Q2 (a) A capacitor of 4μF capacitance is charged to a potential difference of 400Vand then connected in parallel with an uncharged capacitor of 2 μF capacitance. Calculate potential difference across the parallel capacitors.

Answer

Sol. :- Capacitance of first capacitor, $C_1 = 4\ \mu F = 4x10^{-6}$ F

Voltage across first capacitor = 400 V

Charge on the capacitor $Q_1 = C_1 V_1$

$= 4 X 10^{-6} x 400$

$= 1600 x 10^{-6}$ C

Capacitance of second capacitor, $C_2 = 2\ \mu F = 2 x 10^{-6}$ F

when capacitor C_1 and C_2 are connected in parallel

Total capacitance, $C = C_1 + C_2 = 4 + 2 = 6\ \mu F$

$= 6 x 10^{-6}$ F

The charge on capacitor C_1 will be shared by the capacitor C_2.

Therefore, total charge on the two capacitors when connected in parallel,

$Q = Q_1 = 1600 x 10^{-6}$ C

P. d. across the parallel capacitor, V = Q/C

$= 1600 x 10^{-6} /6 x 10^{-6}$

= **266.67 V** *(Ans.)*

Q2 (b) Differentiate between current source and voltage source. Draw and explain the characteristics of ideal and practical sources.

Answer

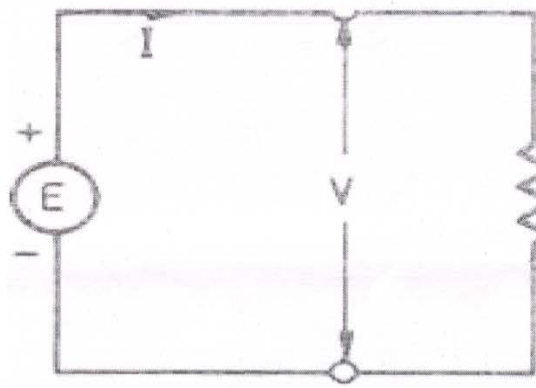
Sol.

Voltage Source:-

A voltage source is a source of electrical energy that supplies electrical energy to the load at a constant voltage. The source terminal voltage remains constant.

Ideal Voltage source:-

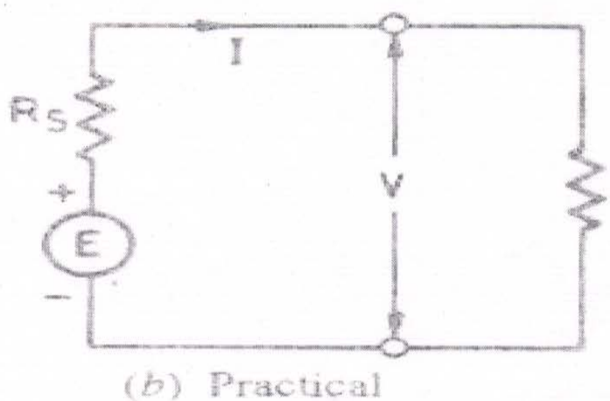
If the internal resistance of a voltage source is zero, the voltage across the source (the emf source) is equal to the terminal voltage (voltage across the load), and is independent of the amount of load current, In other words, the voltage of ideal voltage source is independent of load, This type of source is called ideal voltage source



Practical Voltage source:-

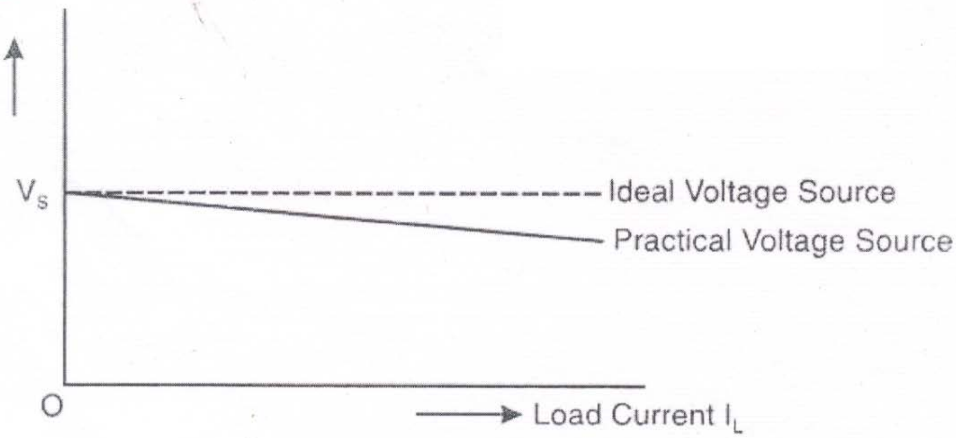
A practical voltage source is one whose internal resistance is not zero. The terminal voltage, in such cases is less than source e,m.f by the drop across the internal resistance Rs.

$V = E - I.R_S = I.R$



(b) Practical

CHARACTERISTICS:-

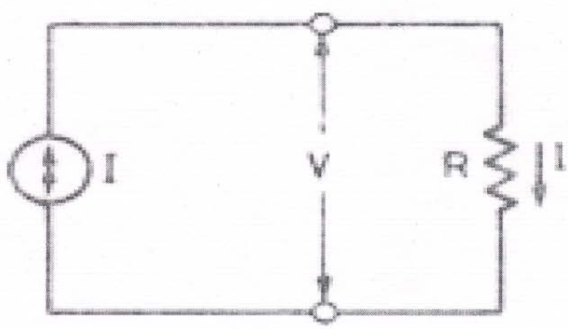


Current Source:-

A current source is a source of electrical energy that supplies electrical energy to the load with a constant current. The source current remains constant.

Ideal current Source:-

It is such a source whose internal conductance is zero ($g_s = 0$ or $R_s = \infty$), the resistance being in parallel with the source. The current of an ideal current source is independent of the load resistance R.

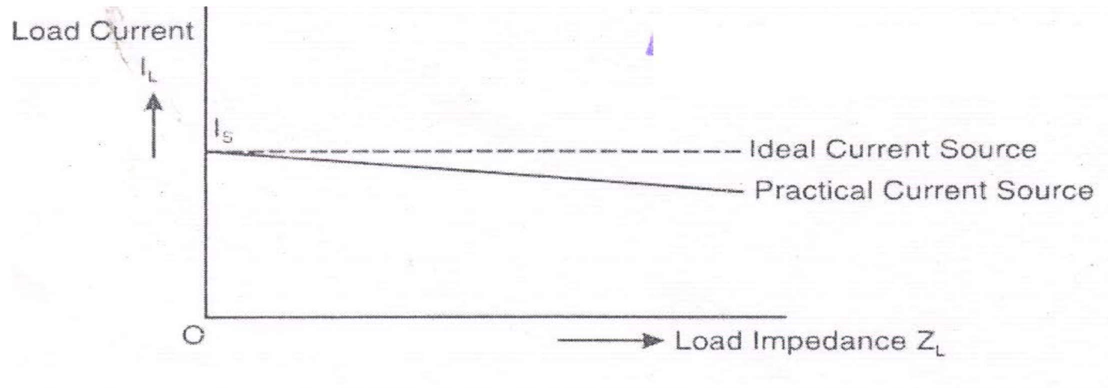


Practical current source:-

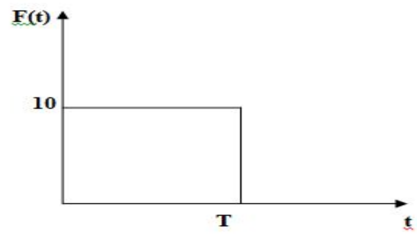
A practical current source is one whose internal conductance is not zero. In such cases, the current supplied by the current source is dependent of the load resistance and is given by

$$I = I_L + I_S$$

Characteristics:-



Q3 (a) Determine the laplace transform of the pulse shown in Fig.1.



Answer:

Sol.

We know $F(s) = \mathcal{L}\{f(t)\} = \int_0^{\infty} f(t)\, e^{-st}\, dt$

For the given wave form of pulse

$$F(s) = \int_0^T 10.\, e^{-st}\, dt$$

$$= 10.\left[\frac{e^{-st}}{-s}\right]_0^T$$

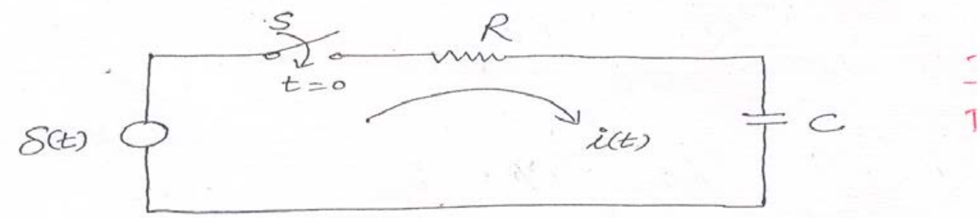
$$= \frac{10}{-s}\left[e^{-st}\right]_0^T$$

$$= \frac{10}{-s}\left[e^{-sT} - 1\right]$$

$$= \frac{10}{s}\left[1 - e^{-sT}\right]$$ Ans.

Q3 (b) Derive an expression for the current i(t) in a series R-C circuit when it is excited by an impulse input with zero initial conditions.

Answer



For zero initial conditions in the circuit above:

$$\boxed{\frac{1}{C}\int_{-\infty}^{t} i(t)\,dt + R\,i(t) = \delta(t)}$$

taking laplace transform of above, we get

$$\frac{1}{Cs} I(s) + R\,I(s) = 1$$

or $$I(s)\left[\frac{1}{Cs} + R\right] = 1$$

or $$I(s) = \frac{1}{\frac{1}{Cs} + R}$$

$$= \frac{1}{R}\left[\frac{1}{\frac{1}{RCs} + 1}\right]$$

$$= \frac{s}{R\left[\frac{1}{RC} + s\right]}$$

adding and subtracting $\frac{1}{RC}$ in numerator.

$$\frac{1}{R}\left[\frac{s + \frac{1}{RC} - \frac{1}{RC}}{s + \frac{1}{RC}}\right]$$

$$\frac{1}{R}\left[1 - \frac{1}{RC}\,\frac{1}{s + 1/RC}\right]$$

$$\frac{1}{R}\left[1 - \frac{1}{RC}\,\frac{1}{s + \frac{1}{RC}}\right] \text{ Ans.}$$

Q4 (a) State and prove maximum power transfer theorem.

Answer

Maximum power transfer theorem:

A resistive load extracts maximum power from a network when the load resistance equals the resistance of the network as viewed from the output terminals, with all energy sources removed, leaving behind their internal resistances.

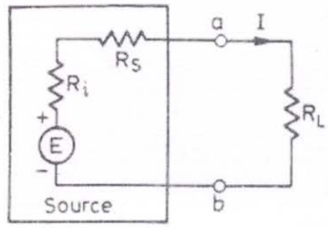


Fig. above shows a simplest resistive network in which a load resistance R_L is connected across the terminals a and b of the network. The network consists of a generator e.m.f E and internal resistance R_i along with a series resistance R_s.

Let, $R = (R_i + R_s)$ = Internal resistance of the network as viewed from a and b.

According to maximum power transfer theorem, RL will abstract maximum power from the network when

$R_L = R$

Proof :

Circuit current $I = \frac{E}{R_L + R}$

Power consumed by load

$$P_L = I^2 R_L$$
$$= \frac{E^2}{(R_L+R)^2} R_L$$

For P_L to be maximum

$$\frac{dP_L}{dR_L} = 0$$

Now $\frac{dP_L}{dR_L} = E^2 \left[\frac{(R_L+R)^2 - 2R_L(R_L+R)}{(R_L+R)^4} \right] = 0$

$$(R_L+R)^2 - 2R_L(R_L+R) = 0$$
$$R_L^2 + R^2 + 2RR_L - 2R_L^2 - 2R_LR = 0$$

or $R^2 - R_L^2 = 0$

$$R^2 = R_L^2$$

or $\boxed{R_L = R}$

Q4 (b) Using Thevenin's theorem, find out current in the resistance connected across the terminals AB shown in Fig.2

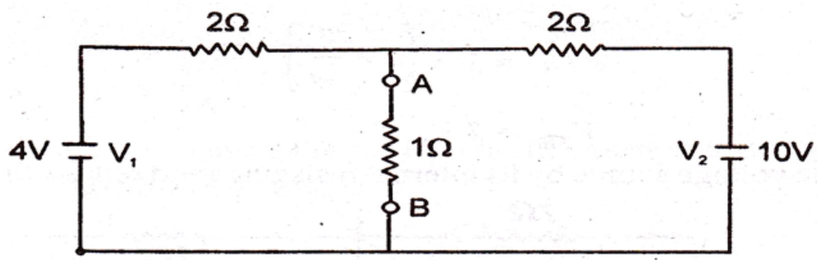
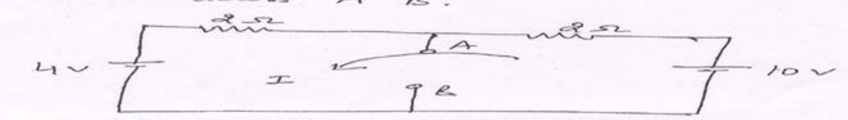


Fig.2

Answer

Sol. :-

For calculating thevenin's voltage, remove resistance connected across A B.



$10 = 2I + 2I + 4$ (K.V.L.)

or $10 = 4I + 4$

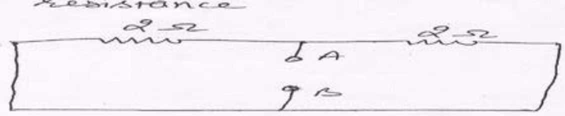
so $I = \frac{10-4}{4} = 1.5A$

Now $V_{TH} = 4 + 1.5 \times 2$

$= 4 + 3$

$= 7V$

For R_{TH}, replace voltage source by it's internal resistance

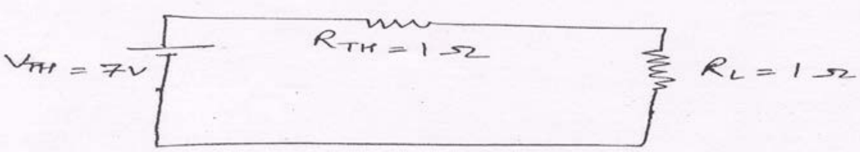


Seeing the circuit through A B

$R_{TH} = 2 // 2$ (Parallel resistors)

$= \frac{2 \times 2}{2+2} = 1\Omega$

So the ckt. reduces to



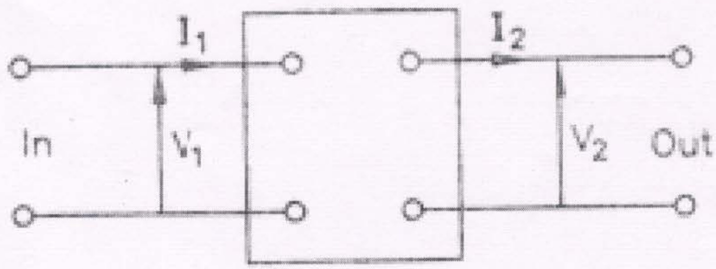
So $I_L = \frac{7}{1+1} = \frac{7}{2} = \underline{3.5A}$ Ans

Q5 (a) Derive an expression for the transmission parameters of a two port network.

Answer

Sol. :-

It is conventional to designate the input port as sending end and the output port as receiving end while representing ABCD parameters.



Here, the ABCD parameter equations are given as

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix} \quad \text{.....(1)}$$

such that $V_1 = AV_2 + B(-I_2)$ .....(2)

and $I_1 = CV_2 + D(-I_2)$ .....(3)

Assuming the receiving end to be open-circuited, $I_2 = 0$

This gives, from equation (2)

$A = V_1/V_2$

and from equation (3)

$C = I_1/V_2$

Being a ratio of voltages, 'A' is called reverse voltage ratio and does not have any unit.

'C' is known as transfer admittance and has the unit mho.

Next, let us assume that the receiving end be short-circuited. Then from equations (1) and (3), with V2 = 0,

$B = V_1/(-I_2)$

$D = I_1/(-I_2)$

D' being a ratio of two currents, it is called reverse current ratio; it is an unit less quantity. While 'B is expressed in ohm and is termed as transfer impedance.

Q5 (b) Is it possible for one class to be a friend of another class? Demonstrate this using a suitable C++ program. Find Z parameters for the circuit shown in Fig.3. Also draw equivalent circuit of the network using Z parameters.

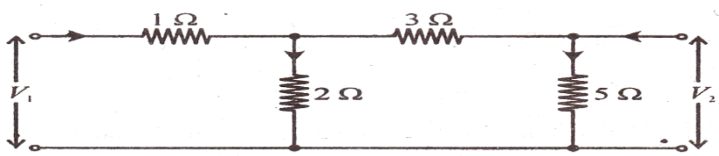


Fig.3

Answer

Sol. :-

From Fig.–1

Condition I when $I_2 = 0$

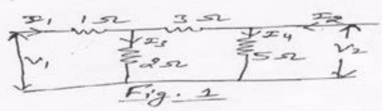


Fig. 1

$Z_{11} = \frac{V_1}{I_1}\Big|_{I_2=0}$

= Impedance seen from Input port

$Z_{11} = [(5+3)\,||\,2] + 1$

$= \frac{8\times2}{8+2} + 1$

$= \frac{16}{10} + 1$

So $\boxed{Z_{11} = 2.6\ \Omega}$ Ans

$Z_{21} = \frac{V_2}{I_1}\Big|_{I_2=0}$

Now $V_2 = 5 I_4$

$I_4 = \frac{I_1 \times 2}{3+5+2} = \frac{2I_1}{10} = \frac{I_1}{5}$

$\therefore V_2 = 5 I_4$

$= 5 \times \frac{I_1}{5} = I_1$

$\therefore \boxed{Z_{21} = \frac{V_2}{I_1} = \frac{I_1}{I_1} = 1\ \Omega}$, Ans

Condition II when $I_1 = 0$

$Z_{22} = \frac{V_2}{I_2}\Big/_{I_1=0}$

= Impedance seen from output port

$= (3+2)\,||\,5$

$\boxed{Z_{22} = \frac{5\times5}{5+5} = 2.5\ \Omega}$ Ans.

$Z_{12} = \frac{V_1}{I_2}\Big/_{I_1=0}$

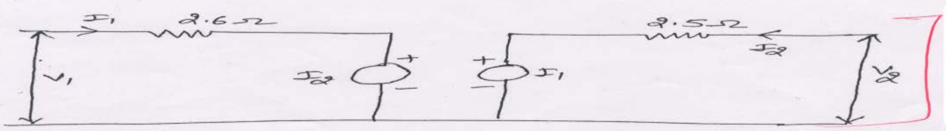
$V_1 = 2 I_3$

$I_3 = \frac{I_2 \times 5}{3+2+5} = 0.5 I_2$

or $V_1 = 2 I_3 = 2 \times 0.5 \times I_2$

$= I_2$

$\boxed{Z_{12} = \frac{V_1}{I_2} = \frac{I_2}{I_2} = 1\ \Omega}$ Ans



Equivalent Circuit

Q6 (a) Determine the parameters of an RLC series circuit that will resonate at 1000 Hz, has a bandwidth of 100 Hz and draws 16 W power from a 200 V generator operating at the resonant frequency of the circuit.

Answer

Sol.

At resonant frequency, $X_L = X_C$

and $Z = R$

V_R = supply voltage = 200V

$$R = \frac{V_R^2}{P}$$

where Power $P = 16W$

$$\therefore \quad R = \frac{(200)^2}{16} = 2500\Omega$$

$$Q \text{ factor} = \frac{F_r}{\text{Bandwidth}}$$

$$= \frac{1000}{100} = 10$$

But $Q = \dfrac{X_L}{R} = \dfrac{2\pi F_r L}{R}$

$$\therefore L = \frac{Q \cdot R}{2\pi F_r} = \frac{10 \times 2500}{2\pi \times 1000}$$

$$\boxed{L = 3.98H} \text{ Ans}$$

Also at resonance

$$2\pi F_r L = \frac{1}{2\pi F_r C}$$

or $$C = \frac{1}{(2\pi F_r)^2 L} = \frac{1}{(2\pi \times 1000)^2 \times 3.98}$$

or $$\boxed{C = 6.36 \times 10^{-9} F} \text{ Ans.}$$

Q6 (b) What is series resonance? Derive an expression for :

(i) resonant frequency

(ii) circuit impedance

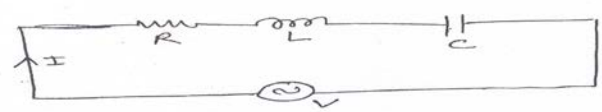
(iii) power factor

(iv) circuit current at resonance

Answer:

Ans:- An a.c. circuit is said to be in resonance when applied voltage and circuit current are in phase. In the condition of resonance, inductive reactance is equal to capacitive reactance.

Series resonance:



A series circuit is at resonance, when the inductive reactance is equal to capacitive reactance.

i.e. $X_L = X_C$

or $2\pi f_r L = \frac{1}{2\pi f_r C}$

$f_r^2 = \frac{1}{4\pi^2 LC}$

or $\boxed{f_r = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}}$ Ans.

Impedance in series circuit

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

But at resonance $X_L = X_C$

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

or $\boxed{Z_r = R}$ (at resonance) Ans

Power factor $\cos\phi = \frac{R}{Z}$

at resonance $Z = R$

$\therefore \quad \boxed{\cos\phi_r = \frac{R}{R} = 1}$ Ans.

Current in circuit $I = \frac{V}{Z}$

at resonance $Z = R$

$\therefore \quad \boxed{I_r = \frac{V}{R}}$ Ans

Curves for impedance and current Vs frequency is given below:

Q7 (a) Explain the factors causing distortion in a transmission line and methods to minimise distortion

Answer

Causes of distortion:

Distortion is caused due to the following three reasons:

(i) The characteristic impedance of the line varies with change in frequency. The line should be terminated in impedance that does not vary with frequency;

(ii) The attenuation of the line varies with frequency. Hence waves of different frequencies are attenuated by different amounts.

(iii) The velocity of propagation varies with frequency. Hence waves of different frequencies arrive at different times at the end of the line.

Methods to Minimise Distortion:

Basically, there are two ways to minimise distortion. The first one is to achieve the condition R/L = G/S. Normally in transmission lines, R/L >> G/L. Hence, the condition can be fulfilled by any of following three ways.

(i) **By decreasing the value of R:** If we decrease, the value of R for a line, the condition of minimum distortion can be achieved. It will also reduce I^2R losses involved with line. But it will require a large conduction, making the system expensive. Also, reduction of R will decrease Z_0, that can further result in reflections from load. Hence, the method is not practically efficient

(ii) **By increasing the value of L:** This is the best method as it can be easily achieved. It also reduces α and improves value of Z_0, The only drawback associated with this method is that it requires additional amount of reactive power in the line.

(iii) **By decreasing value of C**. The value of C can be decreased by increasing the spacing between Capacitor plates. It also reduces attenuation i.e. α, but it increases Z_0 abnormally, that is not acceptable

The **second method** to minimise distortion is use of equalizers. Equalizers are the networks having attenuation characteristics just opposite to that of the transmission line. Hence, the total attenuation becomes constant for a particular frequency range. The use of equalizer also reduces delays distortion. It is used in high quality transmission.

Q7 (b) Explain primary constants of a transmission line and draw the equivalent circuit of transmission line using these constants.

Answer

Ans:

Primary constants/distributed constants of transmission line

These are the electrical properties of a transmission line that depict its behaviour when any signal travels through it. These properties are inbuilt for transmission line and are in dependent of transmission line length. These are:

(i) Loop inductance/unit length (l)
its unit is henry/km.

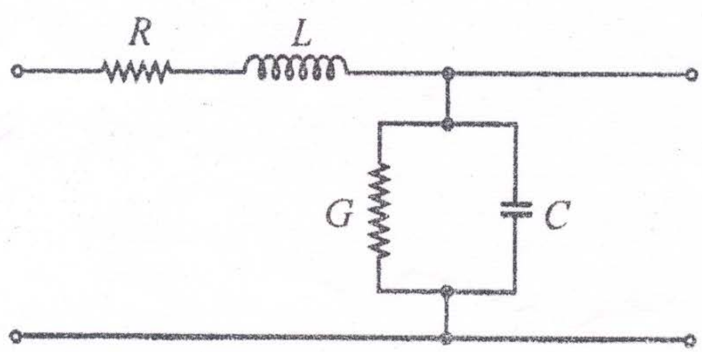
(ii) Loop resistance/Unit length (r)
its unit is ohm/km.

(iii) Shunt capacitance/Unit length (c)
its unit is farad/km.

(iv) Shunt conductance/Unit length (g)
its unit is mho/km.

The constants l,r,c and g are assumed to be distributed throughout the entire transmission line.

Equivalent circuit representation of transmission line:



The total series impedance of the circuit becomes,

$Z = (R + j\omega L)\ \Omega/km$

and total shunt admittance becomes,

Q8 (a) A high frequency transmission line consists of a pair of open wires having a distributed capacitance of 0.01 μF/km and distributed inductance of 4 mH/km. Calculate its characteristic impedance and propagation constant at a frequency of 10 MHz.

Answer

$L = 4 mH/Km$

$C = .01\ \mu F/Km$

$f = 10 MHz$

for a lossless line (where $R=0$ and $G=0$)

Characteristics impedance

$$Z_0 = \sqrt{\frac{L}{C}}$$

$$= \sqrt{\frac{4\times10^{-3}}{.01\times10^{-6}}}$$

$$= \sqrt{\frac{400\times10^{-3}}{1\times10^{-6}}}$$

$$= \sqrt{4\times10^{5}}$$

$$\boxed{Z_0 = 632.45\ \Omega}$$ Ans.

Propogation constant $|\gamma| = \omega\sqrt{LC}$

$$= 2\pi\times10\times10^{6}\times\sqrt{4\times10^{-3}\times.01\times10^{-6}}$$

$$\boxed{|\gamma| = 397.5\ rad/km.}$$ Ans

Q8 (b) Derive an expression for characteristics impedance and propagation constant of a transmission line at radio frequencies.

Answer

At high frequencies, R and G becomes very small as compared to ωL and ωC.

We know

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

As $R << \omega L$ and $G << \omega C$

hence $\boxed{Z_0 = \sqrt{\frac{L}{C}}}$ Ans

Also Propagation constant

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

So at high frequencies:

$$\gamma = \sqrt{(j\omega)^2 LC}$$

or $\boxed{\gamma = j\omega\sqrt{LC}}$ Ans

Q8 (c) Explain the concept of single and double stub impedance matching of lines.

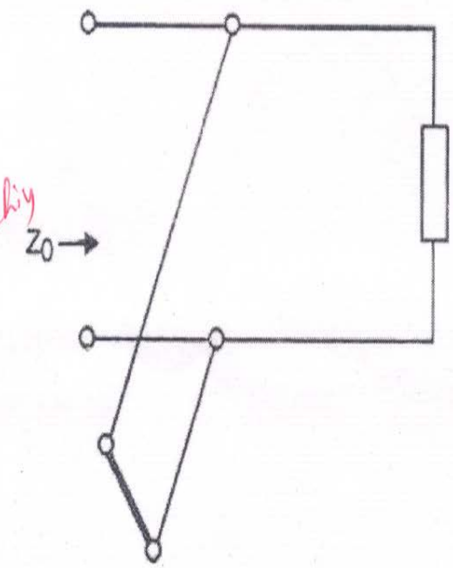
Answer

We know that for maximum power transfer, load impedance should match with source impedance. In transmission line, impedance matching is main requirement.

A short section of line can be used as impedance matching element. This short section of line is called Stub. Stub is connected in parallel with main line at some suitable distance from load end.

1. **Single Stub Matching**:

   As the name indicates, a single stub is used for impedance matching, at some distance from load end. Keeping in view the fact that the nature of reactance *i.e.,* whether the reactance is inductive or capacitive depends upon the length of line used, a specific length of line is used to introduce desired reactance.

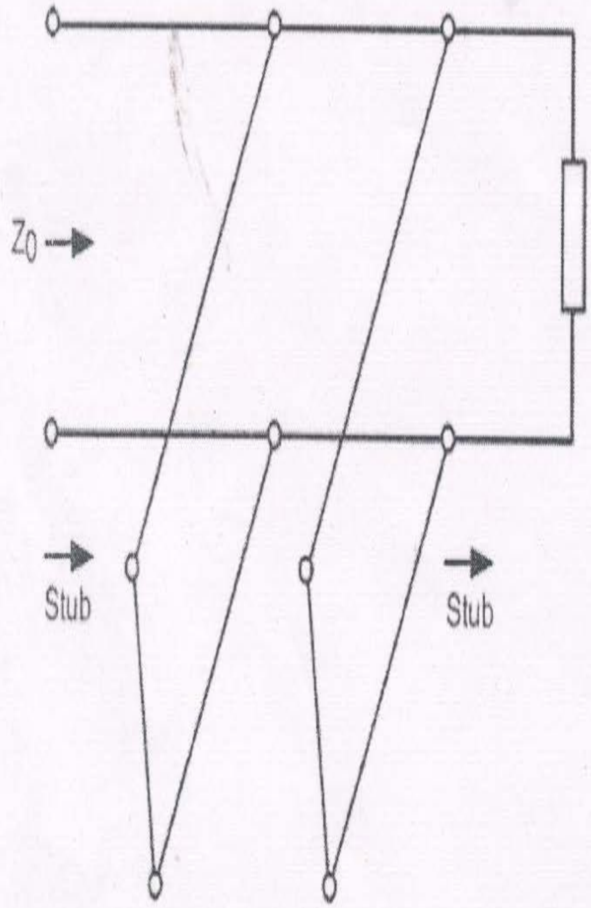


Generally length of stub is kept less than $\lambda/4$, so that it remains lossless at all high frequencies.

Practically, stub should be located near load end and these are inserted in parallel with line in such a manner that characteristic impedance remains same.

2. **Double Stub Matching :**

   As the name indicates, two stubs having some specified distance between them are used in this type of matching.



Generally distance between stubs is maintained λ/8. In this matching system, two short circuited stubs with adjustable length are installed.

Double stub matching is used in HF transmission. As the single stub matching was useful in fixed frequency applications, the double stub matching is preferred over single stub matching in variable frequency conditions.

Q9 (a) Design T and π sections of a constant K high pass filter having cut off frequency of 12 kHz and design impedance R_0 = 500 Ω. Also find attenuation at a frequency of 4 kHz.

Answer

$f_c = 12\,kHz$

$R_0 = 500\,\Omega$

$f = 4\,kHz$

Shunt arm impedance for high pass filter is given by

$$L = \frac{R_0}{4\pi F_c}$$

$$\text{so } L = \frac{500}{4\pi \times 12 \times 10^3}\ H.$$

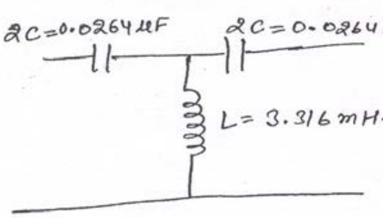
$$= 3.316\ mH$$

The series arm impedance for a high pass filter is given by

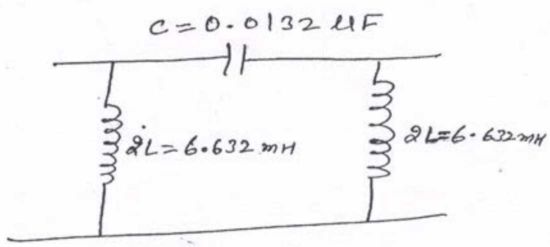
$$C = \frac{1}{4\pi R_0 F_c}$$

$$= \frac{1}{4\pi \times 500 \times 12 \times 10^3}\ F$$

$$= 0.0132\ \mu F$$



T-Section



π- section

Attenuation in attenuation band is given by

$$\alpha = 2\cosh^{-1}\left(\frac{F_c}{f}\right)$$

$$= 2\cosh^{-1}\left[\frac{12 \times 10^3}{4 \times 10^3}\right] \text{ nepar}$$

or $\alpha = \underline{3.525}$ nepar Ans.

Q9 (b) Design a T type symmetrical attenuator, which offers 40dB attenuation with a load of 400 Ω.

Answer

$R_D = 400\Omega$

$D = 20 \log_{10} N = 40 \text{ dB}$

or $N = \text{Antilog}\left(\frac{D}{20}\right)$

$= 10^{\left(\frac{40}{20}\right)}$

$\therefore \quad N = 100 \text{ Nepar}$

By using design equation

$R_1 = R_0 \left(\frac{N-1}{N+1}\right)$

$= 400 \left(\frac{100-1}{100+1}\right)$

$= 400 \times 0.98$

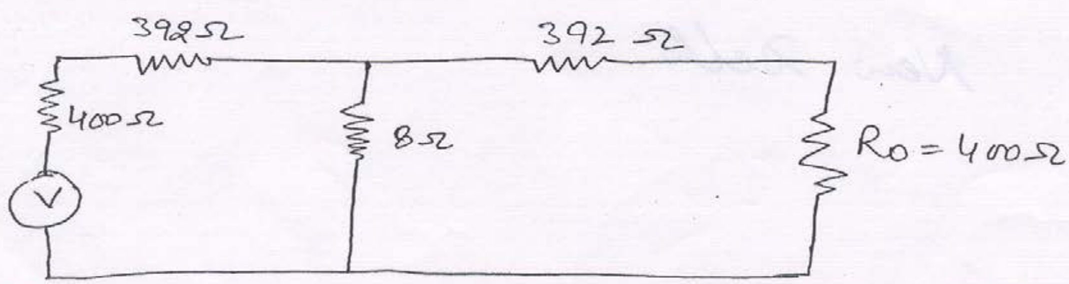
$= 392\ \Omega$

$R_2 = R_0 \left[\frac{2N}{N^2-1}\right]$

$= 400 \left(\frac{2 \times 100}{100^2-1}\right)$

$= 400 \times 0.02$

$\therefore R_2 = 8\ \Omega$



Text Books

1. Network Analysis, G K Mittal, 14th edition (2007) Khanna Publication, New Delhi

2. Transmission Lines & Networks, Umesh Sinha, 8th edition (2003), Satya Prakashan Incorporating Tech India Publications, New Delhi.