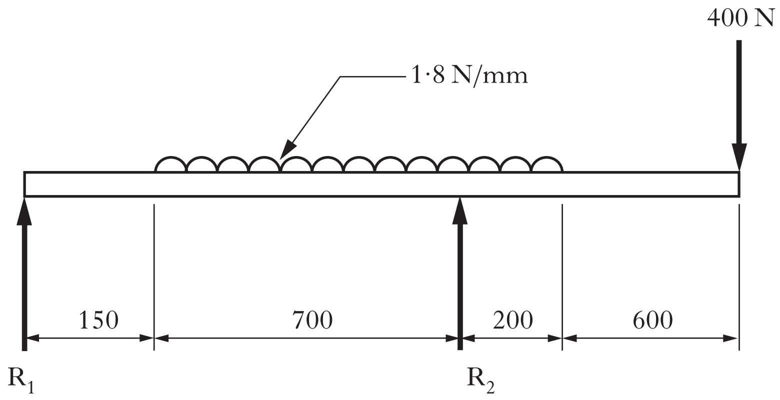
The "solo-run" button is connected to PORT B, pin 0 and the motor to PORT B, pin 7.

(*b*) Write, in assembler code, the main program to carry out the function described above. **17**

Note: Sub-procedures *Mode1* and *Mode2* have been pre-written. The sub-procedure *pause* creates a delay of 1 ms multiplied by the value in the Working Register, W, before the procedure is called. The register files SOLO and COUNTER have been set up. TRISB has been initialised.

10. (continued) *Marks*

A simplified diagram of the loading on the main beam of the trolley structure is shown in Figure Q10(*b*).



All dimensions in mm

Figure Q10(*b*)

(*c*) Calculate reactions at R_1 and R_2. **4**

On **Worksheet Q10**:

(*d*) draw the Shear-Force diagram; **4**

(*e*) complete the Bending-Moment table and draw the Bending-Moment diagram.

Show all working. **12**

(40)

[Turn over

11. A Space Station is shown in the diagram in Figure Q11(a). *Marks*

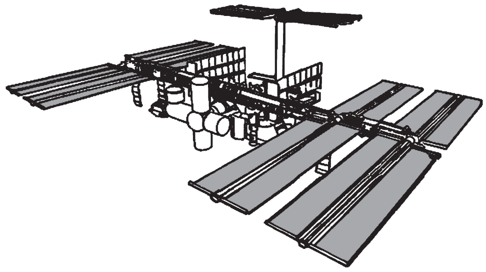


Figure Q11(*a*)

When the space station's propulsion rockets are fired, a device called an accelerometer produces an analogue voltage, V_1, proportional to the space station's acceleration. This voltage is processed by the two-stage integrator circuit shown in Figure Q11(*b*).

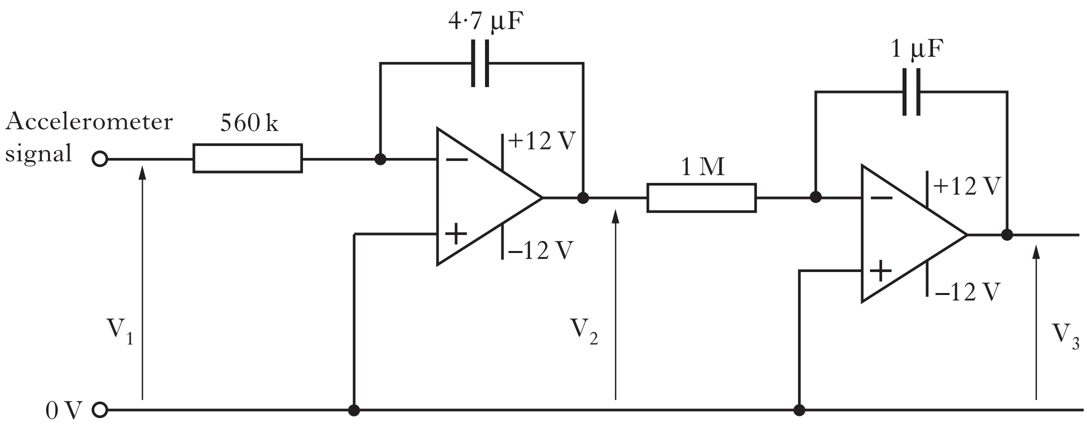


Figure Q11(*b*)

By integrating V_1 with respect to time, V_2 is determined, representing the velocity of the space station. A second integration determines V_3, representing the distance travelled.

Figure Q11(*c*) shows the graph of V_2 against time.

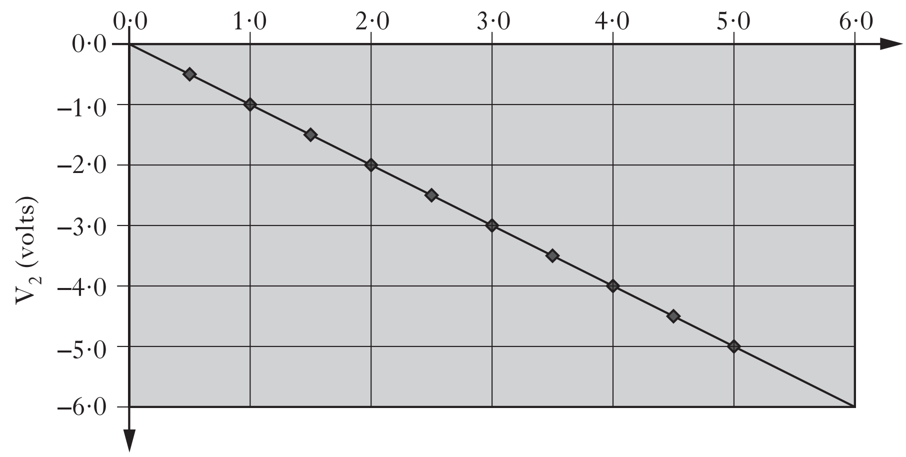


Figure Q11(*c*)

(*a*) Referring to Figure Q11(*b*) and Figure Q11(*c*):

(i) write the equation for V_2 in terms of time; **1**

(ii) write the equation for V_3 in its simplest form (substituting all known values); **5**

(iii) sketch the graph of V_3 with respect to time. Show all significant features and label the axes; **5**

(iv) calculate the value of V_1. **5**

11. (continued) *Marks*

The accelerometer's voltage, V_1, is also processed by the VCO circuit shown in Figure Q11(*d*).

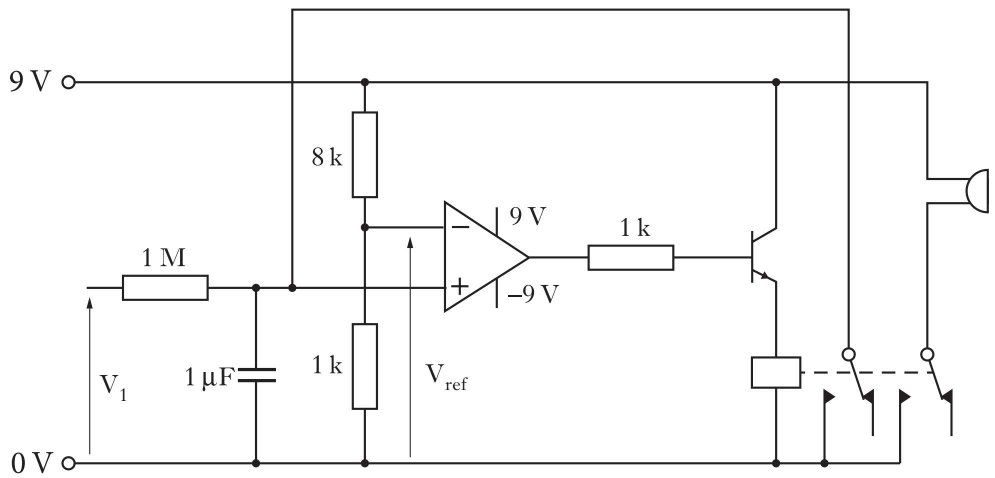


Figure Q11(*d*)

(*b*) Referring to Figure Q11(*d*):

(i) state the full name of the circuit; **1**

(ii) explain in detail the operation of the circuit. **7**

Figure Q11(*e*) shows part of the frame structure connecting the various space-station modules together.

When under acceleration, this part of the structure experiences the external loads shown.

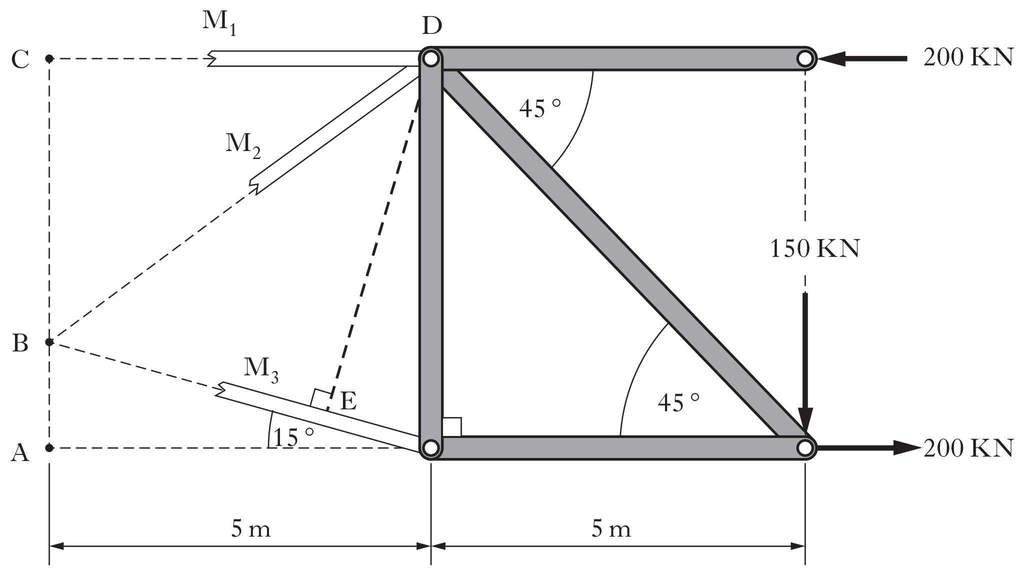


Figure Q11(*e*)

(*c*) Calculate the distances AB, BC, and DE. **3**

(*d*) Calculate, using the *method of sections*, the magnitude and nature of the forces in members M_1, M_2 and M_3. **13**

(40)

[*END OF QUESTION PAPER*]

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X036/13/11

NATIONAL QUALIFICATIONS 2012

FRIDAY, 18 MAY
1.00 PM – 4.00 PM

TECHNOLOGICAL STUDIES
ADVANCED HIGHER
Worksheets for Questions 4 and 10
Information Sheet for Q9

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Date of birth
Day Month Year

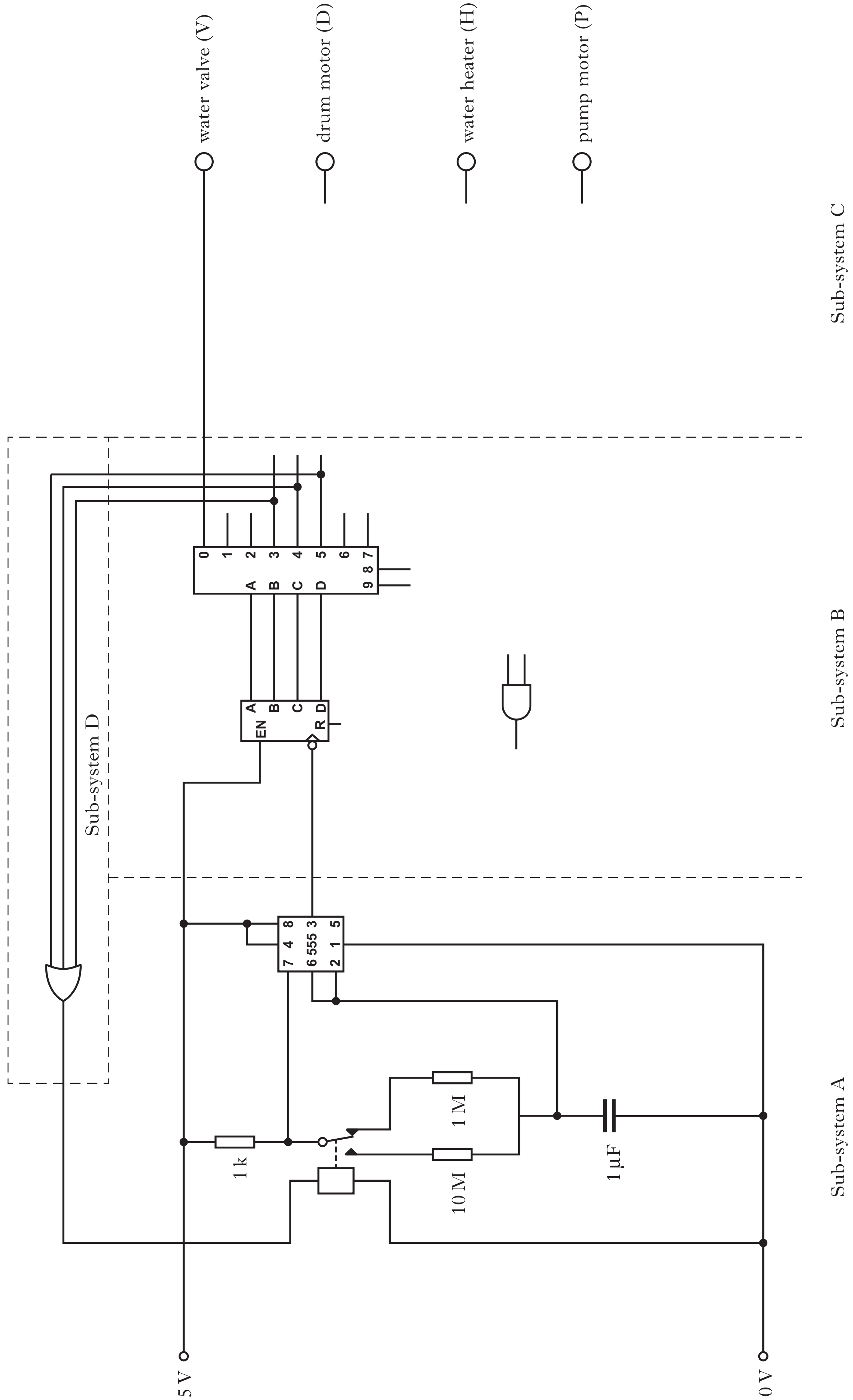
Scottish candidate number

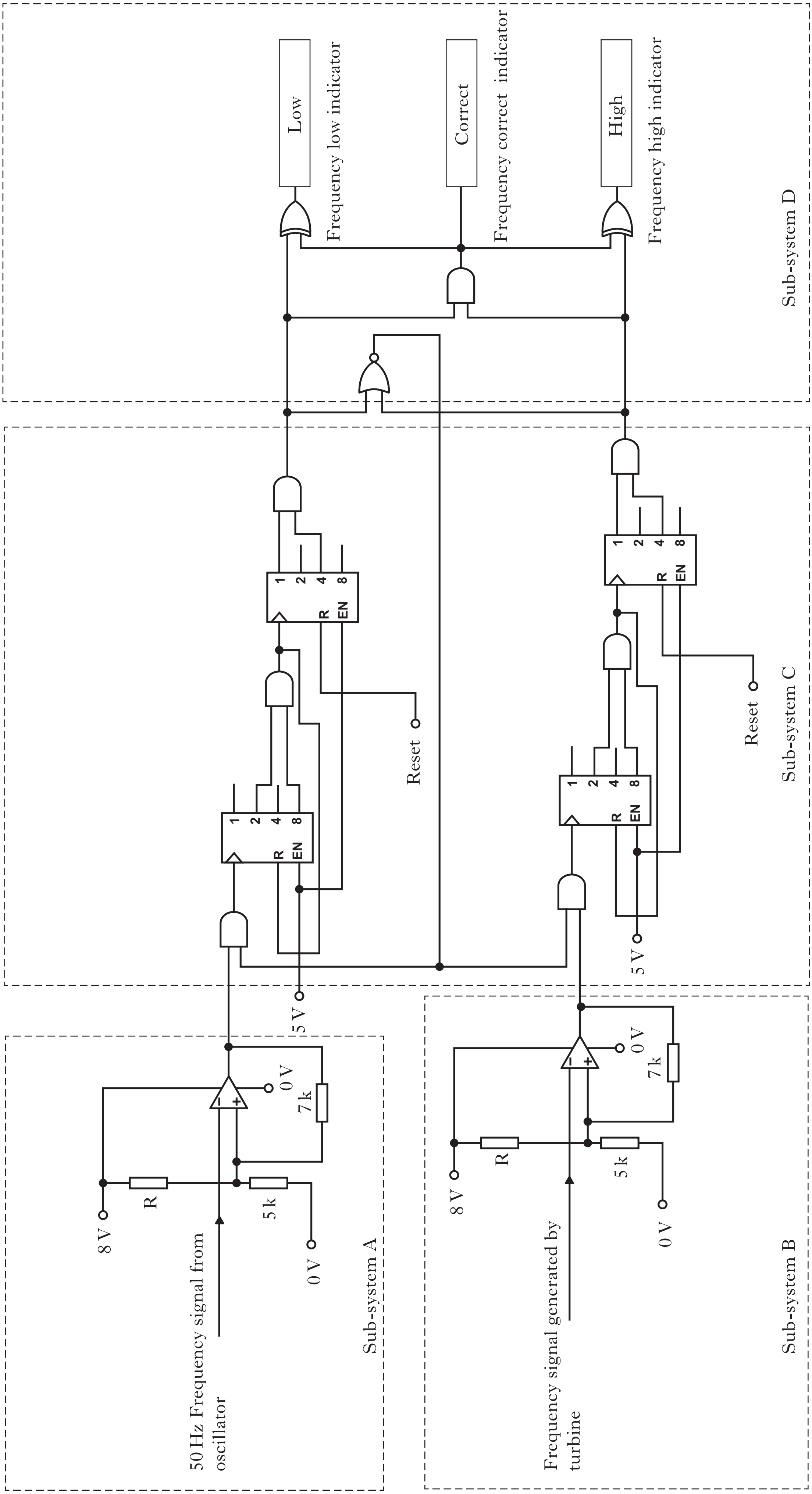
Number of seat

To be inserted inside the front cover of the candidate's answer booklet and returned with it.

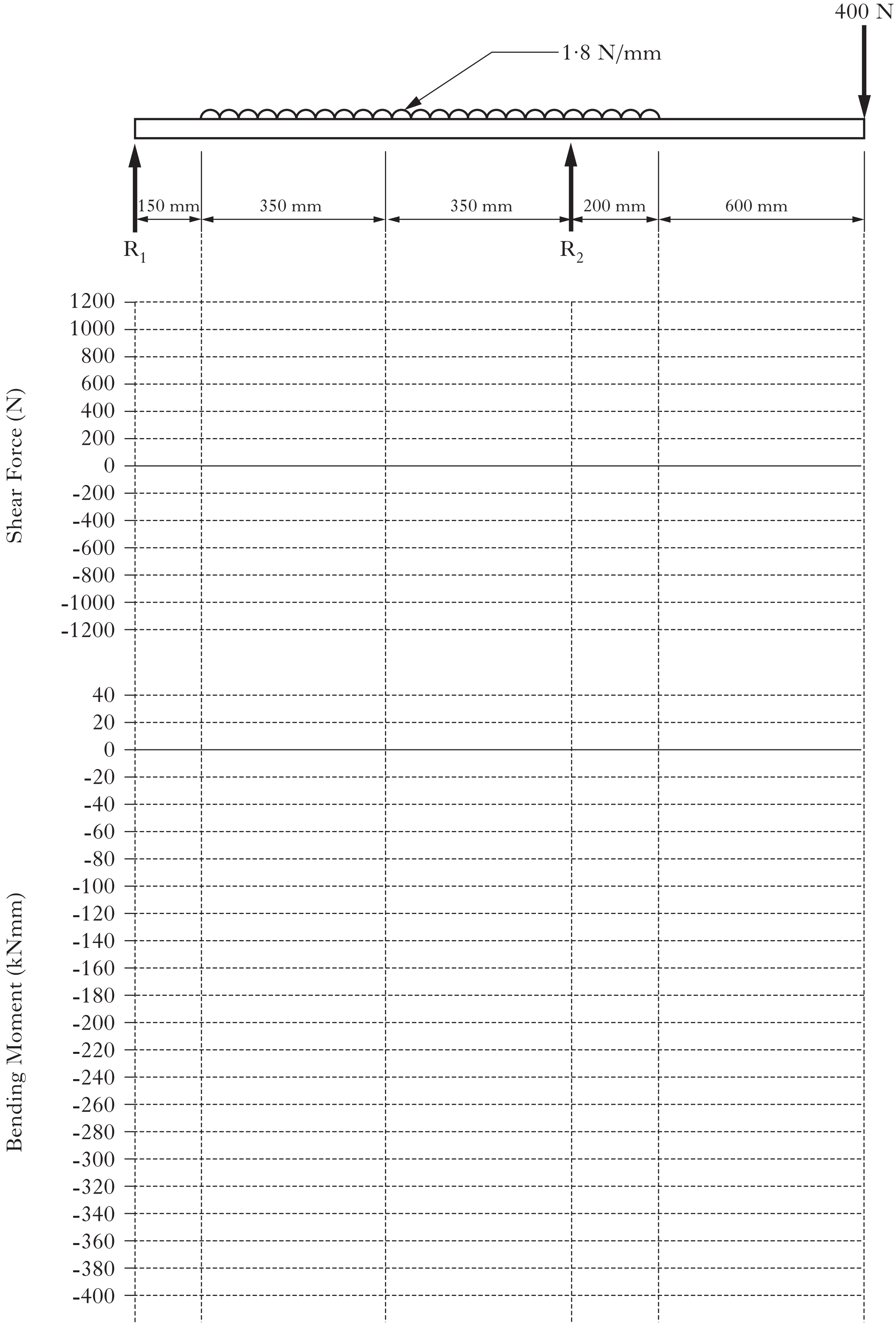
SQA ©

WORKSHEET Q4




Low
Frequency low indicator
Correct
Frequency correct indicator
High
Frequency high indicator
Sub-system D
1
2
4
8
R
EN
Reset
Sub-system C
5 V
8 V
R
5 k
0 V
7 k
50 Hz Frequency signal from oscillator
Sub-system A
Frequency signal generated by turbine
Sub-system B

WORKSHEET Q10



Distance from LHE (mm)	0	150	500	850	1050	1650
Bending Moment (kNmm)						

[*END OF WORKSHEETS*]