NED University of Engineering & Technology

Department of Electrical Engineering

LAB MANUAL

BASIC ELECTRICAL ENGINEERING

(EE-125) For F.E.(EE)

Instructor name:________________________________

Student name:_________________________________

Roll no: Batch:___________________

Semester: Year:________________

To be filled by lab technician

Attendance: Present out of _____ Lab sessions

Attendance Percentage ________

To be filled by Lab Instructor

Lab Score Sheet

Roll No.	Rubric based Lab I	Rubric based Lab II	Rubric based Lab III	Rubric based Lab IV	Rubric based Lab V	Rubric based Lab VI	OEL/PBL Rubric Score A	Final LAB Rubric Score B	Attendance Percentage C	Final weighted Score for MIS System [10(A)+10(B)+5(C)]/25 Round to next higher multiple of 5

EE-125 BEE Rubric Based Labs 2, 5, 6, 7, 8, 10

Note: All Rubric Scores must be in the next higher multiple of 5 for correct entry in MIS system.

LAB MANUAL

For the course

<u>BASIC ELECTRICAL ENGINEERING</u>

<u>(EE-125) For F.E.(EE)</u>

Content Revision Team:

Dr Beenish Sultana, Ms. Ayesha Khan

Last Revision Date: 30 May 2022

Approved By

The Board of Studies of Department of Electrical Engineering

EE-125 Basic Electrical Engineering

About this Lab:

In this lab, the characteristics of a series and parallel circuits, the fundamental electric circuit laws and theorems will be learned and verified experimentally. Students will use them extensively during the entire semester.

You will be communicated Problem Based Learning (PBL) Lab at the start of the session which will be evaluated at the respective weeks during the session. In these labs, students will be working in group of 3-5 students to develop, investigate and perform experiments and submit lab report accordingly.

Lab Assessment:

Labs will be evaluated according to the decided rubrics individually and then the final score will be calculated. The lab marking rubrics are attached on the separate page at the starting of rubric based lab.

At the end of this lab:

After the successful completion of lab tasks, student will be able to:

- Measure Resistance and Capacitance in an electric circuit.
- Verify the equivalent forms of Ohm’s Law.
- Have command on understanding the characteristics of a series and parallel DC circuit.
- Have command on understanding different circuit analysis techniques and laws.
- Have command on understanding the characteristics of an AC circuits.
- Develop ability to think logically and verify the results of developed experiments through Problem Based Learning labs.

EE-125 Basic Electrical Engineering

CLO assessment methods, KPIs

Course Code: -____EE-125_________ Course Title: - ___Basic Electrical Engineering

Department: - Electrical Semester: -

Domain/Taxonomy level	**Assessment Method**	**KPI**	**Timeline for evaluation**
Psychomotor Level 3	Lab demonstration which will be evaluated as per decided lab rubrics	Individual: >50% will be considered as Average Cohort level: >=60% will be considered as Good	At the end of every lab

CONTENTS

Psychomotor / Cognitive Level:
CLO/PLO: DEMONSTRATE the operation of electric circuits validating the fundamental laws and theorems.

** RUBRIC based assessment*

LAB SESSION 01

OBJECTIVE:

Introduction to the Measuring Methods of Resistance and Capacitance

EQUIPMENTS REQUIRED:

- Different Valued Resistors, Capacitors
- VOM (Volt-Ohm-Milliammeter)
- DMM (Digital Multimeter)

THEORY & PROCEDURE:

NOTE:

The purpose of this experiment is to acquaint you with the equipment, so do not rush. Learn how to read the meter scales accurately, and take your data carefully. You must become comfortable with the instruments if you expect to perform your future job function in a professional manner.

"Part 1: Resistance Measurement"

METHOD 1 : Resistance Measurement using VOM/ DMM:

1. Resistance is never measured by an ohm-meter in a live network, due to the possibility of damaging the meter with excessively high currents and obtaining readings that have no meaning.
2. Always start with the highest range of the instrument and switch down to the proper range successively.
3. Use the range in which the deflection falls in the upper half of the meter scale.
4. Try to ascertain the polarity of dc voltages before making the measurement.
5. Whenever measuring the resistance of a resistor in a circuit, note whether there

are any other resistive elements that could cause an error in the reading. It may be necessary to disconnect one side of the resistor before measuring.

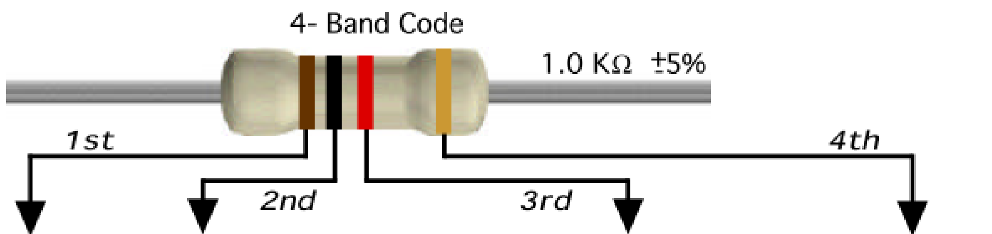
6. Check the zero and ohms adjustments each time the range is changed.
7. When making measurements, grip the test prods by the handles as close to the lead end as possible. Do not allow the fingers to touch the prod tips while measuring.
8. Keep the instruments away from the edge of the workbench, and away from heat and dangerous fumes.
9. There is no zero adjustment on a DMM, but make sure that R=0 ohm when the leads are touching or an adjustment internal to the meter may have to be made. Any resistance above the maximum for a chosen scale will result in an O.L. indication.
10. The ranges are usually marked as multiples of *R*. For example, ***R*x 1; *R*x 10; *R*x 100; *R*x 1 KΩ.**

    The value of the resistor can be found by multiplying the reading by the range setting. For example, a reading of 11 on the *R* x 1 kΩ range is 11 x 1 kΩ = 11 k Ω or 11,000 Ω.

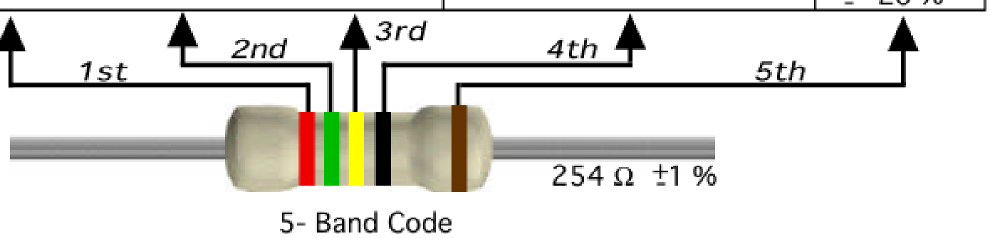
METHOD 2: Resistance Measuring Using Color Coding:

1- The resistance of many resistors can be determined by reading a series of colored bands imprinted on the resistor body. In this scheme called "Resistor Color Code" each colour represents a different decimal digit, as shown below.

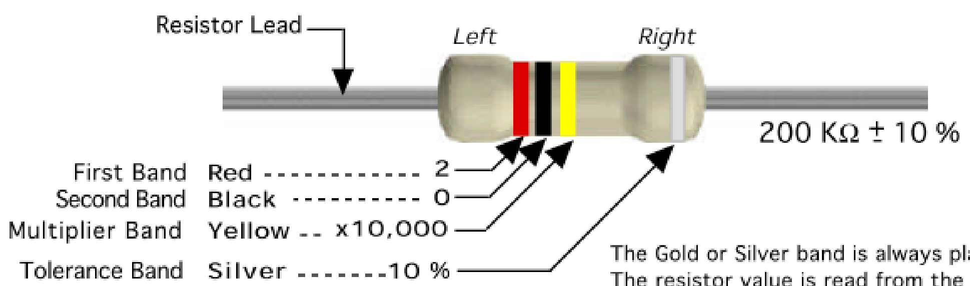
2- The first three bands of the color code are used to specify nominal value of the resistance, and the fourth, or tolerance band, gives the percent deviation from the nominal value that the actual resistor may have. Due to manufacturing variations, the actual resistance may be anywhere in a range equal to the nominal value plus or minus a certain percentage of that value.



Color	1st Band	2nd Band	3rd Band	Decimal Multiplier	Tolerance
Black	0	0	0	1 1	
Brown	1	1	1	10 10	± 1 %
Red	2	2	2	100 100	± 2 %
Orange	3	3	3	1K 1,000	
Yellow	4	4	4	10K 10,000	
Green	5	5	5	100K 100,000	
Blue	6	6	6	1M 1,000,000	
Violet	7	7	7	10M 10,000,000	
Gray	8	8	8	100,000,000	
White	9	9	9	1,000,000,000	
Gold				0.1	± 5 %
Silver				0.01	± 10 %
None					± 20 %



Calculation



The Gold or Silver band is always placed to the right.
The resistor value is read from the left to right.

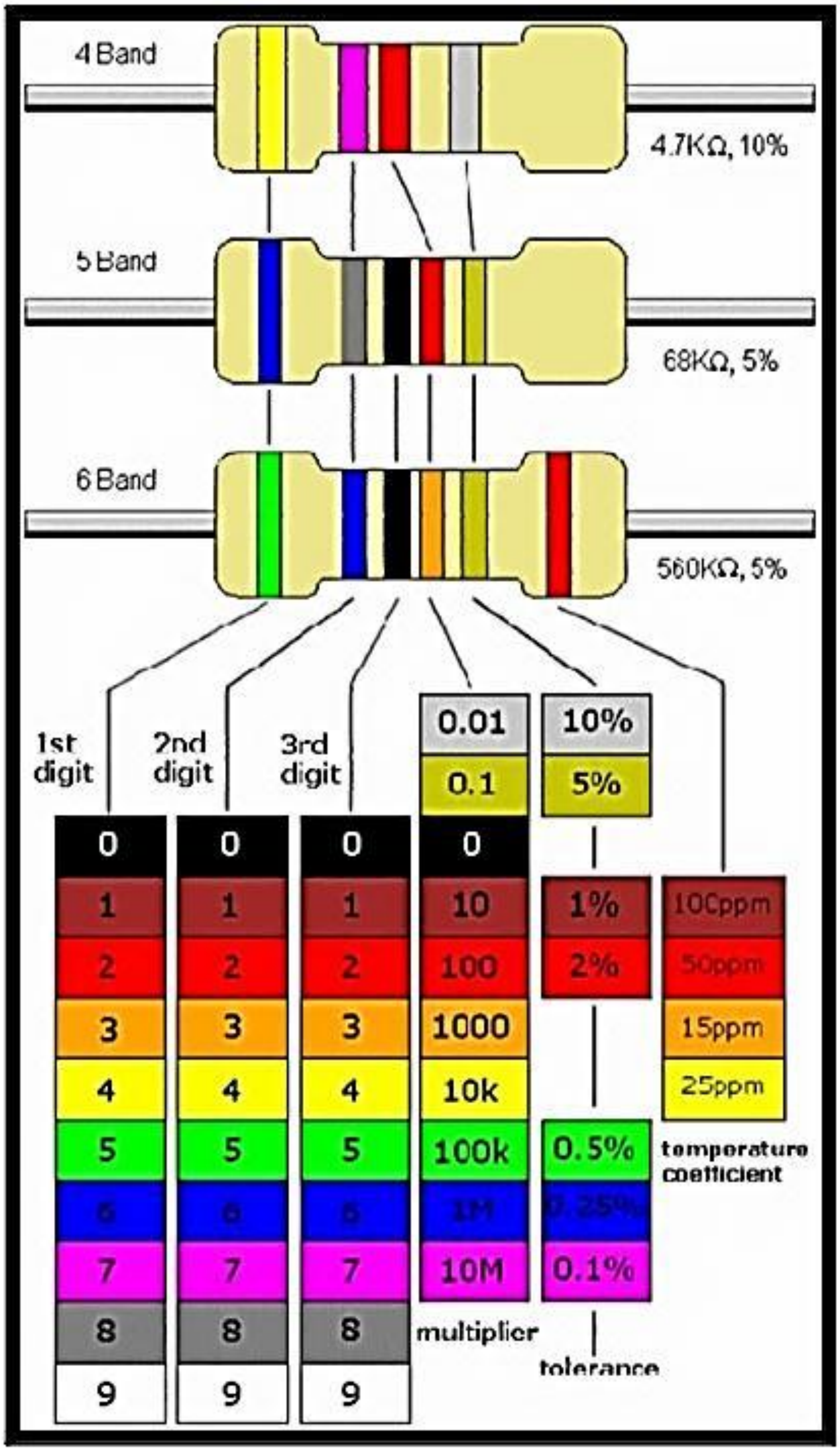
If there is no tolerance band, then find the side that has a band closest to a lead and make that the first band.

Equation

20 x 10,000 = 200,000

1,000 = 1K

Resistor = 200 KΩ
with a ± 10 % Tolerance


4 Band
4.7KΩ, 10%
5 Band
68KΩ, 5%
6 Band
560KΩ, 5%
1st digit
2nd digit
3rd digit
0.01
0.1
10%
5%
0
1
2
3
4
5
7
8
9
0
10
100
1000
10k
100k
10M
multiplier
1%
2%
0.5%
0.1%
tolerance
100ppm
50ppm
15ppm
25ppm
temperature coefficient

3- The first two color bands specify the first two digits of the nominal value, and the third band represents the power of 10 by which the first two digits are multiplied.

4- The example below demonstrates these computations.

Solution:-

Yellow, Violet, Orange, Silver

$47 \times 10^3 + 10\%$

Thus,

Nominal resistance = $\underline{47} \times 10^3\ \Omega = 47k\ \Omega$

The possible range of actual values is:

$47\ k\ \Omega \pm (0.1)\ 47\ k\ \Omega = 47k\Omega \pm 4.7k\ \Omega$

or

From **$42.3\ k\Omega$** to **$51.7\ k\ \Omega$**

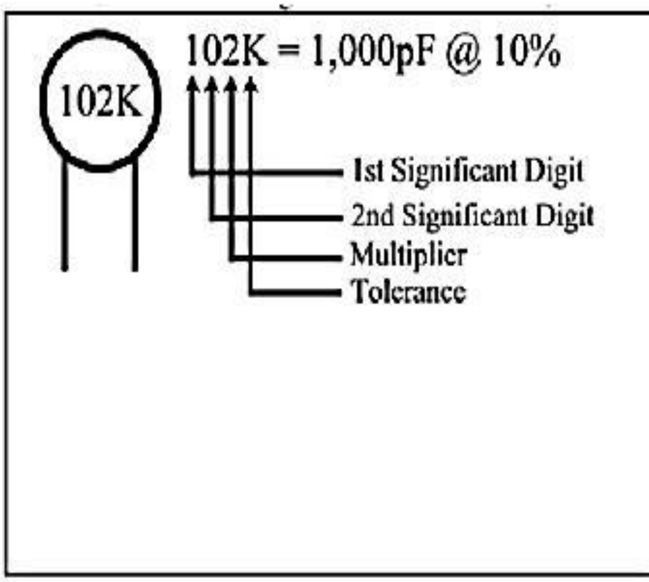
"Part 2: Capacitance measurement:"

CAPACITOR:

There are two types of capacitors, i.e. *electrolyte* and *non - electrolyte* Capacitors. The non-electrolytic capacitors use Paper, Mica, Ceramic, Mylar, Glass, Porcelain, Polycarbonate, and Wax as Insulator. Figure 2 shows symbols of the two types of the capacitor. The difference in the use of the two types of capacitors is that non-electrolytic capacitors can be charged in any direction, whereas the Electrolytic ones can only be charged in one direction. Electrolytic Capacitors are Polar; i.e., one of its two plates is Positive and other is Negative, whereas in non-electrolytic capacitors, both the plates are same, having no polarity.

NUMERICAL CODES

are used with non - electrolytic capacitors to specify their capacitance. Usually, these codes are 3 digit long, specifying the capacitance in Pico Farads; the first two digits are Tens and Units, whereas the third digit is power of 10. For example, a code 102 means:



Common Temperature Coefficient Codes (Ceramic)	
Code	**Tolerance**
C	±0.25pF
J	±5%
K	±10%
M	±20%
D	±0.5pF
Z	+80% / -20%

For example: **102** means 1000pF = 1nF *(not 102pF!)* For example: **472J** means 4700pF = 4.7nF (J means 5% tolerance). For example: **333K** means 33000pF = 33nF (K means 10% tolerance).Take samples and tabulate:

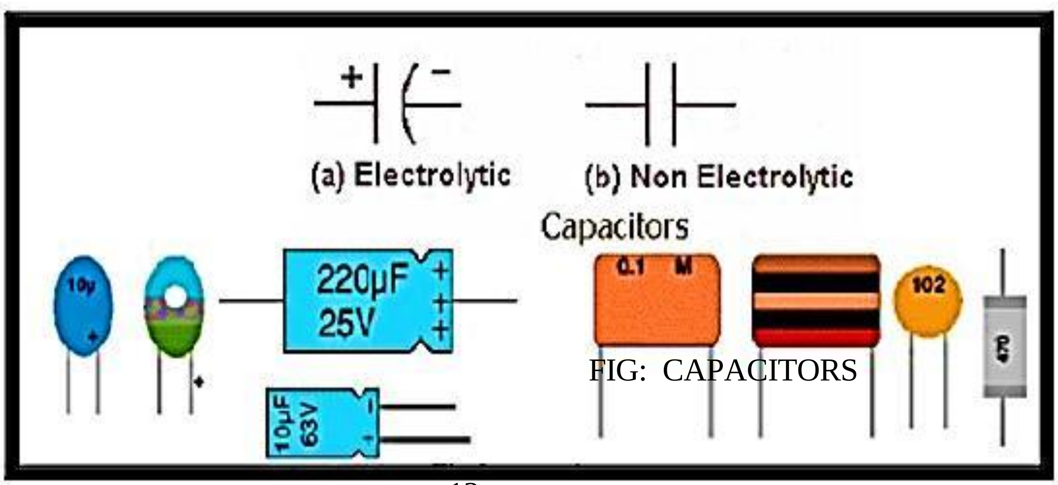


FIG: CAPACITORS

OBSERVATIONS:-

TABLE A:

Resistor	Color Code	Calculated Value	Measured Value
Sample 1			
Sample 2			
Sample 3			
Sample 4			

Answer the following:

Q-1) Is there any difference in measured and calculated value of resistance? If yes then what could be the reason?

Q-2) Practically, how can you differentiate between negative and positive terminals of an electrolytic capacitor?

LAB SESSION 02

OBJECTIVE:

To verify the following two equivalent forms of Ohm's Law:

(a) Express I as a function of V and R.
(b) Express V as a function of I and R.

EQUIPMENTS REQUIRED:

- Variable DC power supply(maximum 30V)
- DMM/Analog multimeter
- 1kΩ resistor(Br,Black,Red)
- Variable resistor (maximum 10 kΩ)

THEORY:

Ohm's law describes mathematically describes how voltage 'V', current 'I', and resistance 'R' in a circuit are related. According to this law:

"The current in a circuit is directly proportional to the applied voltage and inversely proportional to the circuit resistance".

Formula For Voltage:

For a constant value of R ,V is directly proportional to I

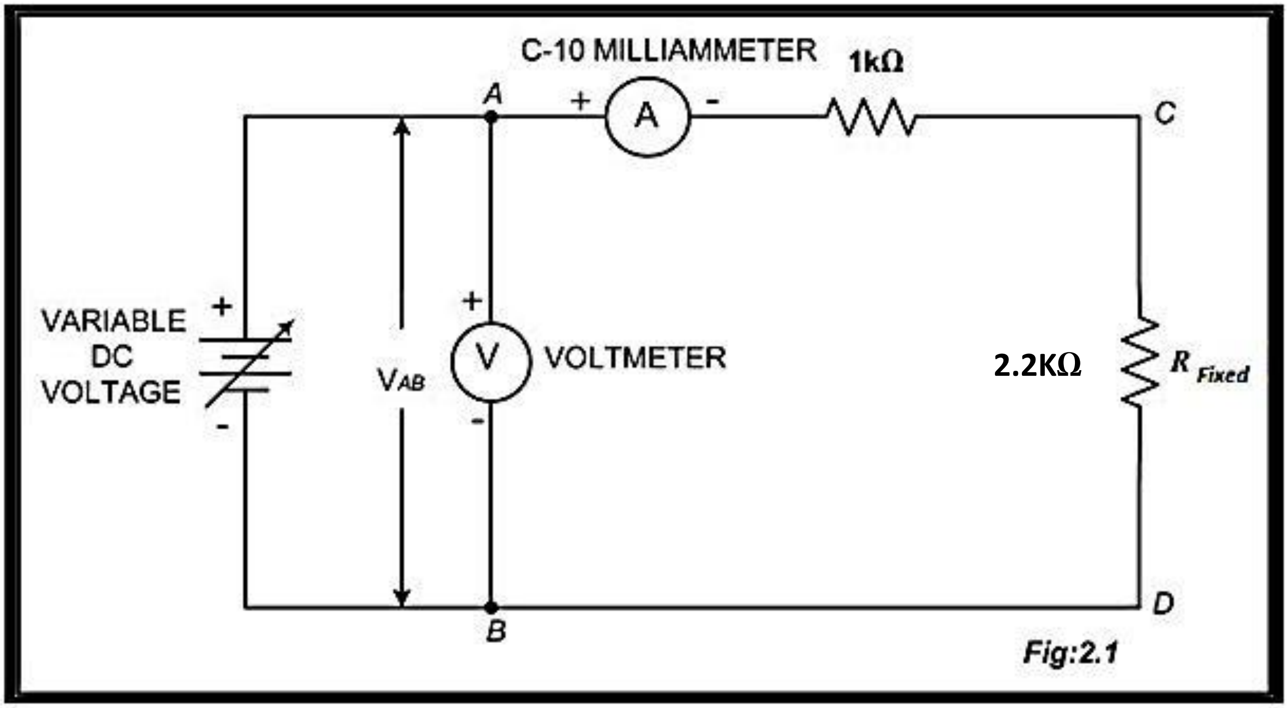
i.e. $V = IR$

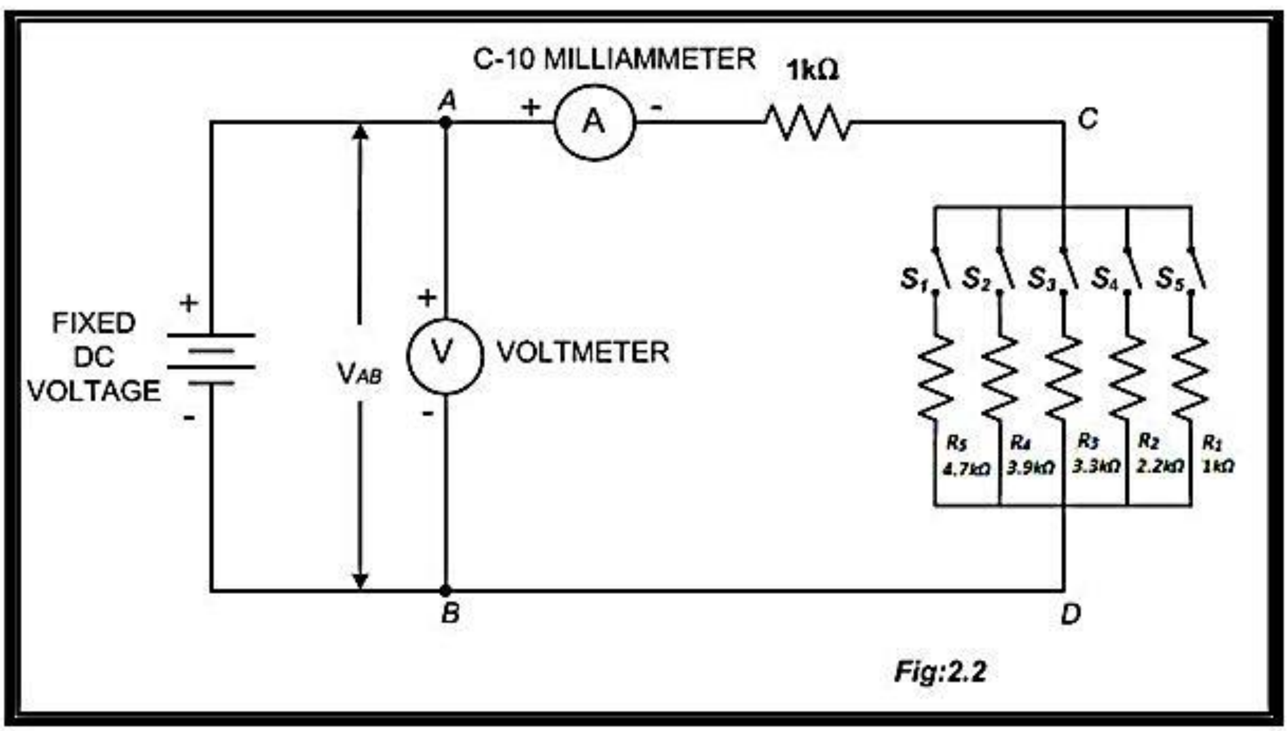
Formula For current:

For a constant value of V ,I is inversely proportional to R

i.e. $I = V/R$

Ohm's Law makes intuitive sense if we apply it to the water-and-pipe analogy. If we have a water pump that exerts pressure (voltage) to push water around a "circuit" (current) through a restriction (resistance), we can model how the three variables interrelate. If the resistance to water flow stays the same and the pump pressure increases, the flow rate must also increase. If the pressure stays the same and the resistance increases (making it more difficult for the water to flow), then the flow rate must decrease. If the flow rate were to stay the same while the resistance to flow decreased, the required pressure from the pump would necessarily decrease.


C-10 MILLIAMMETER
1kΩ
A
+
A
-
C
VARIABLE
DC
VOLTAGE
+
-
VAB
+
V
-
VOLTMETER
2.2KΩ
R Fixed
B
D
Fig:2.1


C-10 MILLIAMMETER
1kΩ
A
+
A
-
C
FIXED
DC
VOLTAGE
+
-
VAB
+
V
-
VOLTMETER
S1
S2
S3
S4
S5
R5 4.7kΩ
R4 3.9kΩ
R3 3.3kΩ
R2 2.2kΩ
R1 1kΩ
B
D
Fig:2.2

PROCEDURE:

a) Current versus voltage:

1) Construct the circuit of fig 2.1.
2) Do not switch on the power supply. Disconnect the variable resistor R from the circuit and set it to 2200Ω by using ohmmeter. Now reconnect it.
3) Turn on the power supply and adjust it to 5V. Measure the current *I* in amperes and record it in the table.
4) Measure and record in turn, the current *I* (in amperes) at each of the voltage settings shown in the table, for *R* = 2,200 Ω.
5) Calculate the value of current I by using $I=V/R_T$. Use measured value of resistance.
6) Plot a graph of I versus V. (use measured values)

b) Current versus resistance:

1) Construct the circuit of fig 2.2.
2) Do not switch on the power supply. Disconnect the variable resistor R from the circuit and set it to 1000Ω by using ohmmeter. Now reconnect it.
3) Turn on the power supply and adjust it to 20V. Measure the current *I* in amperes and record it in the table.
4) Measure and record in turn, the current *I* (in amperes) at each of the resistance settings shown in the table, for *V*= 20V.Be sure to set the resistor values in the same way as described in step (i).
5) Calculate the value of resistance R_T by using R=V/I. Use measured value of Voltage and current.
6) Plot a graph of I versus R. (use measured values)

OBSERVATIONS:

a) Current versus voltage:

S.NO:	Voltage (V)	R (KΩ)	Measured I (mA)	R_T (KΩ)	Calculated I (mA)
1	5	2.2		3.2	
2	10	2.2		3.2	
3	15	2.2		3.2	
4	20	2.2		3.2	
5	25	2.2		3.2	
6	30	2.2		3.2	

(b) Current versus resistance:

S.NO:	Voltage (V)	R(KΩ)	R_T (KΩ)	Measured I (mA)	Calculated R_T (KΩ)
1	20	1			
2	20	2.2			
3	20	3.3			
4	20	3.9			
5	20	4.7			

CALCULATIONS:

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: ____

Laboratory Session: No.______________________ Date: ______________

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
Response Ability to imitate the lab work on his/her own. 15%	Not able to imitate the lab work. 0	Able to slightly imitate the lab work. 15	Able to somewhat imitate the lab work. 30	Able to moderately imitate the lab work. 45	Able to fully imitate the lab work. 60
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 03

OBJECTIVE:

To investigate the characteristics of a series DC circuit.

REQUIRED:

- DMM
- DC Supply (20V)
- Resistors of 220Ω (R, R, Br) x 2, 330Ω (Or, Or, Br) & 470Ω (Y, Vio, Br).

THEORY:

In a series circuit, (Fig 3.1), the current is the same through all of the circuit elements. The

total Resistance $R_T = R_1 + R_2 + R_3 + R_4.$

By Ohm's Law, the Current "I" is

$$I = \frac{E}{R_T}$$

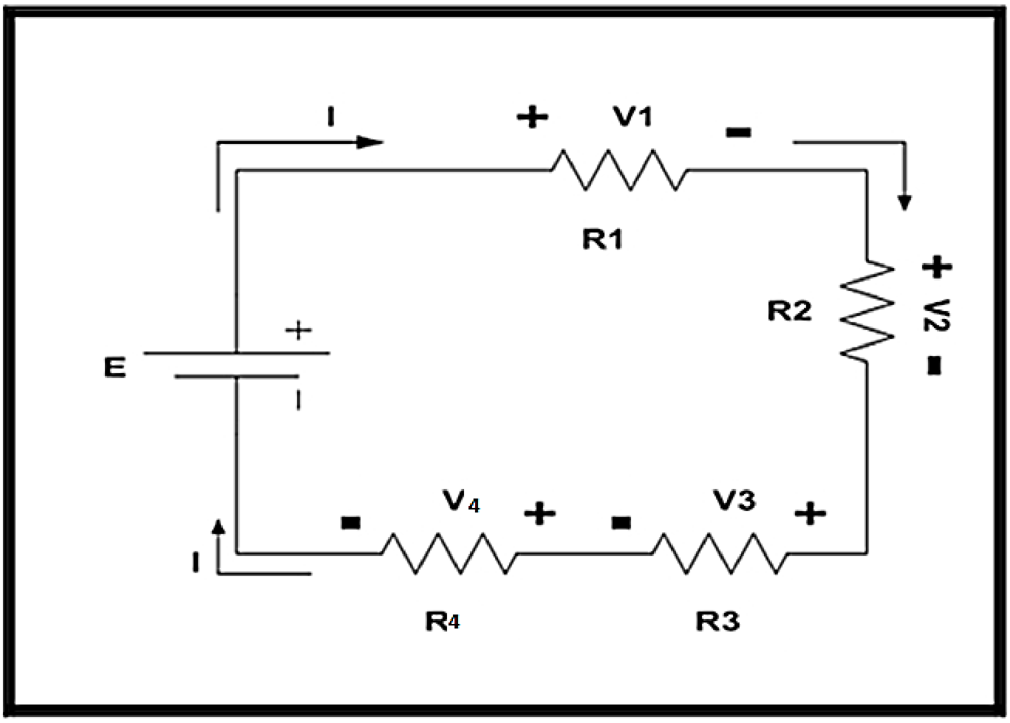
Applying Kirchoff's Voltage Law around closed loop of Fig **3.**1, We find.

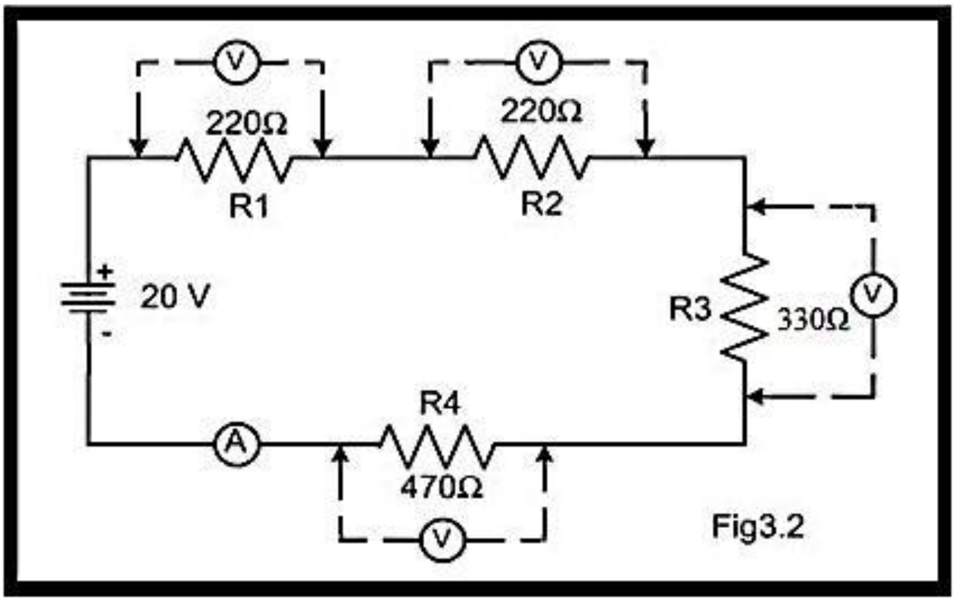
$E = V_1 + V_2 + V_3 + V_4$
Where, $V_1= IR_1$, $V_2= IR_2$, $V_3=IR_3$, $V_4=IR_4$

Note in Fig 2.1, that I is the same throughout the Circuit.

The voltage divider rule states that the voltage across an element or across a series combination of elements in a series circuit is equal to the resistance of the element divided by total resistance of the series circuit and multiplied by the total imp4ressed voltage. For the elements of Fig 3.1

$$V_1 = \frac{R_1 E}{R_T} V_2 = \frac{R_2 E}{R_T} V_3 = \frac{R_3 E}{R_T} V_4 = \frac{R_4 E}{R_T}$$


I
+
V1
-
R1
R2
+
V2
-
E
+
-
V4
+
-
V3
+
I
R4
R3


V
220Ω
R1
V
220Ω
R2
+
20 V
-
R3
330Ω
V
R4
A
470Ω
V
Fig3.2

PROCEDURE:

1- Construct the circuit shown in Fig 3.2.
2- Set the Dc supply to 20V by using DMM. Pick the resistances having values 220Ω, 330Ω & 470Ω. Also verify their resistance by using DMM.
3- Measure voltage across each resistor with DMM and record it in the Table (**b**).
4- Measure Current I delivered by source.
5- Shut down and disconnect the power supply. Then measure input resistance R_T across points A-E using DMM. Record that value.

6- Now Calculate, respective currents (using $I_1=V_1/R_1$) and $R_T = E/I$.

7- Calculate V_1 & V_2 using voltage divider rule and measured resistance value.
8- Create an open circuit by removing R_3 & measure all voltages and current I.

Note: Use measured value of resistance for all calculations.

OBSERVATIONS:

a) Resistors.

S.No	Nominal Value Ω	Measured Value Ω	R_T (Measured) Ω	R_T (Calculated) $(\frac{E}{I})$ Ω
1.	R1=220			
2.	R2=220			
3.	R3=220			
4.	R4=220			

b) Voltages.

S No.	Measured Value (V)	Calculated Value (V) (VDR)	Measured Values When R_3 is Open circuited (V)
1.			
2.			
3.			
4.			

c) Current.

S.No	Measured Value of I(mA)	Calculated Value (mA) (Ohm's Law)	Measured 'I' When R_3 is Open Circuited (mA)
1.	I_1=		
2.	I_2=		
3.	I_3=		
4.	I_4=		

CALCULATIONS:

Answer the following:

Q-1) What can you deduce about the characteristics of a series circuit from observation table ‘b’ & ‘c’?

Q-2) Viewing observation table ‘b’, comment on whether equal resistors in series have equal voltage drops across them?

Q-3) Referring observation table (a). Would you recommend using measured rather than color coded nominal values in the future? Why?

Q-4) Referring to observation tables b & c compare open circuit condition & normal circuit with reference to current & voltage values.

LAB SESSION 04

OBJECTIVE:

To investigate the characteristics of parallel dc circuits.

REQUIRED:

- 15V DC Power Supply.
- DMM.
- 470Ω (Y, Violet, Br).
- 1KΩ (Br, Black, Red).
- 1.8KΩ (R, Grey, Red).

THEORY:

In a parallel circuit (Fig4.1) the voltage across parallel elements is the same.

The total or equivalent resistance (R_T) is given by.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{-------------------} + \frac{1}{R_N}$$

If there are only two resistors in parallel, it is more convenient to use.

$$\mathbf{R_T} = \frac{R_1 \, R_2}{R1+R2}$$

In any case, the total resistance will ***always be less*** than the resistance of the smallest resistor of the parallel network.
For the network of Fig 4.1. The currents are related by the following expression.

$$\mathbf{I_T = I_1 + I_2 + I_3 + \text{-----------} + I_N.}$$

Applying current divider rule (CDR) & the network of Fig 4.2.

$$\mathbf{I_1} = \frac{R_2 I_T}{R_1 + R_2} \quad \text{and}$$

$$\mathbf{I_2} = \frac{R_1 I_T}{R_1 + R_2}$$

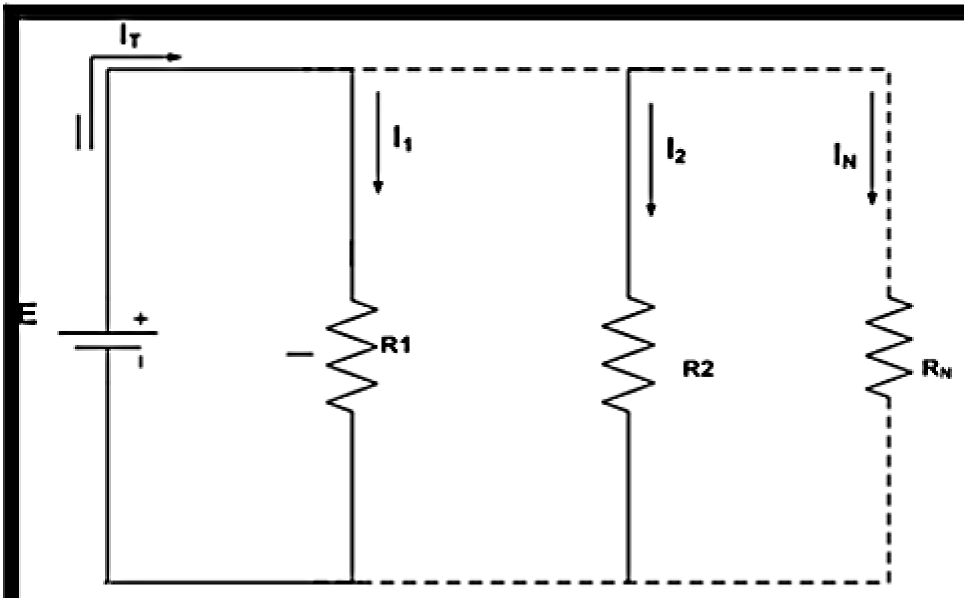


Fig:4.1

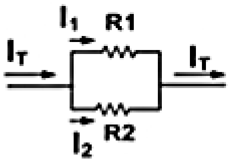


Fig:4.2

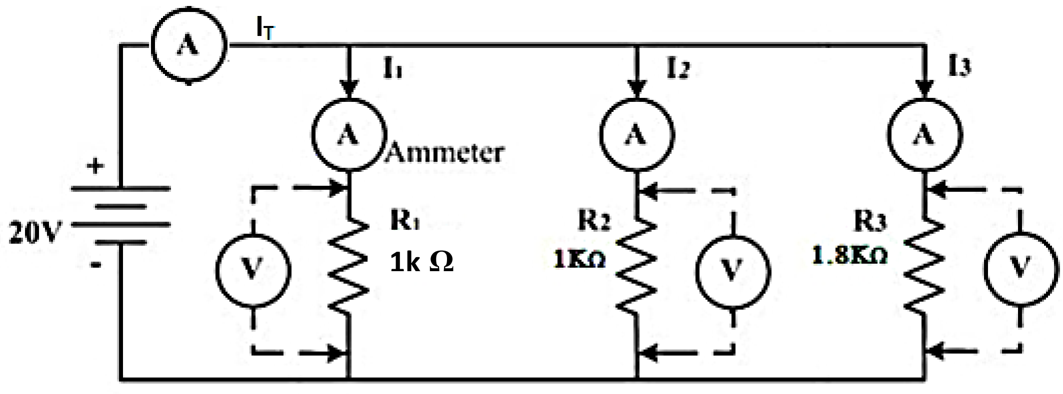


Fig: 4.3

For equal parallel resistors, the current divides equally and the total resistance is the value of one divided by the **'N'** number of equal parallel resistors, i.e:

$$\mathbf{R_T} = \frac{R}{N}$$

For a parallel combination of **N** resistors, the current $\mathbf{I_K}$ through $\mathbf{R_K}$ is.

$$\mathbf{I_K} = \mathbf{I_T} \times \frac{\frac{1}{R_K}}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots\ldots\ldots + \frac{1}{R_N}}$$

PROCEDURE:

1- Construct the circuit shown in Fig 4.3.
2- Set the DC supply to 15V by using DMM.
Pick the resistances values 1Ω, 1K Ω & 1.8K Ω. Also verify their resistance by using DMM.
3- Measure voltage across each resistor with DMM and record it in the Table b. 4- Measure the currents I_T, I_1, I_2, I_3 .
5- Shut down & disconnect the power supply. Then measure input resistance 'R_T' across points A-B using DMM. Record that value.
6- Now calculate respective voltages (using V=IR) and R_T (using equivalent resistance formula).
7- Calculate I_1, I_2 , I_3 using CDR.
8- Create an open circuit by removing R_2 and measure all voltages and currents.

Note: Use measured value of resistance for all calculations.

OBSERVATION:

a) Resistors:

S No.	Nominal Values	Measured Value	R_T (Measured) (kΩ)	R_T (Calculated) kΩ
	R_2 =1KΩ			
	R_3 =1.8K Ω			

(b) Voltages:

S No.		Measured Value (V)	Measured Value (V) when R_2 Open	Calculated Value (V) (Ohm's Law)
1.	V_1			
2.	V_2			
3.	V_3			

c) Current:

S.No	Measured Value (mA)	Measured Value (mA) When R2 is Open Circuited	Measured Value (mA)
1.	I_1=	I_1=	I_1=
2.	I_2=	I_2=	I_2=
3.	I_3=	I_3=	I_3=
4.	I_T=	I_T=	I_T=

CALCULATIONS:

Answer the following:

Q-1) How does the total resistance compare to that of the smallest of the three parallel resistors?

Q-2) Is I_T under normal circuit condition less than I_T for open circuit condition?

Q-3) What can you deduce about characteristics of a parallel circuit from observation table b & c?

Q-4) Viewing observation table b , comment on whether equal resistors in parallel have equal currents through them?

Q-5) Referring to observation tables b & c, compare open circuit condition & normal circuit with reference to current & voltage values:

LAB SESSION 05

OBJECTIVE:

To verify experimentally Kirchhoff's Voltage and Current Law:

REQUIRED:

- Resistors,
- DMM,
- DC power supply.

THEORY:

1)KIRCHOFF'S VOLTAGE LAW:

Explanation:

Consider the simple series circuit Fig. 5-1. Here we have numbered the points in the circuit for voltage reference.

As we are dealing with dc circuits, therefore we should carefully connect the voltmeter while measuring voltage across supply or any of the resistances as shown in fig.5.2, keeping in mind the similarity of polarities of voltage across the element and that of the connected probes of meter. In such case, we will observe that,

$E_{2\text{-}1} = +45\ V$ *voltage from point 2 to point 1*
$E_{3\text{-}2} = -10\ V$ *voltage from point 3 to point 2*
$E_{4\text{-}3} = -20\ V$ *voltage from point 4 to point 3*
$+\ E_{1\text{-}4} = -15\ V$ *voltage from point 1 to point 4*

$0\ V$

This principle is known as ***Kirchhoff's Voltage Law***, and it can be stated as such:

"The algebraic sum of all voltages in a loop must equal zero"

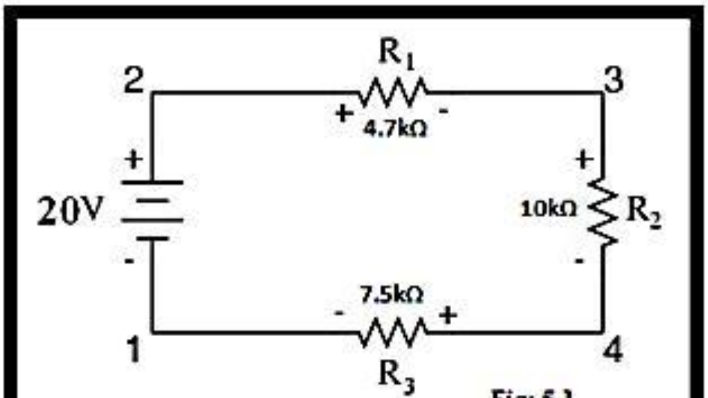


Fig: 5.1

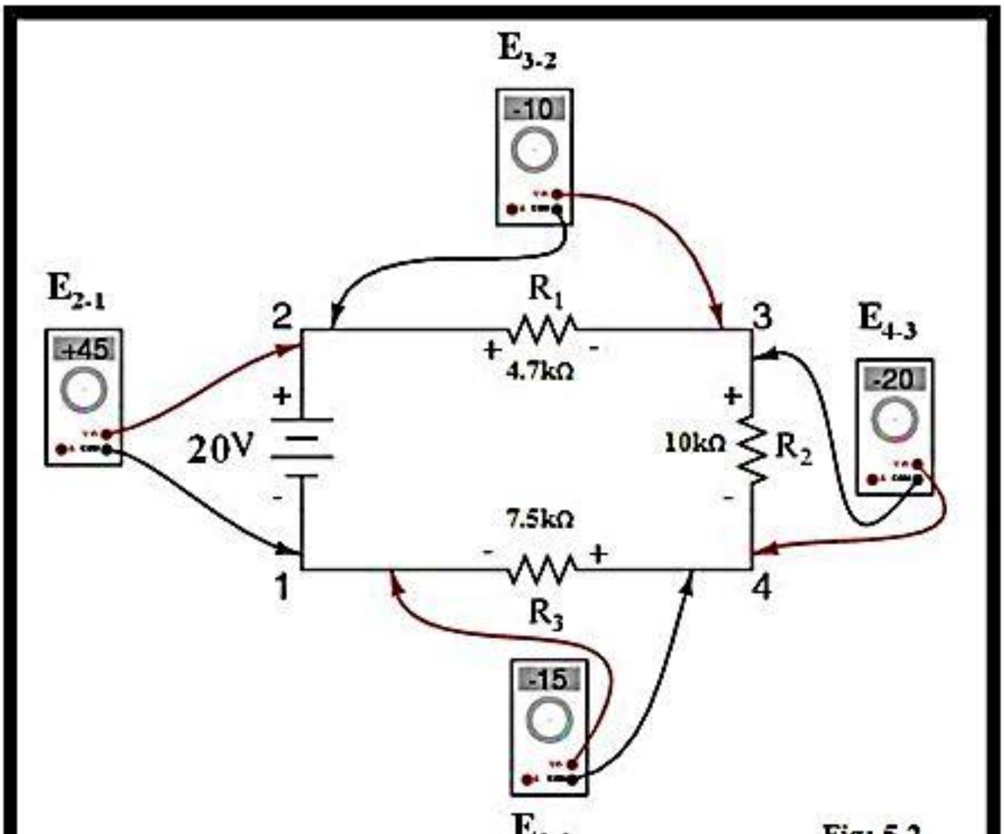


Fig: 5.2

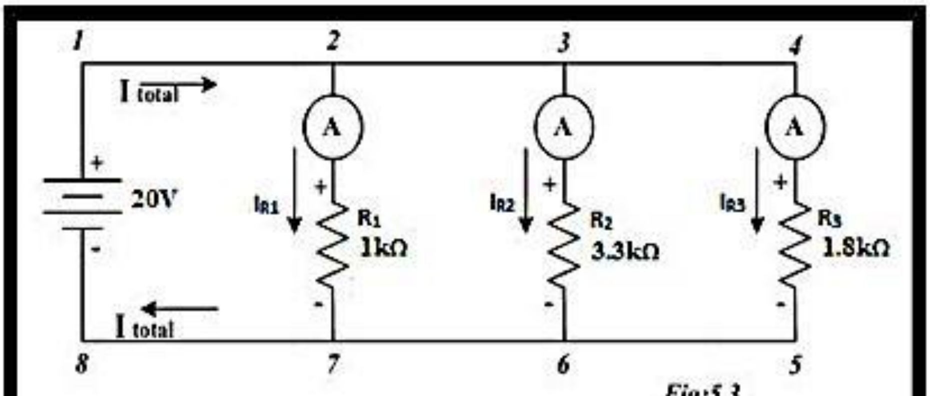


Fig:5.3

2) KIRCHHOFF'S CURRENT LAW:

Let's take a closer look at the circuit given in Fig 5-3: Then,

according to Kirchhoff's Current Law:

"The algebraic sum of all currents entering and exiting a node must equal zero"

Mathematically, we can express this general relationship as such:

$$I_{entering} + (-I_{exiting}) = 0$$

That is, if we assign a mathematical sign (polarity) to each current, denoting whether they enter (+) or exit (-) a node, we can add them together to arrive at a total of zero, guaranteed.

Note:

Whether negative or positive denotes current entering or exiting is entirely arbitrary, so long as they are opposite signs for opposite directions and we stay consistent in our notation, KCL will work.

PROCEDURE:

a)For KVL:

1. Construct circuit of fig. 5-1 using the values R1 , R2, R3 as shown in the figure 5-1.
2. Adjust the output of the power supply so that Vs = 20V. Measure and record this voltage in table. 5-1, also measure and record the voltages V1, V2, V3 and enter the sum in the same table.

b)For KCL:

1- Connect the circuit of Fig.5.3 with Vs =20 V.

2- Measure and record in Table 5-2 currents I_{R1}, I_{R2}, I_{R3} and I_{total}.

OBSERVATIONS:

Table 5-1:

V_T	V_1	V_2	V_3	Sum ($V_1+V_2+V_3$)

Table 5.2:

I_{total}	I_{R1}	I_{R2}	I_{R3}	Sum ($I_{R1}+I_{R2}+I_{R3}$)

CALCULATIONS:

For KVL:

Q-1) In fig.5-1 V_1=10V, V_2=12V, V_3=20V, V_4=15V. The applied voltage Vs must then equal __________ V.

Q-2) In Fig.5-1, V_1=15V,V_2=20V and Vs = 100V. The Voltage V_3=_____________V.

Q-3) Is KVL verified practically as well as mathematically in the above performed lab? If no, why?

For KCL:

Q-1) In fig 5-3,if IR1=5A,IR2=2A and IR3=1A, then Itotal should be equal to ________ A.

Q-2) Is KCL verified practically as well as mathematically in the above performed lab? If no, why?

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Psychomotor Domain Assessment Rubric-Level P3					
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Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
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Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 06

OBJECTIVE:

To become familiar with Star/Delta conversion and calculate power dissipated in each configuration.

EQUIPMENTS REQUIRED:

- 6x100 ohm resistors
- 3x130 ohm resistors
- 6x390 ohm resistors
- DMM
- DC power supply

THEORY:

In series or parallel combination of resistors, we define connection by focusing at two resistors at a time, and then declaring the nature of connection that either it is series or parallel.
However, when we have to analyze three resistances at a time then instead of series and parallel, we define the connectivity of resistors as "star" connection or "delta" connection. Such type of connections becomes more important when we study three phase power systems. Also, these connections are applicable not only for resistor, they are defined either for individual R(resistance), X_L (inductive reactance), X_c (capacitive reactance) or Z (impedance) as whole according to the nature of system under consideration.

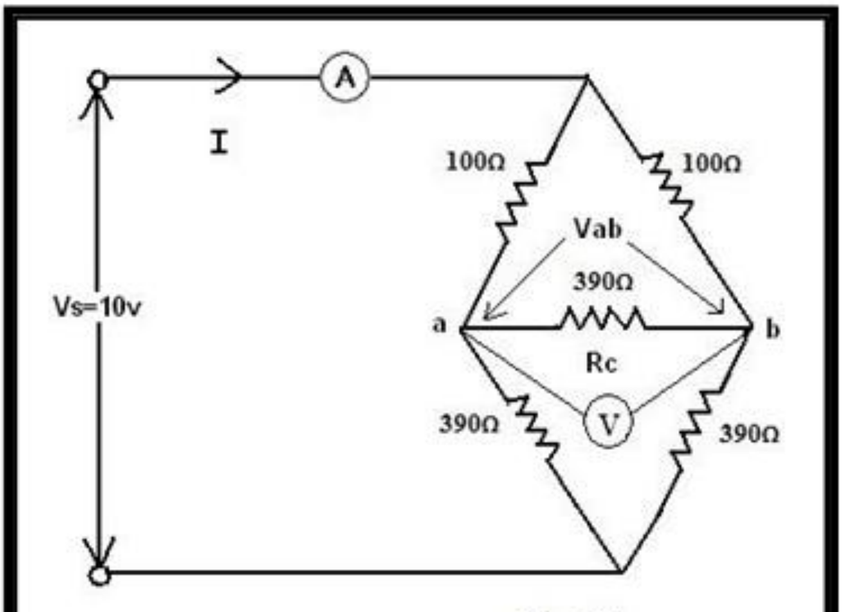
A
I
Vs=10v
100Ω
100Ω
Vab
390Ω
a
b
Rc
390Ω
V
390Ω

Fig: 6.1

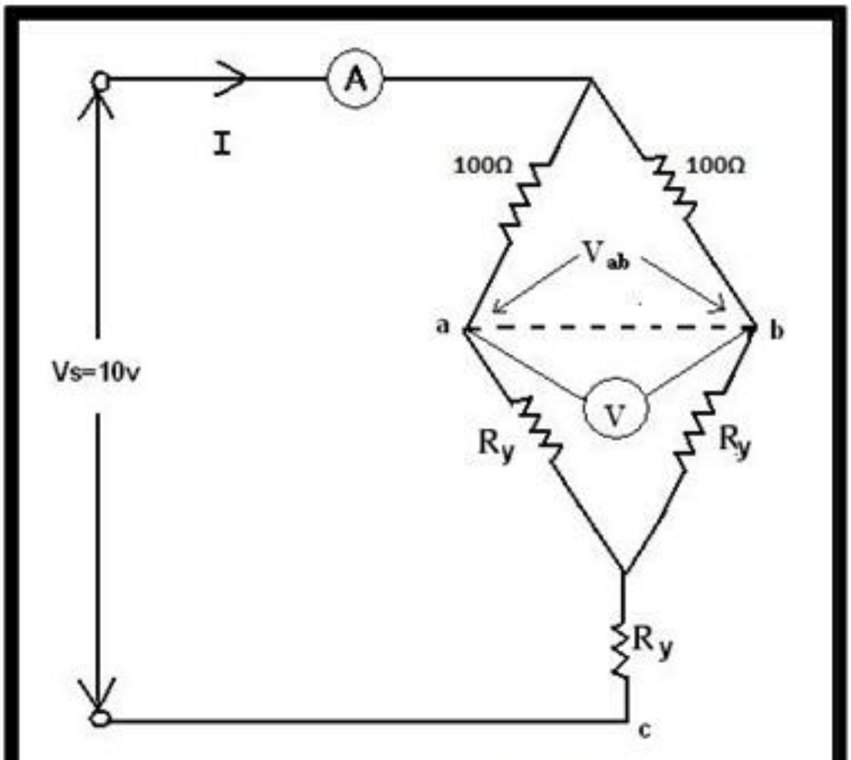
A
I
Vs=10v
100Ω
100Ω
V_{ab}
a
b
V
R_y
R_y
R_y
c

Fig: 6.2

To convert a delta in to star or vice versa we use the following conversion equations:

Delta To Star:

$$R_1 = \frac{R_B \times R_C}{R_A + R_B + R_C}$$

$$R_2 = \frac{R_A \times R_C}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_A \times R_B}{R_A + R_B + R_C}$$

Star To Delta:

$$R_A = R_2 + R_3 + \frac{R_2 \times R_3}{R_1}$$

$$R_B = R_1 + R_3 + \frac{R_1 \times R_3}{R_2}$$

$$R_C = R_1 + R_2 + \frac{R_1 \times R_2}{R_3}$$

If $R_A = R_B = R_C$, then

$$R_Y = R_\triangle / 3$$

If $R_1 = R_2 = R_3$, then

$$R_\triangle = 3 \times R_Y$$

PROCEDURE:

1-Construct the network of fig:6.1.
2-Measure the current 'I' and voltage 'V_{ab}' and record in the observation table.
3- Calculate the equivalent Y for the $\triangle$ formed by three 390 ohm resistors (using $R_Y = R_\triangle / 3$)
4- Insert the values of resistors in the Y as shown in fig:6.2.
5- Measure the current 'I' and voltage 'V_{ab}' and record in the observation table.
6- Construct the network of fig: 6.3.
7-Measure the current 'I' and voltage 'V_{ab}' and record in the observation table.
8- Calculate the power absorbed by using the formula P=I x Vs and record it in the observation table.

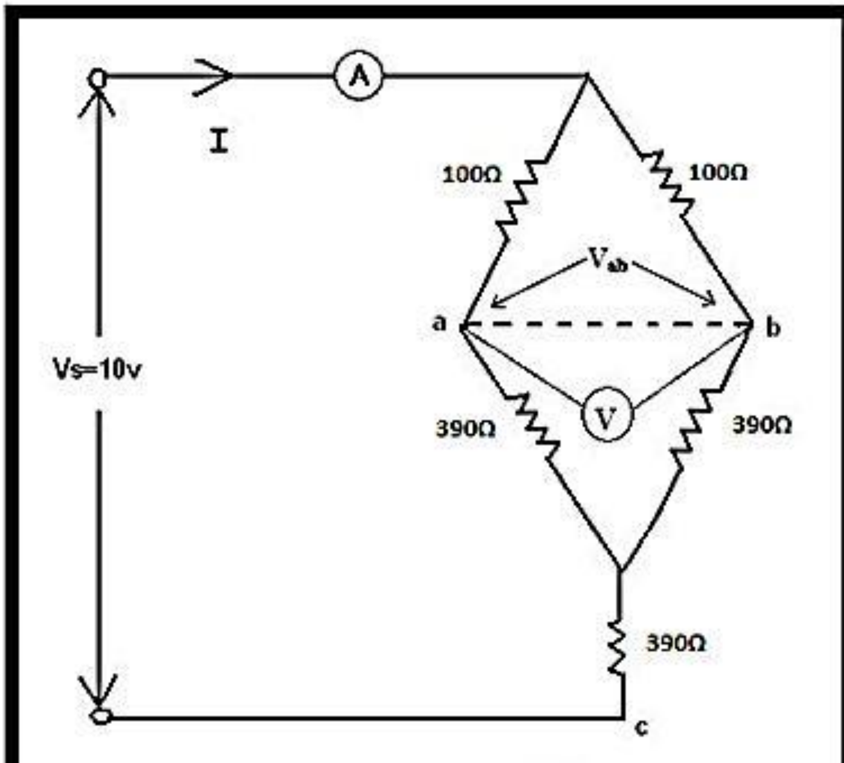

Fig: 6.3

OBSERVATIONS:

	I	V_{ab}	$P = I\,V_S$
Fig: 6.1			
Fig: 6.2			
Fig:6. 3			

CALCULATIONS:

RESULT :

Answer the following:

Q-1) Referring to the observation table, column 2, how much current will be flowing through resistor R_L across (a-b)? Justify your answer mathematically.

Q-2) The power absorbed for the networks of figs 1 and 2 is the same but for the network of fig 3 it is not, what can you infer from it? [Hint: Talk in terms of resistance].

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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 07

OBJECTIVE:

To verify superposition principle in DC Circuits.

EQUIPMENTS REQUIRED:

- DMM,
- 2 DC Power Supplies,
- Resistances (1k Ω, 1.8k Ω, 470Ω).

THEORY:

The superposition principle states that :

"The current through or voltage across, any resistive branch of a multisource network is the algebraic sum of the contribution due to each source acting independently."

When the effects of one source are considered, the others are replaced by their internal resistances. This principle permits one to analyze circuits without restoring to simultaneous equations.

Superposition is effective *only for linear circuit relationship*. Non-linear effects, such as power, which varies as the square of the current or voltage, cannot be analyzed using this principle.

PROCEDURE:

1 - Construct the Network of Fig 7.1, where $R_1 = 1$ k Ω , $R_2 = 470$ Ω , $R_3 = 1.8$ k Ω.

Verify the resistances using DMM.

2 - Using superposition and measured resistance values, calculate the currents indicated in observation table (a), for the network of fig 7.1.

Next to each magnitude include a small arrow to indicate the current direction for each source and for the complete network.

3 - Energize the network of fig.7.1 and measure the voltages indicated in observation table B, calculate current in table (b) using Ohm's Law. Indicate the polarity of the voltages and direction of currents on fig. 7.1.

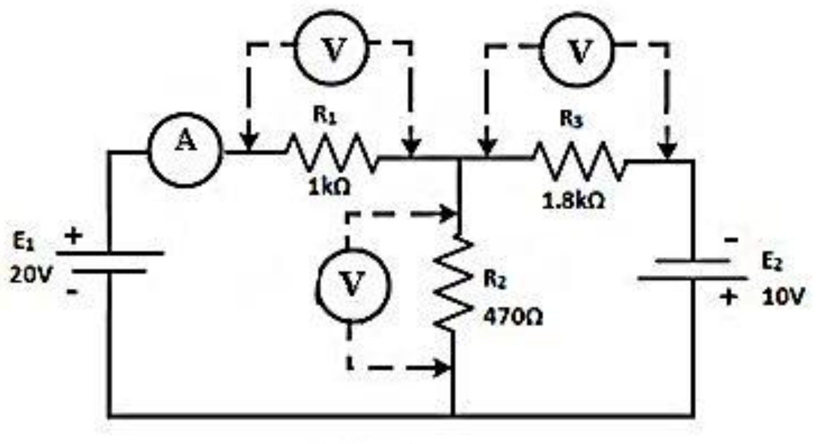

Fig: 7.1

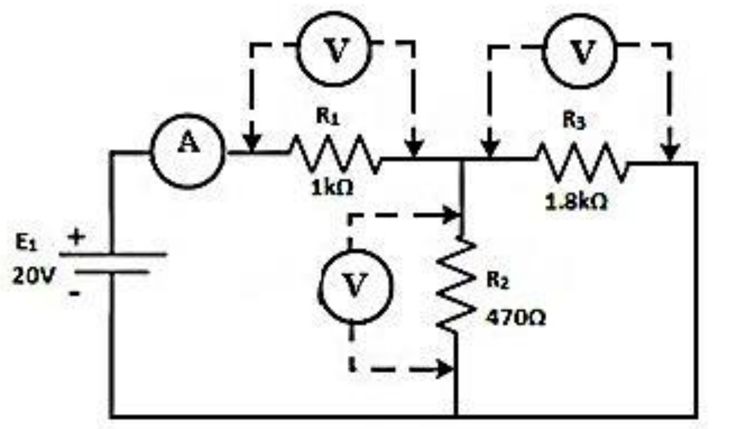

Fig: 7.2

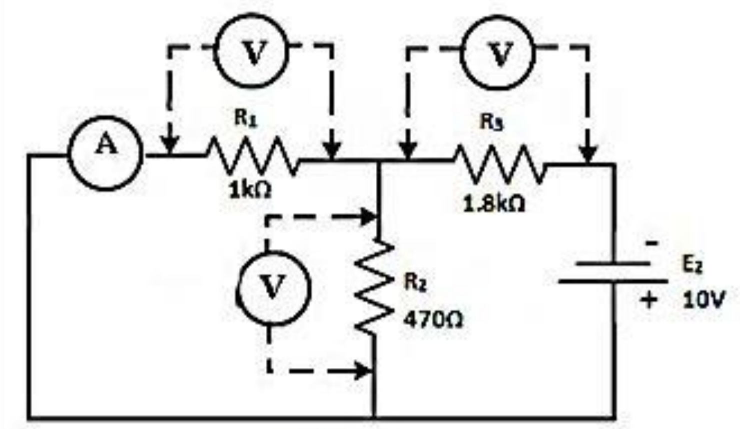

Fig: 7.3

4 - Construct the network of fig.7.2. Note that source E_2 has been removed.

5 - Energize the network of fig.7.2 and measure the voltages indicated in table C. Calculate currents using Ohm's Law.

6 - Repeat steps # 4 & 5 for the network of fig.7.3. Note that E_1 has been removed.

7 - Using the results of steps # 3, 5 and 6, determine the power delivered to each resistor and insert in table (e).

OBSERVATIONS:

Resistors:

	Nominal Values (Ω)	Measured Values (Ω)
1	1 KΩ	
2	470Ω	
3	1.8 KΩ	

a) Calculated Values for the Network of Fig:7.1

Due to E_1		Due to E_2		Algebraic Sum	
I_1' =	V_1'=	I_1'' =	V_1'' =	$I_1 = I_1' + I_1''$=	$V_1 = V_1' + V_1''$=
I_2'=	V_2'=	I_2'' =	V_2'' =	$I_2 = I_2' + I_2''$=	$V_1 = V_1' + V_1''$=
I_3'=	V_3'=	I_3'' =	V_3'' =	$I_3 = I_3' + I_3''$=	$V_1 = V_1' + V_1''$=

b) Measured Values for the Network of Fig: 7.1

V_1 = ______________________

V_2 = ______________________

V_3 = ______________________

I_1 = ______________________

I_2 = ______________________

I_3 = ______________________

c)_ Measured Values for the Network of Fig: 7.2

V_1 = ______________________

V_2 = ______________________

V_3 = ______________________

I_1 = ______________________

I_2 = ______________________

I_3 = ______________________

d) Measured Values for the Network of Fig. 7.3

V_1 = ______________________________

V_2 = ______________________________

V_3 = ______________________________

I_1 = ______________________________

I_2 = ______________________________

I_3 = ______________________________

e) Power Absorbed (use measured values of I and V)

Due to E_1	Due to E_2	Sum of Columns 1 & 2	E1 & E2 Acting Simultaneously	Difference of Columns 3 & 4

CALCULATIONS:

Answer the following:

Q-1) With reference to table (e), whether superposition applies to average power absorbed? if not state why ?

Q-2) Is superposition principle verified?

Q-3) In your words, explain significance of this theorem in circuit analysis, if any:

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Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

LAB SESSION 08

OBJECTIVES:

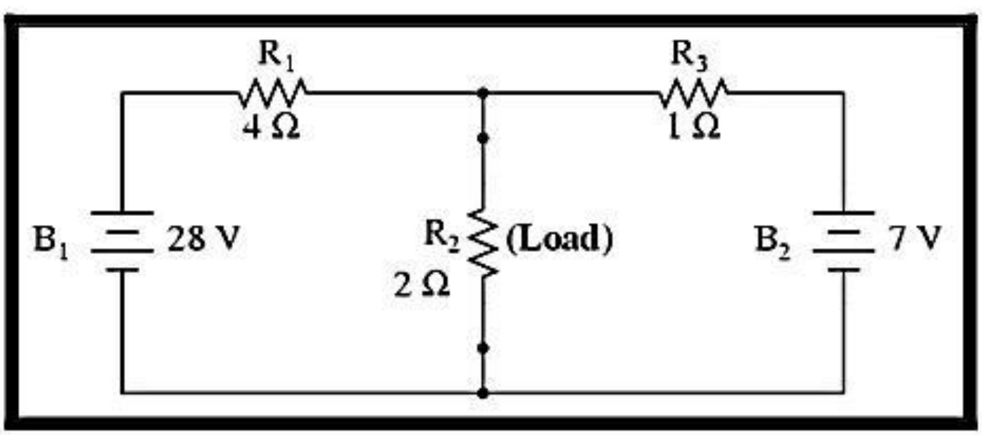
To determine by analysis the values V_{TH} (Thevenin voltage) and R_{TH} (Thevenin resistance) in a dc circuit containing a single voltage source. Also obtain the voltage across and current passing through R_L.

EQUIPMENTS REQUIRED:

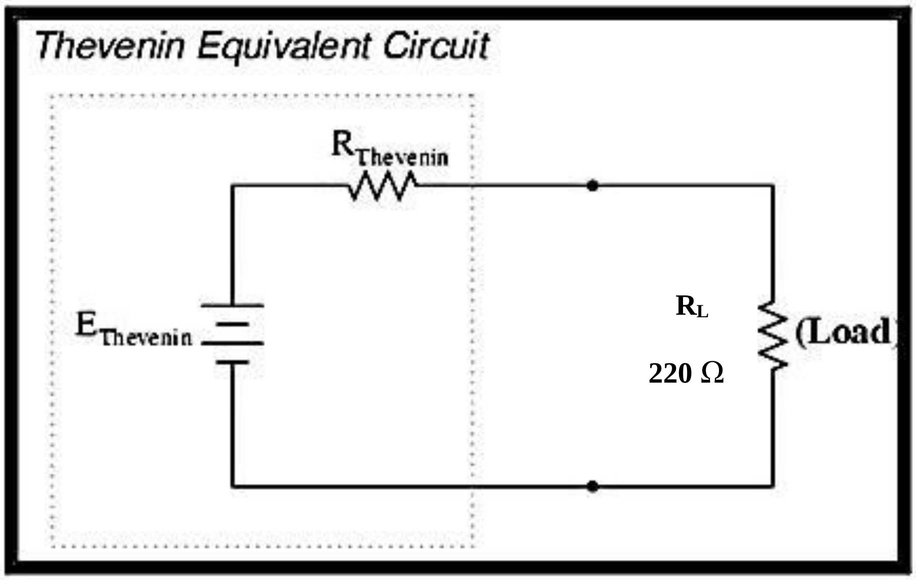
- DC power supply
- Ohmmeter
- DC ammeter
- DC voltmeter
- Resistances of values 47Ω 220 Ω,330 Ω 1K Ω

THEORY:

Thevenin's Theorem states *that* ***it is possible to simplify any linear circuit, no matter how complex, to an equivalent circuit with just a single voltage source and series resistance connected to a load.*** Thevenin's Theorem is especially useful in analyzing power systems and other circuits where one particular resistor in the circuit (called the "load" resistor) is subject to change, and re-calculation of the circuit is necessary with each trial value of load resistance, to determine voltage across it and current through it. Thevenin's Theorem makes this easy by temporarily removing the load resistance from the original circuit and reducing what's left to an equivalent circuit composed of a single voltage source and series resistance. The load resistance can then be re-connected to this "Thevenin equivalent circuit" and calculations carried out as if the whole network were nothing but a simple series circuit.



. . . after Thevenin conversion . . .

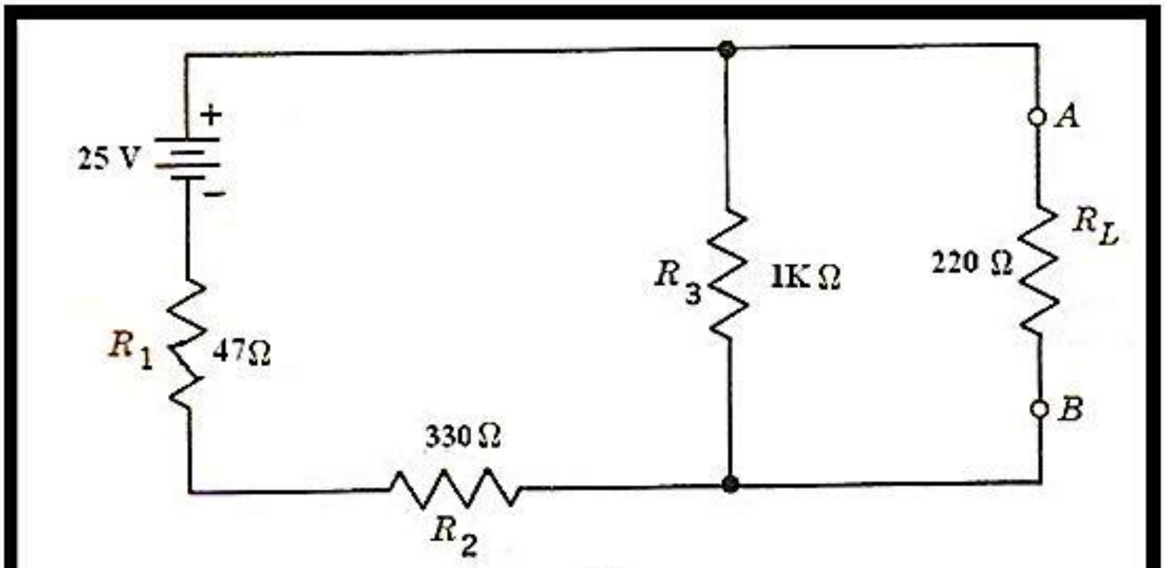


The "Thevenin Equivalent Circuit" is the electrical equivalent of B_1, R_1, R_3, and B_2 as seen from the two points where our load resistor (R_2) connects.

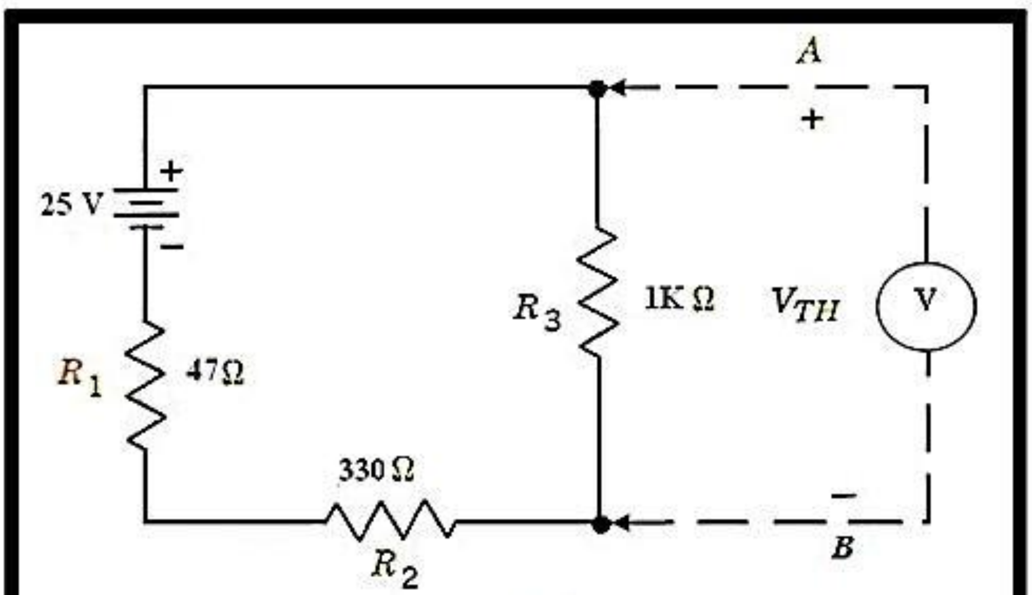
The Thevenin equivalent circuit, if correctly derived, will behave exactly the same as the original circuit formed by B_1, R_1, R_3, and B_2. In other words, the load resistor (R_2) voltage and current should be exactly the same for the same value of load resistance in the two circuits. The load resistor R_2 cannot "tell the difference" between the original network of B_1, R_1, R_3, and B_2, and the Thevenin equivalent circuit of $E_{Thevenin}$, and $R_{Thevenin}$, provided that the values for $E_{Thevenin}$ and $R_{Thevenin}$ have been calculated correctly.

PROCEDURE:

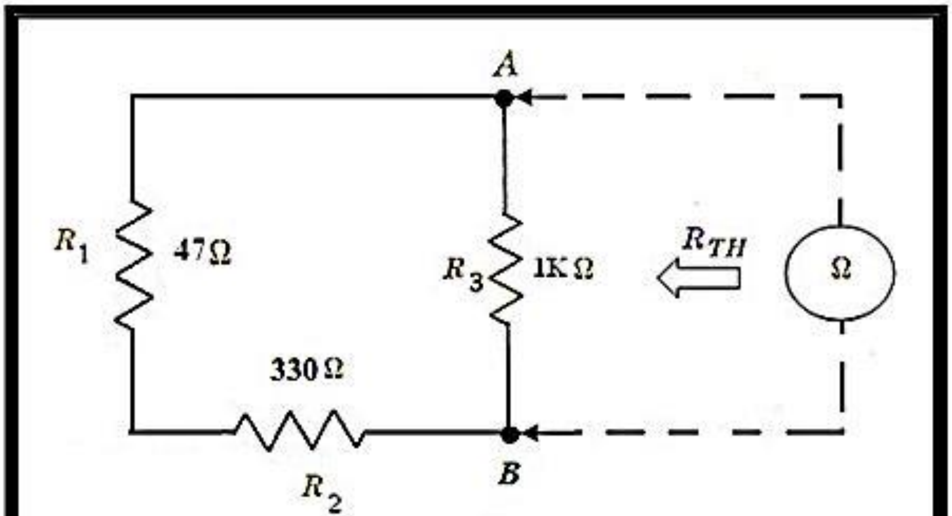
1. Connect the circuit as shown in the above 8.1(a)
2. Remove the R_L from the circuit across which the Thevinin equivalents have to be evaluated.
3. To find the R_{TH} remove the voltage-source from the circuit and short circuit the terminals from which the supply was connected. Now place an ohmmeter across the terminals A and B.
4. Also confirm the value of the equivalent resistance from calculations and record it in the table.
5. To find the value of V_{TH} place a voltmeter across the terminals A and B after retaining the voltage source in the circuit back.
6. Also confirm the value of the equivalent voltage from calculations and record it in the table.
7. Now construct the thevenin equivalent circuit and measure V_{AB} and I_L. Also calculate the se values by using methods other than thevenin theorem.


25 V
+
-
R_1
47Ω
330 Ω
R_2
R_3
1K Ω
220 Ω
R_L
A
B

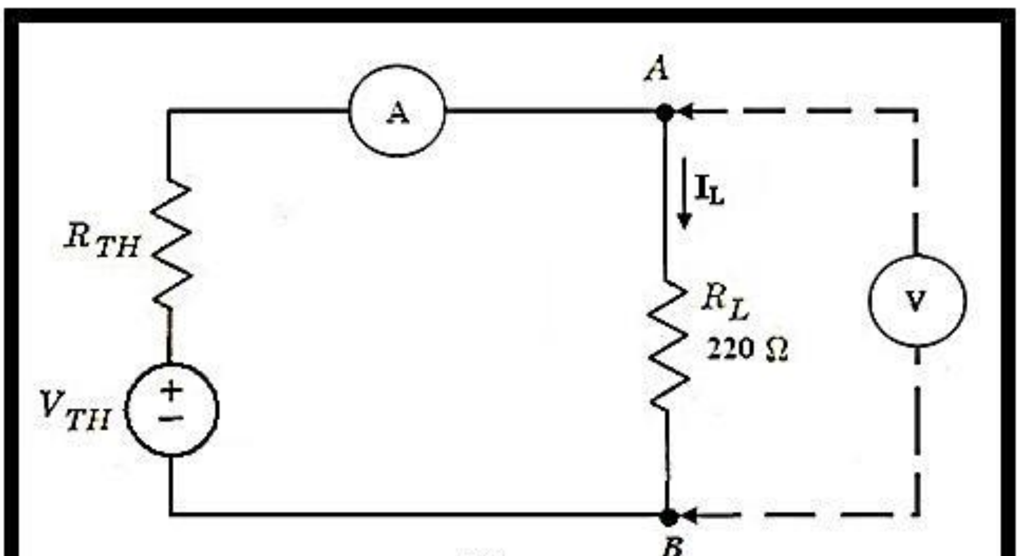
(a)


25 V
+
-
R_1
47Ω
330 Ω
R_2
R_3
1K Ω
A
+
V_{TH}
V
-
B

(b)



(c)



(d)

Fig: 8.1

OBSERVATIONS:

TABLE (a): Resistors

S:No:	Nominal Value(Ω)	Measured Value(Ω)
1	R_1=47	
2	R_2=330	
3	R_3=1000	
4	R_L=220	

TABLE (b): Thevinin Theorem

R_L	V_{TH} (volts)		R_{TH} (ohms)		I_L (A)		V_{AB} (V)	
	Measured	Computed	Measured	Computed	Measured	Computed	Measured	Computed

CALCULATIONS:

Answer the following:

Q-1) How much power is absorbed by $R_{L?}$ Show it. Is this the maximum power that can be drawn from the supply?

Q-2) What value of R_L will draw the maximum power from the circuit? Calculate the maximum power .

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Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
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Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

LAB SESSION 09

OBJECTIVES:

To verify Norton's Theorem and the theory of source transformation.

EQUIPMENTS REQUIRED:

- DC power supply
- Ohmmeter
- DC ammeter
- DC voltmeter
- Resistances of values 47 Ω,220 Ω 330 Ω, 1KΩ

THEORY:

Norton's Theorem

Norton's theorem states that ***any two terminal network may be replaced by a simple equivalent circuit consisting of a constant current source I_N, shunted by an internal resistance R_N,*** Figure 9-*1a* shows the original network as a *block* terminated by a load resistance R_L. Figure 9-*lb* shows the Norton equivalent circuit. The Norton current I_N is distributed between the shunt resistance R_N and the load R_L. The current I_L in R_L may be found from the equation

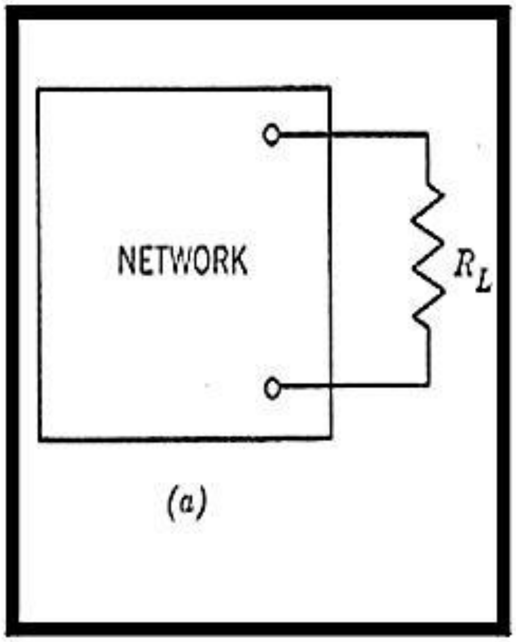
$$I_L = \frac{I_N \times R_N}{R_N + R_L}$$

The rules for determining the constants in the Norton equivalent circuit are as follows:

1. The constant current I_N is the current that would flow in the short circuit between the load resistance terminals if the load resistance were replaced by a short circuit.
2. The Norton resistance R_N is the resistance seen from the terminals of the *open* load, looking into the original network, when the voltage sources in the circuit are replaced by their internal resistance. Thus R_N is defined in exactly the same manner as is R_{TH} in Thevenine's theorem.

The ***theory of source conversion*** says that the Norton and Thevenine circuits can be terminally equivalent and related as follows:

$$R_N = R_T \qquad E_{TH} = I_N R_N$$



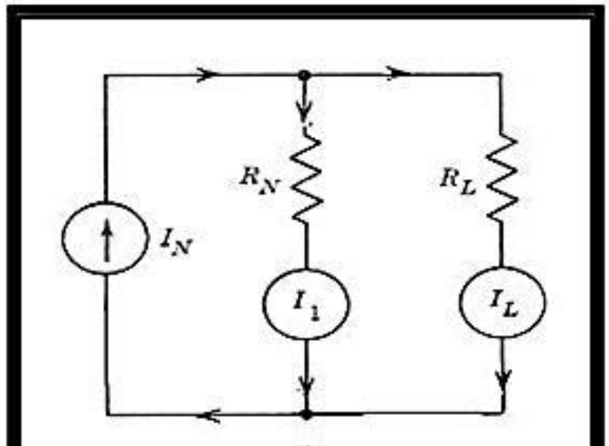
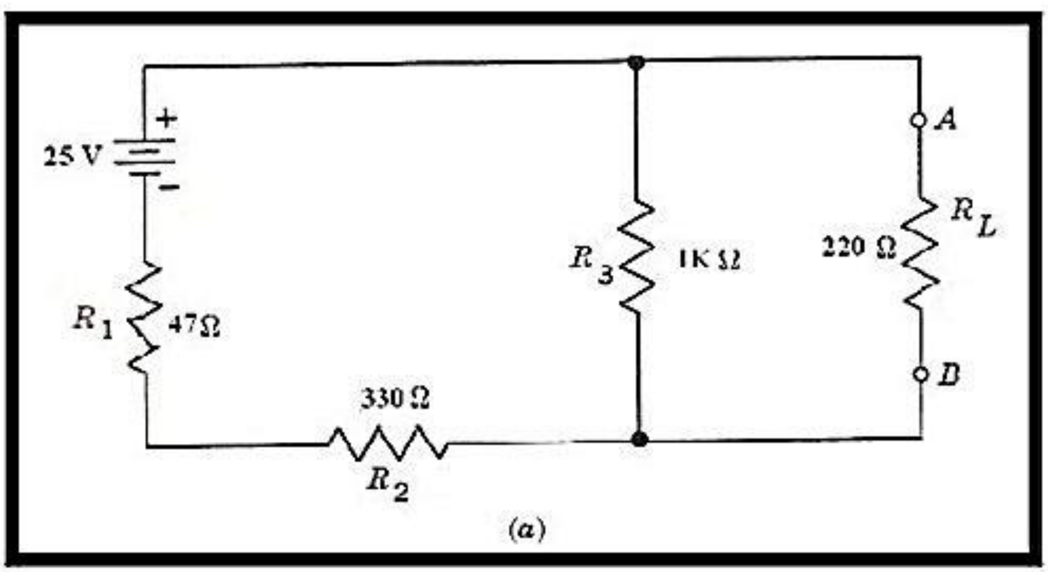
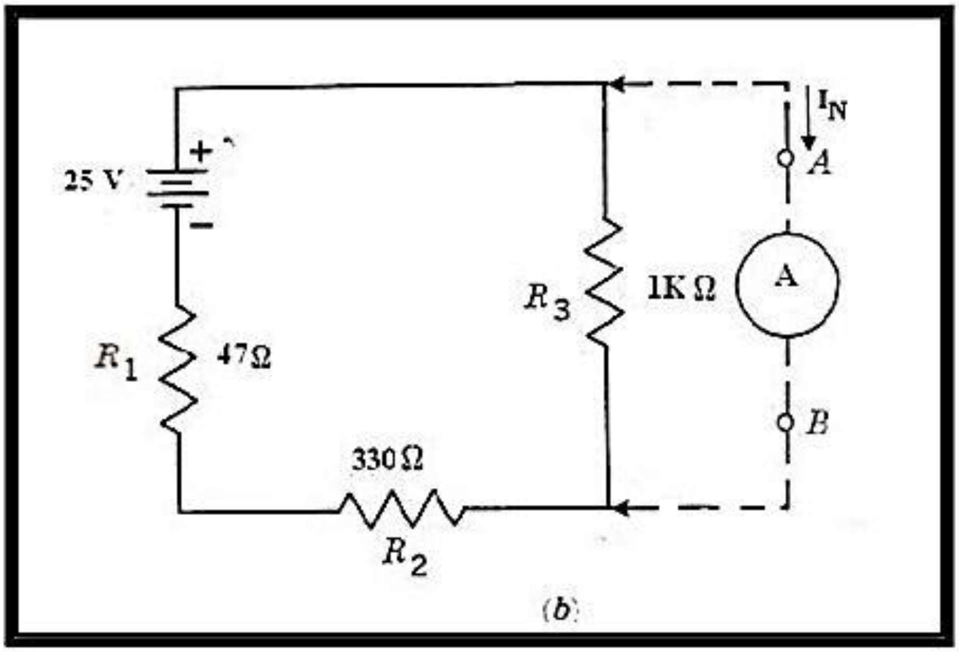
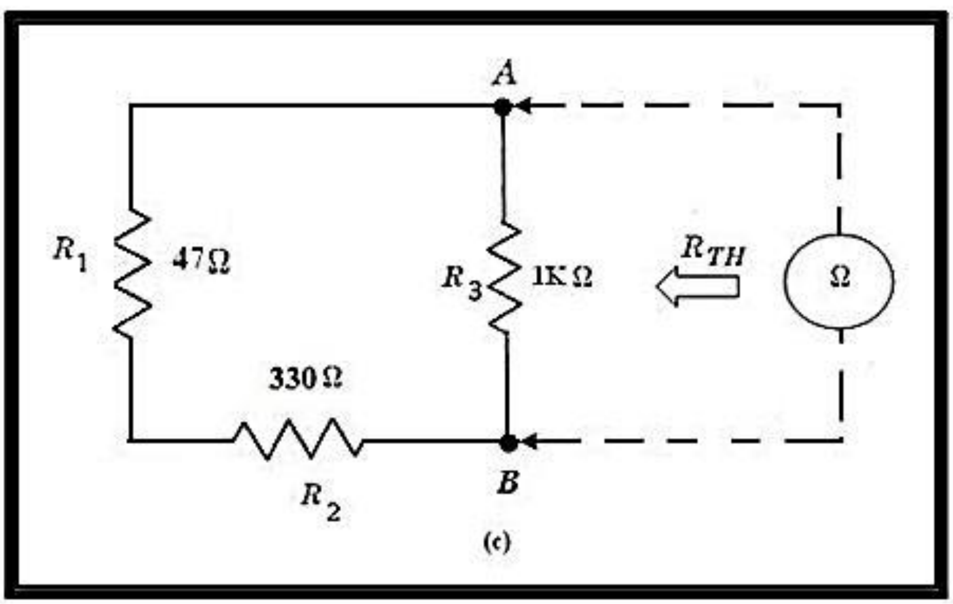


Fig: 9.1





(b)



(c)

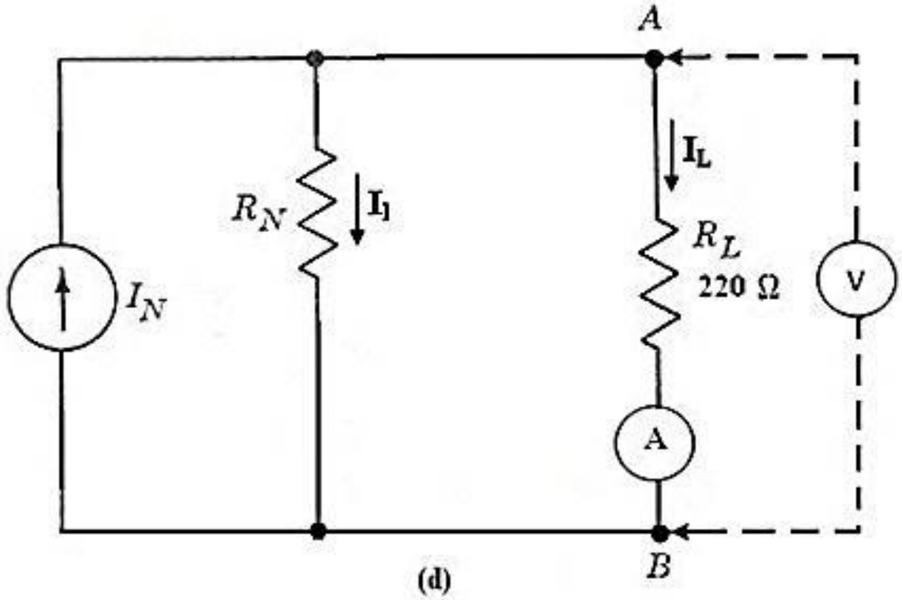


Fig: 9.2

PROCEDURE:

(a) NORTON'S THEOREM:

1. Connect the circuit as shown in figure 9.2(a).
2. Remove the R_L from the circuit across which Norton equivalents have to be found out.
3. For R_N or R_{TH} of the circuit, remove the voltage source and short circuit the open terminals. Now place an ohm meter across A and B.
4. Verify your observation, by calculating the R_{TH}.
5. For I_N, retain the source back into the circuit and place an ammeter connecting the terminals A and B.
6. The value of the current is the short circuit current i.e. I_N.
7. Also compute the value of the Norton's equivalent current and record it in the table.
8. Now construct the Norton's equivalent circuit and measure the I_L and V_{AB}. (That is vary the supply voltage until DMM indicates the value I_N)Also calculate the value of I_L and V_{AB} by using methods other than Norton's theorem.

(b) Source Transformation:

1. Construct the Norton's equivalent circuit (That is vary the supply voltage until DMM indicates the value I_N).
2. Measure the supply voltage. Construct the thevinine equivalent circuit fig no:8.1(d) from previous exp.
3. Measure V_{AB} and I_L. **Are these values the same as obtained in part (a)?**

OBSERVATIONS:

TABLE (a): Resistors

S:No:	Nominal Value(Ω)	Measured Value(Ω)
1	**R_1**=47	
2	**R_2**=330	
3	**R_3**=1000	

TABLE (b): Norton's Theorem

R_L Ω	I_N (A)		R_N (Ω)		I_L (A)		V_{AB} (V)	
	Measured	Computed	Measured	Computed	Measured	Computed	Measured	Computed

CALCULATIONS:

Answer the following questions:

Q-1) Compare the values of V_{AB} and I_L in part (a)with those obtained in the last experiment? Is theory of source transformation verified?

Q-2) On what grounds one can say that Thevenin and Norton are the source transformation of each other?

LAB SESSION 10

OBJECTIVE:

To note the effect of frequency on basic R,L and C components.

EQUIPMENTS REQUIRED:

- DMM
- Oscilloscope
- Function Generator
- Resistors: 1k Ω, 2x100Ω, 120 Ω.
- Inductor: 15 mH
- Capacitor: 0.1 μF.

THEORY:

The resistance of resistor is unaffected by frequency which can be seen mathematically through "Law of resistivity" as:

$$R = \rho L/A$$

The reactance of an inductor is linearly dependent on the frequency applied. That is, if we double the frequency, the reactance gets doubled, as determined by:

$$X_L = 2\pi f L$$

For low frequencies, the reactance is correspondingly very small, while for increasing frequencies, the reactance will increase to a very large value. For DC conditions, we find that $X_L = 2\pi(0)L$ is zero Ohms, corresponding with short circuit representation that we used in our DC analysis. For very high frequencies, X_L is so high that we can often use an open circuit approximation.

The capacitor behaves (as far as reactance is concerned) in a manner opposite to that of the inductor. The capacitive reactance is non-linearly dependent on the frequency, as can be seen by the following mathematical relation:

$$X_c = 1/(j2\pi f C)$$

In this experiment, we will practically verify above stated behaviors of the three basic Electrical passive elements.

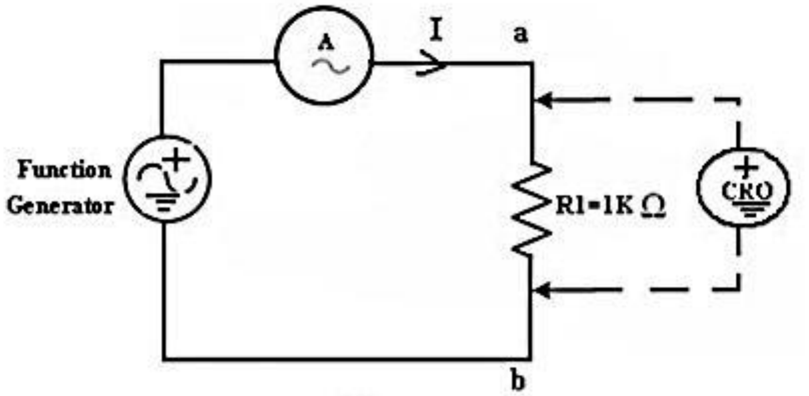


Fig:10.1

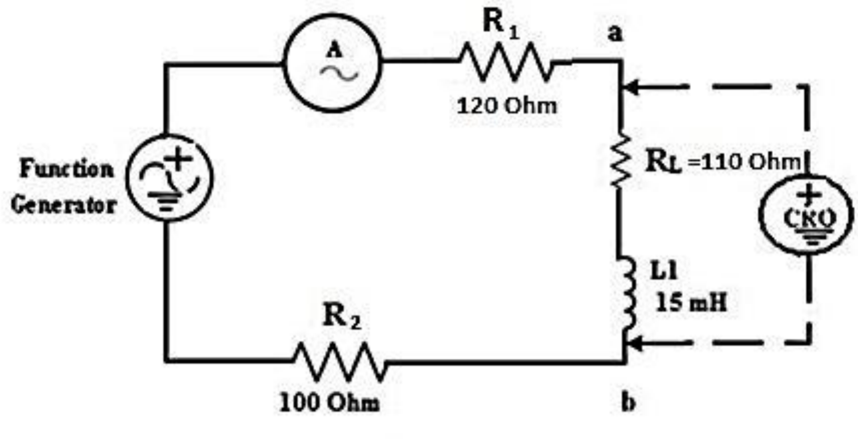


Fig:10.2

R_L = Measured Internal Resistance of inductor

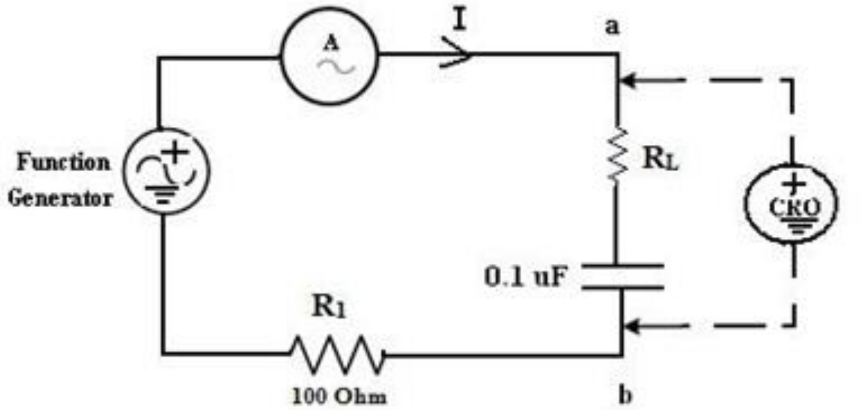


Fig:10.3

PROCEDURE:

Part 1: For Resistors:

1- Voltage across resistor will be held constant while only frequency will be varied, if the resistance is frequency independent, the current through the circuit should not change as a function of frequency.

2- Construct the network of Fig:10.1

3- Set the voltage Vab to 4V(p-p) (measure this voltage with the oscilloscope).

4- Set the frequencies to those shown in table (A), each time monitoring Vab [always 4V (p-p)}] and I.

5- Since we are using DMM for current measurements this value is given as Irms. 6- Record the values in table A.

Part 2:For Inductors:

1- Construct the circuit of Fig:10.2. Measure dc resistance of coil with DMM and record that value as R_l on the Fig:10.2

2- The voltage across the inductor will be kept constant while we very frequency and monitor the current in the circuit.

3- Set Vab to 4V(p-p). Use Oscilloscope to measure Vab.

4- Set the frequencies to those shown in table (B). Each time making sure that Vab = 4 V (p-p) and that you measure the current I. (Remember I will be in rms).

5- Plot measured X_L (on y-axis) versus frequency (on x-axis).

6- From the plot, determine the inductance at 500 Hz. and compare to the defined value.

$L_{calculated}$ = ________________ $L_{defined}$ = ______________

Part 3: For Capacitors:

1-Construct the Circuit of fig: 10.3

2-Following steps as performed in part 2,note down observations in table (C). 3-Plot Xc (measured) on Y-axis versus frequency on X-axis.

4-Determine the reactance of capacitor at 500 Hz from the plot and calculate capacitance using $C = 1/(2f\pi Xc)$. Compare with the defined value.

$C_{Calculated}$ = __________________ $C_{defined}$ = ___________

OBSERVATIONS:

Table A:

S.No	F	$Vab_{(p-p)}$ (V)	$Vab_{(max.)}$ (V)	Vab (rms) $=\sqrt{2}/2$ (Vab)p	Irms (mA)	$R=Vab_{(rms)}/I_{rms}$
1		4				
2		4				
3		4				
4		4				
5		4				

Table B:

R_L(Internal resistance of inductor) =_______

S.No	F	$Vab_{(p-p)}$ (V)	$Vab_{(max.)}$ (V)	Vab (rms) (V)	Irms (mA)	$Z_{(measured)}$ $=Vab_{(rms)}/I_{rms}$	X_L $=\sqrt{Z^2-R_L^2}$	$X_{L(calculatedd)}$ $=2\pi fL$
1		4						
2		4						
3		4						
4		4						
5		4						

Table C:

R_c(Internal resistance of Capacitor) =_______

S.No	F	$Vab_{(p-p)}$ (V)	$Vab_{(max.)}$ (V)	Vab (rms) (V)	Irms (mA)	$Z_{(measured)}$ $=Vab_{(rms)}/I_{rms}$	X_c $=\sqrt{Z^2-R_c^2}$	$X_{c(calculatedd)}$ $=1/2\pi fc$
1		4						
2		4						
3		4						
4		4						
5		4						

CALCULATIONS:

Answer the following:

i) For resistor:

Q)-Is R changing with frequency?

ii) For Inductor:

Q-1) Is the plot straight line? Comment on the shape of the graph?

Q-2) Is the plot passing through $X_L = 0$, at f = 0 Hz. As it should?

Q-3) Why 100 Ω resistor is inserted in the circuit?

iii) For Capacitor:

Q-1) Comment on the shape of plot. Is it linear? Why?

Q-2) Why 100 Ω resistor is included in the circuit?

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Course Code and Title: ____

Laboratory Session: No.________________________________ Date: ____________________

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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

PROBLEM BASED LEARNING LAB 1: Series RL circuit

OBJECTIVE:

1. To verify experimentally that the impedance Z of a series *RL* circuit is given by the equation

   $Z = \sqrt{(R^2 + X^2)}$

2. To measure the phase angle 'θ' between voltage V and the current I.
3. To verify experimentally that following expression hold true for the RL circuit.

$V = V_R + j\,V_L \ldots$ (Vector sum).

$V = \sqrt{(V_R^2 + V_L^2)}$. (Magnitude).

$V_R = V \cos\theta$ (Vector sum).

$V_L = V$ sin theta (Vector sum).

EQUIPMENTS REQUIRED:

- Function generator
- 390 Ω resistor
- 15 mH inductor
- DMM/Analog multimeter

THEORY:

The total opposition to alternating current in an ac circuit is called the impedance of the circuit. If it is assumed that the choke coil *(L)* through which alternating current flows has zero resistance, the current is impeded only by the *XL* of the choke. That is, Z = *XL'*

In this case, if *L* = 8 H and *F* = 60 Hz,

$XL = 2\pi FL = 6.28\times(60)\times(8) = 3{,}015\ \Omega$

How much current *I* will there be in the circuit

If *V*= 6.3 V? Apply Ohm's law,

$$I = V/XL$$

where *I* is in amperes, *V* in volts, and *XL* is in ohms.

Therefore, *I* = 6.3/3015 = 2.09 mA.

If there is resistance *R* associated with the inductance *L,* or if *L* is in series with a resistor of, say, 3,000 Ω (Fig. 12-1), there will be less than 2.09 mA of current. How much current will flow, assuming the same *XL* as previously computed? Measurement shows that there is 1.485 mA in the circuit. It is evident that the total impedance of the resistor *R* connected in series with *L* is *not* simply the arithmetic sum of *R* and *XL'* It can be demonstrated mathematically that Z is the result of the vector sum of *XL* and *R.*
The vector diagram of Fig. 12-2shows that *Rand XL* are at right angles to each other and that *XL* leads *R* by 90°. We say that there is a 90° phase difference between *R* and *XL'* Vector addition is achieved by drawing a line through *A* parallel to *0 B,* and another line through *B* parallel to *OA.* C is the intersection of these two lines and is the terminus of the resultant vector *OC.* In this case, the vector *AC* is the same as *XL'* Hence, *OC* or Z is the resultant of the vector sum of *XL* and *R.*

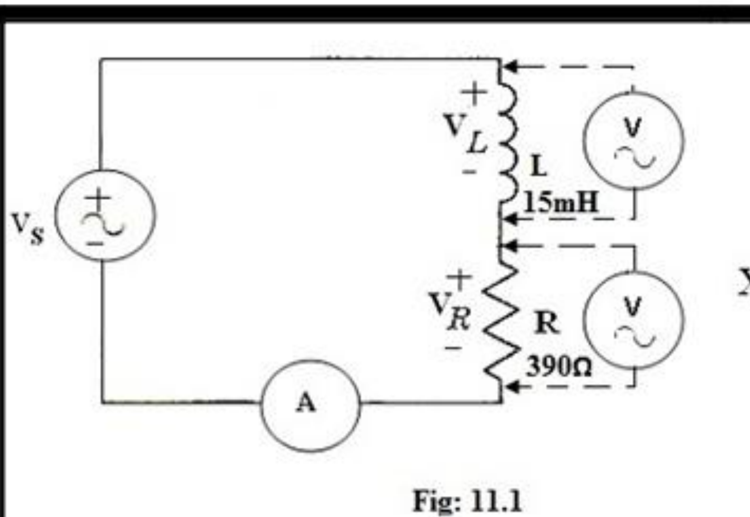


Fig: 11.1

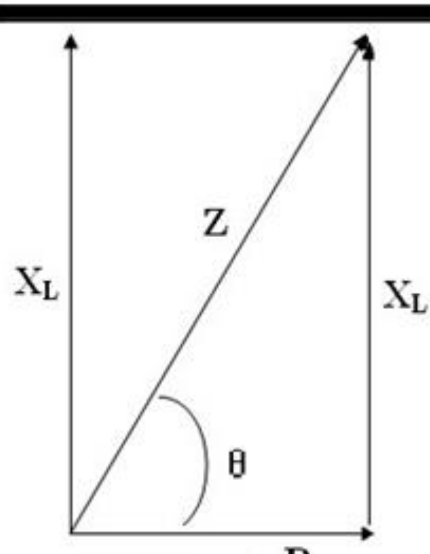
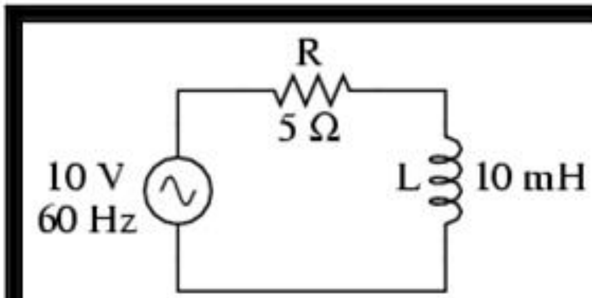


Fig: 11.2

EXAMPLE:

Take this circuit as an example to work with



The resistor will offer 5 Ω of resistance to AC current regardless of frequency, while the inductor will offer 3.7699 Ω of reactance to AC current at 60 Hz. Because the resistor's resistance is a real number (5 Ω ∠ 0°, or 5 + j0 Ω), and the inductor's reactance is an imaginary number (3.7699 Ω ∠ 90°, or 0 + j3.7699 Ω), the combined effect of the two components will be an opposition to current equal to the complex sum of the two numbers. This combined opposition will be a vector combination of resistance and reactance. Now, we need a more comprehensive term for opposition to current than either resistance or reactance alone. This term is called *impedance*, its symbol is Z, and it is also expressed in the unit of ohms, just like resistance and reactance.

Impedance is related to voltage and current, in a manner similar to resistance in Ohm's Law:

Ohm's Law for AC circuits:

$$E = IZ \qquad I = \frac{E}{Z} \qquad Z = \frac{E}{I}$$

All quantities expressed in complex, not scalar, form

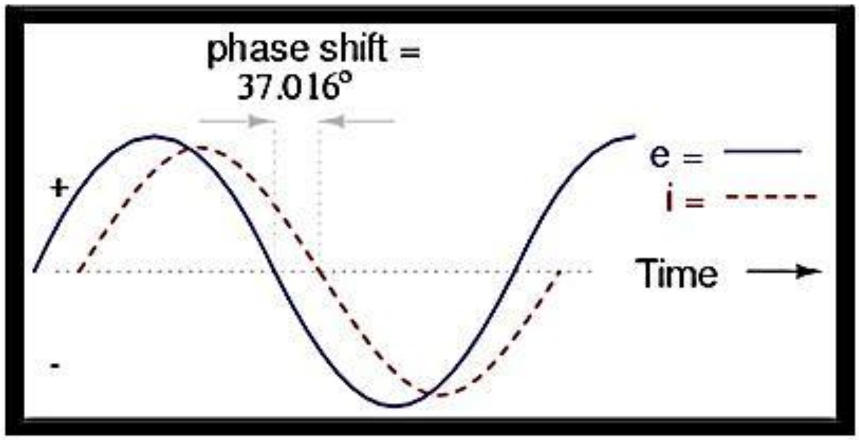
To calculate current in the above circuit, we first need to give a phase angle reference for the voltage source, which is generally assumed to be zero. (The phase angles of resistive and inductive impedance are *always* 0° and +90°, respectively, regardless of the given phase angles for voltage or current).

$$I = \frac{E}{Z}$$

$$I = \frac{10\ V \angle 0^\circ}{6.262\ \Omega \angle 37.016^\circ}$$

$$I = 1.597\ A \angle -37.016^\circ$$

As with the purely inductive circuit, the current wave lags behind the voltage wave (of the source), although this time the lag is not as great: only 37.016° as opposed to a full 90° as was the case in the purely inductive circuit.



For the resistor and the inductor, the phase relationships between voltage and current haven't changed. Across voltage across the resistor is in phase (0^o shift) with the current through it; and the voltage across the inductor is $+90^o$ out of phase with the current going through it. We can verify this mathematically:

$$E = IZ$$

$$E_R = I_R R$$

$$E_R = (1.597\ A \angle -37.016^\circ)(5\ \Omega \angle 0^\circ)$$

$$E_R = 7.9847\ V \angle -37.016^\circ$$

Notice that the phase current of E_R is equal to the phase angle of the current

The voltage across the resistor has the exact same phase angle as the current through it, telling us that E and I are in phase (for the resistor only).

$$E = IZ$$

$$E_R = I_R R$$

$$E_R = (1.597\ A \angle -37.016^\circ)(5\ \Omega \angle 0^\circ)$$

$$E_R = 7.9847\ V \angle -37.016^\circ$$

The voltage across the inductor has a phase angle of 52.984^o, while the current through the inductor has a phase angle of -37.016^o, a difference of exactly 90^o between the two. This tells us that E and I are still 90^o out of phase (for the inductor only).

We can also mathematically prove that these complex values add together to make the total voltage, just as Kirchhoff's Voltage Law would predict:

$$E_{total} = E_R + E_L$$

$$E_{total} = (7.9847\text{ V} \angle -37.016^\circ) + (6.0203\text{ V} \angle 52.984^\circ)$$

$$E_{total} = 10\text{ V} \angle 0^\circ$$

In Fig.12-2, Z is seen to be the hypotenuse of the right triangle of which *XL* and *R* are the legs. Applying the Pythagorean theorem to this right triangle, we note that

$$\mathbf{Z = \sqrt{(R^2 + X_L^2)}}$$

Also we can find θ,

$$\mathbf{\tan\theta = X_L/R.}$$

PROCEDURE:

Part 1: For $Z = \sqrt{(R^2 + X^2)}$:

1. Connect the circuit of Fig. 11-1.Use function generation for 50 Hz sinusoidal AC waveform generation. *R* is a 390Ω resistor. *L* is a 15 mH inductor.

2. Power on. Adjust the output of the ac supply until the meter measures 15 mA (0.015 A). Measure the rms voltage *V* applied to *L* and *R* and record in observation table (b). Also measure the rms value total voltage supplied Vs . Compute and record *XL* and Z. $(X_L = V_L / I;\ Z = V_S / I)\ \Omega$

3. Substitute the value of R and computed value of X_L in the equation
   $$Z = \sqrt{(R^2 + X^2)}$$
   Find Z and record in Table. Show computations.
4. Confirm the measured value of *I* by computation.(that is by using $I=V_R/R$).

Part 2: For $V=\sqrt{(V_R^2 + V_L^2)}$.(Vrms)

1. Now using the same arrangement, connect the circuit to an input voltage of 6.3 rms, 60 Hz.
2. Now with the help of voltmeter measure the respective values of voltages at resistor and inductor.
3. Now verify that V (applied) = $\sqrt{(V_R^2 + V_L^2)}$.

OBSERVATION:

(a)Resistor:

Nominal Value: 390 Ω Measured Value: ____

(b) Impedance Measurement:

R_L(Internal resistance of inductor) =_______Ω

R_T(total resistance of circuit) =R_L+R= _______Ω

I(measured)	V_L	V_R	V_S	X_L (Calculated)	$Z=V_S/I$ (measured)	$Z = \sqrt{(R_T^2 + X_L^2)}$	$I=V_R/R$

(c) Voltage measurement

R Ω	V applied (rms)	V_R (rms)	V_L(rms)	Measured I(rms)	$V=\sqrt{(V_R^2+V_L^2)}$ (rms)

CALCULATIONS:

CALCULATIONS:

Answer the following questions:

Q-1) Do the computed and measured values of Z differ? The formula $Z = \sqrt{(R^2 + X^2)}$ verified?

Q-2) Calculate the power factor of the circuit? Is it lagging?

Q-3) In a series RL circuit if the magnitude of V_R= 10V and Vs= 20 V, then V_L=?

Q4) Draw the complete phasor diagram showing Vs, V_R, V_L.

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Department of Electrical Engineering

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Remarks					
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PROBLEM BASED LEARNING LAB 2:
AC RLC Circuit

OBJECTIVE:

Measure the voltages across each component in series RLC circuits

EQUIPMENTS REQUIRED:

Resistor
Inductor
Capacitor
DMM/Analog multimeter
Function Generator
Oscilloscope

THEORY:

An inductor (L) is an important component of circuits, on the same level as resistors (R) and capacitors (C). The inductor is based on the principle of inductance - that moving charges create a magnetic field (the reverse is also true - a moving magnetic field creates an electric field). Inductors can be used to produce a desired magnetic field and store energy in its magnetic field, similar to capacitors being used to produce electric fields and storing energy in their electric field. At its simplest level, an inductor consists of a coil of wire in a circuit. The circuit symbol for an inductor is shown in Figure 1a. So far we observed that in an RC circuit the charge, current, and potential difference grew and decayed exponentially described by a time constant τ . If an inductor and a capacitor are connected in series in a circuit, the charge, current and potential difference do not grow/decay exponentially, but instead oscillate sinusoidally. In an ideal setting (no internal resistance) these oscillations will continue indefinitely with a period (T) and an angular frequency ω given by

$\omega = 1 \sqrt{LC}$

This is referred to as the circuit's natural angular frequency.

A circuit containing a resistor, a capacitor, and an inductor is called an LC circuit (or LCR), as shown in Figure 1b. With a resistor present, the total electromagnetic energy is no longer constant since energy is lost via Joule heating in the resistor. The oscillations of charge, current and potential are now continuously decreasing with amplitude. This is referred to as damped oscillations. The oscillations in the RLC circuit will not damp out if an external emf source supplies enough energy to account for the energy lost from the resistor. This energy is supplied from an oscillating emf source with an alternating current (AC). If the applied voltage in an RLC is of the form $V = V_0\sin(\omega t + \varphi)$

where V_0 is the maximum amplitude of the emf, then the potential difference across each component can be written as

$V_R = V_{0R} \sin(\omega t)$

$V_C = V_{0C} \sin(\omega t - \pi /2)$

$V_L = V_{0L} \sin(\omega t + \pi /2)$

where V_{0R}, V_{0C}, and V_{0L} are the maximum (amplitude) voltages across the resistor, capacitor, and inductor components respectively. The ω here is the driving angular frequency. Notice that the voltage across the capacitor VC lags VR by 90◦ and the voltage across the inductor VL leads VR by 90◦. All three voltages are plotted in Figure 2.

In this lab we will only discuss series RLC circuits. Since the R, L, and C components are in series, the same current passes through them. The current in the circuit can be expressed in the form of Ohms Law as

$I = V0/ Z$

where Z is the impedance of the circuit. The impedance of a circuit is a generalized measurement of the resistance that includes the frequency dependent effects of the capacitor and the inductor. Notice that the current I is at a maximum when Z is minimum. Thus, for a given resistor R, the amplitude of the current is a maximum $\omega = 1 \sqrt{LC}$. The maximum value of the current occurs when the driving angular frequency matches the natural angular frequency at resonance. In this lab we will study an RLC circuit with an AC source to create a resonant system.

PROCEDURE :

1. You are given a resistor, an inductor and a capacitor with nominal values of R = 12 kΩ, L = 0.1 H, and C = 10 nF, respectively. Using the inductance meter / multimeter measure the values of R, L and C and compare them with the given values.

2. Construct the circuit shown in Figure 1b using the breadboard with jumper-wires. Make sure that the resistor is the last component closest to the ground end of the circuit.

3. Turn on the signal generator and set the frequency of the oscillating signal to be approximately 250 Hz (note: $\omega = 2\pi f$). The time varying voltages will be studied using the oscilloscope. The oscilloscopes allow you to measure potential difference with respect to ground.

4. As a first exercise, we will observe the voltage on the oscilloscope when the “two” sources are in phase with each other. Connect the leads from CH1 and CH2 of the oscilloscope to the LRC circuit 3. This means that both channels will measure the voltage across R.

5. Make sure both signals are visible on the display. Adjust the Horizontal and Vertical scale knobs to obtain a suitable display on the oscilloscope.

6. Are the signals from CH1 and CH2 in phase with each other? Why is this the case? Sketch the signals in your report.

7. Change the display selector from y-t to x-y (x vs. y). Use the display button and the “format” button found in the on-screen menu to toggle between the two settings. If both x and y are in phase with each other (they both reach their peaks and valleys at the same instant), the oscilloscope should display a straight line inclined at an angle (45 degrees if both inputs have the same magnitude and calibration scale). Verify this. Just as you directly observed the waveform in Procedure 6, this is another technique to check if the two signals are in phase with each other. Sketch this display in your report, remember to label the axis appropriately.

8. Change the settings to obtain the signal as in Procedure 5-6. Disconnect CH2 from the circuit and connect it to Point A as shown in Figure 1b. In this position, CH1 is still measuring the voltage across the resistor (V_R), but CH2 is now measuring the voltage across all three components (V_{RLC}). Adjust the vertical and horizontal scales to obtain the best display.

9. Are the two signals in phase with each other? Does V_{RLC} lead or lag V_R and by how much? Sketch this in your report.

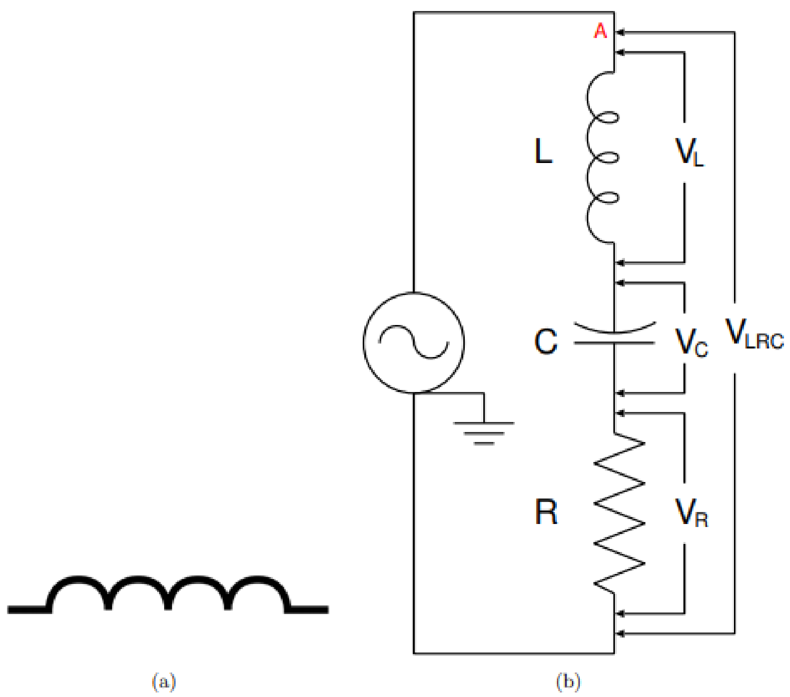

Figure 1: (a) Inductor circuit symbol. (b) An RLC circuit.

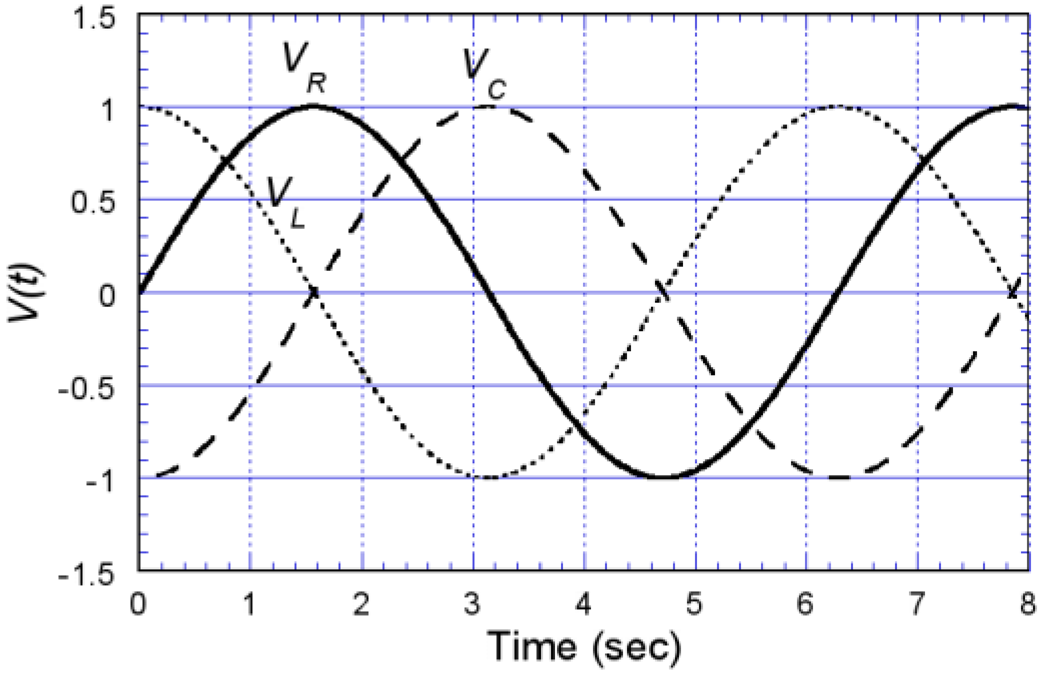

Figure 2: Phase relationships between voltages across the components of an RLC circuit

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