Q.2 a. Differentiate between: (4+4)
(i) Unilateral and Bilateral elements (ii) Distributed and lumped elements.

Answer:

(i) **Bilateral elements:** Network elements are said to be bilateral elements if the magnitude of the current remains the same even if the polarity of the applied voltage is changed. The bilateral elements offer the same impedances irrespective of the flow of current. e.g. Resistors, Capacitors, and Inductors.

2

Unilateral elements: Network elements are said to be unilateral elements if the magnitude of the current passing through and element is affected, when the polarity of the applied voltage is changed. The unilateral elements offer varying impedances with variations in the flow of current. e.g. Diodes, Transistors.

2

(ii) **Lumped elements:** When the circuit elements are lumped as single parameters like single resistance, inductance, capacitance then they are known as lumped elements.

2

Distributed elements: When the elements are distributed throughout the entire line, which are not physically separable then they are known as distributed elements.

2

b. A current I = 10t A flows in a condenser C of value 10 µF. Calculate the voltage, charge and energy stored in the capacitor at time t= 1 sec. (8)

Answer:

Given I = 10t Amp.
C = 10µF,

$\frac{dQ}{dt} = I = 10t$, Where Q is the charge across the condenser

2

$$Q = \int_0^\infty I.dt = \int_0^\infty 10t\ dt$$

The voltage across the condenser is given by

$$V = \frac{1}{C}Q = \frac{1}{C}\int I.dt = \int 10t.\ dt$$

$$= \frac{1}{10\times10^{-6}}\times10\frac{t^2}{2} = 5t^2\times10^5 \text{ Volts}$$

2

When t = 1,
The voltage across the condenser is
$V = 5\times10^5$ Volts
The charge across the condenser is given by

$$Q = \int I.\ dt = \int 10t.\ dt = 10\frac{t^2}{2} = 5t^2 \text{ Coloumbs}$$

2

At t = 1, the charge is given by
Q = 5 x 1 = 5 Coulombs
The energy stored in the capacitor is given by

$$E = \int P.\,dt = \int V.\,I\,.dt \text{ Joules}$$

$$= \int \frac{5t^2}{C}.\,I.\,dt = \int \frac{5t^2}{C}.\,10t.\,dt = \int \frac{50t^3}{C}.\,dt = \frac{50}{C} \times \frac{t^4}{4}$$

$$= \frac{50 \times t^4}{10^{-5} \times 4} = 125 \times 10^4 \times t^4 \text{ Joules}$$

2

At t = 1, the energy stored in the capacitor is given by
E = 125 x 10^4 Joules.

Q.3 a. Find Laplace transform of the following:

(i) t^n **(ii)** $\sin at$ **(2+2)**

Answer: (i)

$$L\left[t^n\right] = \int_0^\infty t^n e^{-st} dt$$

$$= \frac{1}{s^{n+1}} \int_0^\infty (st)^n e^{-st} d(st)$$

$$= \frac{1}{s^{n+1}} \int_0^\infty x^n e^{-x} \quad \text{here } x = st$$

$$= \frac{\underline{|n}}{s^{n+1}}$$

(ii)

$$L\left[\sin at\right] = L\left[\sin hj\, at\right]$$

$$= \frac{ja}{s^2+a^2}$$

$$= \frac{a}{s^2+a^2}$$

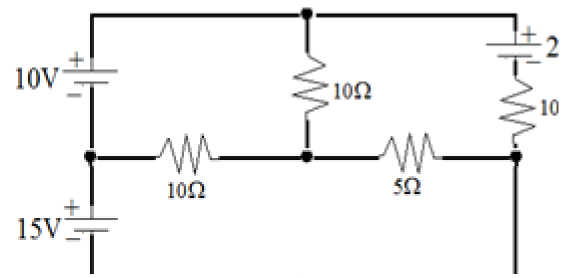
b. Explain shifting theorem of Laplace transform. (4)

Answer: Refer article 7.3, page 275 of Text Book-I

c. **State and prove initial and final value theorems of Laplace transform. (8)**

Answer: Refer article 7.22, page 320 of Text Book-I

Q.4 a. Find the power dissipated in 8 ohm resistors in the circuit shown below if Fig.2 using Thevenin's theorem. (8)



Answer:

To find R_{TH}, open circuiting the 8Ω resistor and short-circuiting the voltage sources

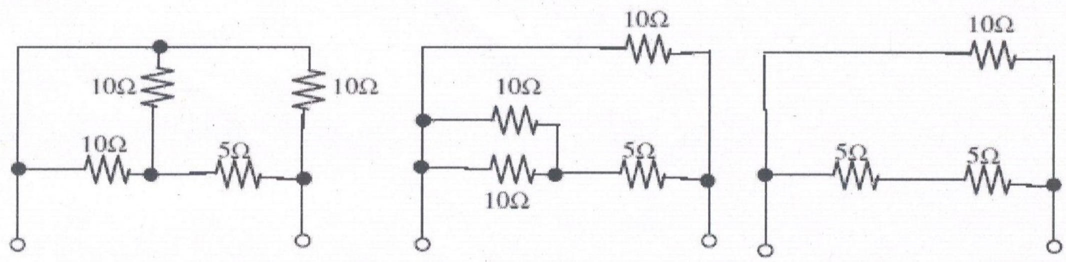
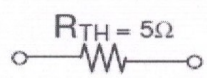


Fig 2.b.2 Fig 2.b.3 Fig 2.b.4

$R_{TH} = 5\Omega$



To find V_{OC},
Let the potential at x be V_1.
On applying kirchoff's current law at point x

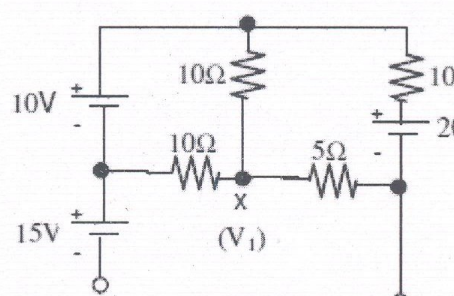


Fig 2.b.5

$$\frac{V_1+20}{10+5}+\frac{V_1}{10}+\frac{V_1+10}{10}=0$$

$$\frac{V_1+20}{15}+\frac{V_1}{10}+\frac{V_1+10}{10}=0$$

$$\frac{2V_1+40+3V_1+3V_1+30}{30}=0$$

$$\Rightarrow 8V_1 + 70 = 0$$

$$\Rightarrow V_1 = -70/8 = -8.75V$$

$\therefore$ Current through 5Ω resistor is

$$\frac{V_1+20}{15} = \frac{20-8.75}{15} = \frac{11.25}{15} A$$

$\therefore$ Drop across 5Ω resistor is

$$5 \times \frac{11.25}{15} = 3.75 \text{ V}$$

2

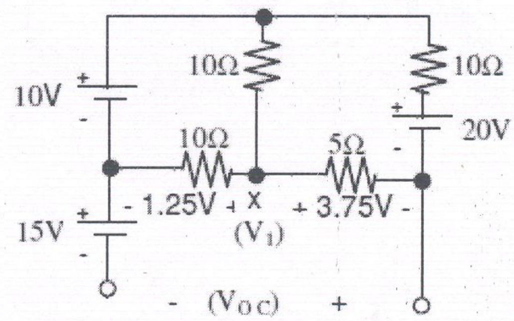


Fig 2.b.6

Current through 10Ω resistor left to point x is

$$\frac{V_1+10}{10} = \frac{10-8.75}{10} = \frac{1.25}{10} = 0.125\text{A}$$

2

Drop across 10Ω resistor is

$$10 \times \frac{1.25}{10} = 1.25\text{V}$$

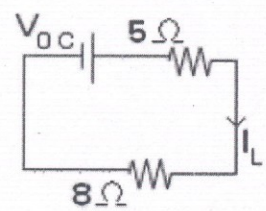


Fig 2.b.7

$\therefore V_{OC} = -15 - 1.25 + 3.75 = -12.5$ V

$$I_L = \frac{V_{OC}}{R_L + R_{TH}} = \frac{12.5}{8+5} = \frac{12.5}{13} = 0.96 \text{ A}$$

Power loss in 8Ω resistor = $(0.96)^2$ x 8 = 7.37 Watts

2

b. State the superposition theorem. Using this theorem find the voltage across the 16 ohm resistor shown in Fig.3. (8)

Answer:

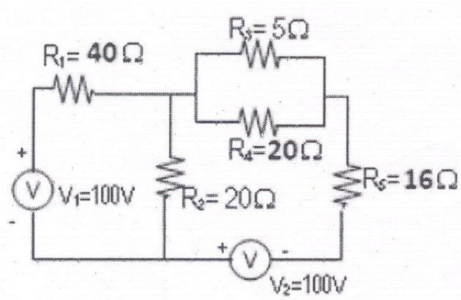


Fig 5.b.1

Superposition theorem: It states that 'if a network of linear impedance contains more than one generator, the current which flows at any point is the vector sum of all currents which would flow at that point if each generator was considered separately and all other generators are replaced at that time by impedance equal to their internal impedances"

2

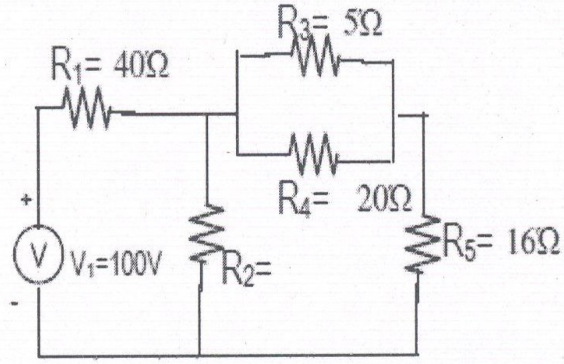
Considering only voltage source V_1 and removing voltage source V_2 as in fig 5.b.2

The equivalent resistance is

$R_{eq} = [((20||5) + 16) || 20] + 40 = [(4 + 16) || 20] + 40$

$R_{eq} = [20 || 20] + 40 = 10 + 40 = 50\Omega$

Current through $R_1 = I_{R1}'$



$$I_{R1}' = \frac{V_1}{R_{eq}} = \frac{100}{50} = 2A$$

2

$$I_{R2}' = \frac{V_x}{R_2} = \frac{20}{20} = 1A$$

Voltage at x is $V_x = 100 - 2 \times 40 = 20$ V

Current through $R_2 = I_{R2}'$

Fig 5.b.2

Considering only voltage source V_2 and removing voltage source V_1 as in fig 5.b.3

The equivalent resistance is

$R_{eq1} = (40 || 20) + (5 || 20) + 16$

$R_{eq1} = 13.33 + 4 + 16$

$R_{eq1} = 33.33\Omega$

Current drawn from V_2

$$\frac{E_2}{R_{eq1}} = \frac{100}{33.33} = 3A$$

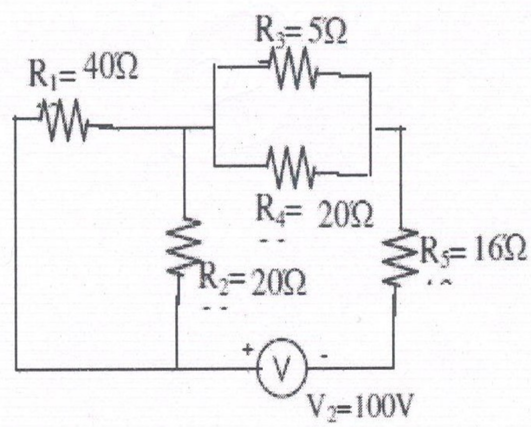


Fig 5.b.3

Current through $R_2 = I_{R2}''$

$$I_{R2}'' = 3 \times \frac{R_1}{R_1 + R_2} = 3 \times \frac{40}{40 + 20} = 2A$$

2

The direction of current in R_2 due to V_2 is upwards, while due to V_1 is downwards.

Hence by superposition theorem the net current in R_2 is $I_{R2} = I_{R2}' + I_{R2}'' = 1 - 2 = -1A$

The current through R_2 is 1A upwards.

2

Q.5 a. Find out the Z parameters and hence the ABCD parameters of the network shown in Fig.4. Check if the network is symmetrical or reciprocal. (10)

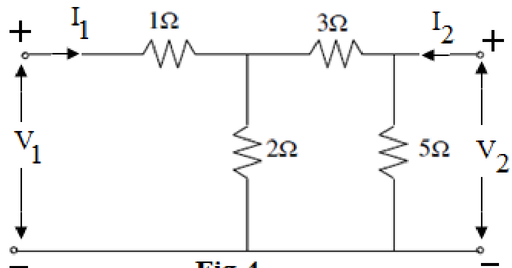


Fig.4

Answer:

On open circuiting the terminals 2-2' as in Fig 5.a.2

Applying Kirchoff's voltage law (KVL) for the first loop

$V_1 = I_1 + 2(I_1 - I_3) = 3I_1 - 2I_3$ --- (1)

Applying KVL for the second loop

$0 = 3I_3 + 5I_3 + 2(I_3 - I_1)$

$0 = 10I_3 - 2I_1$

$10I_3 = 2I_1$

$$I_3 = \frac{2I_1}{10} = \frac{I_1}{5} \qquad \text{---(2)}$$

2

From (1) and (2)

$$V_1 = 3I_1 - \frac{2}{5}I_1 = \frac{13}{5}I_1 \qquad \text{--- (3)}$$

$$V_2 = 5I_3 = I_1 \qquad \text{--- (4)}$$

$$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} = 2.6\ \Omega$$

$$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0} = \frac{I_1}{I_1} = 1\ \Omega$$

2

On open circuiting the terminals 1-1' as in Fig 5.a.3

Applying Kirchoff's voltage law (KVL) for the first loop of Fig 5.a.3

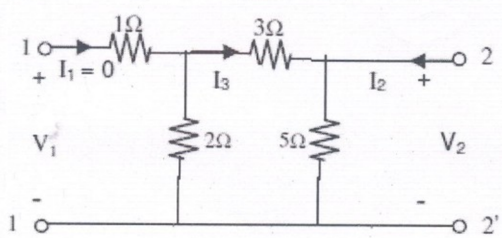


Fig 5.a.3

$V_1 = 2I_3$ --- (5)

Applying KVL for the second loop

$0 = 2I_3 + 3I_3 + 5(I_3 + I_2) = 10I_3 + 5I_2$

$I_2 = -2I_3$ --- (6)

2

$$I_3 = -\frac{1}{2}I_2$$

From (5) and (6)

$$V_1 = -2\times I_3 = \frac{1}{2}\times 2\times I_2 = I_2 \qquad \text{--- (7)}$$

$$V_2 = 5(I_3 + I_2) = 5(-\frac{1}{2}+1)I_2 = \frac{5}{2}I_2 = 2.5I_2 \text{ --- (8)}$$

$$Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0} = 2.5\,\Omega$$

2

$$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0} = 1\,\Omega$$

$$\therefore A = \frac{Z_{11}}{Z_{21}} = \frac{2.6}{1} = 2.6, \quad B = \frac{Z_{11}Z_{22}-Z_{12}Z_{21}}{Z_{21}} = \frac{2.6\times 2.5 - 1\times 1}{1} = \frac{6.5-1}{1} = 5.5\,\Omega,$$

$$\therefore C = \frac{1}{Z_{21}} = 1\,\text{mhos}, \quad D = \frac{Z_{22}}{Z_{11}} = \frac{2.5}{2.6} = 0.96$$

$\Rightarrow A \neq D$

$AD - BC = 2.6\times 0.96 - 5.5\times 1 = -3.004$

2

$\therefore AD - BC \neq 1$

$\therefore$ The circuit is neither reciprocal nor symmetrical.

b. Derive the relationship between Y and ABCD parameter. (6)

Answer:

For a Two port Network, the Y-Parameter equations are given by

$I_1 = Y_{11} V_1 + Y_{12}V_2$ (1)

1

$I_2 = Y_{21} V_1 + Y_{22}V_2$ (2)

The ABCD parameter equations are given by

$V_1 = AV_2 - B I_2$ (3)

1

$I_1 = CV_2 - D I_2$ (4)

From Equations 1 & 2

$Y_{21}V_1 = I_2 - Y_{22}V_2$

$$V_1 = I_2(\frac{1}{Y_{21}}) - (\frac{Y_{22}}{Y_{21}})V_2$$

$$V_1 = (-\frac{Y_{22}}{Y_{21}})V_2 - (-\frac{1}{Y_{21}})I_2 \qquad --(5)$$

$$I_1 = Y_{11}V_1 + Y_{12}V_2 = Y_{11}\left[\left(\frac{-Y_{22}}{Y_{21}}\right)V_2 - \left(-\frac{1}{Y_{21}}\right)I_2\right] + Y_{12}V_2$$

$$I_1 = V_2\left[\frac{-Y_{11}Y_{22} + Y_{12}Y_{21}}{Y_{21}}\right] - \left(\frac{-Y_{11}}{Y_{21}}\right)I_2 \quad 2 \quad --(6)$$

Comparing equations (3) & (5), (4) & (6)

$$A = \frac{-Y_{22}}{Y_{21}}, \qquad B = \frac{-1}{Y_{21}}$$

$$C = \frac{Y_{12}Y_{21} - Y_{11}Y_{22}}{Y_{21}}, \qquad D = \frac{-Y_{11}}{Y_{21}} \quad 2$$

Q.6a. Derive the expression of resonant frequency for a parallel R-L-C circuit in terms of Q, R, L and C. (8)

Answer:

Consider an anti-resonant RLC circuit as shown in Fig. 9.a.i
When the capacitor is perfect and there is no leakage and dielectric loss. i.e. $R_C = 0$ and let $R_L = R$ as shown in Fig 9.a.ii

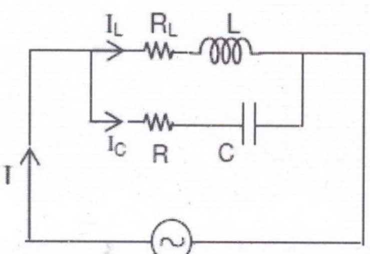


Fig 9.a.i

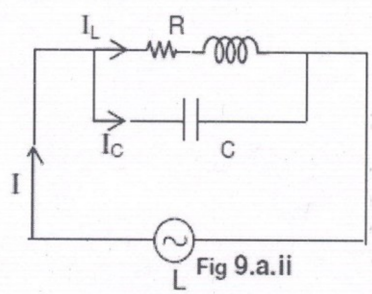


Fig 9.a.ii

The admittance

$$Y_L = \frac{1}{R + j\omega L} = \frac{R - j\omega L}{R^2 + \omega^2 L^2}$$

$$Y_C = j\omega C$$

$$Y = Y_L + Y_C = \frac{R - j\omega L}{R^2 + \omega^2 L^2} + j\omega C$$

$$Y = \frac{R}{R^2 + \omega^2 L^2} + j\left(\omega C - \frac{\omega L}{R^2 + \omega^2 L^2}\right) \quad 2$$

At resonance, the susceptance is zero.

$$\therefore \omega_0 C - \frac{\omega_0 L}{R^2 + \omega_0^{\,2} L^2} = 0 \qquad \Rightarrow \omega_0 C = \frac{\omega_0 L}{R^2 + \omega_0^{\,2} L^2}$$

$$R^2 + \omega_0^{\,2} L^2 = \frac{L}{C}$$

$$\therefore \omega_0^{\,2} = \frac{-R^2}{L^2} + \frac{1}{LC}$$

$$\therefore \omega_0 = \sqrt{\frac{-R^2}{L^2} + \frac{1}{LC}} = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \quad 2$$

If R is negligible $\therefore \omega_0 = \frac{1}{\sqrt{LC}} \therefore f_0 = \frac{1}{2\pi\sqrt{LC}}$ 2

The quality factor, Q of the circuit is given by

$$Q = \frac{\omega_o L}{R} = \frac{1}{\omega_o CR}$$

$$\Rightarrow \omega_o = \frac{RQ}{L} \quad or \quad \omega_o = \frac{1}{QCR}$$ 2

b. For a series resonant circuit, $R = 5\Omega$, L=1H and C=0.25μf. Find the resonance frequency and band width. (8)

Answer:

The resonant frequency of a series resonant circuit is given by

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{1\times 0.25\times 10^{-6}}} = \frac{10^3}{2\pi\times 0.5} = \frac{1000}{\pi} = 318.5Hz$$ 2

The bandwidth of a series resonant circuit is given by,

B.W $= f_2 - f_1 = \frac{f_0}{Q}$, where f_o is the resonant frequency and Q is the quality factor of the circuit and f_1 and f_2 are the upper and lower half power frequencies.

The quality factor Q is given by, $Q \ factor = \frac{\omega_o L}{R} = \frac{L}{R\sqrt{LC}} = \frac{1}{R}\sqrt{\frac{L}{C}}$ 2

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{5}\sqrt{\frac{1}{0.25\times 10^{-6}}} = \frac{2\times 10^3}{5} = 400$$ 2

$$\therefore B.W. = \frac{f_0}{Q} = \frac{318.5}{400} = 0.79625Hz$$ 2

Q.7 a. State the types of distortions in a transmission line. Derive the conditions to eliminate the two types of distortions. (8)

Answer:

Distortion is said to occur when the frequencies are attenuated by different amounts or different frequency components of a complex voltage wave experience different amounts of phase shifts. Distortions in transmission lines are of two types:

Frequency distortion: when various frequency components of the signal are attenuated by different amounts then frequency distortion is said to occur. When the attenuation constant α is not a function of frequency, there is no frequency distortion.

2

$$\alpha = \sqrt{\frac{1}{2}(RG - \omega^2 LC) + \sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)}}$$

To eliminate frequency distortion

$$\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)} = \omega^2 LC + K$$

$$\Rightarrow (R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2) = \omega^4 L^2 C^2 + K^2 + 2K\omega^2 LC$$

$$\Rightarrow R^2 G^2 + \omega^4 L^2 C^2 + \omega^2 (L^2 G^2 + R^2 C^2) = \omega^4 L^2 C^2 + K^2 + 2K\omega^2 LC$$

Comparing the coefficients of ω^2 and the constant terms
K = RG and
Comparing the coefficients of ω^2 and the constant terms
K = RG and

$L^2G^2 + R^2C^2 = 2KLC$

$\therefore L^2G^2 + R^2C^2 = 2RGLC$

$\therefore (LG - RC)^2 = 0$

$\therefore LG = RC$

2

$$\frac{R}{L} = \frac{G}{C}$$

Delay distortion: When various frequency components arrive at different times (delay is not constant) then delay distortion or phase distortion is said to occur. When the

phase velocity is independent of frequency or phase constant β is a constant multiplied by ω, there is no delay distortion or phase distortion.

2

$$\beta = \sqrt{\frac{1}{2}(\omega^2 LC - RG) + \sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)}}$$

To eliminate delay distortion
$\beta = \omega K$

$$\Rightarrow 2\varpi^2 K^2 - \varpi^2 LC + RG = \sqrt{(R^2 + \varpi^2 L^2)(G^2 + \varpi^2 C^2)}$$

$$\Rightarrow (\varpi^2 (2K^2 - LC) + RG)^2 = (R^2 + \varpi^2 L^2)(G^2 + \varpi^2 C^2)$$

$$\Rightarrow \varpi^4 (2K^2 - LC)^2 + R^2 G^2 + 2\varpi^2 (2K^2 - LC)RG = R^2 G^2 + \varpi^4 L^2 C^2 + \varpi^2 (L^2 G^2 + R^2 C^2)$$

Comparing the coefficients of ω^4 and ω^2

$(2K^2 - LC)^2 = L^2C^2$

$4K^4 + L^2C^2 - 4K^2 LC = L^2C^2$

$2K^2(K^2 - LC) = 0$

K = 0 or

$K = \sqrt{LC}$

$L^2G^2 + R^2C^2 = 2RG(2K^2 - LC)$

$L^2G^2 + R^2C^2 = 2RG(2LC - LC)$

$\therefore L^2G^2 + R^2C^2 = 2RGLC$

$\therefore (LG - RC)^2 = 0$

$\therefore LG = RC$

$\frac{R}{L} = \frac{G}{C}$

2

$\therefore$ The condition to eliminate both the frequency and delay distortions is

$\frac{R}{L} = \frac{G}{C}$

b. A generator of 1V, 1000Hz supplies power to 1000 Km long open wire line terminated in its characteristic impedance Z_0 and having the following parameters. R = 15 ohm, L=0.004H, C = 0.008µF, G = 0.5µmhos. Calculate the characteristic impedance, propagation constant and the phase velocity. (8)

Answer:

Given R = 15Ω, L = 0.004H, C = 0.008µF, G = 0.5µmhos.

$\omega = 2\pi f = 2 \times 1000\pi = 2000 \times 3.14 = 6280$ rad/sec

$Z = R + j\omega L = 15 + j \times 6280 \times 0.004 = 15 + j\,25.13 = 29.26\angle 59^0$

2

$Y = G + j\omega C = 0.5 \times 10^{-6} j \times 6280 \times .008 \times 10^{-6} = 10^{-6}(0.5\, j \times 50.24)$

$Y = 50.25 \times 10^{-6} \angle 89.43^0$

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} = \sqrt{\frac{29.26}{50.25 \times 10^{-6}}}\,\frac{1}{2}\angle 59^0 - 89.43^0 = 763\angle -15.22^0$$

2

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \sqrt{29.26 \times 50.25 \times 10^{-6}}\,\frac{1}{2}\angle 59^0 + 89.43^0$$

$$\gamma = 0.038\angle 74.22^0 = 0.038(\cos 74.22^0 + j\sin 74.22^0) = 0.0103 + j0.04 = \alpha + j\beta$$

$\alpha = 0.0103$ Np/Km , $\beta = 0.04$ rad/Km

2

Phase velocity (v_p)

$$v_p = \frac{\omega}{\beta} = \frac{2\pi \times 1000}{0.04} = 157080\ km/\sec$$

2

Q.8 a. Explain single stub impedance matching of lines. (8)

Answer:

b. Explain the basis for construction of Smith chart. Illustrate as to how it can be used as an admittance chart. (8)

Answer:

The use of circle diagram is cumbersome, i.e. S and βl circles are not concentric, interpolation is difficult and only a limited range impedance values can be obtained in a chart of reasonable size. The resistive component, R and reactive component, X of an impedance are represented in a rectangular form while R and X of an impedance are represented in circular form in the Smith charts. Smith charts can be used as impedance charts and admittance charts. If the normalized admittance is Y = Y/YO = g – jb • Any complex admittance can be shown by a single point, (the point of intersection R/YO circle and j X/ZO) on the smith chart. Since the inductive resistance is negative susceptance, it lies in the region below the horizontal axis, and since capacitive reactance is positive susceptance, it lies in the region above the horizontal axis.
• The points of voltage maxima lie in the region 0 to 1 on the horizontal axis since the conductance is equal to 1/S at such points. The points of voltage minima lie in the region 1 to 0 on the horizontal axis, since the conductance is equal to S at such points.
• The movement in the clockwise corresponds to travelling from the load towards generator and movement in the anti-clockwise corresponds to travelling from the generator towards load. • Open circuited end will be point A and short circuited end will be B

Q.9 a. Design a constant K band pass filter section having cut off frequencies of 2 KHz and 5 KHz and a nominal impedance of 600 ohm. Draw the configuration of the filter. (8)

Answer:

According to the design equations

$$L_1 = \frac{R_0}{\pi(f_2 - f_1)} = \frac{600}{\pi(5000-2000)} = 63.68mH$$

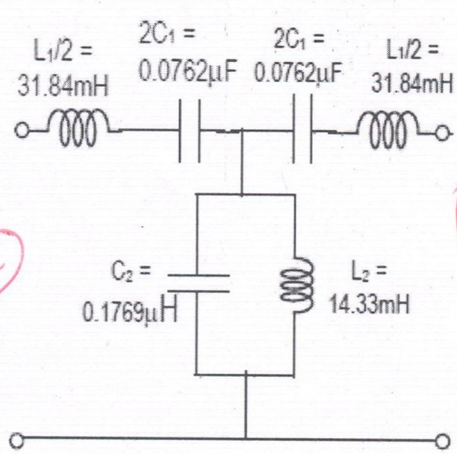
$$\frac{L_1}{2} = \frac{63.68}{2} = 31.8mH$$

$$C_1 = \frac{(f_2 - f_1)}{4\pi R_0 f_1 f_2} = \frac{5000-2000}{4\times\pi\times600\times2000\times5000} = 0.0381\mu F$$

$$2C_1 = 2\times0.0381 = 0.0762\mu F$$

$$L_2 = \frac{R_0(f_2 - f_1)}{4\pi f_1 f_2} = \frac{600(5000-2000)}{4\times\pi\times2000\times5000} = 14.33mH$$

$$C_2 = \frac{1}{\pi R_0(f_2 - f_1)} = \frac{1}{\pi\times600(5000-2000)} = 0.1769\mu F$$



b. Write short notes on: **(4+4)**
  (i) Low-pass filter and its approximation/design
  (ii) Symmetrical Lattice attenuator

TEXT BOOKS

1. **Network Analysis; G. K. Mittal; 14th Edition (2007) Khanna Publications; New Delhi**
2. **Transmission Lines and Networks; Umesh Sinha, 8th Edition (2003); Satya Prakashan, Incorporating Tech India Publications, New Delhi**