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 $75\mu F$ are connected in 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

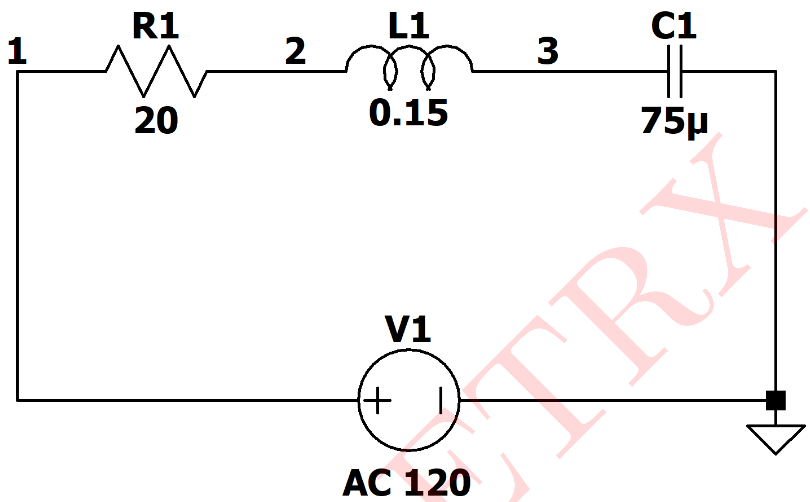

Figure 1: Circuit 1

Solution:

Frequency $f = 60Hz$, angular frequency: ω

$\omega = 2\pi f = 2\pi\,(60) = 120\pi\ rad/s$

Finding Inductive reactance X_L:

$X_L = \omega L_1 = 120\pi \times 0.15 = 18\pi$

$X_L = 56.5487\Omega$

Finding Capacitive reactance for X_C:

$$X_C = \frac{1}{\omega C_1} = \frac{1}{120\pi \times 75 \times 10^{-6}} = \frac{1000}{9\pi}\Omega$$

$X_C = 35.3678\Omega$

Net reactance, X:

$X = X_L - X_C$

$X = 56.5487 - 35.3678$

$\therefore X = 21.1809\Omega$

To find the phase angle ϕ:

$\phi = \tan^{-1}\left(\frac{X}{R_1}\right) = \tan^{-1}\left(\frac{21.1809}{20}\right)$

$\phi = 46.6426°$

To find total impedance, Z:

$|Z| = \sqrt{R_1^2 + (X)^2} = \sqrt{25^2 + (21.1809)^2}$

$\therefore |Z| = 29.1313\Omega$

$Z = 29.1313\angle\phi$

$Z = 29.1313\angle 46.6426°\Omega$

a) Total current drawn by the circuit I,

$I = \frac{V_{in}}{Z} = \frac{120}{29.1313\angle 46.6426°}$

$I = 4.1193\angle - 46.6426° A$

b) V_R, V_L and V_C,

$V_R = I \times R_1 = (4.1193\angle - 46.6426°) \times 20$

$\therefore V_R = 82.3856\angle - 46.643° V$

$V_L = I \times X_L = (4.1193\angle - 46.6426°) \times (56.5487\angle 90°)$

$\therefore V_L = 232.924\angle 43.574° V$

$V_C = I \times X_C = (4.1193\angle - 46.6426°) \times (35.3678\angle - 90°)$

$\therefore V_C = 145.6906\angle - 136.643° V$

c) Power factor $= \cos(\phi) = \cos(46.6426°)$

$\therefore$ Power factor $= 0.6865$ lagging

d) Voltage Phasor diagram:

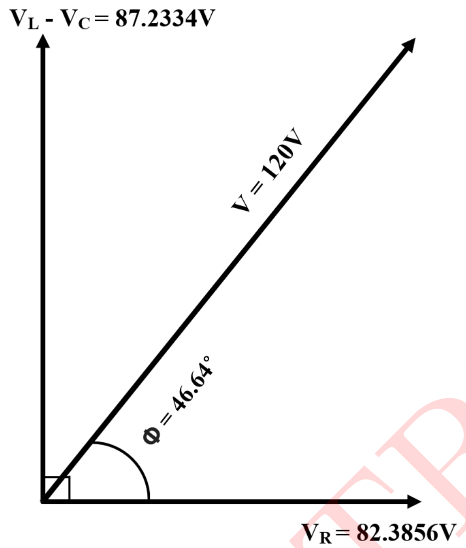

Figure 2: Voltage Phasor diagram

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the graph obtained is as follows:

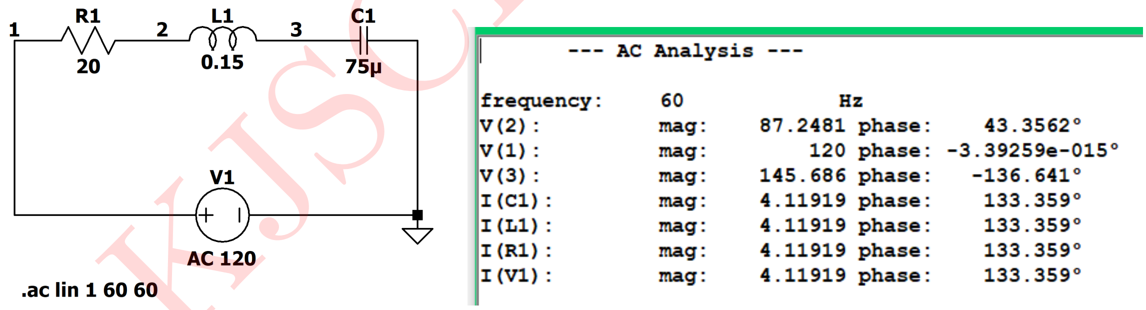

Figure 3: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I	$4.1193A$	$4.1192A$
V_R	$82.3856V$	$82.3838V$
V_L	232.924	232.934
V_C	145.6906	145.686
ϕ	46.6426°	46.6426°
Power Factor	0.6865	0.6865

Table 1: Comparison of calculated and simulated results

Numerical 2: In the R-L circuit given in Figure 4, $R = 5\Omega$, $L = 0.1H$ and a $60Hz$ AC voltage $V = 220\angle 60°$, find:

a) Current through the circuit

b) Power factor

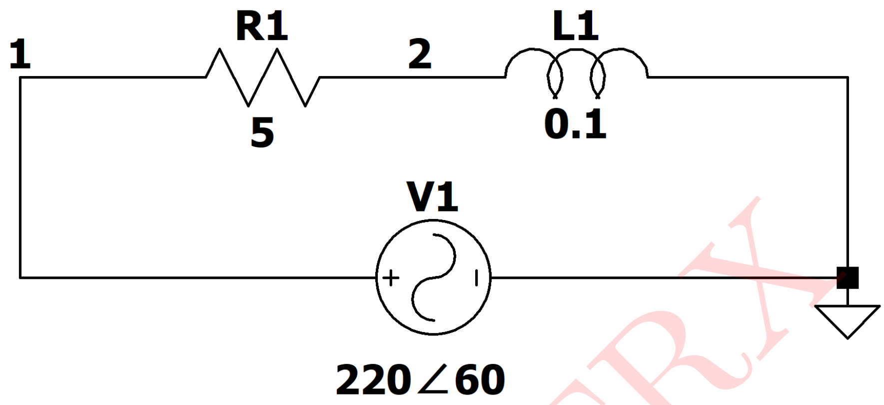

Figure 4: Circuit 2

Solution:

$V_{rms} = \frac{220}{\sqrt{2}} = 155.5635V$

Frequency $f = 60Hz$, angular frequency: ω

$\omega = 2\pi f = 2\pi(60) = 120\pi\ rad/s$

Finding Inductive reactance X_L:

$X_L = \omega L_1 = 120\pi \times 0.1 = 12\pi$

$X_L = 37.699\Omega$

To find the phase angle ϕ:

$\phi = \tan^{-1}\left(\frac{X_L}{R_1}\right) = \tan^{-1}\left(\frac{37.699}{5}\right)$

$\phi = 82.445°$

To find total impedance, Z:

$|Z| = \sqrt{R_1^2 + (X_L)^2} = \sqrt{5^2 + (37.699)^2}$

$\therefore |Z| = 38.029\Omega$

$Z = 38.029\angle\phi$

$Z = 38.029\angle 82.445°\Omega$

Finding RMS current I_{rms},

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{220\angle 60°}{38.029\angle 82.445°}$$

$$I_{rms} = 5.7851\angle -22.445° A$$

a) Current through the circuit I,

$$I = \frac{I_{rms}}{\sqrt{2}}$$

$$I = 4.0907\angle -22.445° A$$

b) Power factor $= \cos(\phi) = \cos(82.445°)$

$\therefore$ Power factor $= 0.1315$ lagging

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the graph obtained is as follows:

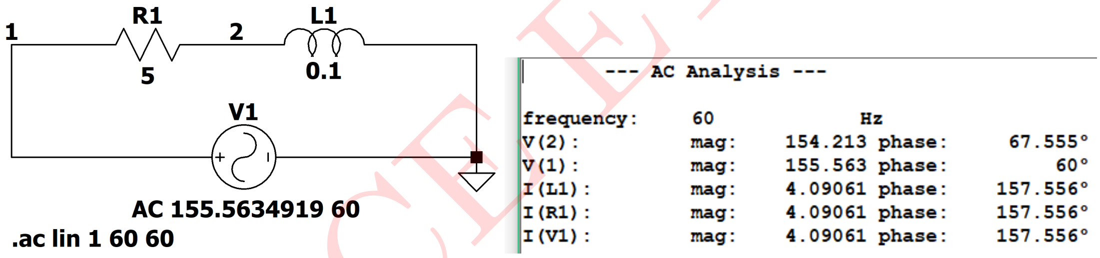

Figure 5: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I	$4.0907A$	$4.09061A$
Power Factor	0.1315	0.1315

Table 2: Comparison of calculated and simulated results

Numerical 3: A voltage $V = 120\ sin314t$ is applied to a circuit consisting of a 25Ω resistor and an $60\mu F$ capacitor in series. Determine:

a) An expression for the value of the current flowing at any instant

b) V_R and V_C

c) Power factor

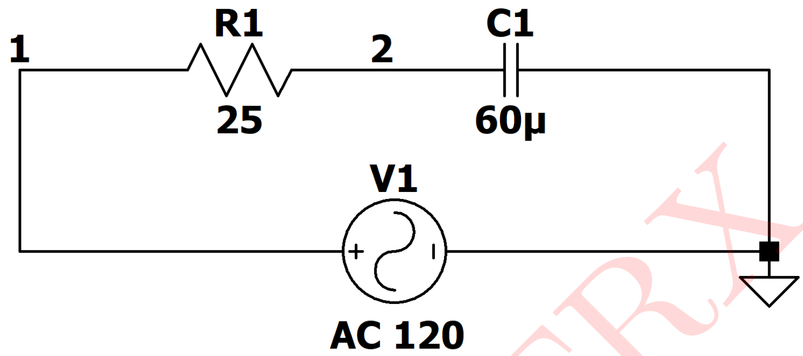

Figure 6: Circuit 3

Solution:

Angular frequency: ω

$\omega = \ 314 rad/s$

Finding Capacitive reactance, X_C:

$X_C = \dfrac{1}{\omega C_1} = \dfrac{1}{314 \times 60 \times 10^{-6}} = 53.079\Omega$

$X_C = 53.079\Omega$

To find the phase angle ϕ:

$\phi = \tan^{-1}\left(\dfrac{-X_C}{R_1}\right) = \tan^{-1}\left(\dfrac{-53.079}{25}\right)$

$\phi = -64.7797°$

To find total impedance, Z:

$|Z| = \sqrt{R_1^2 + (X_C)^2} = \sqrt{25^2 + (53.079)^2}$

$\therefore |Z| = 58.6718\Omega$

$Z = 58.6718\angle\phi$

$Z = 58.6718\angle - 64.7797°\Omega$

a) Current through the circuit I,

$I = \dfrac{V}{Z} = \dfrac{120}{58.6718\angle - 64.7797°}$

$I = 2.045\angle 64.7797° A$

b) Voltage across resistor, V_R:

$V_R = I \times R_1 = (2.045\angle 64.7797°) \times 25$

$\therefore V_R = 51.125\angle 64.7797° V$

Voltage across Capacitor, V_C

$V_C = I \times X_C = (2.045\angle 64.7797°) \times (53.079\angle -90°)$

$\therefore V_C = 108.546\angle -25.22° V$

c) Power factor $= \cos(\phi) = \cos(-64.7797°)$

$\therefore$ Power factor $= 0.42609$ leading

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the graph obtained is as follows:

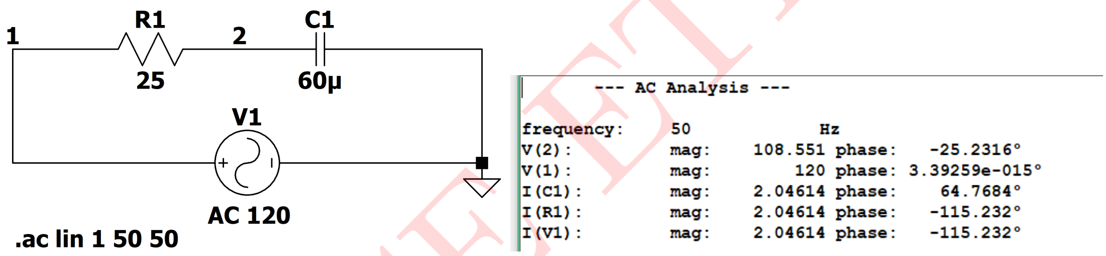

Figure 7: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I	$2.045A$	$2.046A$
V_R	$51.125V$	$51.15V$
V_C	$108.546V$	$108.551V$
Power Factor	0.42609	0.42609

Table 3: Comparison of calculated and simulated results

Numerical 4: The Circuit given in Figure 8 consists of a resistance of 5Ω, an inductance of $14mH$ and a capacitor of $20\mu F$ are connected in parallel across a 110V, 50Hz supply. Calculate:

a) Individual currents drawn by each element
b) Total current drawn from the supply
c) Overall power factor of the circuit
d) Draw the phasor diagram

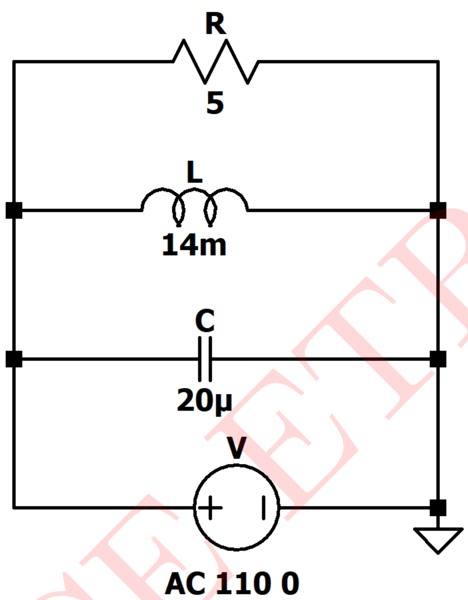

Figure 8: Circuit 4

Solution:

Frequency $f = 50Hz$, angular frequency: ω

$\omega = \; 2\pi f \; = \; 2\pi\,(50) \; = \; 100\pi \; rad/s$

Finding Inductive reactance X_L:

$X_L \; = \; \omega L \; = \; 100\pi \times 14 \times 10^{-3} = 1.4\pi$

$X_L = 4.3982\Omega$

Finding Capacitive reactance for X_C:

$$X_C = \frac{1}{\omega C} = \frac{1}{100\pi \times 20 \times 10^{-6}} = \frac{500}{\pi}\Omega$$

$X_C = 159.1545\Omega$

a) Individual currents drawn by each element:

Current through resistor, I_R:

$I_R = \dfrac{V}{R} = \dfrac{110}{5}$

$I_R = 22A$

Current through Inductor, I_L:

$I_L = \dfrac{V}{X_L} = \dfrac{110}{4.3982j}$

$I_L = 25.0101\angle -90° A$

Current through Capacitor, I_C:

$I_C = \dfrac{V}{X_C} = \dfrac{110}{-159.1545j}$

$I_C = 0.6911\angle 90° A$

b) Total current drawn from the supply, I_{V_1}:

$I_{V_1} = I_R + I_C + I_L$

$I_{V_1} = 22 + 25.0101\angle -90° + 0.6911\angle 90°$

$I_{V_1} = 32.7934\angle -47.866° A$

c) Overall power factor of the circuit:

Power factor of complete circuit $= \cos\phi$ where,

$\phi =$ phase difference between I_{V_1} and V_1

$\phi = -47.866°$

$\therefore \cos\phi = \cos -47.866°$

$\cos\phi = 0.6709$

Since $X_C > X_L$, power factor is leading

Hence, overall power factor $= p.f. = 0.6709$ leading

d) Phasor diagram

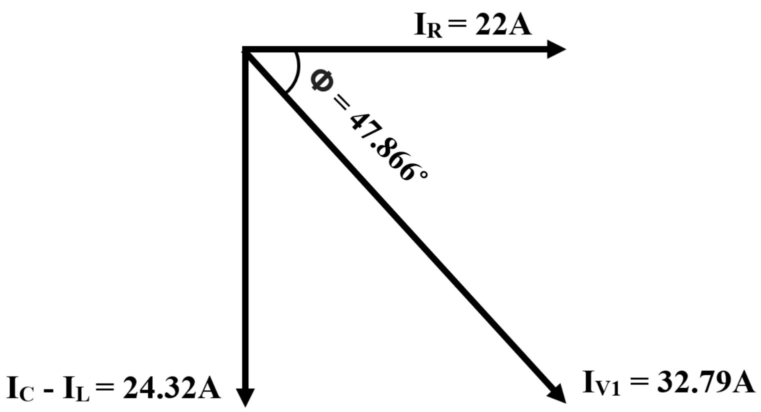

Figure 9: Phasor diagram

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the readings obtained are as follows:

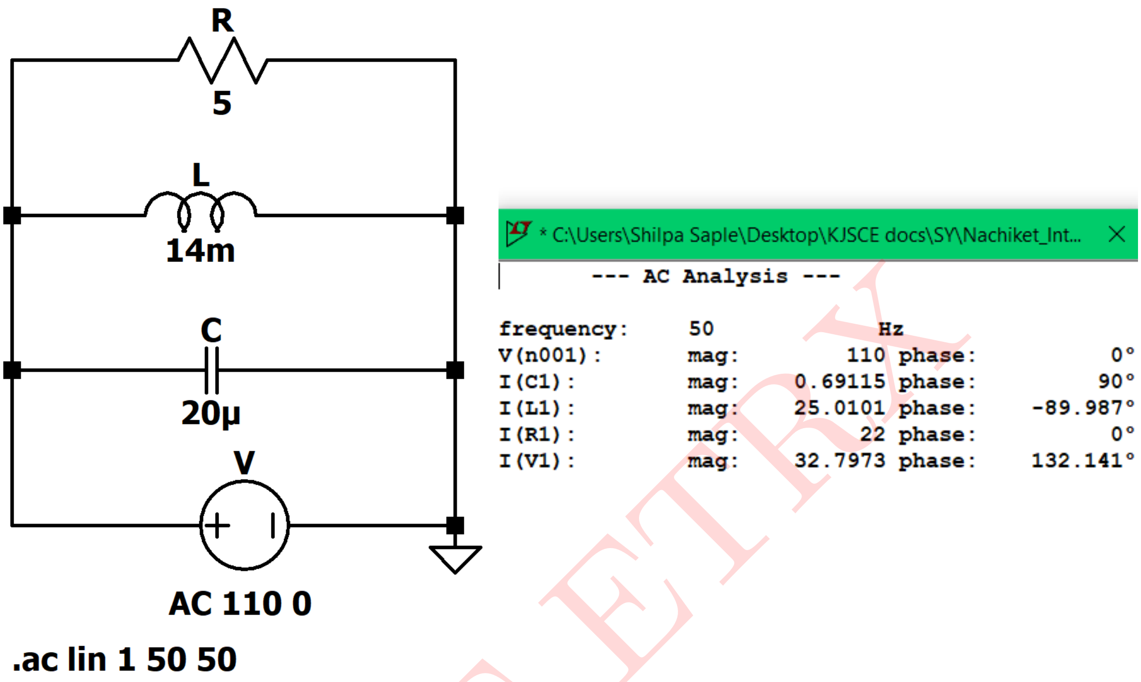

Figure 10: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
I_R	$22\angle 0° A$	$22\angle 0° A$
I_L	$25.01\angle -90° A$	$25.01\angle -89.987° A$
I_C	$0.6911\angle 90° A$	$0.6911\angle 90° A$
I_{V_1}	$32.7934\angle -47.866° A$	$32.7973\angle -47.859° A$
ϕ	47.866°	47.859°
Power Factor	0.6709	0.6709

Table 4: Comparison of calculated and simulated results

Numerical 5: For the circuit given in Figure 11, find the current through all the branches I_1, I_2 and I_3 and the voltage across all the branches if $R_1 = 6\Omega$, $L_1 = j4\Omega$, $R_2 = 20\Omega$, $L_2 = j8\Omega$, $R_3 = 9\Omega$, $C_1 = -j6\Omega$, $V_1 = 100V$ and $f = 50Hz$.

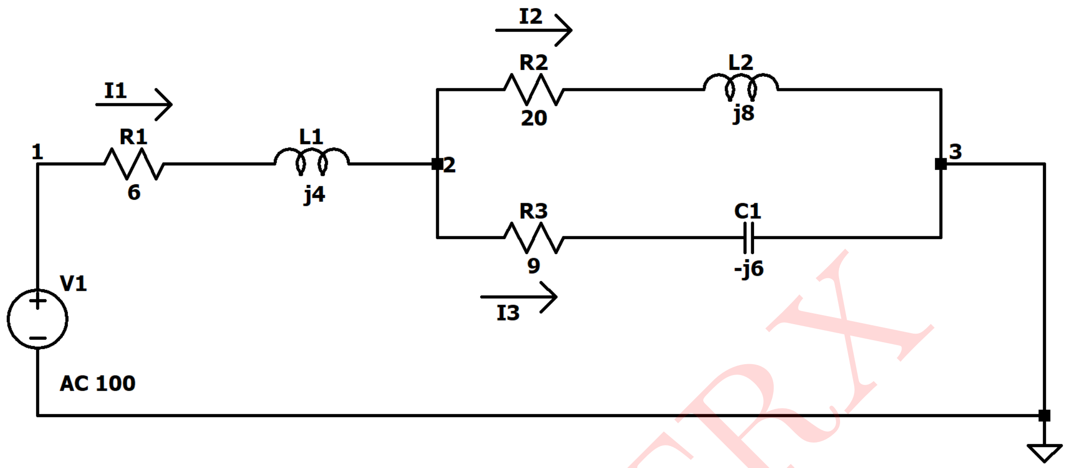

Figure 11: Circuit 5

Solution:

Frequency $f = 50Hz$, angular frequency: ω

$\omega = 2\pi f = 2\pi(50) = 100\pi \ rad/s$

Impedance of branch 1, $Z_1 = 6 + j4\Omega$

Impedance of branch 2, $Z_2 = 20 + j8\Omega$

Impedance of branch 3, $Z_3 = 9 - j6\Omega$

Combined impedance of branch 2 and 3 after parallel combination, Z_4:

$Z_4 = Z_2 || Z_3$

$$Z_4 = \frac{Z_2 \times Z_3}{Z_2 + Z_3}$$

$$Z_4 = \frac{(20 + j8) \times (9 - j6)}{29 + j2}$$

$Z_4 = 7.7112 - j2.1869\Omega$

Total impedance of the circuit, Z:

$Z = Z_1 + Z_4$

$Z = 13.7112 + j1.813\Omega$

$Z = 13.83\angle 7.532°\Omega$

Total current through the circuit i.e. current through branch 1, I_1:

$$I_1 = \frac{V_1}{Z}$$

$$I_1 = \frac{100}{13.83\angle 7.532°}$$

$I_1 = 7.23065\angle -7.532° A$

Current through branch 2, I_2:

From current division rule:

$$I_2 = \frac{Z_3}{Z_2 + Z_3} \times I_1$$

$$I_2 = \frac{9 - j6}{20 + j8 + 9 - j6} \times (7.23065\angle - 7.532°)$$

$$I_2 = 2.6906\angle - 45.167° A$$

Current through branch 3, I_3:

From current division rule:

$$I_3 = I_1 - I_2$$

$$I_3 = (7.23065\angle - 7.532°) - (2.6906\angle - 45.167°)$$

$$I_3 = 5.3581\angle 10.324° A$$

Voltage across first branch, V_{12}:

From voltage division rule:

$$V_{12} = I_1 \times Z_1$$

$$V_{12} = (7.23065\angle - 7.532°) \times (6 + j4)$$

$$V_{12} = (7.23065\angle - 7.532°) \times (7.21\angle 27°)$$

$$V_{12} = 52.141\angle 26.16° V$$

Voltage across second and third branch, V_{23}:

$$V_{23} = V_1 - V_{12}$$

$$V_{23} = (100) - (52.141\angle 26.16°)$$

$$V_{23} = 57.953\angle - 23.34° V$$

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the readings obtained are as follows:

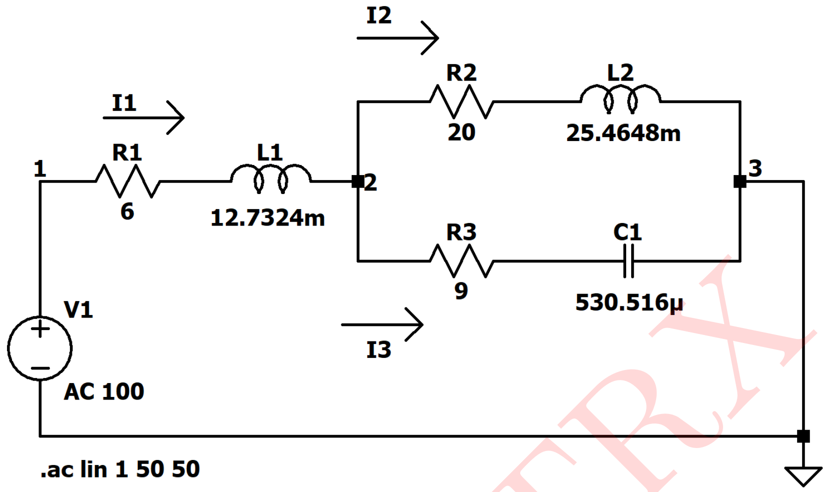

Figure 12: Circuit Schematic

frequency:	50	Hz		
V(1):	mag:	100	phase:	0°
V(n002):	mag:	57.2782	phase:	5.69673°
V(2):	mag:	57.9502	phase:	-23.366°
V(n001):	mag:	21.5213	phase:	44.8264°
V(n003):	mag:	32.145	phase:	-79.6759°
I(C1):	mag:	5.3575	phase:	10.3241°
I(L2):	mag:	2.69016	phase:	-45.1665°
I(L1):	mag:	7.22982	phase:	-7.53132°
I(R3):	mag:	5.3575	phase:	10.3241°
I(R2):	mag:	2.69016	phase:	-45.1665°
I(R1):	mag:	7.22982	phase:	-7.53132°
I(V1):	mag:	7.22982	phase:	172.469°

Figure 13: Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I_1	$7.23065\angle-7.532°A$	$7.22982\angle-7.531°A$
I_2	$2.6906\angle-45.167°A$	$2.69016\angle-45.166°A$
I_3	$5.3581\angle10.324°A$	$5.3575\angle10.324°A$
V_{12}	$52.141\angle26.16°V$	$52.1409\angle26.15°V$
V_{23}	$57.953\angle-23.34°V$	$57.9502\angle-23.36°V$
ϕ	7.532°	7.531°

Table 5: Comparison of calculated and simulated results

Numerical 6: A $50Hz$ sinusoidal voltage $V = 100\sin\omega t$ is applied to a series R-L circuit. The values of the resistance and the inductance are 22Ω and $0.0116H$ 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 $V_S(t)$ and 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 $V_S(t)$ and 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 $V_S(t)$ and 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.

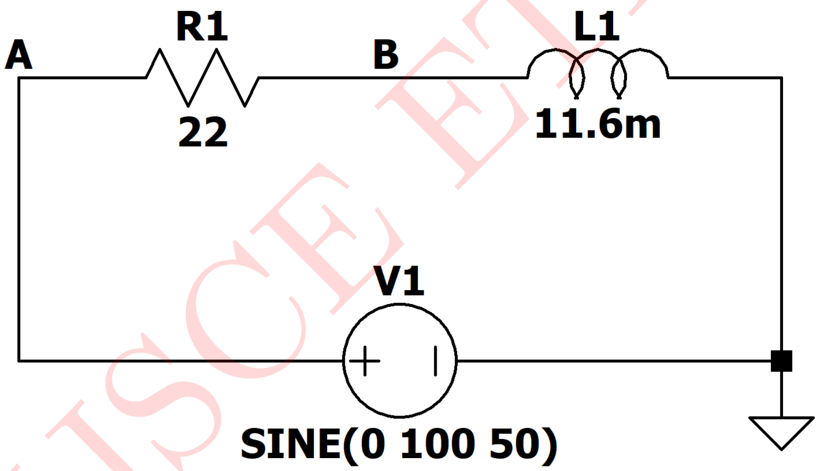

Figure 14: Circuit 6

Solution:

Frequency $f = 50Hz$, angular frequency: ω

$\omega = 2\pi f = 2\pi(50) = 100\pi\ rad/s$

Finding Inductive reactance X_L:

$X_L = \omega L_1 = 100\pi \times 0.0116 = 1.16\pi$

$X_L = 3.6442\Omega$

To find the phase angle ϕ:

$\phi = \tan^{-1}\left(\frac{X_L}{R_1}\right) = \tan^{-1}\left(\frac{3.6442}{22}\right)$

$\phi = 9.4054°$

To find total impedance, Z:

$|Z| = \sqrt{R_1^2 + (X_L)^2} = \sqrt{22^2 + (3.6442)^2}$

$\therefore |Z| = 22.2998\Omega$

$Z = 22.2998\angle\phi$

$Z = 22.2998\angle 9.4054°\Omega$

Total source current in the circuit I,

$I = \dfrac{V_S}{Z} = \dfrac{100}{22.2998\angle 9.4054°}$

$I = 4.4843\angle -9.4054° A$

Voltage across resistor, V_R:

$V_R = I \times R_1 = (4.4843\angle -9.4054°) \times 22$

$\therefore V_R = 98.6556\angle -9.4054° V$

Voltage across inductor, V_L:

$V_L = I \times X_L = (4.4843\angle -9.4054°) \times (3.6442\angle 90°)$

$\therefore V_L = 16.3417\angle 80.59° V$

a) Peak values of V_R, V_L and I:

Peak voltage across resistor $= (V_R)_{max} = 98.6556V$

Peak voltage across inductor $= (V_L)_{max} = 16.3417V$

Peak value of source current $= (I)_{max} = 4.4843A$

b) Plot of input source voltage $V_S(t)$ and input source current $I_S(t)$ in LTspice

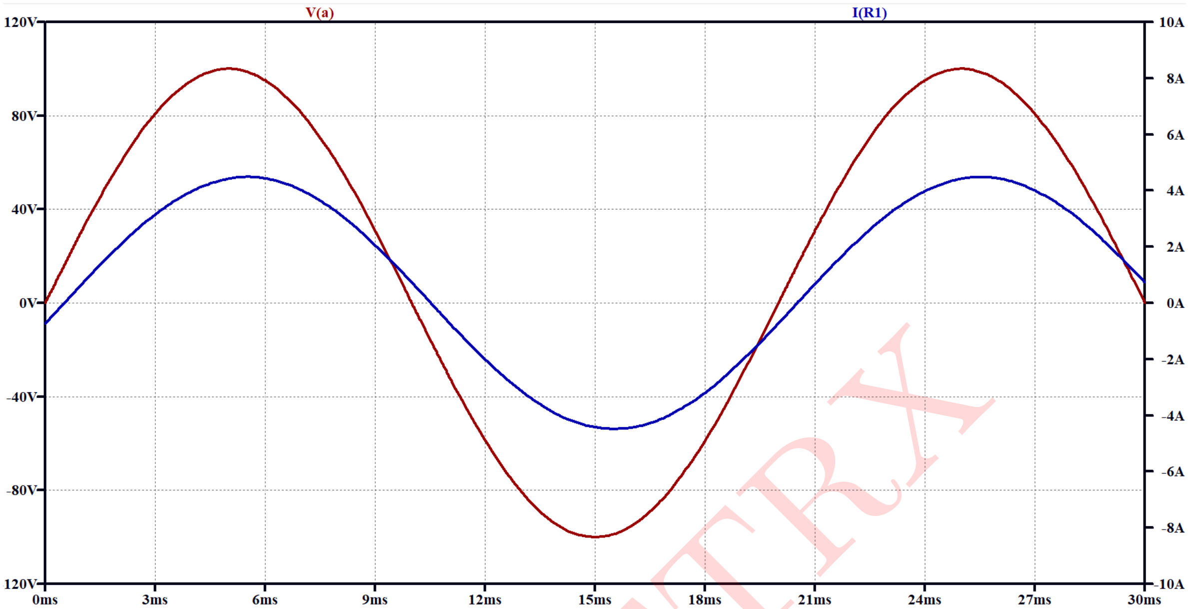

Figure 15: $V_S(t)$ and $I_S(t)$

c) Phase difference between $V_S(t)$ and $I_S(t)$ in time and degrees:

$\Delta\phi_1 = 9.4054°$

$$\Delta t_1 = \frac{\Delta\phi_1}{f \times 360}$$

$$\Delta t_1 = \frac{9.4054}{50 \times 360}$$

$\Delta t_1 = 0.5225ms$

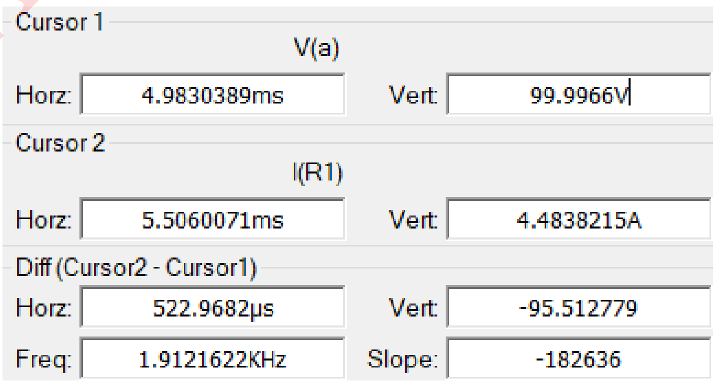

Figure 16: Phase difference from LTSpice

d) Plot of input source voltage $V_S(t)$ vs voltage across resistor $V_R(t)$ in LTspice

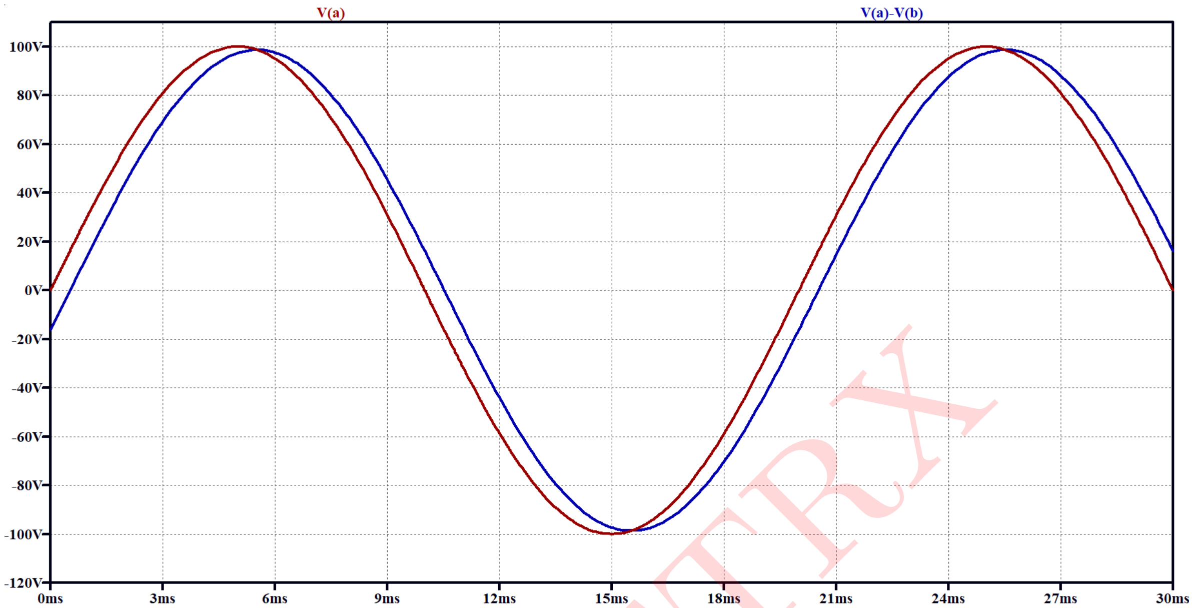

Figure 17: $V_S(t)$ and $V_R(t)$

e) Phase difference between $V_S(t)$ and $V_R(t)$ in time and degrees:

$\Delta\phi_2 = 9.4054°$

$\Delta t_2 = \dfrac{\Delta\phi_1}{f \times 360}$

$\Delta t_2 = \dfrac{9.4054}{50 \times 360}$

$\Delta t_2 = 0.5225ms$

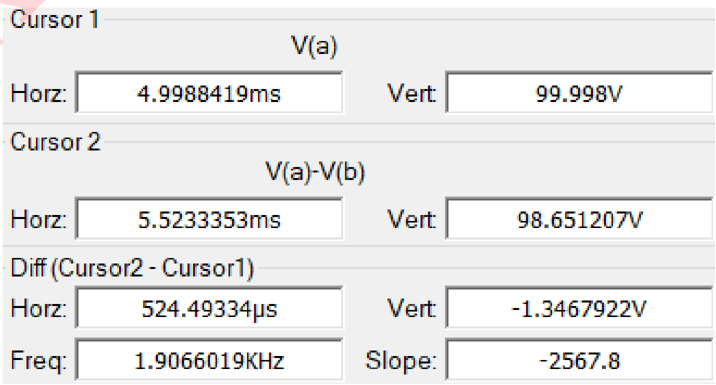

Figure 18: Phase difference from LTSpice

f) Plot of input source voltage $V_S(t)$ vs voltage across inductor $V_L(t)$ in LTspice

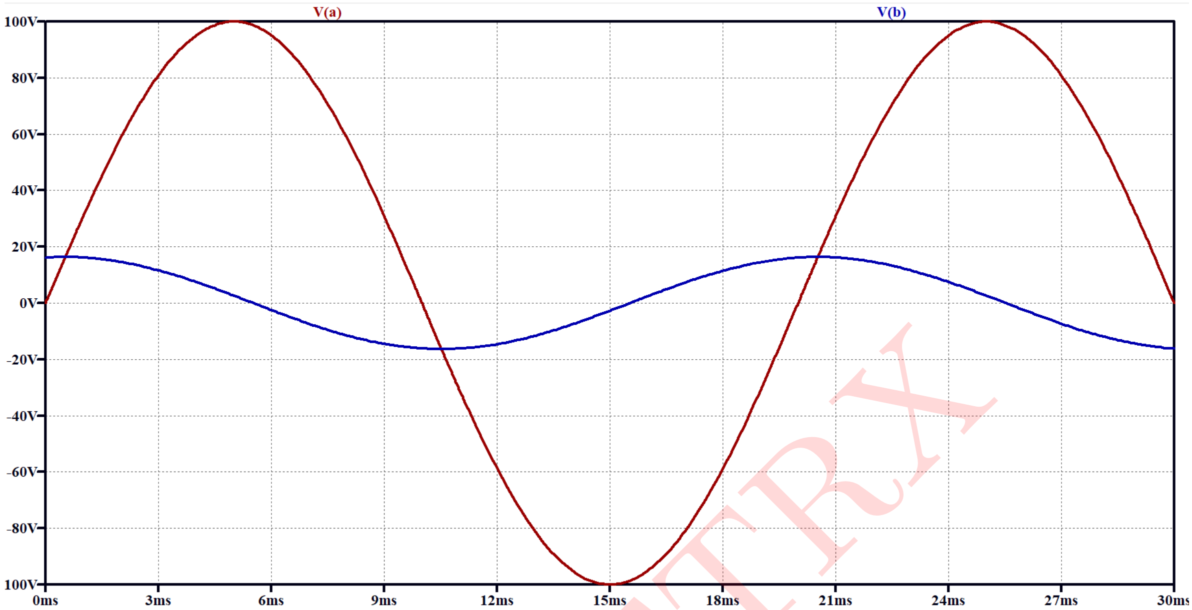

Figure 19: $V_S(t)$ and $V_L(t)$

g) Phase difference between $V_S(t)$ and $V_L(t)$ in time and degrees:

$\Delta\phi_3 = 80.59°$

$$\Delta t_3 = \frac{\Delta\phi_1}{f \times 360}$$

$$\Delta t_3 = \frac{80.59}{50 \times 360}$$

$\Delta t_3 = 4.477ms$

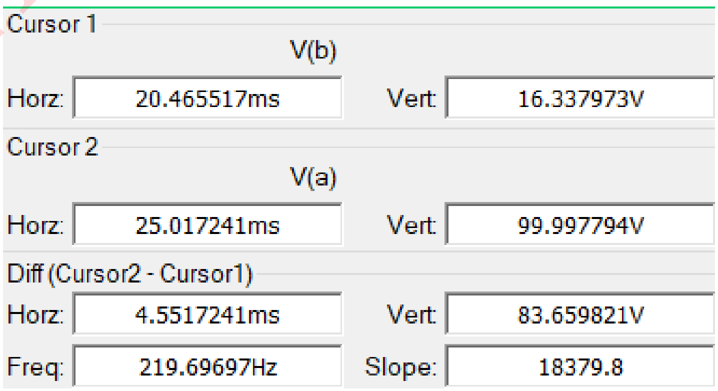

Figure 20: Phase difference from LTSpice

h) Power factor $= \cos(\phi) = \cos(9.4054°)$

$\therefore$ Power factor $= 0.9866$ lagging

Verifying the Calculated Values with Simulated Values:

Quantity	**Calculated Value**	**Simulated Value**
$(V_R)_{max}$	$98.6556V$	$98.651V$
$(V_L)_{max}$	$16.3417V$	$16.3379V$
$(I)_{max}$	$4.4843A$	$4.4838A$
$\Delta\phi_1$	$9.4054°$	$9.4134°$
Δt_1	$0.5225ms$	$0.5229ms$
$\Delta\phi_2$	$9.4054°$	$9.441°$
Δt_2	$0.5225ms$	$0.5245ms$
$\Delta\phi_3$	$80.59°$	$80.58°$
Δt_3	$4.477ms$	$4.5517ms$
Power Factor	0.9866	0.9865

Table 6: Comparison of calculated and simulated results

Numerical 7: A pure resistance of 150Ω is in series with a pure capacitance of $220\mu F$. The series combination is connected across $120V$, $50Hz$ supply.
Determine the following:

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

b) Plot input source voltage $V_S(t)$ and input source current $I_S(t)$ in LTspice

c) Measure the phase delay/difference between $V_S(t)$ and $I_S(t)$ in time and degrees

d) Plot input source voltage $V_S(t)$ and voltage across resistor $V_R(t)$ in LTspice

e) Measure the phase delay/difference between $V_S(t)$ and $V_R(t)$ in time and degrees

f) Plot input source voltage $V_S(t)$ and voltage across capacitor $V_C(t)$ in LTspice

g) Measure the phase delay/difference between $V_S(t)$ and $V_C(t)$ in time and degrees

h) Calculate the power factor of the circuit.

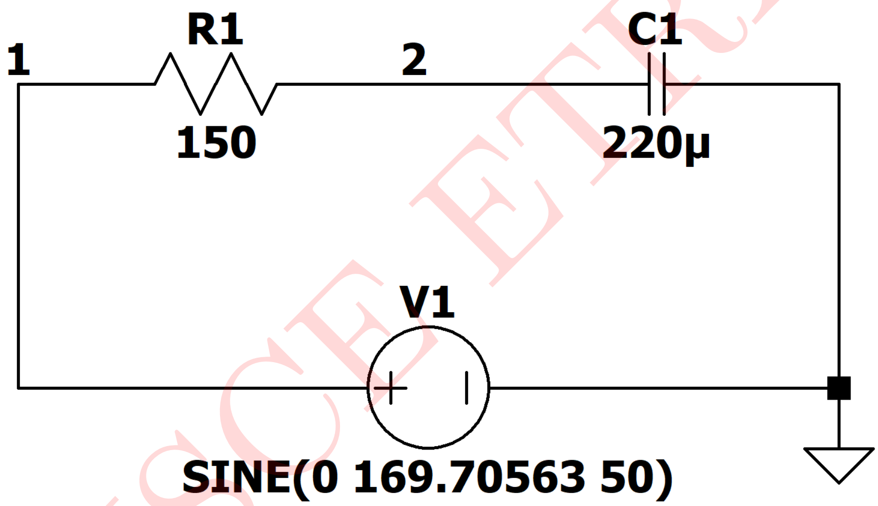

Figure 21: Circuit 7

Solution:

$V_{max} = V_{rms} \times \sqrt{2}$

$V_{max} = 120 \times \sqrt{2} = 169.706V$

Frequency $f = 50Hz$, angular frequency: ω

$\omega = 2\pi f = 2\pi\,(50) = 100\pi rad/s$

Finding Capacitive reactance X_C:

$$X_C = \frac{1}{\omega C_1} = \frac{1}{100\pi \times 220 \times 10^{-6}}$$

$X_C = 14.469\Omega$

To find the phase angle ϕ:

$$\phi = \tan^{-1}\left(\frac{-X_C}{R_1}\right) = \tan^{-1}\left(\frac{-14.469}{150}\right)$$

$\phi = -5.5096°$

To find total impedance, Z:

$|Z| = \sqrt{R_1^2 + (X_C)^2} = \sqrt{150^2 + (14.469)^2}$

$\therefore |Z| = 150.696\Omega$

$Z = 150.696\angle\phi$

$Z = 150.696\angle - 5.5096°\Omega$

Finding RMS current I_{rms},

$I_{rms} = \dfrac{V_{rms}}{Z} = \dfrac{120}{150.696\angle - 5.5096°}$

$I_{rms} = 0.7963\angle 5.5096° A$

Source current, I:

$I = I_{rms} \times \sqrt{2}$

$I = 0.7963\angle 5.5096° \times \sqrt{2}$

$I = 1.1261\angle 5.5096° A$

Maximum voltage across resistor, V_R:

$V_R = I \times R_1 = (1.1261\angle 5.5096°) \times 150$

$\therefore V_R = 168.9218\angle 5.5096° V$

Voltage across capacitor, V_C:

$V_C = I \times X_C = (1.1261\angle 5.5096°) \times (14.469\angle - 90°)$

$\therefore V_C = 16.294\angle - 84.49° V$

a) Peak values of V_R, V_C and I:

Peak voltage across resistor $= (V_R)_{max} = 168.9218V$

Peak voltage across capacitor $= (V_C)_{max} = 16.294V$

Peak value of source current $= (I)_{max} = 1.1261A$

b) Plot of input source voltage $V_S(t)$ and input source current $I_S(t)$ in LTspice

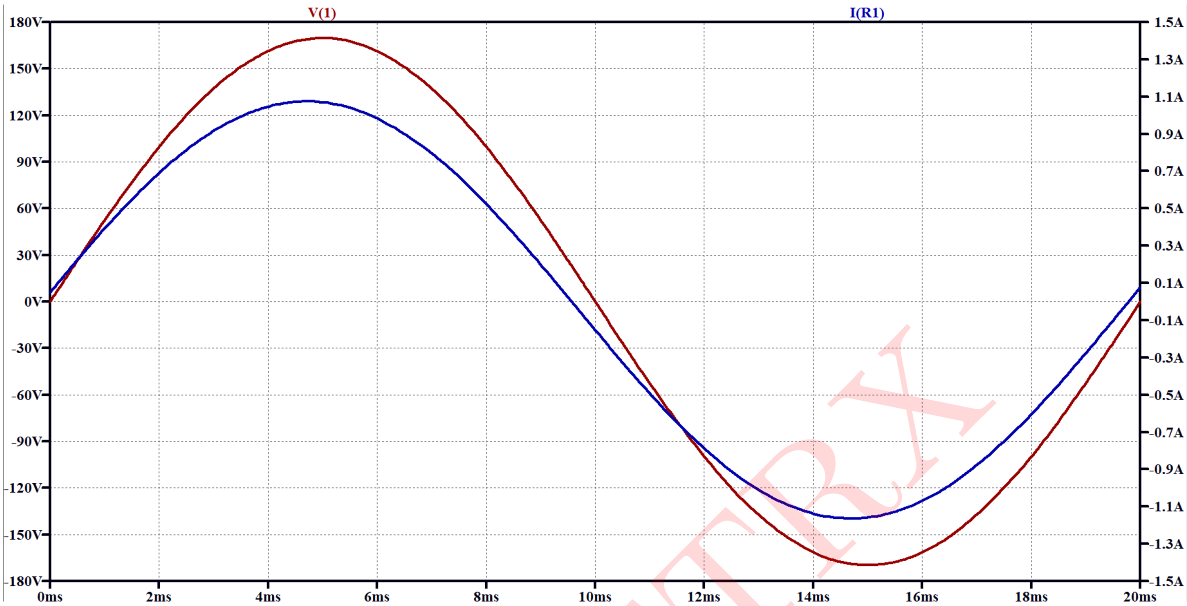

Figure 22: $V_S(t)$ and $I_S(t)$

c) Phase difference between $V_S(t)$ and $I_S(t)$ in time and degrees:

$\Delta\phi_1 = 5.5096°$

$$\Delta t_1 = \frac{\Delta\phi_1}{f \times 360}$$

$$\Delta t_1 = \frac{5.5096}{50 \times 360}$$

$\Delta t_1 = 0.3061ms$

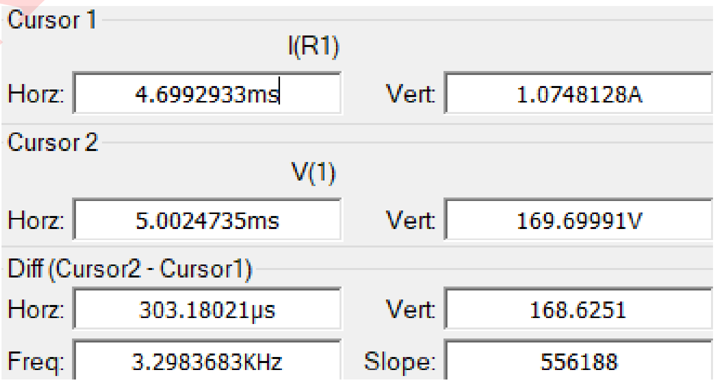

Figure 23: Phase difference from LTSpice

d) Plot of input source voltage $V_S(t)$ vs voltage across resistor $V_R(t)$ in LTspice

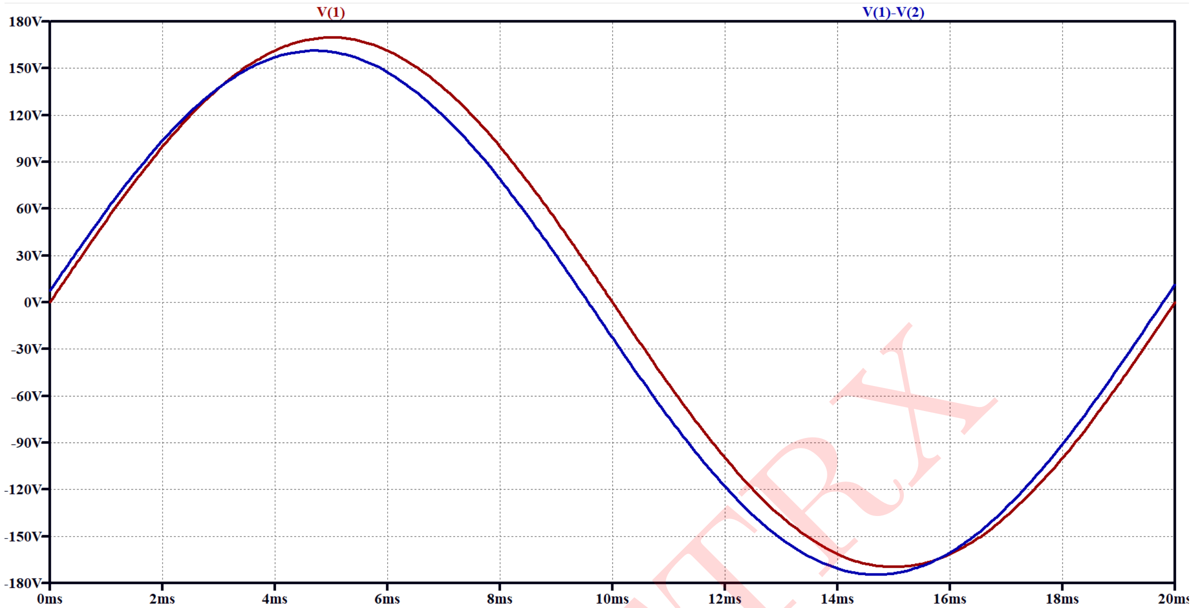

Figure 24: $V_S(t)$ and $V_R(t)$

e) Phase difference between $V_S(t)$ and $V_R(t)$ in time and degrees:

$$\Delta\phi_2 = 5.5096°$$

$$\Delta t_2 = \frac{\Delta\phi_1}{f \times 360}$$

$$\Delta t_2 = \frac{5.5096}{50 \times 360}$$

$$\Delta t_2 = 0.3061ms$$

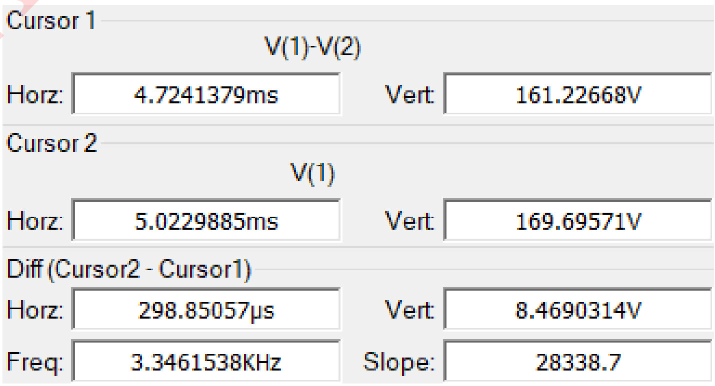

Figure 25: Phase difference from LTSpice

f) Plot of input source voltage $V_S(t)$ vs voltage across inductor $V_C(t)$ in LTspice

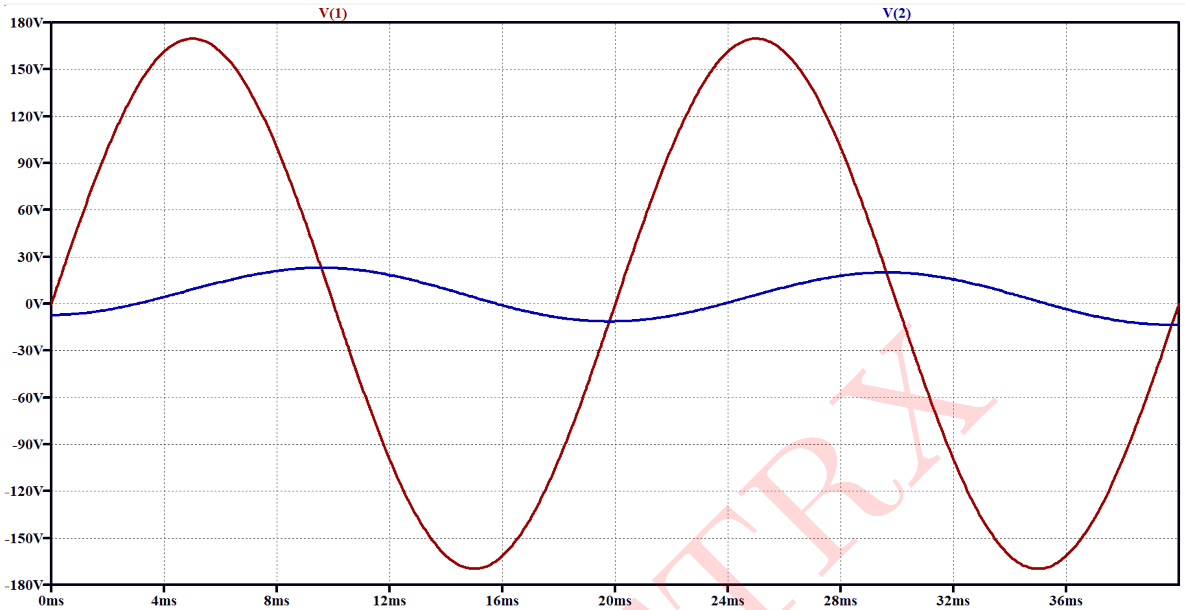

Figure 26: $V_S(t)$ and $V_C(t)$

g) Phase difference between $V_S(t)$ and $V_C(t)$ in time and degrees:

$\Delta\phi_3 = 84.49°$

$$\Delta t_3 = \frac{\Delta\phi_1}{f \times 360}$$

$$\Delta t_3 = \frac{84.49}{50 \times 360}$$

$\Delta t_3 = 4.694ms$

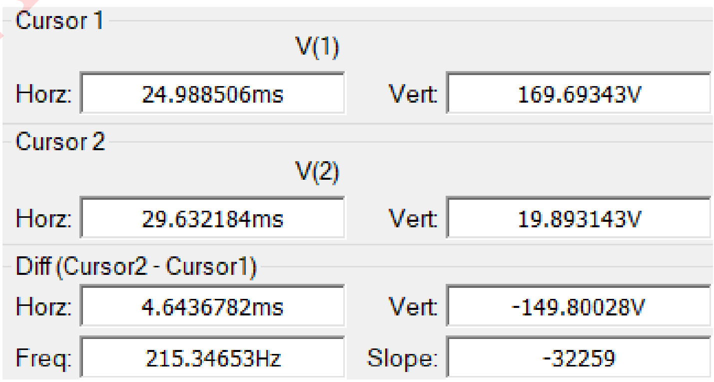

Figure 27: Phase difference from LTSpice

h) Power factor $= \cos(\phi) = \cos(5.5096°)$

$\therefore$ Power factor $= 0.9954$ leading

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
$(V_R)_{max}$	$168.922V$	$161.227V$
$(V_C)_{max}$	$16.294V$	$19.89V$
$(I)_{max}$	$1.1261A$	$1.0748A$
$\Delta\phi_1$	$5.5096°$	$5.4576°$
Δt_1	$0.3061ms$	$0.3032ms$
$\Delta\phi_2$	$5.5096°$	$5.380°$
Δt_2	$0.3061ms$	$0.2989ms$
$\Delta\phi_3$	$84.49°$	$83.59°$
Δt_3	$4.694ms$	$4.644ms$
Power Factor	0.9954	0.9955

Table 7: Comparison of calculated and simulated results

Numerical 8: A series resonance network consisting of a resistor of 24Ω, a capacitor of $1.8\mu F$ and an inductor of $24mH$ is connected across a sinusoidal supply voltage which has a constant output of AC $9V$ at all frequencies. Calculate:

a) Resonant frequency

b) Current at resonance

c) The voltage across the inductor and capacitor at resonance

d) 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.

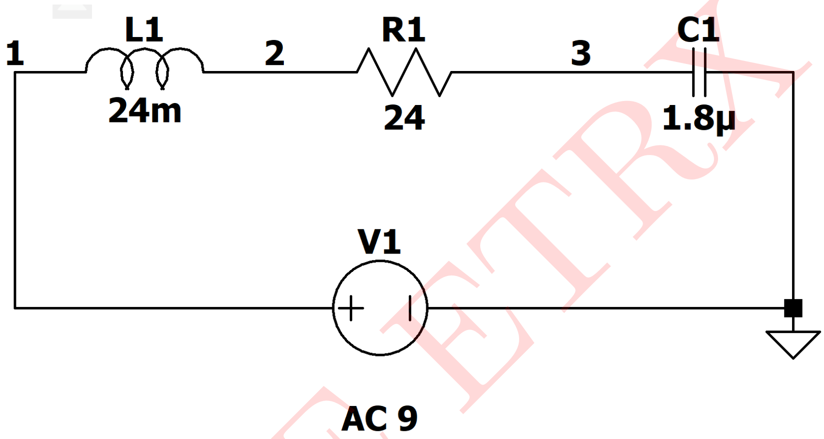

Figure 28: Circuit 8

Solution:

Resonant frequency f_r:

$$f_r = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

$$f_r = \frac{1}{2\pi\sqrt{24 \times 10^{-3} \times 1.8 \times 10^{-6}}}$$

$$f_r = 765.735Hz$$

a) Angular frequency at resonance, ω_r:

$$\omega_r = 2\pi f_r$$

$$\omega_r = 2\pi \times 765.735$$

$$\omega_r = 4811.25rad/s$$

At resonance, $X_L = X_C$

$\therefore$ impedance, $Z_r = R_1$

$Z_r = 24\Omega$

Since, $X_C = X_L$ at resonance:

$X_L = \omega L$

$X_L = 4811.25 \times 24 \times 10^{-3}$

$X_L = 115.47\Omega$

$X_C = X_L = 115.47\Omega$

b) Current at resonance, I_r:

$I_r = \dfrac{V}{Z_r}$

$I_r = \dfrac{9}{24}$

$I_r = 0.375A$

c) Voltage across inductor, V_L and capacitor, V_C:

$V_L = I \times X_L$

$V_L = 0.375 \times 115.47\angle 90°$

$V_L = 43.301\angle 90°V$

$V_C = 43.301\angle -90°V$

d) Quality factor of the circuit, Q

$Q = \dfrac{X_L}{R_1}$

$Q = \dfrac{X_L}{24}$

$Q = 4.811$

Bandwidth of the circuit, BW

$BW = \dfrac{f_r}{Q}$

$BW = \dfrac{765.735}{4.811}$

$BW = 159.16Hz$

SIMULATED RESULTS:
To obtain the resonance curve, the following circuit has been simulated in LTspice and the graph obtained is as follows:

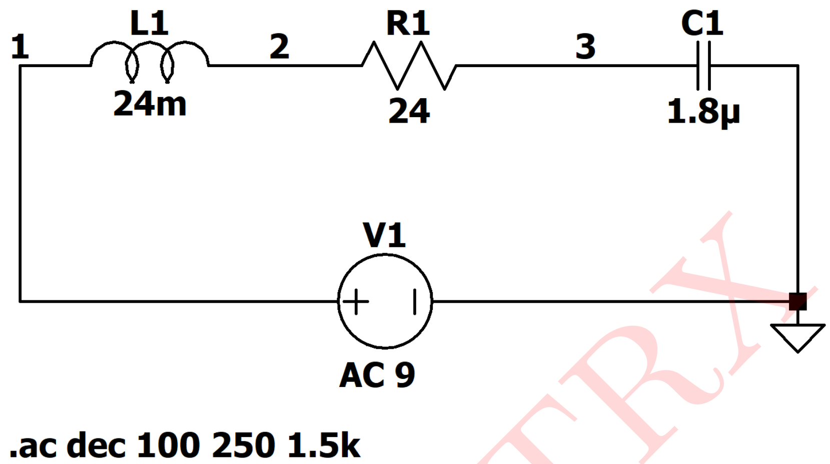

Figure 29: Circuit Schematic

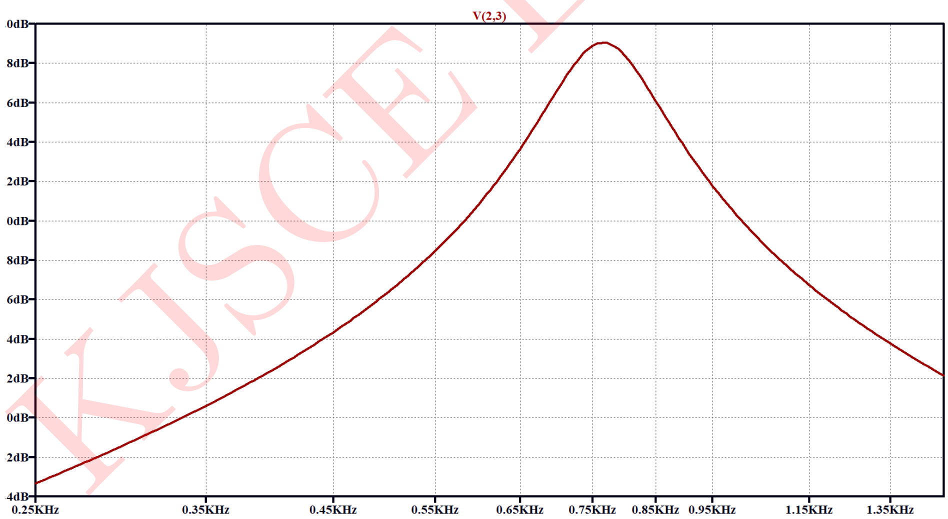

Figure 30: Resonance curve

To obtain the current, voltage across inductor and capacitor at resonance, the following circuit has been simulated in LTspice and the graph obtained is as follows:

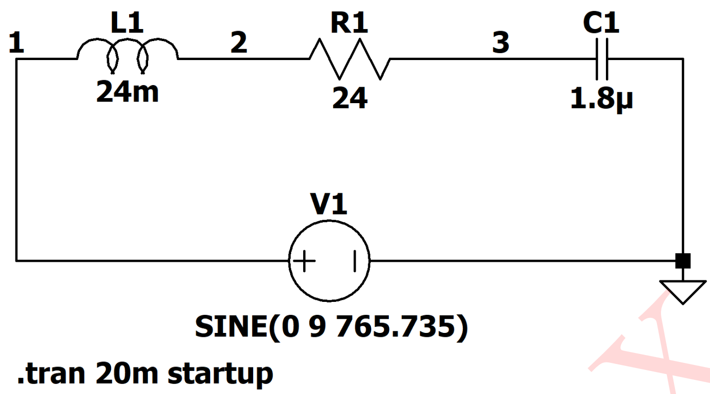

Figure 31: Circuit Schematic

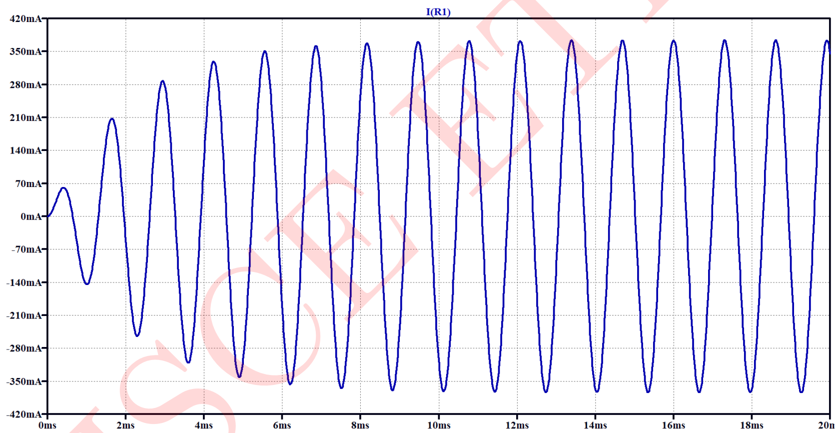

Figure 32: Current at resonance

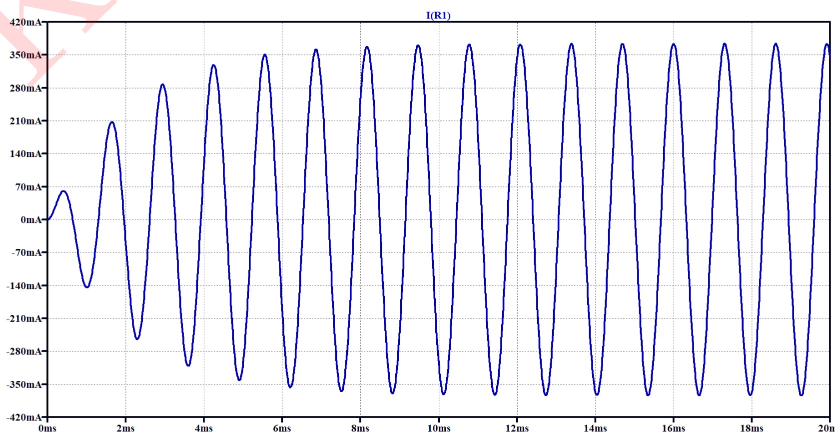

Figure 33: V_L and V_C at resonance

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
f_r	$765.735Hz$	$764.0438Hz$
I_r	$0.375\angle 0^\circ A$	$0.370\angle 0^\circ A$
V_L	$43.301\angle 90^\circ V$	$42.9\angle 90^\circ V$
V_C	$43.301\angle -90^\circ V$	$42.89\angle -90^\circ V$
Q	4.811	4.811
BW	$159.16Hz$	$158.81Hz$

Table 8: Comparison of calculated and simulated results