Q1. The Boolean equation for a particular logic circuit with inputs A and B and output Q is:

$$Q = (A.B) + (\overline{A}.\overline{B})$$

(a) The table below shows intermediate logic signals for the circuit, and the overall output, Q, for all combinations of the inputs A and B.

Complete the missing two entries in the truth table.

A	B	$\overline{A}$	$\overline{B}$	A . B	$\overline{A}$. $\overline{B}$	Q
0	0	1	1	0	1	
0	1	1	0	0	0	0
1	0	0	1	0		0
1	1	0	0	1	0	1

(1)

(b) Complete the diagram in the figure below to show the logic circuit that has the same function as the Boolean equation given above. Your circuit should contain only **two** AND gates, **two** NOT gates, and **one** OR gate.

(3)
(Total 4 marks)

Q2. A fridge is fitted with a temperature-sensing unit to indicate whether the temperature inside the fridge is too high, too low, or at a safe temperature.
The system consists of a temperature sensor that produces a 2−bit binary output, a logic circuit and a low current, common cathode 7−segment display.
Figure 1 shows a block diagram of the system.

Figure 1

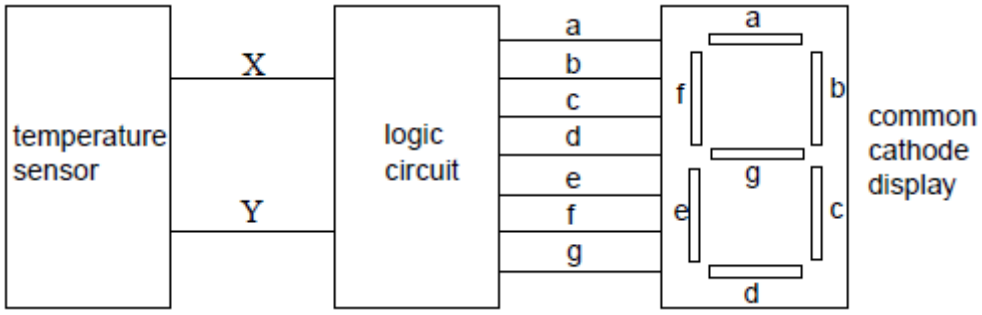


Table 1 shows the operation of the system.

Table 1

Fridge temperature	Temperature sensor output		7-segment display output
	X	Y	
< 3 °C	0	0	L
3 °C to 4 °C	0	1	S
4 °C to 5 °C	1	0	S
> 5 °C	1	1	H

Key

L = low

S = safe

H = high

(a) Complete **Table 2** to show the logic signals required on lines a to g to display the specified characters.

Table 2

X	Y	a	b	c	d	e	f	g	Display
0	0								L
0	1								S
1	0								S
1	1								H

(3)

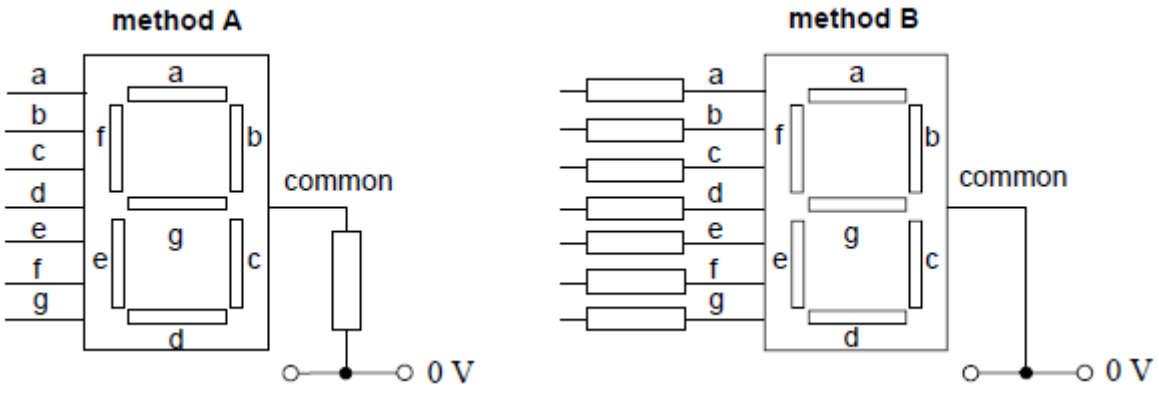
(b) Circle the single logic gate which would generate the required signal for segment **a**.

AND EXOR OR NAND NOR NOT

(1)

(c) The LEDs in the 7−segment display must be protected by current limiting resistors. **Figure 2** shows two methods, **A** and **B**, of connecting current limiting resistors.

Figure 2



(i) State **one** disadvantage of **method A**.

.....

.....

(1)

(ii) Calculate the value of the current limiting resistors required in **method B** to limit the current in each segment to 20 mA.
Assume the voltage from the logic circuit is 5 V and the forward voltage drop across each LED in the 7−segment display is 2.2 V.

.....

.....

.....

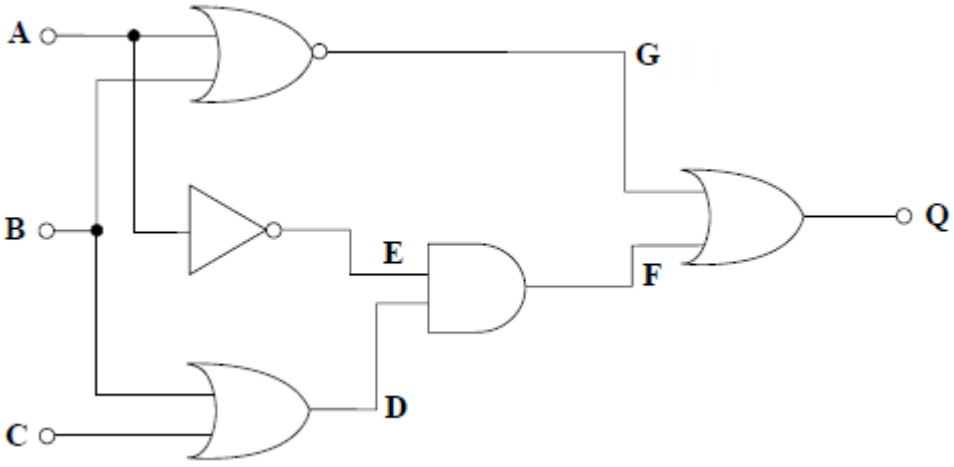
(2)

(iii) Circle the appropriate value for these resistors from the following list of E24 resistors.

110 Ω 150 Ω 270 Ω 1.1 kΩ 1.5 kΩ

(1)
(Total 8 marks)

Q3. The diagram shows a logic circuit with three inputs **A**, **B** and **C**.



(a) Write the Boolean expressions for the signals at the intermediate points **D**, **E**, and **G** in terms of the inputs **A**, **B** and **C** only.

D .....

E .....

G .....

(3)

(b) Complete the truth table below for the logic signals at the intermediate points **D**, **E** and **G**.

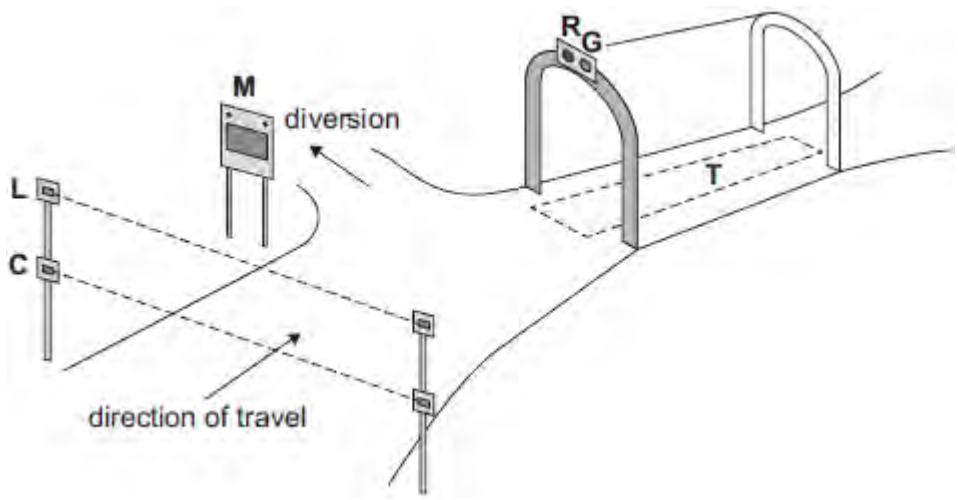
Inputs				Intermediate points		
C	**B**	**A**		**D**	**E**	**G**

0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

(5)
(Total 8 marks)

Q4. Figure 1 shows a simplified diagram of a road safety system for traffic travelling towards a road tunnel. The tunnel is too narrow for two-way traffic and too low for lorries.

Figure 1



C and **L** are laser beam sensors placed at different heights on the road just before the tunnel. When a beam is broken, the sensor produces a logic 1.

Cars will break the beam at sensor **C only**. Lorries will break the beams at both sensor **L** and sensor **C**.

M is an electronic message display that tells lorries to take a diversion. The message display lights up when it receives a logic 1.

T is a sensor buried in the road inside the tunnel. It produces a logic 1 when an oncoming car is in the tunnel.

The red stop light **R** comes on when a lorry is detected or when there is an oncoming car in the tunnel. **R** will light up when it receives a logic 1.

The green go light **G** comes on when a car is detected and there are no oncoming cars in the tunnel. **G** will light up when it receives a logic 1.

(a) Complete the truth table.
Some of the data has already been entered for you.

Input			Output		
Sensor T	**Sensor C**	**Sensor L**	**Message display M**	**Red stop light R**	**Green go light G**
0	0	0	0	0	1
0	0	1	0	0	1
0	1	0		0	
0	1	1		1	
1	0	0		1	
1	0	1	0	1	0
1	1	0		1	
1	1	1		1	

(4)

(b) Write the simplest Boolean expression for the red stop light **R** in terms of **T**, **C** and **L**.

.....

(2)

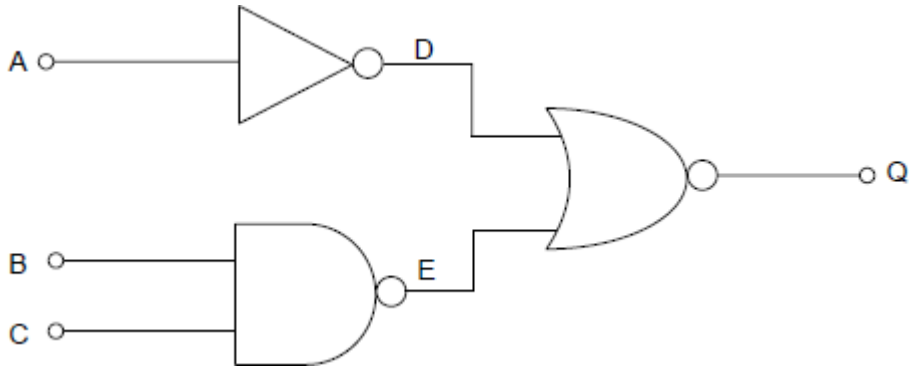
(c) The expression for the green go light **G** could be written as **G** = $\overline{T}.(\overline{C}+\overline{L})$

Draw on **Figure 2** the logic diagram for this expression using only NOT, AND and OR gates.

Figure 2

(3)
(Total 9 marks)

Q5. As part of his project, a student constructs the following logic circuit.



(a) Write down the Boolean expressions for:

D = ...

(1)

E = ...

(2)

(b) Write down the Boolean expression for Q in terms of D and E.

Q = ...

(2)

(c) Complete the truth table below for the logic circuit above.

A	B	C	D	E	Q
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

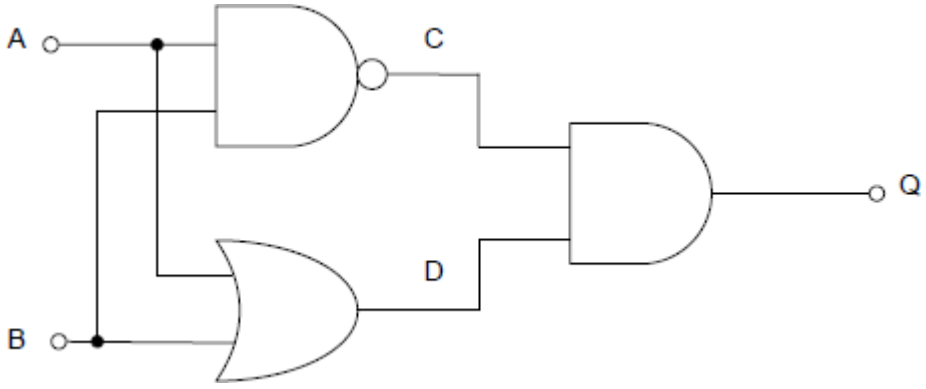
(4)

(d) His supervisor suggests that the logic circuit can be simplified. What single logic gate would have the same function as the whole circuit above?

.....

(1)
(Total 10 marks)

Q6. A student constructs a circuit from the following logic diagram.



(a) Complete the truth table below for this logic diagram.

A	B	C	D	Q
0	0			

0	1			
1	0			
1	1			

(3)

(b) Write down Boolean expressions for the logic signals at C, D and Q in terms of the inputs A and B.

C = ...

(1)

D = ...

(1)

Q = ...

(2)

(c) What single logic gate could perform the function of the whole circuit above?

.....

(1)

(Total 8 marks)