1. PREAMBLE:

The significance of the Electrical Circuits and Simulation Lab is renowned in the various fields of engineering applications. For an Electrical Engineer, it is obligatory to have the practical ideas about the Electrical Circuits and Simulation.

By this perspective we have introduced a Laboratory manual cum Observation for Electrical Circuits and Simulation.

The manual uses the plan, cogent and simple language to explain the fundamental aspects of Electrical Circuits and Simulation in practical. The manual prepared very carefully with our level best. It gives all the steps in executing an experiment

2 OBJECTIVE & RELEVANCE:

The objective of Electric Circuits laboratory is to impart hands on experience in verification of circuit laws and theorems, measurement of circuit parameters, study of circuit characteristics and simulation of time response. It also gives practical exposure to the usage of CRO, power sources, function generator etc

OUTCOME:

At the successful completion of this course, the student is expected to gain the following skills:

- Become familiar with the basic circuit components and know how to connect them to make a real electrical circuit;
- Become familiar with basic electrical measurement instruments and know how to use them to make different types of measurements;
- Be able to verify the laws and principles of electrical circuits, understand the relationships and differences between theory and practice;
- Be able to gain practical experience related to electrical circuits, stimulate more interest and motivation for further studies of electrical circuits; and
- Be able to carefully and thoroughly document and analyze experimental work.

3 LIST OF EXPERIMENTS

Part – 1

PART II

4. TEXT AND REFERENCE BOOKS

Text Books

1. Basic Electrical Engineering- By M.S.Naidu and S. Kamakshiah – TMH.
2. Basic Electrical Engineering –By T.K.Nagasarkar and M.S. Sukhija Oxford

REFERENCES

1. Theory and Problems of Basic Electrical Engineering by D.P.Kothari & I.J.Nagrath PHI.
2. Principles of Electrical Engineering by V.K Mehta, S.Chand Publications.

5. SESSION PLAN

Sl.No	Name of the Experiment	Week of Experiment
1	Thevenin’s Norton’s and Maximum Power Transfer Theorem	Week #1
2	Supr position Theorem and RMS value of Complex wave	Week #2
3	Verification of Compensation theorem	Week #2
4	Reciprocity, Millman’s theorem	Week #2
5	Locus diagrams of RL and RC Series circuits	Week #3
6	Series and parallel resonance	Week #4
7	Determination of self, mutual inductance and coefficient of coupling..	Week #5
8	Z & Y parameters	Week #6
9	Transmission & hybrid parameters	Week #6
10	Measurement of active power for star and delta connected balanced load	Week #7
11	Measurement of active power for star and delta connected balanced loads	Week #8
12	Measurement of 3 Phase power by 2 wattmeter method for unbalanced loads	Week #9
13	Simulation of DC Circuits	Week #10
14	DC Transient Response	Week #11
15	Mesh Analysis	Week #12
16	Nodal Analysis	Week #13

6. EXPERIMENT WRITE UP:

6.1. Thevenin's Norton's and Maximum Power Transfer Theorems.

6.1.1 THEVENIN'S THEOREM

AIM :

To verify Thevenin's Theorem for a linear network.

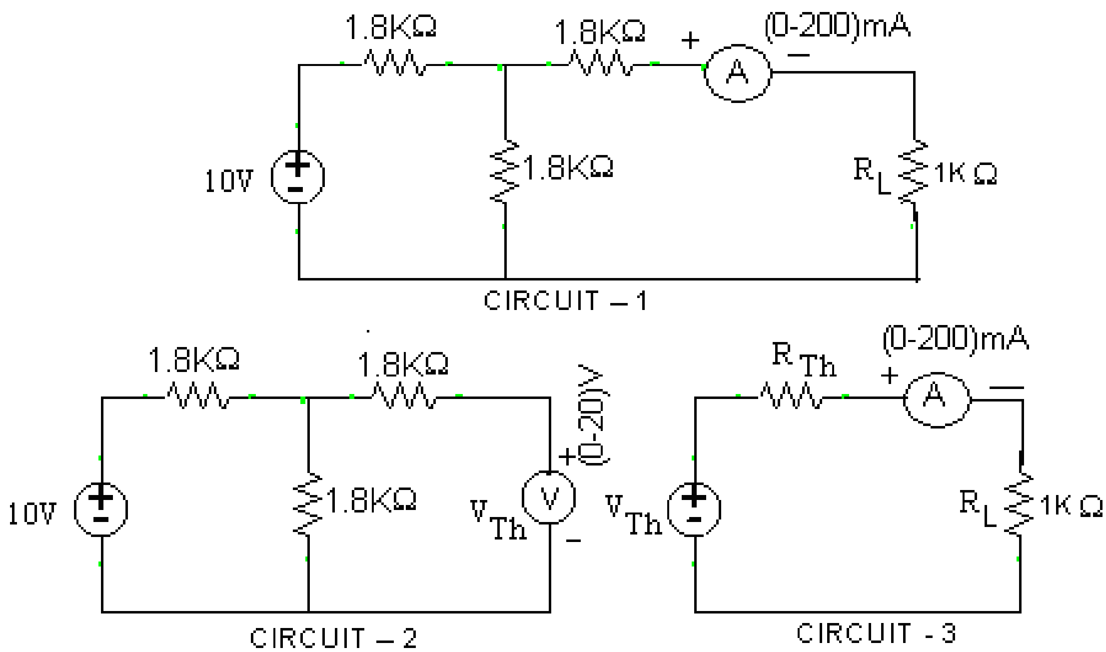
APPARATUS:

	NAME	RANGE	QUANTITY
1.	Bread Board.		
2.	Resistors -	1.8KΩ	3 No.s
		1KΩ	1 No.
3.	Voltmeter	(0-20) V	1 No.
4.	Ammeter	(0-20mA)	1 No.
5.	Multi meter		1 No.
6.	Connecting wires.		

THEORY:

Statement: Any linear bilateral network containing one or more voltage sources can be replaced by an equivalent circuit consisting of a single voltage source whose value is equal to the open circuit voltage across the output terminals, in series with Thevenin's equivalent resistance. The Thevenin's equivalent resistance is equal to the effective resistance measured between the output terminals, with the load resistance removed and with all the energy sources are replaced by their internal resistances.

CIRCUIT DIAGRAM:



PROCEDURE:

1. Connect the circuit as per CIRCUIT-1. Note down the current through the load resistance.
2. Calculate the value of open circuit voltage, Thevenin's equivalent resistance and the current through the load resistance using Thevenin's theorem.
3. Find out R_{Th} by shorting the voltage source and measuring the equivalent resistance across open circuited R_L (1KΩ) terminals using a multimeter. Compare this value with the calculated value.
4. Remove the load resistor R_L and connect the circuit as per CIRCUIT-2 and Note down the reading of voltmeter as V_{Th}.
5. Connect the Thevenin's equivalent circuit as shown in CIRCUIT-3 and Note down the reading of ammeter.
6 If current through the load resistance using Thevenin's theorem is equal to the measured value of the current from circuit1, Thevenin's Theorems is verified.

OBSERVATIONS & CALCULATIONS :

Theoretical:

Open circuit voltage V_{Th} =

Thevenin's Equivalent Resistance R_{Th} =

Current through the load resistor I_L =

Measured

Open circuit voltage V_{Th} =

Thevenin's Equivalent Resistance R_{Th} =

Current through the load resistor I_L =

RESULT :

CONCLUSION :

6.1.2 NORTON'S THEOREM

AIM :

To verify Norton's Theorems for a linear network.

APPARATUS:

	NAME	RANGE	QUANTITY
1.	Bread Board.		
2.	Resistors	1.8KΩ	3 No.s
		1 KΩ	1 No
3.	Voltmeter	(0-20) V	1 No
4.	Ammeter	(0-20mA)	1 No
5.	Multi meter		1 No.
6.	Connecting wires.		

THEORY :

Statement:

Any linear bilateral network containing one or more current sources can be replaced by an equivalent circuit consisting of an equivalent current source, in parallel with an equivalent resistance. Value of current source is equal to the short circuit current through the output terminals with the load resistance shorted. The Norton's equivalent resistance is equal to the effective resistance measured between the output terminals with the load resistance removed, and with all the energy sources replaced by their internal resistances.

PROCEDURE:

1. Connect the circuit as per CIRCUIT-1. Note down the current through the load resistance.
2. Calculate the value of short circuit current, Norton's equivalent resistance and the current through the load resistance using Norton's theorem.

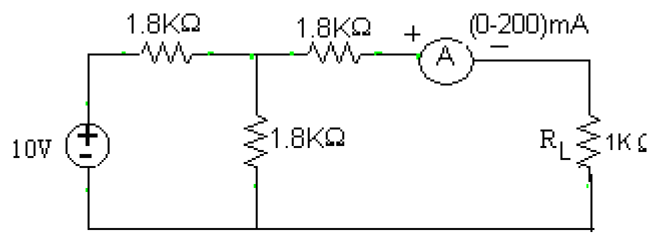
3. Find out R_N by shorting the voltage source and measuring the equivalent resistance across open circuited R_L (1KΩ) terminals using a multimeter. Compare this value with the calculated value.

4. Remove the load resistor R_L and connect the circuit as per CIRCUIT-2 and Note down the reading of ammeter as I_N

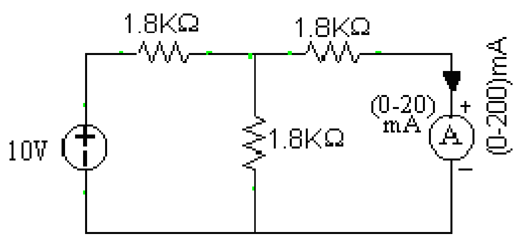
5. Connect the Norton's equivalent circuit as shown in CIRCUIT-3 and Note down the reading of ammeter.

6 If current through the load resistance using Norton's theorem is equal to the measured value of the current from circuit1, Norton's Theorems is verified.

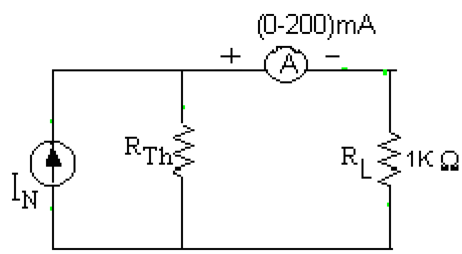
CIRCUIT DIAGRAM:



CIRCUIT – 1



CIRCUIT – 2



CIRCUIT - 3

OBSERVATIONS :

Theoretical:

Short circuit current I_N =

Norton’s Equivalent Resistance R_N =

Current through the load resistor I_L =

Measured:

Short circuit current I_N =

Norton’s Equivalent Resistance R_N =

Current through the load resistor I_L =

RESULT :

CONCLUSION :

6.1.3 MAXIMUM POWER TRANSFER THEOREM

AIM :

To verify the Maximum Power Transfer theorem on DC and AC.

APPARATUS :

1. Resistor - 3.3KΩ.
2. Resistance Box
3. Inductor - 45mH.
4. Inductance Box.
5. Capacitor - 0.01μF
6. AC milli Ammeter - 0-20mA
7. AC Voltmeter - 0-20 V
8. DC milli Ammeter - 0-20mA
9. DC Voltmeter - 0-20V
10. Function Generator
11. Regulated Power Supply.
12. Connecting wires.

THEORY :

Statement:

D.C.:- The maximum power is said to be delivered from the source to the load when the load resistance is equal to the source resistance.

For the given circuit maximum power delivered to the load is given by

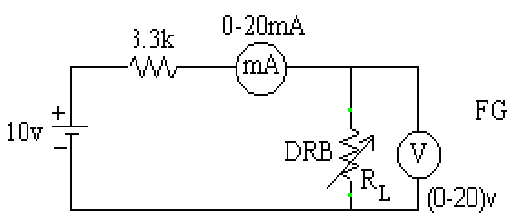
$$P_{max} = \frac{V_s^2}{4R_L}$$

A.C.:- The maximum power is said to be delivered to the load when the source impedance is complex conjugate of load impedance.

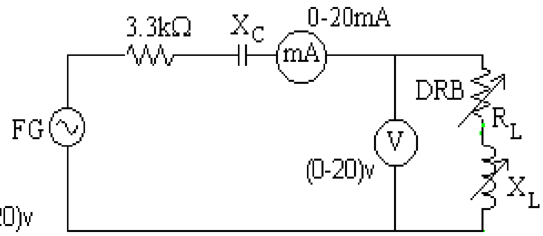
$$P_{max} = \frac{V_s^2}{4R_L}$$

The maximum power transfer theorem finds its application in a radio speaker system supplying the input signals to voltage pre-amplifiers it is necessary to transfer maximum voltage, current or power to the load.

CIRCUIT DIAGRAM:

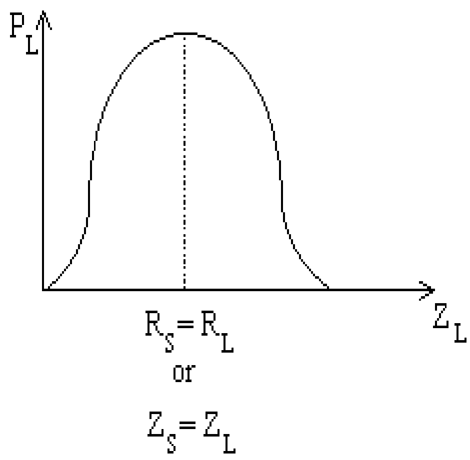


On DC



On AC

EXPECTED GRAPH:



PROCEDURE:

On DC:-

1. Connect the circuit as shown in diagram.
2. Apply 10V DC from the RPS.
3. Take the readings of the milli Ammeter and voltmeter while varying R_L in suitable steps.
4. Tabulate the readings and plot the graph.
5. Verify the maximum power transfer theorem.

On AC:-

1. Connect the circuit as shown in the diagram.
2. Apply 20v (pp) from the FG.
3. Keep X_L=X_C. Take the readings of milli Ammeter and voltmeter while varying the R_L in suitable steps.
4. Plot the graph P_L Vs X_L.
5. Verify that the maximum power transfer occurs at the values predicted by the theorem.

TABULAR FORM:

On DC

S.No	R_L (Ω)	I (A)	V (V)	P_L (W)

On AC

S.No	R_L (Ω)	Z_L (Ω)	I (A)	V (V)	P_L (W)

RESULT :

CONCLUSION :

6.2. Super position Theorem and RMS value of complex wave.

6.2.1 SUPERPOSITION THEOREM

AIM :

To verify the Super position Theorem on DC circuit.

APPARATUS :

	Name	Range	Quantity
1.	Bread Board.		
2.	Resistors	150Ω	2 No.s
		330 Ω	2 No.s
		150 Ω	1 No.
3.	M.C. Voltmeter	0-20 V	1 No.

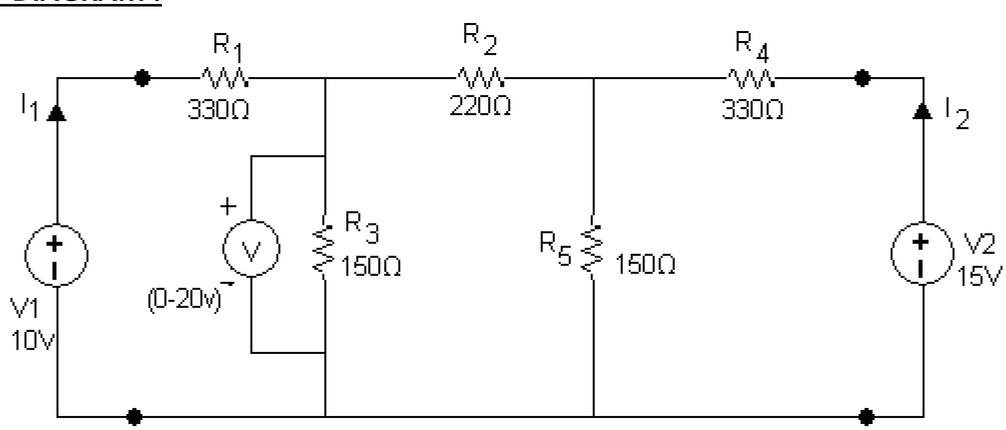
Theory :

Statement : The Super position theorem states that in any linear network containing two or more sources, the response in any element is equal to the sum of the responses caused by individual sources acting alone while the other sources are made inoperative.

We define a linear element as a passive element that has a linear voltage-current relationship. i.e. multiplying the time-varying current through the element by a constant K results in the multiplication of the time-varying voltage across the element by the same constant K.

$V(t) = R\, I\,(t)$.

CIRCUIT DIAGRAM :



PROCEDURE :

1. Connect the circuit as shown in circuit diagram and Note down the reading of the voltmeter as V.
2. Short-circuit the voltage source V_I and Note down the reading of voltmeter as V_I.
3. Now short-circuit the voltage source V_2, keeping V_I in the circuit and Note the reading of voltmeter as V^{II}.
4. If $V = V^I + V^{II}$, Super position theorem is verified.

OBSERVATIONS :

$V =$ $V^{I} =$ $V^{II} =$

RESULT :

CONCLUSION :

6.2.2 RMS VALUE OF COMPLEX WAVE

AIM :

To calculate the RMS value of a complex wave.

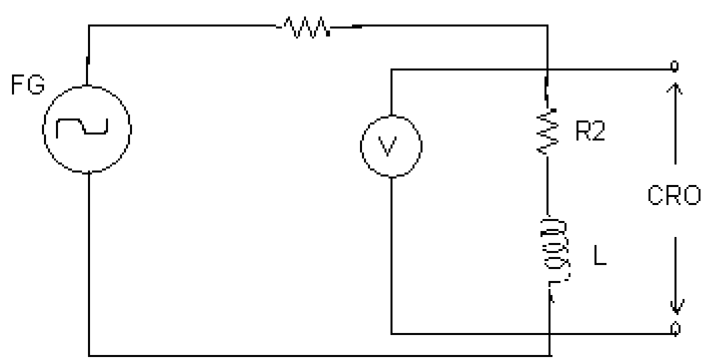
APPARATUS :

	Name	Range	Quantity
1.	Resistors	100Ω	2 Nos
2.	Inductor	1 mH	1 No
3.	Function Generator		1 No
4.	Multimeter		1 No
5.	CRO		1 No

THEORY :

RMS (Root Mean Square) value of an ac wave is the mean of the root of the square of the voltages at different instants. For an ac wave it will be 1/ √2 times the peak value.

CIRCUIT DIAGRAM :



PROCEDURE :

1. Connect the circuit as per the circuit diagram.
2. Apply the sinusoidal wave as input from the Function Generator.
3. Observe the output waveform in the CRO. Note down the peak value of the output wave, from the CRO.
4. Calculate the RMS value and compare with the measured value.
5. Switch OFF the supply.

OBSERVATIONS & CALCULATIONS :

Peak value (V)	Calculated RMS value (V)	Measured value (V)

RESULT :

CONCLUSION :

6.3. VERIFICATION OF COMPENSATION THEOREM

AIM :

To verify the Compensation Theorem.

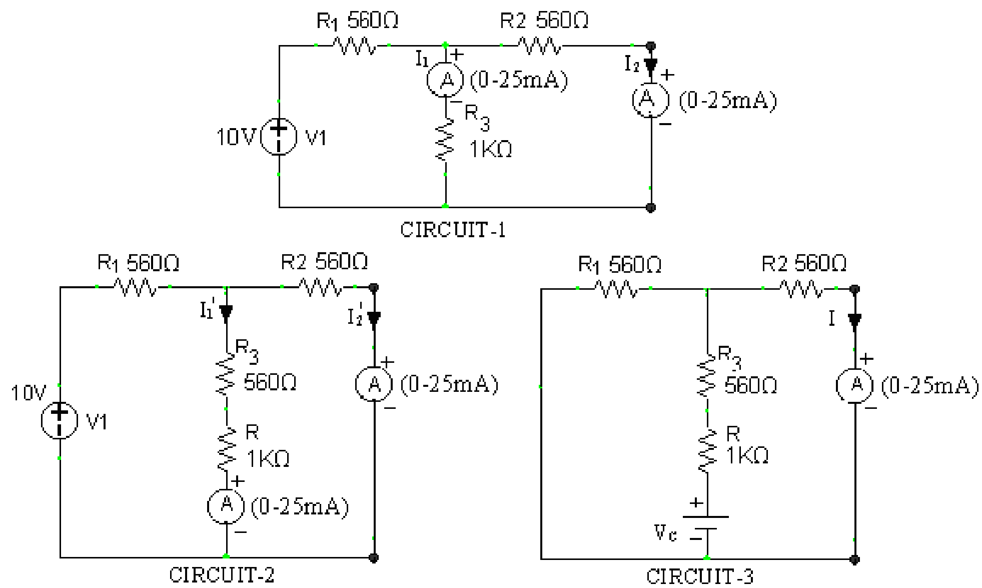
APPARATUS :

NAME	RANGE	QUANTITY
Bread Board.		
Resistors	1K	3 No.s
	560Ω	1 No
Ammeter	(0-25mA) MC	2 Nos

THEORY :

Compensation theorem states that any element in the linear ,bilateral network can be replaced by a voltage source of magnitude equal to the current passing through the element multiplied by the value of current , provided the currents and voltages of the other parts of the circuit remain unaltered. This theorem is useful in finding the changes in current or voltage when the value of resistance is changed in the circuit. If the resistance of any branch of a network is changed from R to (R+▲R) where the current flowing in that branch originally is I, the change of current in the other branches can be calculated by placing a voltage source of the value I(▲R) in the modified branch with all the other sources made ineffective. This theorem is particularly useful in analyzing the networks where the values of the branch elements are varied and for studying the effect of tolerance on such values.

CIRCUIT DIAGRAM:



PROCEDURE :

1)Connect the circuit as shown in CIRCUIT-1, Note down the values of I_1 and I_2 using milli Ammeters.

2) Connect the circuit as shown in CIRCUIT-2, Note down the value of I_2^{l} .

3) Connect the circuit as shown in CIRCUIT-3, where V_C(Compensating voltage)=(I_2^{l} - I_2) 560Ω.

4)Note down the reading of ammeter as I.

5) If $I = I_2^{l} - I_2$, Compensating Theorem is verified.

OBSERVATIONS:

I_1 (mA)	I_2 (mA)	I'_1 (mA)	I'_2 (mA)	Vc (V)	Calculated I (mA)	Measured I (mA)

RESULT :

CONCLUSION:

6.4. RECIPROCITY, MILLMAN'S THEOREMS
6.4.1 MILLMAN'S THEOREM

AIM :

To verify the Millman's Theorem.

APPARATUS :

	NAME	RANGE	QUANTITY
1.	Bread Board.		
2.	Resistors	1.8KΩ	3No.s
3.	Voltmeter	(0-20)V	1 No.

THEORY :

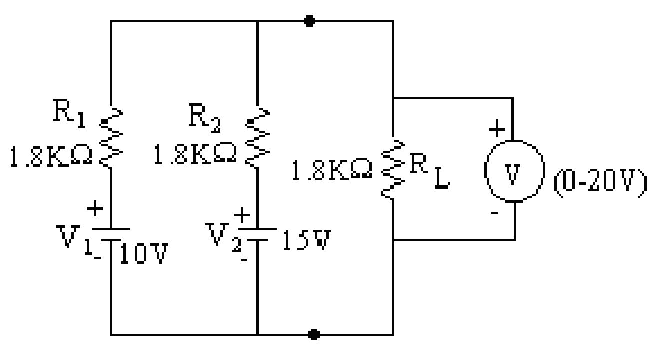
Millman's theorem states that in any network, if the voltage sources V_1, V_2, ….. … V_n in series with internal resistances R_1, R_2,…. R_n respectively are in parallel, then these sources may be replaced by a single voltage source V_{eq} in series with R' where value of the voltage source V_{eq} can be given by

$$V_{eq} = \frac{V_1 G_1 + V_2 G_2 + \dots\dots V_n G_n}{G_1 + G_2 + \dots\dots G_n}$$

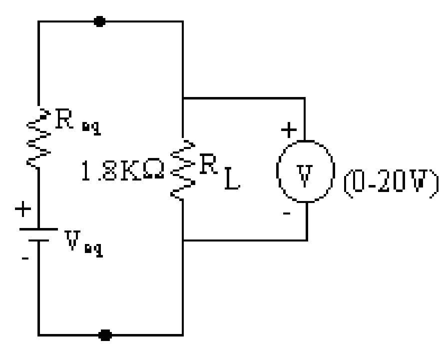
Where Gn is the conductance of the nth branch,

And $R' = 1 / (G_1 + G_2 + \dots\dots + G_n)$

CIRCUIT DIAGRAM:



CIRCUIT-1



CIRCUIT-2

PROCEDURE :

1. Connect the circuit as shown in CIRCUIT-1 and Note down the reading of voltmeter as V_{L1}.
2. Connect the equivalent circuit as shown in CIRCUIT-2 , by calculating
3. $V_{eq}=(V_1G_1 +V_2G_2)/ (G_1 + G_2)$ and $R_{eq}= 1/ (G_1+G_2)$
4. Note down the reading of the voltmeter as V_{L2}.
5. If $V_{L1} = V_{L2}$, the Milliman's Theorem is verified.

OBSERVATIONS:

V_{L1} (V)	V_{L2} (V)

RESULT :

CONCLUSION :

6.4.2 RECIPROCITY THEOREM

AIM :

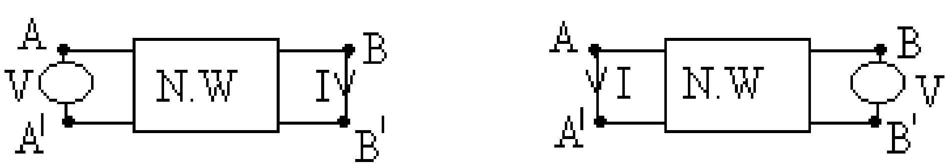
To verify the Reciprocity Theorem.

APPARATUS :

	NAME	RANGE	QUANTITY
1.	Bread Board		
2.	Resistors -	150Ω, 220Ω, 330Ω.	I No each
3.	M.C.Ammeter -	(0-20) mA	I No

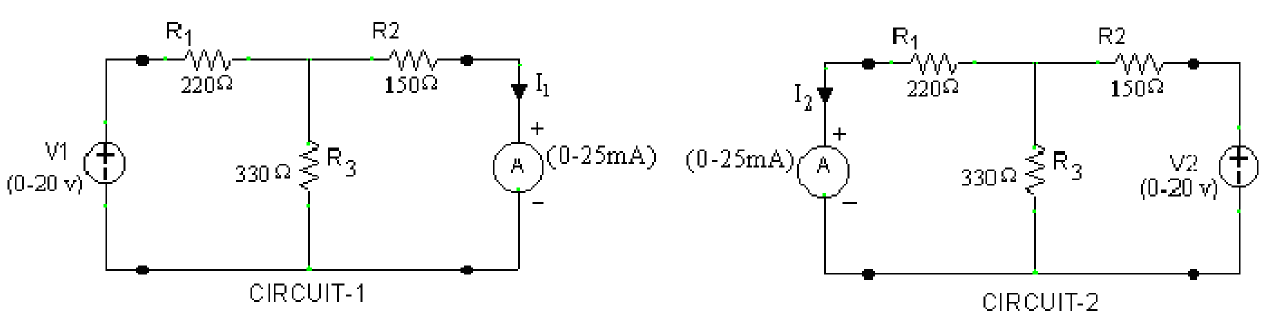
THEORY :

Statement: In any bilateral, linear network, if we apply some input to a circuit the ratio of response (output) in any element to the input is constant even when the position of the input and output are interchanged.



Another way of stating the above is that the receiving and sending points are interchangeable.

CIRCUIT DIAGRAM :



PROCEDURE :

1. Connect the circuit as shown in CIRCUIT-1 and take the reading of Ammeter as I_1.
2. Now change the voltage source to the right hand side as shown in CIRCUIT-2 and measure the current with the help of Ammeter as I_2.
3. If $I_1 = I_2$, then the Theorem is verified.

OBSERVATIONS :

I_1 (mA)	I_2 (mA)

RESULT:

CONCLUSION :

6.5. LOCUS DIAGRAMS OF RL AND RC SERIES CIRCUITS.

AIM :

To Plot the current locus diagrams for RL and RC circuits.

APPARATUS :

1. Resistance Box
2. Inductance Box
3. Capacitance Box
4. Ammeter AC -- (0-20mA) --- 1 No
5. Volt meters AC -- (0-20V) --- 2 No.s
6. Function Generator
7. CRO

THEORY :

Locus diagrams are useful in determining the behaviour or response of an RLC circuit, when one of its parameters is varied while the frequency and voltage are kept constant. The magnitude and phase of the current vector in the circuit depend upon the values of R, L and C and frequency at the fixed source voltage. The path travelled by the tip of the current vector when the parameters R, L or C are varied while frequency and voltage are kept constant is called the locus diagram.

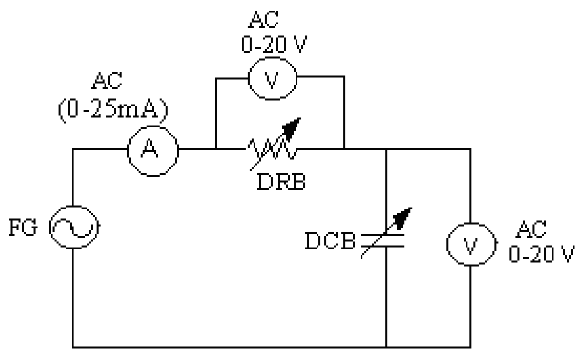
R-varying :

If R = 0, then I = V/ X_L or V/ X_C and has maximum value. It will lag or lead the voltage by 90^0 depending on whether the reactance is inductive or capacitive. The angle θ represents the phase angle ($\theta = \tan^{-1}(V_X/ V_R)$). As R is increased from zero value, I and θ decrease. In the limiting case when R= ∞, then I = 0 and θ = 0^0. The locus of end-point qitI is a semi-circle of radius V / X.

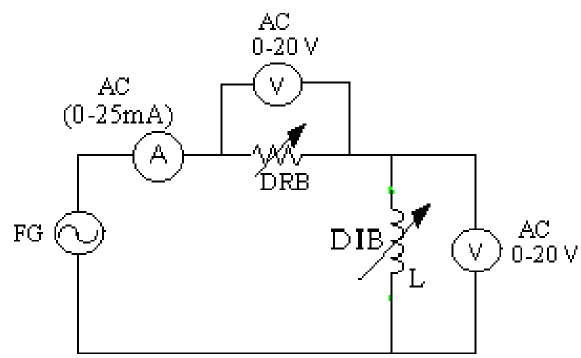
R-Fixed :

If X = 0, then I = V/ R and has maximum value. The current will be in phase with voltage as it is a purely resistive circuit i.e., the phase θ is zero. As X is increased depending on whether the reactance is inductance or apacitance the current starts lagging or leading V i.e., the current I decreases and phase angle θ increases. In the limiting case when X = ∞, then I = 0 and θ = 90^0. The locus of end point of I is a semi-circle of radius V/ R.

CIRCUIT DIAGRAM :



CIRCUIT –1



CIRCUIT - 2

PROCEDURE :

Circuit – 1:

1. Connect the circuit as shown in CIRCUIT – 1. Note down the values of applied voltage and frequency.
2. Fix the resistance at a suitable value (say 1KΩ).
3. Note down the values of V_R, V_C and I for at least three different values of the Capacitor.
4. Now fix the capacitance at a suitable value (say 0.01μF).
5. Note down the values of V_R, V_C and I for at least three different values of the resistor.
6. Draw the corresponding current locus diagrams.

Circuit – 2 :

1. Connect the circuit as shown in CIRCUIT – 2. Note down the values of applied voltage and frequency.
2. Fix the resistance at a suitable value (say 1KΩ).
3. Note down the values of V_R, V_L and I at least three different values of the Inductor.
4. Now fix the Inductance value at a suitable value (say 45mH).
5. Note down the values of V_R, V_L and I at least three different values of the resistor.
6. Draw the corresponding current locus diagrams.

TABULAR COLOUMN :

f = **$V_{i/p}$ =**

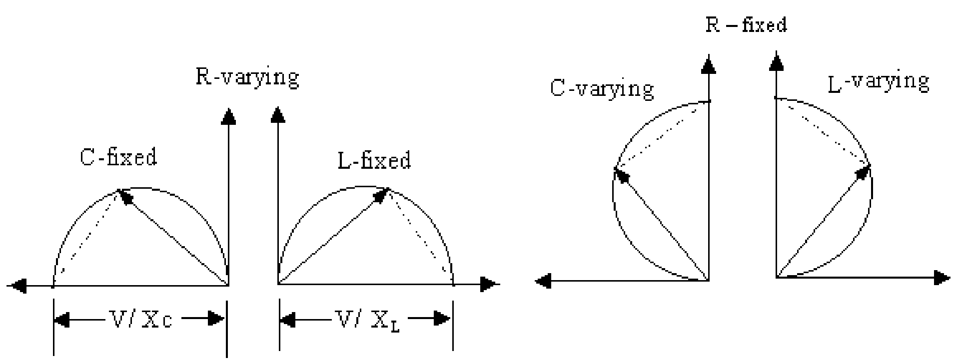
Circuit – 1

R – fixed					
S.No	R (Ω)	C (μF)	V_R (V)	V_C (V)	I (mA)
C – fixed					
S.No	R (Ω)	C (μF)	V_R (V)	V_C (V)	I (mA)

Circuit – 2

R – fixed					
S.No	R (Ω)	C (μF)	V_R (V)	V_L (V)	I (mA)
L – fixed					
S.No	R (Ω)	C (μF)	V_R (V)	V_L (V)	I (mA)

EXPECTED WAVE FORMS:



RESULT :

CONCLUSION :

6.6. SERIES AND PARALLEL RESONANCE

AIM :

To determine resonant frequency, band width and Q-factor for series and parallel RLC circuits

APPARATUS :

	NAME	RANGE	QUANTITY
1.	Resistor	1KΩ	1 No.
2.	Inductor	45mH	1 No
3.	Capacitor	0.01μF	1 No
4.	Milli Ammeter	0-20mA (AC)	1 No
5.	Function generator		

THEORY :

An AC circuit is said to be in Resonance when the applied voltage and current are in phase. Resonance circuits are formed by the combination of reactive elements connected in either series or parallel.

Resonance frequency in series circuit is given by $fr = 1/ (2\pi \sqrt{LC})$ Hz

The impedance of the RLC circuit is

$$Z = R + j (\omega_L – 1/\omega_C) = R + jX$$

The circuit is in resonance when X = 0 ie., when $\omega_L = 1/\omega_C$

In series RLC circuit the current lags behind or leads the applied voltage depending upon the value of X_L and Xc. When X_L is greater than Xc the circuit is inductive and when X_c is greater than X_L, the circuit is capacitive.

Quality factor (Q-factor) or (Selectivity) :

Quality factor can be defined as ,

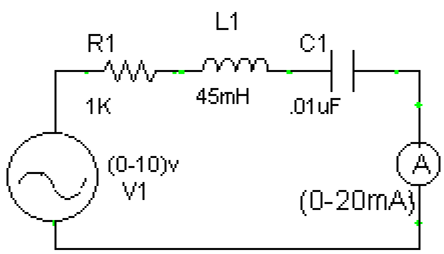
= 2 π (maximum energy stored)/ (energy dissipated per cycle).

$$= (f_2 – f_1) / f_r$$

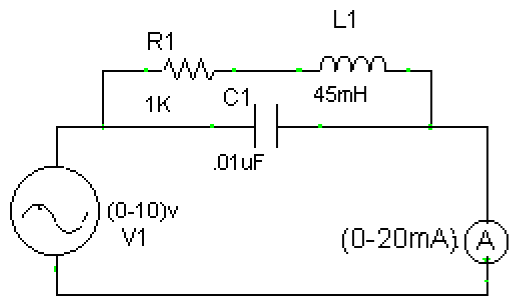
Band width: Band width of a resonance circuit is defined as the band of frequencies on either sides of resonance frequency. This frequency range can be obtained by dropping a vertical in the graph at its half power value, i.e., 1/ √2 times of maximum value.

Band width = $f_2 - f_1$

CIRCUIT DIAGRAM :



CIRCUIT –1



CIRCUIT-2

PROCEDURE :

1. Connect the circuit as shown in diagram(1).
2. Apply 20V (peak to peak) from the Function Generator.
3. Vary the input frequency in suitable steps (starting from 1K Hz to 10K Hz in step of 500 Hz).
4. Note down the readings of the milli Ammeter for different values of frequency.
5. Calculate the Impedance Z.
6. Plot the graphs for current Vs frequency and Z Vs frequency.
7. Identify the values of f_0 , f_1 and f_2 from the graph, Calculate the Q-factor and Band width.
8. Compare with theoretical values.
9. Connect the circuit as per diagram(2).
10. Repeat steps (2) & (3).
11. Note down the readings of the voltmeter and milliammeter for different frequencies.
12. Calculate the Impedance Z.
13. Plot the graphs for current Vs frequency and Z Vs frequency
14. Also plot the graph of Voltage Vs Frequency.
15. Identify the values of f_0 , f_1 and f_2 from the graph, Calculate the Q-factor and Band width.

TABULAR COLOUMN :

Series

S. No	I/P V	Frequency, Hz	$I_{L,}$ Amp	$Z=V/I_L$ Ω

Parallel

S. No	V i/p	Frequency, Hz	I_L, Amp	$Z=V/I_L$ Ω

CALCULATIONS:

For Series Resonance :

$$f_0 = \frac{1}{(2\pi\sqrt{LC})}$$

$$f_1 = f_0 - (R/4\pi L)$$

$$f_2 = f_0 + (R/4\pi L)$$

$$\text{Band width} = f_2 - f_1$$

$$\text{Q-factor} =$$

__For Parallel Resonance :

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$f_1 = f_0 - (R/4\pi L)$$

$$f_2 = f_0 + (R/4\pi L)$$

$$\text{Band width} = f_2 - f_1$$

Q-factor =

THEORETICAL CALCULATIONS :

Series

$$f_0 = \frac{1}{(2\pi\sqrt{LC})}$$

$$f_1 = f_0 - (R/4\pi L)$$

$$f_2 = f_0 + (R/4\pi L)$$

$$\text{Band width} = f_2 - f_1$$

Q-factor =

Parallel

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

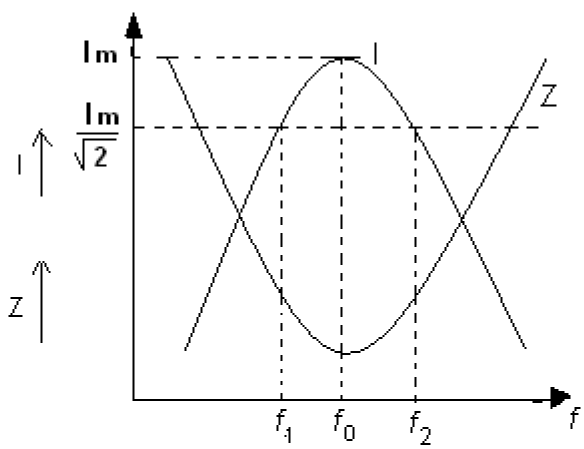
$$f_1 = f_0 - (R/4\pi L)$$

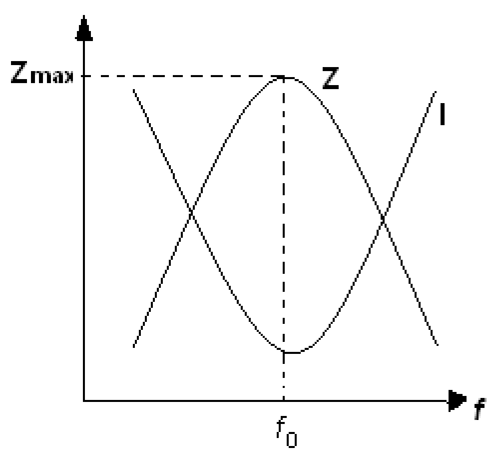
$$f_2 = f_0 + (R/4\pi L)$$

$$\text{Band width} = f_2 - f_1$$

Q-factor =

EXPECTED GRAPH :





RESULT :

CONCLUSION :

6.7. DETERMINATION OF SELF & MUTUAL INDUCTANCES AND COEFFICIENT OF COUPLING

AIM:

To determine the self and mutual inductances and coefficient of coupling for two inductive coils.

APPARATUS :

Name	Type / Range	Quantity
Single phase variac	5 KVA, 230/ (0 – 270) V	1 No
Volt meter	MI , (0 – 300) V	2 No
Ammeter	MI , (0 – 5) A	1 No
Wattmeter	LPF , 300 V , 5 A	1 No.

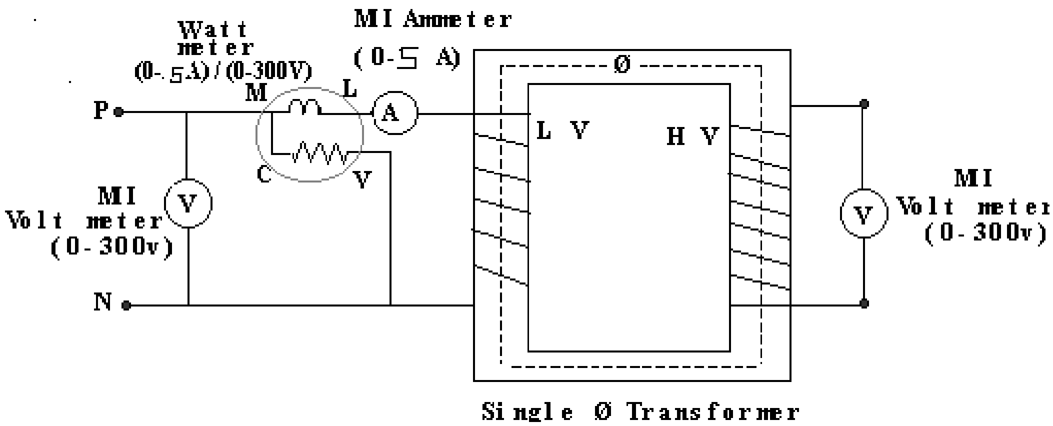
THEORY :

The property by which a coil opposes any change in the current passing through it is known as self inductance. Whenever current passes through an inductor, it produces a magnetic field around the coil and if the current is alternating it produces an emf in the coil. Thus the self inductive reactance and the self inductance can be found out by measuring the emf induced and the current required to produce it.

Mutual inductance is the property by which a coil opposes any change in the current passing through a neighbouring coil. Thus the mutual inductive reactance and the mutual inductance can be found out by measuring the emf induced in the neighbouring coil and the current required to produce it.

The amount of coupling between the inductively coupled coils is expressed in terms of the coefficient of coupling.

CIRCUIT DIAGRAM :



PROCEDURE :

(1) Connect the apparatus as per the circuit diagram.

(2) Adjust the variac and apply a voltage of 115 V at primary.

(3) Note down the voltmeter , ammeter and wattmeter readings in the primary and secondary sides.

(4) Interchange the HV and LV sides.

Mutual Inductive reactance = $X_{M12} = V_H / I\mu$
Mutual Inductance $M_{12} = X_{M12} / 2\pi f$

When connected to HV side :

Power factor $\cos\Phi = W / V_H * I$
Power factor angle $\Phi = \cos^{-1}(W / V_H * I)$
Magnetizing current $I\mu = I * \sin\Phi$
Self Inductive reactance $X_{L2} = V_H / I\mu$
Self Inductance $L_1 = X_{L1} / 2\pi f$
Mutual Inductive reactance = $X_{M12} = V_L / I\mu$
Mutual Inductance $M_{12} = X_{M12} / 2\pi f$
Coefficient of Coupling , $K = M / \sqrt{(L_1 * L_2)}$

(5) Note down the voltmeter , ammeter and wattmeter readings in the primary and secondary sides.

(6) Switch off the supply and disconnect the circuit.

OBSERVATIONS:

When connected to LV side :

S No.	Voltage V_1 (volt)	Current I (Amp)	Power W (watt)	Voltage V_2(volt)

When connected to HV side :

S No.	Voltage V_1 (volt)	Current I (Amp)	Power W (watt)	Voltage V_2(volt)

CALCULATIONS :

When connected to LV side :

Power factor $\cos\Phi = W / V_L * I$

Power factor angle $\Phi = \cos^{-1}(W / V_L * I)$

Magnetizing current $I\mu = I * \sin\Phi$

Self Inductive reactance $X_{L1} = V_L / I\mu$

Self Inductance $L_1 = X_{L1} / 2\pi f$

RESULT :

CONCLUSION:

6.8. Z & Y PARAMETERS

AIM :

To determine the Z, and Y parameters of a Two-port network.

APPARATUS :

	Name		Type / Range	Quantity
1.	Resistors	-	150Ω, 220Ω and 330Ω	each 1 No.s
2.	milli Ammeter	-	(0-20mA)	2 No.s
3.	Voltmeter	-	(0-20v)	1 No
4.	Regulated power Supply	-	30 V, 2A	1 No.
5.	Connecting wires.			

THEORY :

A network is having two pairs of accessible terminals, it is called a two port network. If voltage and current at the input and output terminals are V_1 , I_1 and V_2 , I_2 respectively, there are six sets of possible combinations generated by the four variables, describing a two - port network. Z - parameters and Y- parameters are two among them.

Using Z- parameters the circuit can be represented by the following equations

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

Using Y- parameters the circuit can be represented by the following equations

$$I_1 = Y_{11} V_1 + Y_{12} V_2$$

$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

CIRCUIT DIAGRAM:

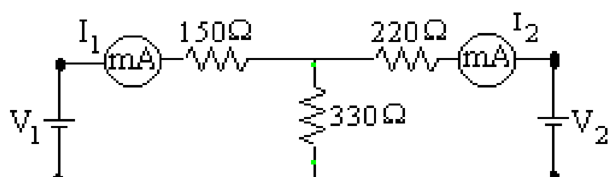


fig-1

PROCEDURE :

Z- parameters:-

1. Connect the circuit as shown in diagram – 1.

For Z_{11} and Z_{21} :

1. Make $I_2 = 0$ by open circuiting the V_2 and Apply $V_1 = 10V$.
2. Note down the readings of V_1, V_2 and I_1.
3. Calculate Z_{11} and Z_{21} .
4. Verify with theoretical values.

For Z_{12} and Z_{22} :

1. Make $I_1 = 0$ by open circuiting the V_1 and Apply $V_2 = 15V$.
2. Note down the readings of V_1, V_2 and I_2.
3. Calculate Z_{12} and Z_{22}.
4. Verify with theoretical values.

Y- parameters :-

1. Connect the circuit as shown in diagram – 1.

For Y_{11} and Y_{21} :

1. Make $V_2 = 0$ by short circuiting it and Apply V_1=10v.
2. Note down the readings of I_1, I_2 and V_1.
3. Calculate Y_{11} and Y_{21} .
4. Verify with theoretical values.

For Y_{12} and Y_{22} :

1. Make $V_1 = 0$ by short circuiting it and Apply V_2 = 15v.
2. Note down the readings of I_1, I_2 and V_2.
3. Calculate Y_{12} and Y_{22}.
4. Verify with theoretical values.

OBSERVATIONS & CALCULATIONS :

For Z-parameters

When V_2 is open circuited,

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

$Z_{11} = V_1 / I_1$ ($I_2 = 0$)

$Z_{21} = V_2 / I_1$ ($I_2 = 0$)

When V_1 is open circuited,

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

$Z_{12} = V_1 / I_2$ ($I_1 = 0$)

$Z_{21} = V_1 / I_1$ ($I_1 = 0$)

For Y -parameters

When V_2 is short circuited,

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

$Y_{11} = I_1 / V_1$ ($V_2 = 0$) =

$Y_{21} = I_2 / V_1$ ($V_2 = 0$)

When V_1 is short circuited,

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

$Y_{12} = I_1 / V_2$ ($V_1 = 0$) ,$Y_{22} = I_2 / V_2$ ($V_2 = 0$)

Result:

6.9. TRANSMISSION AND HYBRID PARAMETERS

AIM :

To determine the Transmission and Hybrid parameters of a Two-port network.

APPARATUS :

Name		Type / Range	Quantity
1. Resistors	-	150Ω, 220Ω and 330Ω	each 1 No.s
2. milli Ammeter	-	(0-20mA)	2 No.s
3. Voltmeter	-	(0-20v)	1 No
4. Regulated power Supply	-	30 V, 2A	1 No.
5. Connecting wires.			

THEORY :

A network is having two pairs of accessible terminals, it is called a two port network. If voltage and current at the input and output terminals are V_1 , I_1 and V_2 , I_2 respectively, there are six sets of possible combinations generated by the four variables, describing a two - port network. Transmission- parameters and Hybrid- parameters are two among them.

Using T- parameters the circuit can be represented by the following equations

$$V_1 = A V_2 - B I_2$$

$$I_1 = C V_2 - D I_2$$

Where A, B, C, D are the transmission parameters.

Using h- parameters the circuit can be represented by the following equations

$$V_1 = h_{11} I_1 + h_{12} V_2$$

$$I_2 = h_{21} I_1 + h_{22} V_2$$

h_{11}, h_{12}, h_{21} , h_{22} are the hybrid parameters.

CIRCUIT DIAGRAM :

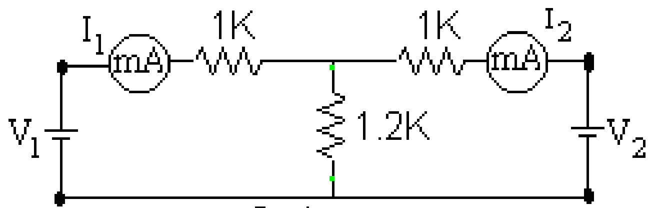


fig-1

PROCEDURE :

T- parameters :-

a. Connect the circuit as shown in diagram – 1.

b. Make $V_2 = 0$ by short-circuiting it and Apply V_1=10V.

c. Note down the readings of V_1, I_2 and I_1.

d. Calculate the values of B and D.

e. Make $I_2 = 0$ by open-circuiting V_2 and Apply V_1=10V

f. Note down the readings of V_1, V_2 and I_1.

g. Calculate the values of A and C

h. Verify with theoretical values.

h – parameters :-

1. Connect the circuit as shown in diagram – 1.
2. Make $V_2 = 0$ by short-circuiting it and Apply V_1=10V.
3. Note down the readings of V_1, I_2 and I_1.
4. Calculate the values of h_{11} and h_{21}.
5. Make I_1=0 by open-circuiting V_1 and Apply V_2=10V
6. Note down the readings of V_1, V_2 and I_1.
7. Calculate the values of h_{12} and h_{22}.
8. Verify with theoretical values.

OBSERVATIONS & CALCULATIONS :

For T-parameters

When V_2 is short circuited,

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

B = V_1 / I_2 ($V_2 = 0$)

D = I_1 / I_2 ($V_2 = 0$)

When V_2 is open circuited,

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

A = V_1 / V_2 ($I_2 = 0$)

C = I_1 / V_2 ($I_2 = 0$)

For h -parameters

When V_2 is short circuited,

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

h_{11} = V_1 / I_1 ($V_2 = 0$)

h_{21} = I_2 / I_{21} ($V_2 = 0$)

When V_1 is open circuited,

9.

V_1 (volt)	V_2 (volt)	I_1 (A)	I_2 (A)

h_{12} = V_1 / V_2 ($I_1 = 0$) h_{22} = I_2 / V_2 ($I_1 = 0$)

Result:

Conclusion:

6.10 Measurement of active power for star and delta connected balanced load

Aim: To measure the active power for the given star and delta network.

Apparatus:

S.No	Name of the equipment	Range	Type	Quantity
1	Wattmeter	0-10A/600V	MI	2
2	Rheostats	0-200 ohms	Wire wound	3
3	Connecting wires	-	-	As per the requirement

Theory:

A three phase balanced voltage is applied on a balanced three phase load when the current in each of the phase lags by an angle Φ behind corresponding phase voltages. Current through current coil of w1=Ir, current through current coil of W2=I**B,** while potential difference across voltage coil of W1=VRN-VYN=VRY(line voltage), and the potential difference across voltage coilof W2= VRN-VYN=VBY.Also , phase difference between IR and VRY is (300+ Φ).While that between IB and VBY is (300- Φ).Thus reading on wattmeter W1 is given by **W1=VRYIYCos(300+ Φ)**While reading on wattmeter W2 is given by **W2=VBYIBCos(300- Φ)**Since the load is balanced, **|IR|=|IY|=|IB|=I** and **|VRY|=|VBY|=VLW1=VLICos(300+ Φ)W2=VLICos(300- Φ).**

Thus total power P is given by

W= W1 +W2 = VLICos(300+ Φ) + VLICos(300- Φ)

= VLI[Cos(300+ Φ) + Cos(300- Φ)]

= [√3/2 *2Cos Φ]VLI

= √3VLICos Φ.

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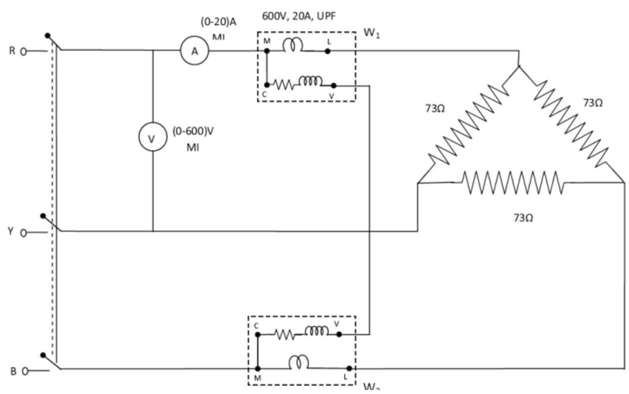
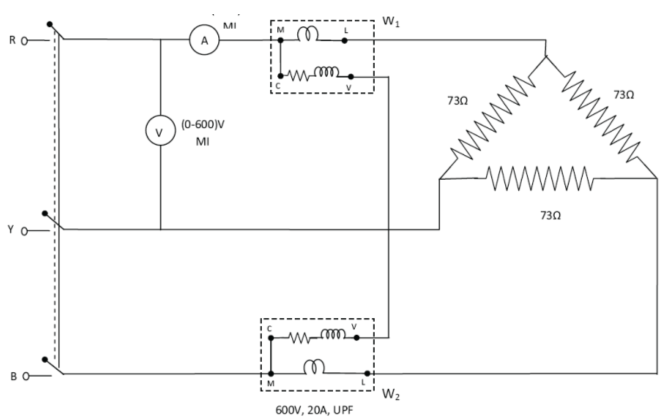
CIRCUIT DIAGRAM :

Star connected load:



Delta connected load :



Procedure:

(Star connection):

1) Connect the circuit as shown in the figure.

2) Ammeter is connected in series with wattmeter whose other end is connected to one of the loads of the balanced loads.

3) The Y-phase is directly connected to one of the nodes of the 3-ph supply.

4) A wattmeter is connected across R-phase & Y-phase as shown in fig. The extreme of Bphase is connected to the third terminal of the balanced 3-ph load.

5) Another wattmeter is connected across Y & B phase, the extreme of B-phase is connected to the third terminal of the balanced three phases load.

6) Verify the connections before switching on the 3-ph power supply.

(Delta connection):

1) Connect the circuit as shown in the figure.

2) Ammeter is connected in series with wattmeter whose other end is connected to one of the loads of the balanced loads.

3) The Y-phase is directly connected to one of the nodes of the 3-ph supply.

4) A wattmeter is connected across Y & B phase, the extreme of B-phase is connected to the third terminal of the balanced 3-ph load.

5) Another wattmeter is connected across R & Yphase, the extreme of R-phase is connected to the third terminal of the balanced three phases load.

6) Verify the connections before switching on the 3-ph power supply.

Precautions:

1. Avoid making loose connections.
2. Readings should be taken carefully without parallax error.

Result: Calculated Active and Reactive Powers for Star and Delta Networks

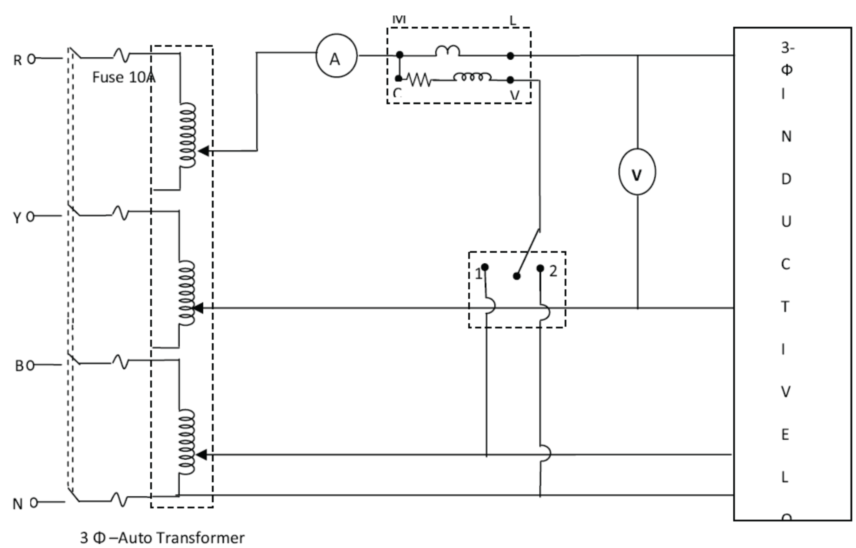
11 Measurement of active power for star and delta connected balanced loads

Aim:- Measurement of Reactive power of an 3- Φ balanced inductance load using one 1- Φ Wattmeter.

Apparatus:-

Theory:-
For the measurement of reactive power in balanced 3-Φ circuit only a single Dynamometer type wattmeter is required.
The current coil is connected in series with load and the pressure coil is connected across the remaining two phase.
Let the current through current coil be Iph & potential appliance across the pressure coil be "V"
VI=VY-VB=√3 VPH.
This potential VI is leading R by 90oα IR by hence wattmeter reading indicates.
WI=√3 VPH IPH. Cos (-90o+ϴ)= =√3 VPH IPH sin ϴ
Total reactive power (Q) obtained by Multiplying the wattmeter reading with =(-√3)i.e Q=√3 WI

CIRCUIT DIAGRAM :



Procedure:-
1) Connect the apparatus as shown as circuit diagram.
2) Vary the auto transformer and set it to rated voltage.
3) Now Vary the 3-Φ balanced load gradually.
4) Note down the reading of voltmeter, Ammeter & Wattmeter.
5) Calculate theoretical and Practical values of reactive power from the given formula.

Precautions:-
1) Avoid lose connections.
2) Avoid parallax errors.

Result:-
The measurement of 3- Φ Reactive power using 1-Φ Wattmeter has been clone and theoretical & practical values has been compared.

Observation Table:-

S.No W1 W2 Volts P=√3* W1 S=√3VI Ө=tan-1(Q/P) Q=√3VI sin Ө Q=√S2-P2 I(Amps)

Result:- Reactive Power is Calculated by using Single Wattmeter Method

6.12. MEASUREMENT OF 3 PHASE POWER BY 2 WATTMETER METHOD

AIM:

To measure the active power consumed by a 3 phase load, using 2 wattmeter method.

APPARATUS:

NAME	RANGE	QUANTITY
Wattmeter	10A/600V	2 Nos
Ammeter	(0-10)A	2Nos
Voltmeter	(0 -600V)	1 No
3-phase Auto transformer		
3-phase load		

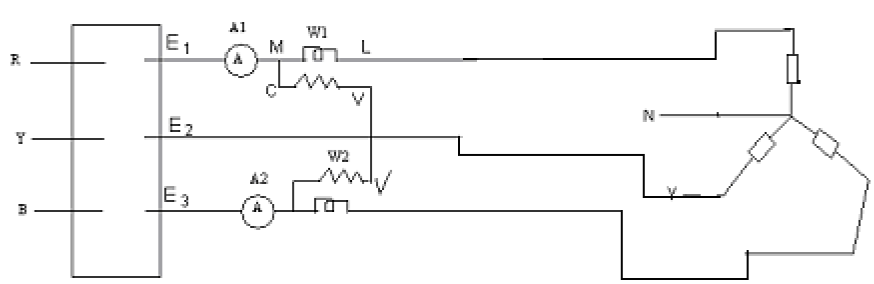
THEORY:

A circuit is said to be unbalanced when the impedance in one or more phases differ from the impedances of the other phases.In such cases phase or line currents are different and are displaced from one another by unequal angles.

In two wattmeter method, we connect the current coil of the wattmeters in two different phases of the 3 phase circuit and the pressure coil will be connected between that particular phase and the third phase. The total power consumed by the load

$$W= W1 + W2$$

CIRCUIT DIAGRAM :



PROCEDURE:

1) Connect the circuit as shown in the circuit diagram. Ensure that the autotransformer is in the minimum position and the load applied is zero.
2) Switch ON the supply. Note down the meter readings.
3) Increase the load gradually and each time note down the meter readings.
4) Calculate the active power from the two wattmeter readings.
5) Gradually decrease the load to zero and switch OFF the supply.

OBSERVATIONS & TABULAR COLUMN:

Phase Voltage ,V =

S No.	A_1 (A)	A_2 (A)	W_1 (W)	W_2 (W)	W (W)

RESULT :

CONCLUSION:

6.13. SIMULATION OF DC CIRCUITS

AIM :

To simulate a simple DC circuits using PSpice

APPARATUS : PC (in working conduct) with PSpice software.

Procedure :

1. Open PSpice A/D windows
2. Create a new circuit file
3. Enter the program representing the nodal interconnections of various components
4. Run the program
5. Observe the response through all the elements in the output file
6. Observe the voltage, current graph of any in probe window.

Result :

Conclusion :

6.14. DC TRANSIENT RESPONSE

AIM :

To simulate a simple DC circuits using PSpice

APPARATUS : PC (in working conduct) with PSpice software.

Procedure :

1. Open PSpice A/D windows
2. Create a new circuit file
3. Enter the program representing the nodal interconnections of various components
4. Run the program
5. Observe the response through all the elements in the output file
6. Observe the voltage, current graph of any in probe window.

Result :

Conclusion :

6.15. MESH ANALYSIS

AIM :

To simulate a simple DC circuits using PSpice

APPARATUS : PC (in working conduct) with PSpice software.

Procedure :

1. Open PSpice A/D windows
2. Create a new circuit file
3. Enter the program representing the nodal intercommoning variations comport
4. Run the program
5. Observe the Nodal voltages, current theory the elements in the output file
6. Observe the voltage, current graph in probe window.

Result :

Conclusion :

6.16. NODAL ANALYSIS

AIM :

To simulate a simple DC circuits using PSpice

APPARATUS : PC (in working conduct) with PSpice software.

Procedure :

1. Open PSpice A/D windows
2. Create a new circuit file
3. Enter the program representing the nodal intercommoning variations comport
4. Run the program
5. Observe the Nodal voltages, current theory the elements in the output file
6. Observe the voltage, current graph in probe window.

Result :

Conclusion :

7. CONTENT BEYOND SYLLABUS

1) Verification of kvl and kcl
2) Ac transients
3) Simulation of dc and ac transient analysis
4) Frequency response of single tuned coupled circuit
5) Mesh and nodal analysis
6) Time response of rl & rc circuits
7) Frequency response of Single tuned coupled circuits.

8. SAMPLE VIVA VOCE QUESTIONS

Exp:1

1) Where we can apply superposition theorem?
2) What is the importance of reciprocity theorem?
3) what is bilateral property of the element?
4) What is the node in the circuit? Define branch in the circuit?
5) State the superposition theorem and reciprocity theorem.

Exp:2

1. State the maximum power transfer theorem.
2 What are the applications of maximum power transfer theorem?
3 What is the difference in the application of maximum power transfer theorem to AC and DC?
4 Is it possible to find maximum power in any circuit without drawing its equivalent thevenin's circuit?

Exp:3

1. Define thevenin's theorem.

2. What are the conditions to apply the thevenin's theorem?

3. What is the importance of Thevenin's theorem?

Exp:4

1. Verify the concept of Ohm's Law for at least two measurements for each value of the R. (To be answered in the draft report and then retyped in the written report)

2. Verify the results obtained in part B theoretically. (To be answered in the draft report and then retyped in the written report).

3. From part (A), plot the voltage, VS, versus the current, I, for each resistance using Excel. Show the slope of each curve (on the curve itself using Excel) and state what they represent.

Exp:5

1. Does the resistor in step 4 operate in the linear region or non-linear region? Explain by considering the power rating of the resistor.
2. An electric heater takes 1.48 kW from a voltage source of 220 V. Find the resistance of the heater?
3. If the current in a resistor doubles, what happens to the dissipated power? (Assume the resistor operates in the linear region).
4. A 4 Ω resistor is needed to be used in circuit where the voltage across the resistor is 3V .If two 4 Ω resistors with 2 W and 3 W power rating are available, which will you use and why?

Exp:6

1. Comment on the sharpness of the maximum of the power curves. Is it necessary to match with great care to achieve maximum power transfer?

2. What is the phase difference between the current and the voltage source when maximum power transfer is achieved?

3. If the frequency of the source is doubled, what change should be done to maintain maximum power transfer to the load? How does this change affect the value of the maximum power? Explain.

4. The term available power is used to describe a source in many communication applications. It is the maximum possible power which the source can deliver to an external load. What is the available power of a source of voltage V and internal resistance R?

Exp:7

1 The frequency of the voltage in your house is 60 Hz. How much time is required for the waveform to complete three cycles?

2- What is the difference between AC and DC coupling of the oscilloscope? Explain how to use them to measure the average value of any periodic signal.

3- Some meters are calibrated to read r.m.s. Value of sinusoidal waveforms from the basic unit that responds to the peak value of the waveform. In terms of the peak value, Vp , the meter will read 2Vp which is the correct r.m.s value for a sinusoidal signal. Can this meter be used to read the correct rms value for other waveforms like square, triangular, etc? Comment.

Exp:8

1. Why the lamp is damaged when the voltage across it goes to 7V? Explain by comparing power dissipation with rated value

Exp:9

1 Compare the values of resistance obtained with ohmmeter, Ohm's law (V/I) and slope of the V-I plot. Comment on your results.

2. How could you tell if the resistances are linear or not?

Exp:10

1 For a resistance and capacitance in series with a voltage source, show that it is possible to draw a phasor diagram for the current and all voltages from magnitude measurement of these quantities only. Illustrate your answer graphically

2. The equivalent impedance of a capacitor in series with an inductor is equivalent to a short circuit (i.e. equal to zero) at a certain frequency. Derive an expression for this frequency.

3. The equivalent impedance of a capacitor in parallel with an inductor is equivalent to an open circuit (i.e. equal to infinity) at a certain frequency. Derive an expression for this frequency

Exp:11

1 Superposition theorem applies for only certain types of circuit. State what is the typ

2 Superposition applies to only some variables or quantities like current and voltage. It does not apply to, for example, power. State why not

Exp:12

1. Thevernin's and Norton's Theorem are very useful. List at least two reasons for it

2. Is the Maximum Power Theorem verified experimentally? Explain**.**

Exp:13

1. Are R4 and R6 in parallel or in series?

2. Are R3 and R4 in parallel or in series?

3. Are Vs and R6 in series or in parallel?

4. Is VDR applicable for applicable for R3 and R4?

5. Is CDR applicable for R4 and R6?

6. Is the parallel combination of R4 and R6 in series or in parallel with R2?

Exp:14

1) Find τ and fc for the circuit in figure 1 if R = 200 Ω and C = 0.5 μF and state the region of frequency, in which the circuit will behave as an integrator**.**

Exp:15

1. Which method is better and why?

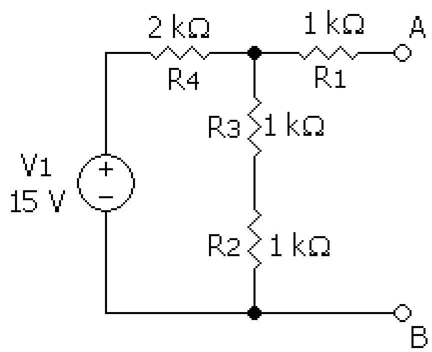
2. Does a computer simulation represent actual circuit behavior? Discuses the point by referring to the results you obtained in this experimen

Exp:16

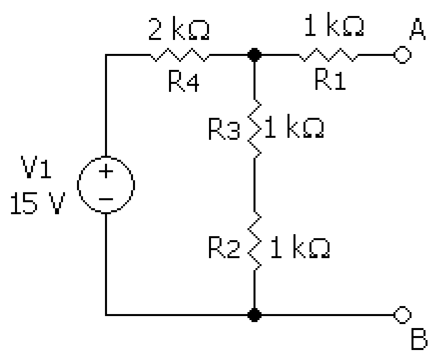
1) Convert the measured values of currents iR, iL and iC obtained in steps 3-5 into phasor form (example, I=5 30 Amp Ð). Compare these values with the ones obtained throughsimulation

9 SAMPLE QUESTION PAPER OF THE LAB EXTERNAL

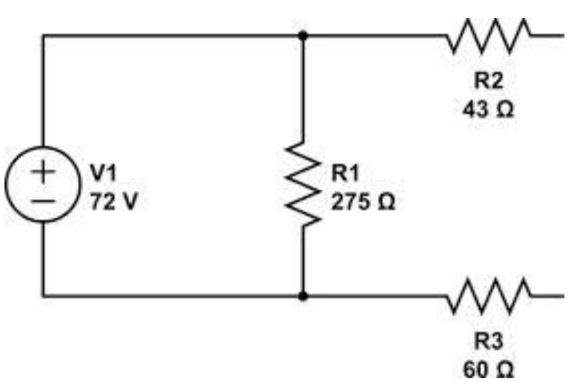
1) Verify the Thevenin's theorem



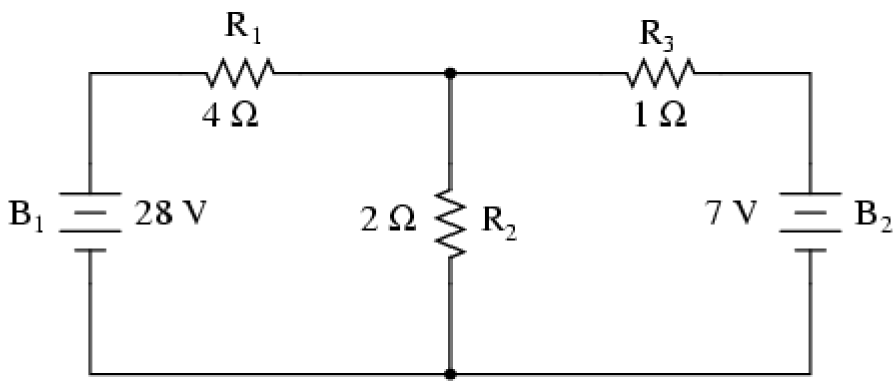
2) Verify the Norton's theorem



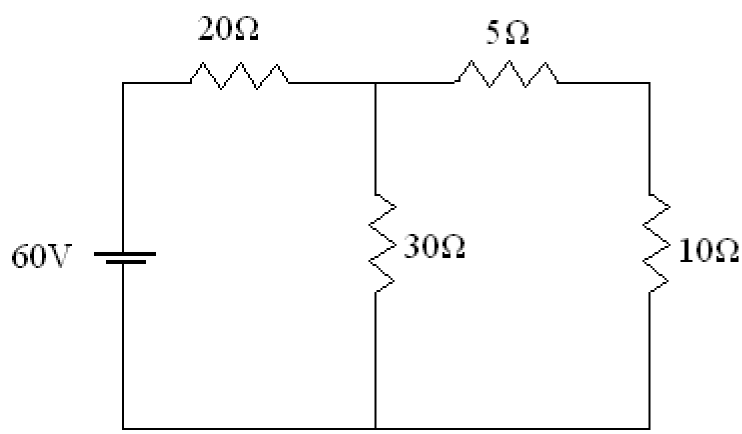
3) Verify the Maximum Power Transfer Theorems



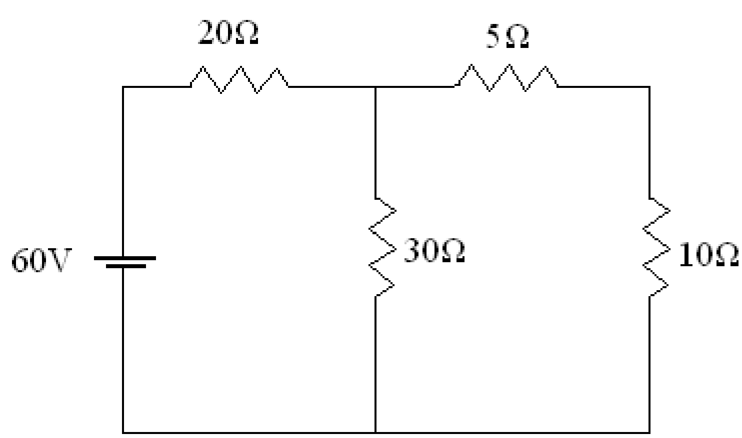
4) Verify the Super position Theorem and RMS value of Complex wave



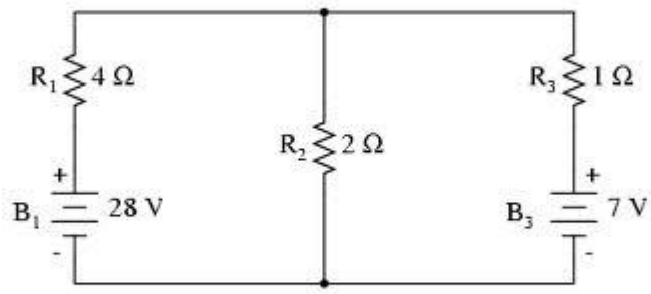
5) Verify the Compensation theorem



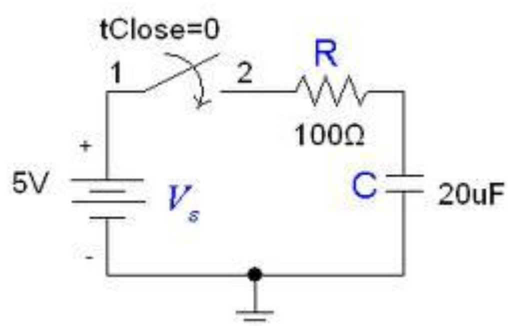
6) Verify the Reciprocity,

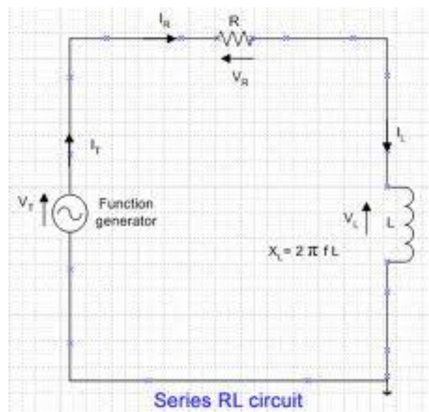


7) Verify the Millman's theorem



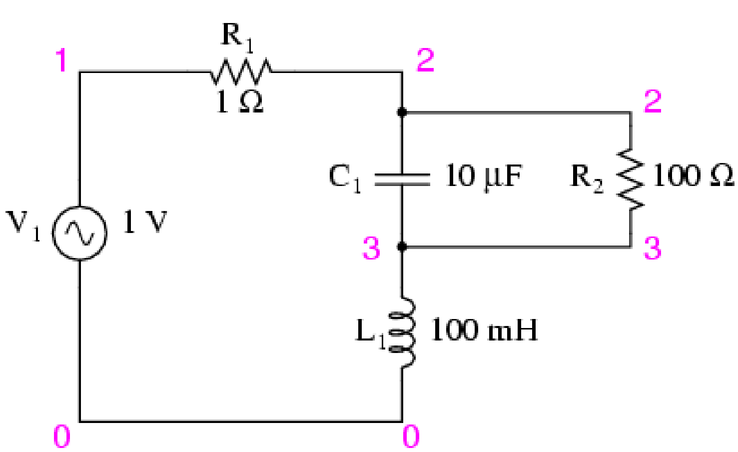
8) Draw the Locus diagrams of RL and RC Series circuits





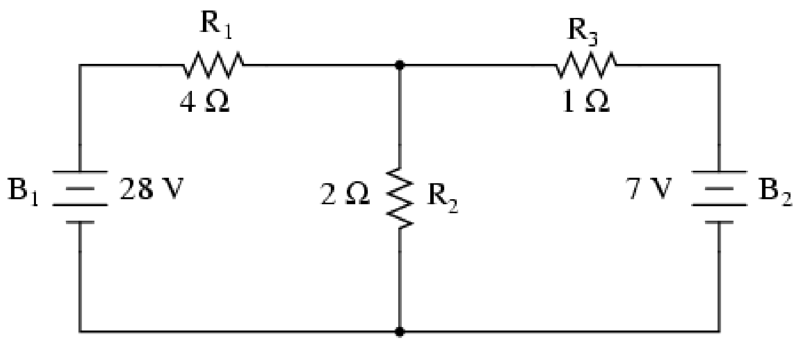
9) Draw the response of Series and parallel resonance

Series LC with resistance in parallel with C

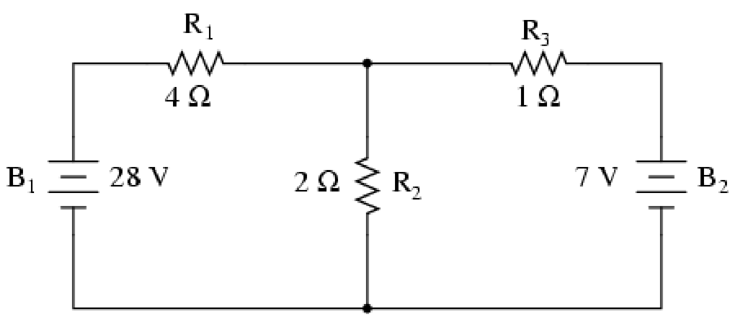


10) Determination of self, mutual inductance and coefficient of coupling

11) Calculate the Z & Y parameters



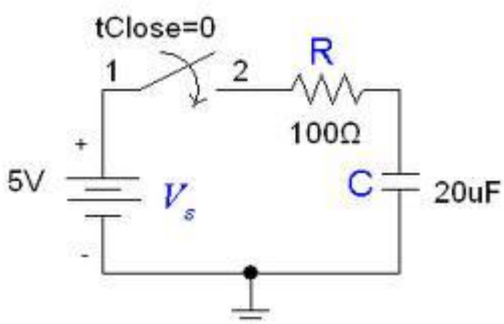
12) Calculate the Transmission & hybrid parameters



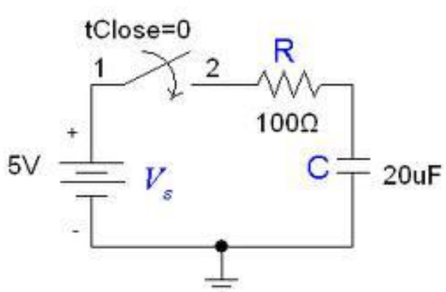
13) Measure the active power for star and delta connected balanced loads

14) Measure the active power for star and delta connected balanced loads

15) Simulate the DC Circuits



16) Simulate the DC Transient Response



10. APPLICATIONS OF THE LABORATORY

1. Getting electrical knowledge in home appliances as well as basic theorems in Electrical engineering.
2. They will get knowledge about different types of supply systems and different types of motors which fall in AC and DC.
3. Simulation of some dc and ac circuits .

11. PRECAUTIONS TO BE TAKEN WHILE CONDUCTING THE LAB

SAFETY – 1

- Power must be switched-OFF while making any connections.
- Do not come in contact with live supply.
- Power should always be in switch-OFF condition, EXCEPT while you are taking readings.
- The Circuit diagram should be approved by the faculty before making connections.
- Circuit connections should be checked & approved by the faculty before switching on the power.
- Keep your Experimental Set-up neat and tidy.
- Check the polarities of meters and supplies while making connections.
- Always connect the voltmeter after making all other connections.
- Check the Fuse and it's ratify.
- Use right color and gauge of the fuse.
- All terminations should be firm and no exposed wire.
- Do not use joints for connection wire.

SAFETY – II

1. The voltage employed in electrical lab are sufficiently high to endanger human life.
2. Compulsorily wear shoes.
3. Don't use metal jewelers on hands.
4. Do not wear loose dress

Don't switch on main power unless the faculty gives the permission

12. CODE OF CONDUCT:

CODE OF CONDUCT FOR THE LABORATORIES

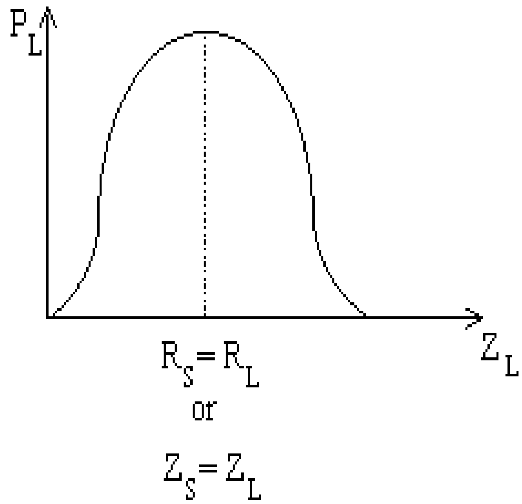
- All students must observe the Dress Code while in the laboratory.
- Sandals or open-toed shoes are NOT allowed.
- Foods, drinks and smoking are NOT allowed.
- All bags must be left at the indicated place.
- The lab timetable must be strictly followed.
- Be PUNCTUAL for your laboratory session.
- Experiment must be completed within the given time.
- Noise must be kept to a minimum.
- Workspace must be kept clean and tidy at all time.
- Handle all apparatus with care.
- All students are liable for any damage to equipment due to their own negligence.
- All equipment, apparatus, tools and components must be RETURNED to their original place after use.
- Students are strictly PROHIBITED from taking out any items from the laboratory.
- Students are NOT allowed to work alone in the laboratory without the Lab Supervisor
- Report immediately to the Lab Supervisor if any injury occurred.
- Report immediately to the Lab Supervisor any damages to equipment.

Before leaving the lab

- Place the stools under the lab bench.
- Turn off the power to all instruments.
- Turn off the main power switch to the lab bench.
- Please check the laboratory notice board regularly for updates

13. GRAPHS if any.

1) Maximum power transfer theorem:



2) series an parallel resonance: