K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
AC CIRCUITS

Numerical 1: A series RLC circuit containing a resistance of 20Ω, an inductance of 0.15H and a capacitor of 75μF are connected series across a 120V, 60Hz supply.
Calculate :-
a) The current drawn by the circuit
b) V_R, V_L and V_C
c) Power factor
d) Draw the voltage phasor diagram

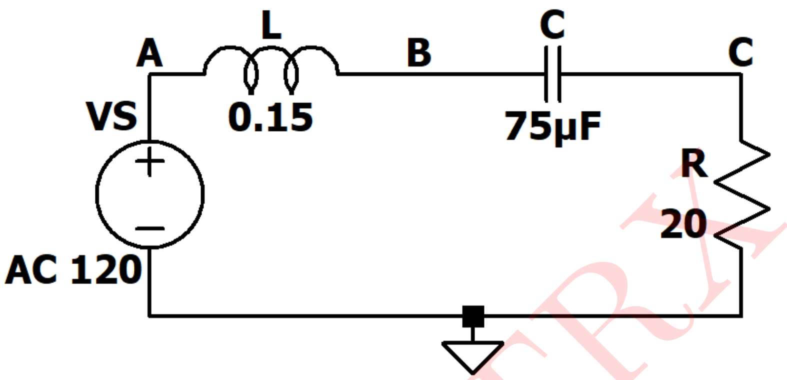

Figure 1: Series RLC Circuit

Solution:

$V_S = 120\text{V},\ f = 60\text{Hz},\ \text{R} = 20\Omega$
$X_L = 2\pi f L = 56.5486\Omega$
$X_C = \dfrac{1}{2\pi f C} = 35.3677\Omega$
$\text{Z} = \text{R} + \text{j}X_L - \text{j}X_C$
$\quad = 20 + 56.5486\text{j} - 35.3677\text{j}$
$\quad = 29.1312\angle 46.6425°\Omega$

a) $\text{I} = \dfrac{V_S}{Z}$
$\quad = \dfrac{120}{29.1312\angle 46.6425°}$
$\quad \mathbf{I = 4.1192\angle{-46.6425}°A}$

b) $V_R = \text{I}\times\text{R}$
$\quad = 4.1192\times 20$
$\quad = \mathbf{82.384V}$
$V_L = \text{I}\times X_L$
$\quad = 4.1192\times 56.5486$
$\quad = \mathbf{232.9349V}$
$V_C = \text{I}\times X_C$
$\quad = 4.1192\times 35.3677$
$\quad = \mathbf{145.6866V}$

c) Power factor $= \cos(\phi)$
$\quad = \cos(46.6425°)$
$\quad = $ **0.6865 lagging**

d) Voltage Phasor Diagram

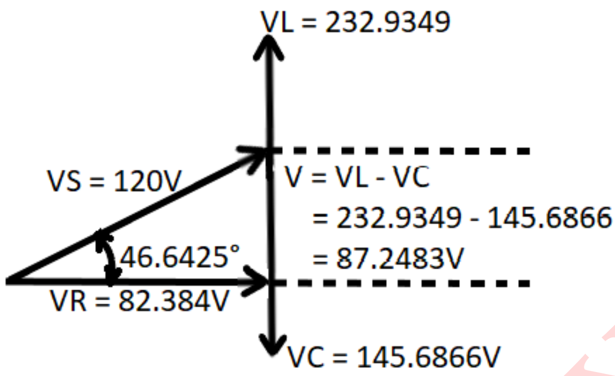

Figure 2: Voltage Phasor Diagram

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

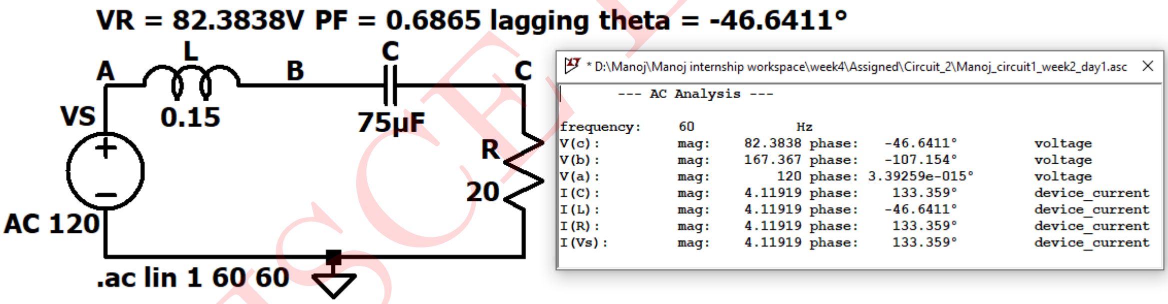

Figure 3: Circuit Schematic and Simulated Results for V_R and Power Factor(PF)

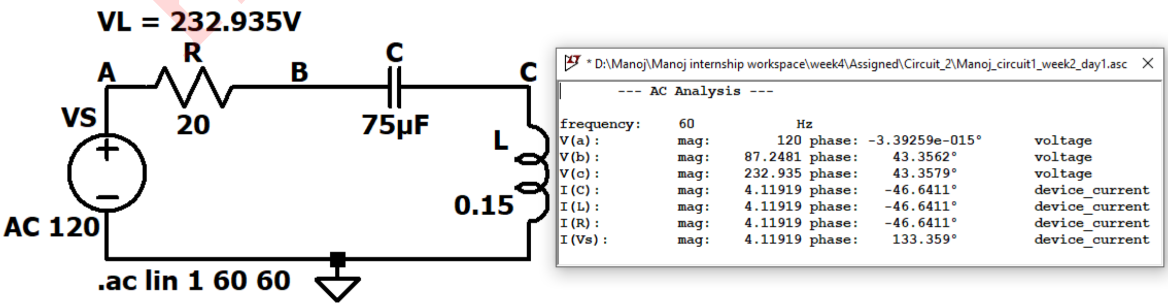

Figure 4: Circuit Schematic and Simulated Results for V_L

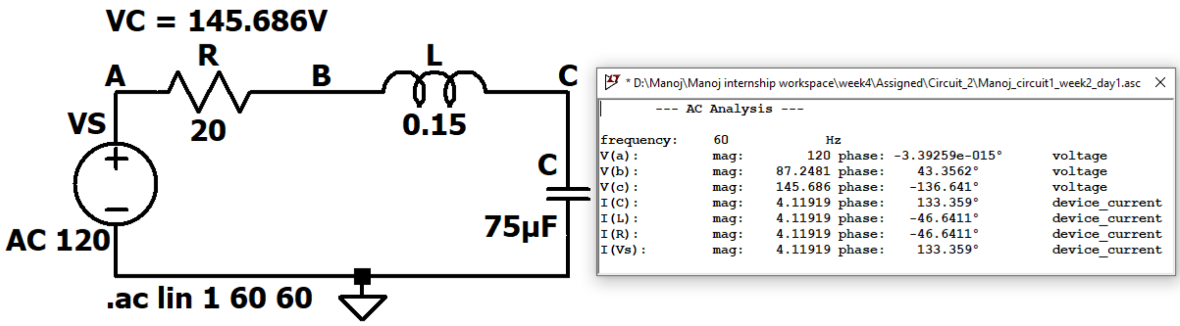

Figure 5: Circuit Schematic and Simulated Results for V_C

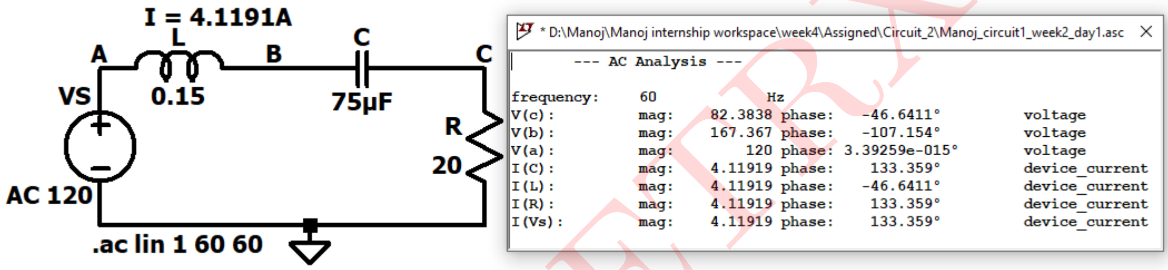

Figure 6: Circuit Schematic and Simulated Results for I

Comparison of Theoretical and Simulated Values:-

Parameters	Theoretical Values	Simulated Values
V_R	82.384V	82.3838V
V_L	232.9349V	232.935V
V_C	145.6866V	145.686V
I	4.1192A	4.1191A
Power factor	0.6865	0.6865

Table 1: Numerical 1

Numerical 2: A coil having a resistance of $R_1 = 3\ \Omega$ and an inductance of $L_1 = 0.05$ H is arranged in parallel with another coil having a resistance of $R_2 = 4\ \Omega$ and an inductance of $L_2 = 0.065$ H. Calculate the currents I, I_1 and I_2 when a voltage of $V_1 = 110$ V at 60 Hz is applied. Also calculate the power factor of the circuit

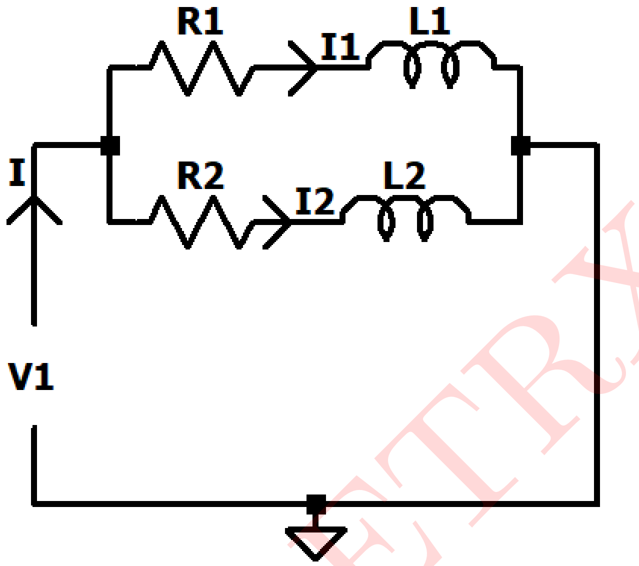

Figure 7: Circuit 1

Solution:

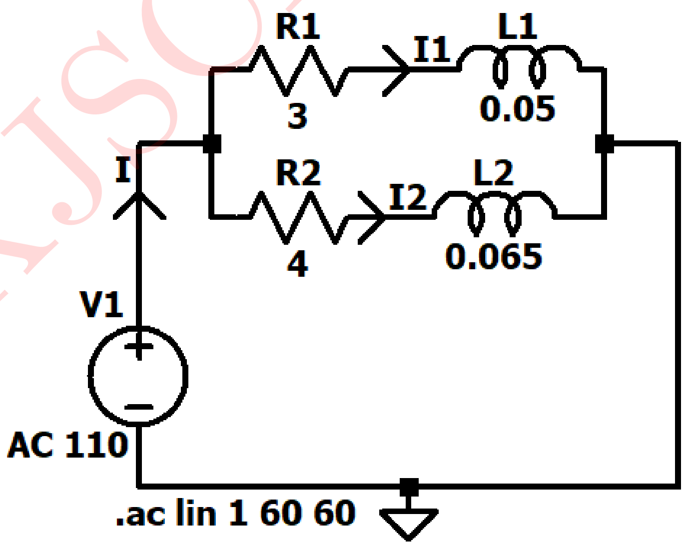

Figure 8: Circuit 2

$R_1 = 3\ \Omega$, $R_2 = 4\ \Omega$, $L_1 = 0.05$ H, $L_2 = 0.065$ H, $Z_1 = 3 + \mathrm{j}X_{L_1}$, $Z_2 = 4 + \mathrm{j}X_{L_2}$,
$X_{L_1} = 2\pi f L_1 = 18.8495\ \Omega$, $X_{L_2} = 2\pi f L_2 = 24.5044\ \Omega$

$$\therefore Z_1 = 3 + \mathrm{j}18.8495$$
$$= 19.0867\angle 80.9569^\circ\ \Omega$$
$$Z_2 = 4 + \mathrm{j}24.5044$$
$$= 24.8287\angle 80.7290^\circ\ \Omega$$

$$\mathrm{Z} = \frac{Z_1 \times Z_2}{Z_1 + Z_2}$$

$$\mathrm{Z} = \frac{473.8979\angle 161.6859^\circ}{43.9153\angle 80.8280^\circ} = 10.7911\angle 80.8578^\circ$$

$$I_1 = \frac{V_1}{Z_1} = \frac{110\angle 0^\circ}{19.0867\angle 80.9569^\circ} = \mathbf{5.7631\angle{-80.9569^\circ}\ A}$$

$$I_2 = \frac{V_1}{Z_2} = \frac{110\angle 0^\circ}{24.8287\angle 80.7290^\circ} = \mathbf{4.4303\angle{-80.7290^\circ}\ A}$$

$$I = \frac{V_1}{Z} = \frac{110\angle 0^\circ}{10.7911\angle 80.8578^\circ} = \mathbf{10.1935\angle{-80.8578^\circ}\ A}$$

$$\text{Power Factor} = \cos(80.8578^\circ)$$
$$= \mathbf{0.1588\ lagging}$$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

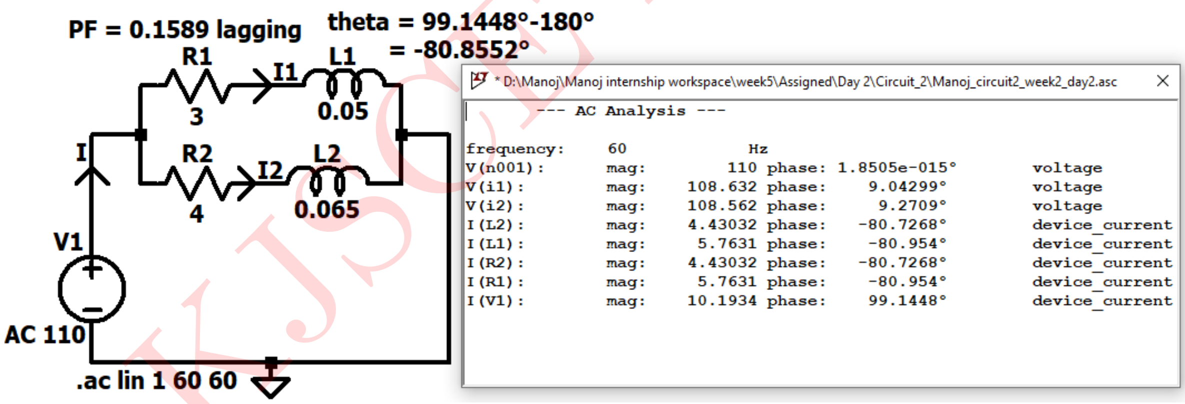

Figure 9: Circuit Schematic and Simulated Results for I_{R1}, I_{R2}, I_{V1} and Power Factor

Comparison of Theoretical and Simulated Values:-

Parameters	Theoretical Values	Simulated Values
I_1	$5.7631\angle-80.9569°$ A	$5.7631\angle-80.954°$ A
I_2	$4.4303\angle-80.7290°$ A	$4.4303\angle-80.7268°$ A
I	$10.1935\angle-80.8578°$ A	$10.1934\angle-80.8552°$ A
Power Factor	0.1588	0.1589

Table 2: Numerical 2

Numerical 3: A circuit consists of resistance of 5Ω, an inductance of 14mH and a capacitor of 20μF are connected in parallel across a 110V, 50Hz supply.
Calculate:
i) Individual currents drawn by each element
ii) Total current drawn from the supply
iii) Overall power factor of the circuit
iv) Draw the phasor diagram

Solution:

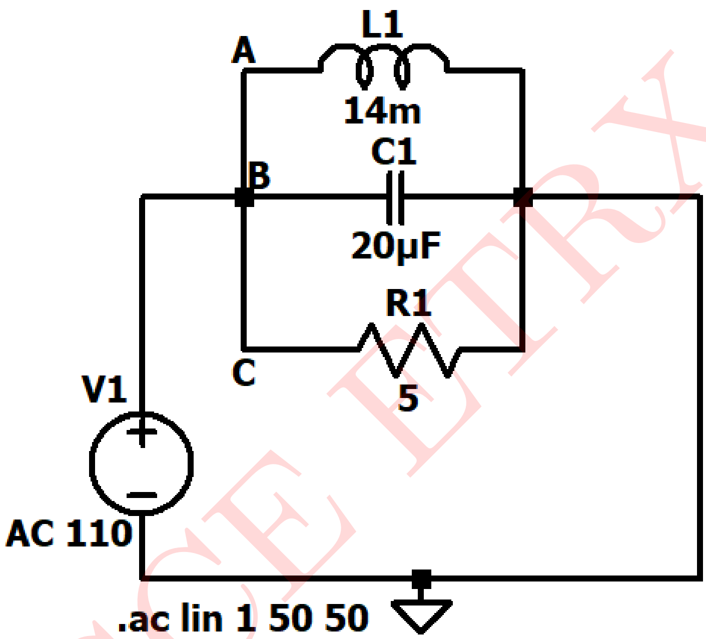

Figure 10: Parallel RLC Circuit

$R_1 = 5\ \Omega$, $L_1 = 14$ mH, $C_1 = 20\ \mu$F, $f = 50$ Hz

$X_{L_1} = 2\pi f L_1 = 4.3982\ \Omega$, $X_{C_1} = \dfrac{1}{2\pi f C_1} = 159.1549\ \Omega$

$Z_{R_1} = 5\angle 0°\ \Omega$, $Z_{L_1} = \text{j}4.3982 = 4.3982\angle 90°\ \Omega$,

$Z_{C_1} = -\text{j}159.1549 = 159.1549\angle{-90}°\ \Omega$

i) $I_{R_1} = \dfrac{V_1}{Z_{R_1}} = \dfrac{110\angle 0°}{5\angle 0°} = \mathbf{22\angle 0°\,A}$

$I_{L_1} = \dfrac{V_1}{Z_{L_1}} = \dfrac{110\angle 0°}{4.3982\angle 90°} = \mathbf{25.0102\angle{-90}°\,A}$

$I_{C_1} = \dfrac{V_1}{Z_{C_1}} = \dfrac{110\angle 0°}{159.1549\angle - 90°} = \mathbf{0.6911\angle 90°\,A}$

ii) I $= I_{R_1} + I_{L_1} + I_{C_1}$
$= 22\angle 0° + 25.0102\angle{-90}° + 0.6911\angle 90°$
$= 22 + 0.6911\text{j} - 25.0102\text{j}$
$= \mathbf{32.7939\angle{-47.8662}°\,A}$, $\phi = 47.8662°$

iii) Overall Power Factor :-

Power Factor = $\cos(\phi) = \cos(47.8662°) =$ **0.6708 lagging**

iv) Phasor diagram :-

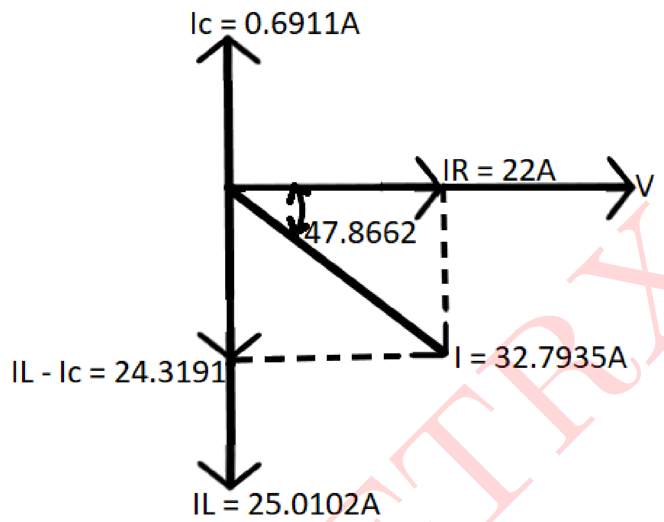

Figure 11: Phasor diagram

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

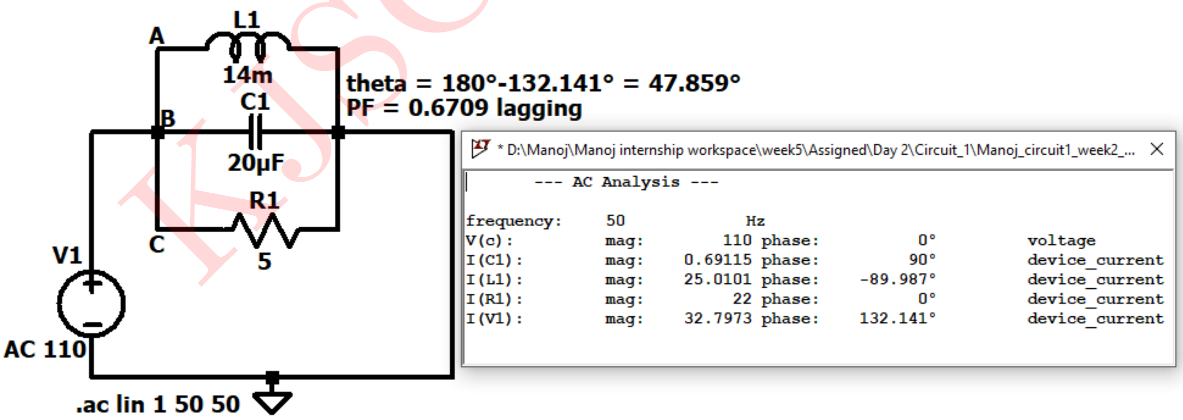

Figure 12: Circuit Schematic and Simulated Results for I_{R1}, I_{L1},I_{C1}, I_{V1} and Power Factor

Comparison of Theoretical and Simulated Values:-

Parameters	**Theoretical Values**	**Simulated Values**
I_{R_1}	$22\angle 0^\circ$ A	$22\angle 0^\circ$ A
I_{L_1}	$25.0102\angle -90^\circ$ A	$25.0101\angle -89.987^\circ$ A
I_{C_1}	$0.6911\angle -90^\circ$ A	$0.6911\angle -90^\circ$ A
I	$32.7935\angle -47.8662^\circ$ A	$32.7973\angle 132.141^\circ$ A
Power Factor	0.6708	0.6709

Table 3: Numerical 3

Numerical 4: Find I, I_1 and I_2 and voltage drop in each branch in the following Figure, If R_1 = 10 Ω, L_1 = j4Ω, R_2 = 20Ω, L_2 = j6Ω, R_3 = 9Ω, C_1 = −j5Ω, V_1 = 100V, f = 50Hz

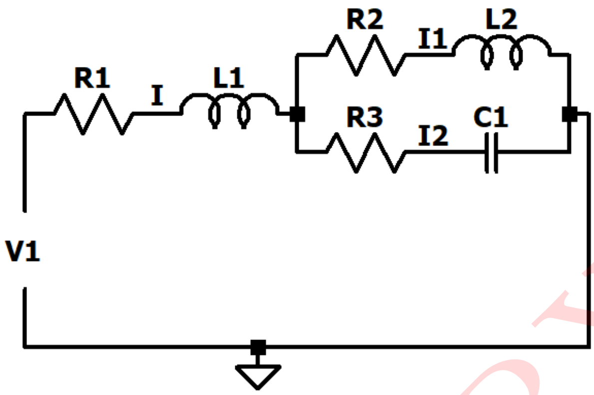

Figure 13: Circuit 3

Solution:

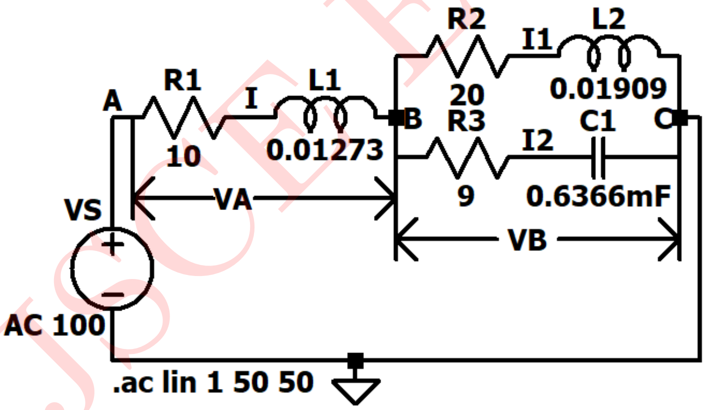

Figure 14: Circuit 4

R_1 = 10 Ω, R_2 = 20 Ω, R_3 = 9 Ω, X_{L_1} = 4 Ω, X_{L_2} = 6 Ω, X_{C_1} = 5 Ω, f = 50 Hz
Z_{I_1} = 20 + j6, Z_{I_2} = 9 − j5, Z_I = 10 + j4

$$Z_T = 10 + \text{j}4 + \frac{214.9790\angle-12.3553^\circ}{29.0172\angle 1.9749^\circ} = 17.3141\angle 7.1874^\circ\ \Omega$$

$$\text{I} = \frac{V}{Z_T} = \frac{100}{17.3141\angle 7.1874^\circ} = 5.7756\angle{-7.1874^\circ}\ \text{A}$$

$$Z_B = \frac{Z_{I_1} \times Z_{I_2}}{Z_{I_1} + Z_{I_2}} = 7.4086\angle{-14.3302^\circ}\ \Omega$$

$$\begin{aligned} V_B &= \text{I}\times Z_B = (5.7756\angle{-7.1874^\circ})\times(7.4086\angle{-14.3302^\circ}) \\ &= 42.7891\angle{-21.5176^\circ}\ \text{V} \end{aligned}$$

$$\begin{aligned} V_1 &= V_A + V_B \\ V_A &= 100\angle 0^\circ - 42.7891\angle{-21.5176^\circ} \\ V_A &= 62.2055\angle 14.6136^\circ \text{V} \end{aligned}$$

$$I_1 = \frac{V_B}{Z_{I_1}} = \frac{42.7891\angle-21.5176^\circ}{20.8806\angle16.6992^\circ} = 2.0492\angle{-38.2168^\circ}\ \text{A}$$

$$I_2 = \frac{V_B}{Z_{I_2}} = \frac{42.7891\angle-21.5176^\circ}{10.2956\angle-29.0546^\circ} = 4.1560\angle7.5370^\circ\ \text{A}$$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

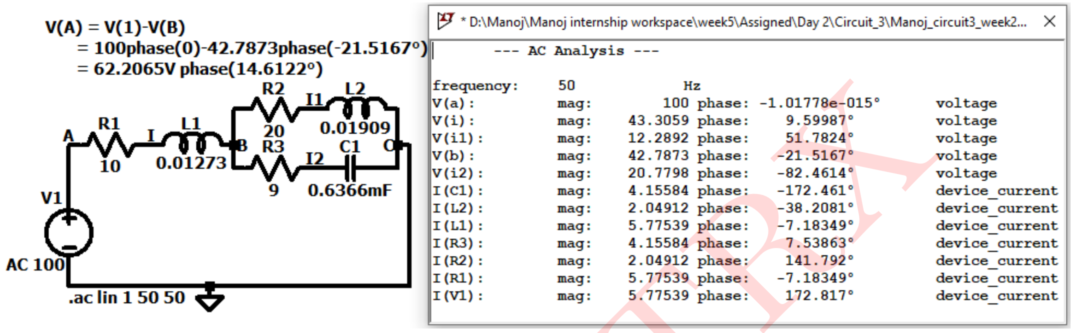

Figure 15: Circuit Schematic and Simulated Results for I, I_1, I_2, V_A and V_B

Comparison of Theoretical and Simulated Values:-

Parameters	Theoretical Values	Simulated Values
I_1	$2.0492\angle{-38.2168^\circ}$ A	$2.0491\angle{-38.2081^\circ}$ A
I_2	$4.1560\angle7.5370^\circ$ A	$4.1558\angle7.5386^\circ$ A
I	$5.7756\angle{-7.1874^\circ}$ A	$5.7753\angle{-7.1834^\circ}$ A
V_A	$62.2055\angle14.6136^\circ$V	$62.2065\angle14.6122^\circ$V
V_B	$42.7891\angle{-21.5176^\circ}$V	$42.7873\angle{-21.5167^\circ}$V

Table 4: Numerical 4

Numerical 5:For a figure 1 shown below, a pure resistance of 40 Ω is in series with a pure capacitance of 125μF. The series combination is connected across 110V, 60 Hz supply.

Determine the following:

a) Calculate the peak voltage across resistor and capacitor and also find the peak value of source current in LTspice.

b) Plot input source voltage $V_{S(t)}$ vs input source current $I_{S(t)}$ in LTspice.

c) Measure the phase delay/difference between $V_{S(t)}$ vs $I_{S(t)}$ in time and degrees.

d) Plot input source voltage $V_{S(t)}$ vs voltage across resistor $V_{R(t)}$ in LTspice.

e) Measure the phase delay/difference between $V_{S(t)}$ vs $V_{R(t)}$ in time and degrees.

f) Plot input source voltage $V_{S(t)}$ vs voltage across capacitor $V_{C(t)}$ in LTspice.

g) Measure the phase delay/difference between $V_{S(t)}$ vs $V_{C(t)}$ in time and degrees.

h) Calculate the power factor of the circuit.

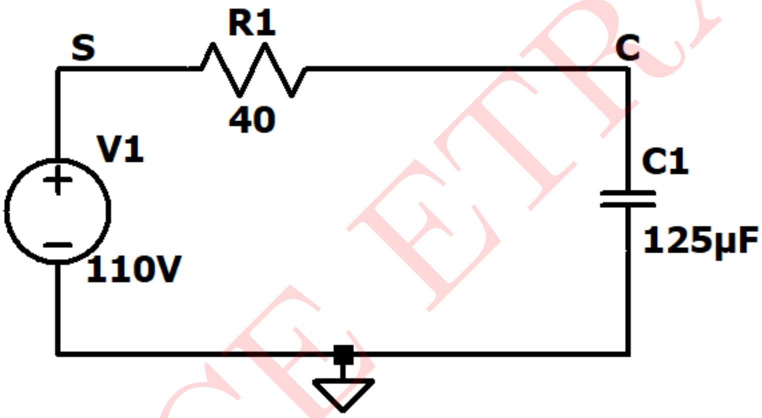

Figure 16: Series RC Circuit

Solution:

$R_1 = 40\Omega$, $C_1 = 125\mu$F, $f = 60$Hz, $V_{rms} = 110$V

$$X_{C_1} = \frac{1}{2\pi f C_1} = 21.2206\Omega$$

$$\begin{aligned}
Z &= R_1 - \mathrm{j}X_{C_1} \\
&= 40 - 21.2206\mathrm{j} \\
&= 45.2804\angle{-27.9466}°\Omega
\end{aligned}$$

$$V_{peak} = \sqrt{2}\times V_{rms} = \sqrt{2}\times 110 = 155.5634\text{V}$$

$$\begin{aligned}
I_{peak} &= \frac{V_{peak}}{Z} \\
&= \frac{155.5634}{45.2804\angle-27.9466°} \\
&= 3.4355\angle 27.9466°\text{A}
\end{aligned}$$

$$(V_{R_1})_{peak} = I_{peak}\times \text{R} = 137.4223\angle 27.9466°\text{V}$$

$$(V_{C_1})_{peak} = I_{peak}\times X_{C_1} = 72.9046\angle{-62.0534}°\text{V}$$

Phase difference between $V_{S(t)}$ and $I_{S(t)}$
$\phi_1 = 0 - 27.9466$
$\phi_1 = -27.9466°$

$$t_1 = \frac{\phi_1}{360° \times f} = \frac{27.9466°}{360° \times 60} = 1.2938ms$$

Phase difference between $V_{S(t)}$ and $V_{R(t)}$
$\phi_2 = 0 - 27.9466$
$\phi_2 = -27.9466°$

$$t_2 = \frac{\phi_2}{360° \times f} = \frac{27.9466°}{360° \times 60} = 1.2938ms$$

Phase difference between $V_{S(t)}$ and $V_{C(t)}$
$\phi_3 = 0 - (-62.0534)$
$\phi_3 = 62.0534°$

$$t_3 = \frac{\phi_3}{360° \times f} = \frac{62.0534°}{360° \times 60} = 2.8728ms$$

$$\begin{aligned} \text{Power factor} &= \cos(\phi_1) \\ &= \cos(27.9466°) \\ &= 0.8833 \end{aligned}$$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

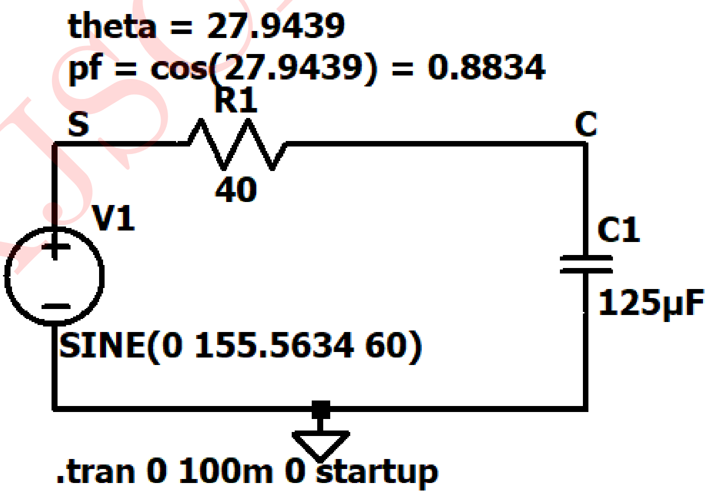

Figure 17: Circuit Schematic for Power Factor

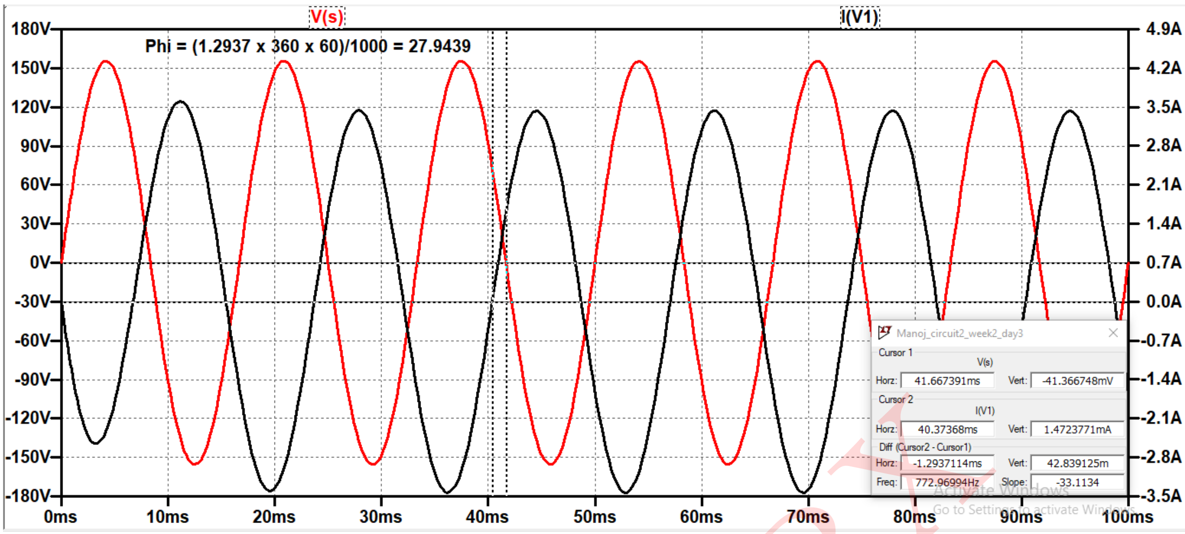

Figure 18: Simulated Results for Phase difference between $V_{S(t)}$ and $I_{S(t)}$

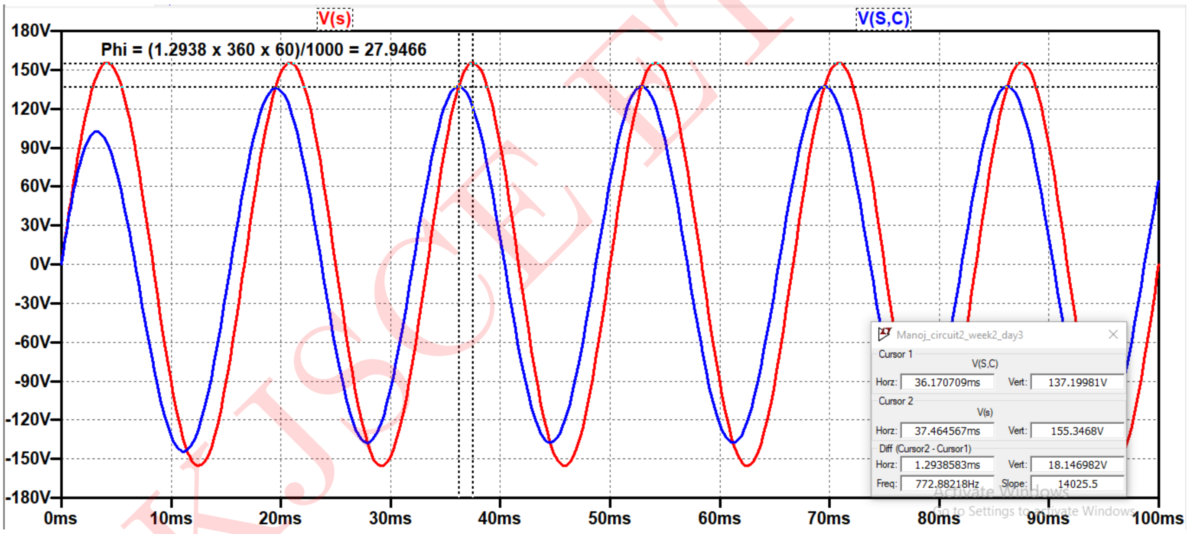

Figure 19: Simulated Results for Phase difference between $V_{S(t)}$ and $V_{R(t)}$

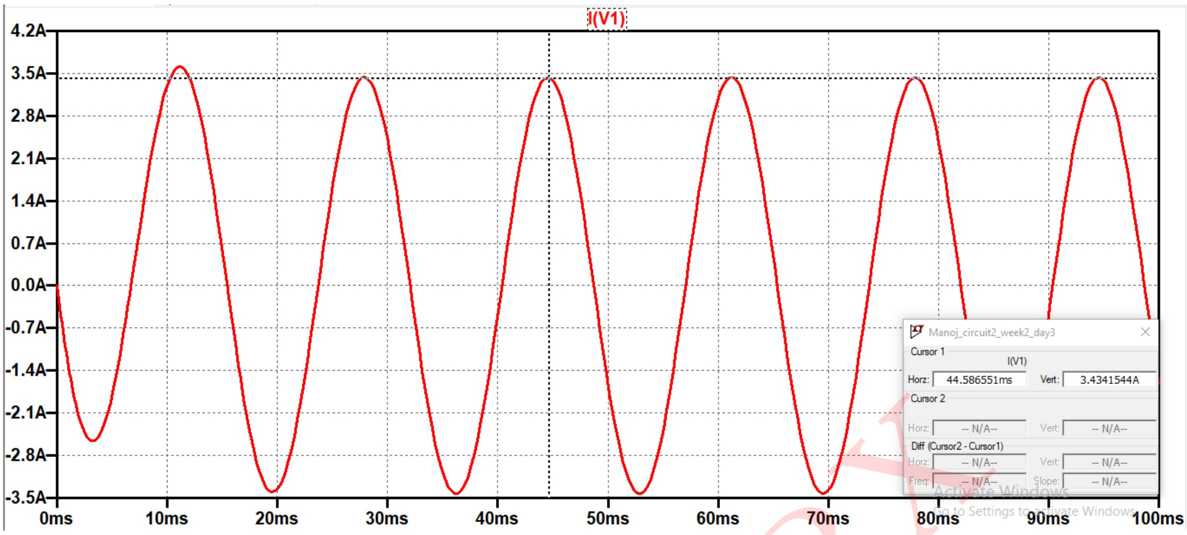

Figure 20: Simulated Results for I_{peak}

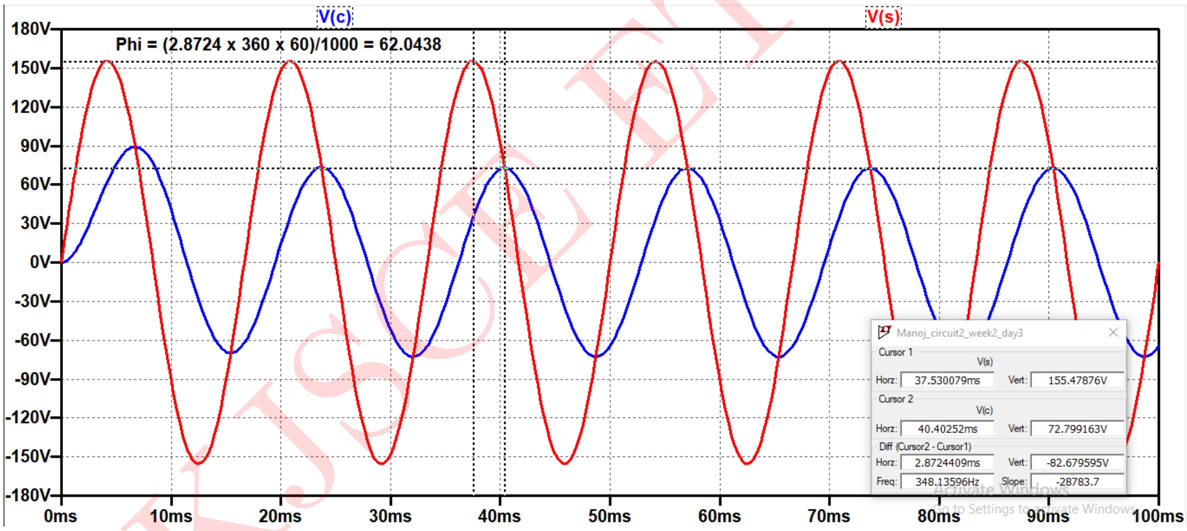

Figure 21: Simulated Results for Phase difference between $V_{S(t)}$ and $V_{C(t)}$

Comparison of Theoretical and Simulated Values:-

Parameters	**Theoretical Values**	**Simulated Values**
$(V_{R_1})_{peak}$	137.4223V	137.1998V
$(V_{C_1})_{peak}$	72.9046V	72.7991V
I_{peak}	3.4355A	3.4341A
Phase difference between $V_{S(t)}$ and $I_{S(t)}$ in degree and time	27.9466° 1.2938ms	27.9439° 1.2937ms
Phase difference between $V_{S(t)}$ and $V_{R(t)}$ in degree and time	27.9466° 1.2938ms	27.9466° 1.2938ms
Phase difference between $V_{S(t)}$ and $V_{C(t)}$ in degree and time	62.0534° 2.8728ms	62.0438° 2.8724ms
Power factor	0.8833	0.8834

Table 5: Numerical 5

Numerical 6: A 60 Hz sinusoidal voltage V = 141 sin wt is applied to a series R-L circuit. The values of the resistance and the inductance are 3.9 Ω and 0.015 H respectively

Determine the following:

a) Calculate the peak voltage across resistor and inductor and also find the peak value of source current in LTspice

b) Plot input source voltage $V_{S(t)}$ Vs input source current $I_{S(t)}$ in LTspice

c) Measure the phase delay/difference between $V_{S(t)}$ Vs $I_{S(t)}$ in time and degrees

d) Plot input source voltage $V_{S(t)}$ Vs voltage across resistor $V_{R(t)}$ in LTspice

e) Measure the phase delay/difference between $V_{S(t)}$ Vs $V_{R(t)}$ in time and degrees

f) Plot input source voltage $V_{S(t)}$ Vs voltage across inductor $V_{L(t)}$ in LTspice

g) Measure the phase delay/difference between $V_{S(t)}$ Vs $V_{L(t)}$ in time and degrees

h) Calculate the power factor of the circuit.

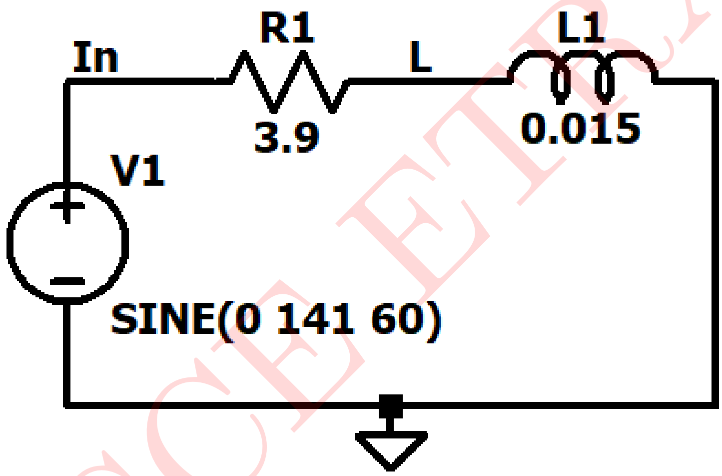

Figure 22: Series RL Circuit

Solution:

$R_1 = 3.9\Omega$, $L_1 = 0.015$H, $f = 60$Hz, $V_{peak} = 141$V

$X_{L_1} = 2\pi f L_1 = 5.6548\Omega$

$$\begin{aligned} \text{Z} &= R_1 + \text{j}X_{L_1} \\ &= 3.9 + 5.6548\text{j} \\ &= 6.8692\angle 55.4067°\Omega \end{aligned}$$

$$\begin{aligned} I_{peak} &= \frac{V_{peak}}{Z} \\ &= \frac{141}{6.8692\angle 55.4067°} = 20.5264\angle -55.4067°\text{A} \end{aligned}$$

$(V_{R_1})_{peak} = I_{peak} \times \text{R} = 20.5264\angle -55.4067° \times 3.9 = 80.0522\angle -55.4067°\text{V}$

$(V_{L_1})_{peak} = I_{peak} \times X_{L_1} = 116.0716\angle 34.5933°\text{V}$

Phase difference between $V_{S(t)}$ and $I_{S(t)}$
$\phi_1 = 0 - (-55.4067)$
$\phi_1 = 55.4067°$

$$t_1 = \frac{\phi_1}{360° \times f} = \frac{55.4067°}{360° \times 60} = 2.5651ms$$

Phase difference between $V_{S(t)}$ and $V_{R(t)}$
$\phi_2 = 0 - (-55.4067)$
$\phi_2 = 55.4067°$

$$t_2 = \frac{\phi_2}{360° \times f} = \frac{55.4067°}{360° \times 60} = 2.5651ms$$

Phase difference between $V_{S(t)}$ and $V_{L(t)}$
$\phi_3 = 0 - 34.5933$
$\phi_3 = -34.5933°$

$$t_3 = \frac{\phi_3}{360° \times f} = \frac{180° - 34.5933°}{360° \times 60} = \frac{145.4067°}{360° \times 60} = 6.7317ms$$

$$\begin{aligned}\text{Power factor} &= \cos(\phi_1)\\ &= \cos(55.4067°)\\ &= 0.5677\end{aligned}$$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

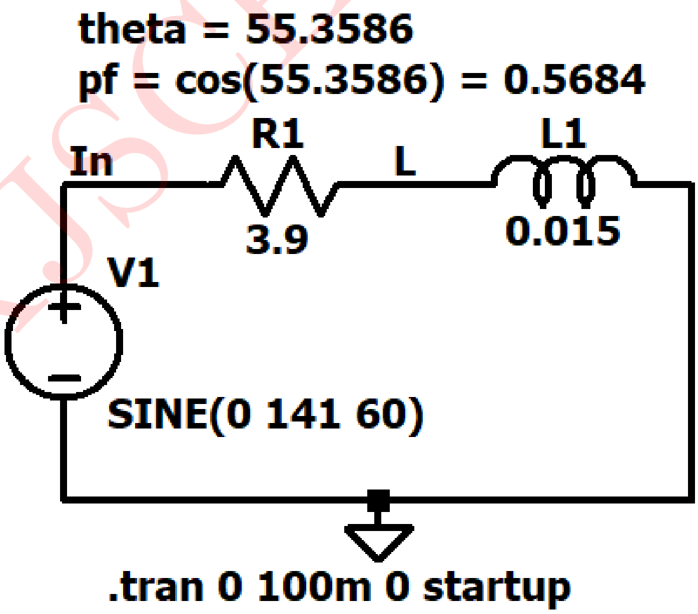

Figure 23: Circuit Schematic for Power Factor

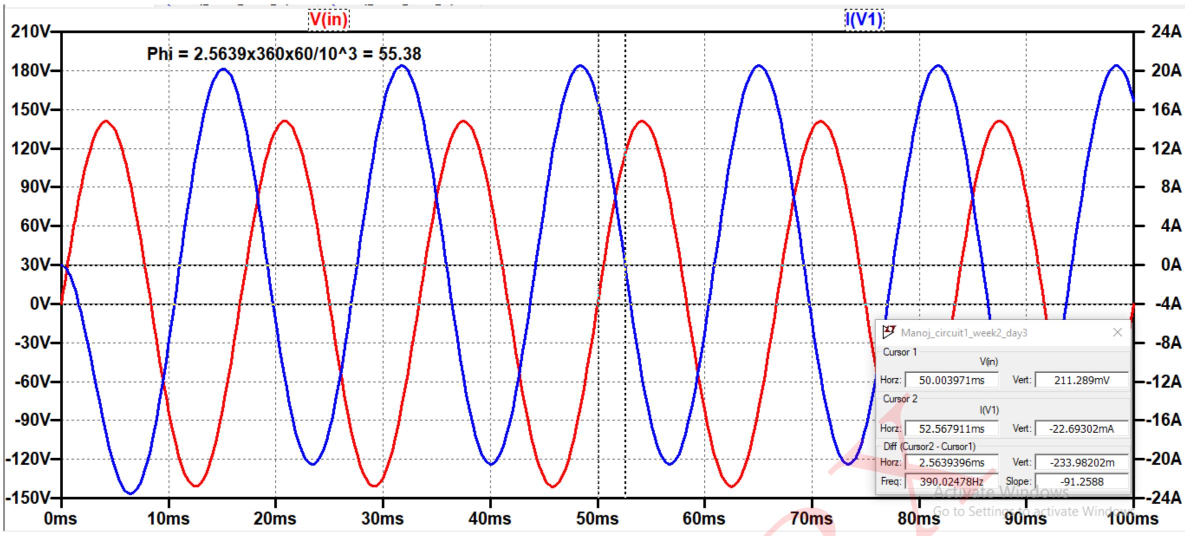

Figure 24: Simulated Results for Phase difference between $V_{S(t)}$ and $I_{S(t)}$

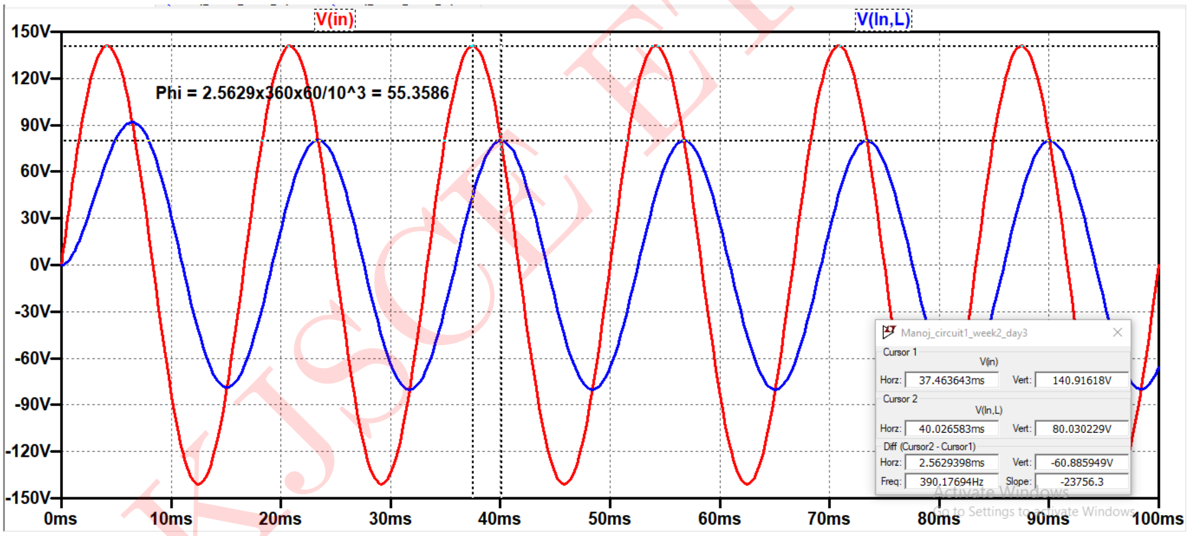

Figure 25: Simulated Results for Phase difference between $V_{S(t)}$ and $V_{R(t)}$

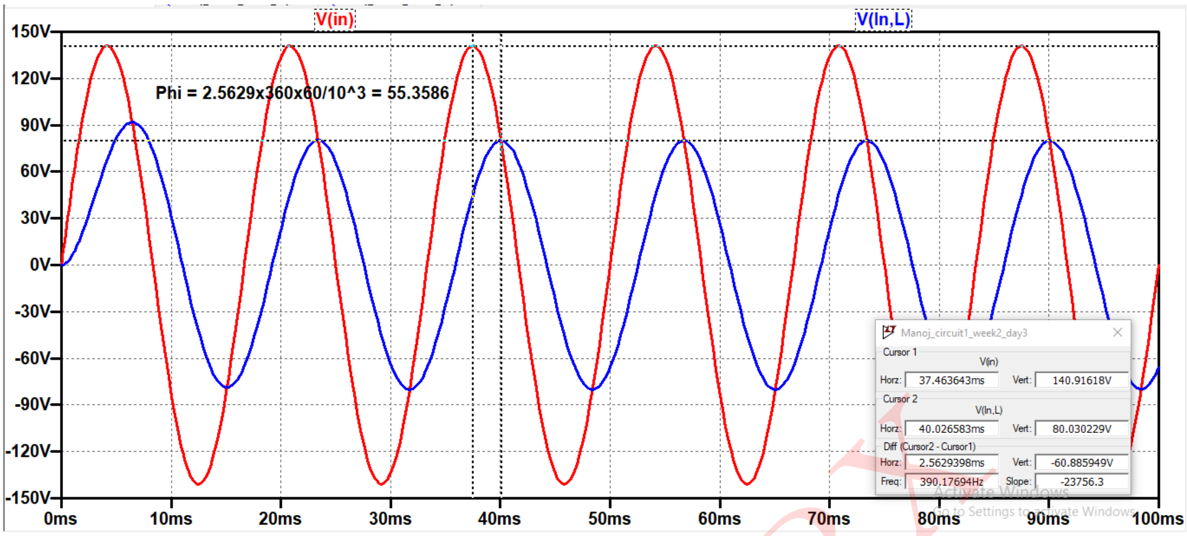

Figure 26: Simulated Results for Phase difference between $V_{S(t)}$ and $V_{R(t)}$

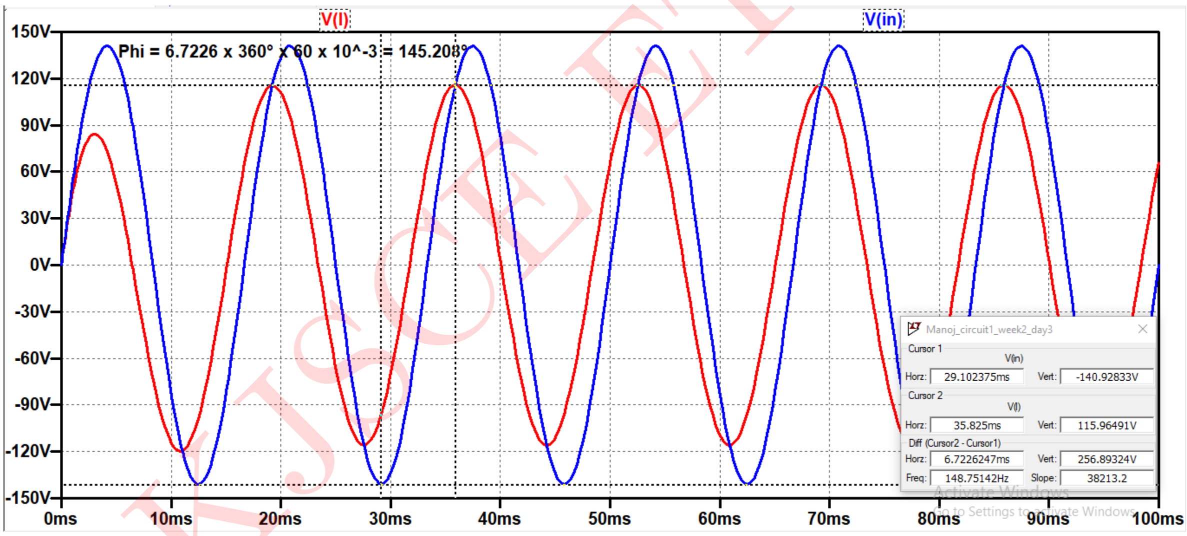

Figure 27: Simulated Results for Phase difference between $V_{S(t)}$ and $V_{L(t)}$

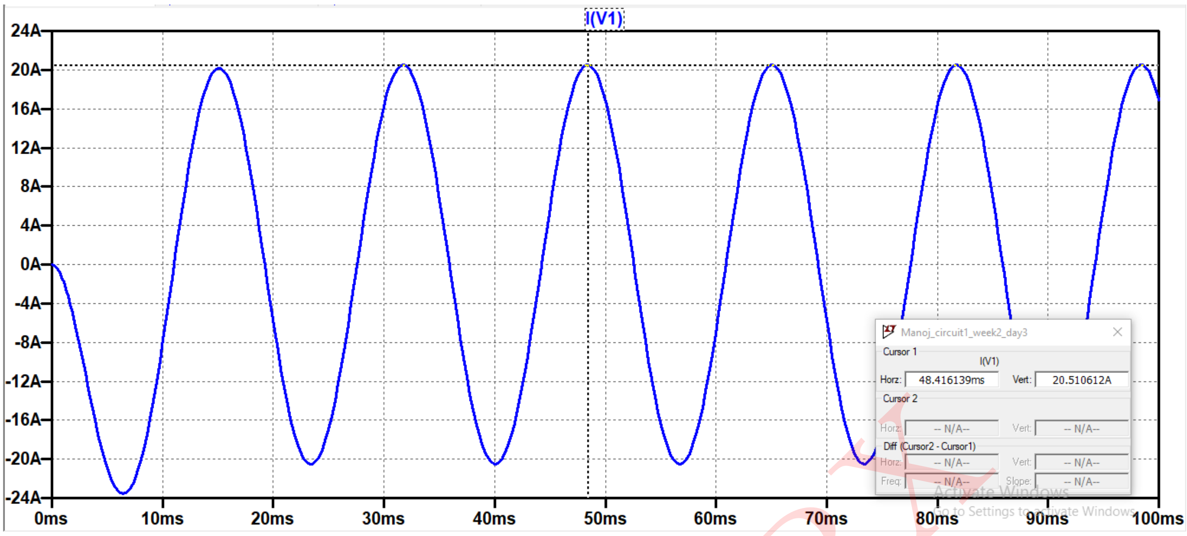

Figure 28: Simulated Results for I_{peak}

Comparison of Theoretical and Simulated Values:-

Parameters	**Theoretical Values**	**Simulated Values**
$(V_{R_1})_{peak}$	80.0522V	80.0302V
$(V_{L_1})_{peak}$	116.0716V	115.9649V
I_{peak}	20.5264A	20.5106A
Phase difference between $V_{S(t)}$ and $I_{S(t)}$ in degree and time	55.4067° 2.5651ms	55.38° 2.5639ms
Phase difference between $V_{S(t)}$ and $V_{R(t)}$ in degree and time	55.4067° 2.5651ms	55.3586° 2.5629ms
Phase difference between $V_{S(t)}$ and $V_{L(t)}$ in degree and time	145.4067° 6.7317ms	145.208° 6.7226ms
Power factor	0.5677	0.5684

Table 6: Numerical 6

Numerical 7: A series resonance network consisting of a resistor of 24Ω, a capacitor of 1.8μF and an inductor of 24mH is connected across a sinusoidal supply voltage which has a constant output of AC 9 volts at all frequencies. Calculate, the resonant frequency, the current at resonance, the voltage across the inductor and capacitor at resonance, the quality factor and the bandwidth of the circuit.
Plot the resonance curve, the current at resonance, the voltage across the inductor and capacitor at resonance in LTspice.

Solution:

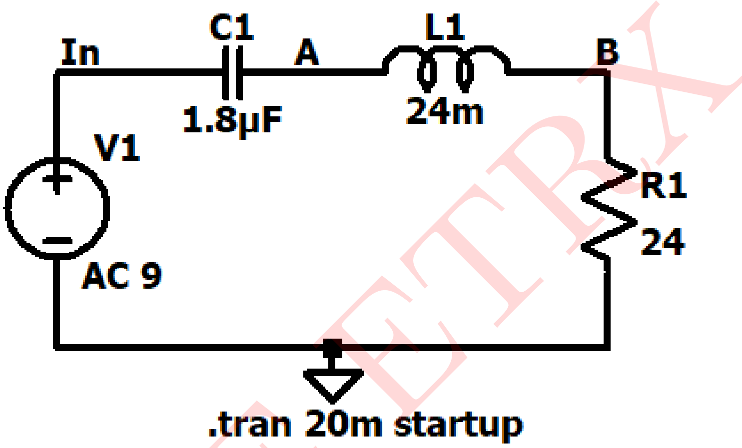

Figure 29: Series RLC Circuit

$R_1 = 24\Omega$, $L_1 = 24$mH, $C_1 = 1.8\mu$F, $V_{rms} = 9$V

$$f_r = \frac{1}{2\pi\sqrt{L_1C_1}} = 765.7345\text{Hz}$$

$$X_{L_1} = 2\pi f_r L_1 = 115.47\Omega$$

$$\therefore X_{C_1} = X_{L_1} = 115.47\Omega$$

$$I_r = \frac{V}{R_1} = \frac{9}{24} = 0.375\text{A}$$

$$V_{L_1} = \text{I}\times X_{L_1} = 43.3012\text{V}$$

$$V_{L_{1peak}} = 43.3012\sqrt{2} = 61.2372\text{V}$$

$$V_{L_{1peak}} = V_{C_{1peak}} = 61.2372\text{V}$$

$$\text{Q-factor} = \frac{1}{R_1}\sqrt{\frac{L_1}{C_1}} = \frac{1}{24}\sqrt{\frac{24\times10^{-3}}{1.8\times10^{-6}}} = 4.8112$$

$$\text{BandWidth} = \frac{R_1}{2\pi L_1} = 159.1549\text{Hz}$$

$$= \frac{141}{6.8692\angle 55.4067^\circ} = 20.5264\angle{-55.4067^\circ}\text{A}$$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

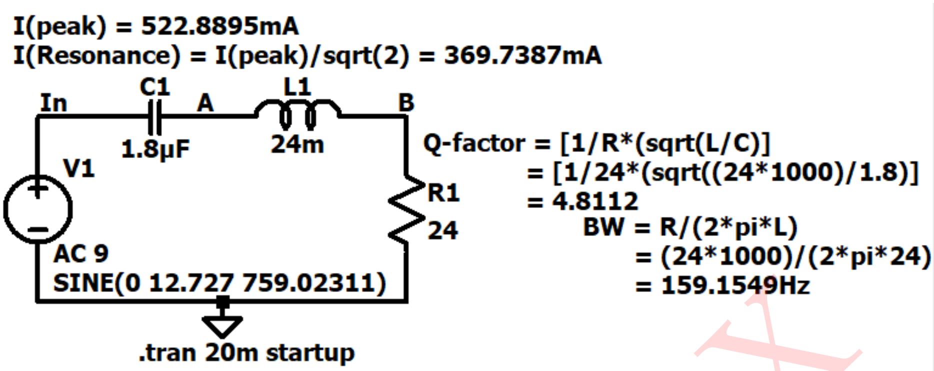

Figure 30: Circuit Schematic

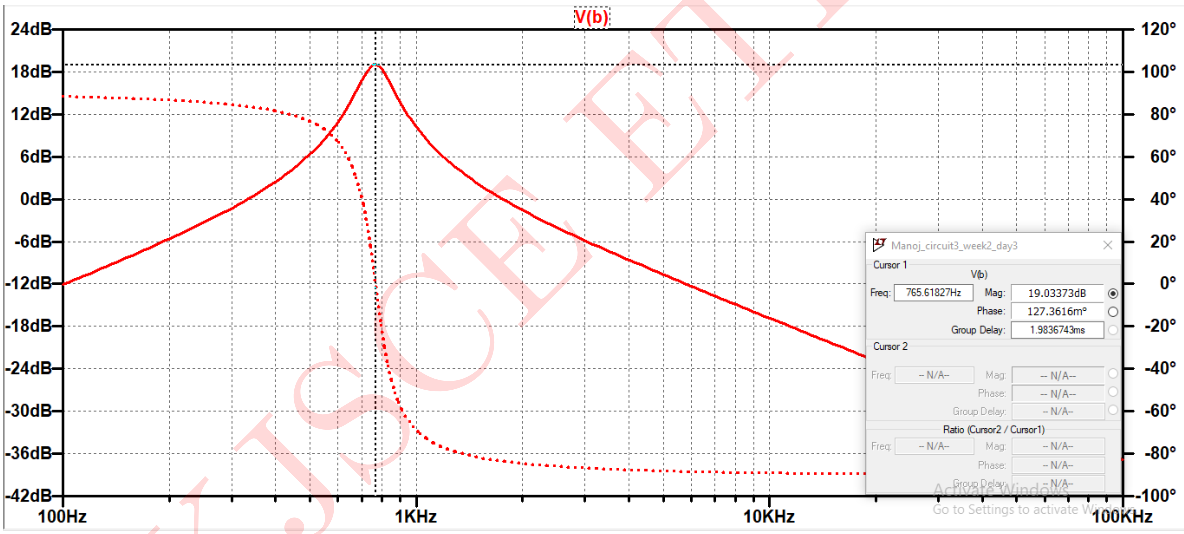

Figure 31: Simulated Results for resonance frequency

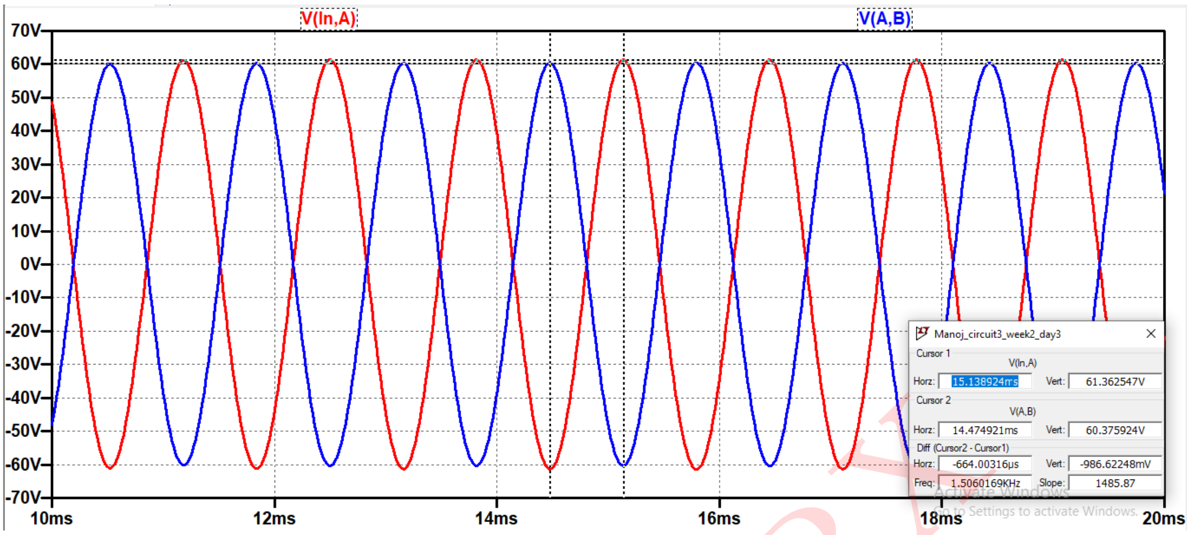

Figure 32: Simulated Results for Phase difference between V_L and V_C

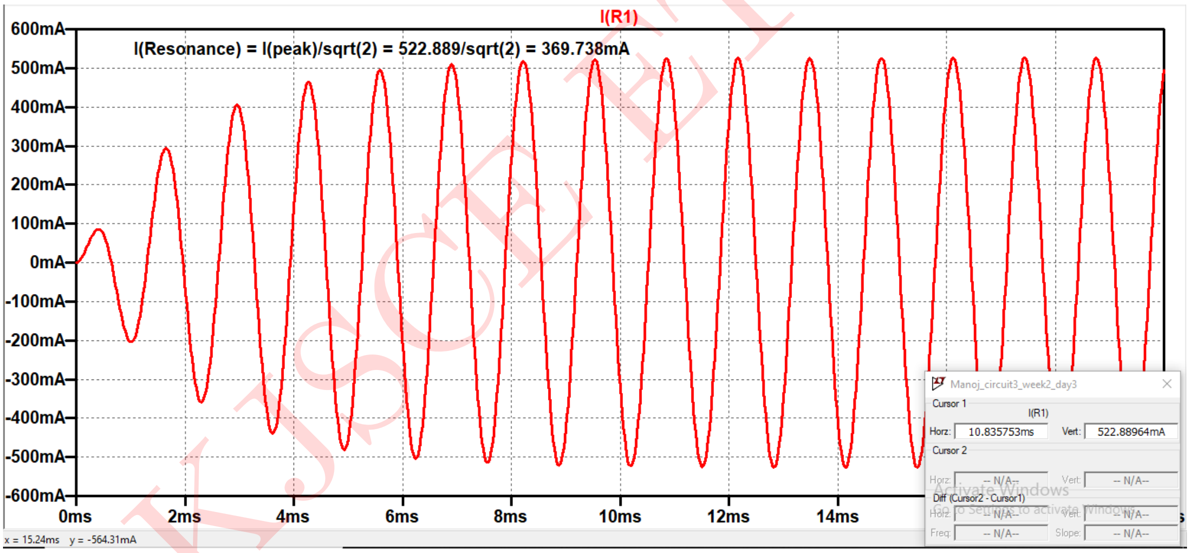

Figure 33: Simulated Results for current at resonance I_r

Comparison of Theoretical and Simulated Values:-

Parameters	Theoretical Values	Simulated Values
$V_{C_{1peak}}$	61.2372V	61.3625V
$V_{L_{1peak}}$	61.2372V	60.3759V
I_r	375mA	369.738mA
f_r	765.7345Hz	765.6182Hz
Q-factor	4.8112	4.8112
BandWidth	159.1549Hz	159.1549Hz

Table 7: Numerical 7

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