NED University of Engineering & Technology

Department of Electrical Engineering

LAB MANUAL

For the courses

EE-116 Principles of Electrical Engineering

EE-118 Basic Electricity and Electronics

EE-119 Fundamentals of Electrical Engineering

EE-120 Basic Electrical Engineering

EE-124 Basic Electricity and Electronics

For FE

(MY, AU, MM, PP, CH, BM, IC, CS, EL, TC, PE, ME)

Instructor name:___________________________________

Student name:_____________________________________

Roll no:____________________ **Batch:**____________________

Semester:__________________ **Year:**______ ____________

LAB MANUAL

For the course

<u>EE-116 Principles of Electrical Engineering</u>

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<u>(MY, AU, MM, PP, CH, BM, IC, CS, EL, TC, PE, ME)</u>

Last Revision Date: 17th October, 2022

Approved By

The Board of Studies of Department of Electrical Engineering

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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

Rubric based labs for BEE (EE-116 118 119 120 124 non EE depts only): 2, 4, 6, 7, 8, 12

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

CONTENTS

PBL : Make a regulated DC power supply with variable voltage from 0V to 15V and 3A maximum current. The input is 220 V AC 50 Hz.

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.**

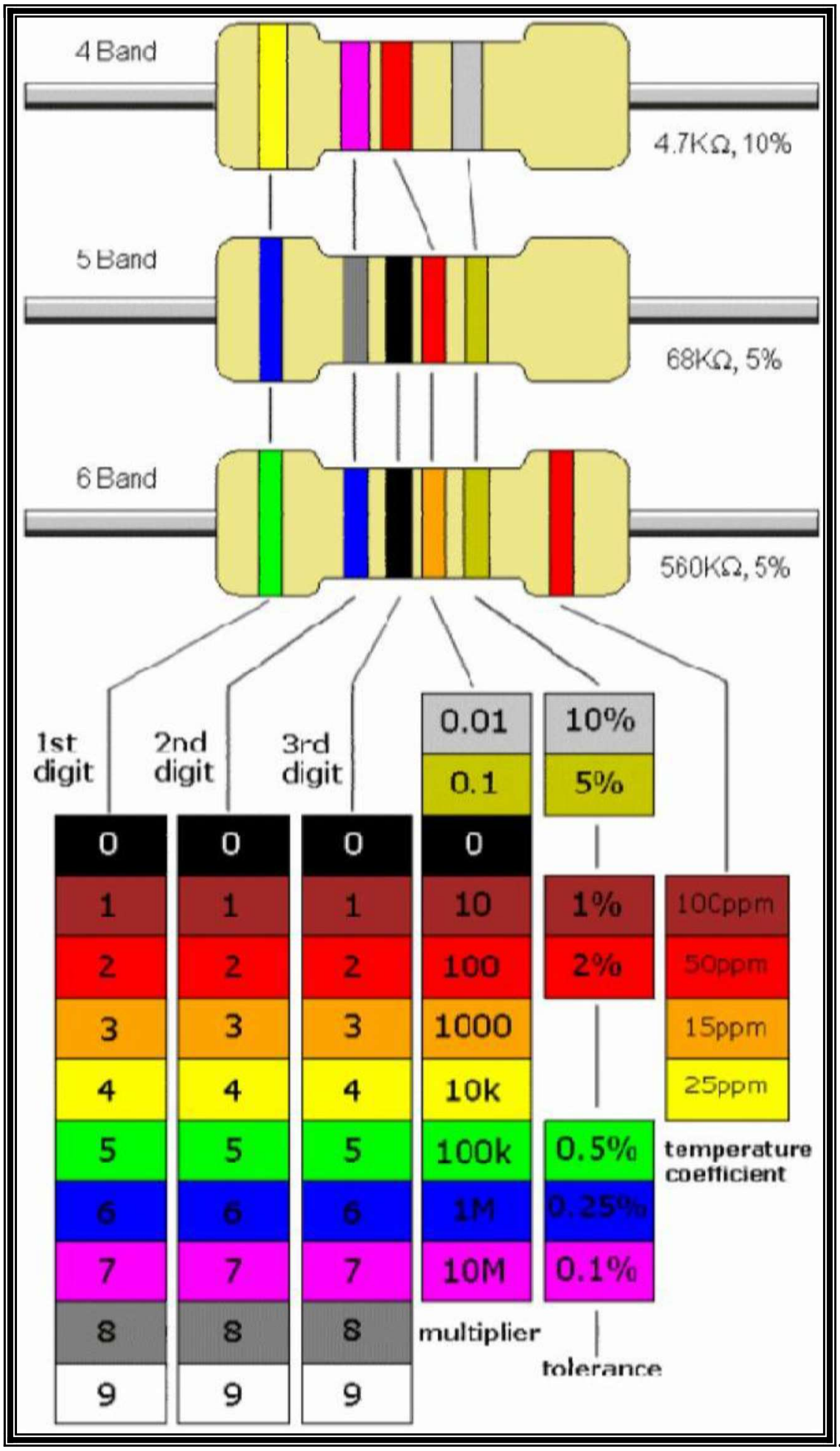
    The value of the resistor can be found by multiplying the reading by the range setting. For example, a reading of 11 on the *R* x 1 kΩ range is 11 x 1 kΩ = 11 k Ω or 11, 000 Ω.

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.

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1K	
Yellow	4	10K	
Green	5	100K	± 0.5%
Blue	6	1M	± 0.25%
Violet	7	10M	± 0.1%
Grey	8		
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%
Digit	Color	Digit	Color
0	**Black**	**7**	**Violet**


4 Band
4.7KΩ, 10%
5 Band
68KΩ, 5%
6 Band
560KΩ, 5%
1st digit
2nd digit
3rd digit
0 1 2 3 4 5 6 7 8 9
0.01
0.1
0
10
100
1000
10k
100k
1M
10M
multiplier
10%
5%
1%
2%
0.5%
0.25%
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

$$\mathbf{47 \times 10^3 \pm 10\%}$$

Thus,
Nominal resistance = $47 \times 10^3\ \Omega = 47\text{k}\ \Omega$

The possible range of actual values is:

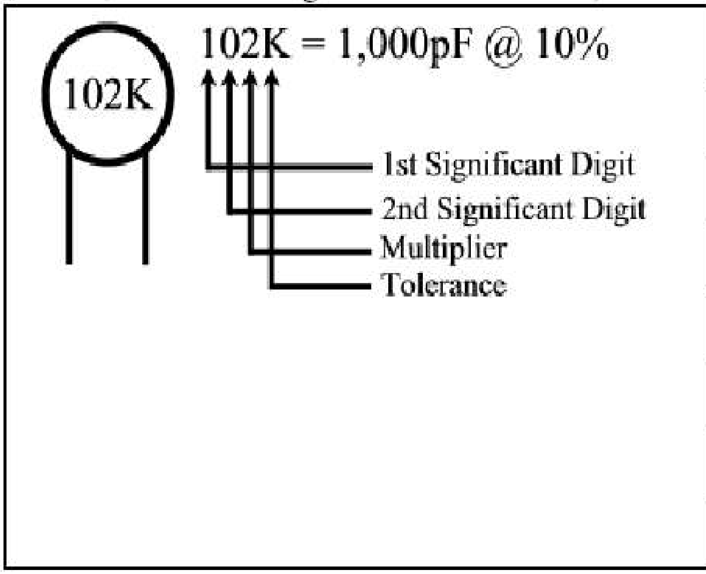
$47\ \text{k}\ \Omega \pm (0.1)\ 47\ \text{k}\ \Omega = 47\text{k}\Omega \pm 4.7\text{k}\ \Omega$
or
From **$42.3\ \text{k}\Omega$** to **$51.7\ \text{k}\ \Omega$**

"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, where as 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, where as 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).

Tens	Units	Power of 10	Capacitance
1	0	2	10×10^2 pF = 1000 pF = 1nF
4	7	2	47×10^2 pF=4.7nF±5%
3	3	3	33x10pF=33nF±10%

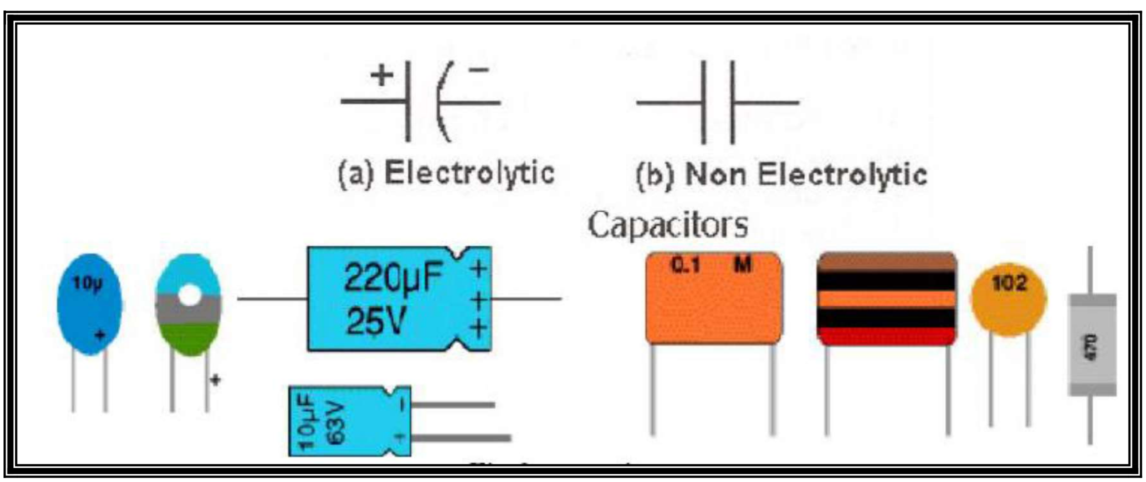


FIG: CAPACITORS

OBSERVATIONS:-

TABLE A:

Resistors	Color Bands (1, 2, 3, 4)	Color Bands (1, 2, 3, 4)	Nominal Resistance	Maximum Resistance	Minimum Resistance
Sample	**Red,Red,Black,Gold**	**2 2 0 5%**	**22Ω**	**23.1Ω**	**20.9Ω**
1					
2					
3					
4					
5					

TABLE B:

Resistor	Measured Value (VOM/DMM)	Falls Within specified tolerance (Yes/No)
Sample	**23Ω**	**Yes**
1		
2		
3		
4		
5		

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.

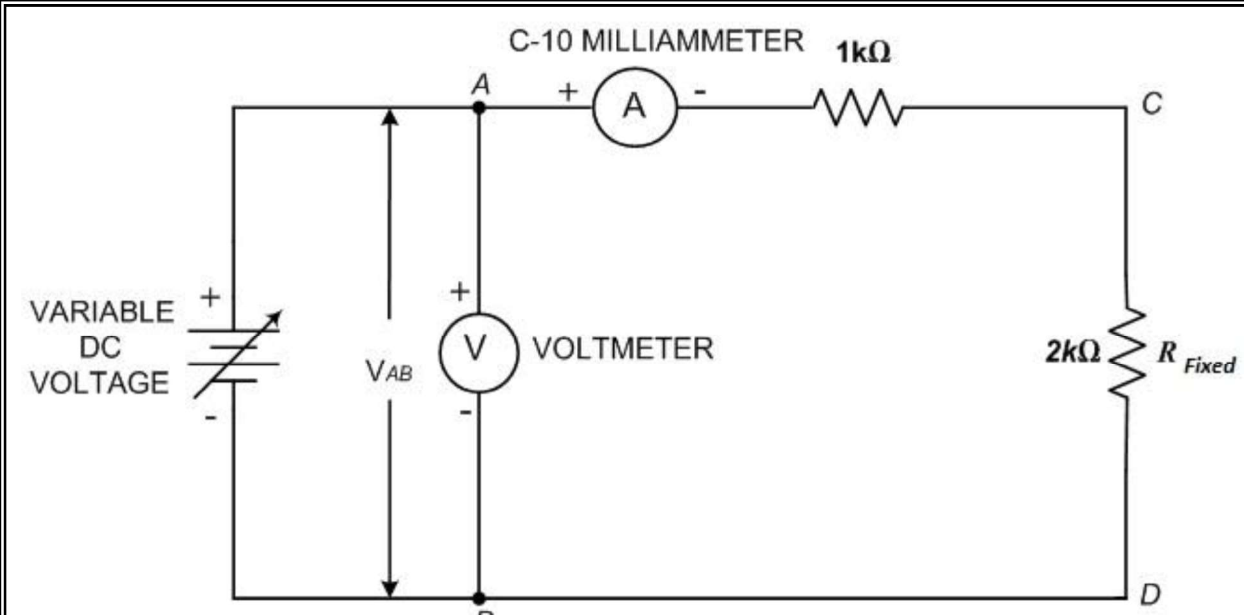

C-10 MILLIAMMETER
1kΩ
A
+
A
-
C
VARIABLE
DC
VOLTAGE
+
-
VAB
+
V
-
VOLTMETER
2kΩ
R Fixed
B
D

Fig:2.1

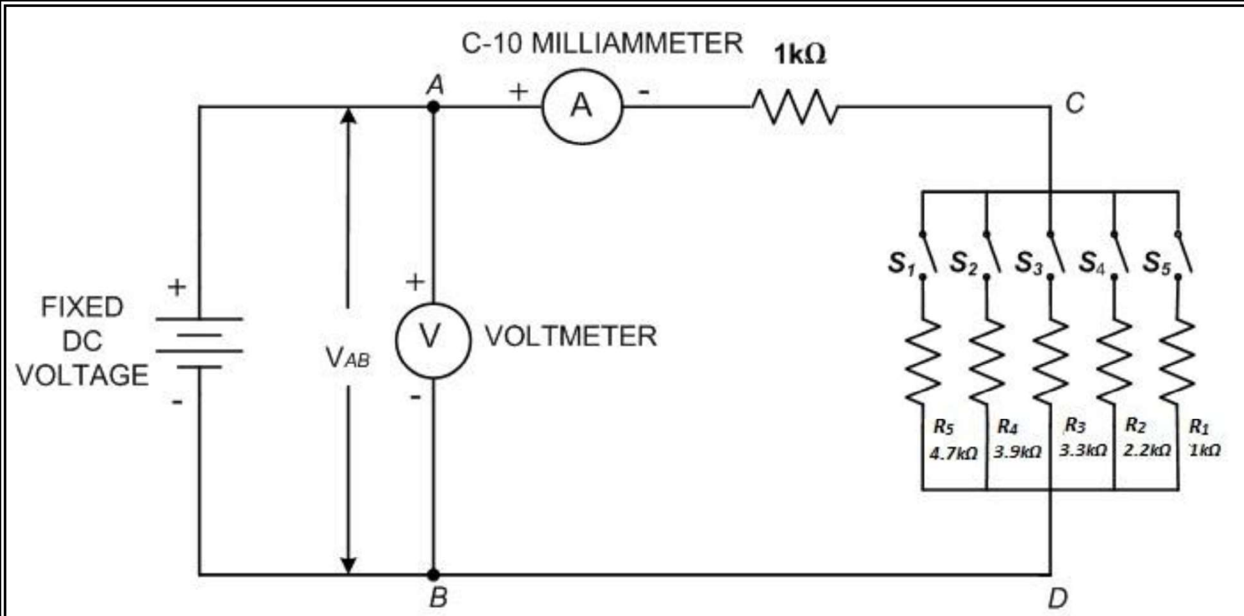

C-10 MILLIAMMETER
1kΩ
A
+
A
-
C
S1
S2
S3
S4
S5
FIXED
DC
VOLTAGE
+
-
VAB
+
V
-
VOLTMETER
R5
4.7kΩ
R4
3.9kΩ
R3
3.3kΩ
R2
2.2kΩ
R1
1kΩ
B
D

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 2000Ω 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 = 2,000 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 (amp)	R_T ((KΩ)	Calculated I (amp)
1	5	2		3	
2	10	2		3	
3	15	2		3	
4	20	2		3	
5	25	2		3	
6	30	2		3	

b) Current versus resistance:

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

CALCULATIONS:

Answer the following:

Q-1) What can you say about the relationship between voltage and current,provided that the resistance is fixed?

Q-2) Two parallel resistors (1KΩ and 3300Ω) are supplied by 15 V battery. It has been found that 3300Ω resistor draws more current? Is the statement correct? Why?

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), 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 $R_T = R_1 + R_2 + R_3$.

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.

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

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

$$\mathbf{V_1} = \frac{R_1 E}{R_T}\ ,\ \mathbf{V_2} = \frac{R_2 E}{R_T}\ ,\ \mathbf{V_3} = \frac{R_3 E}{R_T}$$

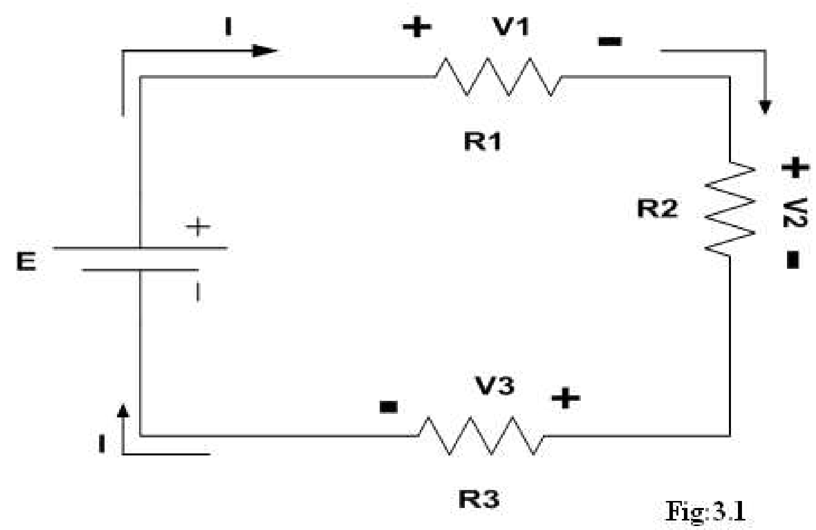


Fig:3.1

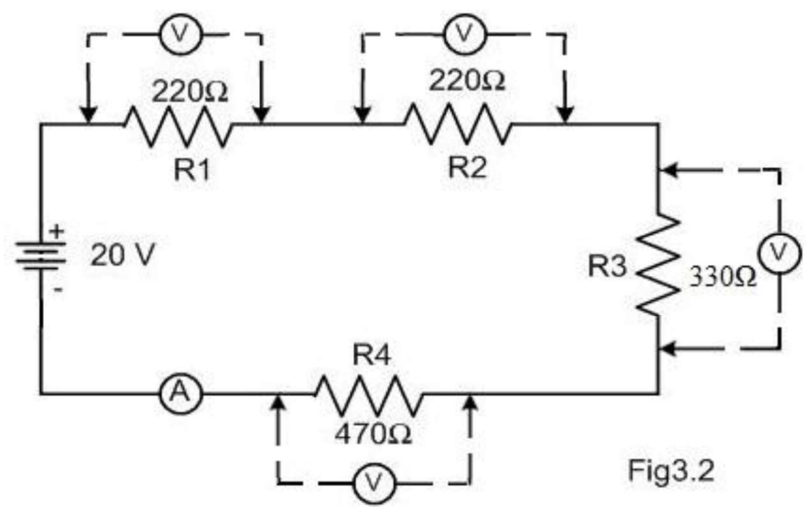


Fig3.2

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 $I_1 = \frac{V_1}{R_1}$) and R_T($R_T = \frac{E}{I}$).
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 Values (Ω)	Measured Value (Ω)	R_T (Measured) (Ω)	R_T (Calculated) ($=\frac{E}{I}$)(Ω)
1.	R_1 =220			
2.	R_2 =220			
3.	R_3 =330			
4.	R_4 =470			

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(A)	Calculated Value (A) (Ohm's Law)	Measured 'I' When R_3 is Open Circuited (A)
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.

$$\mathbf{R_T} = \frac{R_1 R_2}{R_1 + R_2}$$

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.

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

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

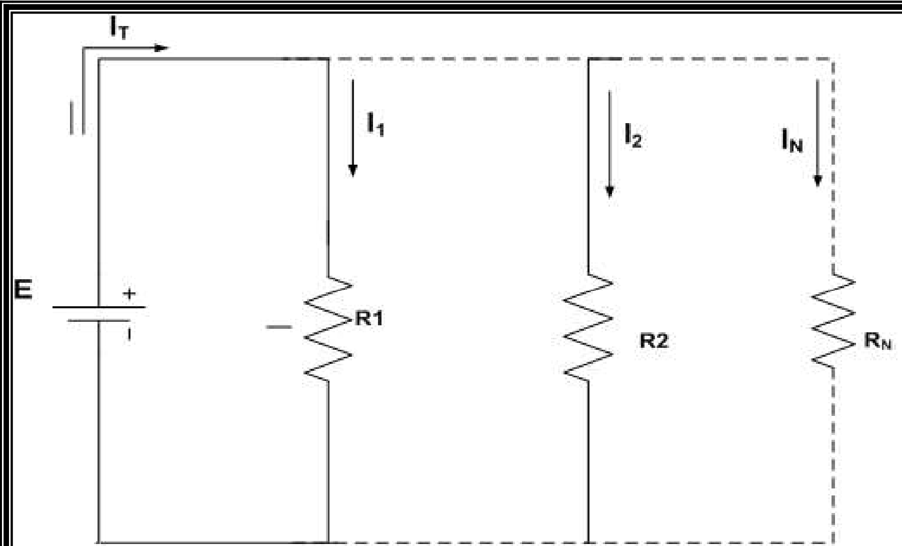


Fig:4.1

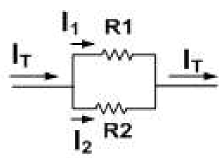


Fig:4.2

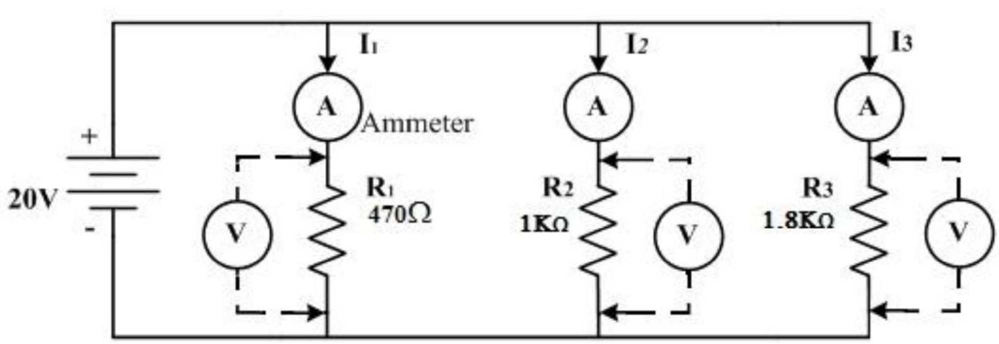


Fig: 4.3

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.

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

PROCEDURE:

1- Construct the circuit shown in Fig 4.3.
2- Set the DC supply to 15V by using DMM.
   Pick the resistances values 470Ω, 1KΩ & 1.8KΩ. 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 (Ω)	Measured Value (Ω)	R_T (Measured) (Ω)	R_T (Calculated) Ω
1.	R_1 =470Ω			
2.	R_2 =1K Ω			
3.	R_3 =1.8K Ω			

b) Voltages:

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

c) Current:

S.No	Measured Value (A)	Calculated Value (A) (CDR)	Measured Value (A) When R_2 is Open Circuited
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=

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 the 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:

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: ____

Laboratory Session: No.____________________________ Date: __________________

Psychomotor Domain Assessment Rubric-Level P3					
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	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
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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 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,

$$
\begin{array}{lll}
E_{2\text{-}1} = & +45\text{ V} & \textit{voltage from point 2 to point 1} \\
E_{3\text{-}2} = & -10\text{ V} & \textit{voltage from point 3 to point 2} \\
E_{4\text{-}3} = & -20\text{ V} & \textit{voltage from point 4 to point 3} \\
+\ E_{1\text{-}4} = & -15\text{ V} & \textit{voltage from point 1 to point 4} \\
\hline
 & 0\text{ V} &
\end{array}
$$

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"

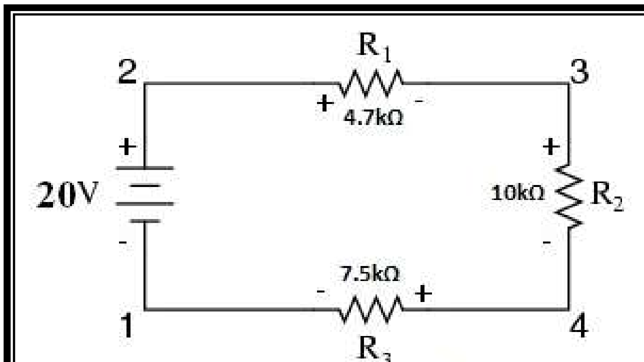


Fig: 5.1

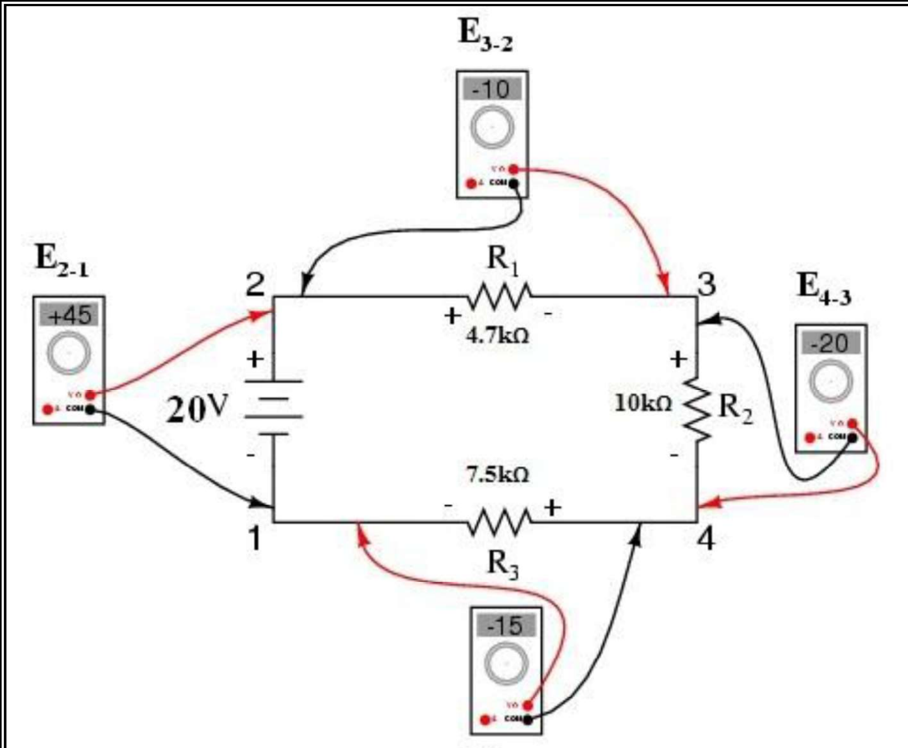


Fig: 5.2

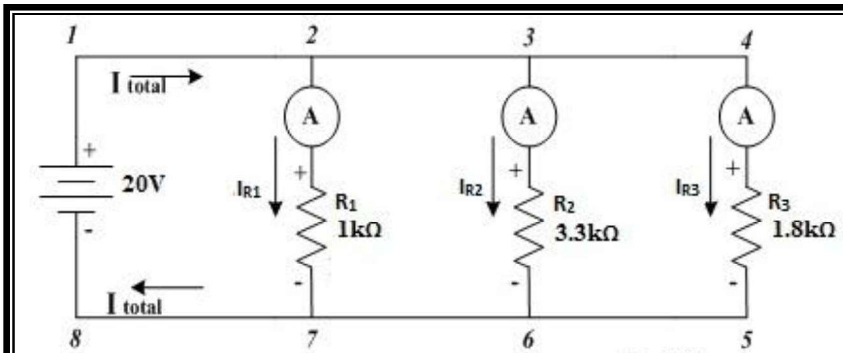


Fig:5.3

2)KIRCHHOFF'S CURRENT LAW:

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

Then, according to Kirchoff'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:

Answer the following:

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 I_{R1}=5A,I_{R2}=2A and I_{R3}=1A, then I_{total} should be equal to _____________ A.

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

LAB SESSION 06

OBJECTIVE:

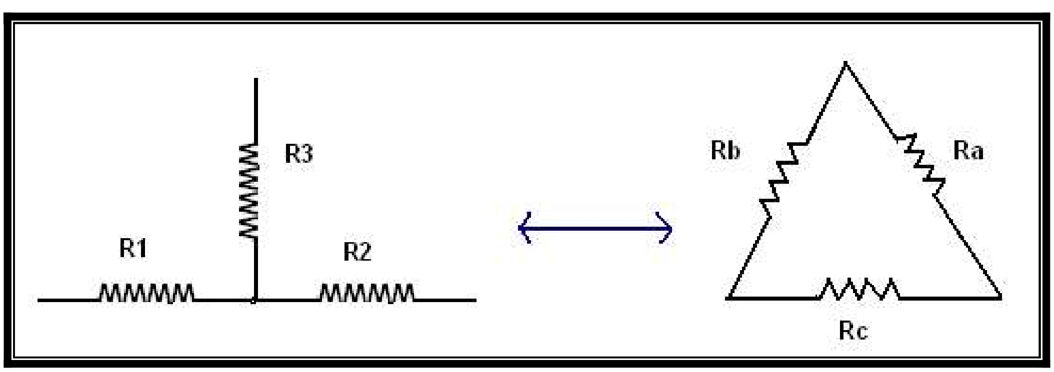
To become familiar with Star/Delta conversion and calculate power dissipated in each configuration.

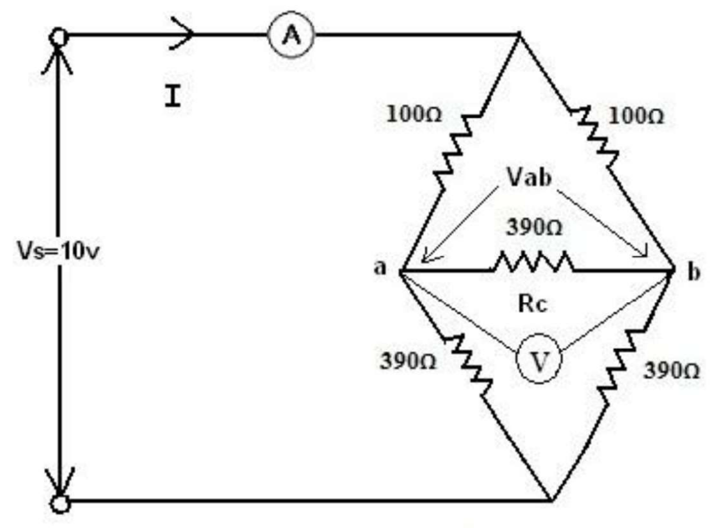
EQUIPMENTS REQUIRED:

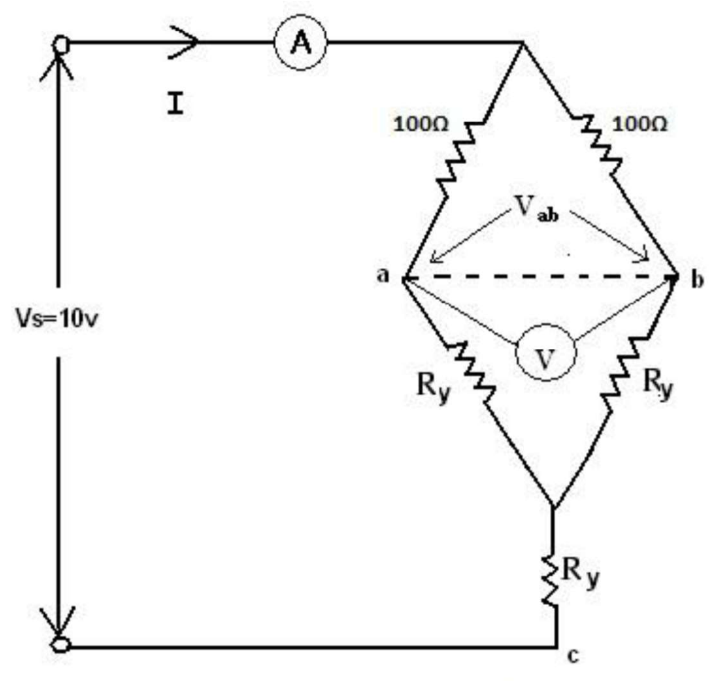
- 6x100 ohm resistors
- 3x130 ohm resistors
- 6x390 ohm resistors
- DMM
- DC power supply

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.




I
100Ω
100Ω
Vab
390Ω
Vs=10v
a
b
Rc
390Ω
V
390Ω
Fig: 6.1


I
100Ω
100Ω
Vab
a
b
Vs=10v
V
Ry
Ry
Ry
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.

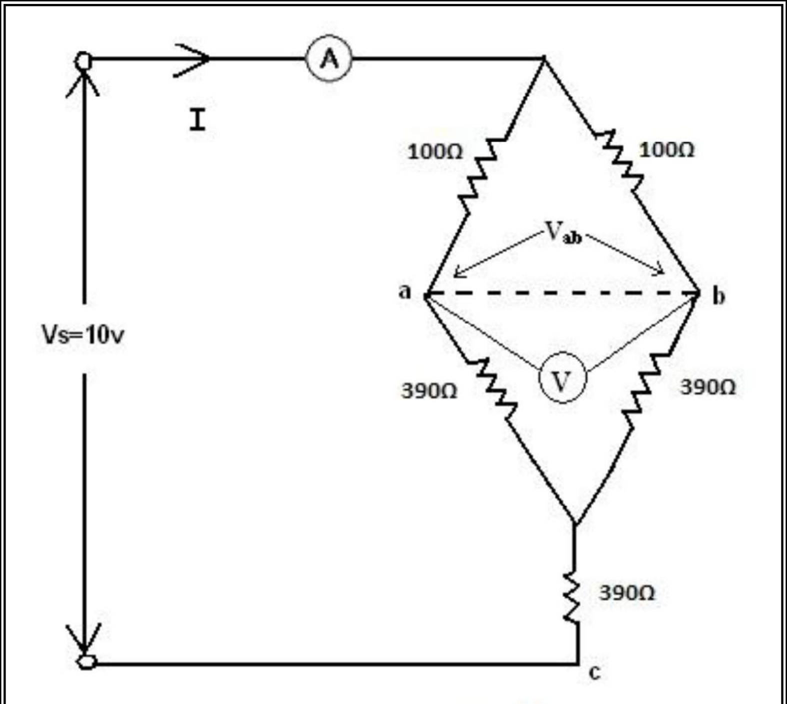


Fig: 6.3

OBSERVATIONS:

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

CALCULATIONS:

RESULT :

The star/Delta transformations are equivalent because the current 'I' and the power absorbed 'P' are the same in both the configurations (Fig:6.1 and Fig :6.2).

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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Psychomotor Domain Assessment Rubric-Level P3					
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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).

CAUTION

Be sure DC supplies have common ground.

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 $R_1 = 1\ k\ \Omega$, $R_2 = 470\ \Omega$, $R_3 = 1.8\ k\ \Omega$.

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.

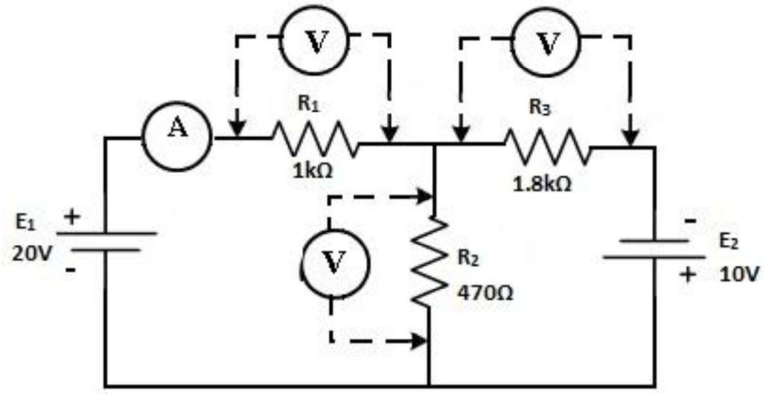

Fig: 7.1

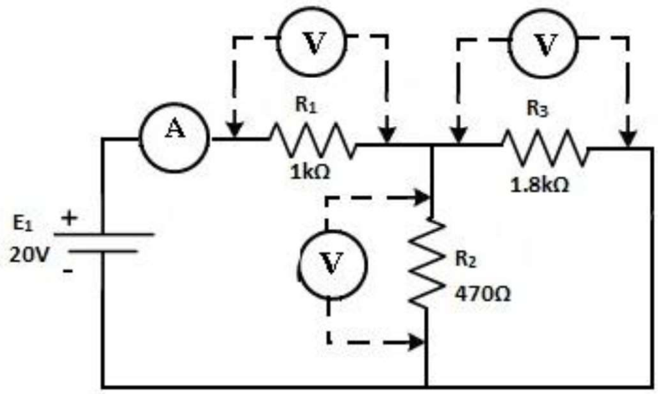

Fig: 7.2

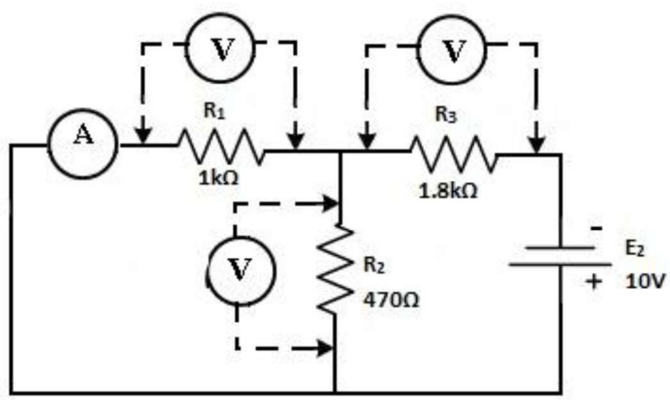

Fig: 7.3

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 =	V_1=
I_2 =	V_2=	I_2 =	V_2=	I_2 =	V_2=
I_3 =	V_3=	I_3 =	V_3=	I_3 =	V_3=

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 1 & 2

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

LAB SESSION 08

OBJECTIVES:

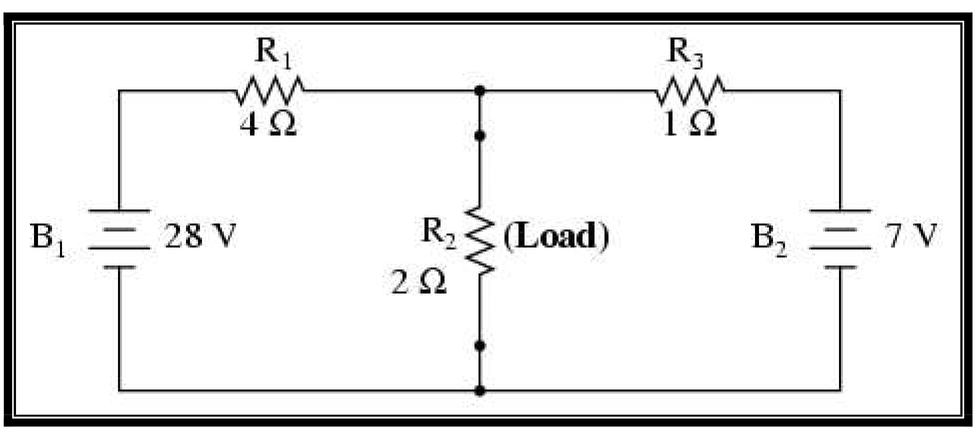
To determine by analysis the values V_{TH} (Thevenin voltage) and R_{TH} (Thevenin resistance) in a dc circuit containing a single voltage source. Also obtain the voltage across and current passing through R_L.

EQUIPMENTS REQUIRED:

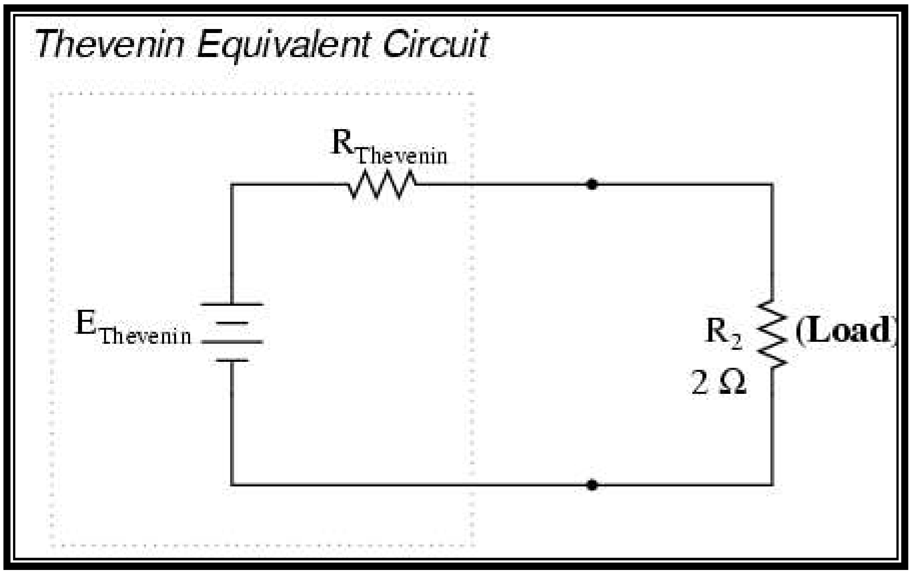
- DC power supply
- Ohmmeter
- DC ammeter
- DC voltmeter
- Resistances of values 47 Ω,220 Ω 330 Ω, 1KΩ.

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 . . .

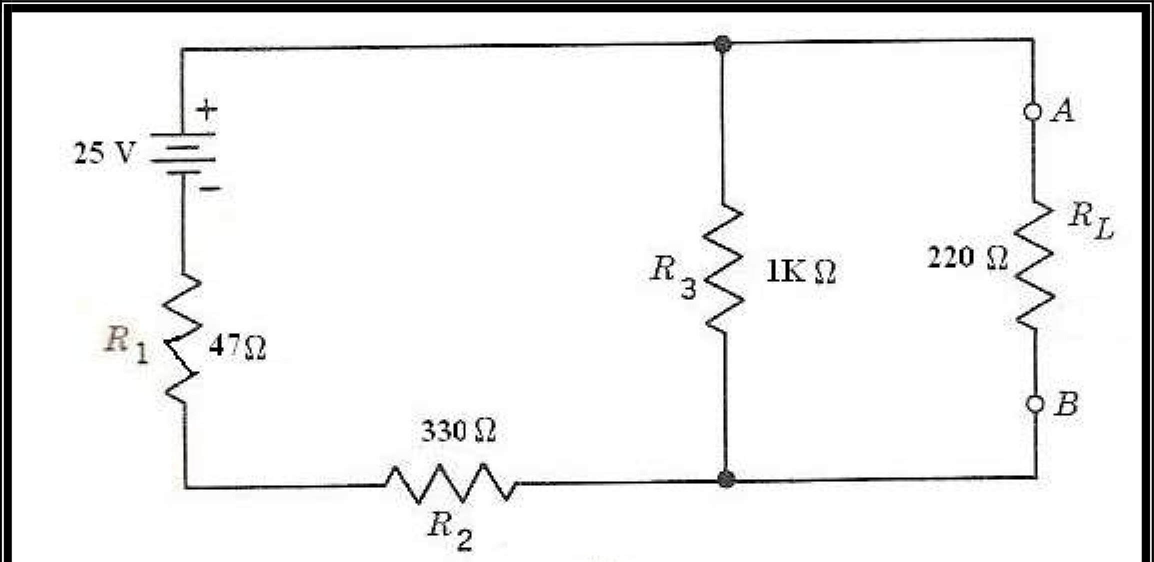


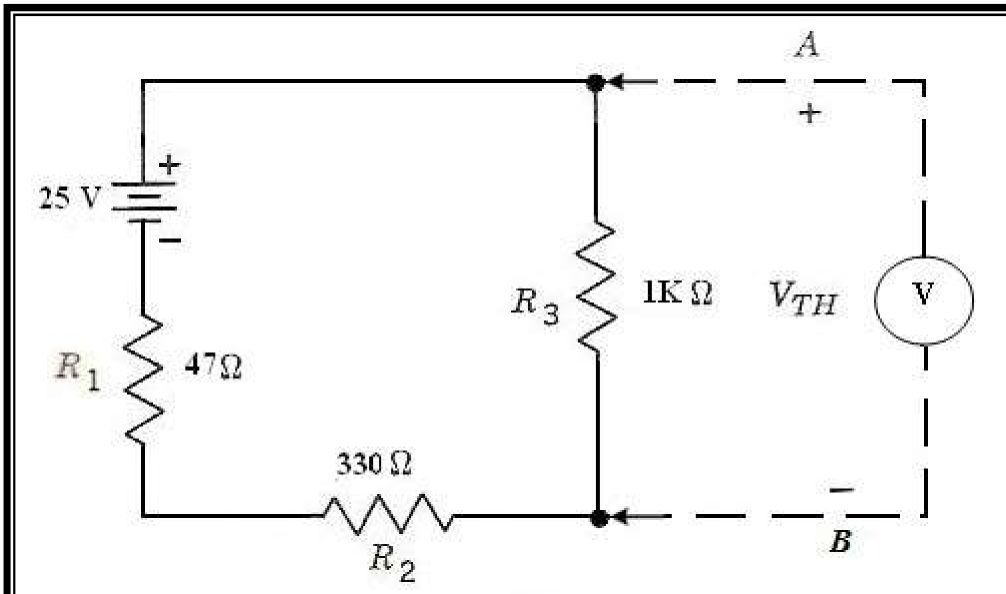
The "Thevenin Equivalent Circuit" is the electrical equivalent of B_1, R_1, R_3, and B_2 as seen from the two points where our load resistor (R_2) connects.

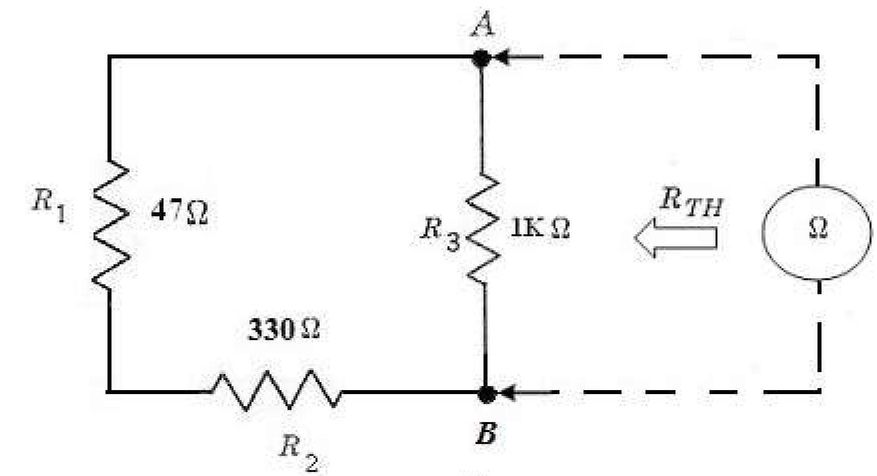
The Thevenin equivalent circuit, if correctly derived, will behave exactly the same as the original circuit formed by B_1, R_1, R_3, and B_2. In other words, the load resistor (R_2) voltage and current should be exactly the same for the same value of load resistance in the two circuits. The load resistor 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:

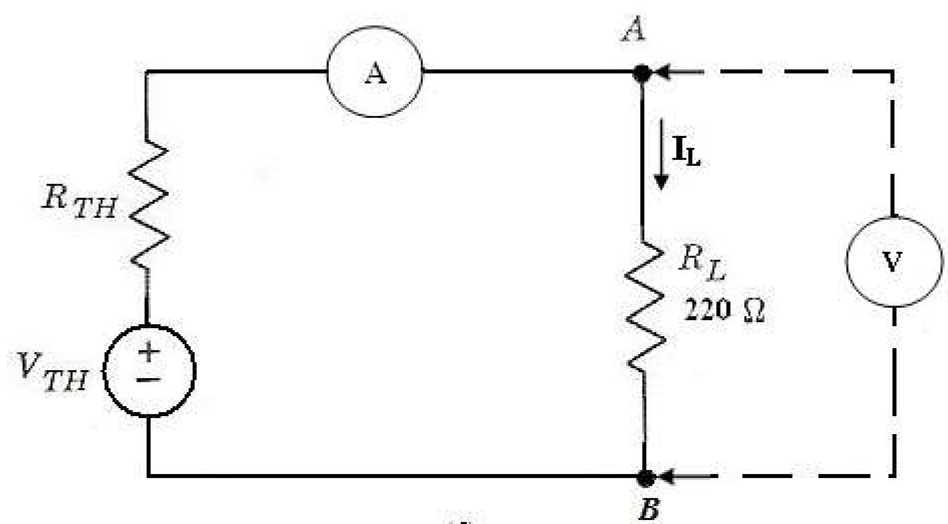
1. Connect the circuit as shown in the above 8.1(a)
2. Remove the R_L from the circuit across which the Thevinin equivalents have to be evaluated.
3. To find the R_{TH} remove the voltage-source from the circuit and short circuit the terminals from which the supply was connected. Now place an ohmmeter 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)


A
+
25 V
+
−
R_1
47Ω
330 Ω
R_2
R_3
1K Ω
V_{TH}
V
−
B
(b)



(c)



(d)

Fig: 8.1

OBSERVATIONS:

TABLE (a): Resistors

S:No:	Nominal Value(Ω)	Measured Value(Ω)
1	47	
2	220	
3	330	
4	1000	

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
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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 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

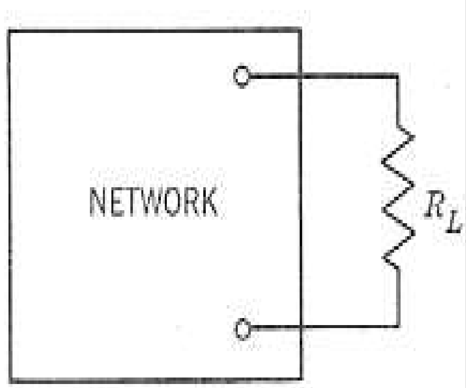
$$I_L = \frac{I_N \times R_N}{R_N + R_L}$$

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

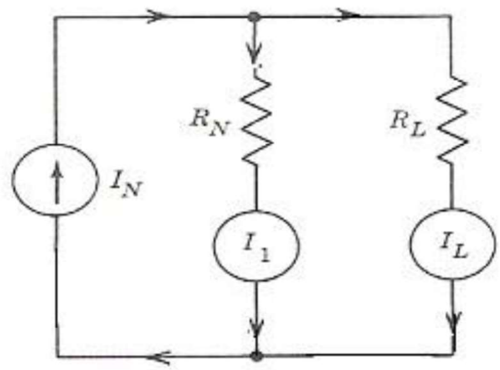
1. The constant current I_N is the current that would flow in the short circuit between the load resistance terminals if the load resistance were replaced by a short circuit.
2. The Norton resistance R_N is the resistance seen from the terminals of the *open* load, looking into the original network, 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:

$$\boxed{R_N = R_T} \qquad \boxed{E_{TH} = I_N R_N} \qquad \boxed{I_N = \frac{E_{TH}}{R_{TH}}}$$

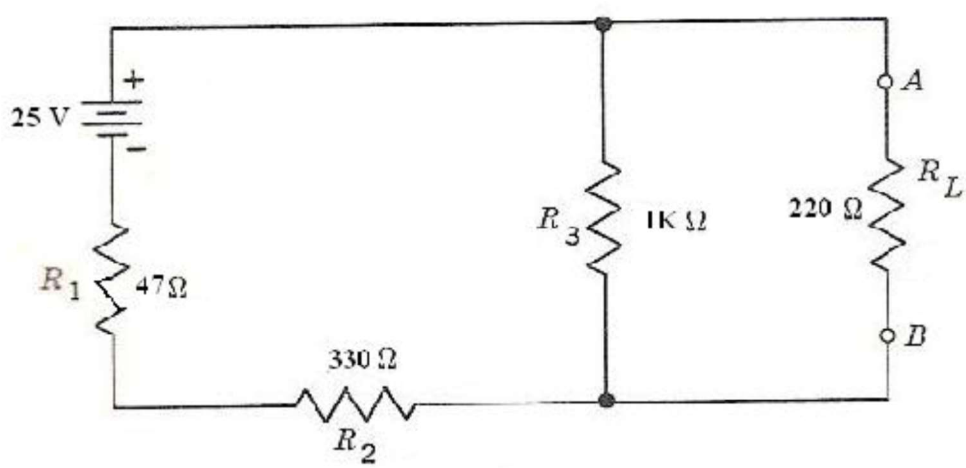


(a)

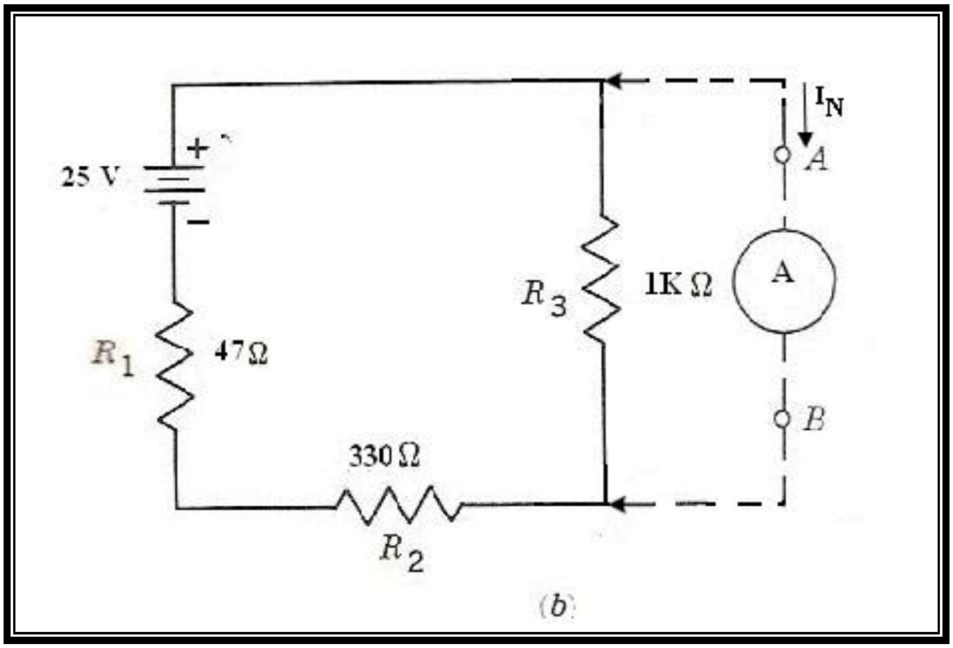


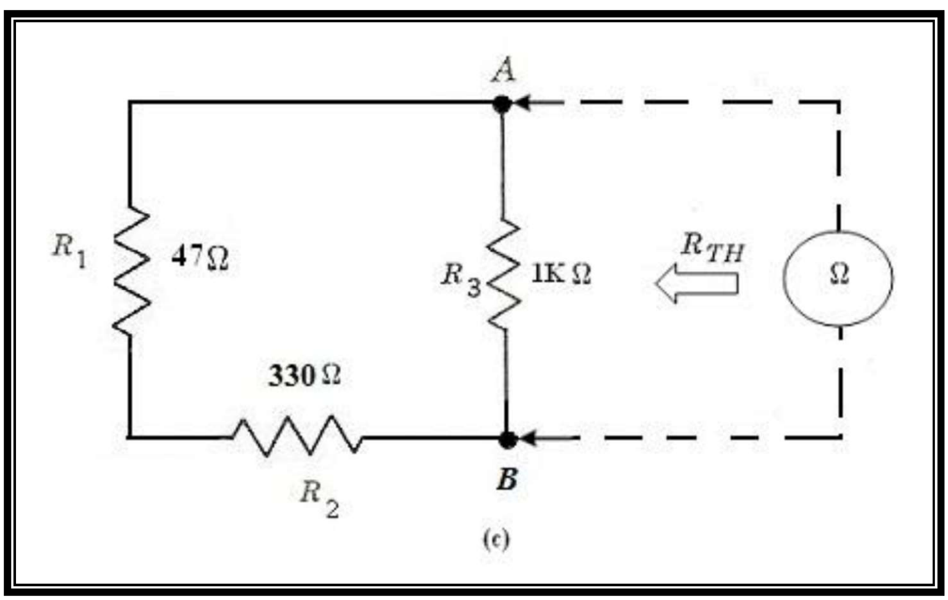
(b)

Fig: 9.1



(a)


I_N
A
25 V
+
−
R3
1K Ω
A
R1
47Ω
B
330 Ω
R2
(b)


A
R1
47Ω
R3
1K Ω
R_TH
Ω
330 Ω
R2
B
(c)

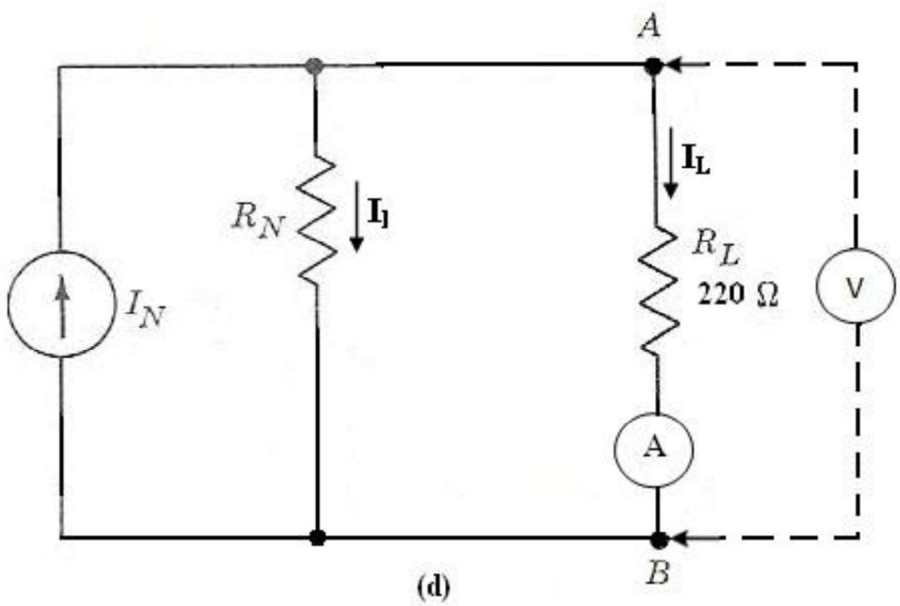


Fig: 9.2

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'sequivalent 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	47	
2	220	
3	330	
4	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 Thevinine 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, 2x120Ω.
- 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:

$$\boxed{R = \rho\ L/A}$$

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:

$$\boxed{X_L = 2\pi fL}$$

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:

$$\boxed{Xc = 1/(j2\pi fC)}$$

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

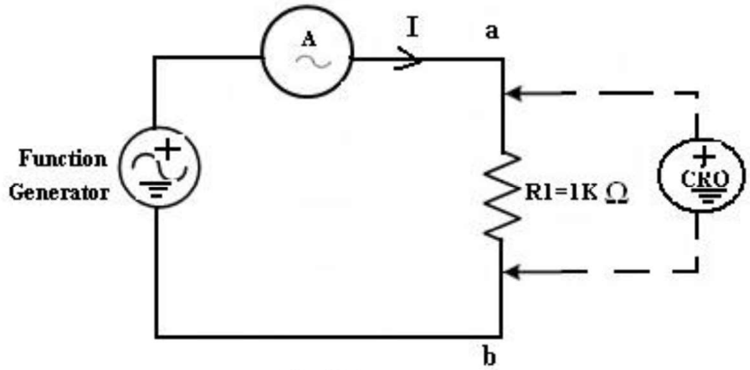


Fig:10.1

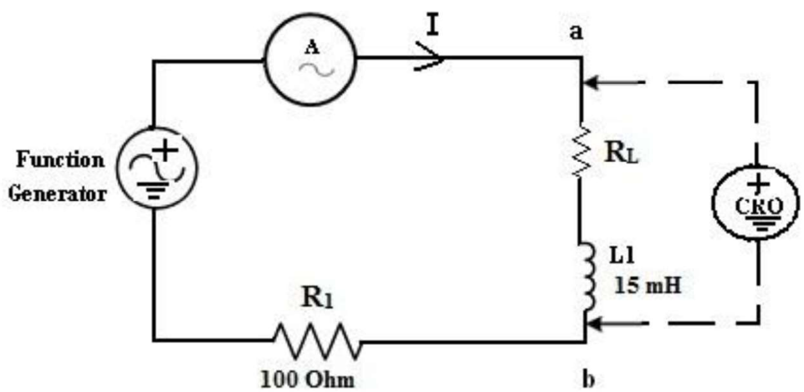


Fig: 10. 2

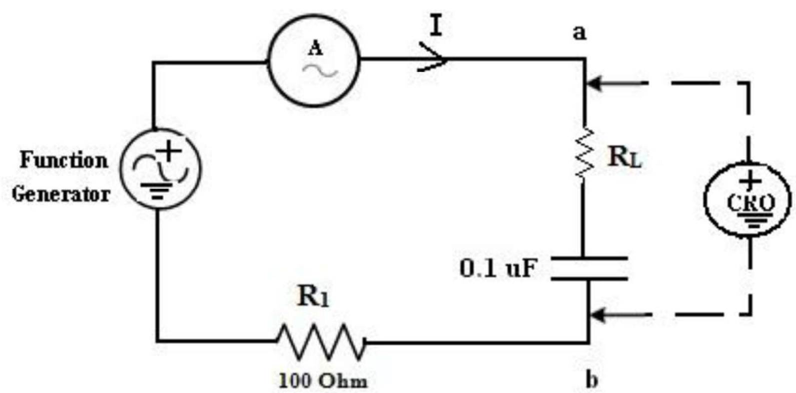


Fig:10.3

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	Frequency	Vab $_{(p-p)}$	Vab $_{(max)}$	Vab $_{(rms)}$ = $\sqrt{2}/2$ (Vab)p	Irms	R = $\frac{Vab_{(rms)}}{I_{rms}}$
1		4				
2		4				
3		4				
4		4				
5		4				

Table B:

S.No	f	Vab $_{(p-p)}$	Vab $_{(max)}$	Vab$_{(rms)}$	I_{rms}	$X_{L(measured)} = \frac{vab(rms)}{Irms}$	$X_{L(Calculated)} = 2\pi fL$
1		4 V					
2		4 V					
3		4 V					
4		4 V					
5		4 V					

Table C:

S.No	f	Vab $_{(p-p)}$	Vab $_{(max)}$	Vab$_{(rms)}$	I_{rms}	$Xc_{(measured)}$ = (Vab/Irms)	X_C (Calculated) = $(1/2\pi fc)$
1		4 V					
2		4 V					
3		4 V					
4		4 V					
5		4 V					

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?

LAB SESSION 11

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.*

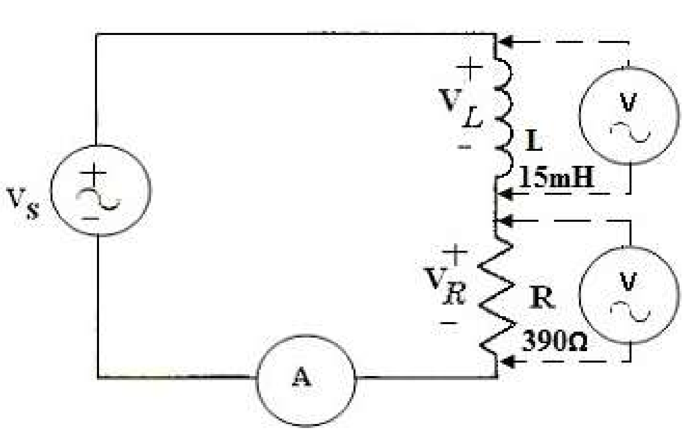


Fig: 11.1

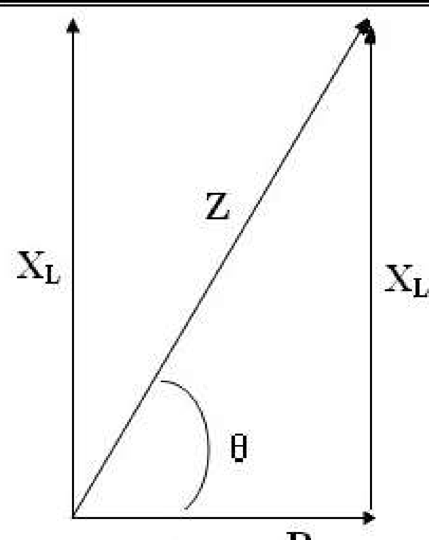
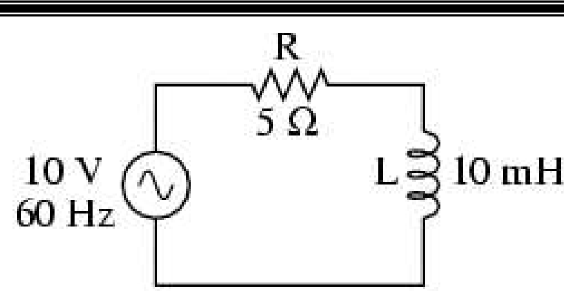


Fig: 11.2

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:

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

All quantities expressed in complex, not scalar, form

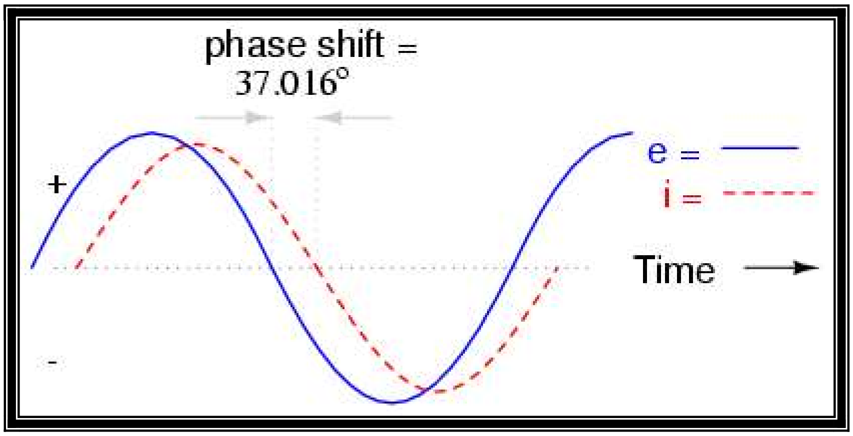
To calculate current in the above circuit, we first need to give a phase angle reference for the voltage source, which is generally assumed to be zero. (The phase angles of resistive and inductive impedance are *always* 0° and +90°, respectively, regardless of the given phase angles for voltage or current).

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

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

$$I = 1.597\ \text{A} \angle -37.016^{\circ}$$

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:

$$E = IZ$$

$$E_R = I_R R$$

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

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

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).

$$E = IZ$$

$$E_R = I_R R$$

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

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

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:

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

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

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

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

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

Also we can find θ,

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

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. *($X_L = V_L / I$; $Z = V_S /I$) Ω*

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:

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

(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:

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) Obtain the power factor of the circuit.

____

____

____

Q-3) Calculate the power factor of the circuit? Is it lagging?

Q-4) In a series RL circuit if the magnitude of V_R= 10V and Vs= 20 V, then V_L=?

Q-5) Draw the complete phasor diagram showing $\vec{V_s}$, $\vec{V_R}$, $\vec{V_L}$.

LAB SESSION 12

OBJECTIVE:

To study working of a transformer.

EQUIPMENTS REQUIRED:

- Resistors: 100 Ω (Br, Black, Brown), 220 Ω (Red, Red, Br)
  10k Ω (Br, Black, Or).
- Transformer: 220V (primary)/ 12V (secondary)
- Instruments: DMM, Function Generator

THEORY:

A transformer is a device that transfers Electrical energy from one circuit to another through electromagnetic induction, without a change in frequency. The winding connected to the energy source is called "Primary", while the winding connected to the load is called " Secondary".
A ***step-up transformer*** receives electrical energy at one voltage and delivers it at a higher voltage. Conversely, ***step-down transformer*** receives electrical energy at one voltage and delivers it at a lower voltage.

For practical applications, the apparent power at input to primary circuit($S=V_p I_p$) is equal to the apparent power at the secondary ($S=V_s I_s$)

i.e:

$V_p I_p = V_s I_s$ ---------------------------(1)

The primary and secondary voltages of a transformer satisfy the following equation:

$V_p/V_s = N_p/N_s$ ------------------------------(2)

The currents in the primary and secondary circuits are related in the following manner:

$I_p/I_s = N_s/N_p$ --------------------------------(3)

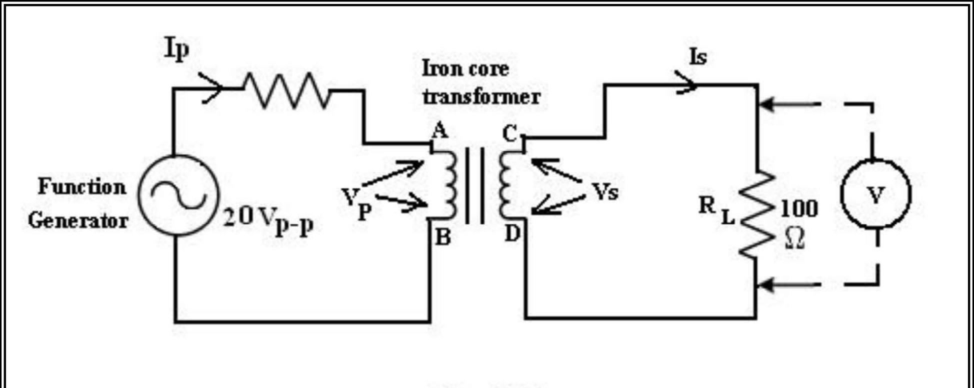


Fig: 12.1

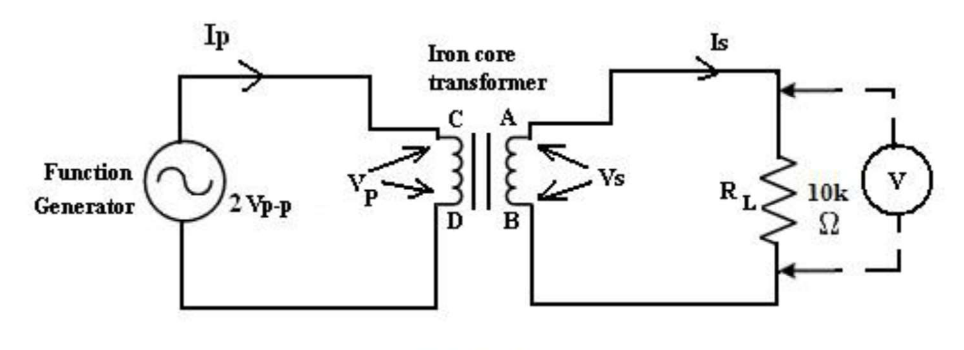


Fig: 12.2

PROCEDURE:

1-Construct the circuit of fig. 12.1. Insert measured resistor values. Set the input voltage to 20V (p-p) using oscilloscope.
2- Measure and record the primary and secondary (rms) voltages with DMM.
3- Using the measured values above, calculate the turns ratio.
4-Construct the circuit of fig. 12.2. Note the new positions of terminals A through D, i.e: transformer is hooked up in the reverse manner. Insert measured resistor values. Set the input voltage to 2V (p-p) using oscilloscope.
5-Measure and record the primary and secondary (rms) voltages with DMM.
6- Using the measured values above, calculate the turns ratio

OBSERVATIONS:

For step 2-4:

i) Vp(rms)=-------------- Vs(rms)=-----------------------

ii) Np/Ns=--------------------------

For step 5-8 :

i) Vp(rms)=-------------- Vs(rms)=-----------------------

ii) Np/Ns=--------------------------

Answer the following:

Q.1) Can a transformer be used as in both ways, (i.e: both as step-up and step-down)?

____
____

Q.2) What is the nature of transformer windings? (resistive, inductive or capacitive).What will happen if we connect primary windings of transformer with dc supply?

____
____
____

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: ____

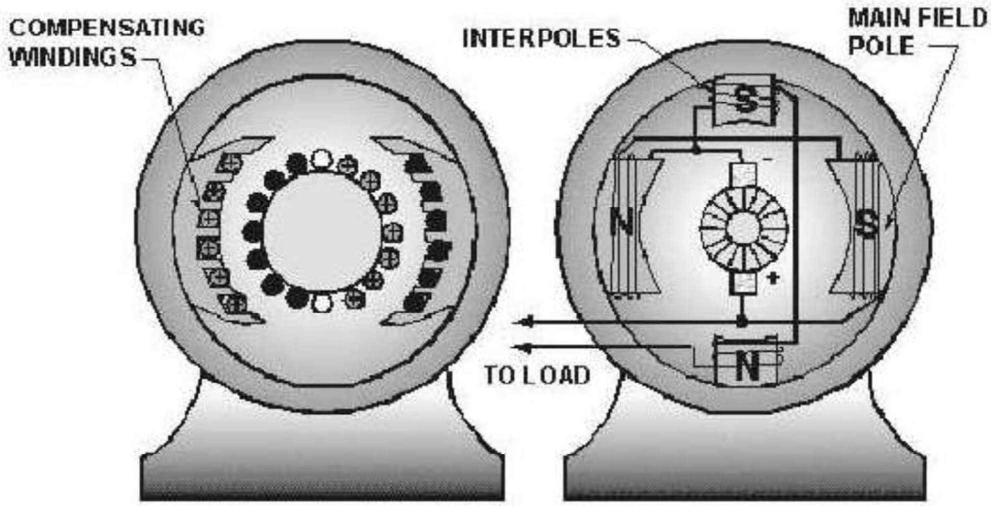
Laboratory Session: No.________________________ Date: ________________

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:					

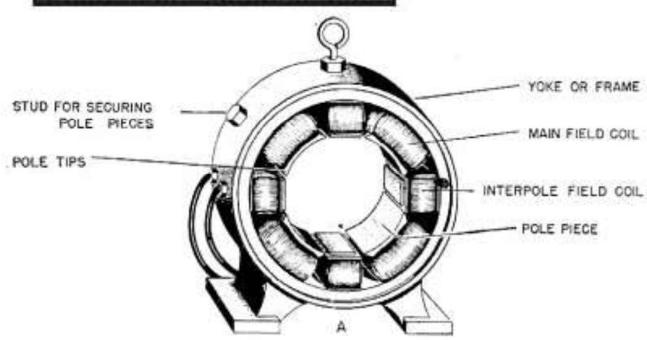
LAB SESSION 13

Object:
To study the Construction of DC Machine (Parts of DC Machine)

Introduction:
A D.C. machine consists mainly of two part the stationary part called stator and the rotating part called stator.



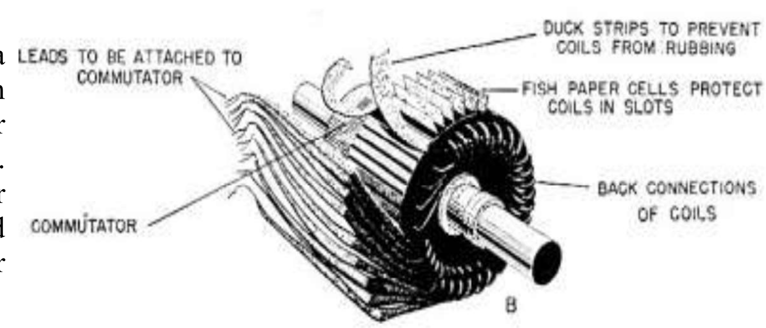
Stator:
The stator consists of main poles used to produce magnetic flux ,commutating poles or interpoles in between the main poles to avoid sparking at the commutator but in the case of small machines sometimes the interlopes are avoided and finally the frame or yoke which forms the supporting structure of the machine.



Yoke:
In early days Yoke was made up of cast iron but now it is replaced by cast steel. This is because cast iron is saturated by a flux density of 0.8 Wb./m^2 where as saturation with cast iron steel is about 1.5 Wb./m^2. So for the same magnetic flux density the cross section area needed for cast steel is less than cast iron hence the weight of the machine too. If we use cast iron there may be chances of blow holes in it while casting, so now rolled steels are developed and these have consistent magnetic and mechanical properties.

Rotor:

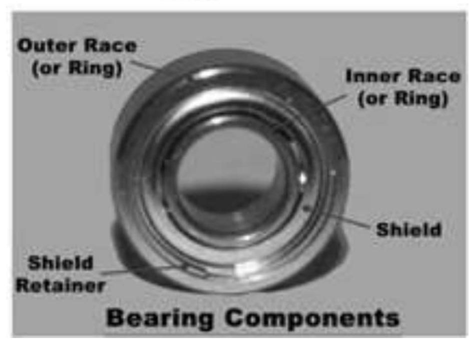
The rotor consist of an armature a cylindrical metallic body or core with slots in it to place armature windings or bars, a commutator and brush gears. The magnetic flux path in a motor or generator is show below and it is called the magnetic structure of generator or motor.



End Shields and Bearings:

If the armature diameter does not exceed 35 to 45 cm then in addition to poles end shields or frame head with bearing are attached to the frame. If the armature diameter is greater than 1m pedestal type bearings are mounted on the machine bed plate outside the frame. These bearings could be ball or roller type but generally plain pedestal bearings are employed. If the diameter of the armature is large a brush holder yoke is generally fixed to the frame.

Bearings: ball-bearings are frequently employed because of their reliability, though for heavy duties, roller bearings are preferable. The ball and rollers are generally packed in hard oil for quieter operation and for reduced bearing wear, sleeve bearings are used which are lubricated by ring oilers fed from oil reservoir in the bearing bracket.



Pole Cores and Pole Shoes:

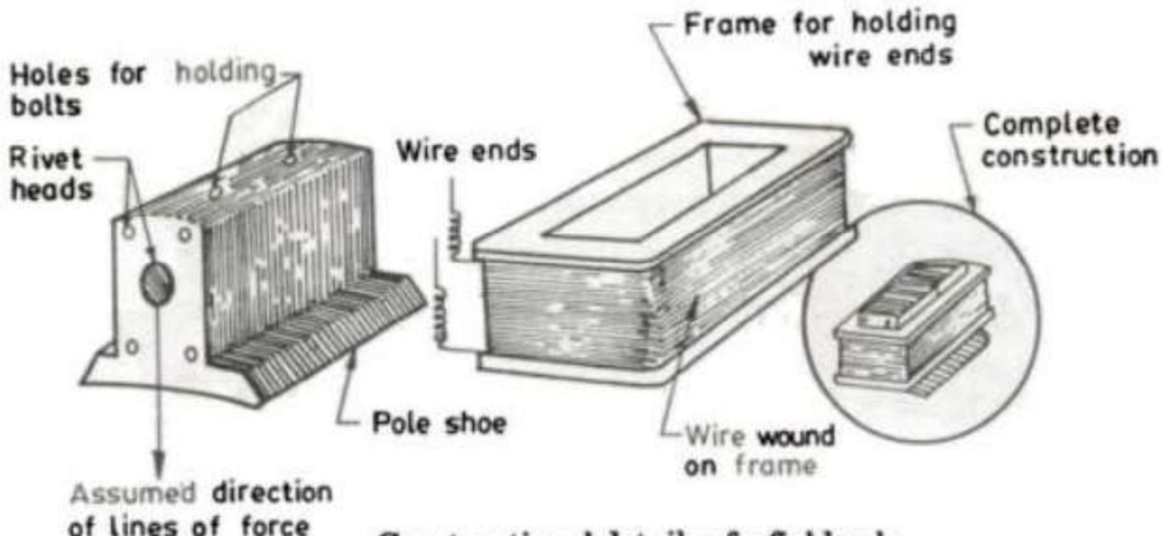
The field magnet consists of pole ores and pole shoes. The pole shoes have two purposes

(i) They spread out the flux in the air gap and also, being larger cross section, reduce the reluctance of the magnetic path.
(ii) They support the exciting coils (field coils)

Fixing pole to the yoke.

Field Poles:
The pole cores can be made from solid steel castings or from laminations. At the air gap, the pole usually fans out into what is known as a pole head or pole shoe. This is done to reduce the reluctance of the air gap. Normally the field coils are formed and placed on the pole cores and then the whole assembly is mounted to the yoke.

Field Coils:
The field coils are those windings, which are located on the poles and set up the magnetic fields in the machine. They also usually consist of copper wire are insulated from the poles. The field coils may be either shunt windings (in parallel with the armature winding) or series windings (in series with the armature winding) or a combination of both.



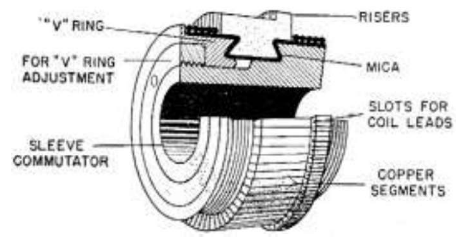
Constructional details of a field pole.

Armature Core or Stack:
The armature stack is made up thin magnetic steel laminations stamped from sheet steel with a blanking die. Slots are punched in the lamination with a slot die. Sometimes these two operations are done as one. The laminations are welded, riveted, bolted or bonded together.
It houses the armature conductors or coils and causes them to rotate and hence cut the magnetic flux of the field magnets. In addition to this its most important function is to provide a path of low reluctance to the flux through the armature from a N-pole to a S-pole. It is cylindrical or drum shaped and is built up of usually circular sheet discs or laminations approximately 5mm thick. It is keyed to the shaft.

Armature Windings:
The armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape in a coil puller. Various conductors of the coil are insulated from each other. The conductors are placed in the armature slots which are lined with tough insulating material. This slot insulation is folded over above the armature conductors placed in the slot and is secured in place by special hard wood or fiber wedges.

Commutator:

A commutator is an electrical switch that periodically reverses the current in an electric motor or electrical generator. It converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit.



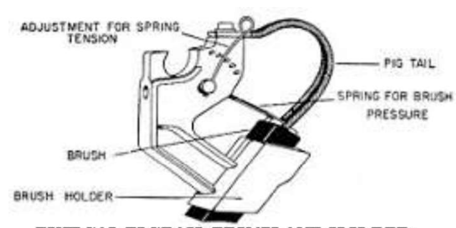
It typically consists of a set of copper contacts, fixed around the circumference of the rotating part of the machine (the rotor), and a set of spring-loaded carbon brushes fixed to the stationary part of the machine (the stator) that complete the electrical circuit from the rotor's windings to the outside of the machine. Friction between the copper contacts and the brushes eventually causes wear to both surfaces. The carbon brushes, being made of a softer material, wear faster and are designed to be replaced easily without dismantling the machine. The copper contacts are usually inaccessible and, on small motors, are not designed to be repaired. On large motors the commutator may be re-surfaced with abrasives. Each segment of the commutator is insulated from the adjacent segments; a large motor may contain hundreds of segments.

Carbon Brush

The brushes, whose function is to collect current from commutator, are usually made of carbon or graphite and are in the shape of a rectangular block. These brushes are housed in brush-holders usually of the box type variety.

Brush Holder:

Usually we use box type brush holders in all D.C. machines. At the outer end of arm a brush box is provided which is open at top and the bottom is attached. The brush is pressed to the commutator by means of a clock spring and this pressure could be adjusted by a level arrangement in the spring. The brush is connected to a flexible conductor called pigtail. The flexible conductor may be attached to the brush by a screw or may be soldered. Brush boxes are generally made of bronze casting or sheet brass. For small machines working on low voltage commutation conditions are easy and galvanized steel boxes are employed. There are individual and multiple brush holders available on the market. In multiple brush holders a number of single brush holders are built into one long assembly.



TYPICAL PIGTAIL BRUSH AND HOLDER

Rockers:
Brush holder are connected or fixed to brush rockers with bars. The brush rockers arranged concentrically round the commutator. Cast iron is usually used for brush rockers.

Result: Hence we studied the structure of DC machine.

LAB SESSION 14

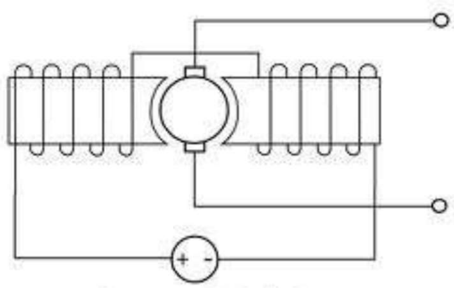
Object: To determine and compare the characteristics of DC Shunt Generator and DC separately-excited generator.

Apparatus:

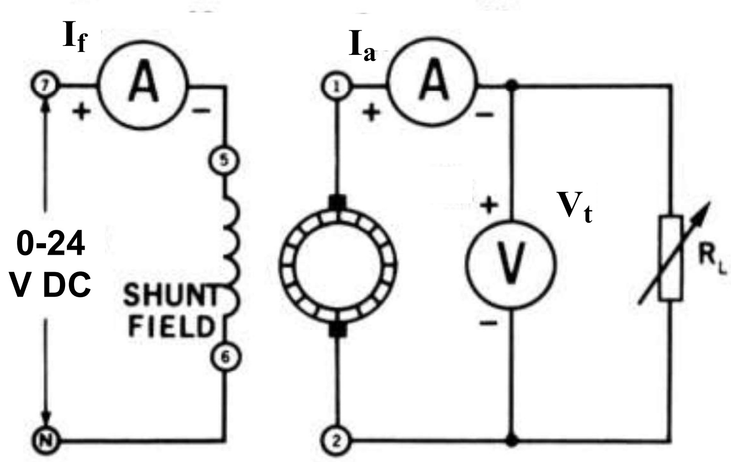
1.	3-Phase Induction Motor	1No.
2.	Auto transformer (1-Phase)	1No.
3.	VoltmeterDC	1No.
4.	Ammeters DC	2No.
6.	Digital tachometer	1No.
7.	DC Power Supply Unit	2No.

DC Separately-Excited Shunt Generator

Theory003A



The field windings may be separately excited from an external DC source as shown in Fig above. The required field current is a very small fraction of the rated armature current on the order of 1to 3percent in the average generator. Because of this, a small amount of power in the field circuit may control a relatively large amount of power in the armature circuit; i.e., the generator is a power amplifier.



Procedure:

1. Due to its constant speed, DC motor (Fig. above) will be used to drive the DC generators.

2. Construct the circuit implementing the DC separately excited shunt generator as shown in Figure above.
3. Set up the load resistance to ∞ (open circuit). Make sure that the switch in the DC motor is open (lower position). Close the motor's switch. Vary the shunt field current by changing the DC voltage on the PS.
4. Measure and record in a Data table the values of terminal voltage V_t, armature current I_a, and field current.
5. Reverse the polarity of the shunt field by interchanging the leads to terminals 5 and 6 on the generator. Turn ON the PS and adjust for a field current of 100 mA. Record the values of currents and voltage in your data table. Return the voltage to zero and turn OFF the PS.
7. Reverse the rotation of the driving motor by interchanging any two of the stator lead connections (terminals 1, 2, or 3) to the DC motor. Turn ON the PS and adjust for a field current of 300 mA. Record the values of currents and voltage in your data table. Return the voltage to zero and turn OFF the PS.
8. By the proper selection of resistance switches, set the load resistance to 120 Ω (refer to Table 08-1 for help).

Table 08-1

I_f	100 mA			150 mA			200 mA		
R_L \ rpm	1200	600	300	1200	600	300	1200	600	300
∞									
20 Ω									
15 Ω									
12 Ω									
10 Ω									
8.0 Ω									
7.5 Ω									

9. Turn ON the PS and adjust the shunt field current I_F until the output voltage of the generator is 120 V. The output current must be approximately 1 A. Record the values of voltage and currents in the Data table. The value of the field current is nominal at the rated power output (24 V, 10A, 240 W) of the DC generator.
10. Adjust the load resistance to obtain each of the values listed in Table above while maintaining the nominal field current found in Part 7. Record armature voltage and current and the field current in your data table for each load resistance. Note: although the nominal output current rating of the generator is 10 A, it may be overloaded by 50 % without any harm.
11. With the load resistance of 7.5 Ω, turn the field current OFF by setting the voltage by the PS to zero. Do you notice that the driving motor seems to work harder when the generator is delivering power to the load?

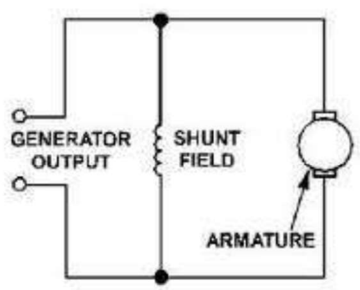
DC Self-excited Shunt Generator

Theory:

A DC generator whose field magnet winding is supplied current from the output of the generator itself is called a self-excited generator.
There are three types of self-excited generators depending upon the manner in which the field winding is connected to the armature, namely;

(i) Series generator;
(ii) Shunt generator;
(iii) Compound generator

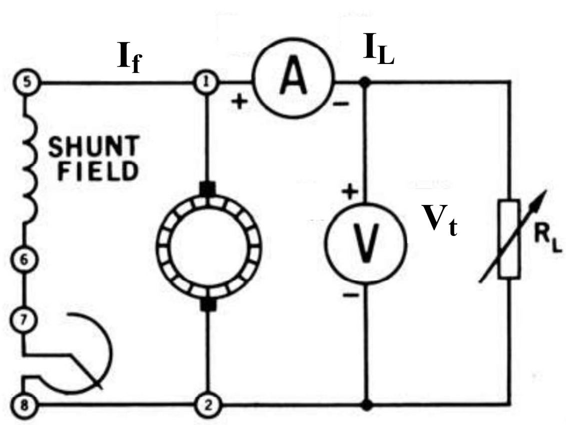
Shunt generator



In a shunt generator, the field winding is connected in parallel with the armature winding so that terminal voltage of the generator is applied across it. The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of armature current flows through shunt field winding and the rest flows through the load. The connections of a shunt-wound generator.

Procedure:

01. Construct the circuit of the DC self-excited shunt generator as shown in Figure 08-4. Place the resistance switches to the no-load positions. Turn the DC generator field rheostat control knob to its utmost clockwise position for minimum resistance.08-4.



02. Turn ON the PS. The DC motor should start running. Notice if the armature voltage E_A builds up. If not, turn OFF the PS and interchange the shunt field leads at terminals *5* and *6*. Vary the field rheostat and notice if the armature voltage changes.
03. Set up the load resistance to 120 Ω and adjust the field rheostat until the generator delivers the output voltage of 120 V. Consult with your instructor if 120 V cannot be

reached (the generator brushes may need adjustment). The armature current must be approximately 1 A. Once the rated voltage and current are delivered to the load, the correct setting for the field rheostat is achieved. Do not readjust the field rheostat for the remainder of the experiment with self-excited generator!

04. Adjust the load resistance switches to obtain each of the values listed in Table 08-1. Record the values of armature voltage, armature current, and power delivered to the load in a new Data table. Turn OFF the PS.
05. Reverse the rotation of the driving motor by interchanging any two of the stator lead connections (terminals 1, 2, or 3) to the synchronous motor. Remove the generator's load. Turn ON the PS. Does the generator voltage build up?

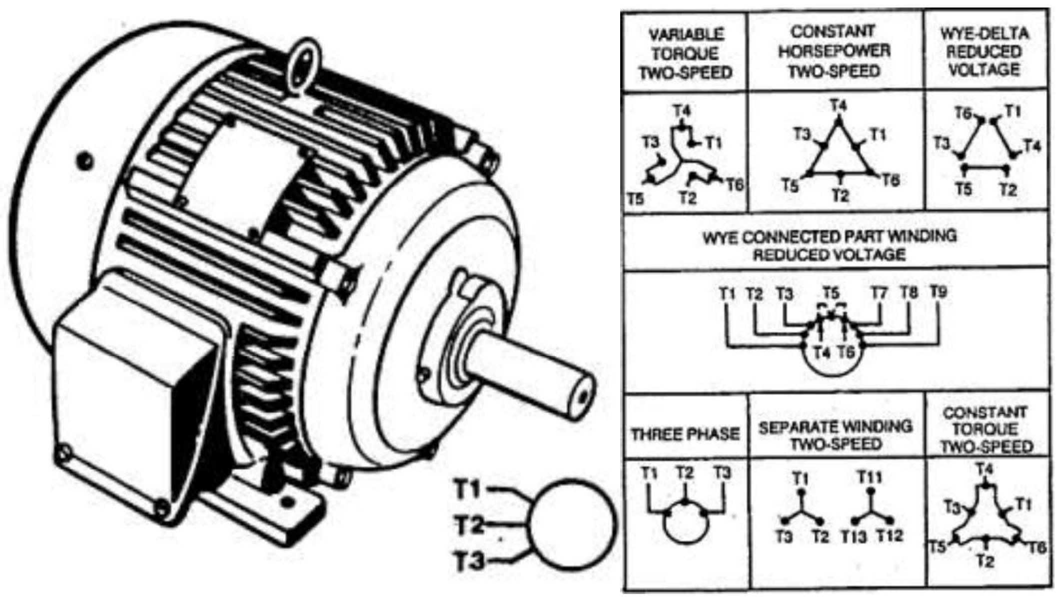
Result: Hence we studied the working of shunt generator and separately excited generator on load.

LAB SESSION 15

Object:
To study The Three Phase AC induction motors and their parts.

Apparatus:
1. AC motors
2. Tool Kit

Three-Phase Alternating Current Motors:
One of the classifications of parts of electric motors is according to the state of component i.e. stationary or rotating. If it is rotating, it is called rotor otherwise it is known as stator. Construction of rotor in DC motor is different from rotor used in 3-phase induction motor.
Most of the power-generating systems produce AC. For this reason, a majority of the motors used operate on AC. There are other advantages to using AC. In general, AC motors are less expensive and easier to maintain than DC machines.
An AC motor is particularly well suited for constant speed operations. This is because its speed is determined by the frequency of the power source and the number of poles constructed in the motor.
Alternating current motors are built in different sizes, shapes, and ratings for many different applications. It is impossible to address all forms of AC motors in this text. This article will address only the squirrel cage induction motor.

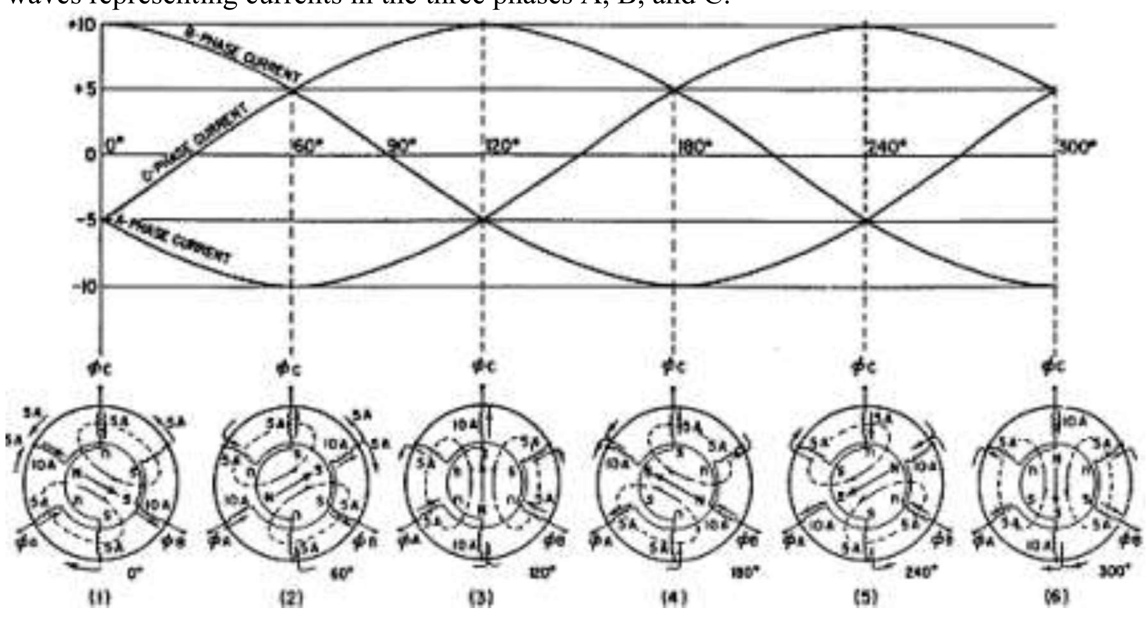


Induction Motor Principle:
The principle of the revolving magnetic field is the key to the operation of the AC motor. Induction motors rely on revolving magnetic fields in their stators (stationary windings) to cause their rotors to turn. Stators themselves do not turn. Stators are permanently attached to the inside of the motor housing in the same manner that the stationary windings in the generator are connected to the main frame. The revolving

magnetic fields created in the stator windings provide the necessary torque to move the rotor.
A magnetic field in a stator can be made to appear to rotate electrically, around the inside periphery of the motor housing. This is done by overlapping several different stator windings. A magnetic field is developed in each different stator winding at a different time. Just before the magnetic field of one winding decays, the winding overlapping it develops the same magnetic polarity. As this second magnetic field decays in the second winding develops a magnetic field of the same polarity, and the sequence repeats itself. Successive stator windings develop magnetic fields in an orderly procession and appear to progressively move around the inside of the motor housing. These individual magnetic fields are the property of current flow in the motor stator. This current flow comes from the three individual phase currents of the three-phase generator output. The figure shows the three single-phase voltages/currents that develop in the generator main armature completing individual circuits. Circuit A-B in the generator armature has a like A-B winding in the motor's stator. Each of the three circuit combinations (A-B, B-C, and C-A) are developed independently in the generator over a short period of time. The generator circuits are then completed through the motor's stator windings in a similar manner. As long as the current and magnetic field develops and decays in an orderly, progressive manner around the periphery of the motor frame, a revolving magnetic field exists.
A revolving magnetic field in the stator is only part of the operation. Another magnetic field needs to be created in the rotor so that the torque and rotation can develop using the principles of magnetic attraction and repulsion. The magnetic field developed in the rotor is a product of induction. As soon as the stator and the rotor windings develop their magnetic affiliation, torque will develop, and the rotor will turn.

Revolving Field Operation:

The rotating field is set up by out-of-phase currents in the stator windings. The figure below shows the manner in which a rotating field is produced by stationary coils or windings when they are supplied by a three-phase current source. For the purpose of explanation, rotation of the field is developed in the figure by "stopping" it at six selected positions, or instants. These instants are marked off at 60-degree intervals on the sine waves representing currents in the three phases A, B, and C.



At instant 1, the current in phase B is maximum positive. (Assume plus 10 amperes in this example.) Current is considered to be positive when it is flowing out from a motor terminal. At the same time (instant 1), current flows into A and C terminals at half value (minus 5 amperes each in this case). These currents combine at the neutral (common connection) to supply plus 10 amperes out through the B phase. The resulting field at instant 1 is established downward and to the right as shown by the arrow N_S. The major part of this field is produced by the B phase (full strength at this time) and is aided by the adjacent phases A and C (half strength). The weaker parts of the field are indicated by the letters n ands. The field is a two-pole field extending across the space that would normally contain the rotor.
At instant 2, the current in phase B is reduced to half value (plus 5 amperes in this example). The current in phase C has reversed its flow from minus 5 amperes to plus 5 amperes, and the current in phase A has increased from minus 5 amperes to minus 10 amperes.
The resulting field at instant 2 is now established upward and to the right as shown by the arrow N_S. The major part of the field is produced by phase A (full strength) and the weaker parts by phases B and C (half strength).
At instant 3, the current in phase C is plus 10 amperes, and the field extends vertically upward. At instant 4 the current in phase B becomes minus 10 amperes, and the field extends upward and to the left. At instant 5, the current in phase A becomes plus 10 amperes, and the field extends downward and to the left. At instant 6, the current in phase C is minus 10 amperes, and the field extends vertically downward. In instant 7 (not shown), the current corresponds to instant 1 when the field again extends downward and to the right.
Thus, a full rotation of the two-pole field has been done through one full cycle of 360˚ electrical of the three-phase currents flowing through the stator windings.

Synchronous Speed:

The number of poles in the motor will determine how many times the magnetic field in the stator revolves for any given generated frequency. The following definition of a motor pole gives it a practical application value: A motor pole is the completed circuit of a motor stator winding that, when energized by a current, will produce a magnetic field concentration, or polarity.
The speed of the revolving stator field is called synchronous speed. The synchronous speed depends on two factors:
- The number of poles.
- The frequency of the power source.

The synchronous speed, in turn, determines the speed of the motor rotor. Just as with the generator prime mover speed, the generated frequency and rotor speed are directly related. The number of poles in the motor determines how fast the revolving field will move around the inside periphery of the motor housing at a given frequency. The table shows the speed of the revolving field (or synchronous speed) for a 50-Hz.
generated power supply.

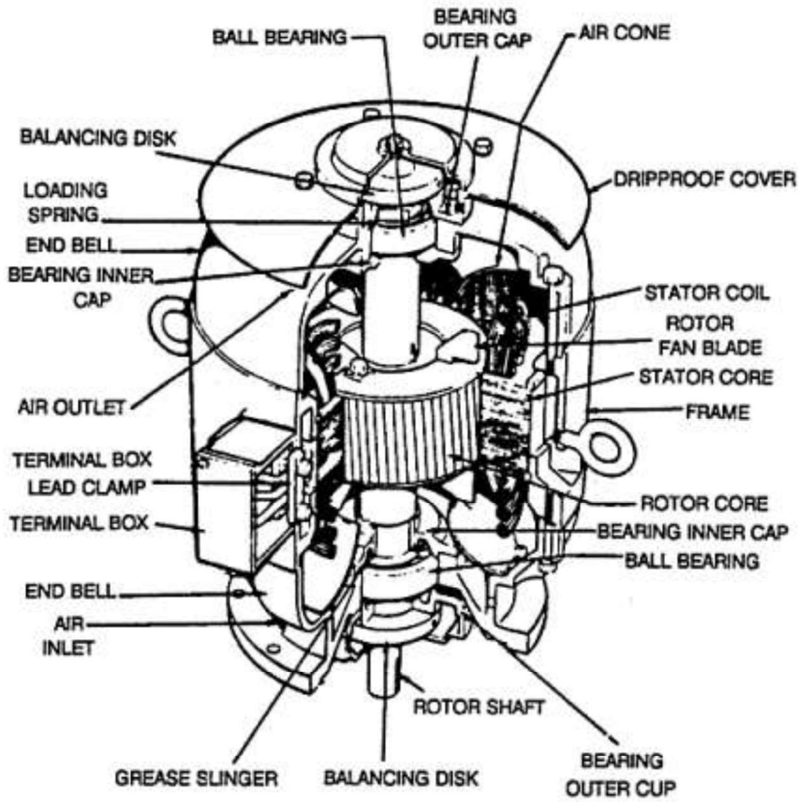
No. of Poles in the Motor	Stator Revolving Field (Synchronous Speed)
2 Poles	3000 RPM
4 Poles	1500 RPM
6 Poles	1000 RPM
8 Poles	750 RPM
12 Poles	500 RPM

Direction of Rotation:

The direction of rotation of three-phase machines is determined by the phase sequence. Normal phase sequence is A-B-C, which can be verified from the switchboard, a set of lights indicates the phase sequence from the power source.
As the generator rotates, current flow is induced in the armature. Each phase in the armature becomes electrically active. The order in which the phases become electrically active determines the order in which the motor's stator receives the current. The motor that receives current A-B-C-A-B-C will rotate in a given direction. If any two leads change places, then the two affected phases change their sequence of arrival. If phases B and C are exchanged, then phase C will follow phase A. This reverses the direction of the revolving magnetic field in the stator. Current arrives at the motor C-BA-C-B-A. When the revolving field in the motor's stator changes direction, the motor's rotor changes direction. Reversing the generator's output will turn the motor’s rotor in the opposite direction as well. If the generator's output is reversed, then it is known as C-B-A phase sequence.
By reversing any two phase wires, either at the generator's armature or the motor's terminals, the phase sequence will change at that point. Reversing any two leads, at the same point, will restore normal phase sequence. Industry standard dictates configuration control by identifying the conductors to be exchanged: the A and C phase for generators, P1 and P3 for feeders, L1 and L3 for branch circuits, or T1 and T3 for motor terminals.

Construction and Operation:

The next figure shows a cutaway view of a three-phase induction motor. There is very little difference between the AC motor and the AC generator. The rotor is supported by bearings at each end. The stator is freed in position to the inside of the motor frame. The frame encloses all the components of the motor.



Frame:

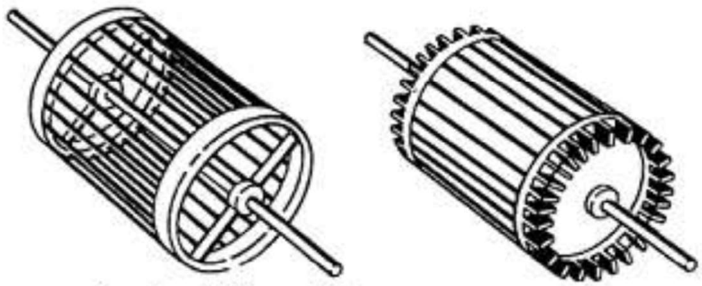
The motor frame, among other considerations, is a determining factor in the placement of the motor. Each motor frame enclosure has certain characteristics and specific vessel applications. There are seven basic types of enclosures:
In an open-type enclosure, the end bells are open and provide for maximum motor ventilation. This is the lowest cost motor enclosure.
In a semi-guarded enclosure, the end bells are open, but screens are provided to prevent objects from falling into the motor. There is no protection against water or liquids.
In a guarded enclosure, screens and guards exist over any opening in the motor housing. Limited openings are provided to limit access to live and rotating components within the motor enclosure. Generally, the holes must prevent a 1/2-inch diameter rod from entering the closure.
In a drip-proof enclosure, the end bells are covered to prevent liquid from entering the enclosure at an angle not greater than 15 degrees from the vertical.
In a splash-proof enclosure, the motor openings are constructed to prevent liquid drops or solid particles from entering the motor at any angle not greater than 100 degrees from the vertical.
A waterproof enclosure prevents any moisture or water leakage from entering the motor and interfering with its successful operation.
A watertight enclosure prevents a stream of water from a hose (not less than 1 inch in diameter, under a head of 35 feet, from a distance of 10 feet) from any direction from entering the motor for a period of at least 15 minutes.
Electric equipment exposed to the weather or in a space where it is exposed to seas, splashing or similar conditions must be watertight or in a watertight enclosure.

Stator Windings:

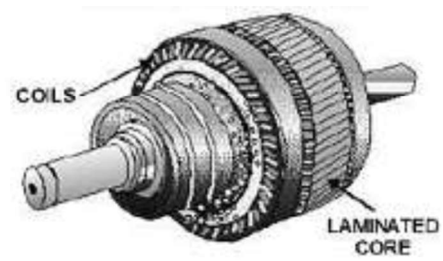
The motor stator is the stationary winding bolted to the inside of the motor housing. The stator windings have a very low resistance. The three-phase AC generator armature is built very similar to the three-phase AC motor stator. Each machine has the stationary conductor winding insulated its entire length to prevent turn-to-turn shorts. The winding is also insulated from the frame. The motor stator winding is identical to a generator armature that has a like amount of poles. Each winding is overlapped and is electrically and mechanically 120 degrees out of phase.
The figure above shows an end view of the stationary windings. Each of the three-phase windings are divided into many additional coils uniformly distributed throughout the stator. This even distribution allows more effective use out of the magnetic fields that will be developed within the stator windings when current is present. This also produces a more even torque (pulling and pushing by magnetic forces) for the rotor.

Rotors and Rotor Windings:

Squirrel Cage Rotor:
Almost 90 percent of induction motors are squirrel-cage type, because this type of rotor has the simplest and most rugged construction imaginable and is almost indestructible. The rotor consists of a cylindrical laminated core with parallel slots for carrying the rotor conductors which, it should be noted clearly, are not wires but consists of heavy bars of copper, aluminum or alloys. One bar is placed in each slot; rather the bars are inserted from the end when semi-closed slots are used. The rotor bars are brazed or electrically welded or bolted to two heavy and stout short-circuiting end-rings, thus giving us, what is so picturesquely called, a squirrel-case construction. It should be noted that the rotor bars are permanently short-circuited by themselves; hence it is not possible to add any external resistance in series with the rotor circuit for starting purposes. The rotor slots are usually not quite parallel to the shaft but are purposely given a slight skew. This is useful in two ways:
(1) It helps to make the motor run quietly by reducing the magnetic hum and
(2) It helps in reducing the locking tendency of the rotor i.e. the tendency of the rotor teeth to remain under the stator teeth due to direct magnetic attraction between the two.
Phase-wound Rotor:
This type of rotor is provided with 3-phase, double-layer, distributed winding consisting of coils as used in alternator. The rotor is wound for as many poles as the number o stator poles and is always wound 3-phase even when the stator is wound two-phase `. The three phases are starred internally; the other winding terminals are brought out and connected to three insulated slip-rings mounted on the shaft with brushes resting on them.
These three brushes are further externally connected to a three-phase star-connected rheostat, this makes possible the introduction of additional resistance in the rotor circuit during the starting period for increasing the starting torque of the motor and for changing its speed torque/ current characteristics. When running under normal conditions, the slip-rings are automatically short-circuited by means of a metal collar, which is pushed along the shaft and connects all the rings together. Next, the brushes are automatically lifted from the slip-rings to reduce the frictional losses and the wear and tear. Hence, it is seen that under normal running condition, the wound rotor is short-circuited on itself just like the squirrel-case rotor.



Squirrel Cage Rotors



Phase-wound Rotor

Rotor Current:

These short-circuited rotor bars become a transformer secondary. The magnetic field established in the stator induces an EMF in the rotor bars. The rotor bars and the shorting rings complete a circuit, and a current flow is then established in these rotor bars. Remember, whenever a current flow is established so is a magnetic field. Since this magnetic field is the property of induction and induction opposes that which creates it, the magnetic field pole in the rotor is of the opposite polarity of the stator field pole that generated it. Magnetism principles apply, the rotor's polarity is attracted to the stator's opposite polarity. The revolving field of the stator, in effect the revolving magnetic polarity, pulls and pushes the initially established rotor field in the rotor. The pulling and pushing produces torque, and the motor rotor turns.

Slip:

If the rotor could turn at synchronous speed, then there would be no relative motion between the magnetic field of the stator and the rotor conductor bars. This would end the induction process in the rotor, and the rotor would lose its magnetic field.
This is not possible with an induction motor. If rotor speed equaled synchronous speed, the rotor would stop. However, as soon as the rotor slowed, even slightly, induced EMF and current would again flow in the rotor winding. Rotor speed would be maintained somewhere below synchronous speed. Slip is the difference between the synchronous speed and the actual speed of the rotor. Slip is more often expressed as a percentage:
Percent slip = (synchronous speed - rotor speed) x 100 / synchronous speed
Percent slip = (1,500 RPM - 1,450 RPM) x 100/ 1,500 RPM
Percent slip = 50 x 100/ 1,500
Percent slip = 3.33 percent
An induction motor will always has a difference in speed between the rotor and the stator field. Without this difference, there would be no relative motion between the field and rotor and no induction or magnetic field in the rotor.
Rotor and therefore motor speed is determined by the number of poles, the frequency, and the percentage of slip.

Rotor Resistance:

Induction motor rotors are designed to have a specific amount of resistance. The resistance in the rotor determines the comparative ease with which the magnetic field in the rotor becomes established. The motor starting current, slip, and torque are modified by the rotor resistance. By developing a motor with a high rotor resistance, a larger slip is developed because the magnetic field of the rotor cannot develop very quickly. A step-by-step sequence of events portrays the actions between the stator and rotor in a

relatively high rotor resistance induction motor:
- Alternating current in the revolving stator field induces an EMF in the rotor bars.
- The high resistance in the rotor prevents the rapid building of the rotor's magnetic field.
- The inability of the rotor to rapidly build a magnetic field fails to allow the rotor to increase in speed rapidly.
- Because the rotor does not increase in speed rapidly, there is a greater relative motion between the revolving stator field and the slow-moving rotor.
- The greater relative motion, from a slow-moving rotor, increases the EMF into the rotor bars.
- The increased rotor EMF generates an increased current flow in the short-circuited rotor bars.
- The increased current increases the rotor's magnetic field.
- The increased magnetic field increases the magnetic attraction of the rotor to the stator's revolving field.
- The rotor develops a greater torque to operate heavier loads.

However, extra torque does not come without some complications. Increased torque means an increased current demand on the distribution system. There is also an increase in slip at full load. Higher resistance rotors are not acceptable for all applications. This is the reason for the many rotor designs.
The rotor resistances are identified by the National Electrical Manufacturers Association (NEMA) and designated by design.

Procedure:

1. Open the machine with the help of proper tools.
2. Study all the parts as shown above.
3. Use bearing puller for the extraction of ball bearings.

Conclusion:

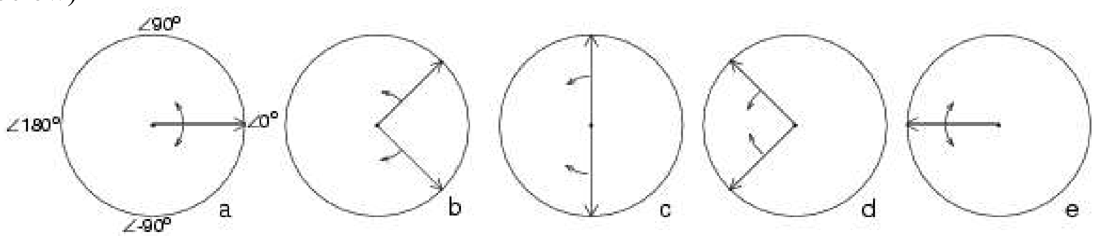
Hence we studied the AC asynchronous motors and their parts.

LAB SESSION 16

Object:
To verify double field revolving theory with the help of single phase induction motor.

Apparatus:
1. Single phase induction motor
2. Variable single phase supply
3. Capacitor
4. AC Ammeters
5. AC Voltmeter
6. Wattmeter

Theory:
The single coil of a single phase induction motor does not produce a rotating magnetic field, but a pulsating field reaching maximum intensity at 0^o and 180^o electrical. (Figure below)



Single phase stator produces a nonrotating, pulsating magnetic field.

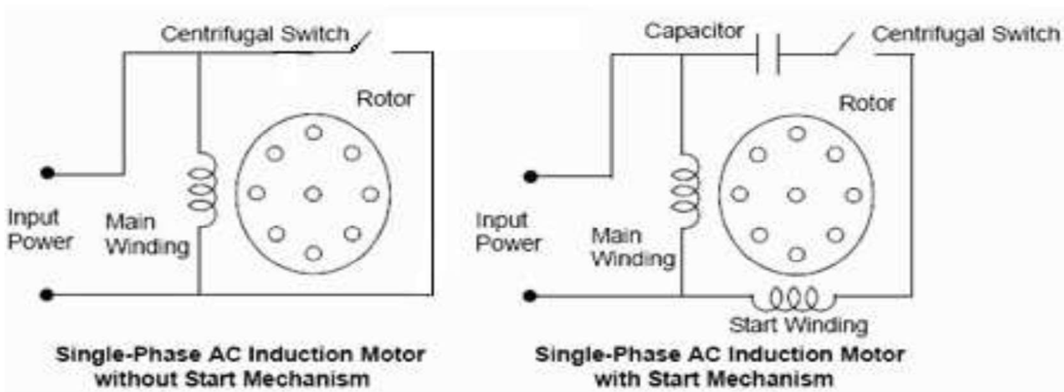
Another view is that the single coil excited by a single phase current produces two counter rotating magnetic field phasors, coinciding twice per revolution at 0^o (Figure above-a) and 180^o (figure e). When the phasors rotate to 90^o and -90^o they cancel in figure b. At 45^o and -45^o (figure c) they are partially additive along the +x axis and cancel along the y axis. An analogous situation exists in figure d. The sum of these two phasors is a phasor stationary in space, but alternating polarity in time. Thus, no starting torque is developed.

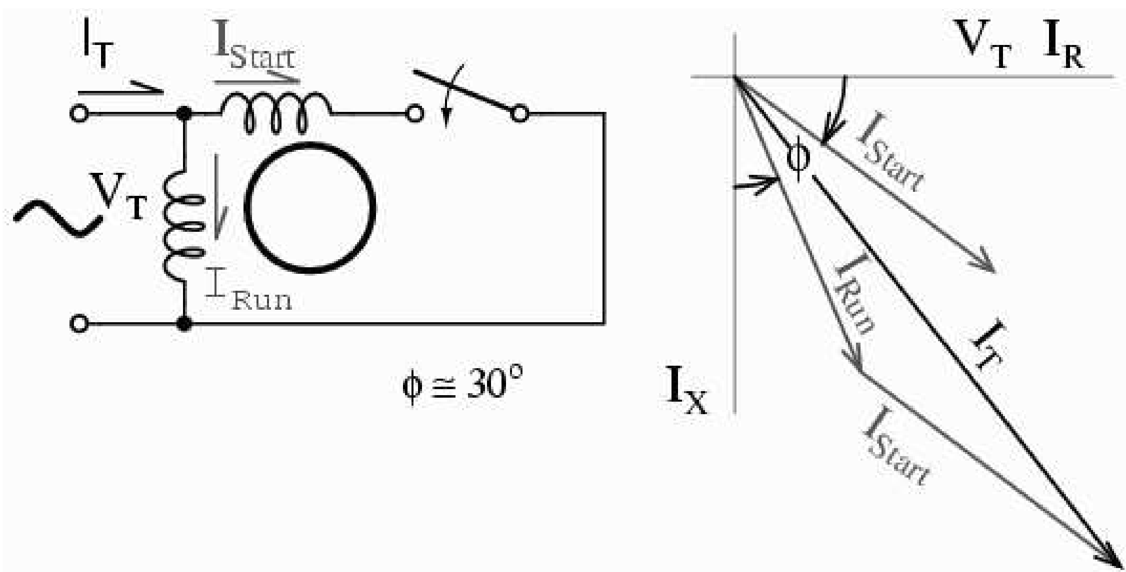
However, if the rotor is rotated forward at a bit less than the synchronous speed, it will develop maximum torque at 10% slip with respect to the forward rotating phasor. Less torque will be developed above or below 10% slip. The rotor will see 200% - 10% slip with respect to the counter rotating magnetic field phasor. Little torque other than a double frequency ripple is developed from the counter rotating phasor. Thus, the single phase coil will develop torque, once the rotor is started. If the rotor is started in the reverse direction, it will develop a similar large torque as it nears the speed of the backward rotating phasor.

Single phase induction motors have a copper or aluminum squirrel cage embedded in a cylinder of steel laminations, typical of poly-phase induction motors.

To make single phase induction motors self starting, we need to have rotating magnetic field that's why we go for phase splitting option. Therefore, in single phase induction motors we have two windings, one is called main winding or running winding and other is called starting winding or auxiliary winding. Capacitor is connected in series with starting winding. Basic advantage of using capacitor instead of resistor is the production of higher starting torque.

Circuit Diagram:





Procedure:

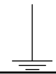
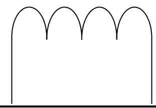
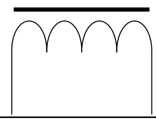
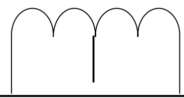
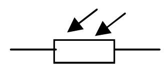
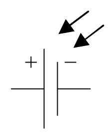
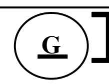
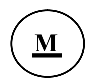
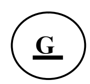
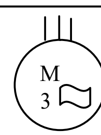
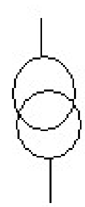
7. Connect the single phase induction motor with variable supply
8. Gradually increase the supply and apply torque on shaft on induction motor in a direction by hand. After it gets accelerated, disconnect its supply.
9. Gradually increase the supply and apply torque on shaft on induction motor in other direction by hand. After it gets accelerated, disconnect its supply.
10. Now energize single phase induction motor after connecting starting winding without capacitor and observe the behavior.
11. Now energize single phase induction motor after connecting starting winding with capacitor and observe the behavior.

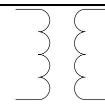
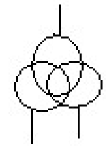
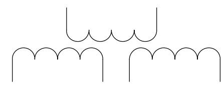
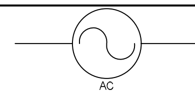
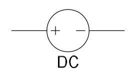
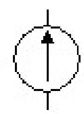
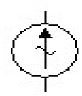
Observations:

S. No.	V_T	I_{Start}	I_{Run}	I_T
01.	230 Volts			
02.	225 Volts			
03.	220 Volts			
04.	215 Volts			
05.	210 Volts			
06.	200 Volts			
07.	195 Volts			
08.	190 Volts			

Result:

We observed that a capacitor-start motor is a single-phase induction motor with a main winding arranged for direct connection to the power source and an auxiliary winding connected in series with a capacitor and starting switch for disconnecting the auxiliary winding from the power source after starting.

Earth Symbol	
Conductor, Line	
Inductor, Coil, Winding, Choke	
Inductor with magnetic core	
Inductor with fixed tapings,(one shown)	
Light dependent resistor	
Photovoltaic cell	
D.C. permanent magnet generator	
D.C. motor,	
D.C. generator	
Induction motor, three phase, squirrel cage	
Transformer with two windings	

Transformer with two windings (multi-line representation)	
Transformer with three windings	
Transformer with three windings (multi-line representation)	
AC Voltage Source	
DC Voltage Source	
DC Current Source	
AC Current Source	
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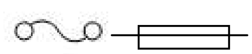
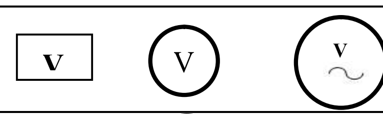
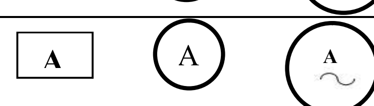
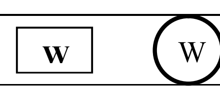
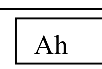
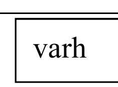
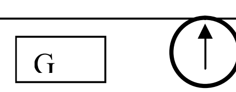
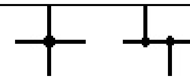
Break contact	
Fuse	
Voltmeter	
Ammeter	
Wattmeter	
Ampere-hour-meter	
Var-hour-meter	
Galvanometer	

Wires, Connected, Crossing	
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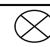
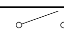
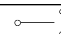
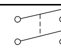
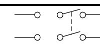
Circuit breaker	
Lamp	
Single Pole Single Throw Switch (SPST)	
Single Pole Double Throw Switch (SPDT)	
Double Pole Single Throw Switch (DPST)	
Double Pole Double Throw Switch (DPDT)	

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:					

Cover Page for Each PBL/OEL

Course Code:	EE 116 118 119 120 124
Course Name:	Principles of Electrical Engineering, Basic Electricity and Electronics, Fundamentals of Electrical Engineering, Basic Electrical Engineering
Semester:	Fall / Spring
Year:	20__
Section:	
Batch:	
Lab Instructor name:	
Submission deadline:	

PBL or OEL Statement: Make a regulated DC power supply with variable voltage from 0V to 15V and 3A maximum current. The input is 220 V AC 50 Hz.

Deliverables: Hardware circuit with transformer, rectifier, regulator, filtering capacitors, current and voltage displays and control knob to change voltage. Overcurrent and overvoltage protection are necessary. Write a separate report detailing the circuit diagram and all calculations.

Methodology: 1. Draw the circuit diagram of a regulated DC power supply. 2. Calculate the values of the components required. 3. Run the simulation in Multisim® to validate results by attaching load resistors and indicators or probes. 4. Develop the breadboard prototype to check the working of the power supply. 5. Make a PCB or solder on a Veroboard with proper input and output terminals.

Guidelines: The report should be maximum 5 pages long which should include circuit diagram, calculations, simulation results and brief theory of the components used. Attach these two pages on top of the report.

Rubrics:
Standard hardware based rubrics as used in the lab manual.

NED University of Engineering & Technology
Department of Electrical Engineering

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:					