X036/701

NATIONAL QUALIFICATIONS 2009

MONDAY, 8 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 (2008 edition) which is provided.

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SECTION A

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

1. A pedometer is an electronic device that counts the number of steps a person walks, as shown in Figure Q1(*a*).

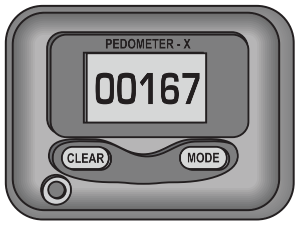

Figure Q1(*a*)

A system diagram for the pedometer is shown in Figure Q1(*b*).

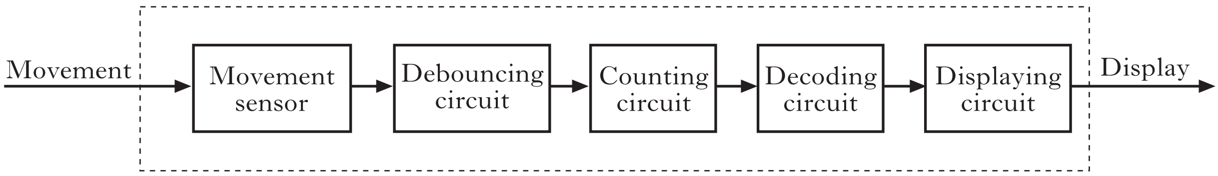

Figure Q1(*b*)

The counting-circuit sub-system can be modelled using a 4-bit counter.

Draw a 4-bit **up** counter constructed from:

(*a*) positive-edge triggered D-type bistables; **3**

(*b*) negative-edge triggered J-K bistables. **3**

(6)

2. A car audio-system manufacturer intends to develop a microcontroller-based user interface for the product shown in Figure Q2. It must accept both analogue and digital inputs and must be able to store some of the values. The setting and status of the interface are displayed on an LCD screen and a number of LEDs.

Figure Q2

A product developer is tasked with producing a specification for a microcontroller prototype.

(*a*) Identify **four** features that a suitable microcontroller must have for this application. **2**

The developer carries out four steps in producing an assembler code program for the prototype.

(*b*) Describe these steps, identifying any software or hardware used. **4**

(6)

Marks

3. An automatic dough-making machine is shown in Figure Q3.

Figure Q3

The machine is controlled sequentially by the two integrated circuits (ICs) shown on **Worksheet Q3**.

(*a*) (i) Explain the meaning of the term "sequential control". **1**

(ii) Describe the difference between "time-based" and "event-based" sequential control. **1**

(*b*) Describe the function of each of the ICs shown on **Worksheet Q3**. **2**

The required sequence of dough manufacture is shown in the table below.

	OUTPUTS				
Clock pulse	Flour	Salt	Water	Mixer	Auger
0	1	1	0	1	0
1	1	0	0	1	0
2	1	0	0	1	0
3	0	0	1	1	0
4	0	0	1	1	0
5	0	0	0	1	0
6	0	0	0	1	0
7	0	0	0	1	0
8	0	0	1	1	0
9	0	0	1	1	0
10	0	0	0	1	0
11	0	0	0	1	0
12	0	0	0	1	0
13	0	0	0	0	1
14	RESET				

(*c*) On **Worksheet Q3**, complete the wiring diagram and design a logic array that will produce dough in the required sequence. The sequence should begin when the "start" switch is pressed. **5**

(9)

4. A vending machine for dispensing hot drinks is shown in Figure Q4(*a*).

Figure Q4(*a*)

The vending machine is controlled by a microcontroller. The PORTB pin connections for coffee selection are shown in the table below.

	INPUTS	OUTPUTS	
"Carousel installed" switch	0	4	Buzzer
	1	5	Refill warning lamp
"Coffee select" switch	2	6	Carousel motor
	3	7	Hot water valve

The "coffee select" switch signal is debounced by the microcontroller, using a sub-procedure *debounce*. The flowchart for *debounce* is shown in Figure Q4(*b*).

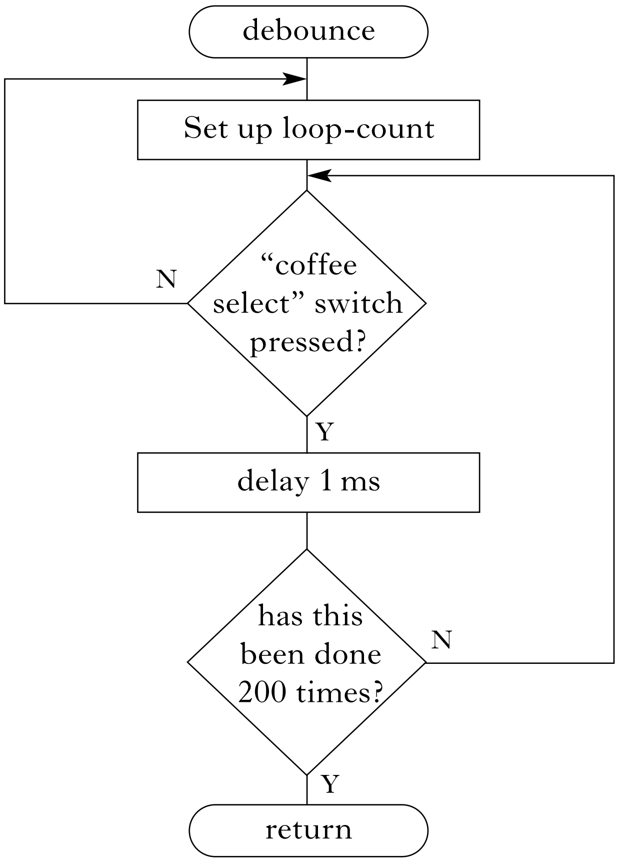

Figure Q4(*b*)

4. (continued)

(*a*) Write the assembler code program for the sub-procedure *debounce*.

TRISB has been initialised and register file LOOPCOUNT has been defined. The pre-written time-delay sub-procedure *pause* produces a time delay of 1 millisecond multiplied by the value held in the Working Register, W. **3**

The vending machine operates according to the following sequence:

An operator installs a new carousel containing 100 prepared cups into the machine and presses the "carousel installed" switch. The refill warning lamp is extinguished and the machine is then ready to dispense coffee.

When the "coffee select" switch is pressed, its signal is debounced by calling the sub-procedure *debounce*. The buzzer sounds for 0·5 seconds to acknowledge a successful selection. The carousel motor runs for 1·5 seconds to dispense a cup. The hot water valve is turned on for 10 seconds. The total number of cups dispensed is counted. When the count reaches 100, the refill warning lamp is illuminated and the machine stops dispensing until a new carousel is installed.

(*b*) Write, in assembler code, the main program that will control the vending machine as described above.

TRISB has been initialised, register file CUPCOUNT has been defined and *debounce* is prewritten. The sub-procedure *wait* produces a time delay of 0·1 seconds multiplied by the value held in the Working Register, W. **7**

(10)

[Turn over

Marks

5. An electronics engineer investigating an oscillator circuit discovers that the output has the waveform shown in Figure Q5.

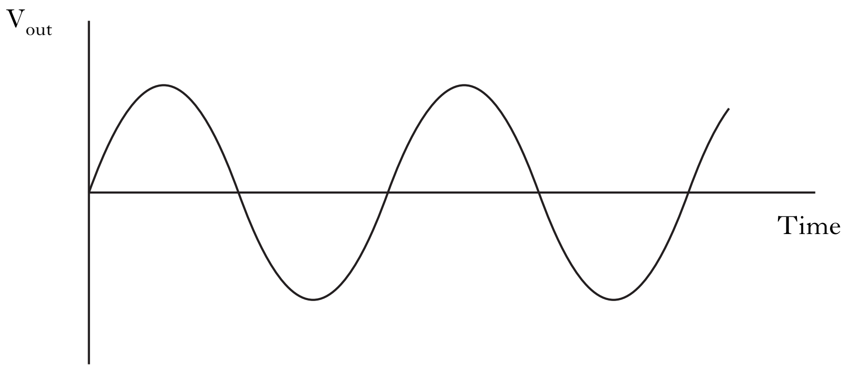

Figure Q5

(*a*) State the name of an oscillator circuit that would produce this waveform. **1**

The engineer feeds the waveform into a Schmitt trigger to provide a clock signal for a digital circuit.

(*b*) Explain why a Schmitt trigger would be suitable for this purpose. **1**

The output of the Schmitt trigger goes low when the input voltage rises to 5 V. The value of the resistor connected between 0 V and the non-inverting input is 5 kΩ and the feedback resistor is 9 kΩ. The op-amp supply rails are 9 V and 0 V.

(*c*) (i) Sketch the complete circuit. **2**

(ii) Calculate the value of the unknown resistor required to achieve the operation described. **5**

(*d*) State the names of two other oscillator circuits that would produce a digital waveform. **1**

(10)

6. The forces acting in the farm gate shown in Figure Q6(*a*) are to be analysed by the *method of sections*.

Figure Q6(*a*)

A force diagram for the gate is shown in Figure Q6(*b*).

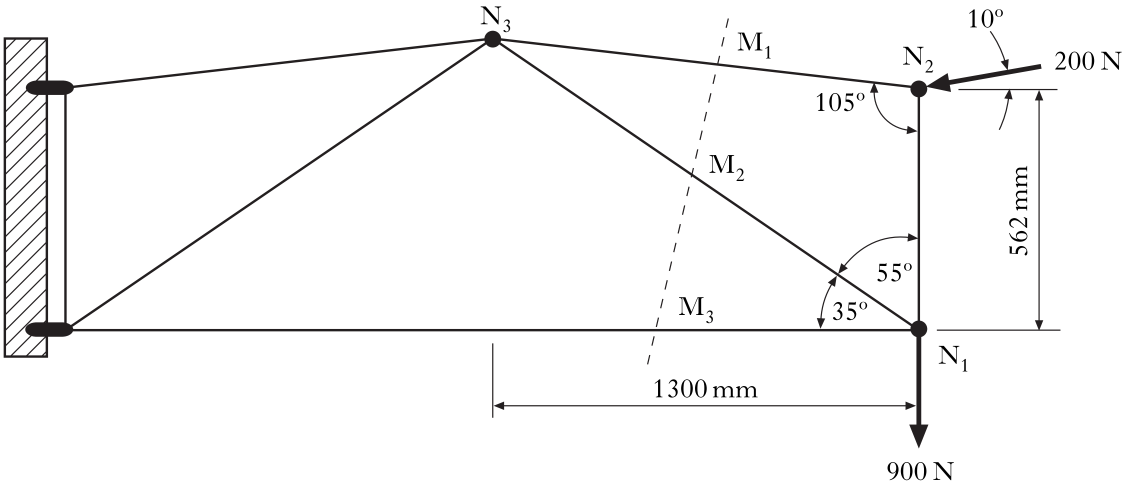

Figure Q6(*b*)

(*a*) For the *method of sections*:

(i) explain why the members must be considered to be pin-jointed; **1**

(ii) state the maximum number of members that may be analysed by a single imaginary cut. **1**

(*b*) Using the *method of sections,* determine the **magnitude** and **nature** of the forces in M_1, M_2 and M_3. **9**

(11)

[Turn over

Marks

7. A "USB" turntable is shown in Figure Q7(*a*). The turntable enables analogue music on vinyl records to be converted into a digital format and transferred via a USB port to a personal computer.

Figure Q7(*a*)

The turntable is driven by a stepper motor and an output-driver IC which are controlled by a microcontroller. A three-position switch enables the selection of different turntable speeds, as shown in Figure Q7(*b*).

A diagram of the arrangement is shown in Figure Q7(*b*).

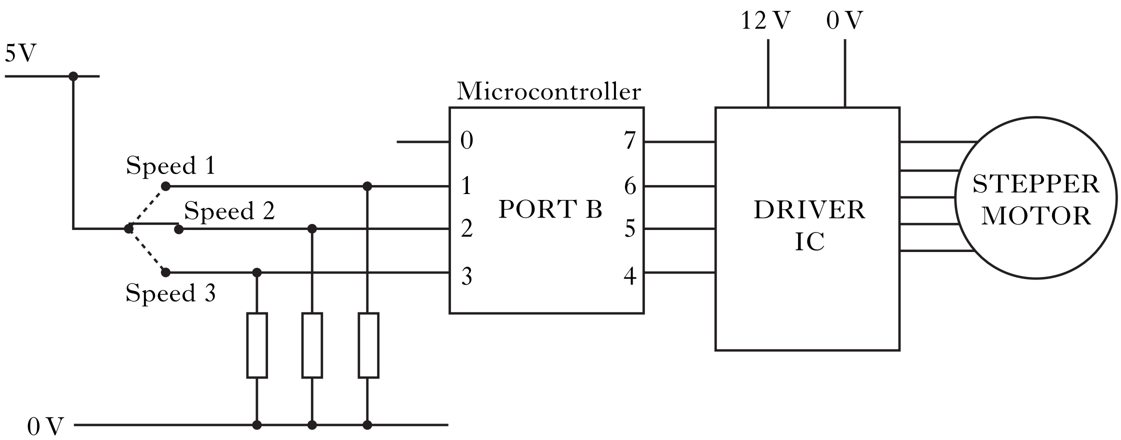

Figure Q7(*b*)

7. (continued)

The step-angle of the stepper motor is 7·5°. The table below shows the order in which the output pins of the microcontroller are switched on to produce four steps.

	Output pins			
Step	**7**	**6**	**5**	**4**
1	1	1	0	0
2	0	1	0	1
3	0	0	1	1
4	1	0	1	0

Speed 2 is 45 rev/min.

(*a*) Calculate the time delay required between steps for **speed 2**. **1**

A program called *main* tests each switch and then calls the appropriate sub-procedure (*speed1, speed2,* or *speed3*) to drive the turntable at the correct speed.

(*b*) (i) Write, in assembler code, the program *main*. **4**

(ii) Write, in assembler code, the sub-procedure *speed2*. **3**

The sub-procedure *pause* produces a time delay of 1 millisecond multiplied by the value held in the Working Register, W.

(8)

[*END OF SECTION A*]

[Turn over

SECTION B

Attempt any two questions in this section.

Each question is worth 20 marks

8. An example of electronic bathroom scales is shown in Figure Q8(a).

Figure Q8(a)

When the scales are switched on by a foot switch, each display flashes all 7 segments (to test the LEDs are functioning) prior to displaying the actual weight. A sub-system diagram is shown in Figure Q8(b).

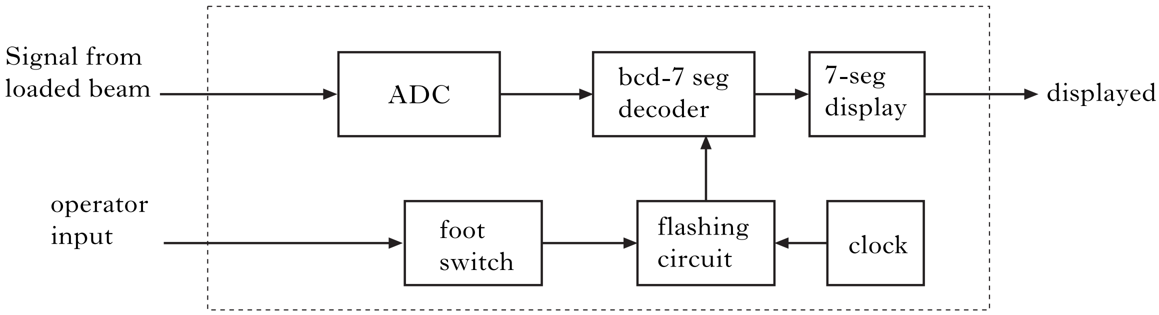

Figure Q8(b)

The "flashing circuit" sub-system requires a clock pulse that is produced using a 555 timer in astable mode. The required frequency f = 0·33 Hz. Resistor R_1 = 1 kΩ and capacitor C = 1 μF.

(a) Calculate the value of resistor R_2 that will produce the required frequency. **2**

An electronic circuit diagram is shown on **Information Sheet Q8**.

The LED flashing feature uses the "Lamp Test" $(\overline{LT})$ and "Blanking Input" $(\overline{BI})$ pins of the 7-segment display decoder. The inputs operate as shown below.

$\overline{\textbf{LT}}$	$\overline{\textbf{BI}}$	**7-segment display**
0	0	all segments high
0	1	all segments high
1	0	all segments low
1	1	BCD number displayed

(b) Explain the function of the electronic circuit in terms of the sub-systems A to F. **6**

8. (continued)

The ADC sub-system shown in Figure Q8(*b*) uses a feedback resistor $R_f = 100\,k\Omega$. The digital value 1111 is equivalent to an analogue voltage of 5 V. The incomplete ADC is shown on **Worksheet Q8**.

(*c*) On **Worksheet Q8**, complete the circuit diagram for the 4-bit ADC. Show all appropriate component values. **5**

The value displayed by the 7-segment display is obtained from a strain-gauged stainless-steel beam which deflects in proportion to the applied load. The beam has a length of 200 mm with "built-in" ends, and a central point load of 1 kN. The cross-section of the beam is shown in Figure Q8(*c*).

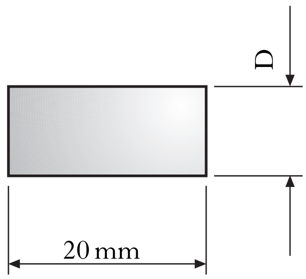

Figure Q8(*c*)

(*d*) Calculate the maximum bending moment. **1**

The maximum stress due to bending must not exceed 100 N/mm^2.

(*e*) Calculate:

(i) the depth (D) of the beam; **4**

(ii) the deflection of the beam. **2**

(20)

[Turn over

9. One method of repairing bridges like the one shown in Figure Q9(*a*) is by wrapping the timber beams in glass-reinforced polymer (GRP).

Figure Q9(*a*)

Prior to repair, samples of GRP-wrapped beams may be subjected to bending tests. The test-rig shown in Figure Q9(*b*) applies loads at two points through pistons controlled by a microcontroller.

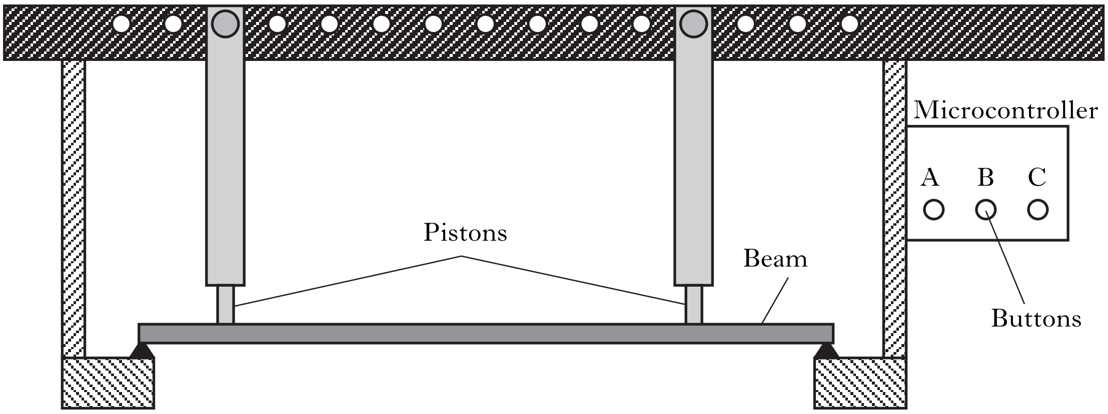

Figure Q9(*b*)

Three buttons are provided to control the operation of the pistons. These buttons are monitored continuously; if one of the buttons is pressed then the pistons apply a load to the beam for a certain time. This time is determined by modifying a value already held in a register file called LOADTIME, and then calling the sub-procedure *delay* (which uses the value held in LOADTIME).

When button A is pressed the value in LOADTIME is halved. When button B is pressed the value is doubled, and when button C is pressed the value is multiplied by 8. LOADTIME will not exceed 255 after manipulation.

9. (continued)

The table below shows the input and output connections to PORTB of the microcontroller.

Input connections	PORTB pins	Output connections
	7	Left piston
	6	Right piston
	5	
	4	
	3	
Button C	2	
Button B	1	
Button A	0	

(*a*) Write, in assembler code, the sub-procedure *testbeam* which would perform the function described. **8**

The free-body diagram of a loaded GRP beam is shown in Figure Q9(*c*).

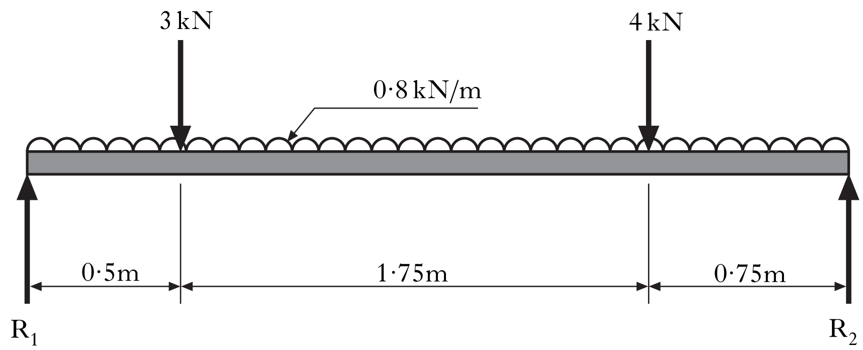

Figure Q9(*c*)

(*b*) Calculate the reactions at R_1 and R_2. **2**

(*c*) On **Worksheet Q9**, complete the shear-force diagram. **2**

(*d*) (i) Calculate the **position** and **magnitude** of the maximum bending moment. **2**

(ii) On **Worksheet Q9**, complete the table of results and draw the bending-moment diagram. **6**

(20)

[Turn over

10. Figure Q10(*a*) shows part of a touch-screen system used in a motorway-signalling control room. When the user touches the screen, current is drawn from electrodes at each corner and is "earthed" through the finger. By comparing the four currents, the position of the touch on the screen can be determined.

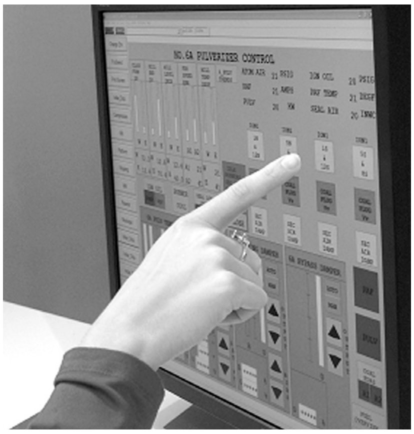

Figure Q10(*a*)

The current flow from each corner is processed by an integrator circuit, similar to the one shown in Figure 10(*b*), and a voltage signal is produced.

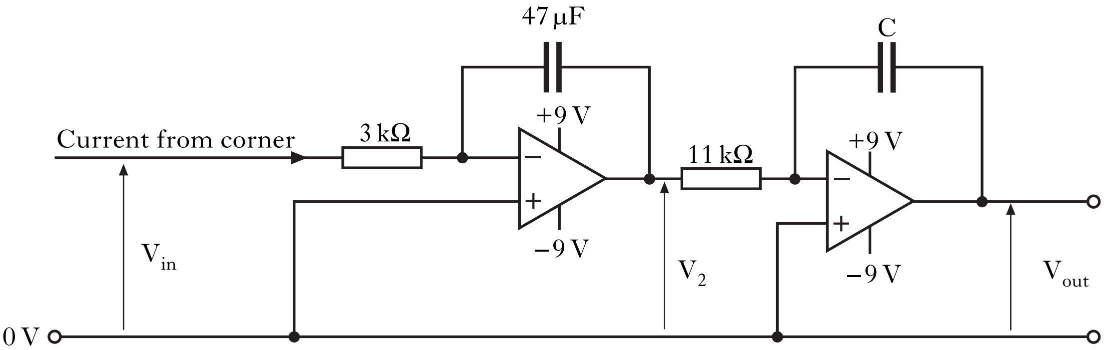

Figure Q10(*b*)

For a particular position on the screen, $V_{in} = 5\,V$. For this value:

(*a*) (i) sketch a graph showing how the voltage V_{out} varies with time; **1**

(ii) write, in its simplest form, the expression for V_{out} in terms of t. **3**

(*b*) After an elapsed time of 0·1 seconds, $V_{out} = 2\,V$.

Calculate:

(i) the voltage V_2; **1**

(ii) the value of capacitor C. **2**

10. (continued)

The V_{out} signal from each integrator circuit is further processed and converted into a digital value for input to a microcontroller. The four digital values produced from the four corners are stored in register files called TR (top right), TL (top left), BL (bottom left) and BR (bottom right).

When the screen is switched on, a high signal is sent to the microcontroller and the electrodes go high. Two sub-procedures *getx* and *gety* are then called in sequence. The screen switch is checked again, and if it is low then the electrodes go low. The program then monitors the screen switch in a loop until it goes high again.

The *gety* sub-procedure obtains the **y-position** of the finger-touch by summing the values in TR and TL, and storing the result in the register file TOPSUM; the BL and BR values are then summed and the result is stored in the register file BOTTOMSUM. The TOPSUM value is then subtracted from the BOTTOMSUM value and the result is stored in the register file YPOS. The sub-procedure *getx* functions in a similar way to obtain the **x-position**.

The table below shows the input and output connections to PORTB of the microcontroller.

Input connections	PORTB pins	Output connections
	7	Electrodes
	6	
	5	
	4	Warning lights
	3	
Screen switch (1 = on)	2	
	1	
	0	

(*c*) Write, in assembler code, the main program and the sub-procedure *gety*. **7**

Another sub-procedure uses the touch-position to check if an emergency bar across the screen has been touched, as shown in Figure Q10(*c*).

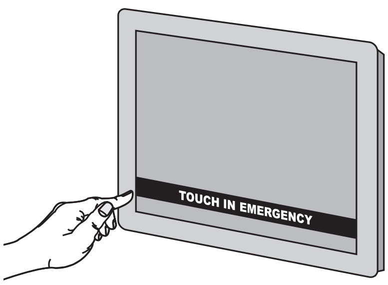

Figure Q10(*c*)

The bar is positioned in the vertical range 8–38. If the bar is touched, a set of motorway emergency warning lights flashes on and off for 5 minutes, with a mark time of 0·6 seconds and space time of 1·4 seconds.

(*d*) Write, in assembler code, a sub-procedure *testbar* that will perform this function. **6**

When the sub-procedure *testbar* is called, the position obtained for the finger-touch (by *gety*), is already stored in register file YPOS.

The sub-procedure *wait* produces a time delay of 0·1 seconds multiplied by the value held in the Working Register, W.

(20)

[*END OF QUESTION PAPER*]

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X036/702

NATIONAL QUALIFICATIONS 2009

MONDAY, 8 JUNE
1.00 PM – 4.00 PM

TECHNOLOGICAL STUDIES
ADVANCED HIGHER
Worksheets for Questions 3, 8 and 9, Information Sheet for Q8.

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 book and returned with it.

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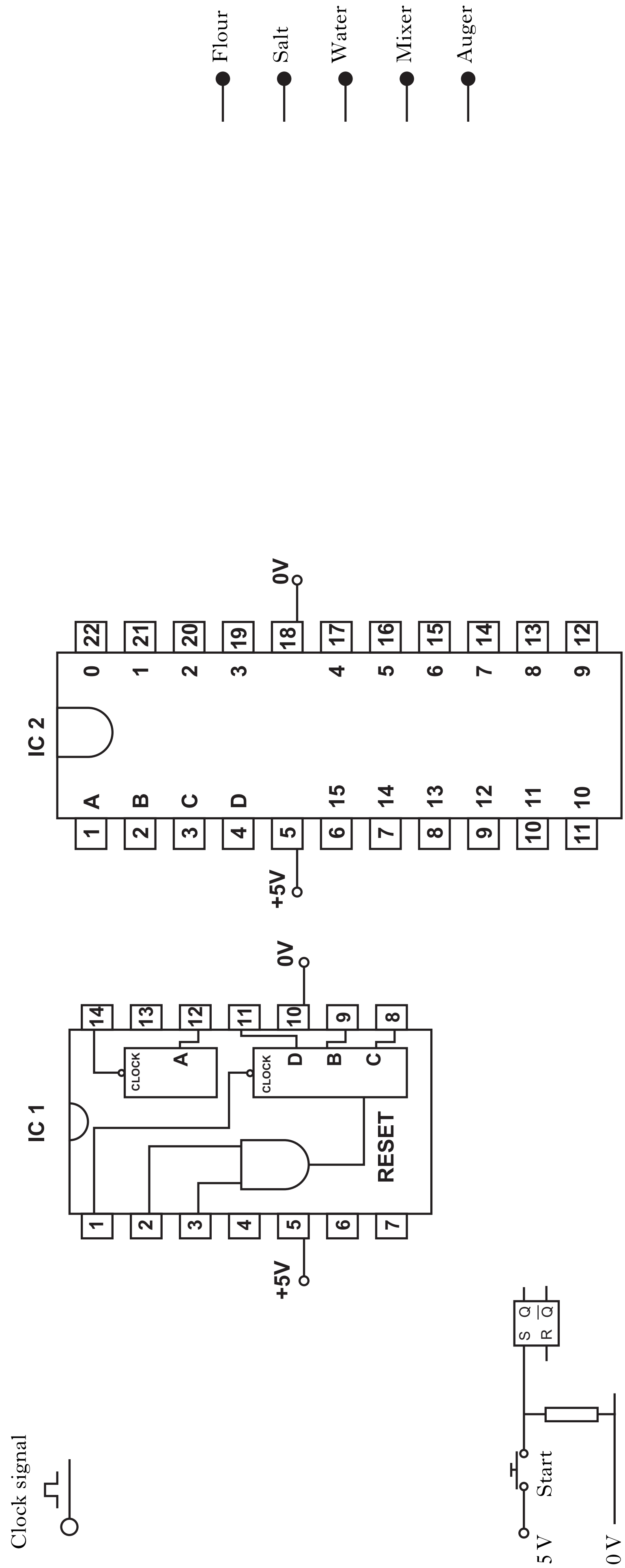
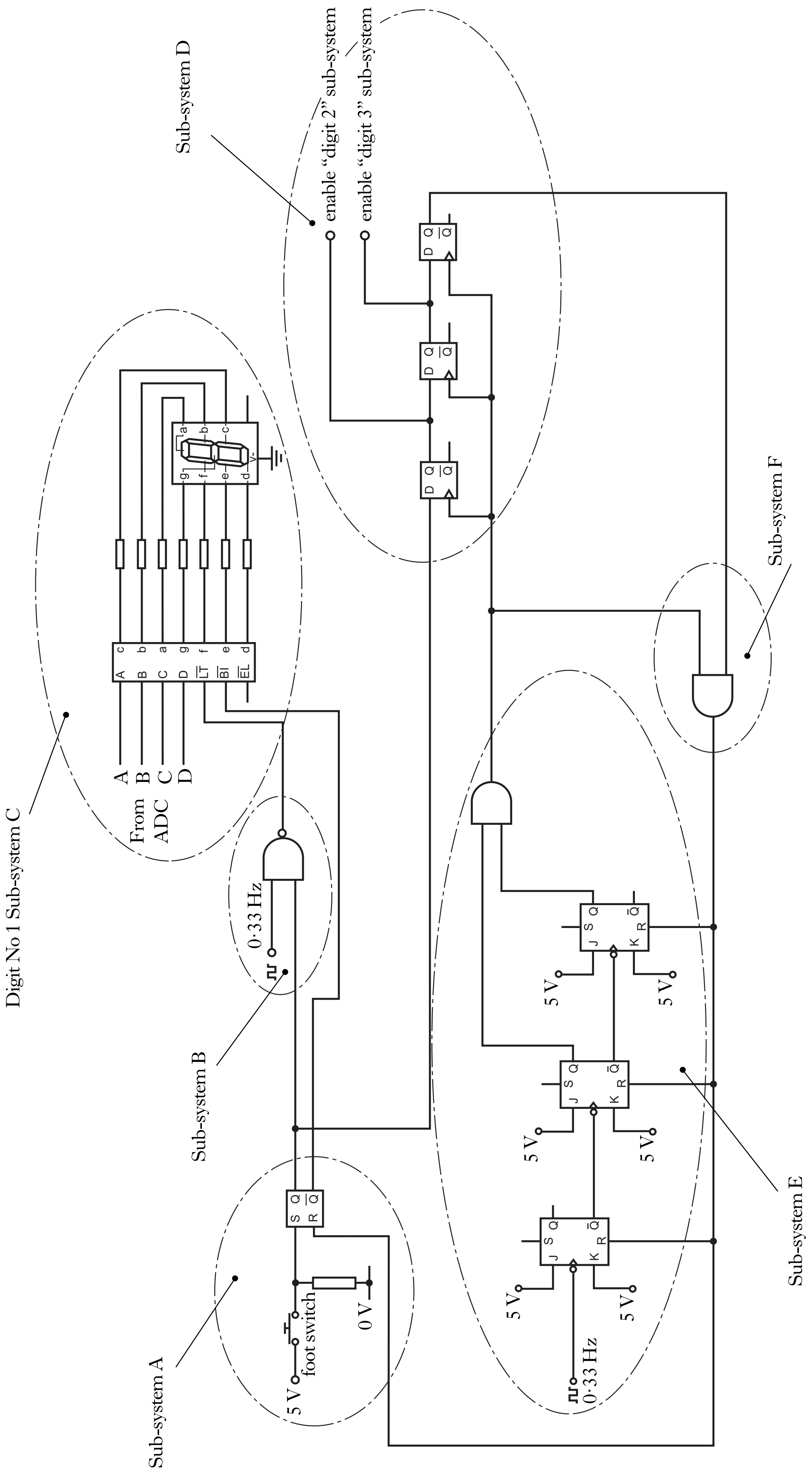
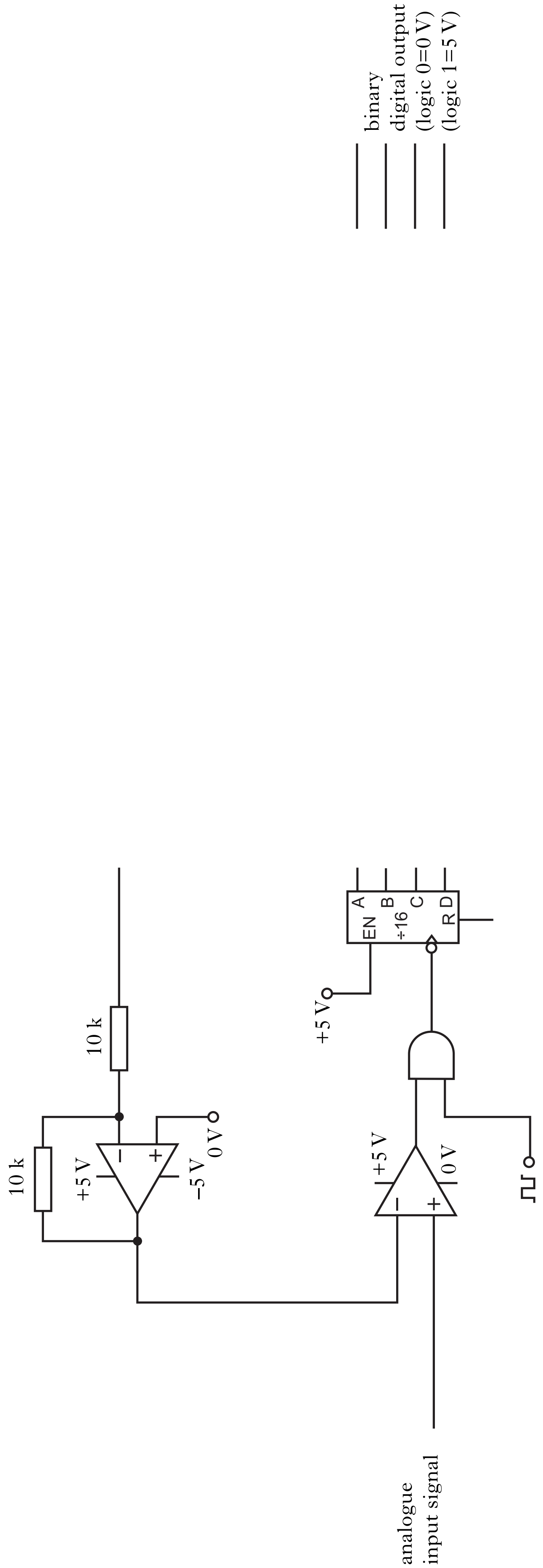
WORKSHEET Q3



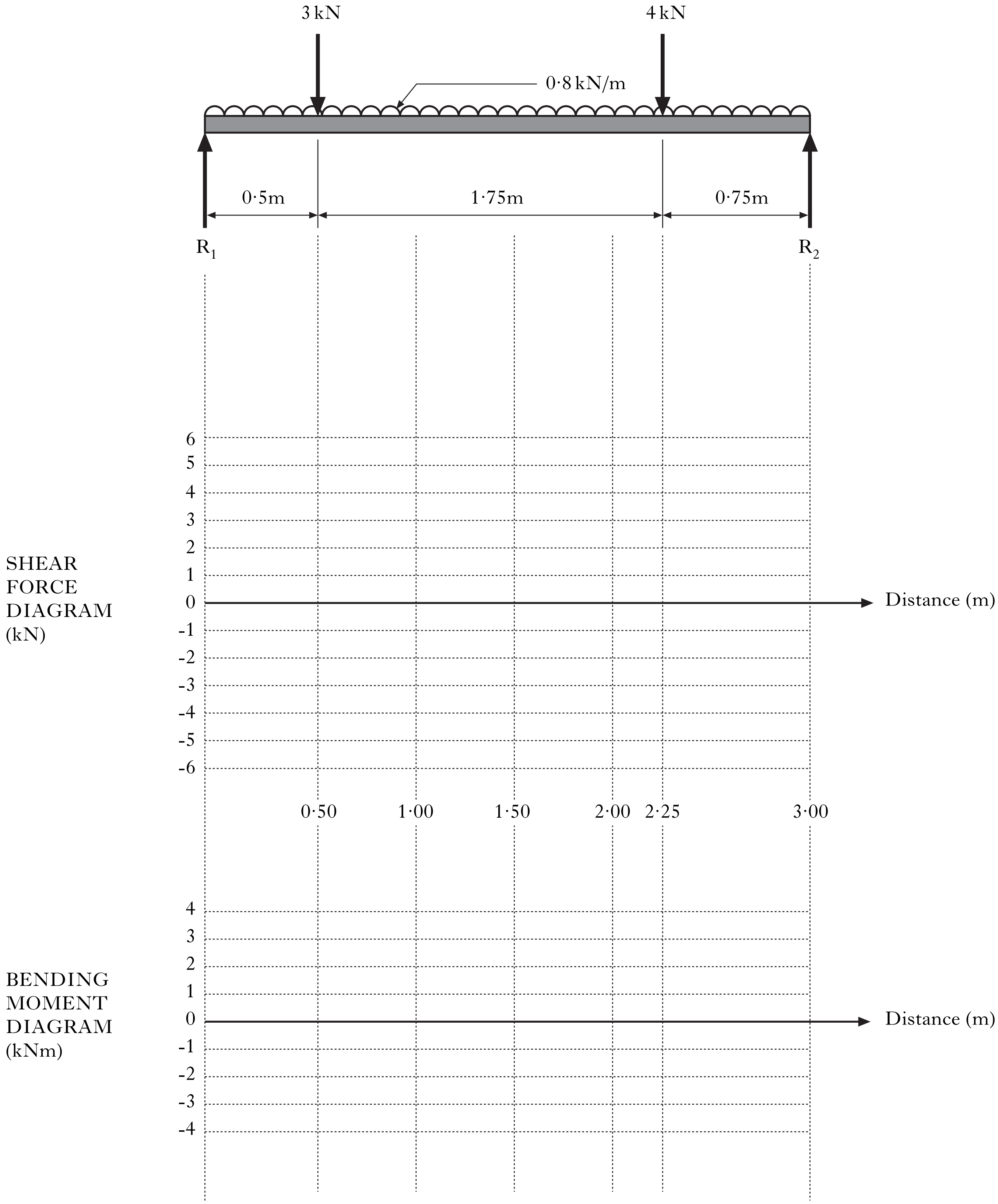
INFORMATION SHEET Q8



WORKSHEET Q8



WORKSHEET Q9



DISTANCE FROM LEFT END (m)	0·00	0·50	1·00	1·50	2·00	2·25	3·00
BENDING MOMENT (kNm)							

[*END OF WORKSHEETS*]

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