ii. For the network shown in figure 8, determine the current i(t) when the switch is closed at t= 0 with zero initial conditions. **7** 03 02 02 01

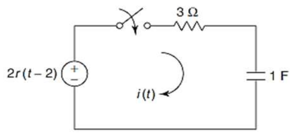


Figure 8

OR iii. In the network of figure 9 , the switch is moved from the position 1 to 2 at t = 0, steady-state condition having been established in the position 1. Determine i (t) for t > 0. **7** 03 02 02 1

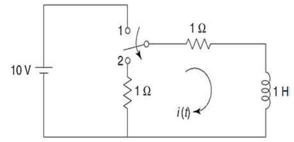


Figure 9

Q.5 i. What does y_{22} represent in Y-parameters? **2** 02 01 05 01

ii. Find Z-parameters for the network shown in figure 10. **8** 03 02 05 1

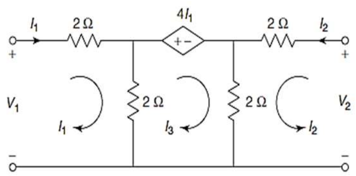


Figure 10

OR iii. Find h-parameters for the network shown in figure 11. **8** 03 02 05 01

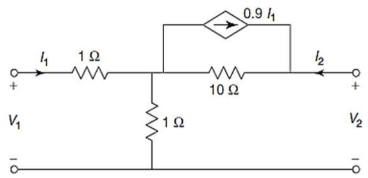


Figure 11

Q.6 i. What is the significance of pole-zero analysis in determining the stability of a system? **2** 02 01 05 01

ii. Determine the Foster-I form realisation of the RC impedance function- **8** 03 02 05 02

$$Z(s) = \frac{(s+1)(s+3)}{s(s+2)(s+4)}$$

OR iii. Determine the Cauer-I form of the RL impedance function- **8** 03 02 05 02

$$Z(s) = \frac{s(s+4)(s+8)}{(s+1)(s+6)}$$

******

Total No. of Questions: 6 *Total No. of Printed Pages:4*

Enrollment No....................................

Faculty of Engineering
End Sem Examination Dec 2024
EC3CO05 Circuit Analysis & Synthesis

Programme: B.Tech. Branch/Specialisation: EC

Duration: 3 Hrs. **Maximum Marks: 60**

Note: All questions are compulsory. Internal choices, if any, are indicated. Answers of Q.1 (MCQs) should be written in full instead of only a, b, c or d. Assume suitable data if necessary. Notations and symbols have their usual meaning.

			Marks	BL	PO	CO	PSO
Q.1	i.	A dependent (controlled) source in a circuit depends on:	**1**	01	01	01	01

(a) The value of another voltage or current in the circuit
(b) The internal resistance of the source
(c) Only the input power supply
(d) The type of circuit configuration

ii. In mesh analysis, which of the following is primarily calculated? **1** 02 01 01 01

(a) Node voltages (b) Branch voltages
(c) Loop currents (d) Equivalent resistance

iii. In the network shown in figure 1, the switch is closed at t=0.With the capacitor uncharged, value of current i at t=0+. **1** 03 02 02 01

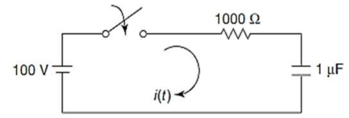


Figure 1

(a) 0 A (b) 0.1 A (c) 100 A (d) 1000 A

iv. The maximum power transfer theorem states that maximum power is transferred from a source to a load when: **1** 02 01 03 01

(a) The load resistance is maximum
(b) The load resistance equals the source resistance
(c) The load resistance is zero
(d) The load resistance is double the source resistance

v. Which property of the Laplace transform states that L [f(t−T) u(t−T)]= e^{-Ts} F(s) ? **1** 02 01 04 01
(a) Linearity (b) Convolution
(c) Frequency Shifting (d) Time Shifting

vi. The Laplace transform of a unit impulse function δ(t−T) is- **1** 01 01 04 01
(a) e^{-Ts} (b) s e^{-Ts} (c) T e^{-Ts} (d) s^T e^{-Ts}

vii. The value of Z_{11} for the network shown in figure 2- **1** 03 02 05 01

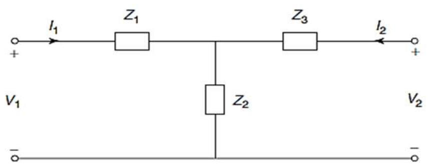


Figure 2

(a) Z_2+Z_3 (b) Z_1 (c) Z_1+Z_2 (d) Z_2

viii. In a two-port network with ABCD parameters, the condition of symmetry is given by: **1** 01 01 05 01
(a) A=D (b) B=C (c) AD−BC=0 (d) A=B

ix. A Hurwitz polynomial is defined as a polynomial where: **1** 02 01 05 01
(a) All coefficients are positive
(b) All roots lie in the right-half of the s-plane
(c) All roots lie in the left-half of the s-plane
(d) All roots are real and positive

x. What is the primary application of the Foster-I form in network synthesis? **1** 02 01 05 01
(a) To design active filters
(b) To ensure stability of the network
(c) To create low-pass and high-pass filters
(d) To achieve the desired impedance characteristics

Q.2 i. What is source transformation in circuit analysis? **2** 02 01 01 01

ii. Find the current in the 5 Ω resistor of the network shown in figure 3. **3** 03 02 02 01

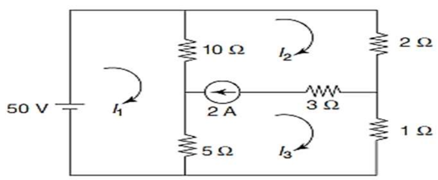


Figure 3

iii. For the circuit shown in figure 4, draw its graph and write the fundamental cutset matrix. **5** 04 02 01 02

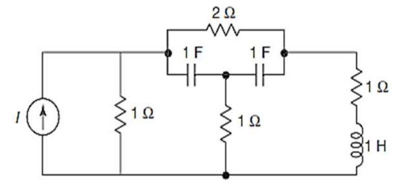


Figure 4

OR iv. For the circuit shown in figure 5, draw its graph and write the tieset matrix. **5** 04 02 01 02

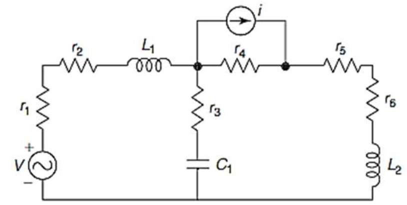


Figure 5

Q.3 i. Define Tellegen's Theorem. **2** 02 01 03 01

ii. Derive the expression for the power delivered to the load in terms of load and source resistance and use it to find the condition for maximum power transfer. **3** 03 01, 02 03 01

iii. Use Superposition theorem to find the current through the 6 Ω resistor shown in figure 6. **5** 03 02 02 01

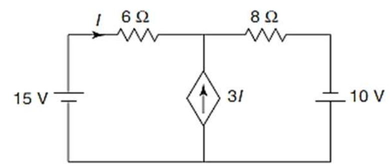


Figure 6

OR iv. Use Thevenin's theorem to find the current through the 1 Ω resistor shown in figure 7. **5** 03 02 02 01

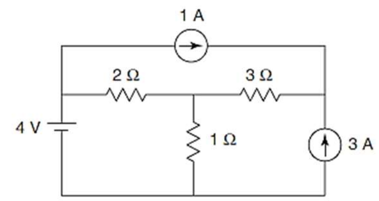


Figure 7

Q.4 i. State the initial value theorem and the final value theorem in Laplace transforms and their significance. **3** 02 01 04 01

Marking Scheme
EC3CO05 (T) Circuit Analysis & Synthesis (T)

Q.1 i) A dependent (controlled) source in a circuit depends on: **1**

a) The value of another voltage or current in the circuit.

ii) In mesh analysis, which of the following is primarily calculated? **1**

c) Loop currents

iii) In the network shown in Figure 1,the switch is closed at t=0.With the capacitor uncharged, value of current i at t=0+. **1**

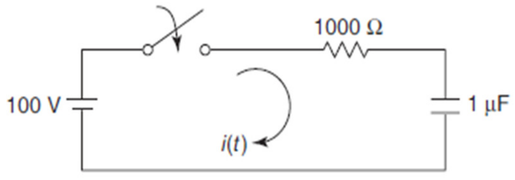


Figure 1

b) 0.1 A

iv) **The Maximum Power Transfer Theorem states that maximum power is transferred from a source to a load when:** **1**

b) The load resistance equals the source resistance.

v) Which property of the Laplace transform states that L [f(t−T) u(t−T)]= e^{-Ts} F(s) ? **1**

d) Time Shifting

vi) The Laplace transform of a unit impulse function δ(t−T) is **1**

a) e^{-Ts}

vii) The value of Z_{11} for the network shown in Figure 2. **1**

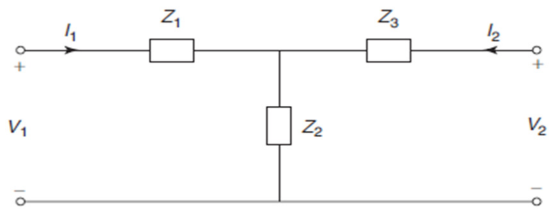


Figure 2

c) Z_1+Z_2

viii) **In a two-port network with ABCD parameters, the condition of symmetry is given by:** **1**

a) A=D

ix) **A Hurwitz polynomial is defined as a polynomial where:** **1**

c) All roots lie in the left-half of the s-plane.

x) **What is the primary application of the Foster-I form in network synthesis?** **1**

d) To achieve the desired impedance characteristics.

Q.2 i. Source transformation is the process of converting a voltage source in series with a resistor into an equivalent current source in parallel with the same resistor, and vice versa. It simplifies circuit analysis. **2**

ii. **Solution** Applying KVL to Mesh 1, **3**

$$50-10(I_1-I_2)-5(I_1-I_3)=0$$

$$15I_1-10I_2-5I_3=50 \quad \ldots(i)$$

Meshes 2 and 3 will form a supermesh as these two meshes share a common current source of 2 A.

Writing current equation for the supermesh,

$$I_2-I_3=2 \quad \ldots(ii)$$

Applying KVL to the outer path of the supermesh,

$$-10(I_2-I_1)-2I_2-1I_3-5(I_3-I_1)=0$$

$$-15I_1+12I_2+6I_3=0 \quad \ldots(iii)$$

Solving Eqs (i), (ii) and (iii),

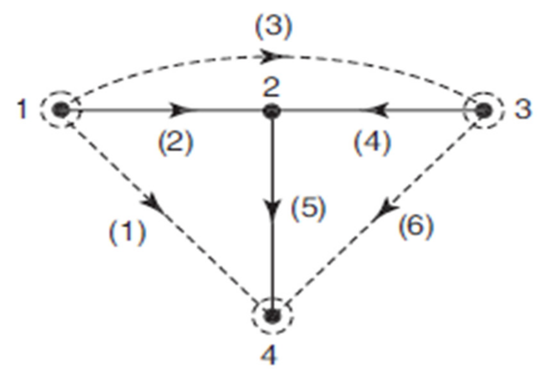
$$I_1=20\text{ A}$$

$$I_2=17.33\text{ A}$$

$$I_3=15.33\text{ A}$$

Current through the 5 Ω resistor $= I_1 - I_3 = 20 - 15.33 = 4.67$ A

iii. **5**

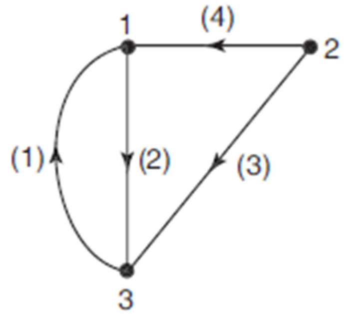


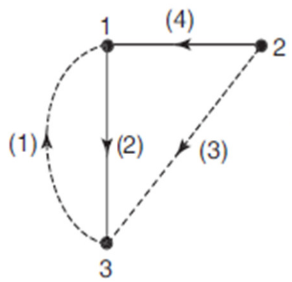
Twigs: {2, 4, 5}
f-cutset 2: {2, 1, 3}
f-cutset 4: {4, 3, 6}
f-cutset 5: {5, 1, 6}

Fundamental Cutset Matrix (Q)

$$Q = \begin{array}{c} \\ 2 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 1 \end{bmatrix} \end{array}$$

OR iv. **5**





Links: {1, 3}
Tieset 1: {1, 2}
Tieset 3: {3, 2, 4}

$$B = \begin{array}{c} \\ 1 \\ 3 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & -1 & 1 & -1 \end{bmatrix} \end{array}$$

Q.3 i. Tellegen's Theorem states that for any electrical network, the sum of power across all branches (the sum of products of voltage and current for each branch) is zero. **2**

ii. **Answer:** The power delivered to the load P_L is given by: **3**

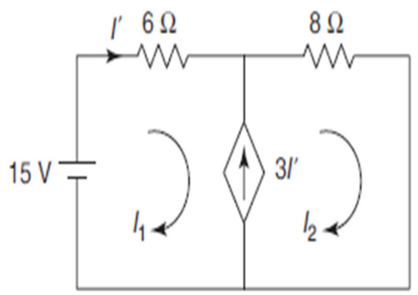
$$P_L = I^2 R_L = \left(\frac{V_s}{R_s + R_L}\right)^2 R_L$$

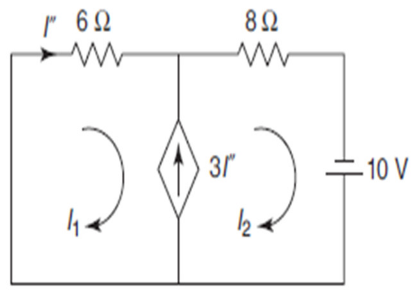
where V_s is the source voltage. Simplifying, we get:

$$P_L = \frac{V_s^2 R_L}{(R_s + R_L)^2}$$

To find the maximum power, take the derivative of P_L with respect to R_L and set it to zero. This yields $R_L = R_s$ as the condition for maximum power transfer.

iii. **5**





$$I' = I_1 \qquad \ldots\text{(i)}$$

Meshes 1 and 2 will form a supermesh.
Writing current equation for the supermesh,

$$I_2 - I_1 = 3I' = 3I_1$$
$$4I_1 - I_2 = 0 \qquad \ldots\text{(ii)}$$

Applying KVL to the outer path of the supermesh,

$$15 - 6I_1 - 8I_2 = 0$$
$$6I_1 + 8I_2 = 15$$

Solving Eqs (ii) and (iii),

$$I_1 = 0.39\text{A}$$
$$I_2 = 1.57\text{A}$$
$$I' = I_1 = 0.39 \text{ A } (\rightarrow)$$

$$I'' = I_1 \qquad \ldots\text{(i)}$$

Meshes 1 and 2 will form a supermesh.
Writing current equation for the supermesh,

$$I_2 - I_1 = 3I'' = 3I_1$$
$$4I_1 - I_2 = 0 \qquad \ldots\text{(ii)}$$

Applying KVL to the outer path of the supermesh,

$$-6I_1 - 8I_2 + 10 = 0$$
$$6I_1 + 8I_2 = 10$$

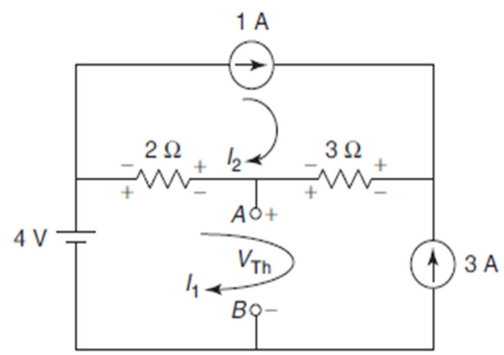
Solving Eqs (ii) and (iii),

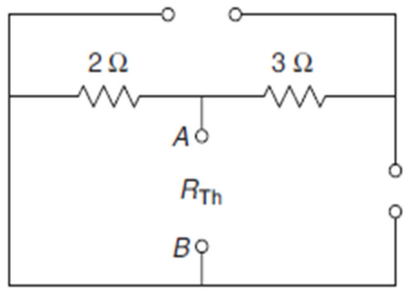
$$I_1 = 0.26 \text{ A}$$
$$I_2 = 1.05 \text{ A}$$
$$I'' = I_1 = 0.26 \text{ A} \quad (\rightarrow)$$

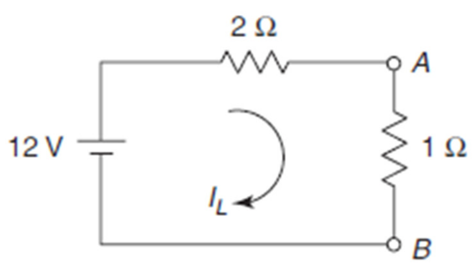
Step III By superposition theorem,

$$I = I' + I'' = 0.39 + 0.26 = 0.65 \text{ A}$$

OR iv. **5**





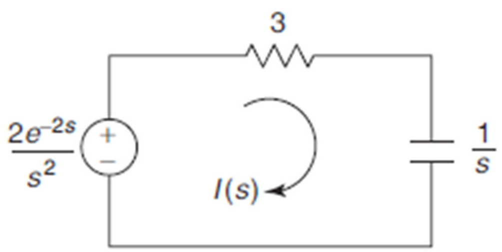


$$I_L = \frac{12}{2+1} = 4\text{ A}$$

Q.4 i. **Answer:** 3

- The **Initial Value Theorem** states: $\lim_{t\to 0^+} f(t) = \lim_{s\to\infty} sF(s)$. It provides the initia value of the time-domain function without needing to compute the inverse Laplace Transform.
- The **Final Value Theorem** states: $\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s)$. It helps determine the steady-state or long-term behavior of the function. These theorems are useful for quickl finding initial and final values in system analysis.

ii. 7



$$\frac{2e^{-2s}}{s^2} - 3\,I(s) - \frac{1}{s}I(s) = 0$$

$$\left(3+\frac{1}{s}\right)I(s) = \frac{2e^{-2s}}{s^2}$$

$$I(s) = \frac{2e^{-2s}}{s^2\left(3+\frac{1}{s}\right)} = \frac{0.67e^{-2s}}{s(s+0.33)}$$

By partial-fraction expansion,

$$\frac{0.67}{s(s+0.33)} = \frac{A}{s} + \frac{B}{s+0.33}$$

$$A = \left.\frac{0.67}{s+0.33}\right|_{s=0} = 2$$

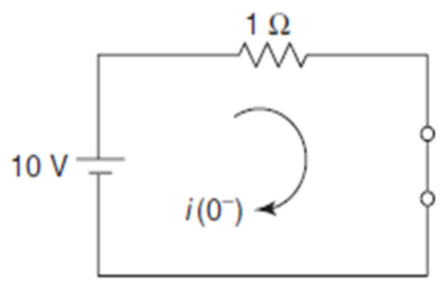
$$B = \left.\frac{0.67}{s}\right|_{s=-0.33} = -2$$

$$I(s) = e^{-2s}\left(\frac{2}{s} - \frac{2}{s+0.33}\right) = 2\frac{e^{-2s}}{s} - 2\frac{e^{-2s}}{s+0.33}$$

Taking inverse Laplace transform,

$$i(t) = 2u(t-2) - 2e^{-0.33(t-2)}u(t-2) \qquad \text{for } t>0$$

OR iii. 7



$$i(0^-) = \frac{10}{1} = 10\text{ A}$$

Since the current through the inductor cannot change instantaneously,

$$i\,(0^+) = 10\text{ A}$$

Applying KVL to the mesh for $t > 0$,

$$-I(s) - I(s) - sI(s) + 10 = 0$$
$$I(s)(s+2) = 10$$
$$I(s) = \frac{10}{s+2}$$

Taking inverse Laplace transform,

$$i\,(t) = 10e^{-2t} \quad \text{for } t > 0$$

Q.5 i. **y_{22}, the output admittance,** is the ratio of output current I2 to output voltage V_2 when the input voltage V_1 is zero. It is given by **2**

$y_{22} = I_2/V_2$ when $V_1 = 0$

ii. **8**

Solution Applying KVL to Mesh 1,

$$V_1 = 2I_1 + 2(I_1 - I_3)$$
$$= 4I_1 - 2I_3$$

Applying KVL to Mesh 2,

$$V_2 = 2I_2 + 2(I_2 + I_3)$$
$$= 4I_2 + 2I_3$$

Applying KVL to Mesh 3,

$$-2(I_3 - I_1) - 4I_1 - 2(I_3 + I_2) = 0$$
$$I_1 + I_2 = -2I_3$$

Substituting Eq. (iii) in Eq. (i),

$$V_1 = 4I_1 + I_1 + I_2$$
$$= 5I_1 + I_2$$

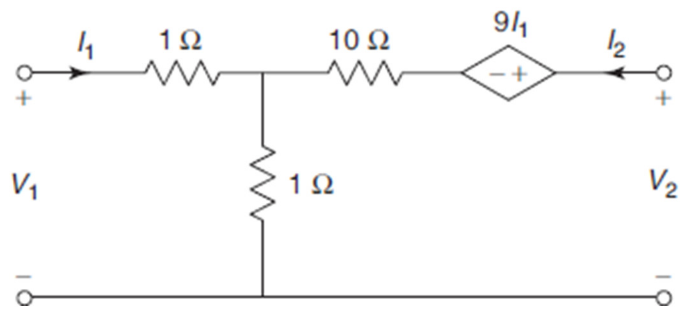
Substituting Eq. (iii) in Eq. (ii),

$$V_2 = 4I_2 - I_1 - I_2$$
$$= -I_1 + 3I_2$$

Comparing Eqs (iv) and (v) with Z-parameter equations,

$$\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} = \begin{bmatrix} 5 & 1 \\ -1 & 3 \end{bmatrix}$$

OR iii. **8**



$$V_1 = 2I_1 + I_2 \qquad \ldots\text{(i)}$$

Applying KVL to Mesh 2,

$$V_2 = 9I_1 + 10I_2 + 1(I_1 + I_2)$$
$$= 10I_1 + 11I_2 \qquad \ldots\text{(ii)}$$

Comparing Eqs (i) and (ii) with Z-parameter equations,

$$\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} = \begin{bmatrix} 2 & 1 \\ 10 & 11 \end{bmatrix}$$

***h*-parameters**

$$h_{11} = \frac{\Delta Z}{Z_{22}} = \frac{12}{11}\,\Omega, \qquad h_{12} = \frac{Z_{12}}{Z_{22}} = \frac{1}{11}$$

$$h_{21} = -\frac{Z_{21}}{Z_{22}} = -\frac{10}{11}, \qquad h_{22} = \frac{1}{Z_{22}} = \frac{1}{11}\,\mho$$

Hence, h-parameters are

$$\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} = \begin{bmatrix} \frac{12}{11} & \frac{1}{11} \\ -\frac{10}{11} & \frac{1}{11} \end{bmatrix}$$

Q.6 i. Pole-zero analysis involves examining the poles and zeros of a system's transfer function. For a system to be stable, all poles must be in the left half of the complex plane (for continuous systems), indicating that system responses decay over time without oscillations. **2**

ii. **8**

Solution

Foster I Form The Foster I form is obtained by the partial-fraction expansion of the impedance function $Z(s)$.

By partial-fraction expansion,

$$Z(s) = \frac{K_0}{s} + \frac{K_1}{s+2} + \frac{K_2}{s+4}$$

where

$$K_0 = sZ(s)\big|_{s=0} = \frac{(1)(3)}{(2)(4)} = \frac{3}{8}$$

$$K_1 = (s+2)Z(s)\big|_{s=-2} = \frac{(-2+1)(-2+3)}{(-2)(-2+4)} = \frac{(-1)(1)}{(-2)(2)} = \frac{1}{4}$$

$$K_2 = (s+4)Z(s)\big|_{s=-4} = \frac{(-4+1)(-4+3)}{(-4)(-4+2)} = \frac{(-3)(-1)}{(-4)(-2)} = \frac{3}{8}$$

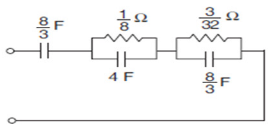
$$Z(s) = \frac{\frac{3}{8}}{s} + \frac{\frac{1}{4}}{s+2} + \frac{\frac{3}{8}}{s+4}$$

The first term represents the impedance of a capacitor of $\frac{8}{3}$ F. The remaining terms represent the impedance of a parallel RC circuit for which

$$Z_{RC}(s) = \frac{\frac{1}{C_i}}{s + \frac{1}{R_i C_i}}$$

By direct comparison,

$$R_1 = \frac{1}{8}\,\Omega, \qquad C_1 = 4\text{ F}$$
$$R_2 = \frac{3}{32}\,\Omega, \qquad C_2 = \frac{8}{3}\text{ F}$$



OR iii. ***Cauer I Form*** The Cauer I form is obtained by continued fraction expansion of $Z(s)$ about the pole at infinity. **8**

$$Z(s)=\frac{s^3+12s^2+32s}{s^2+7s+6}$$

By continued fraction expansion,

$$s^2+7s+6\,\big)\,s^3+12s^2+32s\,\big(\,s\leftarrow Z$$

$$\underline{s^3+7s^2+6s}$$

$$5s^2+26s\,\big)\,s^2+7s+6\,\Big(\,\frac{1}{5}\leftarrow Y$$

$$\underline{s^2+\frac{26}{5}s}$$

$$\frac{9}{5}s+6\,\Big)\,5s^2+26s\,\Big(\,\frac{25}{9}s\leftarrow Z$$

$$\underline{5s^2+\frac{50}{3}s}$$

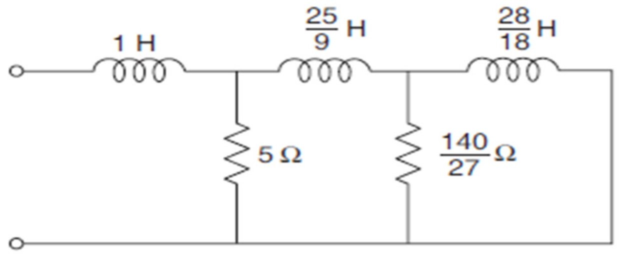
$$\frac{28}{3}s\,\Big)\,\frac{9}{5}s+6\,\Big(\,\frac{27}{140}\leftarrow Y$$

$$\underline{\frac{9}{5}s}$$

$$6\,\Big)\,\frac{28}{3}s\,\Big(\,\frac{28}{18}s\leftarrow Z$$

$$\underline{\frac{28}{3}s}$$

$$0$$



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