Classroom

ESE Mains Achiever's Study Plan

Electronics & Communication Engineering

Networks Part-2

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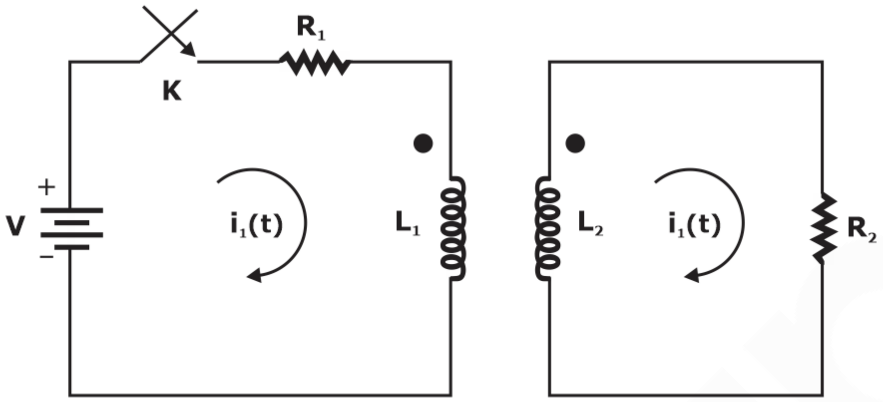
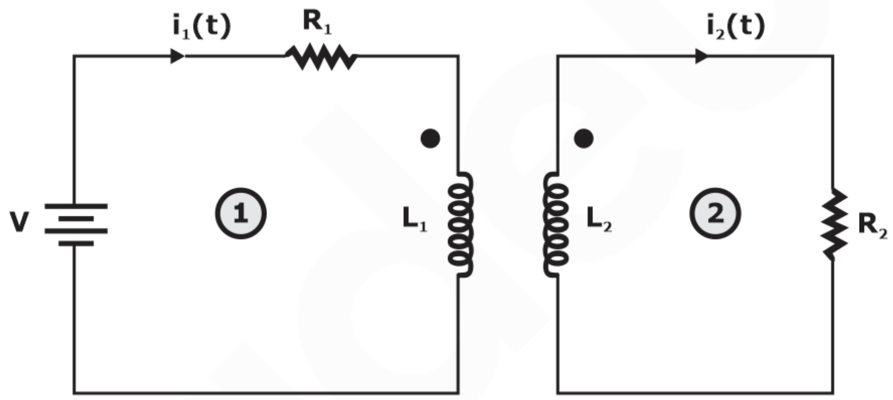
1. The circuit shown below is unenergized before closing the switch K at t = 0, the circuit parameters are L_1 = 1H, L_2 = 8H, M = 2H, R_1 = 2Ω, R_2 = 2Ω, V = 10 V. Find $i_1(t)$ from the instant switch is closed.



Sol. The circuit for time t > 0



Applying KVL in loop (1)

$$V = i_1(t)R_1 + L_1\frac{di_1(t)}{dt} - M\frac{di_2(t)}{dt} \text{.....(i)}$$

Applying KVL in loop (2)

$$L_2\frac{di_2(t)}{dt} + R_2 i_2(t) - M\frac{di_1(t)}{dt} = 0 \text{....(ii)}$$

Taking Laplace transform of equation (i) & (ii)

$$\frac{V}{s} = R_1 I_1(s) + sL_1 I_1(s) - sMI_2(s) \text{.....(iii)}$$

$sL_2I_2(s) + R_2I_2(s) - sMI_1(s) = 0$ ......(iv)

$(sL_2 + R_2)\ I_2(s) = sMI_1(s)$

$$\underline{I_2(s)} = \frac{sM}{(sL_2 + R_2)} I_1(s) \text{....(v)}$$

By (iii) & (v)

$$\frac{V}{s} = (R_1 + sL_1) I_1(s) - \frac{sM.sM}{(sL_2 + R_2)} I_1(s)$$

$$\frac{V}{s} = \left[R_1 + sL_1 - \frac{s^2M^2}{(sL_2) + R_2}\right] I_1(s)$$

Putting values of parameters:

$$\frac{10}{s} = \left[2 + s - \frac{4s^2}{8s + 2}\right] I_1(s)$$

$$\frac{10}{s} = \frac{\left[(s+2)(8s+2) - 4s^2\right]}{(8s+2)} I_1(s)$$

$$= \left[\frac{8s^2 + 16s + 2s + 4 - 4s^2}{(8s+2)}\right] I_1(s)$$

$$I_1(s) = \frac{10(8s+2)}{4s^2 + 18s + 4}$$

$$= \frac{2.5(8s+2)}{(s^2 + 4.5s + 1)}$$

$$= \frac{A}{s + 0.234} + \frac{B}{s + 4.26}$$

Solving partial differentiation:

As + 4.26A + Bs + 0.264B = 2.5 × 8s + 2.5 × 2

A + B = 20

4.26 A + 0.234 B = 5

So, A = 0.0795

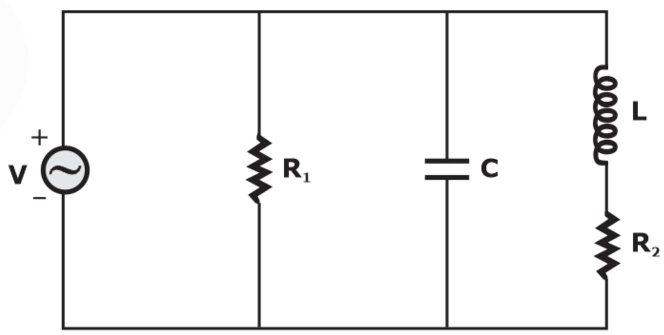
B = 19.920

$$I_2(s) = \frac{0.0795}{s + 0.234} + \frac{19.920}{s + 4.26}$$

$$i_1(t) = 0.0795 e^{-0.234t} + 19.920\ e^{-426t} A$$

2. Obtain resonant frequency of the circuit shown in figure below.

Given value of parameters as L = 1H, R_1 = 1Ω, R_2 = 10Ω, C = 1F



Sol. To find resonant frequency we know that imaginary part of admittance is zero in case of parallel circuit.

$$Y(j\omega) = \text{admittance} = \frac{1}{R_2 + j\omega L} + j\omega C + \frac{1}{R_1}$$

$$Y(j\omega) = \frac{1}{10 + j\omega(1)} + j\omega(1) + \frac{1}{1}$$

$$Y(j\omega) = \frac{10 - j\omega}{100 - \omega^2} + j\omega + 1$$

Img [Y(jω)] = 0

$$\frac{-\omega}{100 - \omega^2} + \omega = 0$$

$$\omega = \frac{\omega}{100 - \omega^2}$$

$100 - \omega^2 = 1$

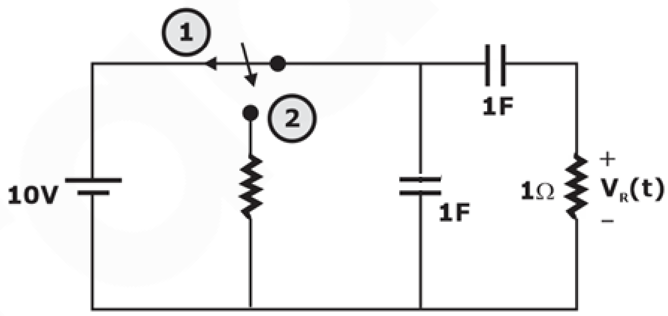
$100 - 1 = \omega^2$

$$\omega = \pm\sqrt{99}$$

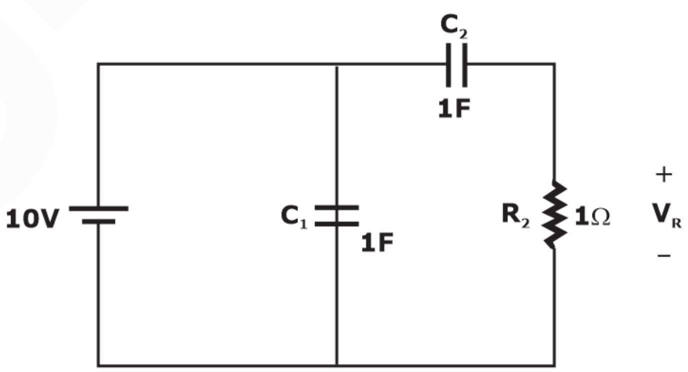
$$\omega = \pm 9.95 \text{ rad / sec}$$

The resonant frequency for this parallel combination is 9.95 rad / sec.

3. The network shown in figure below, switch 'K' is connected at position (1) for long time. At t = 0, the switch 'K' is transferred to position (2) Determine the voltage $V_R(t)$



Sol. For t < 0-

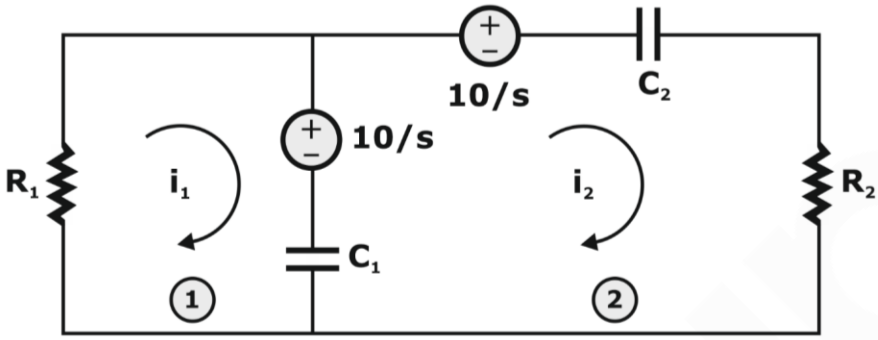


$V_{C1}(0^-) = 10\ V$

$V_{C2}(0^-) = 10\ V$

[voltage across capacitor in parallel to voltage source is same as voltage source at steady state]

At $t = 0^+$ switch moved to position (2) for $t = 0^+$, the circuit will be



Applying KVL in loop (1)

$$\frac{-10}{s} + I_1(s)R_1 + \frac{1}{C_1 s}\left[I_1(s) - I_2(s)\right] = 0$$

$$I_1(s)\left[R_1 + \frac{1}{C_1 s}\right] - I_2(s)\frac{1}{C_1 s} = \frac{10}{s} \text{ ......(i)}$$

KVL in loop (2)

$$\frac{-10}{s} + \frac{10}{s} + \frac{1}{C_1 s}\left[I_2(s) - I_1(s)\right] + \left[\frac{1}{C_2 s} + R_2\right]I_2(s) = 0$$

$$-\frac{1}{C_1 s}I_1(s) + \left[R_2 + \frac{1}{C_1 s} + \frac{1}{C_2 s}\right]I_2(s) = 0 \text{ .....(ii)}$$

Putting values of parameter in equation (i) and (ii)

$$I_1(s)\left[1 + \frac{1}{s}\right] + \frac{1}{s}\left[-I_2(s)\right] = \frac{10}{s} \text{ .....(iii)}$$

$$-\frac{1}{s}I_1(s) + \left[1 + \frac{1}{s} + \frac{1}{s}\right]I_2(s) \text{ .....(iv)}$$

By (iv)

$I_1(s) = (s + 2)I_2(s)$

$$I_2(s) = \frac{1}{s+2}I_1(s) \text{ ....(v)}$$

By (iii) & (v)

$$I_1(s)\left[\frac{s+1}{s}\right] + \frac{1}{s}\left(\frac{1}{s+2}\right)I_1(s) = \frac{10}{s}$$

$$I_1(s)\left[\frac{s+1}{s} + \frac{1}{s(s+2)}\right] = \frac{10}{s}$$

$$I_1(s) = \frac{10 \times s \times s(s+2)}{s[s(s+1)(s+2)+s]}$$

$$I_1(s) = \frac{10(s+2)}{s^2+3s+3}$$

$$I_2(s) = \frac{I_1(s)}{s+2} = \frac{10}{s^2+3s+3}$$

(By V)

$$\text{So, } I_2(s) = \frac{10}{s^2+3s+\left(\frac{3}{2}\right)^2-\left(\frac{3}{2}\right)^2+3}$$

$$= \frac{10}{\left(s+\frac{3}{2}\right)^2+\left(\frac{\sqrt{3}}{2}\right)^2}$$

$I_2(t) = L^{-1}[I_2(s)]$

$$= L^{-1}\left[\frac{10 \times \sqrt{3}/2}{\sqrt{3}/2\left[\left(s+\frac{3}{2}\right)^2+\left(\frac{\sqrt{3}}{2}\right)^2\right]}\right]$$

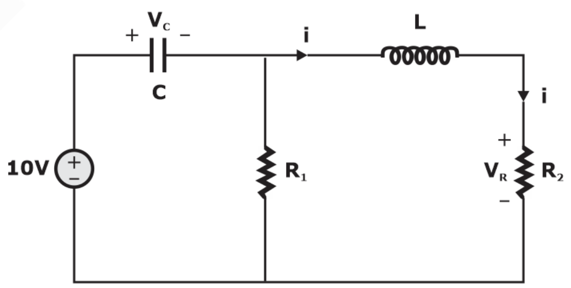
$$= 10\frac{2}{\sqrt{3}}e^{-(3/2)t}\sin\left(\frac{\sqrt{3}}{2}t\right)$$

$$i_2(t) = \frac{20}{\sqrt{3}}e^{-(3/2)t}\sin\left(\frac{\sqrt{3}}{2}t\right)$$

VR (t) R2 i2 (t)

$$V_R(t) = \frac{20}{\sqrt{3}}e^{-1.5t}\sin\left(\frac{\sqrt{3}}{2}t\right)$$

4. Determine the voltage V_R in the circuit given below

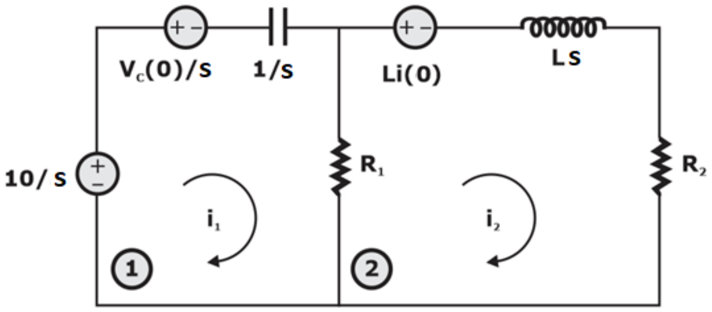


The values of parameters are C = 1 F, $R_1 = R_2 = 1\Omega$

L = 1 H, V_c (0) = 8V, i (0) = 1A

Find the value of i(t) for time t > 0

Sol. Drawing circuit considering the initial conditions



Applying KVL in loop (1)

$$-\frac{10}{S}+\frac{V_c(0)}{S}+\left[R_1+\frac{1}{Cs}\right]I_1(s)-R_1I_2(s)=0$$

$$\left(1+\frac{1}{s}\right)I_1(s)-I_2(s)=\frac{10}{s}-\frac{8}{s}=\frac{2}{s}\ ...(i)$$

Applying KVL in loop (2)

$$-I_1(s)R_1+(R_2+Ls+R_1)I_2(s)-Li(0^+)=0$$

$$-I_1(s)+(2+s)I_2(s)=1\ ....(ii)$$

$$Eq^n(ii)\times\left(\frac{s+1}{s}\right)+Eq^n(i)$$

$$\Rightarrow-\left(\frac{s+1}{s}\right)i_1(s)+(2+s)\times\frac{(s+1)}{s}I_2(s)$$
$$=\left(\frac{s+1}{s}\right)+\frac{2}{s}+\left(\frac{s+1}{s}\right)I_1(s)-I_2(s)$$

$$\Rightarrow\frac{(s+1)(s+2)}{s}I_2(s)-I_2(s)=\left(\frac{s+3}{s}\right)$$

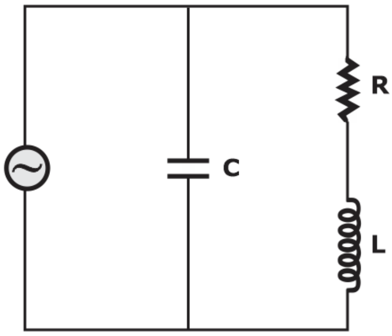
$$I_2(s)=\frac{s+3}{s^2+2s+2}$$

$$I_2(s)=\frac{s+1}{(s+1)^2+1}+\frac{2}{(s+1)^2+1}$$

$$i_2(t)=e^{-t}\cos t+2e^{-t}\sin t$$

$\therefore I_2(t) = e^{-t}\cos t + 2e^{-t}\sin t$ for $t > 0$

5. For the circuit shown below, derive the condition & expression of resonant frequency. Also calculate resonant frequency if parameters are L = 1, C = 1nF, R = 1 KΩ , V=1.5V



Sol. The equivalent impedance is given by

$Z = (R + X_L) \,||\, (X_C)$

$$= (R + j\omega L) \,||\, \frac{1}{j\omega C}$$

$$= \frac{(R + j\omega L) \times \frac{1}{j\omega C}}{\left(R + j\omega L + \frac{1}{j\omega C}\right)}$$

$$= \frac{(R + j\omega L)}{Rj\omega C - \omega^2 Lc + 1}$$

$$= \frac{R + j\omega L}{(1 - \omega^2 LC) + j\omega RC}$$

$$= \frac{(R + j\omega L)\left[(1 - \omega^2 LC) - j\omega RC\right]}{(1 - \omega^2 LC)^2 + \omega^2 R^2 C^2}$$

At resonance imaginary part is zero as current and voltage are in phase at resonance

So,

$-j\omega R^2 C + j\omega L(1 - \omega^2 LC) = 0$

$R^2C/L = 1 - \omega^2 LC$

$\omega^2 LC = 1 - R^2C/L$

$$\omega^2 = \frac{1}{LC} - \frac{R^2 C}{L^2 C}$$

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

The expression for resonant frequency is derived as

$$f - \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

So, putting values R, L and C the value of resonant frequency will be

$$f - \frac{1}{2\pi}\sqrt{\frac{1}{1\times10^{-9}} - \frac{\left(10\times10^{3}\right)^{2}}{\left(1\right)^{2}}}$$

$$= \frac{1}{2\pi}\sqrt{10^{9} - 10^{8}}$$

f = 4774.6Hz

The resonant frequency will be 4774.6 Hz or 4.77 KHz.

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