(For Counsellor's use only)

Grade . . . . Name . . . .

Evaluated by . . . . Enrolment Number . . . .

EXPERIMENT 1

A STUDY OF NETWORK THEOREMS

Structure

1.1 INTRODUCTION

Electric circuits form the backbone on which the study of most electrical phenomena is based. These circuits may contain resistors, capacitors, inductors which are **passive** elements, or some **active** devices such as vacuum tubes, transistors etc. In order to understand the nature of the circuits and their applications, one is required to perform the analysis for currents, voltages, power or frequency responses in the circuit. If the circuit is simple, one can do the analysis just using Ohm's Law. However, many circuits are complicated and analysis becomes difficult. Hence systematic methods should be developed to simplify the circuits and to make the analysis easy. In order to perform the analysis of a complicated circuit in a simplified **manner,** some theorems have been developed. These theorems are known as **Network** Theorems.

Objectives

After performing the experiments, you will be able to:

- Verify **maximum** power, superposition, **reciprocity** and **Thevenin's** theorems.
- Apply **above theorems** to **different** networks.

1 2 APPARATUS:

Two transistorised power supplies (0 - 15V), **resistors** (100 - **1000** ohms), **multimeters,** connecting wires.

1.3 STUDY MATERIAL:

Before performing the experiments you may be interested in knowing more about a network and the theorems mentioned in the Objectives.

1.31 Network

An electrical network is any interconnection of electric circuit elements such **as inductors,** resistors, capacitors, generators, or branches where each branch may include *R,L,C.* or other types of linear elements. A linear **clearent** is one in which the current is proportional to the voltage. **Such** a linear network having two distinct pairs of terminals is called a four-terminal network 1,1 : **2,2.** as shown 'in Fig. 1.1 .a. However **if** one **of** the 1,1 **terminals** is common to the 2,2 pair, the circuit is known as 3-terminal network as shown in **Fig.1.1.b.** If the 2,2 terminals are short circuited, it **becomes** two-terminal net**work.**

Networks may be of the following types:

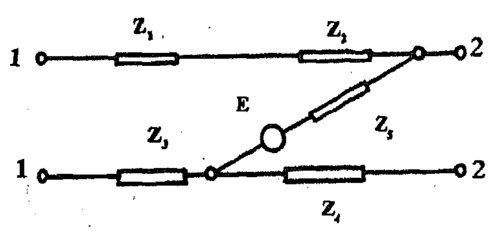


Fig.1.1.a

4-Terminal Network

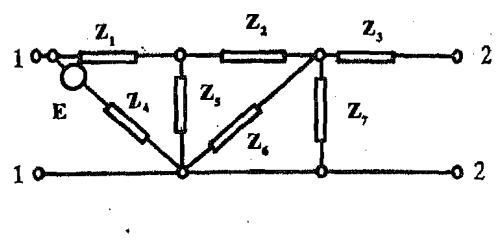


Fig.1.1.b

3-Terminal Network

PASSIVENETWORK:

A network containing circuit elements without any **energy** source such as a battery, is known as passive network.

ACTIVENETWORK:

A network containing generators or energy sources along with other elements is known as an **active** network.

A specific path between two **points** in a network is called a branch.

In a network a set of branches forming a closed path in such a way that if one branch is omitted the remaining branches do not form a closed path, is known as a **Mesh.**

A terminal of any branch of network, or a **terminal** common to two or **more branches** is known as a **Node** or Junction.

We can now **summarise** thata network may have active or passive elements, branches, nodes, meshes, Our aim is to **analyse** any such network for current in any loop or **the** voltage across any element using appropriate network theorems. We will first try to understand **some of** the important network theorems and then proceed **further** for their applications **using** practical network circuits.

1.3.2 Superposition Theorem:

Let us consider the following **circuits.**

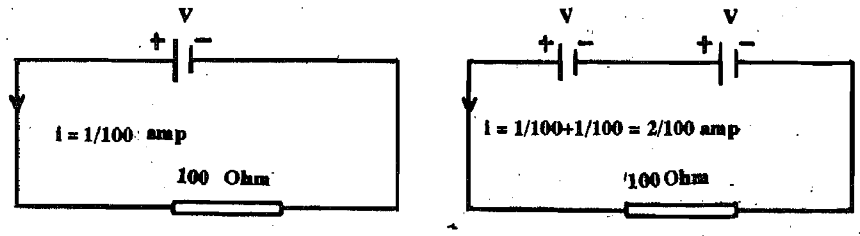


Fig. 1.2

A battery of 1 volt applied to a resistance of 100 ohms, causes a current **of 1/100** ampere to **flow .** Two batteries in series, each of 1 volt connected to the same 100 ohm resistance, each cause **1/100** ampere to flow. Together they cause **2/100** ampere to flow. The total current is thus the sum of the currents produced by the individual batteries. This statement if generalised is known as the Superposition Theorem. This can be stated as **follows.**

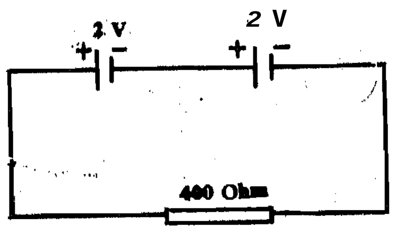
Each emf in a linear network **produces current** in any **given** branch independent of the action of other emf's, and that the resultant **total current in any** branch is the algebraic sum **of** the contribution of **current** due to each of the emf's.

You will be able to verify this theorem by performing the experiment.

SAQ

In the following circuit calculate **the** current caused to flow **through** the resistor due to **the** individual sources separately. Calculate the current when both sources are present.

Verify your result experimentally, later **on.**



Answer: With V_1 alone, the current expected is .... With V_2 alone the current is .... With both **V1** and V_2 the current expected is ....

Fig. 1.3

13.3 Reciprocity Theorem:

The reciprocity theorem states that if an emf *E* is placed in one branch of an **electrical** circuit, giving rise to a **current I** in another bra'nch, the same **current I** is obtained in the **original** branch when the **emf** *E* is **transferred** to the branch where the current **I** arose.

In--order to **understand** clearly, let us consider the following circuit, as an example.

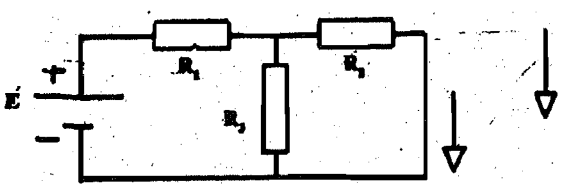


Fig. 1.4 .a

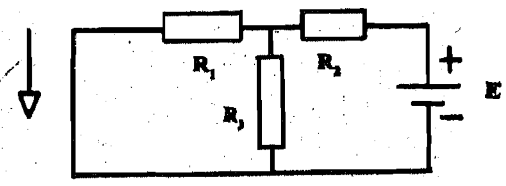


Fig. 1.4.b

The Reciprocity Theorem assures that $I_1 = I_2$ since E is the same in each circuit.

1.3.4 Thevenin's Theorem:

Let us consider a simple circuit as shown in the Fig. 1.5.

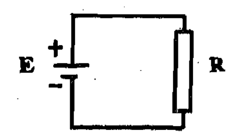


Fig.1.5

If you want to find out the current through the load R you can apply Ohm's Law and get $I=E/R$. However if the circuit (outlined in dashes) is complicated such as shown in Fig. 1.6, it is difficult to find the current or the voltage across the load R_L using Ohm's Law.

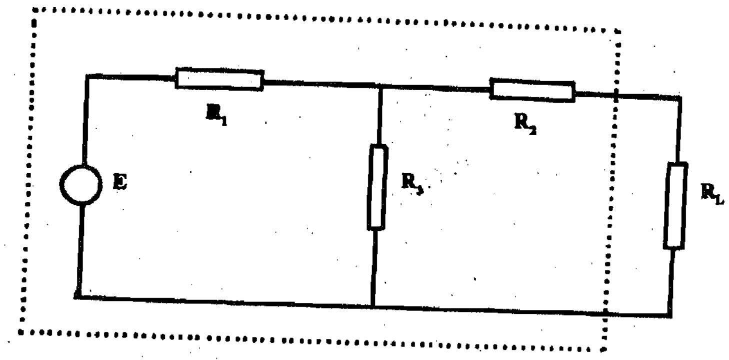
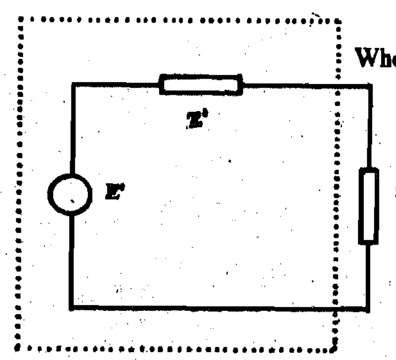


Fig.1.6

In order to **analyse** such circuits, **Thevenin's Theorem** is used.

This theorem states that any two **terminal** linear network containing energy sources and impedances can be replaced with an equivalent **circuit consisting** of a voltage source E' in **series** with an **impedance** R'. **The** value of E' is the open circuit voltage between the terminals of the network **and** R' is the impedance measured between the terminals with all energy sources eliminated (but not their **impedances).**

Thus the Thevenin's equivalent circuit of the above network is shown below.



Where $E' = E*R_3/(R_1+R_3)$

$R' = R_2 + R_1*R_3/(R_1+R_3)$

Fig.1.7

We will study the application of Thevenin's Theorem in a network while performing the experiment.

1.4 PRECAUTIONS:

a) Before using the power supply make sure that you are getting the necessary voltage range, by measuring with the **multimeter.**

b) Before using the resistance make sure of their values, by measuring with a multimeter.

c) Before using the Ammeter and Voltmeter check for zero setting.

1.5 EXPERIMENTS

1.1 Verification of Maximum Power Transfer Theorem.

APPARATUS:

Power supply (10Vdc), multimeter, resistors: 100 ohms, 200 ohms, ·300 ohms, 400 ohms, 500 ohms, 600 ohms, 800 ohms, 1000 ohms (nominal values).

PROCEDURE:

Arrange the circuit as shown in **Fig.1.8.** Make R = 500 ohms, and R_L as 100 ohms. Connect a voltmeter accross the load to **measure** the voltage drop accross the load (R,). Keep the output of the power supply at 10V with the output-varying knob. Note the voltage across the load resistor in Observation Table I. Now replace the load resistor by another resistor of different value and measure the voltage across it. Make V_I = 10 volts by **adjustment,** before you measure and note the value of voltage across R,. Repeat the experiment with at least 8 different resistors. In each case record your **measurements** in the Observation Table I.

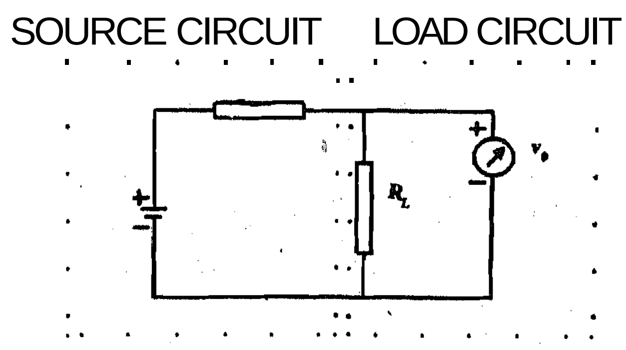


Fig. 1.8

OBSERVATION TABLE I

Value of source impedance (R) = 500 ohms
Source voltage (V_s) = 10 volts.

S.NO.	Load Resistance (R_L) ohms	Output voltage V_o Volts	Power Transfer (calculate) $P = V_o^2/R_L$ Watts
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

Now plot a graph between load resistance RL and power transfered.

P
O
W
E
R

LOAD RESISTANCE

With the help of **the** graph explain your **result**, and record your findings in the space below. What do you observe **from the** nature of **the** graph?. What is **the condition** for **maximum** power transfer?

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SAQ

When the maximum power is transfered from source to the load,. then, the output voltage V_o compared to V,? More? Less? Somewhat is the write your choice & your comments:

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1.5.2 Application of Superposition Theorem,

APPARATUS

Two voltage sources, multimeter, and three resistors 500 ohms each.

PROCEDURE :

STEP 1:

Connect the circuit as shown in Fig.1.9.a. Set V1 about 10 volts, and V2 about 5 volts. Before turning on the power supplies, calculate the current expected. Write the value here............... Choose an appropriate multimeter range, and turn on the power supplies.

Record the supply voltage in each loop & the current in the first loop. Record the current as I_a, in Observation Table II. Repeat Step 1 three times.

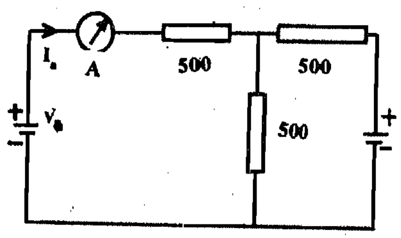

Fig. 1.9.a

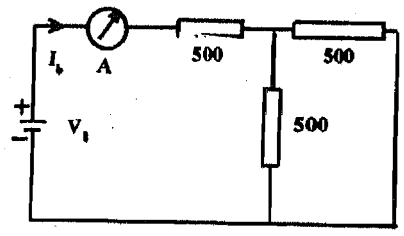

Fig. 1.9.b

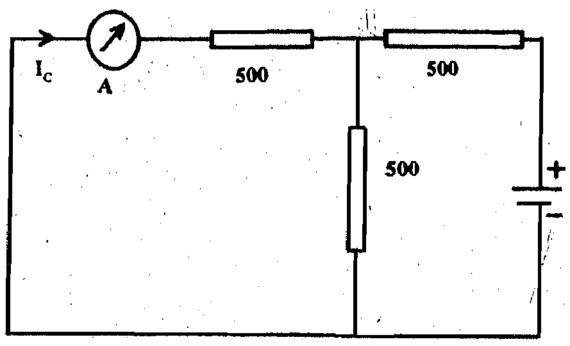

Fig. 1.9.c

STEP 2:

Now change the circuit to that of Fig.1.9.b. With V_1 at the same value, note the current in the first loop as I_b. Repeat Step *2* three times.

STEP 3:

Now change the circuit to that of Fig.1.9.c. With V_2 the same as in STEP 1, note the current in the first loop as I_c. Repeat step 3 three times.

Repeat the three steps for V_1 = 5volts and V_2 = 5 volts.

Repeat the three steps for V_1 = 2 volts and V_2 = 6 volts.

All readings should be recorded in Observation Table II.

OBSERVATION TABLE II

S.NO.	V_1 (volts)	V_2 (volts)	I_a (amp)	I_{ob} (amp)	I_c (amp)	$I_b + I_c$ (calculate) (amp)

With the help of the results compare the values I_a and $I_o + I_c$ taking 'into account the experimental error your observe. Explain how it confirms the Superposition Theorem, in the space provided below.

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1.5.3 Verification of the Reciprocity Theorem

APPARATUS:

Two voltage sources (0 to 10 volts), multimeter, three resistors 500 ohms each, one 1000 ohms.

PROCEDURE :

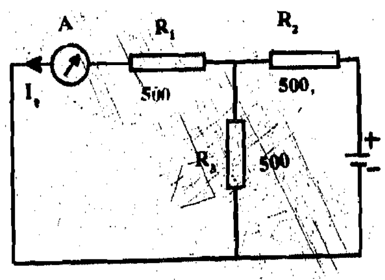

Fig.1.10.a

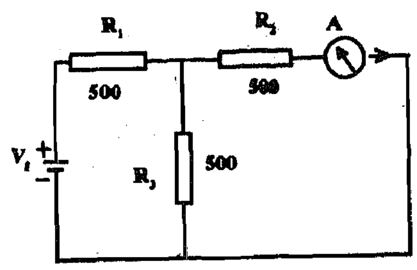

Fig.1.10.b

STEP 1:
Arrange the circuit as shown in **Fig.1.10.a.** Set V_2 at approximately **5** volts, and measure V_2 and I_1, noting them in Observation Table III. **Repeat** Step 1 three times.

STEP 2:
Now connect the circuit of **Fig.1.10.b.** Set V_1 at approximately **3** volts and measure V_1 and I_2, noting them in Observation Table III. **Repeat** Step 2 three times.

STEP 3:
Calculate V_2/I_1 and V_1/I_2, and enter in the Observation Table III. Repeat Step 3 **three** times.

'Repeat the steps above, using R_1 = 1000 ohms and R_2 = R_3 = 500 ohms.

Repeat the steps again, using the same set of resistors but with V_1 about 7 volts and V_2 about 10 volts.

OBSERVATION TABLE III

Sl. No.	V_1 (volts)	I_2 (amps)	V_2 (volts)	I_1 (amps)	V_2/I_1 (ohms)	V_1/I_2 (ohms)

How do the **calculations** agree with the predictions of the **Reciprocity Theorem,** taking into account the **experimental** errors **experienced?**

SAQ:

In the above experiments, will the Theorem hold good if the two voltages V_1 and V_2 are present at the same time?

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1.5.4 Application of Thevenin's Theorem.

APPARATUS:

Variable power supply (0 to 10 V), two resistors of 500 ohms each, a variable resistor and a multimeter.

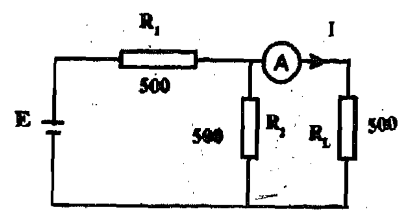

Fig.1.11.a

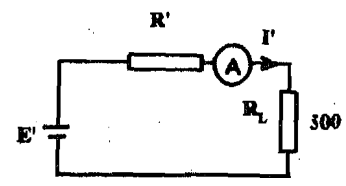

Fig.1.11.b

PROCEDURE:

Arrange the circuit as shown in Fig.1.11.a. Measure the current I through the load R_L. Now arrange the Thevenin's equivalent circuit Fig.1.11.b by calculating the value of R' and E' as :

$$R' = \frac{R_1 * R_2}{R_1 + R_2} \quad ; \quad E' = \frac{E_1 * R_2}{R_1 + R_2}$$

Measure the current I' through the load in the equivalent circuit. Repeat the experiment using two different pairs of resistors R_1 and R_2. Record the data in Observation Table IV. Repat the Procedure three times.

OBSERVATION TABLE IV

E = ... Volt R_L = 500 ohm

S.NO.	R_1	R_2	I	E'	R'	I'

Compare the values I and I'.

Explain your result and record your findings in the space given below, taking into account the experiment errors experienced.

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In the above experiment, calculate the values of currents I and I' using ohms's law and compare with your measured values

1.6 CONCLUSIONS:

After the experiments, list your findings.

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