UNIVERSITY OF NAIROBI

DEPARTMENT OF ENVIRONMENTAL AND BIOSYSTEMS ENGINEERING

2ND YEAR ELECTRICAL CIRCUIT THEORY LAB MANUAL

Title: NETWORK THEOREMS

Object: To verify some of the network theorems.

Introduction:

Statements of the Theorems to be verified

a) Thevenin's Theorem

The current in any branch of a network is the same as if the branch was connected to a generator of e.m.f. E_g and internal impedance Z, where E_g is the potential difference appearing across the branch when open-circuited and Z is the output impedance of the network between the branch terminals, all sources of e.m.f. in the network being replaced by their internal impedances.

b) Delta-Star Transformation

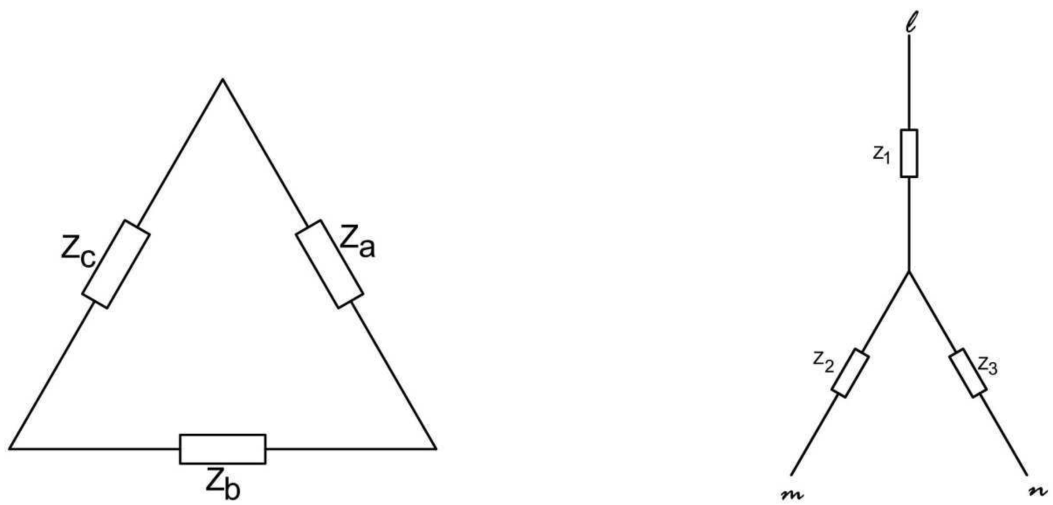


Fig.1: Delta-Star Transformation.

The two networks given in Fig.1 will be identical with respect to terminals L, m and n if the following equations are satisfied:

$$Z_1 = \frac{ZaZc}{Za + Zb + Zc} \quad \text{..............} \quad (1)$$

$$Z_2 = \frac{ZbZc}{Za + Zb + Zc} \quad \text{..............} \quad (2)$$

$$Z_3 = \frac{ZaZc}{Za + Zb + Zc} \quad \text{..............} \quad (3)$$

c) Reciprocity Theorem

If an e.m.f. Ep in circuit P produces a current I_Q in circuit Q, the same e.m.f. E_p in circuit Q produces the same current I_Q in circuit P.

d) Compensation Theorem

For a given set of circuit conditions, any impedance Z in a network carrying a current I can be replaced in the network by a generator of zero internal impedance and e.m.f. E - I.Z.

e) Parallel Generator Theorem

The common terminal V of a number generators connected in parallel to a load R_L is:

$$V = I_{sc.} Z. \qquad \ldots\ldots\ldots\ldots\ldots \qquad (4)$$

Where I_{sc}. Is the sum of the short-circuit currents of the individual generator branches and Z is the effective parallel impedance of all branches, including the load.

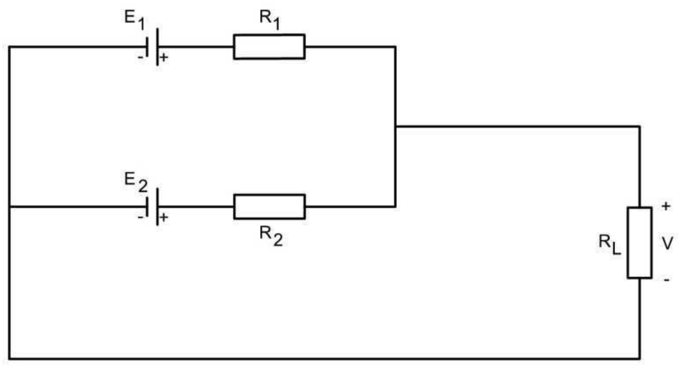


Fig. 2: Circuit of the Parallel Generator Theorem.

f) Norton's Theorem

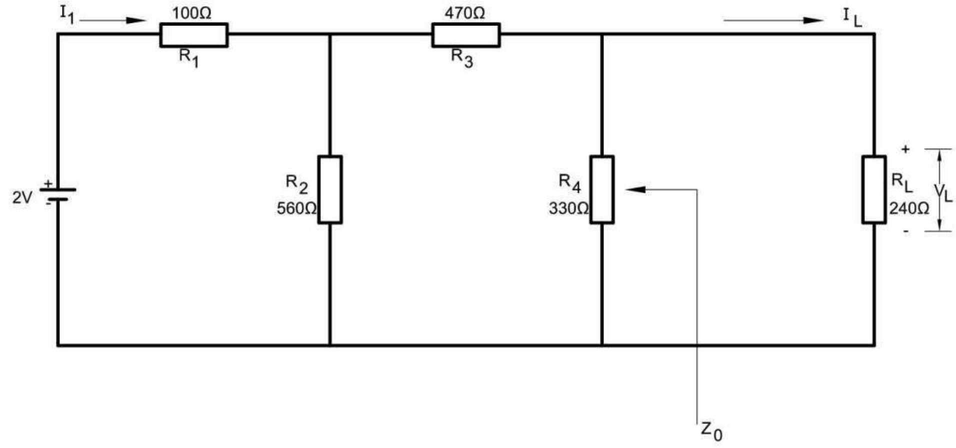
If an impedance Z is added to a branch of a network, the resulting branch current I is given by:

$$I = \frac{I_o}{1 + Z / Z_o}$$

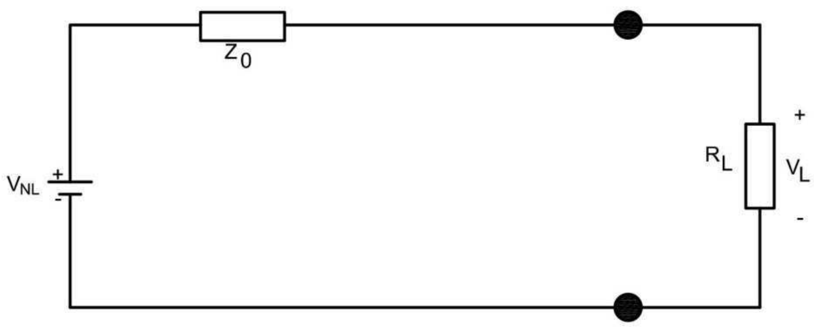
Where I, is the branch current before insertion of the added impedance and Z_o is the impedance looking into network from the branch, before insertion of Z

Homework

1. Consider the following circuit:



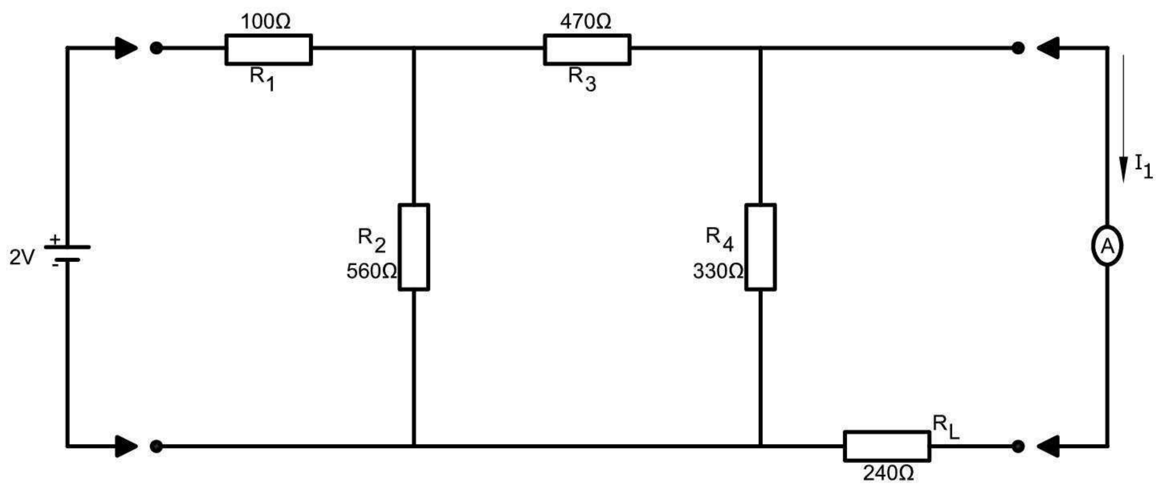
By using the Thovenin Theorem convert the circuit to the following:



Find VL V_{NL} and Zo as functions of V, R_1,R_2,R_3,R_4 and R_L then insert the values.

2. When $Z_a = 470\Omega$, $Z_b = 330\Omega$ and $Zc = 560\Omega$ find from equations 1,2 and 3 the values for Z_1,Z_2 and Z_3 in the Delta-star transformation.

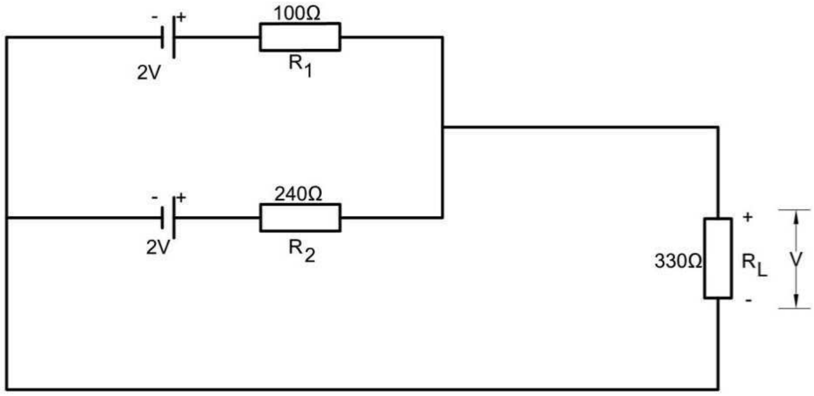
3. Prove the resiprocity theorem on the circuit shown below:



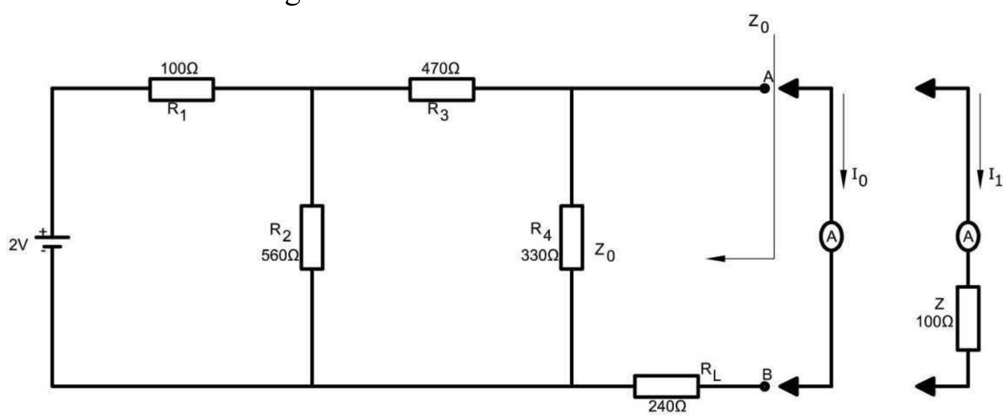
Find the current I_1, interchange the battery and ammeter and find, by calculation, the new current, I_2, through the ammeter. First find the currents, I_1, and I_2, as functions of V, R_1, R_2, R_3, R_4 and R_L, then insert the values for the resistors. Make use of the results from question 1.

4. In the circuit in question 1 find the battery voltage that will compensate the voltage drop across R_L according to the compensation theorem.

5. From the circuit below find the common terminal voltage V as given in equation. 4, the parallel generator theorem.



6. Consider the following circuit:



Find the output impedance Z_o between A and B. If an ammeter is connected between A and B find the current I_o.

If an ammeter and an impedance Z is connected between A and B find the new current I.
Find the currents and functions of V, R_L, R_2, R_3, R_4, and then insert their values.
Check the result with the formula:

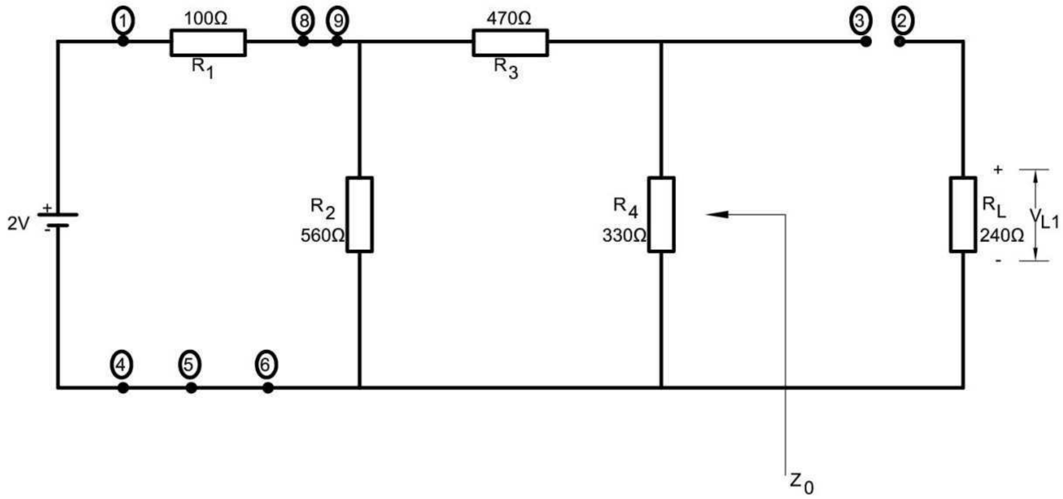
$$I = \frac{I_o}{1 + Z / Z_o}$$

LAB WORK:

Whenever you change resistance scales on the AVO meter, remember to "zero" the meter readings.

1. Thevenin's Theorem.

Connect up the following circuit:



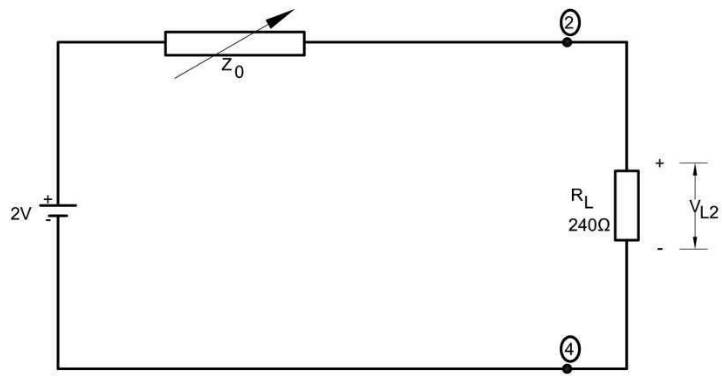
Links between 8 and 9, and 5 and 6.

a) Measure the no load voltage, V_{NL}, between 3 and 6.

b) Connect 2 to 3 and measure V_{L1}.

c) Disconnect R_L and the battery V. Measure the output impedance, Z_o, when I and 4 are connected together.

d) Connect up the Thevenin equivalent below:

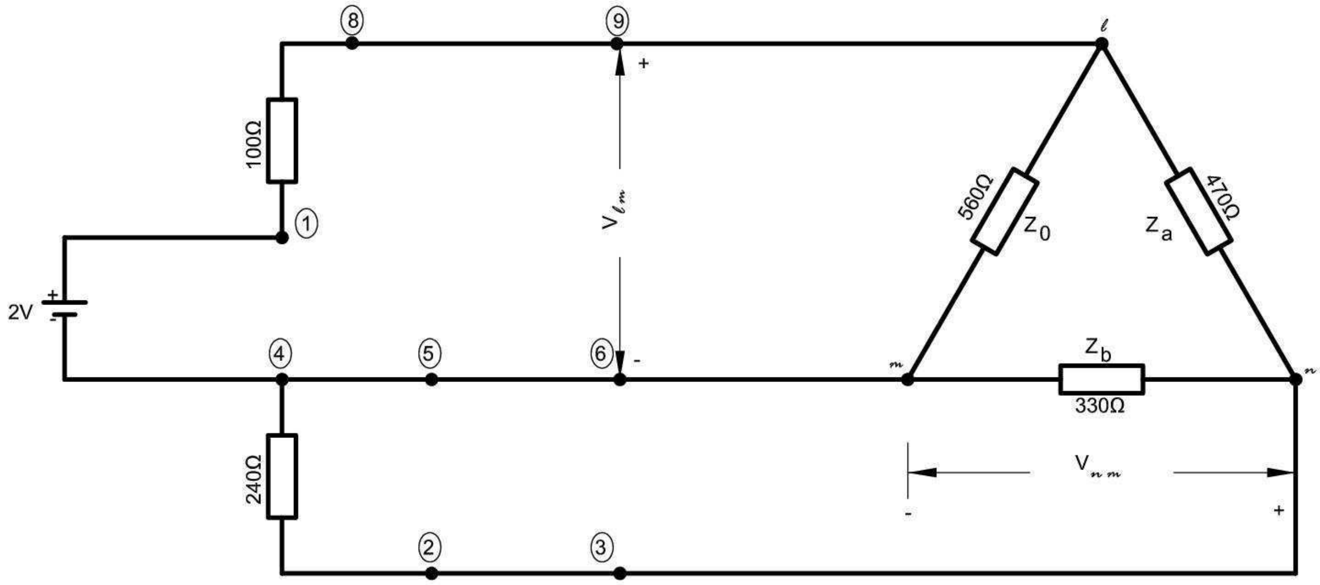


Set the variable resistor to Z_o and measure V_{L2}.

e) How do the values (Z_o V_{L1} and V_{L2}) compare, theoretically and practically?

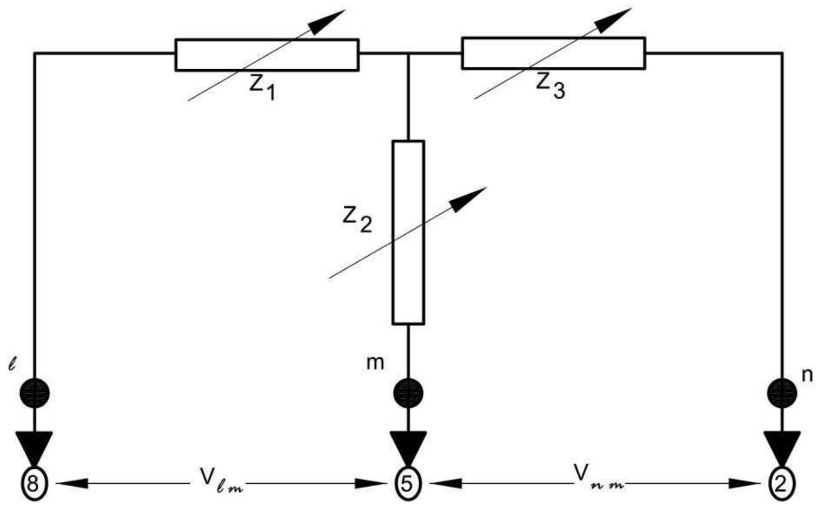
2. Delta-star transformation

a) Connect up the following circuit:



Links between 8 and 9, 5 and 6 and 2 and 3. Measure the voltages $V_{\ell n}$ and V_{nm}.

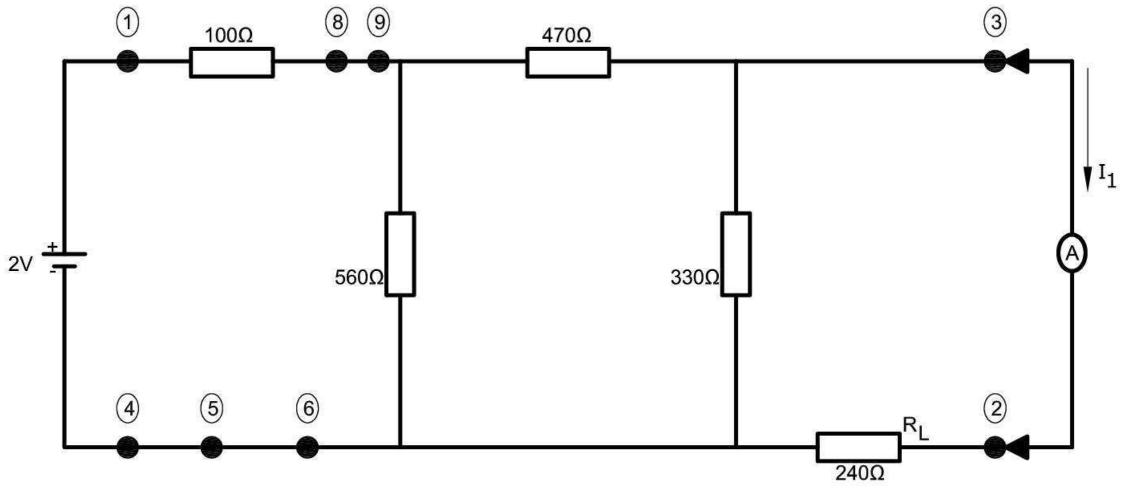
b) Remove links 8-9, 5-6, 2-3. Connect the star transformation as shown below (values of Z_1, Z_2 and Z_3 as found in homework):



Measure the voltages V_{lm} and V_{nm}. How much do they differ from those found in 2 (a)?

3. Reciprocity Theorm.

a) Connect up the following circuit:



Links between 8 and 9, and 5 and 6. Measure the I_1.

b) Interchange the battery and mA meter (battery between 3 and 2, mA meter between 1 and 4) and measure the new current I_1 through the mA meter. How much do I_1 and I_2 differ and why?

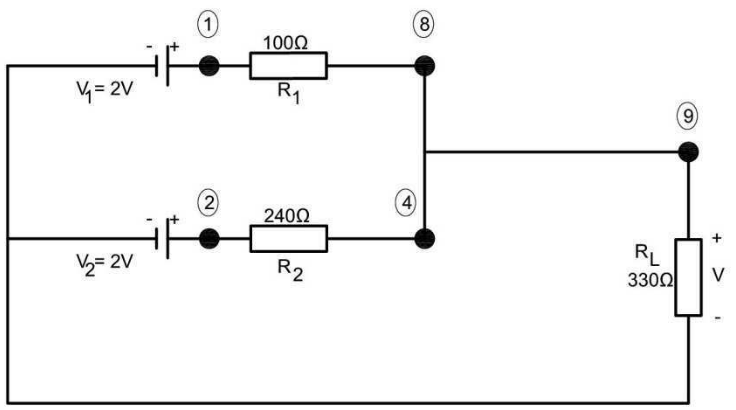
4. Compensation Theorem.

a) Connect up the circuit as in 3(a). Measure the current through R_L.

b) Remove the mA meter and insert between 3 and 6 (no connection between 2 and 3) a dc voltage source ($E = -I_I - R_L$) in series with the mA meter. Be careful with the sign of E: Measure the new current I2 through the m Ammeter. How much do I_1 and I_2 differ and why?

5. Parallel Generator Theorem.

a) Connect up the following circuit:



Point 4, 8 and 9 connect with links. Measure the voltage V.

b) Find the short circuit current I_{scI}, of branch 1 (V_1 in series with R_1), and the short circuit current, I_{sc2}, of branch 2 (V_2 in series with R_2).

Disconnect the batteries; connect R_1, R_2 and R_L in parallel and measure the resultant parallel impedance Z.

Check with the parallel generator formula:

$V = (I_{sc1}\ 1\ I_{sc2}).Z$

How much do the results from 5a) and b) differ, compare with the homework.

8. Norton's Theorem.

Connect up the circuit from 3a).

a) Measure the current, I_I, through the mA meter.

b) Connect a 100Ω resistor in series with the mA meter and measure the new current L.

c) Disconnect the battery, mA meter and 100Ω resistor. Connect the input terminals (1 and 4) together and measure the impedance between 3 and 2, Z_o.

d) Check the result with the formula.

$$I = \frac{I_1}{1 + Z/Z_o}$$

and the homework. How do they agree?

Apparatus:

1 Power supply.
1 Accumulator, 2V
1 Voltmeter, dc
3 Decade resistor boxes.
1 mA meter, dc.
1 Veroboard "Network Theorems" and box.

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SECOND YEARS: WORKSHOP TECHNOLOGY

DAY 1

Introduction to instruments, identification and inventory
These include,

Ammeters	Various transformers
Voltmeters	resistance boxes
C.RO's	Capacitance boxes
Power supplies	Inductances
Signal generators	

The exercise will include how to read the Instruments – ranges, accuracy etc.

DAY 2

Verification for circuit laws, ohms law, kirchoffs law.

Objective:

- To establish the consistence of ohms current, voltage law.
- To establish consistence of Kirchhoff's node-currents and loop-voltages laws.
- To understand and correct use of ammeters and voltmeters in circuit networks.

RESEARCH (HOME WORK)
NB: It is important you research and finish your homework before coming to do the experiments in the laboratory.

Assign theoretical but typical values of ammeter internal resistance (R_G) and voltmeter resistance (Rv) using circuits below, investigate to find out which set-up is more accurate, Explain why.

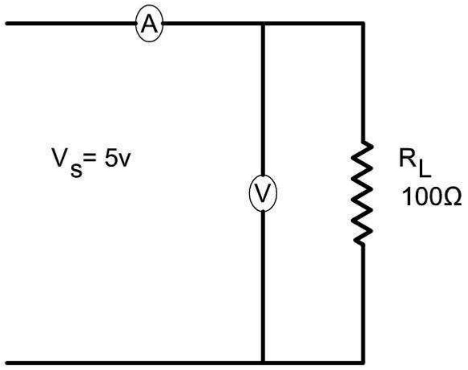

FIG. I

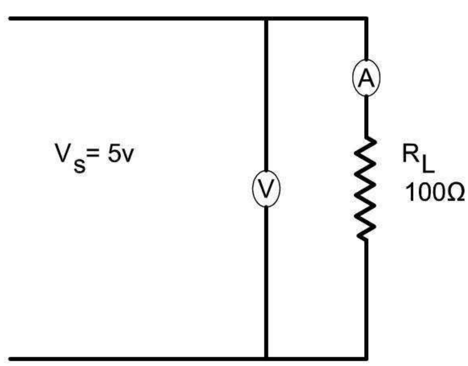

FIG. II

Now substitute R_1, with a very high resistance, say 9000Ω which network is more accurate. Explain why.

EXPERIMENT

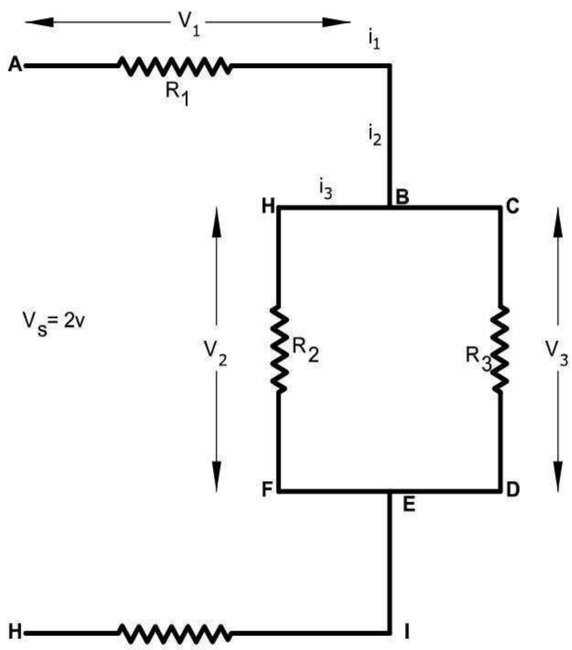

FIG. I

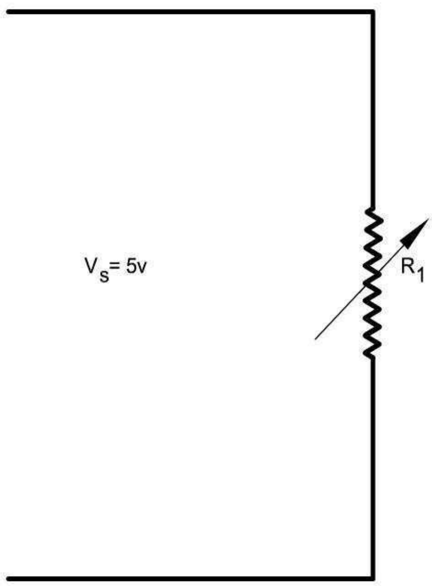

FIG. II

APPARATUS:

Resistance boxes, (or Rheostat) Ammeters (D.C) voltmeters (D.C), power supply.

PROCEDURE:

a) Connect up the circuit in Fig. II above insert an ammeter and voltmeter in appropriate places and with RL fixed at 8Ω, vary the supply voltage from 5V to 1V Record the corresponding current values tabulate your results.

b) Now alter the load resistance value to R_L = 15Ω. Repeat procedure as in (a) above.

c) Connect the circuit in Fig. I and measure the following values, with R_3 = 8Ω. R2 = 8Ω and R_1 = 4Ω.

   i_1, i2, i3, V_1, V_2, V_3,

d) With the same circuit as in (c), increase R_2 to 1_2 and repeat the measurement of currents and voltages.

RESULTS

i) Plot the graphs of V against I for the tabulated results in (a) and (b) above on the same axis.
   Explain the practical meaning of the graph-gradients.
   How do you establish the consistence of ohm's law from these graphs?

ii) Find the algebraic sum of currents at nodes B and E in fig. I for both procedures (c) and (b). Also find the algebraic sum of voltages in the following loops. ABGFEHA, ABCDEHA and BCDEFGB (Fig. I)

CONCLUSION
Suggest possible causes of error in the circuit measurements in figs. I and II.

Given resistance values as in procedure a, b, c, d and the supply voltages values, calculate the theoretical values of currents i_1, i_2, i_3 and voltages V_1, V_2, V_3, for fig. I. Calculate V and I values for fig. II. Compare these values with the practical values obtained to justify the causes of error suggested above.

DAY 3

CRO 1

Objectives:-
1. To understand the operating of a CRO.
2. To identify all the terminals and controls of the CRO.
3. To investigate the functions of the controls.
4. To derive a systematic "SETTING UP PROCEDURE" to test the functioning of the instrument.

Research

Explain the primary use of the CRO.
Draw a functional diagram of a basic CRO and indicate the positions of important controls associated with the instrument function. Give a brief description of the different functional units associated with the CRO, and the role of the controls of each unit.

Experiment
Identify the CALIBRATION voltage source on the instrument. It is normally specified as:

1.0 volts peak to peak or
0.5 volts peat to peak

the period of the waveform is 20 millisecs. Using this voltage as the INPUT to the Y axis deflection and by suitable setting of the TIMEBASE and TRIGGERING controls obtain a suitable display on the screen to give a stationery display of three cycles of the waveform.

Moving each control one at a time investigate carefully the effect of the control on the screen trace and thus identify controls associate with:

Beam production,
Deflection in the Y axis,
Deflection in the X axis,
Timebase controls
Triggering

Investigate the effects of all the controls in a systematic manner under the groupings, remembering to return the screen to the original condition each time.

Results:

Indicate a logical “SETTING UP PROCEDURE” to test the servisibility of the CRO indicating the settings of the controls in the following groups:-

1. Beam location.
2. Fine adjustments of the beam.
3. Location of y-axis 3(a) Scale setting
4. Location of x-axis 4(a) Scale setting
5. Time-base setting.
6. Triggering to the calibration voltage on the input.

Conclusion

Comment on the advantages and disadvantages of the instrument.