

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 4

LEFEL 4

EXAMINATION PERIOD
MAY 2026

CYFNOD ARHOLIADAU
MAI 2026

SOLUTION

MODULE CODE: GOEE4003

ELECTRICAL AND ELECTRONICS PRINCIPLES

TIME: 2 HOURS

ANSWER ALL QUESTIONS

Show all workings clearly

Equipment or materials required – calculators & formula book

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Question One (20 marks)

- a. A 20 V DC supply is connected to a network of six resistors arranged in a combination of series and parallel, as shown in Figure 1. The resistor values are: $R_1 = 24\ \Omega$, $R_2 = 12\ \Omega$, $R_3 = 8\ \Omega$, $R_4 = 2\ \Omega$, $R_5 = 6\ \Omega$, and $R_6 = 10\ \Omega$. Calculate the following:

1. equivalent resistance of the circuit [5]
2. The total current supplied by the source [1]
3. The total power dissipated in the circuit [1]
4. The voltage across the $10\ \Omega$ resistor [1]
5. Determine the voltage across terminals a–b [2]
6. The current through the $2\ \Omega$ resistor [1]
7. The voltage across the $6\ \Omega$ resistor [1]
8. The voltage across the $8\ \Omega$ resistor [2]
9. The current through the $24\ \Omega$ resistor [2]

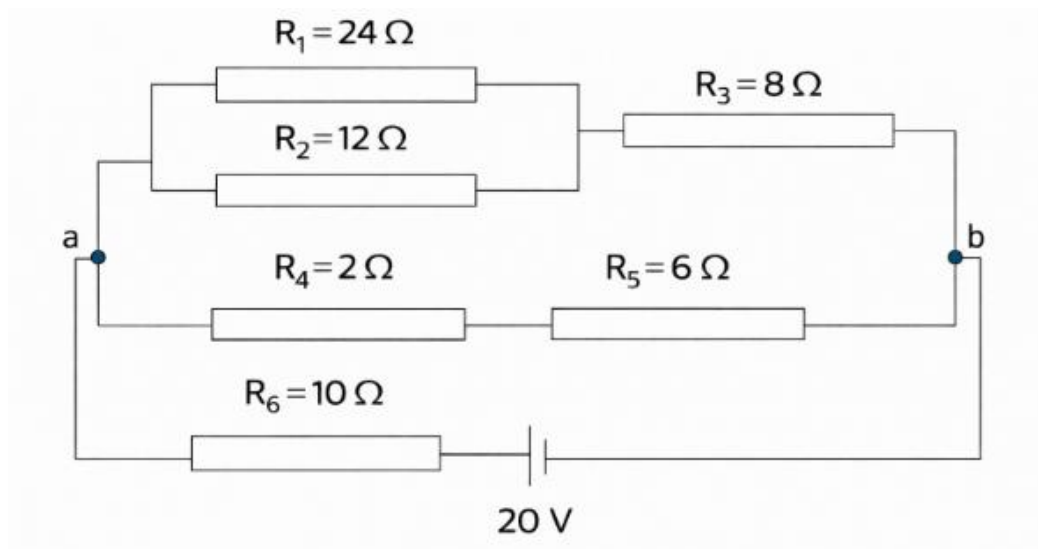


Figure 1

The equivalent resistance of the circuit

$$\begin{aligned} R_{12} &= \frac{R_1 \times R_2}{R_1 + R_2} = \frac{12 \times 24}{12 + 24} \\ R_{12} &= 8\ \Omega \\ R_{123} &= 8 + 8 = 16\ \Omega \\ R_{45} &= 2 + 6 = 8\ \Omega \\ R_{12345} &= \frac{R_{123} \times R_{45}}{R_{123} + R_{45}} = \frac{16 \times 8}{16 + 8} \\ R_{12345} &= 5.33\ \Omega \end{aligned}$$

$$R_T = R_{12345} + R_6 = 5.33 + 10$$

$$\mathbf{R_T = 15.33 \, \Omega}$$

[5]

The total current of the circuit

$$I = \frac{V}{R_T} = \frac{20}{15.33}$$

$$\mathbf{I = 1.30 \, A}$$

[1]

The power dissipated by the circuit

$$P = I^2 R = (1.30^2)(15.33)$$

$$\mathbf{P = 26 \, W}$$

[1]

The voltage across the 10 Ω resistor

$$V_{10\Omega} = I R_6$$

$$\mathbf{V_{10\Omega} = 1.30 \times 10 = 13 \, V}$$

[1]

Determine the voltage across terminals a-b

$$V_{a-b} = V_T - V_{10\Omega} = 20 - 13.0 = 7 \, V$$

$$\mathbf{V_{a-b} = 7 \, V}$$

[2]

The current through the 2 Ω resistor

The current through the 2 Ω resistor is
$$I_{R_{45}} = \frac{V_{a-b}}{R_{45}} = \frac{7}{8} = \mathbf{0.88 \, A}$$

[1]

The voltage across the 6 Ω resistor

The current through the 6 Ω resistor = the current through the 2 Ω resistor

The current through the 6 Ω resistor is = 0.88 A

$$\mathbf{V_{6\Omega} = 0.88 \times 6 = 5.28 \, V}$$

[1]

The voltage across the 8 Ω resistor

$$I_{R_{123}} = I_T - I_{R_{45}} = 1.3 - 0.88$$

$$\mathbf{I_{R_{123}} = 0.42 \, A}$$

$$\mathbf{V_{8\Omega} = I_{R_{123}} \times 8 = 3.36 \, V}$$

[2]

The current through the 24 Ω resistor

$$\mathbf{V_{24\Omega} = V_{a-b} - V_{8\Omega} = 7 - 3.36 = 3.64 \, V}$$

$$I_{24\Omega} = \frac{V_{24\Omega}}{R_{24\Omega}} = \frac{3.64}{24} = \mathbf{0.15 \, A}$$

[2]

- b. In the circuit shown in Figure 2, the current through the $1\ \Omega$ resistor is 4 A . Assuming the battery has negligible internal resistance, determine the terminal voltage V .

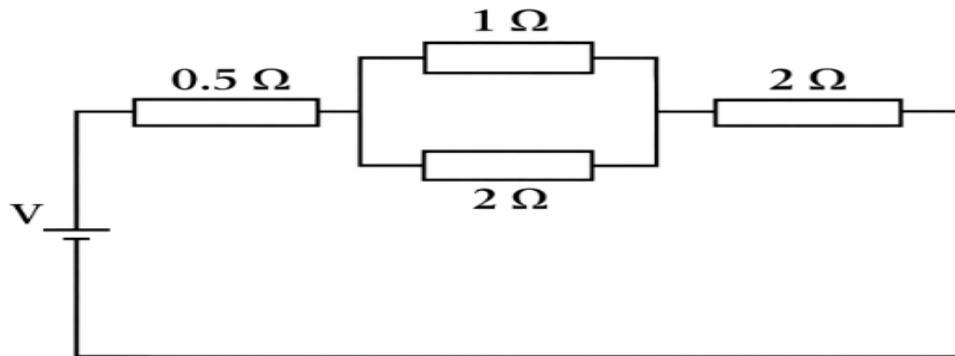


Figure 2

[4]

Solution

The $1\ \Omega$ resistor carries 4 A , so the voltage across it is

$$V_{\text{parallel}} = IR = 4 \times 1 = 4\text{ V}$$

Since the $1\ \Omega$ and $2\ \Omega$ resistors are in parallel, the voltage across the $2\ \Omega$ resistor is also 4 V .

Current in the $2\ \Omega$ (parallel) resistor

$$I_{2\Omega} = \frac{V}{R} = \frac{4}{2} = 2\text{ A}$$

The current entering the parallel section is the sum of the branch currents:

$$I_{\text{total}} = 4 + 2 = 6\text{ A}$$

This same 6 A flows through the $0.5\ \Omega$ and $2\ \Omega$ series resistors.

Across $0.5\ \Omega$:

$$V = IR = 6 \times 0.5 = 3\text{ V}$$

Across $2\ \Omega$ (right side):

$$V = 6 \times 2 = 12\text{ V}$$

Add all voltage drops:

$$V_{\text{battery}} = 3 + 4 + 12 = 19\text{ V}$$

Question Two (30 marks)

- a. For the circuit shown in Figure 3, determine the current flowing through the $12\ \Omega$ resistor and the power dissipated in this resistor.

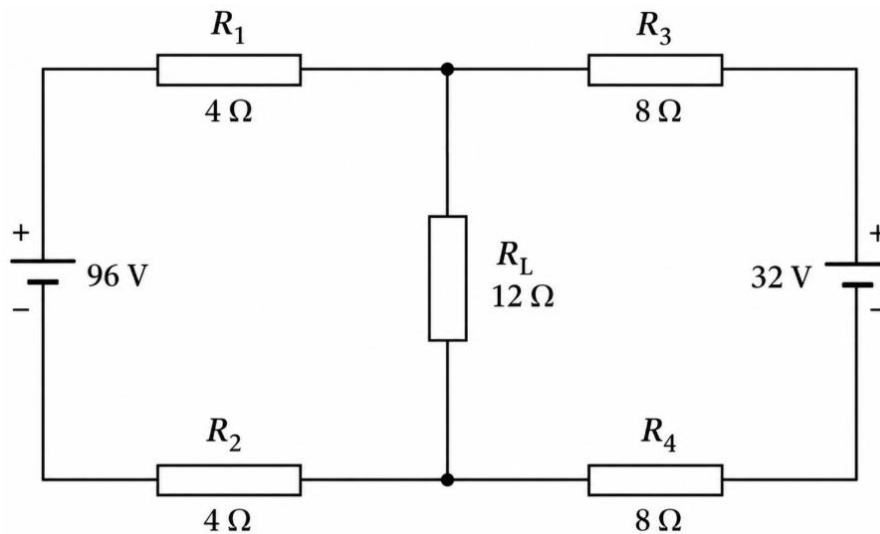


Figure 3

[15]

Solutions:

Obtain the mesh currents using KVL.

For mesh 1.

$$-96 + 4I_1 + 12(I_1 + I_2) + 4I_1 = 0$$

$$-96 + 4I_1 + 12I_1 + 12I_2 + 4I_1 = 0$$

$$20I_1 + 12I_2 = 96$$

$$5I_1 + 3I_2 = 24 \quad [4 \text{ marks}]$$

For mesh 2:

$$-32 + 8I_2 + 12(I_1 + I_2) + 8I_2 = 0$$

$$-32 + 8I_2 + 12I_1 + 12I_2 + 8I_2 = 0$$

$$12I_1 + 28I_2 = 32$$

$$3I_1 + 7I_2 = 8 \quad [4 \text{ marks}]$$

$$5I_1 + 3I_2 = 24 \quad (1)$$

$$3I_1 + 7I_2 = 8 \quad (2)$$

$$15I_1 + 9I_2 = 72 \quad (1)$$

$$15I_1 + 35I_2 = 40 \quad (2)$$

Subtract (-)

$$-26I_2 = 32$$

$$I_2 = -1.23A$$

$$5I_1 + 3I_2 = 24 \quad (1)$$

$$5I_1 + 3(-1.23) = 24$$

$$5I_1 = 24 + 3.69$$

$$5I_1 = 27.69$$

$$I_1 = 5.53 A$$

[4 marks]

for I_{RL} :

$$I_{RL} = I_1 + I_2 = -1.23 + 5.53$$

$$I_{RL} = 4.308A$$

$$P_{RL} = I_{RL}^2 \times 12 = 4.308^2 \times 12$$

$$P_{RL} = 222.7 W$$

[3 marks]

b. For the circuit shown in Figure 4, find:

1. The Thevenin equivalent circuit for the network [8]
2. The value of the resistance R that results in maximum power transfer across the terminals AB [2]
3. The maximum power transferred in the load [2]
4. Find Norton's equivalent circuit for the network. [3]

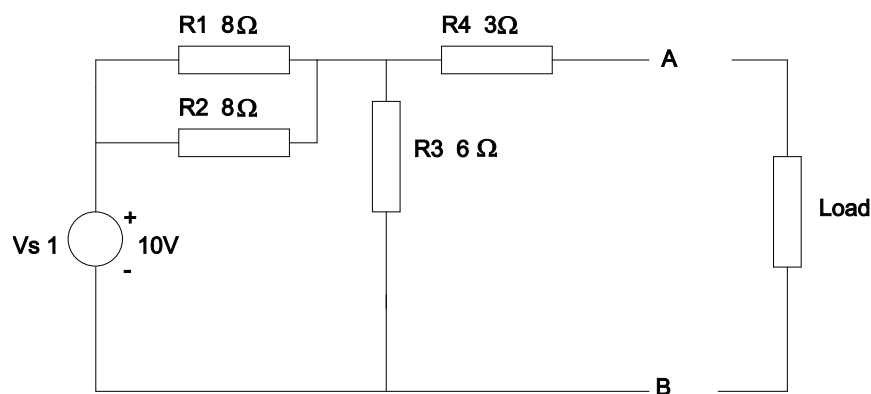


Figure 4

1. Thevenin Equivalent Circuit

Thevenin Voltage V_{TH}

$$R_{12} = \frac{R_1 R_2}{R_1 + R_2} = \frac{8 \times 8}{8 + 8} = 4 \Omega$$

$$V_{TH} = \left(\frac{R_3}{R_{12} + R_3} \right) V_s = \frac{6}{10} \times 10 = 6 \text{ V}$$

Thevenin Resistance R_{TH}

Deactivate the source (replace the voltage source with a short circuit).

$$R_{12} = 4 \Omega$$

$$R_{123} = \frac{R_{12} R_3}{R_{12} + R_3} = \frac{4 \times 6}{4 + 6} = 2.4 \Omega$$

$$R_{TH} = R_{123} + R_4 = 2.4 + 3 = 5.4 \Omega$$

Thevenin Equivalent

$$V_{TH} = 6 \text{ V}$$

$$R_{TH} = 5.4 \Omega$$

[8]

2. Load Resistance for Maximum Power Transfer

$$R_L = R_{TH} = 5.4 \Omega$$

[2]

3. Maximum Power Transferred to the Load

$$P_{\max} = \frac{V_{TH}^2}{4R_{TH}}$$
$$P_{\max} = \frac{6^2}{4 \times 5.4} = \frac{36}{21.6} = 1.67 \text{ W}$$

[2]

4. Norton Equivalent Circuit

Norton Current

$$I_N = \frac{V_{TH}}{R_{TH}} = \frac{6}{5.4} = \boxed{1.11 \text{ A}}$$

Norton Resistance

$$R_N = R_{TH} = 5.4 \, \Omega$$

[3]

Question Three (20 marks)

A series RLC circuit is supplied from a 200 V rms, 50 Hz single-phase AC source, as shown in Figure 5. The circuit consists of a resistor of 8 Ω , an inductor of 32 mH and a capacitor of 800 μF . Calculate:

1. The circuit impedance Z [7]
2. The current flowing in the circuit [1]
3. The voltage across each component [3]
4. The phase angle between voltage and current [2]
5. The value of the net reactance required for the magnitude of the circuit impedance to be 100 Ω . [5]
6. State whether the circuit would be inductive, capacitive or at resonance for the condition found in part (5), giving a reason for your answer. [2]

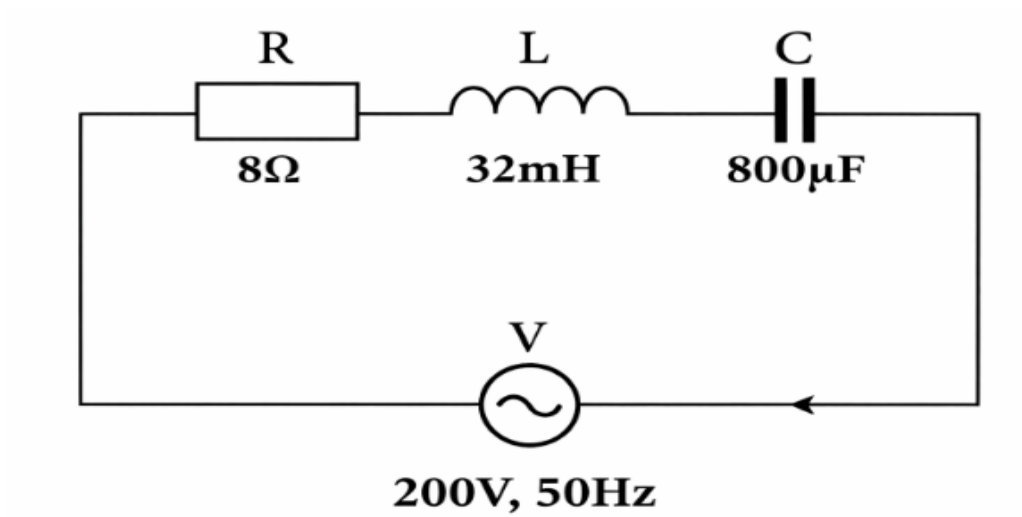


Figure 5

The circuit impedance

$$X_L = 2\pi fL$$

$$X_L = 2\pi(50)(32 \times 10^{-3})$$

$$\mathbf{X_L = 10.05 \, \Omega}$$

[2]

$$X_C = \frac{1}{2\pi fC}$$

$$X_C = \frac{1}{2\pi(50)(800 \times 10^{-6})}$$

$$\mathbf{X_C = 3.98 \, \Omega}$$

[2]

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{8^2 + (10.05 - 3.98)^2}$$

$$\mathbf{Z = 10.04 \, \Omega}$$

[3]

The current flowing in the circuit

$$I = \frac{V}{Z}$$
$$I = \frac{200}{10.07}$$
$$I = 19.9 \text{ A}$$

[1]

The voltage across each component

$$V_R = I \times R = 19.9 \times 8 = 159.2 \text{ V}$$
$$V_L = I \times X_L = 19.9 \times 10.05 = 200 \text{ V}$$
$$V_C = I \times X_C = 19.9 \times 3.98 = 79.2 \text{ V}$$

[3]

The phase angle between voltage and current

$$\tan \phi = \frac{(X_L - X_C)}{R}$$
$$\phi = \tan^{-1} \frac{(10.05 - 3.98)}{8}$$
$$\phi = \tan^{-1} 0.76$$
$$\phi = 37.2^\circ$$

[2]

Net reactance for impedance magnitude of 100 Ω

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$Z^2 = R^2 + (X_L - X_C)^2$$
$$(X_L - X_C)^2 = Z^2 - R^2$$
$$X_L - X_C = \sqrt{Z^2 - R^2} = \sqrt{100^2 - 8^2} = 99.68 \Omega$$

[5]

Nature of the circuit at this condition

The circuit would be inductive.

Reason:

The net reactance is positive ($X = +99.7 \Omega$), meaning the inductive reactance is greater than the capacitive reactance. Therefore, the current would lag the voltage.

[2]

Question Four (30 marks)

- a. Figure 6 shows a single stage common emitter amplifier. Under DC operating conditions, the transistor has a collector current $I_C = 2mA$ and $V_{CE} = 10V$. Assume: $V_{BE} = 0.7V$, $I_E = I_C$ and the base current is negligible compared to the divider current. Calculate:

1. The emitter voltage V_E [2]
2. The base voltage V_B [2]
3. The voltage across R_1 [2]
4. The current going through R_2 [1]
5. The resistance value of R_1 [1]
6. The collector voltage V_C [2]
7. The resistance value of R_C [2]

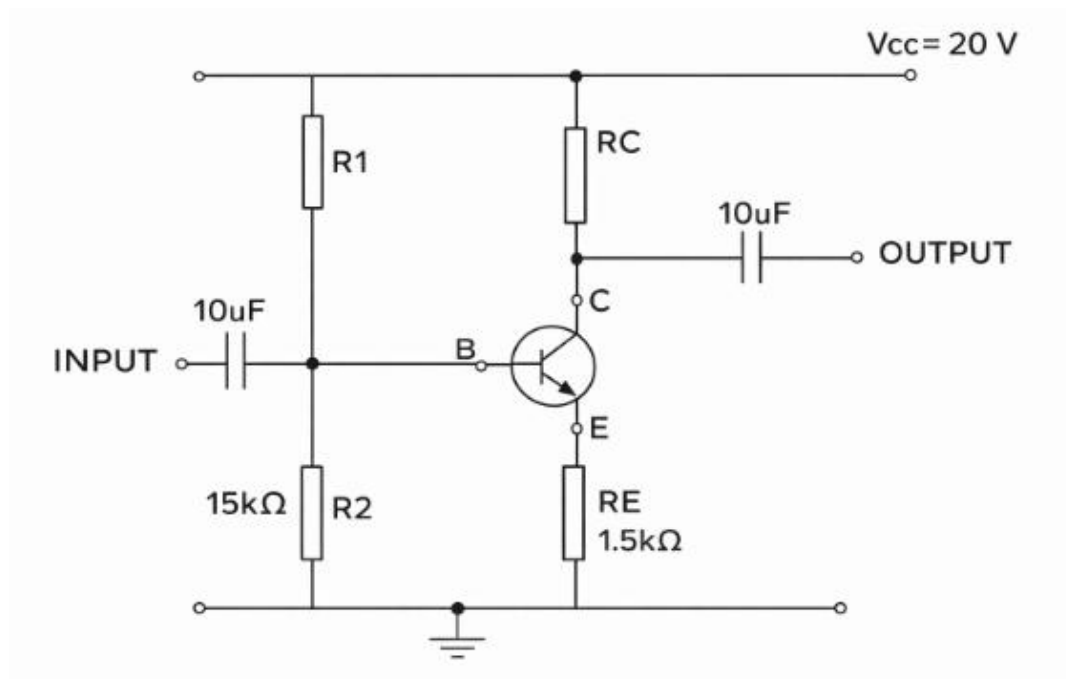


Figure 6

Solutions

1. The emitter voltage V_E .

$$V_{CE} = 10V,$$

$$I_C = 2mA$$

$$\text{Consider } I_C \approx I_E \text{ so } I_E \approx 2mA$$

$$R_E = 1.5K\Omega$$

$$V_E = I_E R_E$$

$$V_E = 2 \text{ mA} \times 1.5 \text{ K}\Omega$$

$$V_E = 2 \times 10^{-3} \times 1.5 \times 10^3$$

$$V_E = 3 \text{ V}$$

2. The base voltage V_B

$$V_B = V_{BE} + V_E$$

$$V_{BE} = 0.7 \text{ V}$$

$$V_B = V_{BE} + V_E = 0.7 \text{ V} + 3 \text{ V} = 3.7 \text{ V}$$

$$V_B = 3.7 \text{ V}$$

3. The voltage across R_1

$$V_{R_1} = V_{CC} - V_B$$

$$V_{R_1} = 20 - 3.7$$

$$V_{R_1} = 16.3 \text{ V}$$

4. The current going through R_2

$$I_{R_2} = \frac{V_B}{R_2} = \frac{3.7}{15 \times 10^3}$$

$$I_{R_2} = 0.25 \text{ mA}$$

5. The resistance value of R_1

$$I_{R_1} = I_{R_2} = 0.25 \text{ mA}$$

$$R_1 = \frac{V_{R_1}}{I_{R_1}} = \frac{16.3}{0.25 \times 10^{-3}}$$

$$R_1 = 65.2 \text{ K}\Omega$$

6. The collector voltage V_C

$$V_{CE} = 10 \text{ V}, \quad V_E = 3 \text{ V}$$

$$V_C = V_{CE} + V_E$$

$$V_C = 10\text{ V} + 3\text{ V}$$

$$V_C = 13\text{ V}$$

7. The resistance value of R_C

$$R_C = \frac{V_{R_C}}{I_C} = \frac{V_{CC} - V_C}{I_C} = \frac{20 - 13}{2 \times 10^{-3}}$$

$$R_C = 3.5\text{ K}\Omega$$

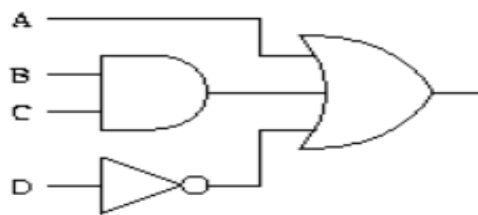
[12]

b. Draw the logic circuit design for the following Boolean equations below.

1. $output = A + BC + \bar{D}$

[3]

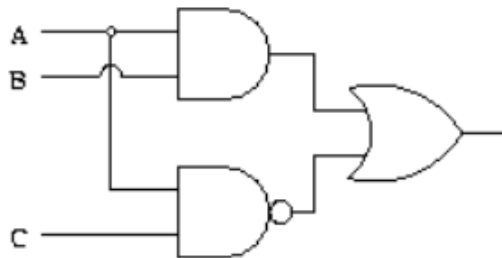
Solution



2. $output = (AB) + \overline{(AC)}$

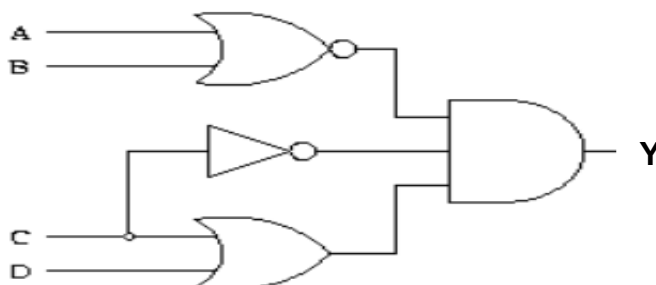
[3]

Solution



c. Write Boolean algebraic expressions for the circuit below.

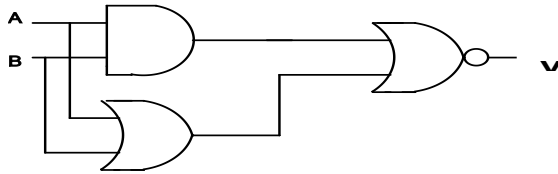
1.



Solution

$$Y = \overline{(A + B)} (C + D) \bar{C}$$

2.



solution

$$Y = \overline{(AB) + (A + B)}$$

$$A + AB = A$$

$$AB + (A + B) = A + B$$

$$Y = \overline{(A + B)}$$

d. Simplify the output function Y using DeMorgan's theorem.

$$Y = \overline{(A + B)(\bar{B} + C)}$$

[6]

$$Y = \overline{(A + B)(\bar{B} + C)}$$

$$Y = \overline{(A + B)} + \overline{(\bar{B} + C)}$$

$$Y = (A + B) + (\bar{\bar{B}} \cdot \bar{C})$$

$$Y = (A + B) + (B \cdot \bar{C})$$

$$Y = A + B + B \cdot \bar{C}$$

$$Y = B + B\bar{C} = B$$

$$Y = A + B$$

END