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Student ID: 202052307

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EE160: Experiment 3

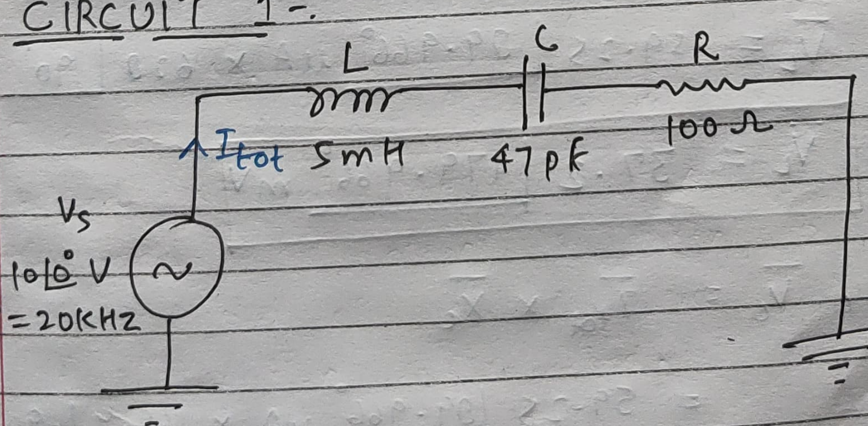
Objectives:- (i) Design and simulate given circuits in SPICE. Plot the voltage (across each element), currents (through each element) and total current. Find the phase difference between source voltage and all other currents and voltages.

(ii) Calculate the above required voltages and currents theoretically. Compare theoretical results with SPICE results. Draw a phasor diagram.

(iii) Perform "RLC Circuit Analysis" experiment.

Mathematical Expressions and Theoretical Calculations

CIRCUIT 1 -:



$X_L = 2\pi f L = 628\,\Omega$

$X_C = \dfrac{1}{2\pi f C} = 169399.647\,\Omega \approx 169.4\,k\Omega$

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$\therefore Z = R + j(X_L - X_C)$

$Z = 100 + j(628 - 169399.647)\ \Omega$

$Z = 100 - j\,168771.647\ \Omega$

$\bar{Z} = 168771.67 \angle -89.966^\circ\ \Omega$

$\therefore \bar{I}_{tot} = \dfrac{\bar{V}_s}{\bar{Z}}$

$= \dfrac{10\angle 0^\circ}{168.77\angle -89.966^\circ\ K} = 59.25\angle 89.966^\circ\ \mu A$

$\boxed{\bar{I}_{tot} = 59.25\ \mu A \quad \phi_{I_{tot}} = 89.966^\circ}$

$\boxed{I_L = I_R = I_C = I_{tot} = 59.25\angle 89.966^\circ\ \mu A}$

$\therefore \bar{V}_L = \bar{I}_{tot} \times \bar{X}_L$

$\bar{V}_L = 59.25\angle 89.966^\circ\ \mu A \times 628\angle 90^\circ\ \Omega$

$\boxed{\bar{V}_L = 37.2\angle 179.966^\circ\ mV}$

and, $\bar{V}_C = \bar{I}_{tot} \times \bar{X}_C$

$= 59.25\angle 89.966^\circ\ \mu A \times 169.4\angle -90^\circ\ K\Omega$

$\boxed{\bar{V}_C = 10.037\angle -0.034^\circ\ V}$

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and $\overline{V_R} = \overline{I_{tot}} \times \overline{R}$

$= 59.25 \angle 89.966^\circ \ \mu A \times 100\,\Omega \angle 0^\circ$

$$\boxed{\overline{V_R} = 5.925 \angle 89.966^\circ \ mV}$$

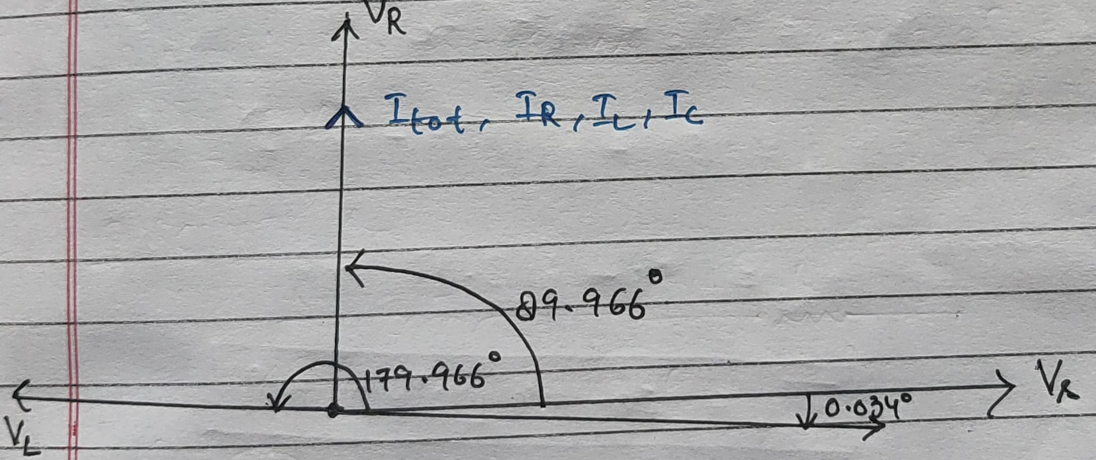
Phase Difference between source voltage and total current ϕ.

$\phi = \phi_v - \phi_{I_{tot}}$

$= 0^\circ - 89.966^\circ$

$$\boxed{\phi = -89.966^\circ}$$

Phasor Diagram



Comparison between Spice Results and Theory Calculations

The theoretical results match well with the SPICE AC-Analysis results. The only error in SPICE results is that it shows the phase angle of I_{tot} to be -90.034°.

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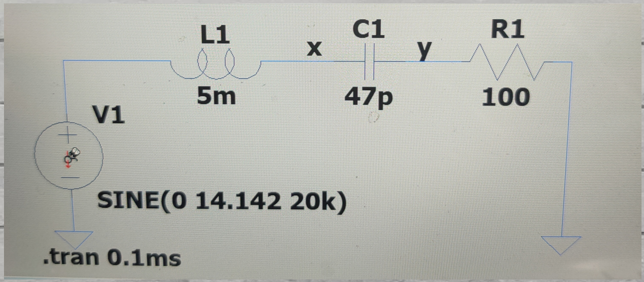
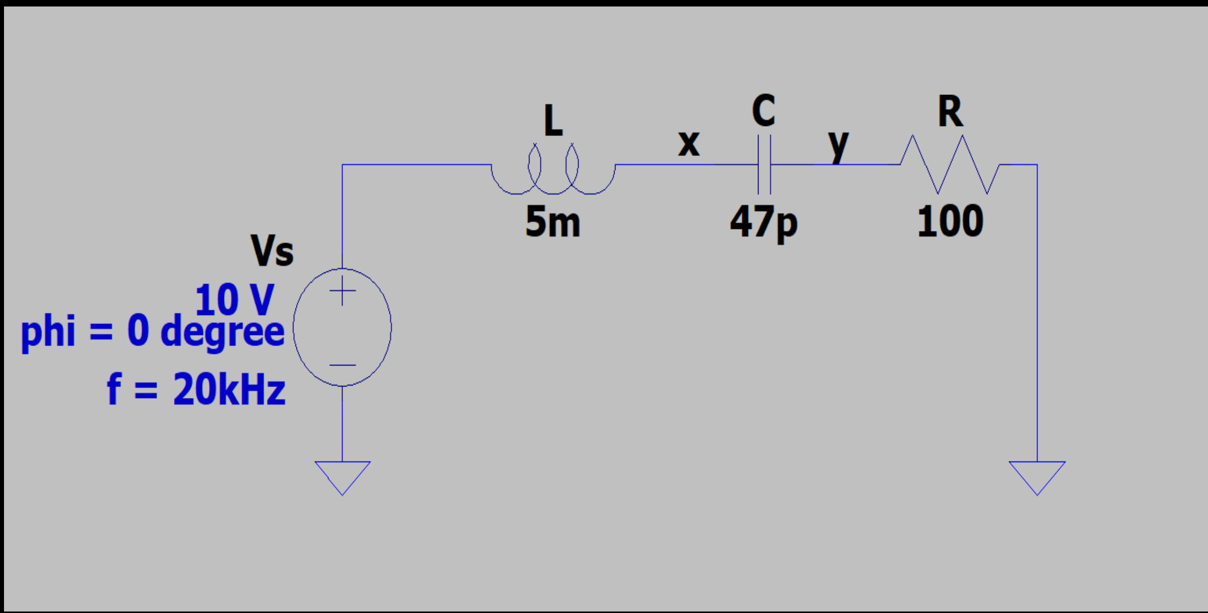
This is not an error actually, the reason behind this is that the direction of current (I_{tot}) for theory calculation is taken to be coming out from voltage source's positive terminal, but in SPICE this direction is reversed.



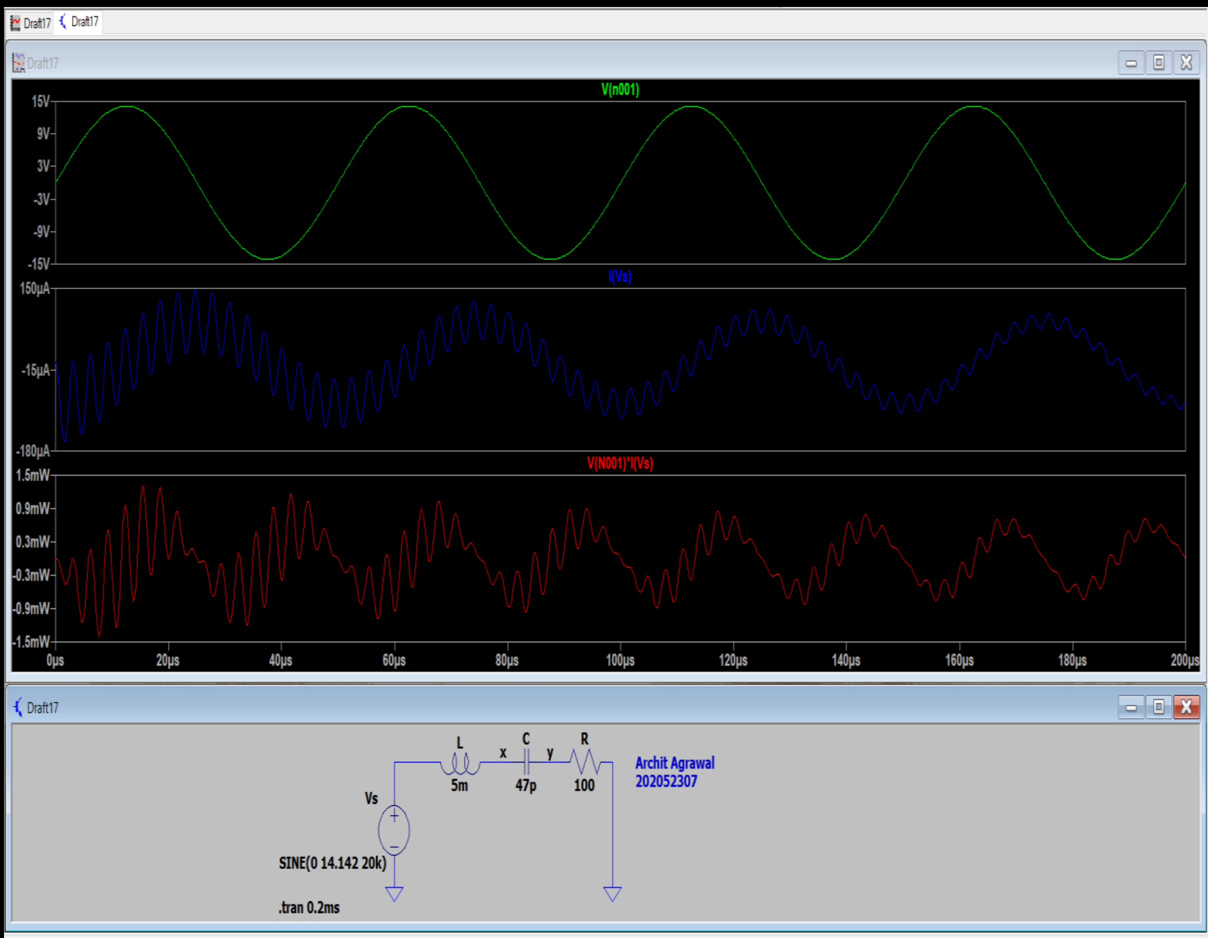
Hence, the phase of I_{tot} reduces by 180° in SPICE. Clearly, $89.966^\circ - 180^\circ = -90.034^\circ$.

EE160 : Experiment 3

Circuit

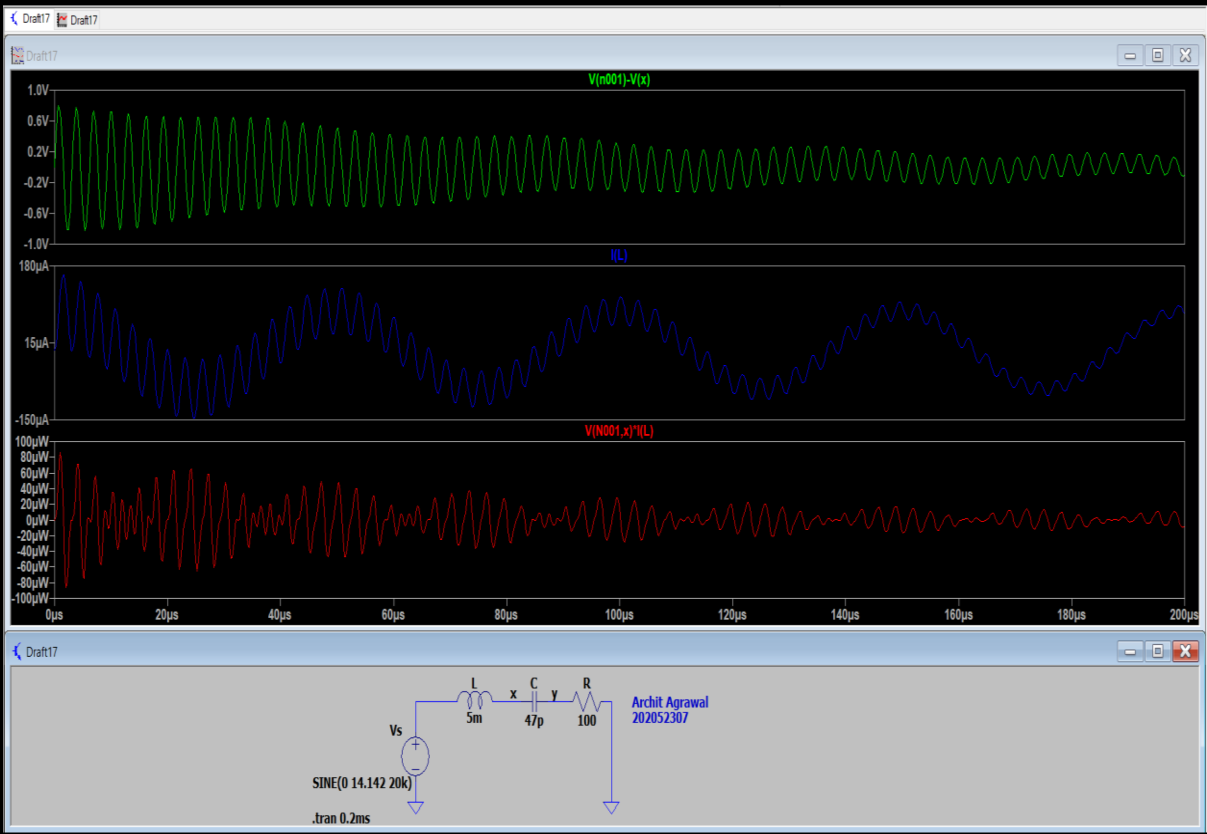


Source Voltage, Total Current and Total Power

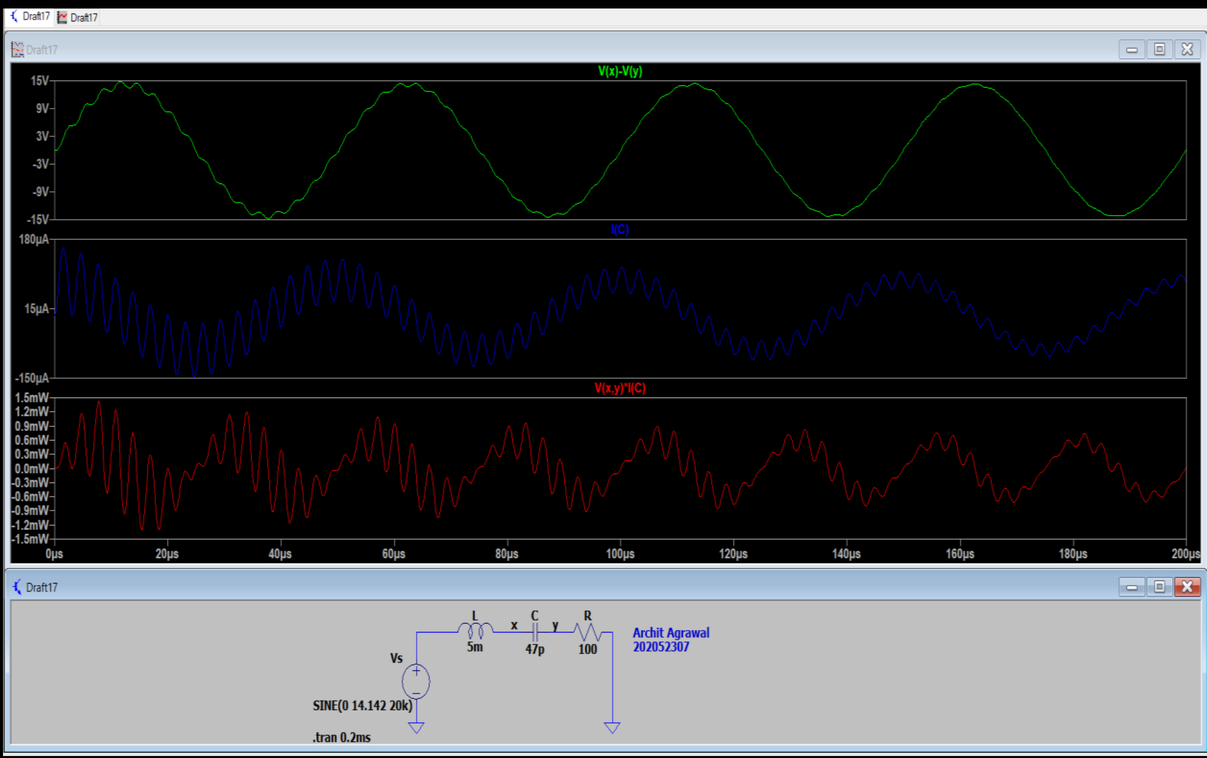


EE160 : Experiment 3

Voltage, current and Power across Inductor

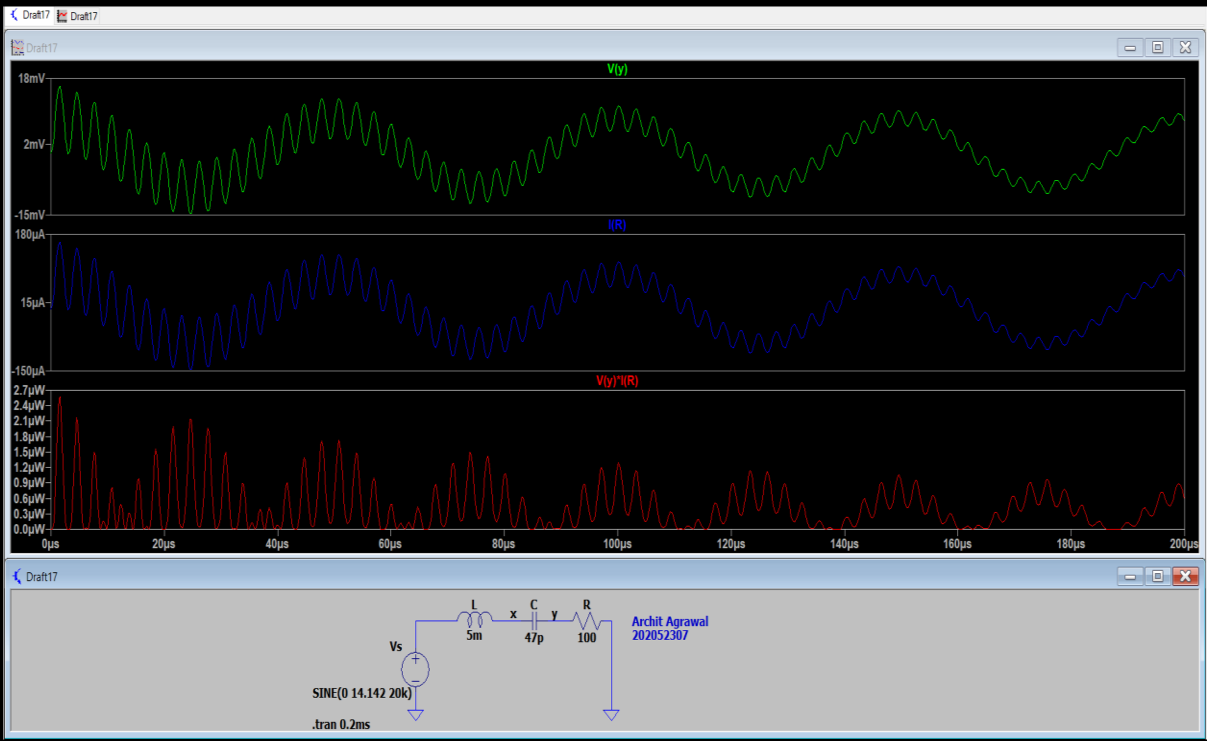


Voltage, current and Power across Capacitor



EE160 : Experiment 3

Voltage, current and Power across Resistor



AC Analysis

```
        --- AC Analysis ---

frequency:      20000           Hz
V(n001):        mag:            10 phase:           0°         voltage
V(x):           mag:       10.0372 phase:  -0.000126387°       voltage
V(y):           mag:    0.00592819 phase:       89.966°        voltage
I(C):           mag:   5.92819e-005 phase:       89.966°       device_current
I(L):           mag:   5.92819e-005 phase:       89.966°       device_current
I(R):           mag:   5.92819e-005 phase:       89.966°       device_current
I(Vs):          mag:   5.92819e-005 phase:      -90.034°       device_current
```

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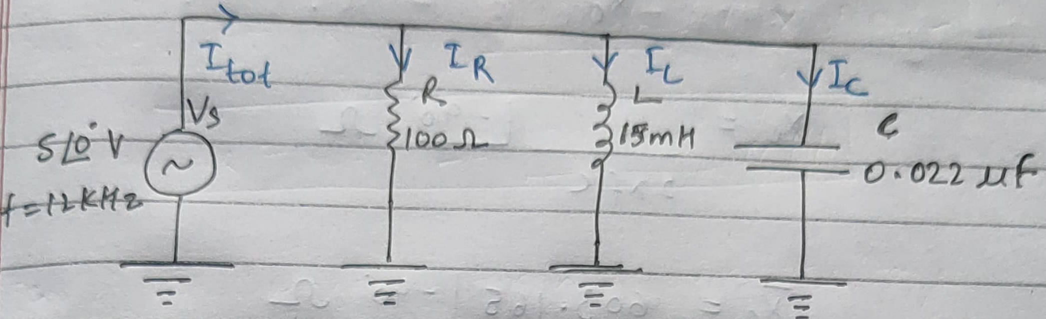
CIRCUIT 2:



Since, $\boxed{\bar{V}_R = \bar{V}_L = \bar{V}_C = \bar{V}_s = 5\angle 0° \ V}$

$$\therefore \bar{I}_R = \frac{\bar{V}_s}{\bar{Z}_R} = \frac{5\angle 0°}{100\angle 0°} A$$

$$\boxed{\begin{aligned} \bar{I}_R &= 50\angle 0° \ mA \\ I_R &= 50 + j0 \ mA \end{aligned}}$$

and $\bar{I}_L = \dfrac{\bar{V}_s}{\bar{X}_L}$

$$\bar{X}_L = 2\pi f L \angle 90° \ \Omega$$
$$= 1130.4\angle 90° \ \Omega$$

$$\therefore \bar{I}_L = \frac{5\angle 0°}{1130.4\angle 90°} A$$

$$\boxed{I_L = 4.42\angle -90° \ mA}$$

$$I_L = 0 - j(4.42) \ mA$$

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and $\bar{I}_c = \dfrac{\bar{V}_s}{\bar{X}_c}$

$$\bar{X}_c = \frac{1}{2\pi f C} \angle -90^\circ \ \Omega$$

$$\bar{X}_c = 603.165 \angle -90^\circ \ \Omega$$

$$\therefore \bar{I}_c = \frac{5 \angle 0^\circ}{603.165 \angle -90^\circ} \ A$$

$$\boxed{\begin{gathered}\bar{I}_c = 8.29 \angle 90^\circ \ mA \\ I_c = 0 + j(8.29) \ mA\end{gathered}}$$

Now, $I_{tot} = I_R + I_L + I_c$

$$\therefore I_{tot} = 50 + j(8.29 - 4.42) \ mA$$

$$I_{tot} = 50 + j\,3.87 \ mA$$

$$\boxed{\bar{I}_{tot} = 50.149 \angle 4.426^\circ \ mA}$$

Phase Difference between source voltage and total current ϕ

$$\phi = \phi_v - \phi_{I_{tot}}$$

$$\phi = 0^\circ - 4.426^\circ$$

$$\boxed{\phi = -4.426^\circ}$$

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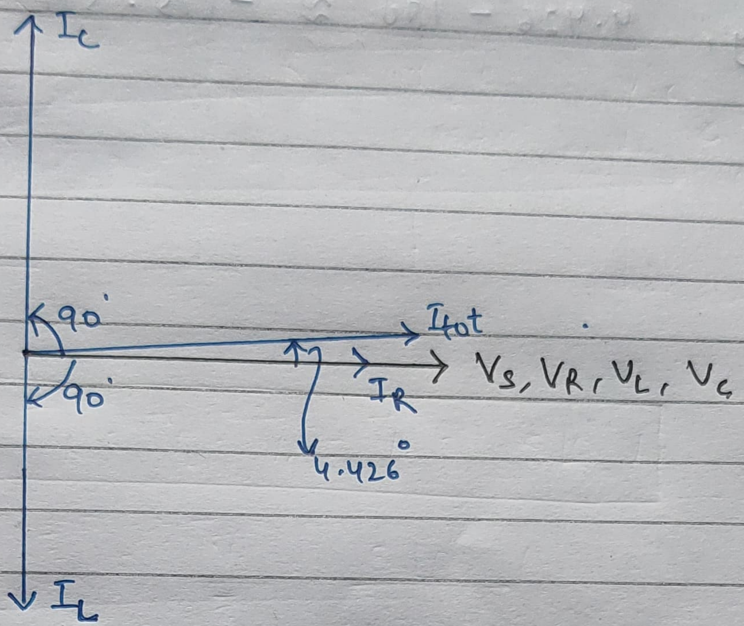
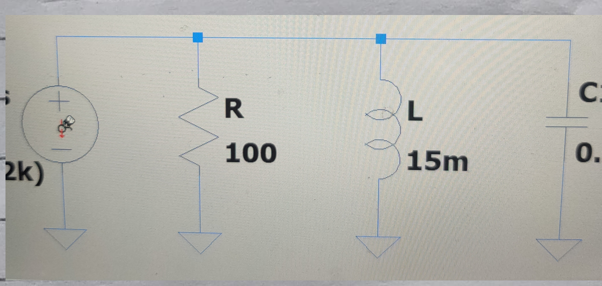
Phasor Diagram



Comparison Between SPICE results and Theory Calculations

The theoretical results match well with the SPICE AC-analysis results. The only error in SPICE results is that it shows the phase angle of I_{tot} to be −175.571.

The reason behind this is that the direction of current (I_{tot}) for theory calculation is taken to be coming out of voltage source's positive terminal, but in SPICE this direction is reversed.



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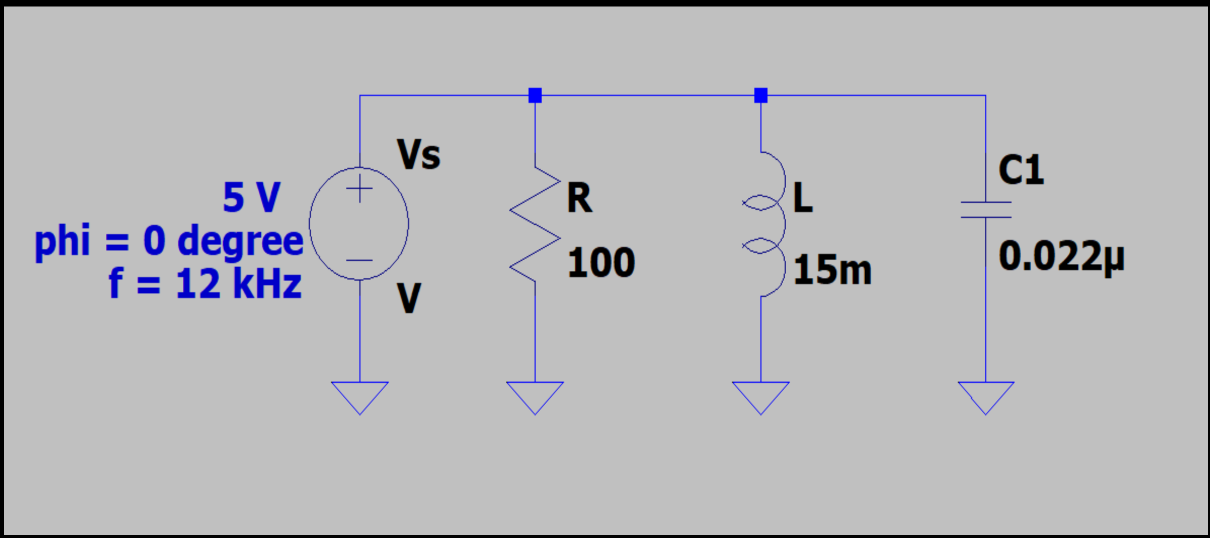
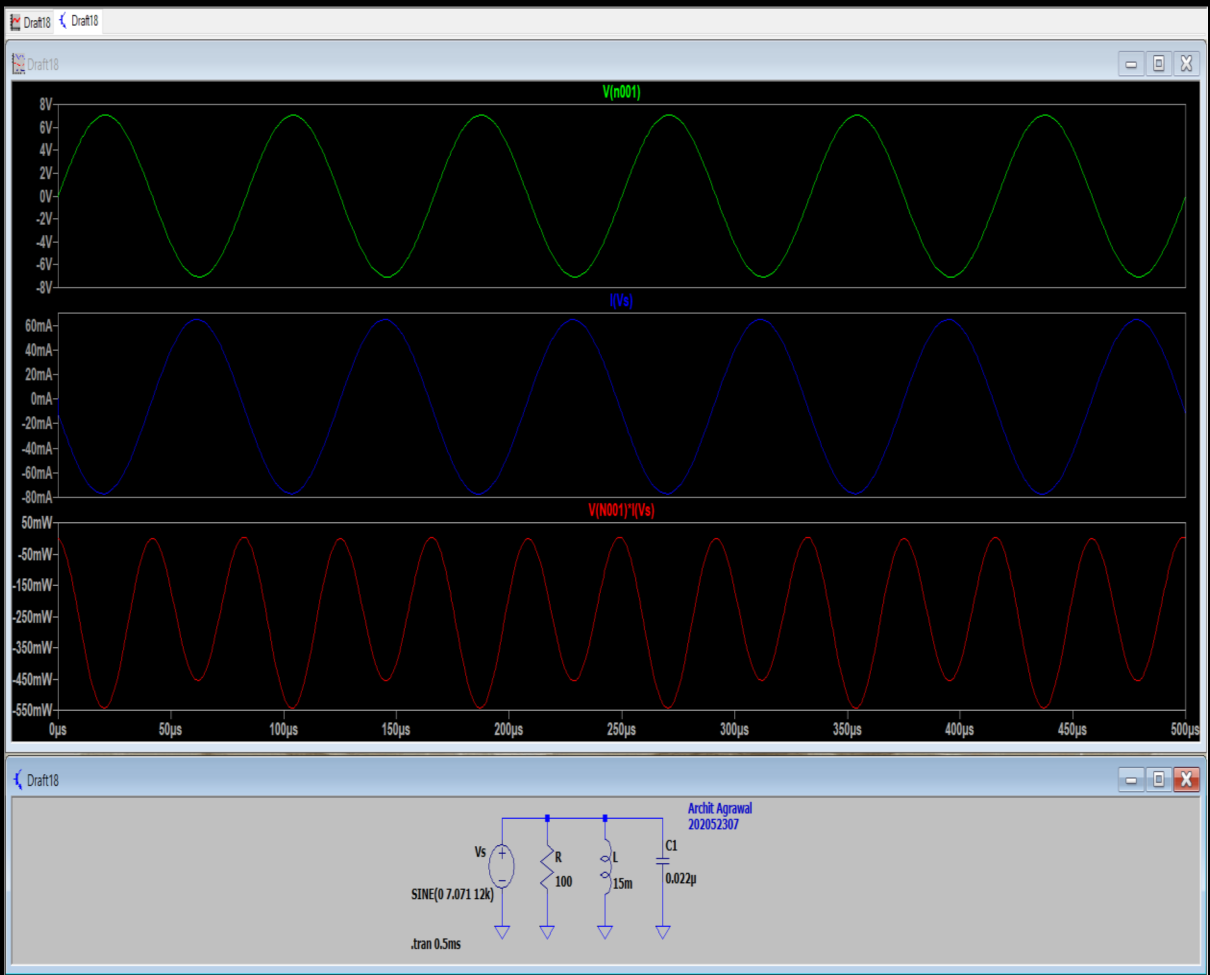
Hence, phase of I_{tot} is reduced by 180°.
Clearly, $4.426^\circ - 180^\circ \approx -175.571^\circ$.

EE160 : Experiment 3

Circuit

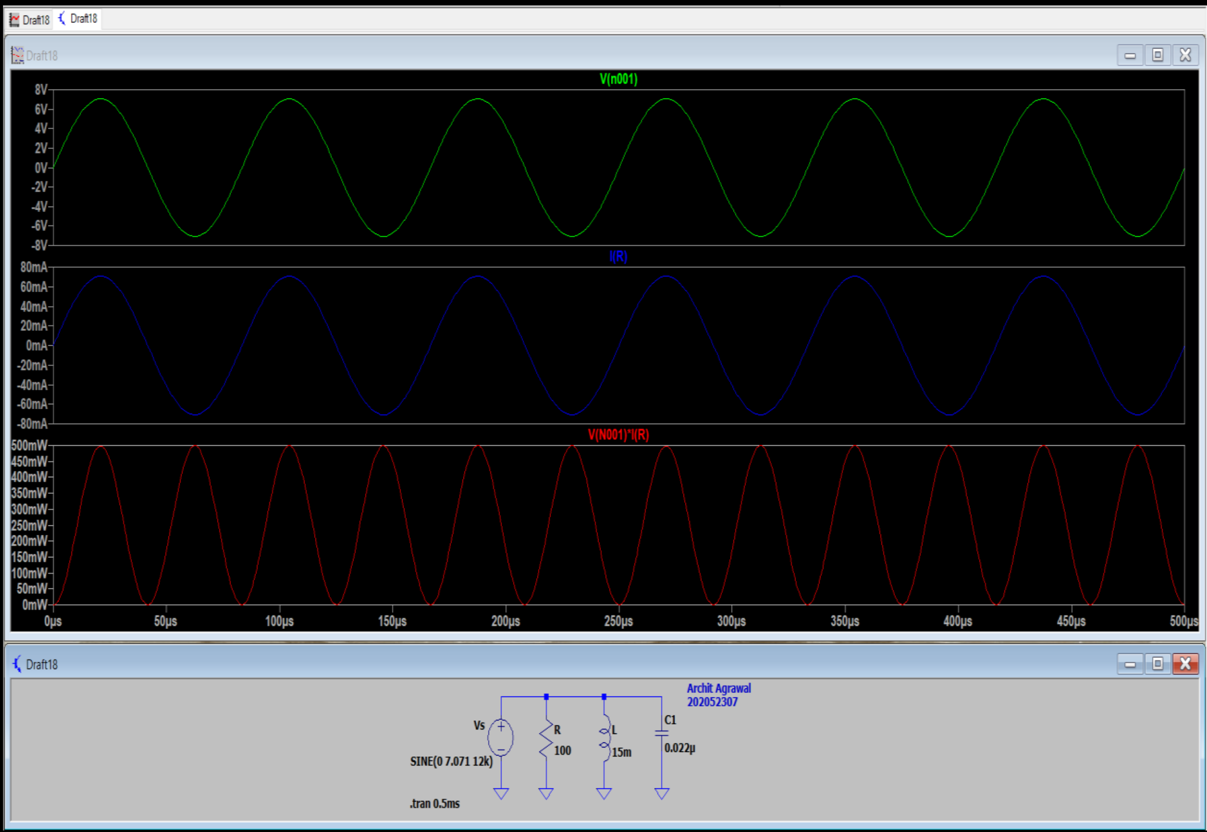


Source Voltage, Total Current and Total Power

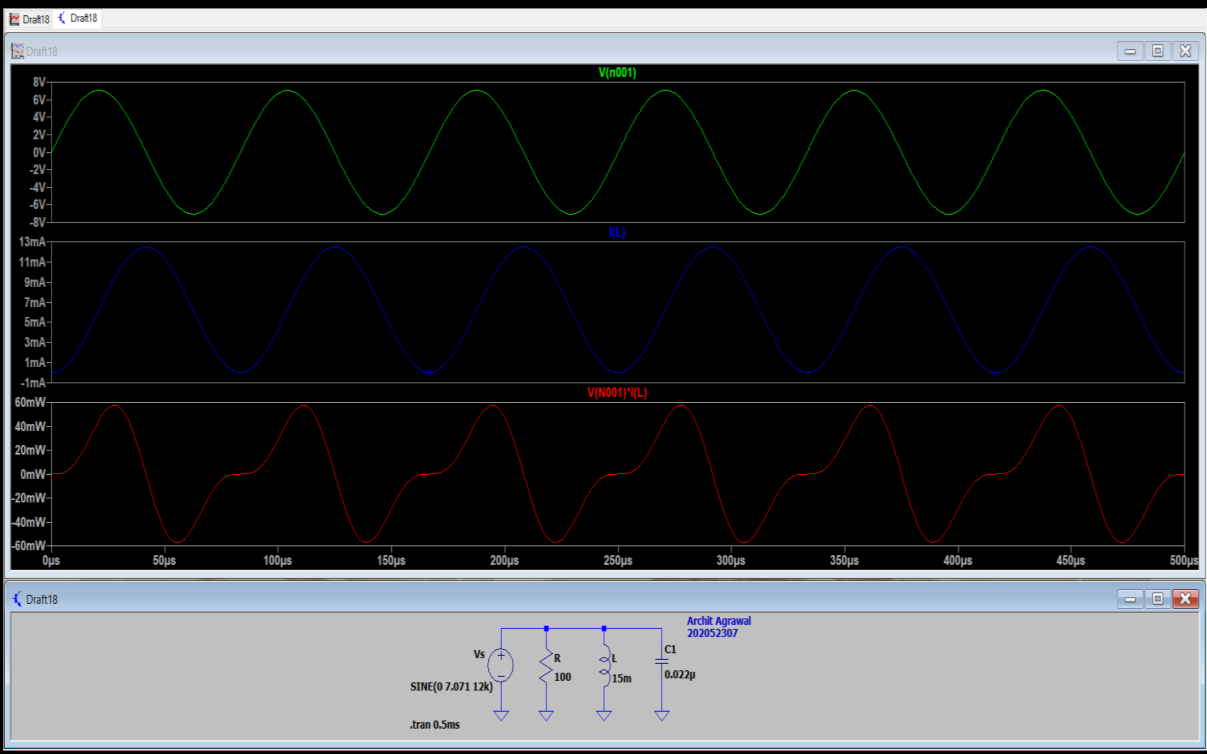


EE160 : Experiment 3

Voltage, current and Power across Resistor

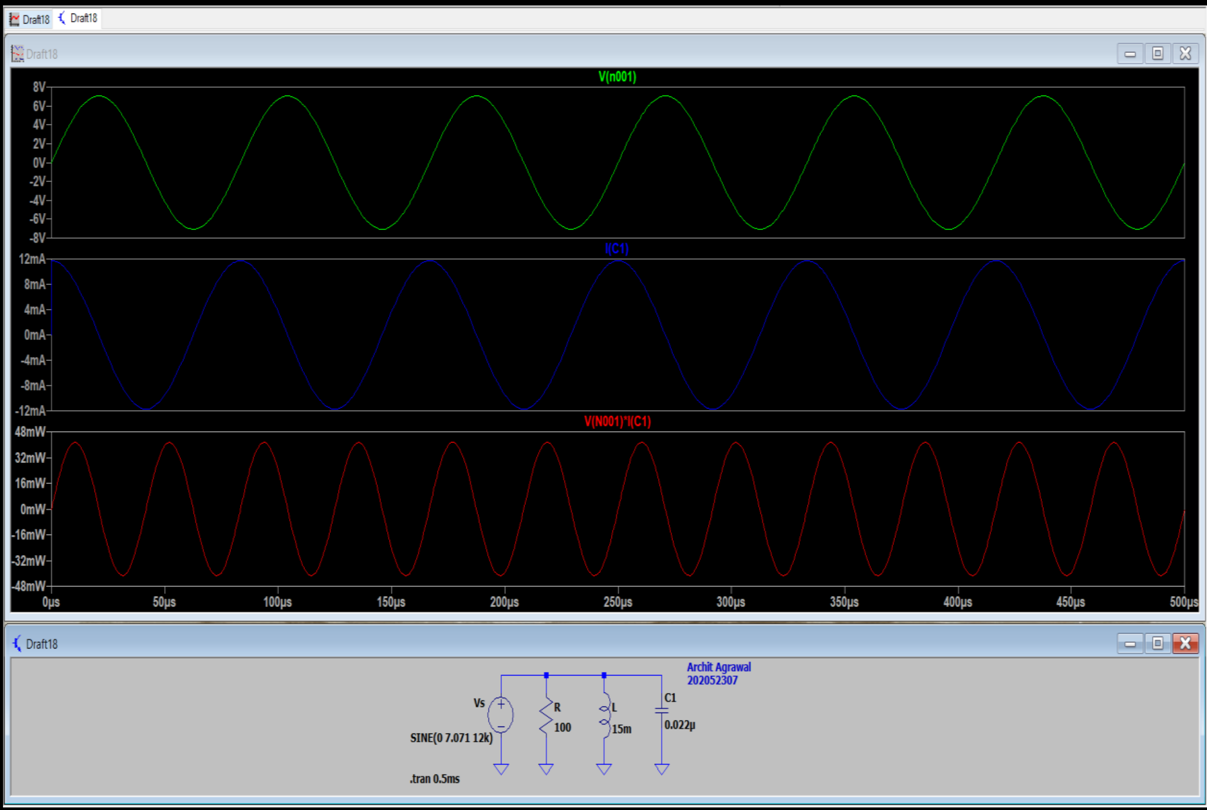


Voltage, current and Power across Inductor



EE160 : Experiment 3

Voltage, current and Power across Capacitor



AC Analysis

```
       --- AC Analysis ---

frequency:     12000          Hz
V(n001):       mag:           5 phase: -6.36111e-016°      voltage
I(C1):         mag:   0.0082938 phase:           90°      device_current
I(L):          mag:  0.00442097 phase:     -89.9999°      device_current
I(R):          mag:        0.05 phase: -6.36111e-016°      device_current
I(Vs):         mag:   0.0501498 phase:     -175.571°      device_current
```

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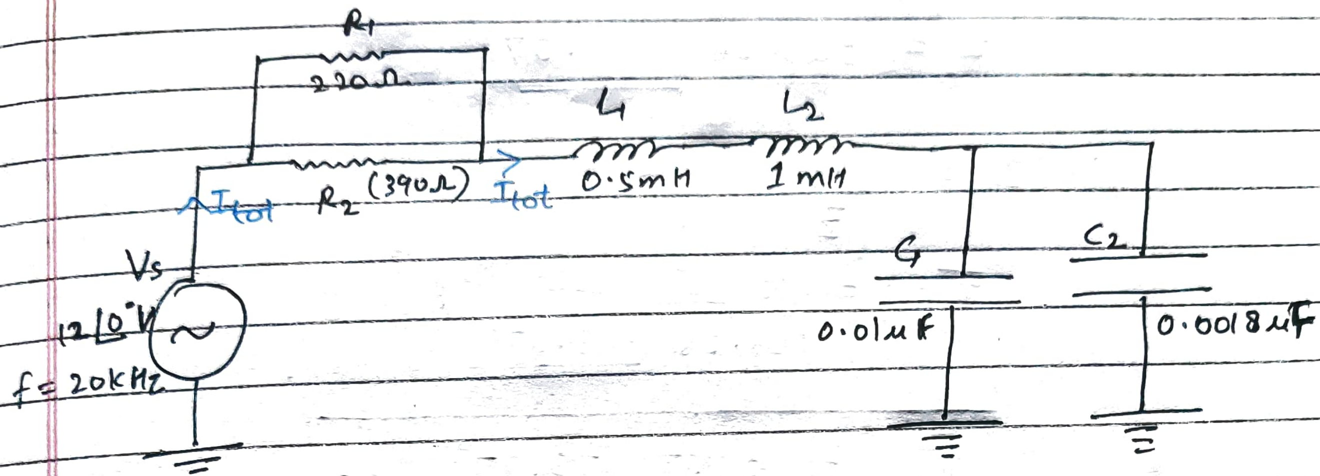
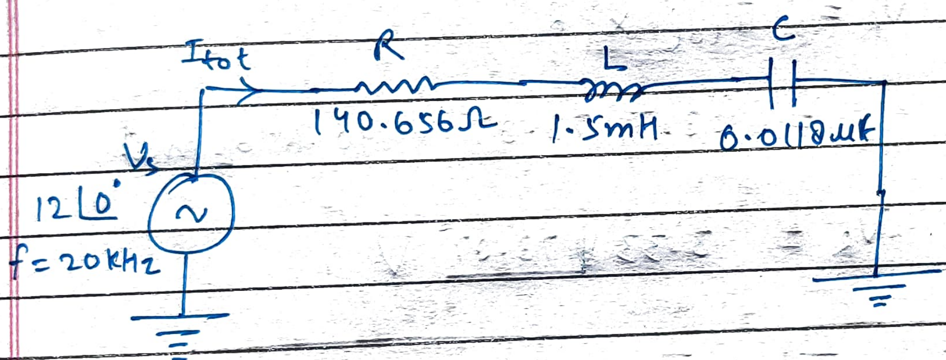
CIRCUIT 3



The circuit can be redrawn as



where $R = R_1 || R_2$

$$R = \frac{220 \times 390}{220 + 390}\ \Omega = 140.656\ \Omega$$

Now, $X_L = 2\pi f L = 2\pi(20K)(1.5m) = 188.4\ \Omega$

and, $X_C = \dfrac{1}{2\pi f C} = 674.727\ \Omega$

$$\therefore\ Z = R + j(X_L - X_C)$$

$$Z = 140.656 + j(188.4 - 674.727)\ \Omega$$

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$$Z = 140.656 - j\,486.327\ \Omega$$

$$\overline{Z} = 506.26 \angle -73.87^\circ$$

$$\therefore \overline{I_{tot}} = \frac{\overline{V_s}}{\overline{Z}}$$

$$\overline{I_{tot}} = \frac{12 \angle 0^\circ}{506.26 \angle -73.87^\circ}\ A$$

$$\boxed{\overline{I_{tot}} = 23.7 \angle 73.87^\circ\ mA}$$

$$\therefore \overline{V_R} = \overline{I_{tot}} \times R$$

$$= 23.7 \angle 73.87^\circ \times 140.656 \angle 0^\circ\ m\cancel{V}$$

$$\overline{V_R} = 3.33 \angle 73.87^\circ\ V$$

$$\therefore \boxed{\overline{V_{R_1}} = \overline{V_{R_2}} = \overline{V_R} = 3.33 \angle 73.87^\circ\ V}$$

$$\therefore \overline{I_{R_1}} = \frac{\overline{V_{R_1}}}{R_1}$$

$$I_{R_1} = \frac{3.33 \angle 73.87^\circ}{220 \angle 0^\circ}\ A$$

$$\boxed{\overline{I_{R_1}} = 15.136 \angle 73.87^\circ\ mA}$$

$$\overline{I_{R_2}} = \frac{3.33 \angle 73.87^\circ}{390 \angle 0^\circ}\ A$$

$$\boxed{\overline{I_{R_2}} = 8.54 \angle 73.87^\circ\ mA}$$

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From the circuit, it is clear that $\overline{I}_{L_1} = \overline{I}_{L_2} = \overline{I}_{tot}$

$$\therefore \boxed{\overline{I}_{L_1} = \overline{I}_{L_2} = 23.7 \angle 73.87^\circ \ mA}$$

$$\therefore \overline{V}_{L_1} = \overline{I}_{L_1} \times \overline{X}_{L_1}$$

$$\overline{X}_{L_1} = 2\pi f L_1 \angle 90^\circ \ \Omega$$
$$= 62.8 \angle 90^\circ \ \Omega$$

$$\therefore \overline{V}_{L_1} = 23.7 \angle 73.87^\circ \times 62.8 \angle 90^\circ \ mV$$

$$\boxed{\overline{V}_{L1} = 1.488 \angle 163.87^\circ \ V}$$

and, $\overline{V}_{L_2} = \overline{I}_{L_2} \times \overline{X}_{L_2}$

$$\overline{X}_{L_2} = 2\pi f L_2 \angle 90^\circ$$
$$= 125.6 \angle 90^\circ \ \Omega$$

$$\therefore \overline{V}_{L_2} = 23.7 \angle 73.87^\circ \times 125.6 \angle 90^\circ \ mV$$

$$\boxed{\overline{V}_{L_2} = 2.976 \angle 163.87^\circ \ V}$$

Now, $\overline{V}_C = \overline{I}_{tot} \times \overline{X}_C$

$$\overline{V}_C = 23.7 \angle 73.87^\circ \times 674.727 \angle -90^\circ \ mV$$

$$\overline{V}_C = 15.99 \angle -16.13^\circ \ V$$

Clearly $\boxed{\overline{V}_{C_1} = \overline{V}_{C_2} = \overline{V}_C = 15.99 \angle -16.13^\circ \ V}$

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$\therefore \overline{I_{C_1}} = \overline{V_{C_1}} \,/\, \overline{X_{C_1}}$

$$\overline{X_{C_1}} = \frac{1}{2\pi f C_1} \angle -90^\circ \ \Omega$$

$$\overline{X_{C_1}} = 796.178 \angle -90^\circ \ \Omega$$

$$\therefore \overline{I_{C_1}} = \frac{15.99 \angle -16.13^\circ}{796.178 \angle -90^\circ} \ A$$

$$\boxed{\overline{I_{C_1}} = 20.08 \angle 73.87^\circ \ mA}$$

and, $$\overline{I_{C_2}} = \frac{\overline{V_{C_2}}}{\overline{X_{C_2}}}$$

$$\overline{X_{C_2}} = \frac{1}{2\pi f C_2} \angle -90^\circ \ \Omega$$

$$\overline{X_{C_2}} = 4423.21 \angle -90^\circ \ \Omega$$

$$\therefore \overline{I_{C_2}} = \frac{15.99 \angle -16.13^\circ}{4423.21 \angle -90^\circ} \ A$$

$$\boxed{\overline{I_{C_2}} = 3.615 \angle 73.87^\circ \ mA}$$

Phase Difference between source voltage and total current ϕ

$$\phi = \phi_{V_S} - \phi_{I_{tot}} = 0^\circ - 73.87^\circ$$

$$\boxed{\phi = -73.87^\circ}$$

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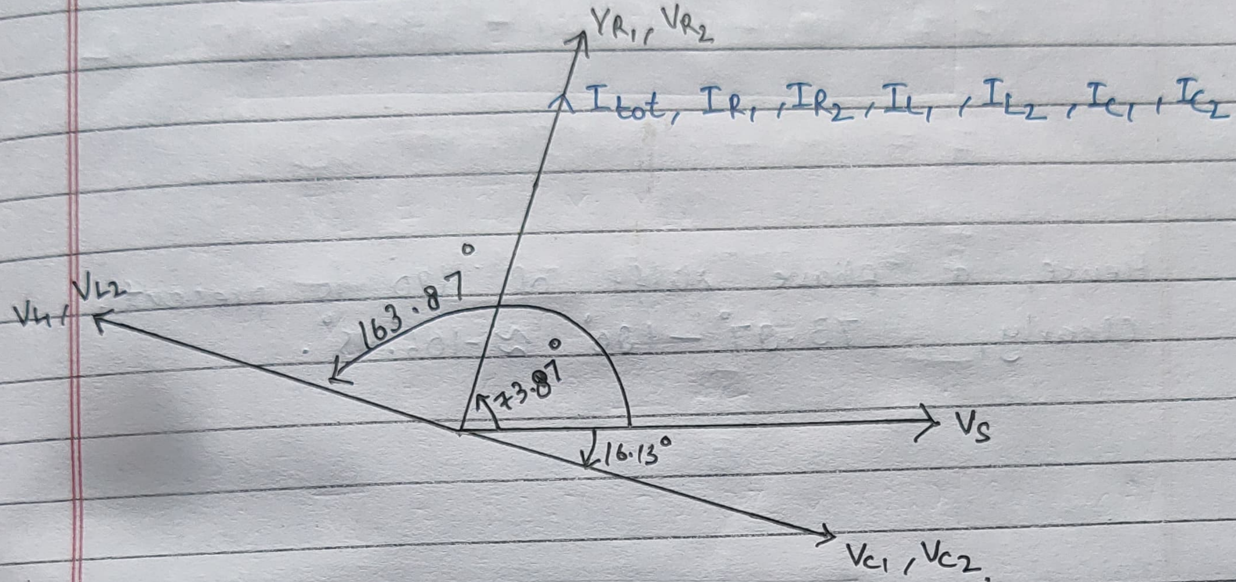
Phasor Diagram



Comparison between SPICE Results and theory calculations

The theoretical results match well with the SPICE AC-Analysis results. The only ~~difference~~ error in the SPICE results is that it shows the phase angle of I_{tot} to be $-106.45°$.

This is not an error actually, the reason behind this is that the direction of current (I_{tot}) for theory calculation is taken to be coming out of voltage source but in SPICE the direction is reversed.

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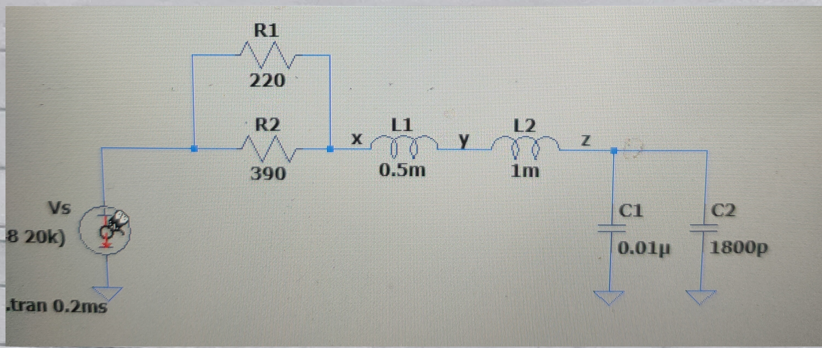
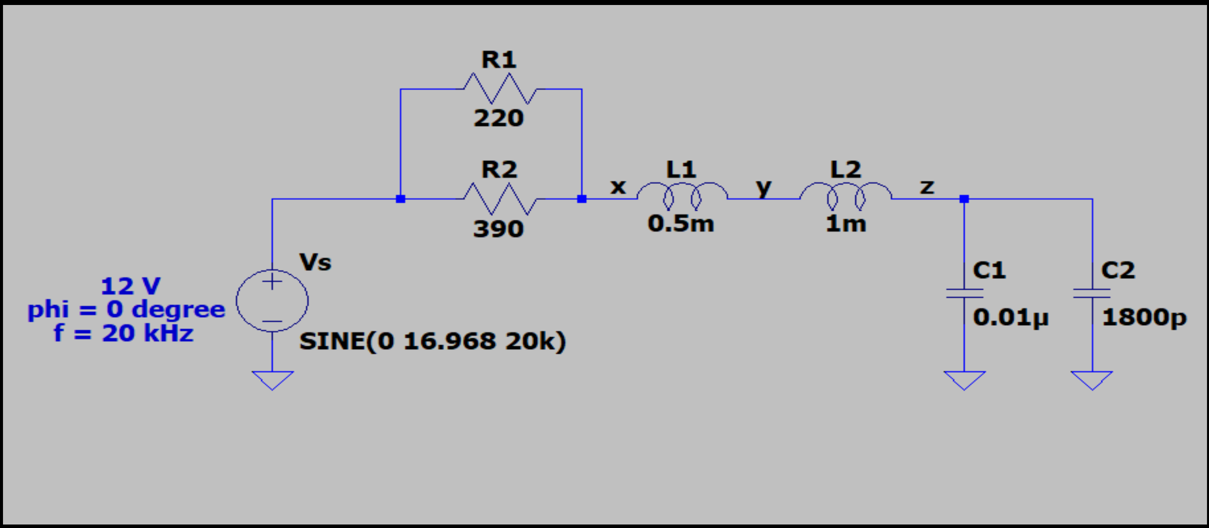


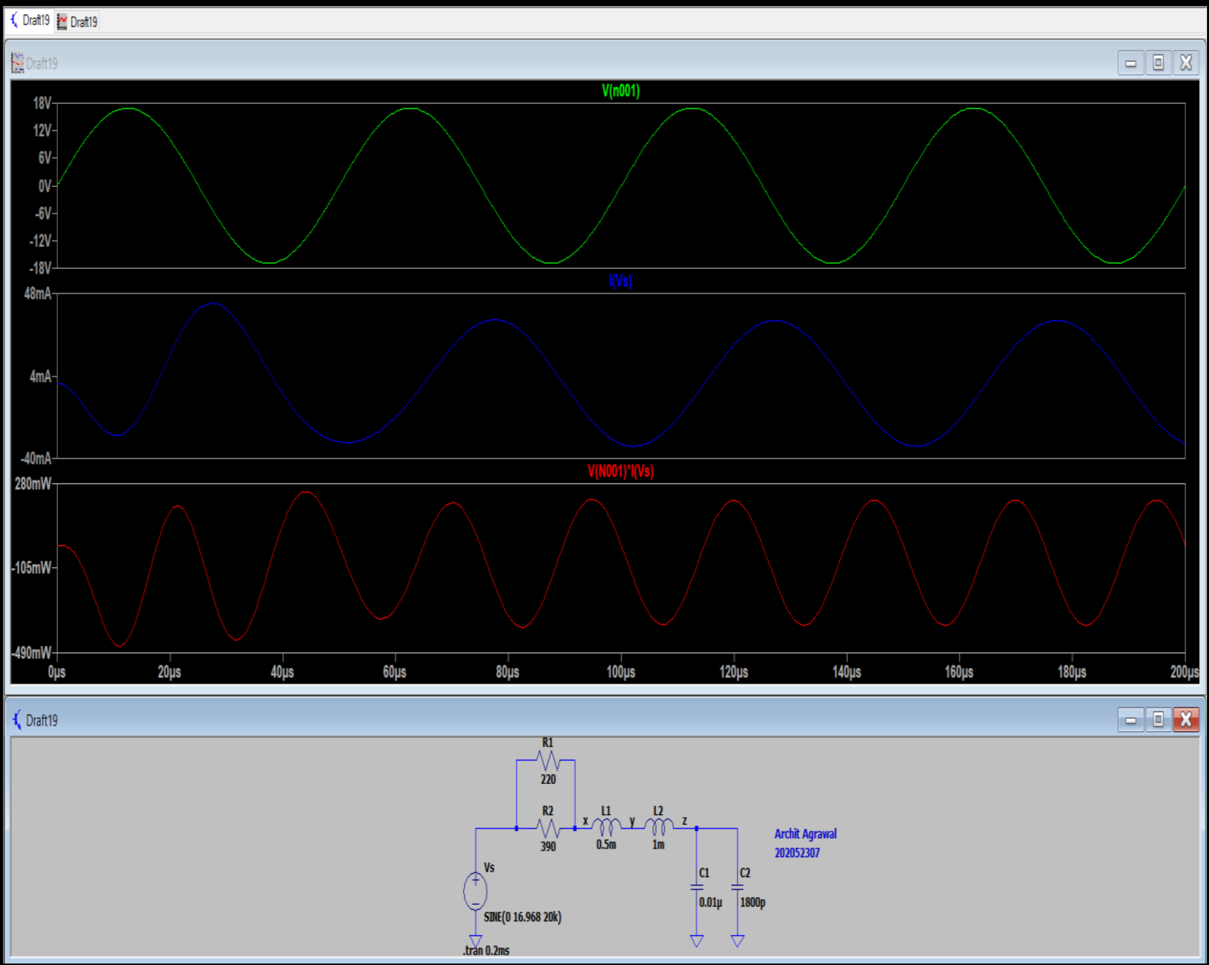
Hence, a phase shift of 180° is present.
Clearly, $73.87^\circ - 180^\circ \approx -106.45^\circ$.

EE160 : Experiment 3

Circuit

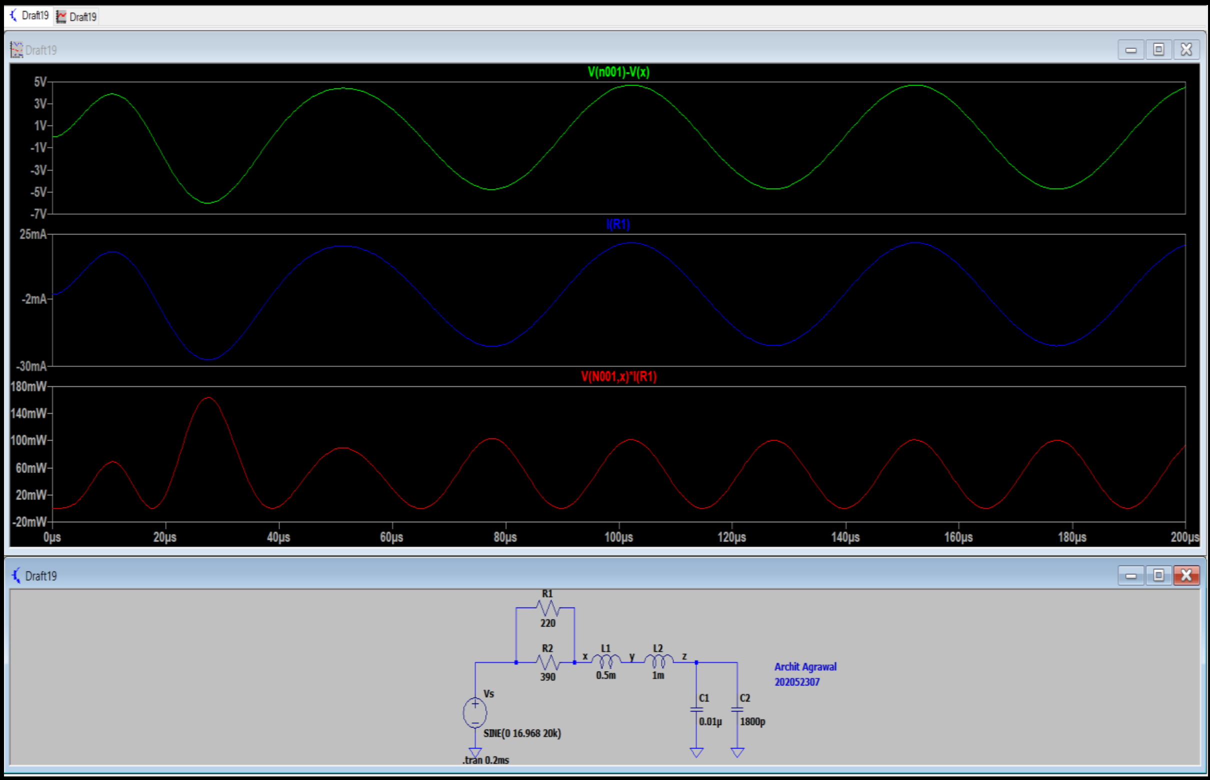


Source Voltage, Total Current and Total Power

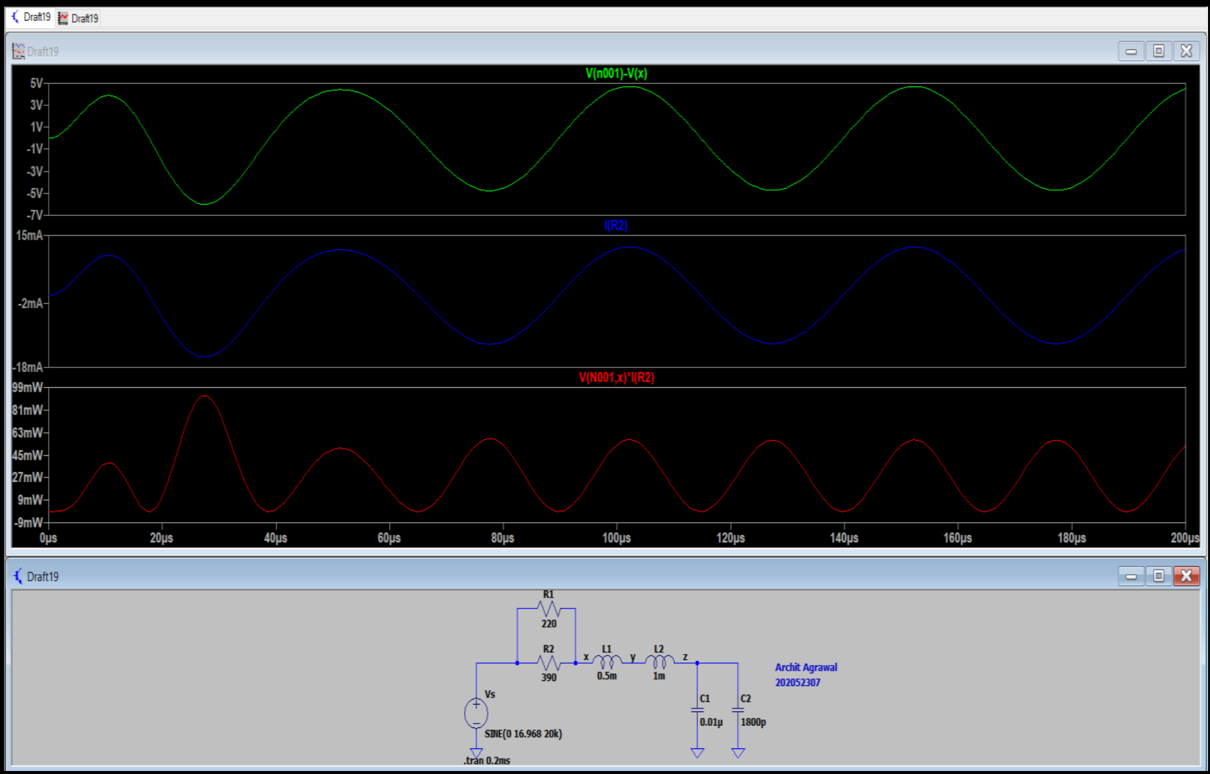


EE160 : Experiment 3

Voltage, current and Power across Resistor R_1

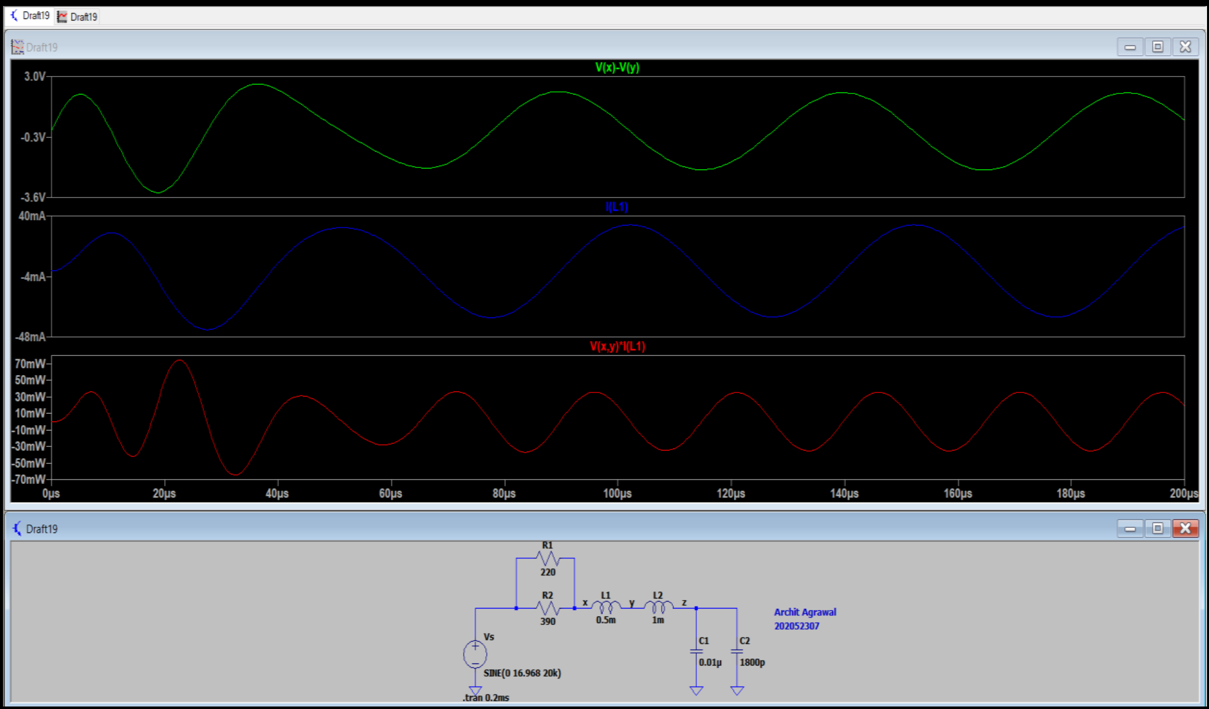


Voltage, current and Power across Resistor R_2

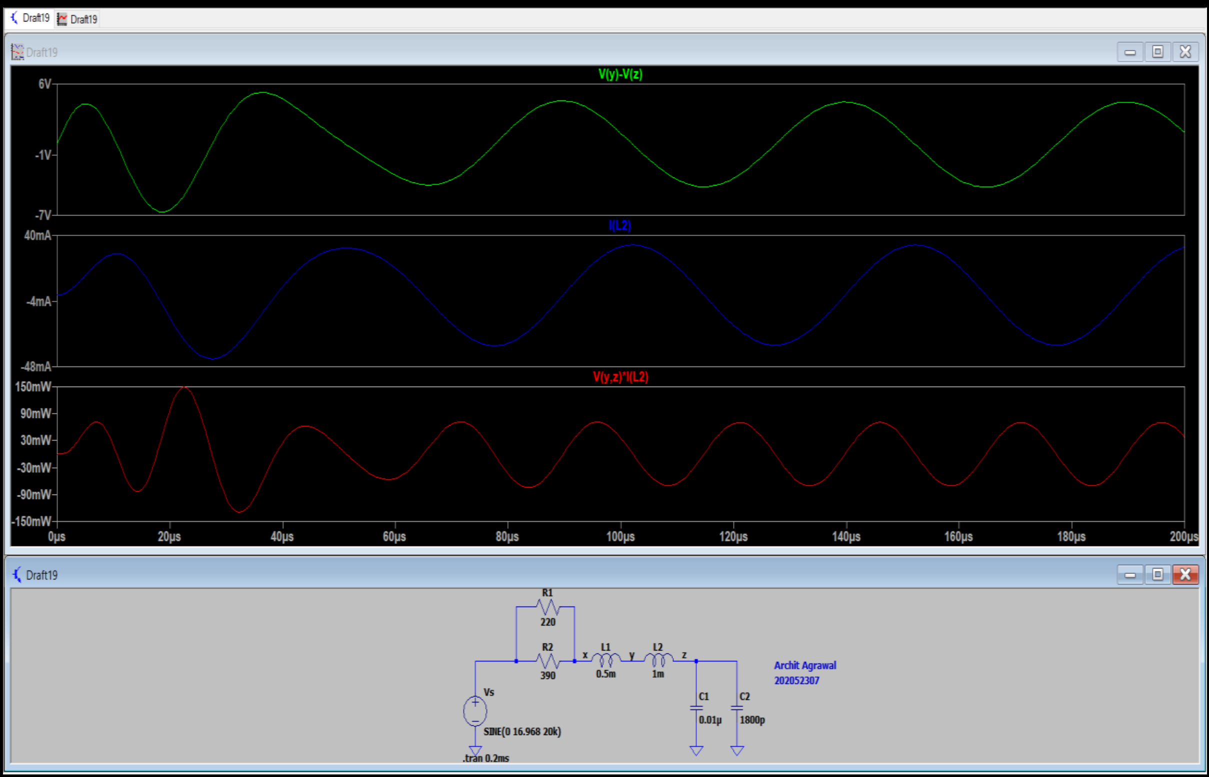


EE160 : Experiment 3

Voltage, current and Power across Inductor L_1

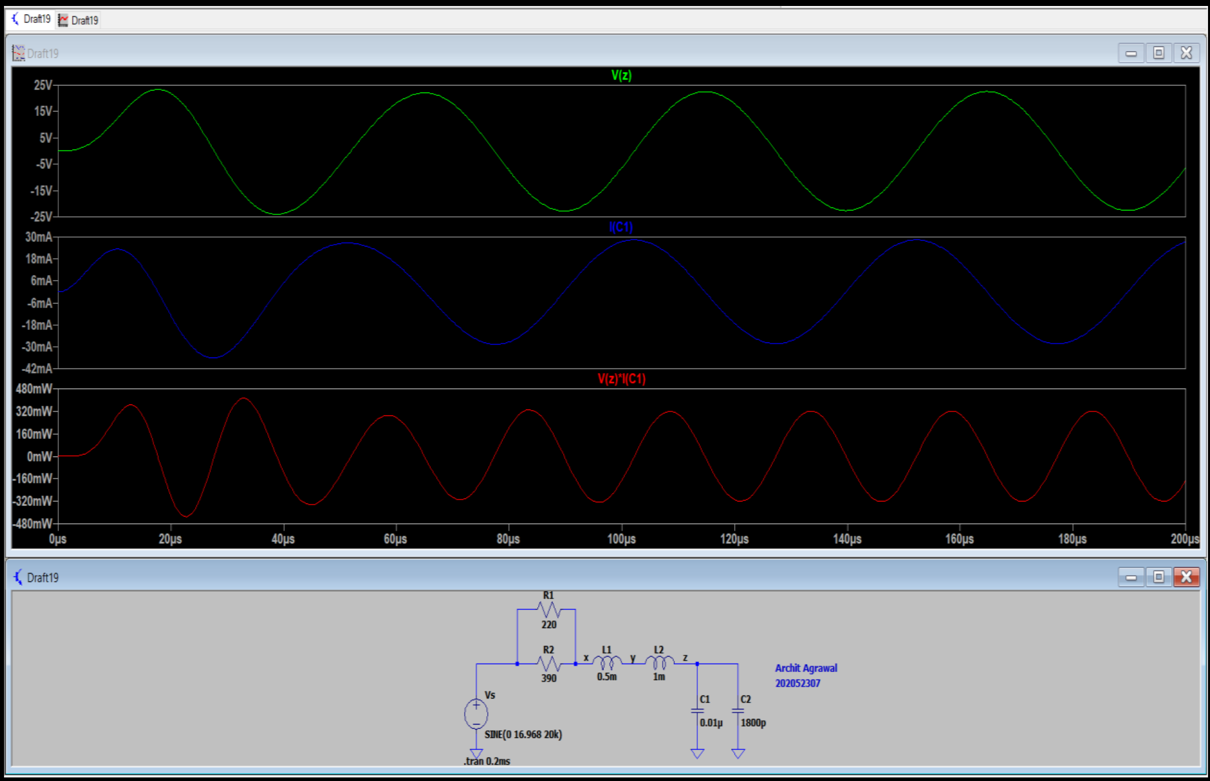


Voltage, current and Power across Inductor L_2

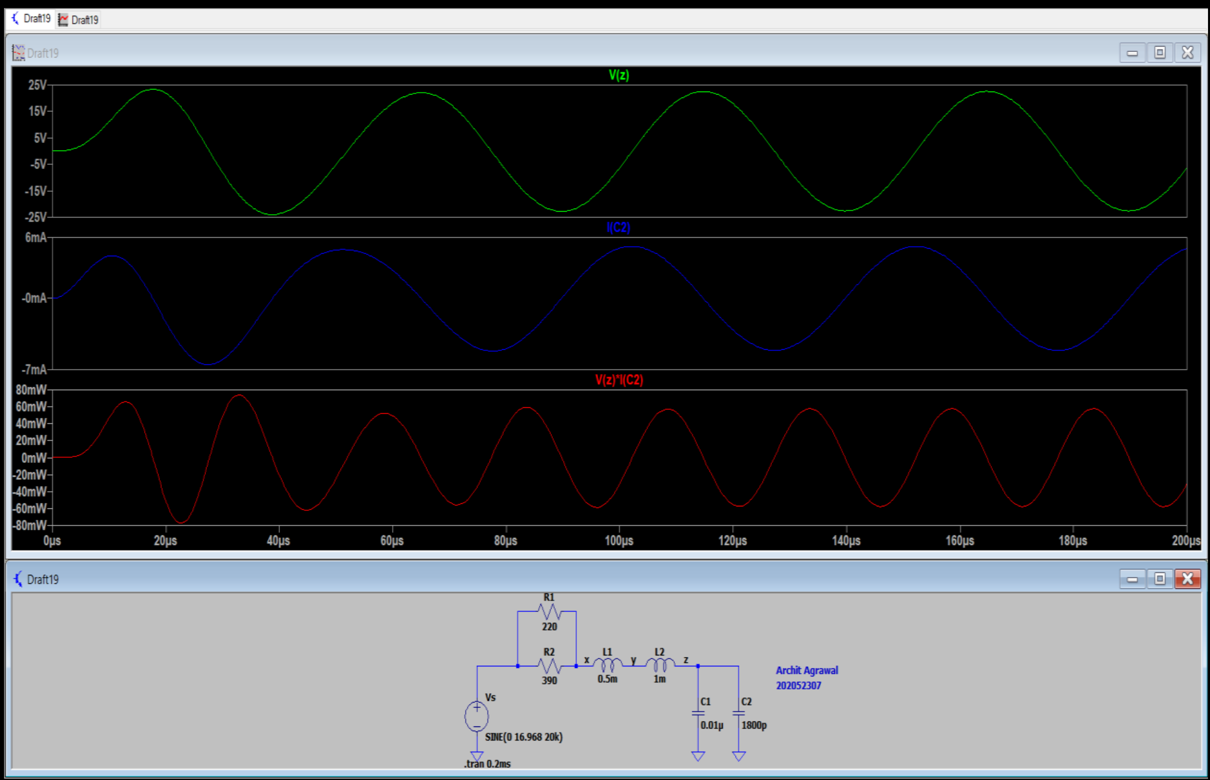


EE160 : Experiment 3

Voltage, current and Power across Capacitor C_1



Voltage, current and Power across Capacitor C_2



EE160 : Experiment 3

AC Analysis

```
       --- AC Analysis ---

frequency:     20000         Hz
V(n001):       mag:        12 phase: 2.12037e-015°       voltage
V(x):          mag:   11.5267 phase:    -16.1447°       voltage
V(y):          mag:   13.0173 phase:    -16.1448°       voltage
V(z):          mag:   15.9984 phase:    -16.1449°       voltage
I(C2):         mag: 0.00361875 phase:    73.8551°       device_current
I(C1):         mag:  0.0201042 phase:    73.8551°       device_current
I(L2):         mag:  0.0237229 phase:    73.8551°       device_current
I(L1):         mag:  0.0237229 phase:    73.8551°       device_current
I(R2):         mag: 0.00855582 phase:    73.8551°       device_current
I(R1):         mag:  0.0151671 phase:    73.8551°       device_current
I(Vs):         mag:  0.0237229 phase:   -106.145°       device_current
```

EE160 : Experiment 3

VIRTUAL

LAB

SIMULATIONS

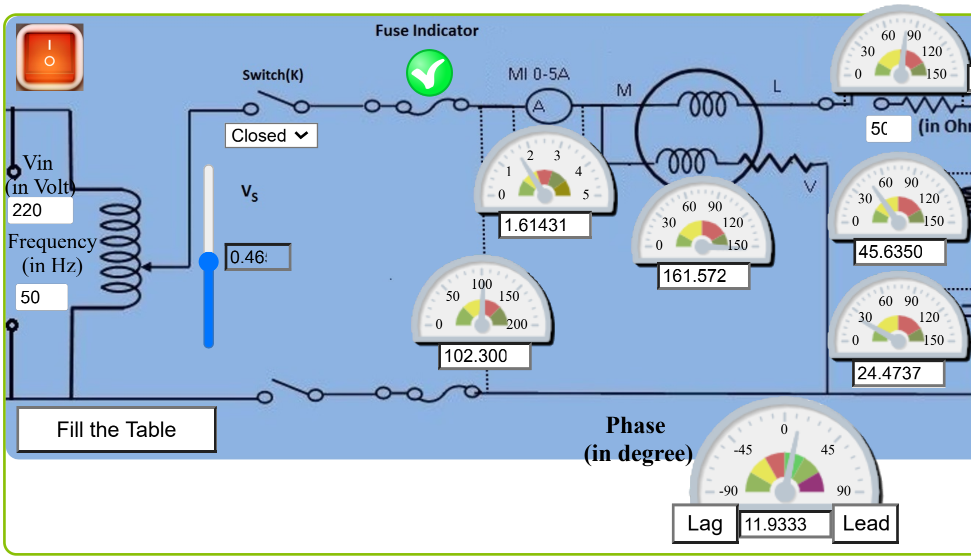
EE160 : Experiment 3

Keeping inductance and capacitance constant and varying the resistance.

R-L-C Circuit Analysis

Procedure: (For Balanced Load)

1. Closed the Switch(K). Set Input Voltage V_{in}=220V.
2. Set power supply voltage (V_S) at=0V. Keep all the resistance, Inductance, capacitance at maximum position.
3. Adjust the voltage across the circuit (VS) to about 70 V and note current(I), V_s, V_L, V_C, V_R and power(W) from the meters.
4. Adjust the rheostat for several settings and repeat step 2.
5. Adjust the rheostat to the maximum setting and change the capacitance to 0uF, 140 uF, 70uF and change the inductance to 0mH, 30 mH, 60mH repeat step 2.
6. Draw phasor diagrams showing VR, VL, VC, VS, & I for different sets of readings.



Observation Table

Serial no. of Observation	Power Supply Vs (in Volt)	Current I (in Amp)	Power (in Watt)	VR (in Volt)	VL (in Volt)	VC (in Volt)	Theta (in degree)	Power factor (in degree)
1	102.300000	3.62403056	170.736767	47.1123973	102.447719	54.9420197	27.6587351	27.6587351
2	102.300000	2.73717974	172.319518	62.9551342	77.3773343	41.4969413	20.5241377	20.5241377
3	102.300000	2.09657848	153.847446	73.3802469	59.2681771	31.7851227	15.5777724	15.5777724
4	102.300000	1.84097842	142.346465	77.3210938	52.0426191	27.9101048	13.6391587	13.6391587
5	102.300000	1.61431315	130.300348	80.7156578	45.6350186	24.4737520	11.9333075	11.9333075

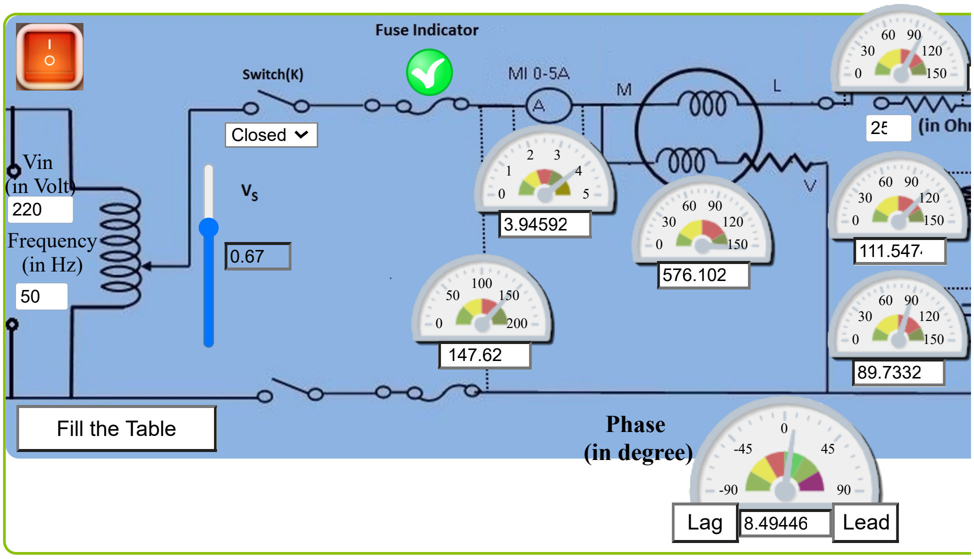
EE160 : Experiment 3

Keeping resistance and capacitance constant and varying the inductance.

R-L-C Circuit Analysis

Procedure: (For Balanced Load)

1. Closed the Switch(K). Set Input Voltage V_{in}=220V.
2. Set power supply voltage (V_S) at=0V. Keep all the resistance, Inductance, capacitance at maximum position.
3. Adjust the voltage across the circuit (VS) to about 70 V and note current(I), V_s, V_L, V_C, V_R and power(W) from the meters.
4. Adjust the rheostat for several settings and repeat step 2.
5. Adjust the rheostat to the maximum setting and change the capacitance to 0uF, 140 uF, 70uF and change the inductance to 0mH, 30 mH, 60mH repeat step 2.
6. Draw phasor diagrams showing VR, VL, VC, VS, & I for different sets of readings.



Observation Table

Serial no. of Observation	Power Supply Vs (in Volt)	Current I (in Amp)	Power (in Watt)	VR (in Volt)	VL (in Volt)	VC (in Volt)	Theta (in degree)	Power factor (in degree)
1	147.62	4.36802934	476.992008	109.200733	0	99.3320904	-42.2735310	42.2735310
2	147.62	4.62587863	534.968827	115.646965	43.5896543	105.195766	-24.6561486	24.6561486
3	147.62	4.44250035	493.395235	111.0625089	83.7233617	101.025614	-6.72829034	6.72829034
4	147.62	3.94592777	389.258650	98.6481944	111.5474323	89.7332009	8.49446422	8.49446422
5								

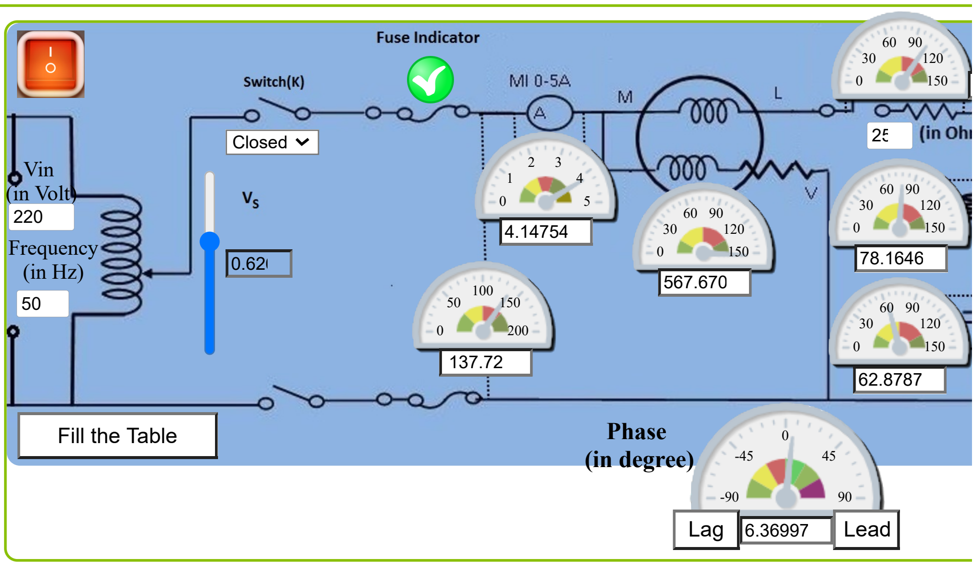
EE160 : Experiment 3

Keeping resistance and inductance constant and varying the capacitance.

R-L-C Circuit Analysis

Procedure: (For Balanced Load)

1. Closed the Switch(K). Set Input Voltage V_{in}=220V.
2. Set power supply voltage (V_S) at=0V. Keep all the resistance, Inductance, capacitance at maximum position.
3. Adjust the voltage across the circuit (VS) to about 70 V and note current(I), V_s, V_L, V_C, V_R and power(W) from the meters.
4. Adjust the rheostat for several settings and repeat step 2.
5. Adjust the rheostat to the maximum setting and change the capacitance to 0uF, 140 uF, 70uF and change the inductance to 0mH, 30 mH, 60mH repeat step 2.
6. Draw phasor diagrams showing VR, VL, VC, VS, & I for different sets of readings.



Observation Table

Serial no. of Observation	Power Supply Vs (in Volt)	Current I (in Amp)	Power (in Watt)	VR (in Volt)	VL (in Volt)	VC (in Volt)	Theta (in degree)	Power factor (in degree)
1	137.72	0	0	0	0		-89.9637896	
2	137.72	3.24749398	263.655430	81.1873497	61.2022717	147.700640	-38.8925235	38.8925235
3	137.72	4.14456814	429.436127	103.614203	78.1085312	94.2504239	-6.72829034	6.72829034
4	137.72	4.14754729	430.053714	103.688682	78.1646763	62.8787813	6.36997139	6.36997139
5								