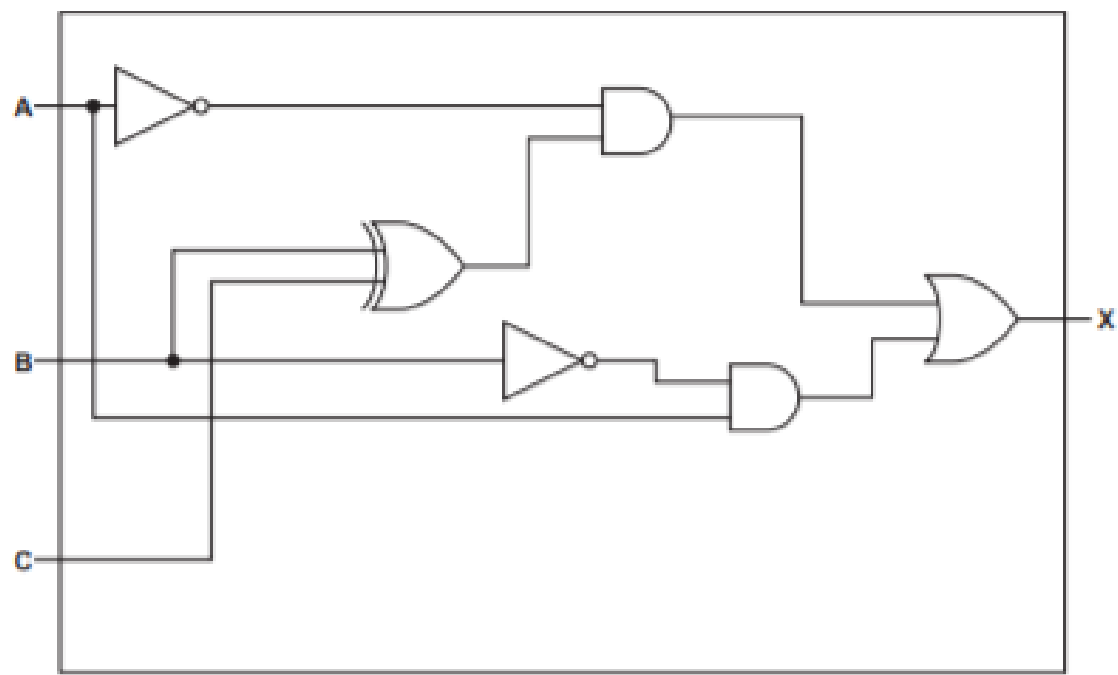# LOGIC GATES

## Question 1

5  (a)  A logic circuit is given:



Complete the following truth table for the logic circuit.

| A | B | C | Working space | X |
|---|---|---|---|---|
| 0 | 0 | 0 | | 0 |
| 0 | 0 | 1 | | 1 |
| 0 | 1 | 0 | | 1 |
| 0 | 1 | 1 | | 0 |
| 1 | 0 | 0 | | 1 |
| 1 | 0 | 1 | | 1 |
| 1 | 1 | 0 | | 0 |
| 1 | 1 | 1 | | 0 |

[4]

**(b)** Identify **one** logic gate not used in the logic circuit in **part (a)**.

Draw the symbol for this logic gate **and** complete its truth table.

Logic gate: ..................................................

Symbol:

Truth table:

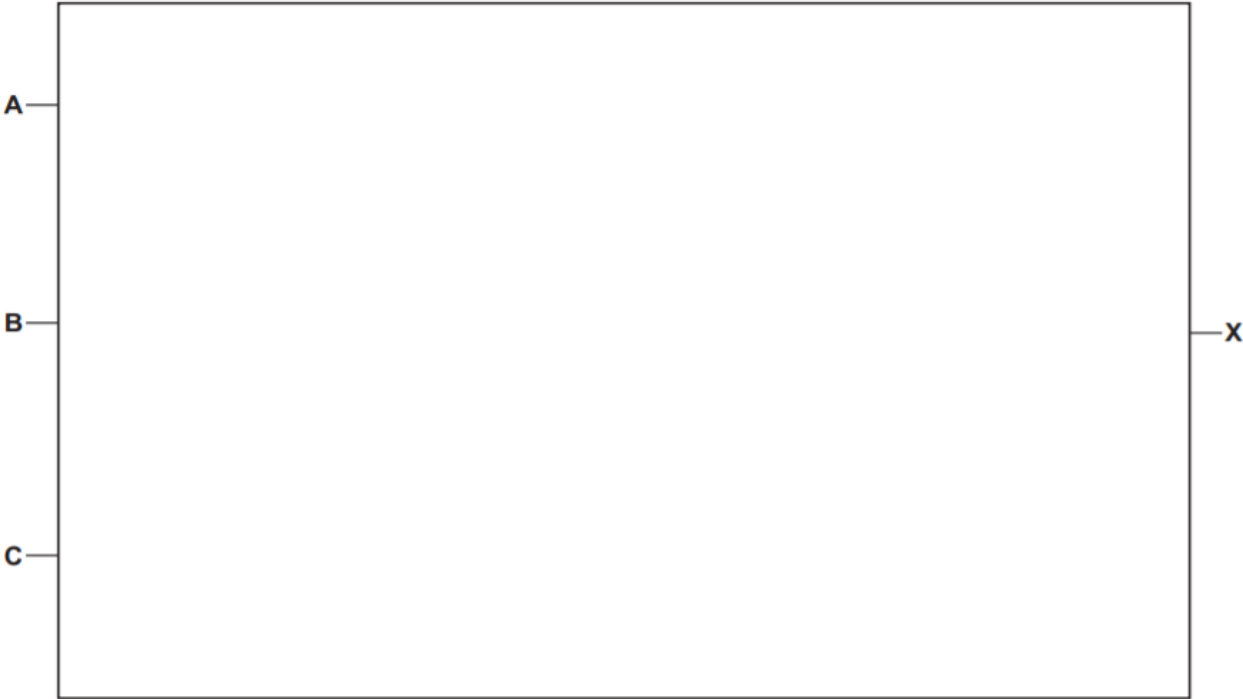| Input | | Output |
|---|---|---|
| **A** | **B** | |
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

[3]

## Question 2

**3** The following is a logic expression.

$$X = \text{NOT } (A \text{ AND } B) \text{ OR NOT } (\text{NOT } B \text{ OR } C)$$

Draw the logic circuit for the given expression using a maximum of **four** gates.

A —

B —

C —

— X

[4]

## Question 3

3   **(a)**   The following is a logic expression.

$$X = NOT(A \; OR \; B) \; OR \; (A \; AND \; (B \; XOR \; C))$$

Draw the logic circuit for the given expression, using a maximum of **four** logic gates.

A ——

B ——

  —X

C ——

[4]

**(b)** Complete the truth table for the logic expression:

$$X = \text{NOT}(A \text{ OR } B) \text{ OR } (A \text{ AND } (B \text{ XOR } C))$$

| A | B | C | Working space | X |
|---|---|---|---|---|
| 0 | 0 | 0 | | 1 |
| 0 | 0 | 1 | | 1 |
| 0 | 1 | 0 | | 0 |
| 0 | 1 | 1 | | 0 |
| 1 | 0 | 0 | | 0 |
| 1 | 0 | 1 | | 1 |
| 1 | 1 | 0 | | 1 |
| 1 | 1 | 1 | | 0 |

[4]

**(c)** The following is a logic expression.

$$A \text{ AND } B \text{ XOR } C \text{ OR NOT } A$$

Identify **one** logic gate that would **not** be used in the logic circuit for this expression.
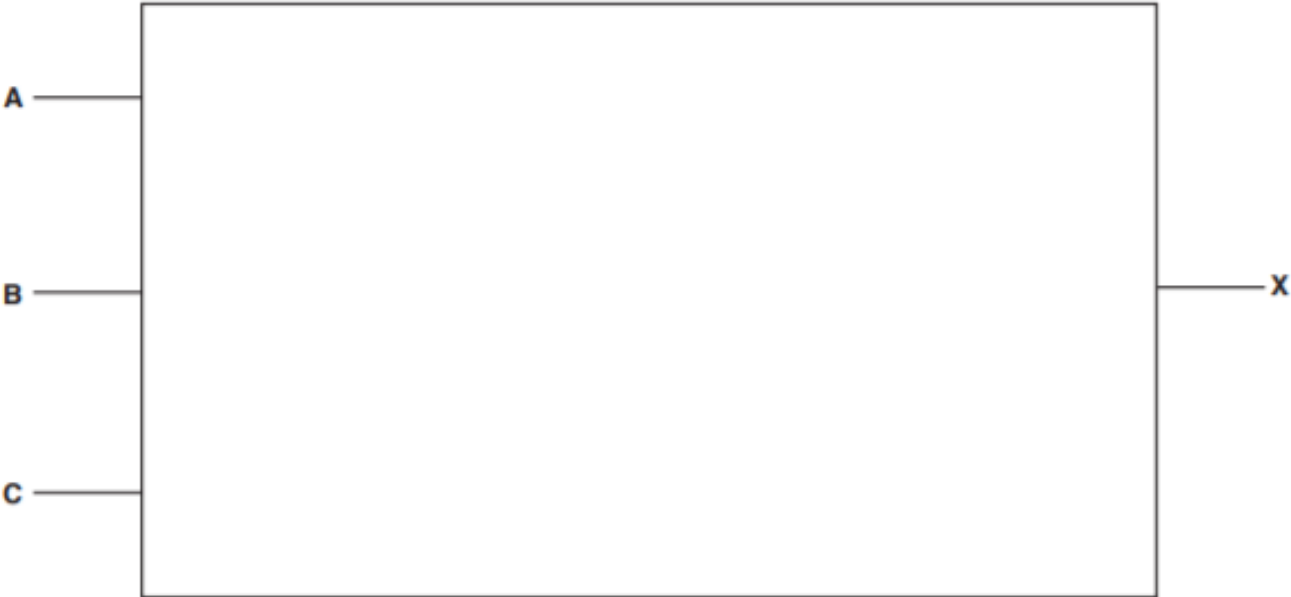Draw the symbol for the logic gate.

Logic gate .................................................................................................................................................................

Logic gate symbol:

**Question 4**

6 (a) Draw a logic circuit to represent the logic expression:

$$X = A \text{ OR } (B \text{ AND NOT } C) \text{ OR } (A \text{ AND } B)$$



[5]

(b) Complete the truth table for the logic expression in **part (a)**.

| A | B | C | Working space | X |
|---|---|---|---|---|
| 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]

## Question 5

3  (a)  A bank approves a customer for an account based on the criteria in the following table.

| Parameter | Description of parameter | Binary value | Condition |
|-----------|--------------------------|--------------|-----------|
| A | Employed | 1 | True |
|   |          | 0 | False |
| B | Self-employed | 1 | True |
|   |               | 0 | False |
| C | Over 21 | 1 | True |
|   |         | 0 | False |
| D | Earn more than 30 000 | 1 | True |
|   |                       | 0 | False |
| E | Another account | 1 | True |
|   |                 | 0 | False |

A customer is approved (**X** = 1) if the person:

- is over 21 **and** employed
  **or**
- is over 21 **and** self-employed **and**

  - **either** earns more than 30000
    **or**
  - has another account.

Draw a logic circuit to represent the model.



[5]

(b) Complete the truth table for the logic expression:

X = (A AND C) OR (NOT A AND (B XOR C))

| A | B | C | Working space | X |
|---|---|---|---|---|
| 0 | 0 | 0 | | 0 |
| 0 | 0 | 1 | | 1 |
| 0 | 1 | 0 | | 1 |
| 0 | 1 | 1 | | 0 |
| 1 | 0 | 0 | | 0 |
| 1 | 0 | 1 | | 1 |
| 1 | 1 | 0 | | 0 |
| 1 | 1 | 1 | | 1 |

[4]

# Question 6

2  (a)  Draw a logic circuit to represent the following logic expression:

$$X = NOT (A \ AND \ B) \ AND \ (C \ XOR \ D)$$



A ——

B ——

C ——

D ——

—— X

[4]
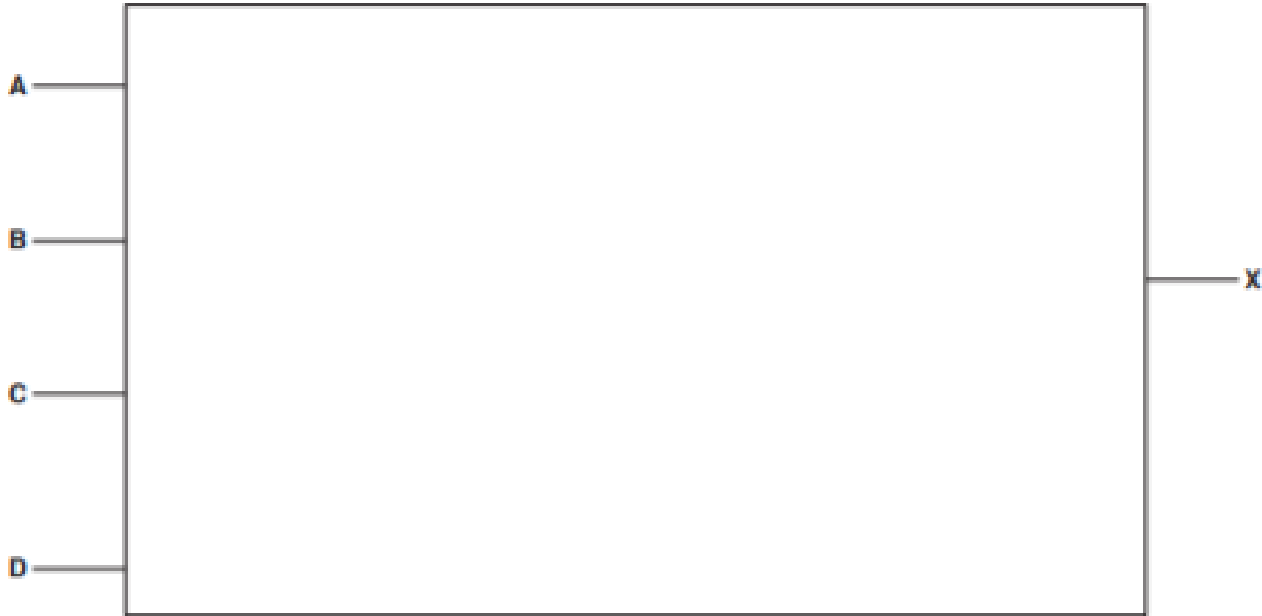
(b)  Complete the truth table for the logic expression:

$$X = NOT (A \ AND \ B) \ OR \ (A \ AND \ (B \ XOR \ C))$$

| A | B | C | Working space | X |
|---|---|---|---------------|---|
| 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]

**Question 7**

5  (a)  Draw a logic circuit to represent the logic expression:

X = NOT (A OR C) OR (A AND NOT B)



A

B ———— X

C

[5]

(b)  Complete the truth table for the logic expression:

X = NOT (A OR C) OR (A AND NOT B)

| A | B | C | Working space | X |
|---|---|---|---|---|
| 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]

## Question 8

4 (a) An alarm system (X) is enabled and disabled using either a switch (A) or a remote control (B). There are **two** intra-red sensors (C, D) and **one** door pressure sensor (E).

| Parameter | Description of parameter | Binary value | Condition |
|---|---|---|---|
| A | Switch | 1 | Switch enabled |
| | | 0 | Switch disabled |
| B | Remote control | 1 | Remote enabled |
| | | 0 | Remote disabled |
| C | Infra-red sensor | 1 | Activated |
| | | 0 | Not activated |
| D | Infra-red sensor | 1 | Activated |
| | | 0 | Not activated |
| E | Door pressure sensor | 1 | Activated |
| | | 0 | Not activated |

The alarm sounds (X = 1) if the alarm is enabled **and** any one or more of the sensors is activated.

Draw a logic circuit to represent the alarm system.

A ⎯

B ⎯

C ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ X

D ⎯

E ⎯

[3]

(b) Complete the truth table for the logic expression: **X = A** OR (**B** XOR **C**)

| A | B | C | Working space | X |
|---|---|---|---------------|---|
| 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]

**Question 9**

2   (a)  A greenhouse control system has four input parameters (H, D, T, W) and two outputs (X, Y).

| Parameter | Description of parameter | Binary value | Condition |
|---|---|---|---|
| H | Humidity | 0 | Too low |
| | | 1 | Acceptable |
| D | Day | 0 | Night |
| | | 1 | Day |
| T | Temperature | 0 | Too high |
| | | 1 | Acceptable |
| W | Windows | 0 | Closed |
| | | 1 | Open |

The watering system turns on (X = 1) if:

**either**      it is daytime **and** the temperature is too high

**or**      the humidity is too low.

The fan turns on (Y = 1) if the temperature is too high **and** the windows are closed.

Draw a logic circuit to represent the greenhouse control system.



[6]

(b) Complete the truth table for the logic expression: X = NOT A AND (B NAND C)

| A | B | C | Working space | X |
|---|---|---|---------------|---|
| 0 | 0 | 0 | | 1 |
| 0 | 0 | 1 | | 1 |
| 0 | 1 | 0 | | 1 |
| 0 | 1 | 1 | | 0 |
| 1 | 0 | 0 | | 0 |
| 1 | 0 | 1 | | 0 |
| 1 | 1 | 0 | | 0 |
| 1 | 1 | 1 | | 0 |

[4]

## Question 10

5 (a) A student needs to design a logic circuit to model the requirements for membership of a snooker club. Membership (X) depends on four criteria, as shown in the table:

| Parameter | Description of parameter | Binary value | Condition |
|---|---|---|---|
| A | Over 18 | 1 | True |
| | | 0 | False |
| B | Recommended | 1 | True |
| | | 0 | False |
| C | Full-time | 1 | True |
| | | 0 | False |
| D | Retired | 1 | True |
| | | 0 | False |

Membership is approved (X = 1) if the person:

- is over the age of 18 **and** has been recommended by a pre-existing member **and**
- **either** is working full-time **or** is retired, but not both.

Draw a logic circuit to represent the membership requirements.

A

B

C

D

X

[3]

(b) Complete the truth table for the logic expression: **X = (A XOR B) AND NOT C**

| A | B | C | Working space | X |
|---|---|---|---|---|
| 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]

## Question 11

8 (a) Draw a logic circuit to represent the logic expression:

**X = (A XOR B) OR (NOT(C AND A))**

A ─

B ─                                        ─ X

C ─

[4]

(b) Complete the truth table for the logic expression in **part (a)**.

| A | B | C | Working space | X |
|---|---|---|---|---|
| 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]

## Question 12

5 A motor is controlled by a logic circuit. The circuit has inputs (0 or 1) from three sensors R, T and W. The motor is switched off when the output from the logic circuit is 1.

The following table shows the three sensors and the conditions being monitored.

| Sensor | Description | Binary value | Condition |
|---|---|---|---|
| R | rotation | 0 | rotation < 4000 rpm |
| | | 1 | rotation >= 4000 rpm |
| T | temperature | 0 | temperature >= 90 °C |
| | | 1 | temperature < 90 °C |
| W | water flow rate | 0 | water flow rate >= 50 litre/min |
| | | 1 | water flow rate < 50 litre/min |

The output, X, is 1 if:

temperature >= 90 °C and rotation >= 4000 rpm

or

temperature < 90°C and water flow rate >= 50 litre/min

(I)   Draw a corresponding logic circuit.

R ——

T ——                                                                          — X

W ——

[5]

(II)   Give a logic statement corresponding to the logic circuit in part **(I)**.

.....................................................................................................................................

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

(III)   Complete the truth table for this system.

| INPUT | | | Workspace | OUTPUT |
|---|---|---|---|---|
| R | T | W | | X |
| 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]

## Question 13

1  (a)  A student writes the following logic expression:

X is 1 IF  (B is NOT 1  AND  S is NOT 1)  OR  (P is NOT 1  AND  S is 1)

Draw a logic circuit to represent this logic expression.

Do not attempt to simplify the logic expression.

B ———

S ——————— X

P ———

[6]

(b)  Complete the truth table for the logic expression given in **part (a)**.

| B | S | P | Working space | X |
|---|---|---|---|---|
| 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]

## Question 14

5    A motor is controlled by a logic circuit. The circuit has inputs (0 or 1) from three sensors R, T and W. The motor is switched off when the output from the logic circuit is 1.

The following table shows the three sensors and the conditions being monitored.

| Sensor | Description | Binary value | Condition |
|---|---|---|---|
| R | rotation | 0 | rotation < 4000 rpm |
| | | 1 | rotation >= 4000 rpm |
| T | temperature | 0 | temperature >= 90 °C |
| | | 1 | temperature < 90 °C |
| W | water flow rate | 0 | water flow rate >= 50 litre/min |
| | | 1 | water flow rate < 50 litre/min |

The output, X, is 1 if:

temperature >= 90 °C and rotation >= 4000 rpm

or

temperature < 90 °C and water flow rate >= 50 litre/min

(i)   Draw a corresponding logic circuit.

R —

T —           — X

W —

[5]

(ii)   Give a logic statement corresponding to the logic circuit in part (i).

...................................................................................................................................................

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

(iii)   Complete the truth table for this system.

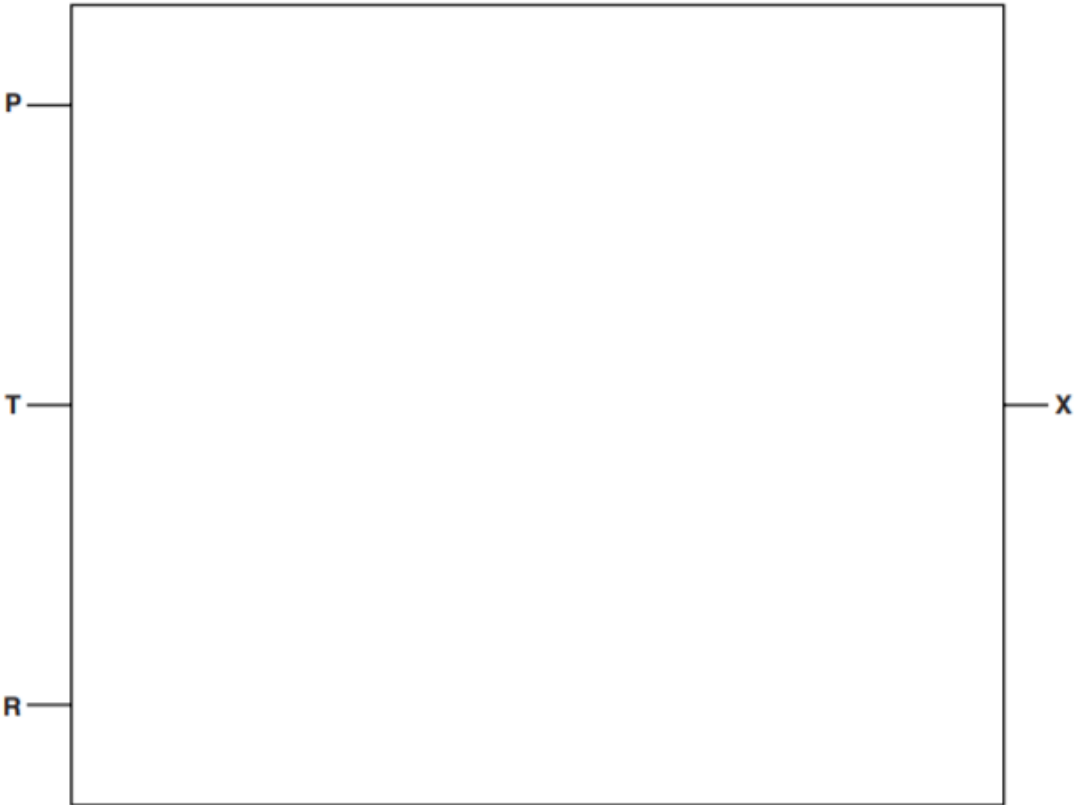| INPUT | | | Workspace | OUTPUT |
|---|---|---|---|---|
| R | T | W | | X |
| 0 | 0 | 0 | | |
| 0 | 0 | 1 | | |
| 0 | 1 | 0 | | |
| 0 | 1 | 1 | | |
| 1 | 0 | 0 | | |
| 1 | 0 | 1 | | |
| 1 | 1 | 0 | | |
| 1 | 1 | 1 | | |

[4]

## Question 15

**7** A system is monitored using sensors. The sensors output binary values corresponding to physical conditions, as shown in the table:

| Parameter | Description of parameter | Binary value | Description of condition |
|---|---|---|---|
| P | oil pressure | 1 | pressure >= 3 bar |
| | | 0 | pressure < 3 bar |
| T | temperature | 1 | temperature >= 200°C |
| | | 0 | temperature < 200°C |
| R | rotation | 1 | rotation <= 1000 revs per minute (rpm) |
| | | 0 | rotation > 1000 revs per minute (rpm) |

The outputs of the sensors form the inputs to a logic circuit. The output from the circuit, X, is 1 if any of the following three conditions occur:

**either**      oil pressure >= 3 bar **and** temperature >= 200°C

**or**      oil pressure < 3 bar **and** rotation > 1000 rpm

**or**      temperature >= 200°C **and** rotation > 1000 rpm

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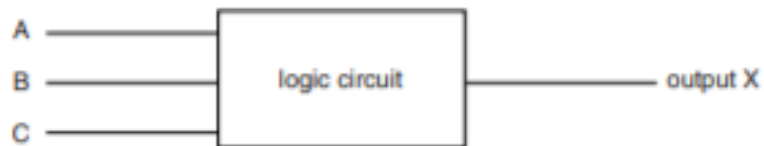(a) Draw a logic circuit to represent the above system.

P ——

T ——                                                —X

R ——

[5]

(b) Complete the truth table for this system.

| P | T | R | Workspace | X |
|---|---|---|---|---|
| 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]

## Question 16

6 (a) Three digital sensors A, B and C are used to monitor a process. The outputs from the sensors are used as the inputs to a logic circuit.

```
A ─────────┌──────────────┐
B ─────────│ logic circuit │────────── output X
C ─────────└──────────────┘
```

Output, X, has a value of 1 if either of the following two conditions occur:

• sensor A outputs the value 1  OR  sensor B outputs the value 0

• sensor B outputs the value 1  AND  sensor C outputs the value 0

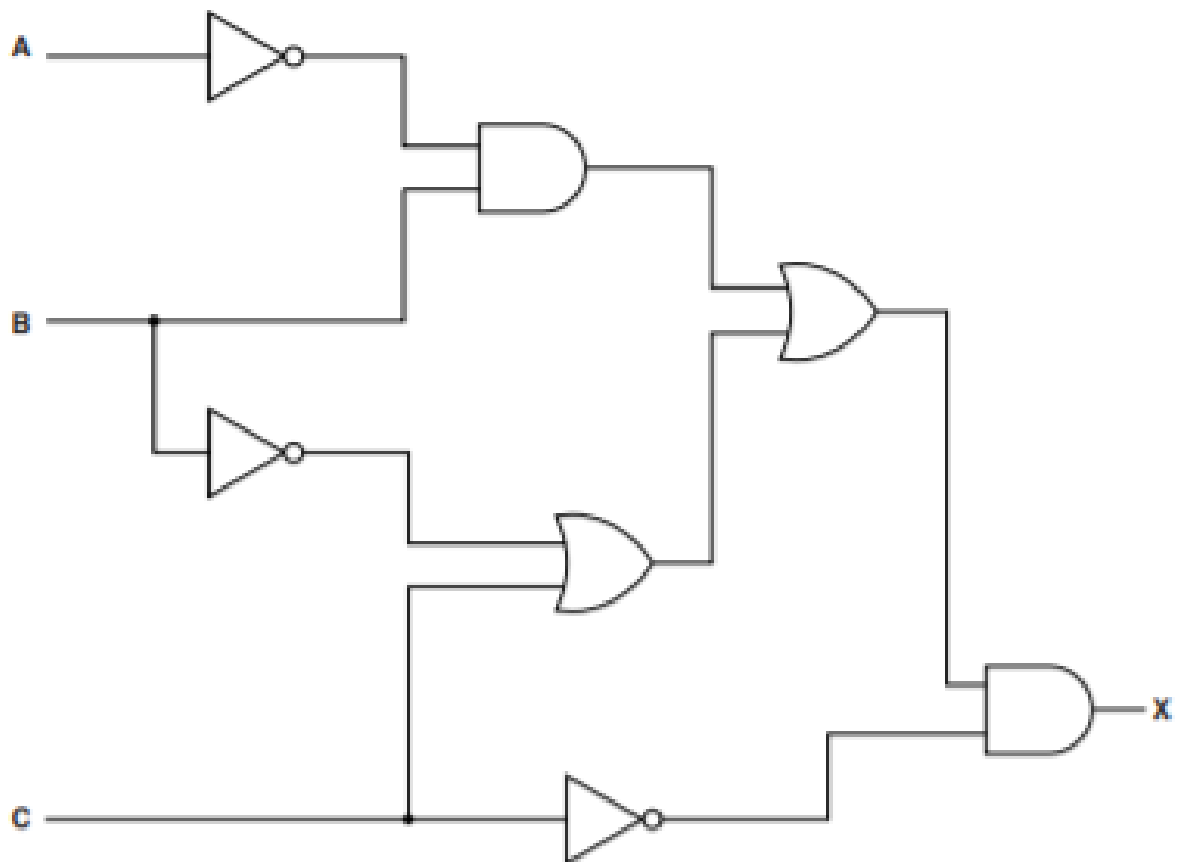Draw a logic circuit to represent these conditions.

A ─────

B ───── X

C ─────

[5]

(b) Complete the truth table for the logic circuit described in **part (a)**.

| A | B | C | Working Space | X |
|---|---|---|---------------|---|
| 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]

(c) Write a logic statement that describes the following logic circuit.



......................................................................................................................................................

......................................................................................................................................................

......................................................................................................................................................

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

**Question 17**

6   (a)   A student wrote the following logic statement:

X is 1 if (B is NOT 1 AND S is NOT 1) OR (P is NOT 1 AND S is 1)

Draw a logic circuit to represent the above logic statement.



B ———

S ——— X

P ———

[6]
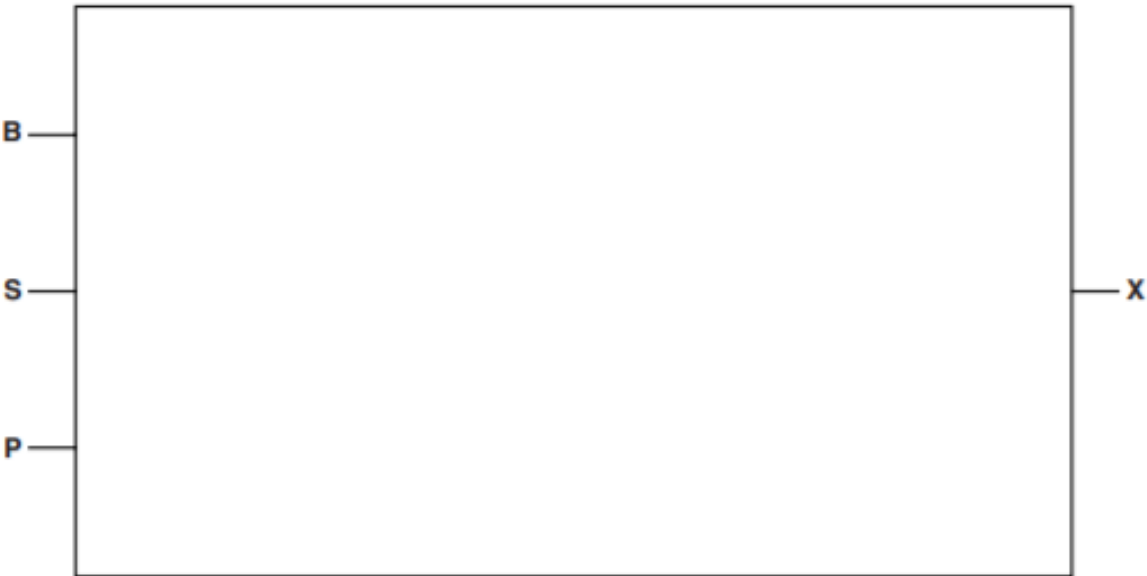
(b)   Complete the truth table for this system.

| B | S | P | Working space | X |
|---|---|---|---|---|
| 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]

**Question 18**

8   A car has an engine management system (EMS). The EMS outputs the following signals.

| signal | value | description |
|---|---|---|
| A | 0 | temperature within limits |
| | 1 | temperature too high (fault condition) |
| B | 0 | pressure within limits |
| | 1 | pressure too high (fault condition) |
| C | 0 | carbon emissions within limits |
| | 1 | carbon emissions too high (fault condition) |

(a) (i)   Draw a logic circuit for the following fault condition:

All three signals (A = 1, B = 1 and C = 1) indicate a fault.  The driver is warned to stop the engine – output X = 1.

A ───

B ───                                                                                    ──X

C ───

[2]

**(ii)** Draw a logic circuit for the fault condition:

Either (A = 1 and B = 1) or (B = 1 and C = 1) indicate a fault. The driver is warned that the engine needs a service – output Y = 1.

A ─

B ─                                                                        ─Y

C ─
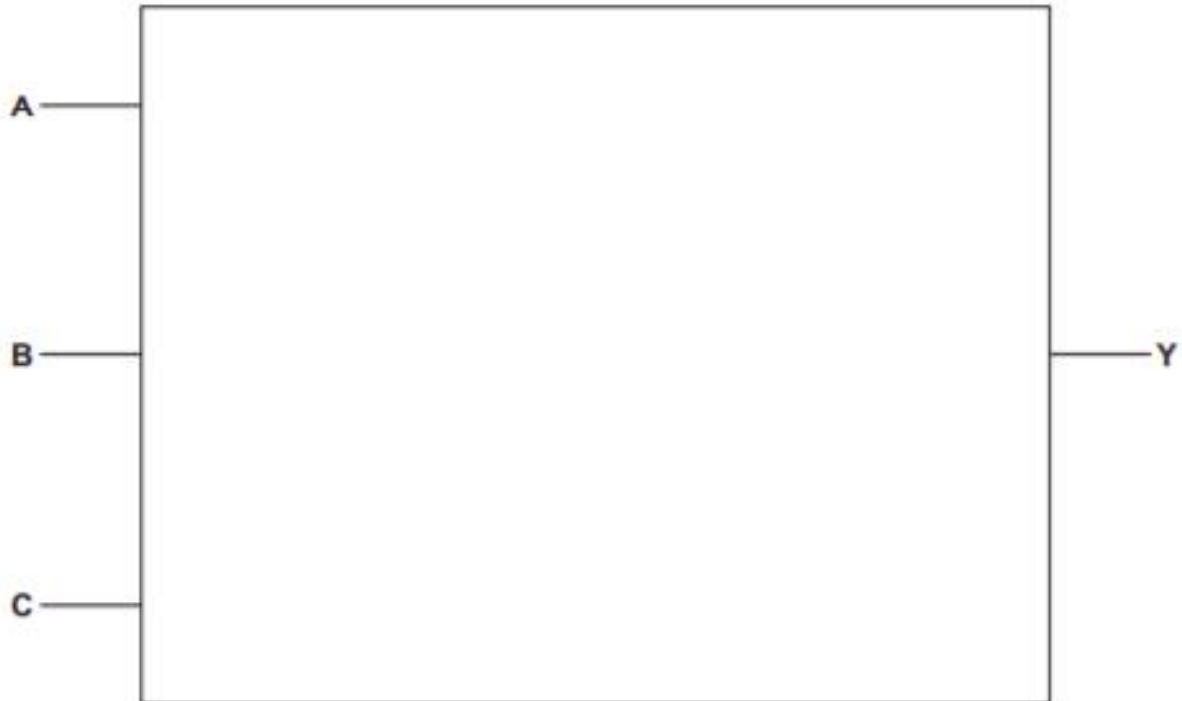
[2]

**(iii)** Draw a logic circuit for the fault condition:

Either A = 1 or B = 1 or C = 1 indicate a fault. A red warning light shows up on the dashboard – output Z = 1.

A ─

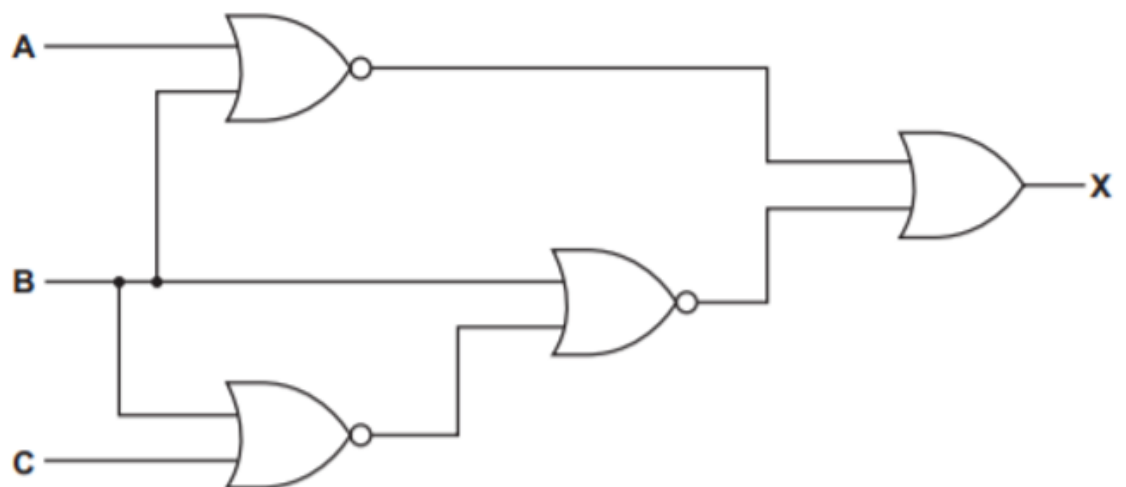B ─                                                                        ─Z

C ─

[2]

**(b)** Complete the truth table for the three fault conditions:

| A | B | C | working | X | Y | Z |
|---|---|---|---------|---|---|---|
| 0 | 0 | 0 | | | | |
| 0 | 0 | 1 | | | | |
| 0 | 1 | 0 | | | | |
| 0 | 1 | 1 | | | | |
| 1 | 0 | 0 | | | | |
| 1 | 0 | 1 | | | | |
| 1 | 1 | 0 | | | | |
| 1 | 1 | 1 | | | | |

[6]

**Question 19**

**8** **(a)** Complete the truth table for the following logic circuit:



216

| A | B | C | working | X |
|---|---|---|---------|---|
| 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]

**(b)** Draw a logic circuit corresponding to the following logic statement:

X = 1 if ( A = **NOT** 1 **OR** B = 1 ) **AND** ( B = **NOT** 1 **AND** C = **NOT** 1)

A ————

B ———— X

C ————

[6]

217
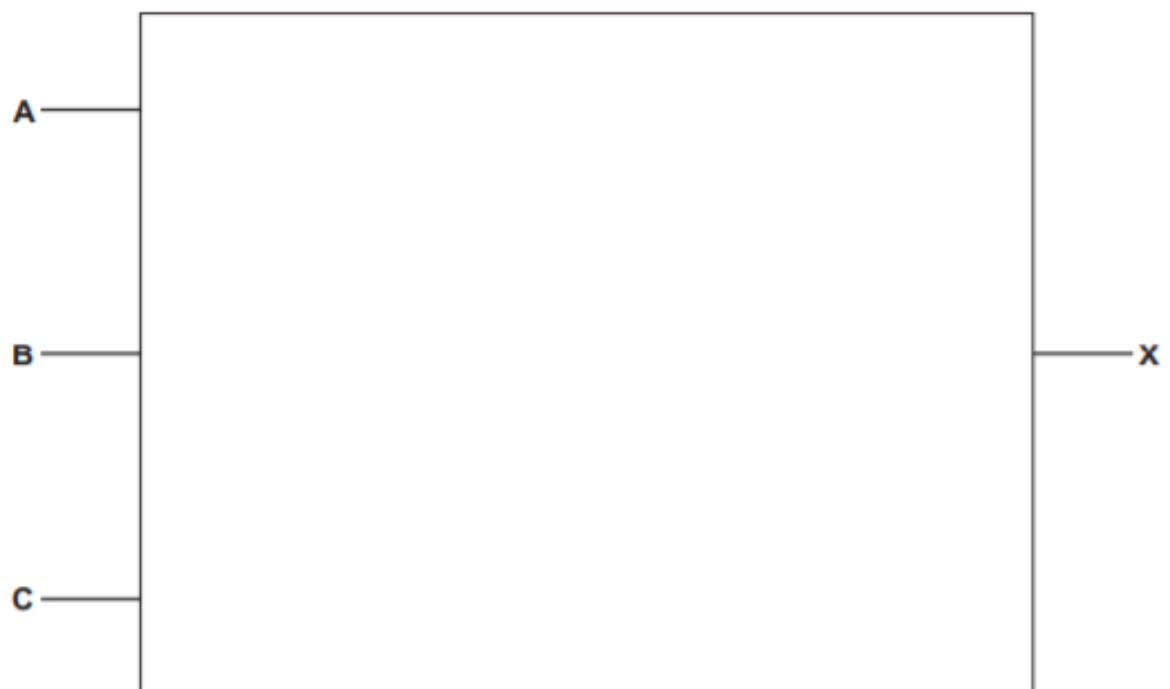
**Question 20**

6   A wind turbine must shut down when certain conditions are met.

The three variables and the conditions which dictate their values are shown in the table:

| variable | | binary value | condition |
|---|---|---|---|
| name | description | | |
| W | wind speed | 1 | wind speed ⩾ 100 kilometres per hour (kph) |
| | | 0 | wind speed < 100 kilometres per hour (kph) |
| P | oil pressure | 1 | oil pressure **low** |
| | | 0 | oil pressure **normal** |
| T | motor temperature | 1 | motor temperature ⩾ 50°C |
| | | 0 | motor temperature < 50°C |

A logic circuit is to be designed where the output, **X**, is 1 if:

either   wind speed ⩾ 100 kph and oil pressure normal

or   motor temperature ⩾ 50°C and oil pressure low

or   wind speed < 100 kph and motor temperature ⩾ 50°C

**(a)** Draw a logic circuit.

W ——

P —— X

T ——

[7]

**(b)** Complete the truth table for this system:

| W | P | T | working | X |
|---|---|---|---------|---|
| 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]

**Question 21**

9  **(a)** Draw the logic circuit corresponding to the following logic statement:

X = 1 IF (A is 1 AND B is 1) OR (B is 1 OR C is NOT 1)
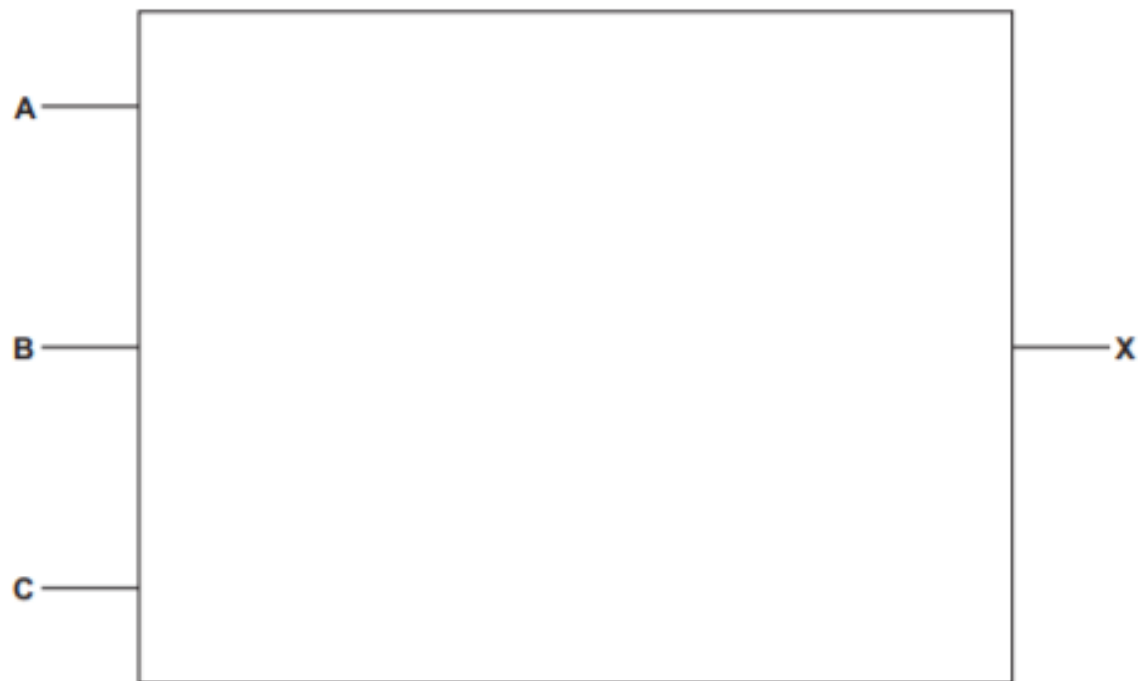


A

B ————————————X

C

[4]

**(b)** Complete the truth table for the above logic statement:

| A | B | C | Working space | X |
|---|---|---|---------------|---|
| 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]

**Question 22**

4 **(a)** Draw the logic circuit that directly corresponds to the following logic statement:

X = 1 IF (A is NOT 1 OR B is 1) AND (B is 1 OR C is 1)
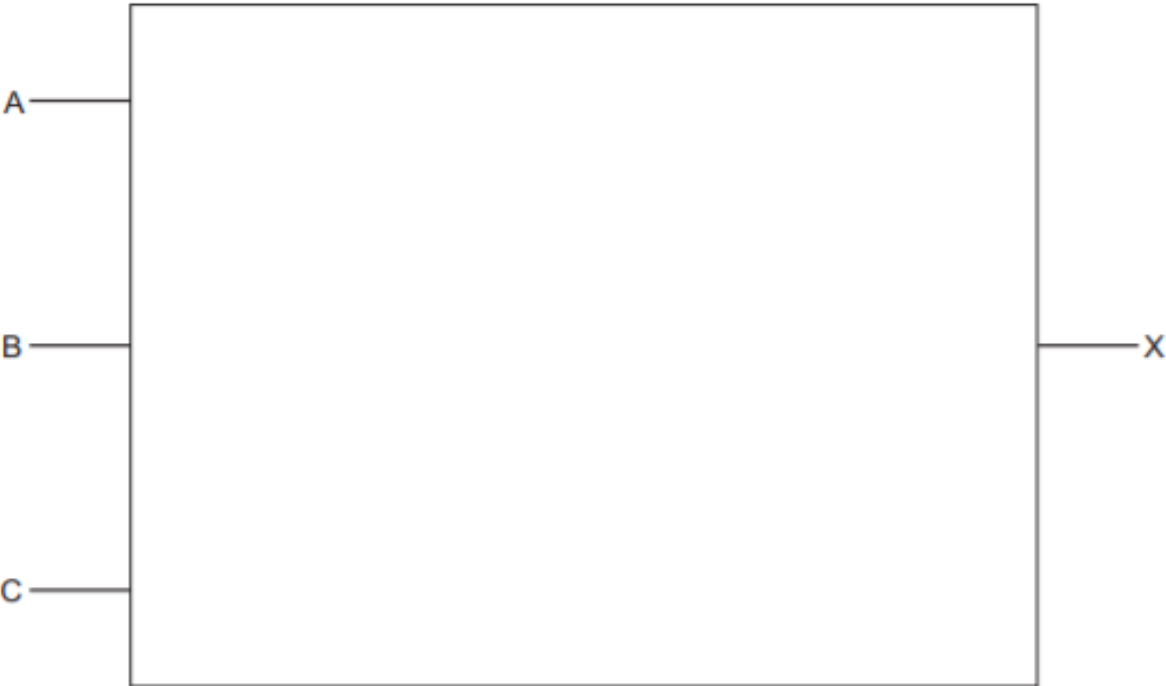
A ————

B ———— X

C ————

[4]

**(b)** Complete the truth table for the above logic statement.

| A | B | C | Working space | | X |
|---|---|---|---|---|---|
| 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]

**Question 23**

9   (a)  Complete the truth table to show the output from the logic gate shown.



| A | B | X |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |

[2]

(b)  Complete the truth table to show the outputs from the logic circuit shown.



| A | B | C | D | Y |
|---|---|---|---|---|
| 0 | 0 |   |   |   |
| 0 | 1 |   |   |   |
| 1 | 0 |   |   |   |
| 1 | 1 |   |   |   |

[4]