الجامعة الإسلامية العالمية ماليزيا
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

REPORTS ON

ECE 1101: ENGINEERING LAB – I

EXPERIMENT NO. :

TITLE:

No.	Evaluation Items	Marks 20%	Marks obtain
1	Objectives	1	
2	Brief Theory	2	
3	Equipment list	2	
4	Experiment Set-up	2	
5	Results/Observations	8	
6	Discussion and Conclusion	5	
	TOTAL	**20**	

Date of Experiment: __________________ Date of Submission:__________________

Section No. :

Matric No: ___________ Name : ____

Matric No: ___________ Name : ____

Matric No: ___________ Name : ____

Evaluation Criteria

<table>
<tr><th colspan="2">Range of scores</th><th>Grade</th><th></th></tr>
<tr><td>0</td><td>6.5</td><td>F</td><td rowspan="4">Poor</td></tr>
<tr><td>7</td><td>7.5</td><td>E</td></tr>
<tr><td>8</td><td>8.5</td><td>D-</td></tr>
<tr><td>9</td><td>9.5</td><td>D</td></tr>
<tr><td>10</td><td>10.5</td><td>C</td><td rowspan="2">Fair</td></tr>
<tr><td>11</td><td>11.5</td><td>C+</td></tr>
<tr><td>12</td><td>12.5</td><td>B-</td><td rowspan="3">Good</td></tr>
<tr><td>13</td><td>13.5</td><td>B</td></tr>
<tr><td>14</td><td>14.5</td><td>B+</td></tr>
<tr><td>15</td><td>16.5</td><td>A-</td><td>Very Good</td></tr>
<tr><td>17</td><td>20</td><td>A</td><td>Excellent</td></tr>
</table>

DRESS CODES AND ETHICS

وَقُل لِّلْمُؤْمِنَاتِ يَغْضُضْنَ مِنْ أَبْصَارِهِنَّ وَيَحْفَظْنَ
فُرُوجَهُنَّ وَلَا يُبْدِينَ زِينَتَهُنَّ إِلَّا مَا ظَهَرَ مِنْهَا ۖ وَلْيَضْرِبْنَ
بِخُمُرِهِنَّ عَلَىٰ جُيُوبِهِنَّ ۖ وَلَا يُبْدِينَ زِينَتَهُنَّ إِلَّا لِبُعُولَتِهِنَّ
أَوْ آبَائِهِنَّ أَوْ آبَاءِ بُعُولَتِهِنَّ أَوْ أَبْنَائِهِنَّ أَوْ أَبْنَاءِ بُعُولَتِهِنَّ
أَوْ إِخْوَانِهِنَّ أَوْ بَنِي إِخْوَانِهِنَّ أَوْ بَنِي أَخَوَاتِهِنَّ أَوْ نِسَائِهِنَّ
أَوْ مَا مَلَكَتْ أَيْمَانُهُنَّ أَوِ التَّابِعِينَ غَيْرِ أُولِي الْإِرْبَةِ مِنَ
الرِّجَالِ أَوِ الطِّفْلِ الَّذِينَ لَمْ يَظْهَرُوا عَلَىٰ عَوْرَاتِ النِّسَاءِ ۖ
وَلَا يَضْرِبْنَ بِأَرْجُلِهِنَّ لِيُعْلَمَ مَا يُخْفِينَ مِن زِينَتِهِنَّ ۚ وَتُوبُوا
إِلَى اللَّهِ جَمِيعًا أَيُّهَ الْمُؤْمِنُونَ لَعَلَّكُمْ تُفْلِحُونَ ٣١

TRANSLATION IN ENGLISH

(An-Nur 24:31) And say to the believing women that they should lower their gaze and guard their modesty; that they should not display their beauty and ornaments except what (must ordinarily) appear thereof; that they should draw their veils over their bosoms and not display their beauty except to their husbands, their fathers, their husband's fathers, their sons, their husbands' sons, their brothers or their brothers' sons, or their sisters' sons, or their women, or the slaves whom their right hands possess, or male servants free of physical needs, or small children who have no sense of the shame of sex; and that they should not strike their feet in order to draw attention to their hidden ornaments. And O ye Believers! turn ye all together towards Allah, that ye may attain Bliss.

TRANSLATION IN BAHASA MELAYU

Katakanlah kepada wanita yang beriman: ”Hendaklah mereka menahan pandangannya, dan memelihara kemaluannya, dan janganlah mereka menampakkan perhiasannya, kecuali yang (biasa) nampak daripadanya. Dan hendaklah mereka menutup kain kudung ke dadanya, dan janganlah menampakkanperhiasannya, kecuali kepada suami mereka, atau ayah mereka, atau ayah suami mereka, atau putera-putera mereka, atau putera-putera suami mereka, atau saudara-saudara laki-laki mereka, atau putera-putera saudara laki-laki mereka, atau putera-putera saudara perempuan mereka, atau wanita–wanita Islam, atau budak-budak yang mereka miliki, atau pelayan-pelayan laki-laki yang tidak mempunyai keinginan (terhadap wanita) atau anak-anak yang belum mengerti tentang aurat wanita. Dan janganlah mereka memukulkan kakinya agar diketahui perhiasan yang mereka sembunyikan. Dan bertaubatlah kamu sekelian kepada Allah, hai orang-orang yang beriman supaya beruntung. (An-Nuur 31)

SAFETY

- Safety in the electrical laboratory, as everywhere else, is a matter of the knowledge of potential hazards, following safety precautions, and common sense.
- Observing safety precautions are vitally important due to pronounced hazards in any electrical/computer engineering laboratory. Death is usually certain when 0.1 ampere or more current flows through the head or upper thorax and have been fatal to persons with coronary conditions.
- The current depends on body resistance, the resistance between body and ground, and the voltage source. If the skin is wet, the heart is weak, the body contact with ground is large and direct, then 40 volts could be fatal. Therefore, never take a chance on "low" voltage.
- When working in a laboratory, injuries such as burns, broken bones, sprains, or damage to eyes are possible and precautions must be taken to avoid these as well as the much less common fatal electrical shock.
- Make sure that you have handy emergency phone numbers to call for assistance if necessary. If any safety questions arise, consult the lab demonstrator or technical assistant/technician for guidance and instructions.
- Observing proper safety precautions is important when working in the laboratory to prevent harm to yourself or others.
- The most common hazard is the electric shock which can be fatal if one is not careful.

Acquaint yourself with the location of the following safety items within the lab.

a. **Fire Extinguisher**
b. **First Aid Kit**
c. **Telephone and Emergency numbers**

ECE Department	:	*03-6196 4530*
Kulliyyah of Engineering Deputy Dean's Student Affairs	:	*03-6196 4447*
IIUM Security	:	*03-6196 4172*
IIUM Clinic	:	*03-6196 4444*

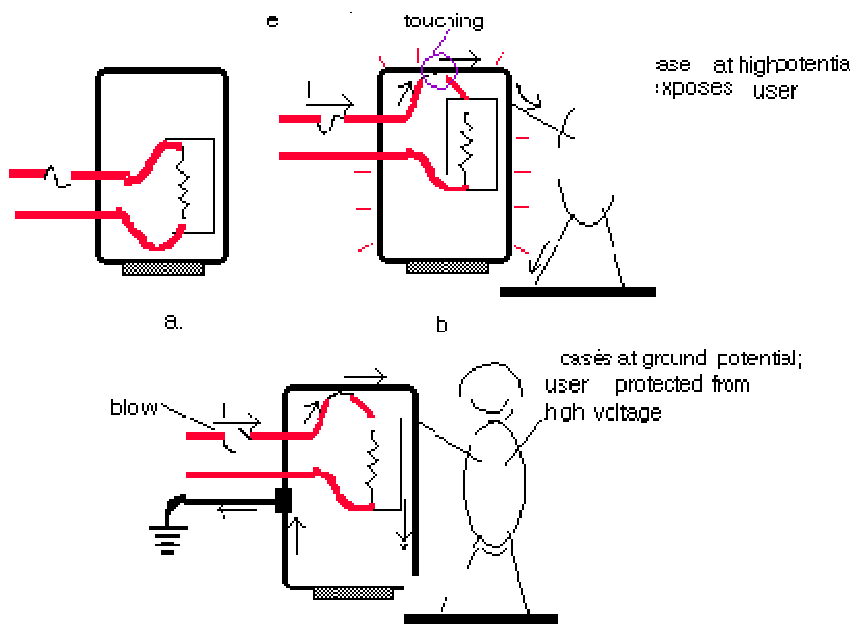
Electric Shock

Shock is caused by passing an electric current through the human body. The severity depends mainly on the amount of current and is less function of the applied voltage. The threshold of electric shock is about 1 mA which usually gives an unpleasant tingling. For currents above 10 mA, severe muscle pain occurs and the victim can't let go of the conductor due to muscle spasm. Current between 100 mA and 200 mA (50 Hz AC) causes ventricular fibrillation of the heart and is most likely to be lethal. For voltage effect to be fatal depends on the skin resistance. Wet skin can have a resistance as low as 150 Ω and dry skin may have a resistance of 15 kΩ. Arms and legs have a resistance of about 100 Ω and the trunk 200 Ω. This implies that 240 V can cause about 500 mA to flow in the body if the skin is wet and thus be fatal. In addition skin resistance falls quickly at the point of contact, so it is important to break the contact as quickly as possible to prevent the current from rising to lethal levels.

Equipment Grounding

Grounding is very important. Improper grounding can be the source of errors, noise and a lot of trouble. It is vital to focus on equipment grounding as a protection against electrical shocks. Electric instruments and appliances have equipment cases that are electrically insulated from the wires that

carry the power. The isolation is provided by the insulation of the wires as shown in Figure a. However, if the wire insulation gets damaged and makes contact to the case, the case will be at the high voltage supplied by the wires.
If the user touches the instrument he or she will feel the high voltage. If, while standing on a wet floor, a user simultaneously comes in contact with the instrument case and a pipe or faucet connected to ground, a sizable current can flow through him or her, as shown in Figure b. however, if the case is connected to the ground by use of a third (ground) wire, the current will flow from the hot wire directly to the ground and bypass the user as illustrated in Figure c.



c.

Equipment with a three wire cord is thus much safer to use. The ground wire (3rd wire) which is connected to metal case, is also connected to the earth ground (usually a pipe or bar in the ground) through the wall plug outlet.

Always Observe The Following Safety Precautions When Working In The Laboratory:

1. Do not work alone while working with high voltages or on energized electrical equipment or electrically operated machinery like a drill.

2. Power must be switched off whenever an experiment or project is being assembled, disassembled, or modified. Discharge any high voltage points to grounds with a well insulated jumper. Remember that capacitors can store dangerous quantities of energy.

3. Make measurements on live circuits or discharge capacitors with well insulated probes keeping one hand behind your back or in your pocket. Do not allow any part of your body to contact any part of the circuit or equipment connected to the circuit.

4. After switching power off, discharge any capacitors that were in the circuit. Do not trust supposedly discharged capacitors. Certain types of capacitors can build up a residual charge after being discharged. Use a shorting bar across the capacitor, and keep it connected until ready for use. If you use electrolytic capacitors, do not :
   - put excessive voltage across them

- put ac across them
- connect them in reverse polarity

5. Take extreme care when using tools that can cause short circuits if accidental contact is made to other circuit elements. Only tools with insulated handles should be used.

6. If a person comes in contact with a high voltage, immediately shut off power. Do not attempt to remove a person in contact with a high voltage unless you are insulated from them. If the victim is not breathing, apply CPR immediately continuing until he/she is revived, and have someone dial emergency numbers for assistance.

7. Check wire current carrying capacity if you will be using high currents. Also make sure your leads are rated to withstand the voltages you are using. This includes instrument leads.

8. Avoid simultaneous touching of any metal chassis used as an enclosure for your circuits and any pipes in the laboratory that may make contact with the earth, such as a water pipe. Use a floating voltmeter to measure the voltage from ground to the chassis to see if a hazardous potential difference exists.

9. Make sure that the lab instruments are at ground potential by using the ground terminal supplied on the instrument. Never handle wet, damp, or ungrounded electrical equipment.

10. Never touch electrical equipment while standing on a damp or metal floor.

11. Wearing a ring or watch can be hazardous in an electrical lab since such items make good electrodes for the human body.

12. When using rotating machinery, place neckties or necklaces inside your shirt or, better yet, remove them.

13. Never open field circuits of D-C motors because the resulting dangerously high speeds may cause a "mechanical explosion".

14. Keep your eyes away from arcing points. High intensity arcs may seriously impair your vision or a shower of molten copper may cause permanent eye injury.

15. Never operate the black circuit breakers on the main and branch circuit panels.

16. In an emergency all power in the laboratory can be switched off by depressing the large red button on the main breaker panel. Locate it. It is to be used for emergencies only.

17. Chairs and stools should be kept under benches when not in use. Sit upright on chairs or stools keeping the feet on the floor. Be alert for wet floors near the stools.

18. Horseplay, running, or practical jokes must not occur in the laboratory.

19. Never use water on an electrical fire. If possible switch power off, then use CO_2 or a dry type fire extinguisher. Locate extinguishers and read operating instructions before an emergency occurs.

20. Never plunge for a falling part of a live circuit such as leads or measuring equipment.

21. Never touch even one wire of a circuit; it may be hot.

22. Avoid heat dissipating surfaces of high wattage resistors and loads because they can cause severe burns.

23. Keep clear of rotating machinery.

Precautionary Steps Before Starting An Experiment So As Not To Waste Time Allocated

1. Read materials related to experiment before hand as preparation for pre-lab quiz and experimental calculation.

2. Make sure that apparatus to be used are in good condition. Seek help from technicians or the lab demonstrator in charge should any problem arises.

    - Power supply is working properly i.e. Imax (maximum current) LED indicator is disable. Maximum current will retard the dial movement and eventually damage the equipment. Two factors that will light up the LED indicator are short circuit and insufficient supply of current by the equipment itself. To monitor and maintain a constant power supply, the equipment must be connected to circuit during voltage measurement. Digital multimeter (DMM) are not be used simultaneously with oscilloscope to avert wrong results.
    - DMM with low battery indicated is not to be used. By proper connection, check fuse functionality (especially important for current measurement). Comprehend the use of DMM for various functions. Verify measurements obtained with theoretical values calculated as it is quite often where 2 decimal point reading and 3 decimal point reading are very much deviated.
    - The functionality of voltage waveform generator is to be understood. Make sure that frequency desired is displayed by selecting appropriate multiplier knob. Improper settings (i.e. selected knob is not set at minimum (in direction of CAL – calibrate) at the bottom of knob) might result in misleading values and hence incorrect results. Avoid connecting oscilloscope together with DMM as this will lead to erroneous result.
    - Make sure both analog and digital oscilloscopes are properly calibrated by positioning sweep variables for VOLT / DIV in direction of CAL. Calibration can also be achieved by stand alone operation where coaxial cable connects CH1 to bottom left hand terminal of oscilloscope. This procedure also verifies coaxial cable continuity.

3. Internal circuitry configuration of breadboard or veroboard should be at students' fingertips (i.e. holes are connected horizontally not vertically for the main part with engravings disconnecting in-line holes).

4. Students should be rest assured that measured values (theoretical values) of discrete components retrieved i.e. resistor, capacitor and inductor are in accordance the required ones.

5. Continuity check of connecter or wire using DMM should be performed prior to proceeding an experiment. Minimize wires usage to avert mistakes.

6. It is unethical and unislamic for students to falsify results as to make them appear exactly consistent with theoretical calculations.

INTRODUCTON CONTENT

1. Basic Guidelines.
2. Lab. Instructions.
3. Lab. Reports.
4. Grading.
5. Schedule.

1. Basic Guidelines

All experiments in this manual have been tried and proven and should give you little trouble in normal laboratory circumstances. However, a few guidelines will help you conduct the experiments quickly and successfully.

1. Each experiment has been written so that you follow a structured logical sequence meant to lead you to a specific set of conclusions. Be sure to follow the procedural steps in the order which they are written.

2. Read the entire experiment and research any required theory beforehand. Many times an experiment takes longer that one class period simply because a student is not well prepared.

3. Once the circuit is connected, if it appears "dead'' spend few moments checking for obvious faults. Some common simple errors are: power not applied, switch off, faulty components, lose connection, etc. Generally the problems are with the operator and not the equipment.

4. When making measurements, check for their sensibility.

5. It's unethical to "fiddle" or alter your results to make them appear exactly consistent with theoretical calculations.

2. Lab Instructions

1. Each student group consists of a maximum of two students. Each group is responsible in submitting 1 lab report upon completion of each experiment.

2. Students are to wear proper attire i.e. shoe or sandal instead of slipper. Excessive jewelleries are not advisable as they might cause electrical shock.

3. Personal belongings i.e. bags, etc are to be put at the racks provided. Student groups are required to wire up their circuits in accordance with the diagram given in each experiment.

4. **A permanent record in ink of observations** as well as results should be maintained by each student and enclosed with the report.

5. The recorded data and observations from the lab manual need to be approved and signed by the lab instructor upon completion of each experiment.

6. Before beginning connecting up it is essential to check that all sources of supply at the bench are switched off.

7. Start connecting up the experiment circuit by wiring up the main circuit path, then adds the parallel branches as indicated in the circuit diagram.

8. After the circuit has been connected correctly, remove all unused leads from the experiment area,

set the voltage supplies at the minimum value, and check the meters are set for the intended mode of operation.

9. The students may ask the lab instructor to check the correctness of their circuit before switching on.

10. When the experiment has been satisfactory completed and the results approved by the instructor, the students may disconnect the circuit and return the components and instruments to the locker tidily. Chairs are to be slid in properly.

3. Lab Reports

Each group is required to submit a report within **7 days** after performing the experiment. Marks will be deducted due to late submission based on instructor's discretion on the basis of 2 marks/day. Each member of the group will take turn in writing the report. The report writer's name shall be indicated on the cover page of the report. Strictly no make-up lab is allowed.

a. Report format and Evaluation:

The following format should be adhered to by the students in all their laboratory reports unless otherwise advised (refer to the back leaf of each experiment for marking scheme):

No.	Evaluation Items	Marks 20%
1	Objectives	1
2	Brief Theory	2
3	Equipment list	2
4	Experiment Set-up	2
5	Results/Observations	8
6	Discussion and Conclusion	5
	TOTAL	**20**

Take a note that the evaluation scheme of each part/section is given in the above table as a guideline; however this may change if particular sections carry more weight compared to others. All the parts of those listed above should be included in the reports of the students and should be clearly given with the appropriate heading of the reports. The information to be given in each section is set out below:

(i) Objective:
This should state clearly the objective of the experiment. It may be the verification of law, a theory or the observation of particular phenomena. Writing out the aim of the experiment is important to the student as it emphasizes the purpose for which the experiment is conducted.

(ii) Equipment List:
In this section a record should be made of all major equipments used in the experiment. The

information is best given in tabulated form and would include:

- all meters used, giving the make, model and range used.
- all power supplies used, giving the make, model, and range used.
- as much detail as possible on any resistor, coil, capacitor, or other item of equipment essential to the object of the experiment.

(iii) Experiment Setup:
In this section, the student should not give a description of that repetitious procedure which is necessary to obtain a set of experiment results.

It should contain a clear explanation of the procedures taken and the reasons why they were taken. Some specific procedures in the experiment may need explanation so that the reader may fully interpret the results and the conclusions of the experiment. If no specific procedures or precautions are necessary for satisfactory results then this section may be deleted.

(iv) Results/Observations:
Results must be tabulated neatly. Wherever necessary, use the given tables in the lab experiment manuals.
The results must be analyzed before any fact can be deduced from them. Both theoretical and experimental calculations must be done before a comparison can be made between the two. The percentage of errors must be calculated whenever appropriate.

$$\% \text{ of Relative Error} = \frac{|\text{Theoretical Value} - \text{Experimental Value}| * 100\%}{\text{Theoretical Value}}$$

A graph of the experimental results might be used to show a clear picture of the relationship between the measured quantities in the experiment.

(v) Discussion & Conclusion
Once the analysis of the results is complete, the student must form some deductions on the results of his analysis. Usually this involves deducing whether the final results show that the aim of the experiment has been achieved or not, and if they verify some law or theory presented to the student during the lectures. In making a decision on the former point, the student should reread the aim; and on the latter, the text book should be referred to, to ascertain whether there is theoretical agreement or not.

The student should give considerable thought to the material that he intends to submit in this section. It is here that he is able to express his own ideas on the experiment results and how they were obtained. It is the best indication to his teacher of whether he has understood the experiment and of how well he has been able to analyze the results and make deductions from them.

It is recommended that the conclusion should be taken up by the student's clear and concise explanation of his reasoning, based on the experimental results, that led to the deductions from which he was able to make the two statements with which he began the conclusion.

It is very rare experiment in which the results are entirely without some discrepancy. The student should explain what factors, in his opinion, may be the possible causes of these discrepancies. Similarly, results of an unexpected nature should form the basis for a discussion of their possible nature and cause. The student should not be reluctant to give his opinions even though they may not be correct. He should regard his discussion as an opportunity to demonstrate his reasoning ability.

Should the results obtained be incompatible with the aim or with the theory underlying the experiment, then an acceptable report may be written suggesting reasons for the unsatisfactory results. It is expected that the student should make some suggestions as to how similar erroneous results for this experiment might be avoided in the future.

The student must not form the opinion that an unsatisfactory set of results makes a report unacceptable.

b. Presentation of Lab. Reports:

All students are required to present their reports in accordance with the following instructions.

i) Reports have to be **handwritten** for submission.
ii) Writing should appear on one side of each sheet only.
iii) All sheets, other than graph sheets, should contain a margin approximately three centimeters wide on the left-hand side: no writing should appear in the margin.
iv) The cover page of the report **must be** as in page i.
v) All sections such as aim, method, and so on, should be titled on the left hand side of the working space of the page.
vi)
- Each type of calculation pertaining to the experiment should be preceded by a brief statement indicating its objective.
- All calculations are to be shown in sufficient details to enable the reader to follow their procedure.
- All formulas used are to be written in correct symbols prior to the substitution of the known quantities.

vii) All diagrams (circuits or otherwise) can be neatly hand drawn or electronically drawn.
viii) All graphs are to be drawn on graph paper in blue or black ink. Other colors may be used for identification.
ix) The abscissa and ordinate are to be drawn in all times and scaled with the value clearly indicated at each major division. The quantity at each axis represents and the unit in which it is calibrated should be clearly indicated.
x) Each graph is to be titled so as to indicate clearly what it represents.
xi) The report submitted by each student should contain a conclusion and discussion of more than 300 words.

4. Grading

The work in the Electric Circuits related lab carries 50% of total marks for the ECE 1101 subject (ENGINEERING LAB 1).

The distribution of marks for Electric Circuits Lab is as follows:

Quizzes	20%
Lab Reports	40%
Final Lab Test	40%
Total	**100%**

5. Schedule

Weeks	Topics
1	Introduction to Lab
3	Library course
4	***Experiment #1***: Basic Ohm's Law & Series and parallel circuits (Part 1)
5	***Experiment #1***: Basic Ohm's Law & Series and parallel circuits (Part 2)
6	***Experiment#2***: Kirchoff's voltage and current laws
7	***Experiment#3***: Thevenin's and Norton's theorem and Maximum power transfer
8	***Experiment#4***: Superposition
9	***Experiment#5:*** Transient Response of an RC Circuit
10	***Experiment#6:*** AC peak, RMS and phase measurement (Part 1)
11	***Experiment#6:*** AC peak, RMS and phase measurement (Part 2)
12	Make-up Lab (Optional)
13	**Final Lab Test**

- All lab report should be submitted **7 days** after performing the experiment to the lecturer/demonstrators on duty for your section.
- Late submission of the lab report will not be entertained and will be given **Nil** for the report.
- Strictly no make-up lab due to absenteeism is allowed without sound reason.

2:256 Let there be no compulsion in religion: Truth stands out clear from Error: whoever rejects evil and believes in Allah hath grasped the most trustworthy hand-hold that never breaks. And Allah heareth and knoweth all things.

Experiment 1

Basic Ohm's Law & Series and Parallel Circuits

Test (a): Resistor Color Code

Aims:

- To determine the value of resistors from their Electronic Industries Association *(EIA)* color code.
- To investigate the properties of potentiometer.

Apparatus:

- Digital Multimeter.
- Resistors : R1=150Ω, R2=20kΩ and R3=5.1MΩ
- Linear 10kΩ potentiometer

Background:

Resistor

The *ohm* is the unit of resistance, and it is represented by the symbol Ω (Greek letter omega). Resistance values are indicated by a standard color code that manufacturers have adopted. This code uses color band on the body of resistor. The colors and their numerical values are given in the resistor color chart, **Table 1a-1.** This code is used for 1/8-w, 1/4-w, 1/2- w, 2-w, and 3-w resistors.(w stands for watt, i.e.is the power dissipation ability of the resistance).

The basic resistor is shown in **Figure 1a-1**. The standard color code marking consists of four bands around the body of the resistor. The color of the first band indicates the first significant figure of the resistance value. The second band indicates the second significant figure. The color of the third band indicates the number of zeros that follow the first two significant figures. For example: 1kΩ color codes are arranged from the leftmost to the rightmost to be brown, black, red and gold.

The fourth band indicates the percent tolerance of the resistance. Percent tolerance in the amount the resistance may vary from the value indicated by the color code. Because resistors are mass produced, variations in materials will affect their actual resistance. Many circuits can still operate as designed even if the resistors in the circuit do not have the precise value specified. Tolerances are usually given as plus or minus the nominal, or color code value.

Wire wound, high-wattage resistors usually are not color coded but have the resistance value and wattage rating printed on the body of resistor. To avoid having to write all the zeros for high value resistors the metric abbreviations of k (for 1000) and M for (1000000) are used. For example:

- 33,000 Ω can be written as 33kΩ. (pronounced 33 kay, or 33 kilohms)
- 1,200,000 Ω can be written as 1.2MΩ. (Pronounced 1.2 meg, or 1.2 megohms).

Color	Significant figure (First & second band)	No. of Zeros (Multiplier) (third band)	%Tolerance (Forth band)
Black	0	0(10^0)	-
Brown	1	1(10^1)	-
Red	2	2(10^2)	-
Orange	3	3(10^3)	-
Yellow	4	4(10^4)	-
Green	5	5(10^5)	-
Blue	6	6(10^6)	-
Violet	7	7(10^7)	-
Gray	8	8(10^8)	-
White	9	9(10^9)	-
Gold	-	-1(10^{-1})	5
Silver	-	-2(10^{-2})	10
No color	-	-	20

Table 1a-1: Resistor color code

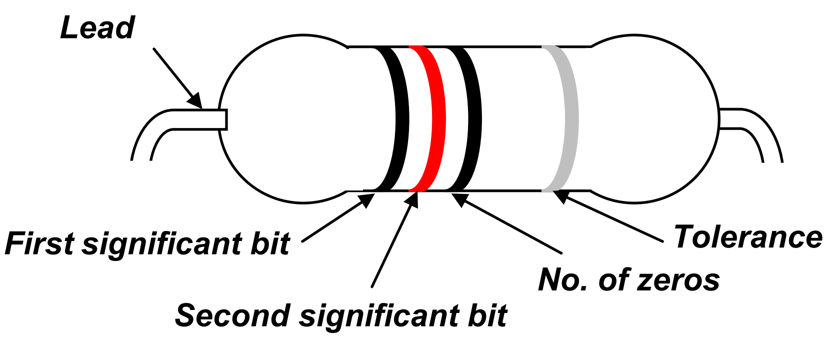


Figure 1a-1: resistor color code

Variable resistors

In addition to the fixed-value resistors, variable resistors are used. The two types of variable resistors are the rheostat and the potentiometer. Volume controls used in radio is a typical example of potentiometer.

A rheostat is essentially a two-terminal device. Its circuit symbol is shown in **Figure 1a-2**. Points **a** and **b** are connected to the circuit. A rheostat has a maximum resistance value, specified by the manufacturer, and a minimum value, usually 0Ω. The arrow head indicates a mechanical means of adjusting the rheostat so that the resistance, measured between points **a** and **b**, can be adjusted to any intermediate value within the range of variation.

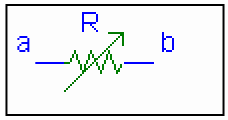


Figure 1a-2

The circuit symbol of potentiometer, **Figure 1a-3**, shows that this is a three-terminal device. The resistance between the terminals **a** and **c** is fixed. Point **b** is the variable arm of the potentiometer, the wiper. The arm is a metal contactor that slides along the uninsulated surface of the resistance element. The resistance between points **a** and **c** varies as the length of element included between points **a** and **b**. The same is true for points **c** and **b**.

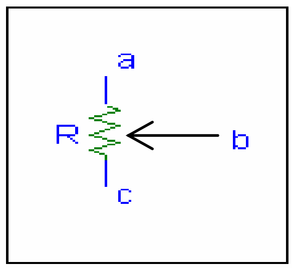


Figure 1a-3

A potentiometer may be used as a rheostat if the center arm and one of the end terminals are connected into the circuit and the other end terminal is left disconnected.

Method:

Resistor color code:

1. The color code on each resistor defines the nominal value about which the tolerance is defined. The nominal value is that value of resistance that the resistor would have if its tolerance were 0 percent. Use the color code to determine the nominal value for each resistor and record them in **Table 1a-2**.
2. Determine the tolerance and record the values for each of the resistor.
3. Determine the theoretical maximum and minimum values for each resistor in turn.
4. Measure and record the actual value of resistor, and check to see whether or not this value falls between the calculated limits in step 2.

Variable resistor:

1. Identify the end terminals and the wiper terminal for the potentiometer. Number them 1, 2 and 3 with 2 being the wiper.
2. Position the ohmmeter between terminals **1-2**, **2-3** and **1-3** and record these measured values in **Table 1a-3**.
3. Add the values measured between terminals **1-2** and **2-3** and compare the result with the value measured between **1-3** (theoretical value).
4. Reposition the shaft of the potentiometer and repeat steps 2 and 3 for the other two trials.

Test (b): Voltage and Current Measurements

Aim:

- To measure voltage and current in DC circuit.

Apparatus:

- DC voltage supply, 2k resistor, and two Digital Multimeters (2DMMs).

Background:

The test will familiarize you with the basic voltage and current measurements that is connected to a dc power supply.

Voltage Measurements

- A voltemeter must always be connected with probes **across the** component under test; that is, the circuit need never be broken (see **Figure 1b-1**). This is often referred to as parallel connection.
- Polarity: It is a good practice to place the correct leads at the proper nodes. Eg. Red lead at the positive node and the black lead at the negative node.

Current Measurements

- In measuring current (**Figure 1b-2**), the meter must always be inserted within the circuit in such a manner that ***the current to be measured will flow through the meter*** and it is similar to a series connection. You **must break** the circuit to perform a current measurement.

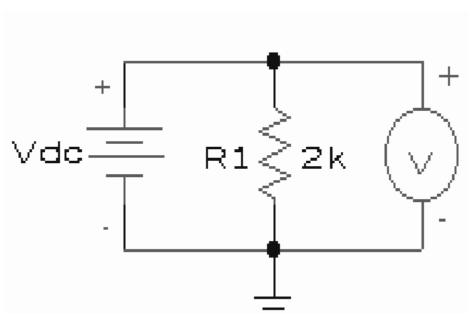


Figure 1b-1

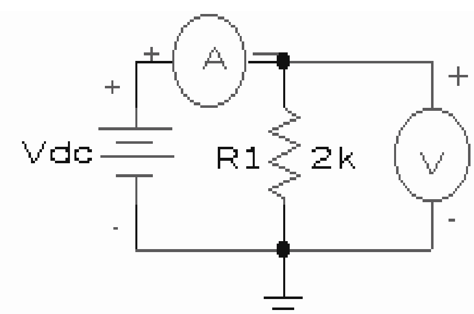


Figure 1b-2

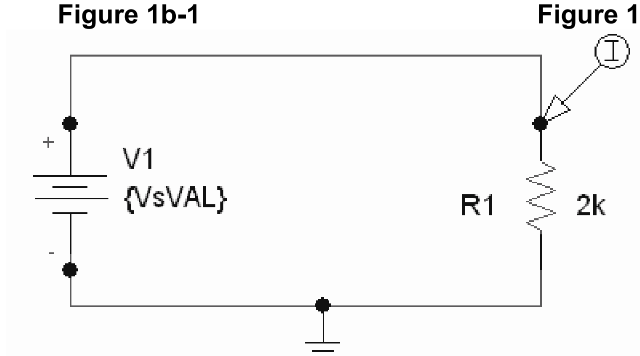


Figure 1b-3

Method:

1. Switch on the power supply and set for the minimum output voltage.
2. Set the digital multi-meter to measure voltage.
3. Connect the voltmeter directly to the power supply terminals.
4. Observe the effect of tuning the output voltage control and adjust the voltage value to 2 Volts.
5. Remove the meter and connect 2kΩ resistor across the terminals of the power supply as shown in **Figure 1b-1**. Reconnect the meter as shown. Observe the value measured by the meter.
6. Now break the circuit as shown in **1b-2** and insert the other meter set on mA current range. The meter will now be reading the current flowing in the circuit.
7. Record the current in **Table 1b-1**.
8. Increase the voltage in 2-Volt steps. For each of the voltage increment, measure and record the current changes.

Test (c): Ohm's Law

Aim:

- To verify Ohm's law (V=IR).

Apparatus:

- Voltage dc supply, resistors 5.1kΩ and two digital DMMs.

Background:

Ohm's Law is the basis of many electrical circuit calculations which indicates V=IR. In this experiment Ohms Law has to be verified and will prove that the current through a resistor is proportional to the voltage across it. The way in which we accomplish this is to measure the voltage across and the current through a known resistor for several different pairs of values. Data can then be plotted on a graph, and if the relationship is truly linear, it should yield a straight line.

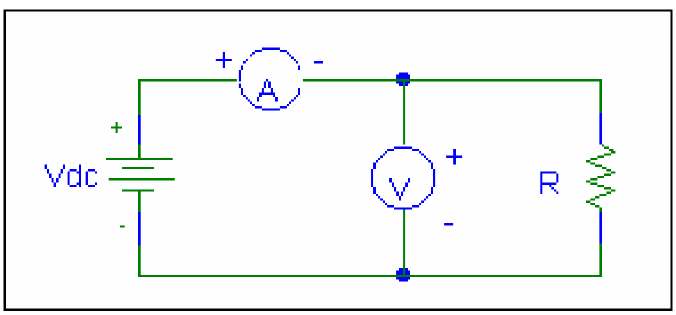


Figure 1c-1

Method:

1. Measure the actual value of the resistor R and record the result in **Table 1c-1**.
2. Connect the circuit in **Figure 1c-1** with R= 5.1kΩ.
3. Beginning at 0 volt, increase the voltage across R in 1-Volt steps until 9 Volts. Measure and record the resulting current in **Table 1c-1** for each increment of voltage.
4. Plot the graphs of I verses V for results in Table 1c-1. (Assign I to the vertical axis and V to the horizontal axis).

5. Construct a right triangle on the graph and from this, re-determine the slope and hence evaluate the conductance G.
6. From this information, evaluate the resistance R. Record G and R for the graph in the appropriate column in **Table 1c-2.**
7. Compare these experimentally obtained values with those measured values recorded in the respective tables.

Analysis, deductions and conclusion:

1. Has Ohm's law been verified?
2. What are the facts supporting this decision?
3. State the factors affecting resistance of a material with a uniform cross-sectional area?
4. What are the common types of fixed and variable resistors? State usage of each type.
5. If the Resistor from the experiment above is changed to 10kΩ, deduct what will happen to the slope of I-V graph. What effect on the conductance G?
6. Do all resistors obey ohm's law? Justify your answer by stating some examples.

Test (d): Series and Parallel Circuits

Aims:

- To verify that in a series circuit;
  1) The total resistance is equal to the sum of the individual resistors.
  2) The voltage drops across the resistors equals to the applied voltage.
  3) The value of the current is the same in all parts of the circuit.
- To verify that in parallel circuits;
  1) The equivalent resistance is the reciprocal of the sum of reciprocals of the individual resistors.
  2) The branch current in parallel equal to the supply current.
  3) The voltage drop across each resistor in parallel is the same.
- To verify by measurement and calculation for two different networks: the total current and the branch values, the voltage drop across various parts of the networks and the method for determining the equivalent resistance of such networks.

Apparatus:

- 15 volt dc supply.
- Two digital multi-meters.
- Resistors ; 1.0kΩ, 1.5kΩ, 6.8kΩ

<u>Circuit Diagram:</u>

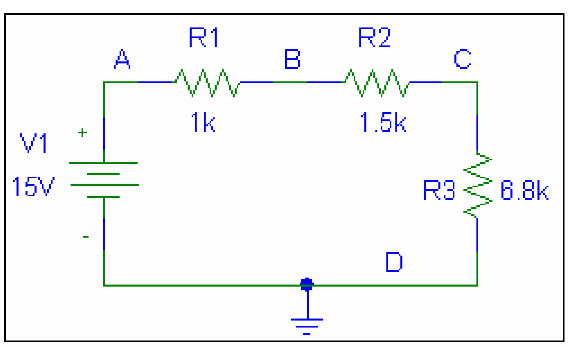


Figure 1d-1

(a) Series Circuit

Method:

1. Connect the circuit shown in **Figure 1d-1**.
2. Adjust the supply voltage to 15V.(Note the value must be kept constant throughout the test by connecting voltmeter across the voltage supply in the circuit to observe the voltage.)
3. Switch off the supply. Connect the ammeter in position A.
4. Switch on the supply. Read the current through resistor R1.
5. Connect the voltmeter across R1 and measure the voltage drop across it.
6. Repeat 3 until 5 for the ammeter positions B, C, and D and the voltmeter positions across resistors R2, and R3.
7. Record the voltage for close and open loop. Fill up the measured values in **Table 1d-1**

(b) Parallel Circuits

Circuit Diagram:

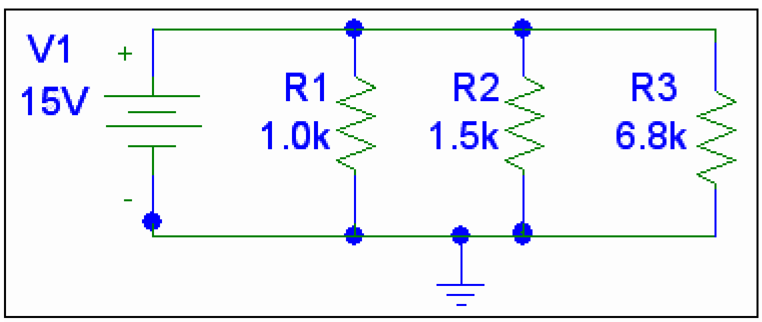


Figure 1d-2

Method:

1. Connect the circuit shown in **Figure 1d-2**.
2. Adjust the supply voltage 15V.(Note the value of the supply voltage and keep it constant throughout the test.)
3. Switch off the supply. Connect the ammeter in position A, the total current, I_{Total}. Switch on the supply. Read the current through resistor R1 and the voltage drop across it.
4. Repeat 4 for the ammeter positions B, C, and D and the voltmeter positions across resistors R2, and R3. Be careful not to touch R3 during measurement as it might be hot.
5. Fill up the measured values in **Table 1d-2.**

Analysis, deductions and conclusions:

1. Have the aims been achieved?
2. What are the facts supporting these decision for each point of the aim?
3. What are the probable factors, which contributed to the discrepancies in the results for each point of the aim?
4. Indicate which circuit the principle of voltage division and current division is applicable to.
5. State the formula for each condition.

Table of Results

Resistor	R1	R2	R3
Nominal Value			
Tolerance %			
Maximum Value			
Minimum Value			
Measured Value			

Table 1a-2

	1st trial	2nd trial	3rd trial
R1-2			
R2-3			
R1-3			
R1-2+R2-3			

Table 1a-3

V supply (volt)	2	4	6
Current (mA) (Measured)			
Current (mA) (Calculated)			

Table 1b-1

Nominal Resistance R=5.1kΩ	Measured Resistance R =							
Voltage Source (Vs)	(V)	0	1	2	3	4	5	6
Current (Measured values)	(mA)							
Current (Theoretical values)	(mA)							

Table 1c-1

	Slope (G)	R (1/G)
Measured Values		
Theoretical Values		

Table 1c-2

Supply voltage (volt)	V1 (volts)	V2 (volts)	V3 (volts)	Σ Voltage (volts)
Supply current (mA)	I1 (mA)	I2 (mA)	I3 (mA)	I Total (mA)
Total resistance (Ohms)	R1 (Ohms)	R2 (Ohms)	R3 (Ohms)	Σ R R1+R2+R3

Table 1d-1

Supply current (ampere)	I1 (amperes)	I2 (amperes)	I3 (amperes)	Σ Current
Supply voltage (volt)	V1 (volts)	V2 (volts)	V3 (volts)	
Equivalent resistance	R1 (Ohms)	R2 (Ohms)	R3 (Ohms)	Equivalent resistance
Total conductance	G1 (Siemens)	G2 (siemens)	G3 (siemens)	Σ G

Table 1d-2

3:191 Men who celebrate the praises of Allah, standing, sitting, and lying down on their sides, and contemplate the (wonders of) creation in the heavens and the earth, (With the thought): "Our Lord! not for naught Hast Thou created (all) this! Glory to Thee! Give us salvation from the penalty of the Fire.

Experiment 2

Kirchhoff's Voltage and Current Laws

Aim:

- To verify Kirchhoff's voltage and current laws.

Apparatus:

- One DC supply 10V
- Three digital multimeters
- Resistors 300Ω (2), 330Ω, 1.8kΩ, 2.7kΩ, 3.0kΩ

Circuit diagrams:

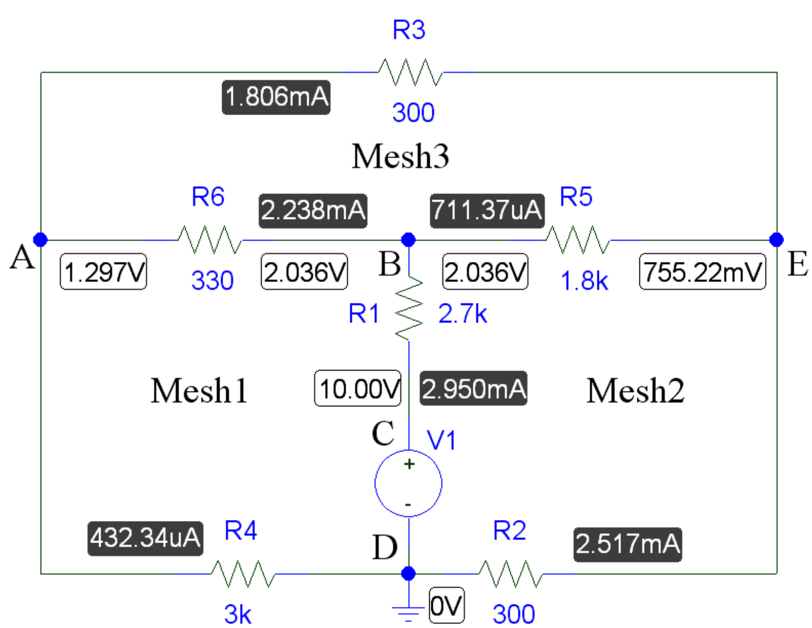


Figure 2-1

Method:

(a) Kirchhoff's Voltage Law:

1. Measure the resistance of each resistor. Set the supply voltage to 10V. Record the measured values in **Table 2-1a**.
2. Construct the circuit shown in **Figure 2-1**
3. Commence at point A and measure the potential difference between each successive pair of lettered terminals for Mesh 1. i. e. A-B, B-C, C-D and D-A.
   (Note: DMM's probes have to be placed consistently.)
4. Record down the measured values in **Table 2-1b**.
5. Measure the potential difference for the points AC, CE and EA. Verify Kirchhoff's voltage law using the displayed values. (Note that V_{CA} is actually V_C – V_A). What can be deduced from this condition? Record the measured values in Table 2-1c.

(b) Kirchhoff's Current Law:

1. Measure the branch currents entering node A by placing ammeter as shown in **Figure 2-1**.
2. Record the magnitude and the direction of the current as indicated by each ammeter in **Table 2-2**.

Analysis, deductions and conclusion:

1. Has Kirchhoff's laws been verified? What facts determined for the results of this test support this decision?
2. Are there any circuit configurations for which Kirchhoff's laws are not applicable? Substantiate your answer.
3. For what type of circuit configurations would it be prudent not to apply Kirchhoff's laws?

Table of Results

Measured components values

V1	R1	R2	R3	R4	R5	R6

Table 2-1a

Reference points	Measured Values		Theoretical Values	
	Potential Difference (V)	Sign (+ or -)	Potential Difference (V)	Sign (+ or -)
A-B				
B-C				
C-D				
D-A				

Table 2-1b

Reference points	Measured Values		Theoretical Values	
	Potential Difference (V)	Sign (+ or -)	Potential Difference (V)	Sign (+ or -)
A-C				
C-E				
E-A				

Table 2-1c

Resistance	Current	Current direction
R3		
R4		
R6		

Table 2-2

6:59 With Him are the keys of the unseen, the treasures that none knoweth but He. He knoweth whatever there is on the earth and in the sea. Not a leaf doth fall but with His knowledge: there is not a grain in the darkness (or depths) of the earth, nor anything fresh or dry (green or withered), but is (inscribed) in a record clear (to those who can read).

Experiment 3

Thevenin's & Norton's Theorem and Maximum Power Transfer

Aims:

- To applied Thevenin's and Norton's theorems in finding the current flowing in a particular resistor (variable load) in a particular network.
- To verify the theorems by comparing the simulated values to those obtained by measurement.

Apparatus:

- DC supply (Vs=15V)
- Digital multimeters
- Resistors R1=1.8kΩ; R2=3.6kΩ; R3=820Ω; R4=R5=100Ω; R_L=180

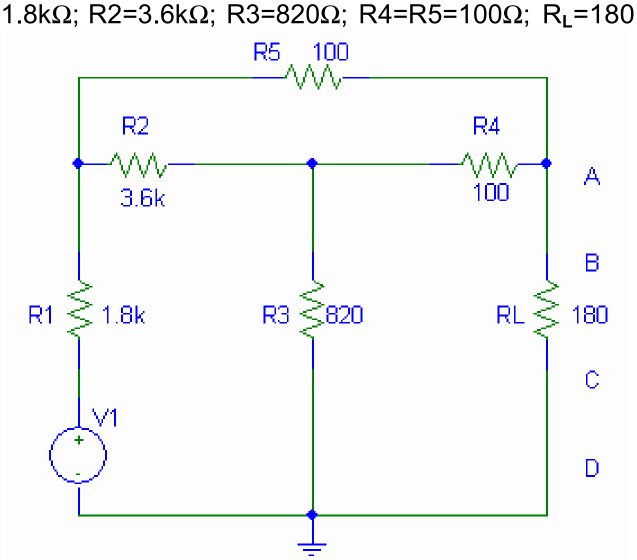


Figure 3-1

Method:

(a) Thevenin's Theorem:

1. Measure the supply voltage and resistance of each resistor. Record these values in **Table 3-1**. Select RL as the resistor where it is proposed to determine the current value.
2. Construct the circuit in **Figure 3-1**. Do not turn on the supply.
3. Remove resistor RL from the network.
4. Turn on the supply. Measure the voltage between the points A and D of the network. This is the Thevenin's voltage. Record the value in **Table 3-2**.
5. Switch off the power supply. Replace the power supply V1 with a short circuit.
6. Measure the resistance between terminals A and D. This is the Thevenin's resistance. Record the value in **Table 3-2**.
7. Place back the resistor RL in circuit with an ammeter is connected between terminals A and B or C and D.
8. Remove the short circuit connection and place back the supply in the circuit.
9. Turn on the supply. Read and record the current value flowing in the resistor RL.
10. Draw Thevenin's equivalent circuit inclusive of resistor RL.

(b) Norton's Theorem:

1. Construct the circuit as shown in **Figure 3-1**. Do not turn on the supply
2. Remove resistor RL from the network. RL is selected as the resistor where it is proposed to determine the current value.
3. Turn on the supply. Read the current shown by the ammeter between terminals A and D. This is Norton's current, I_N. Record its value in **Table 3-3.**
4. Switch off the power supply. Replace the supply with a short circuit.
5. Measure the resistance between terminals A and D. This is Norton's resistance, record the value in **Table 3-3**.
6. Place back the resistance RL in circuit with an ammeter is connected between terminals A and B or C and D.
7. Place back the power supply in the circuit and remove the short circuit connection.
8. Read and record the current value flowing in the resistor RL.
9. Draw Norton's equivalent circuit inclusive of resistor RL.

Analysis, deductions and conclusion:

1. Have the aims of the test been achieved?
2. What facts deduced from the results of this test indicate whether the theorems have been verified or not?
3. Is Thevenin's theorem is likely to be widely used in practice?
4. Is the fact that the Norton's theorem is based on the concept of a constant current generator likely to limit its usage? Why?
5. What type of problems each theorem is most applicable in the circuit analysis?
6. Are the theorems valid if there is more than one supply in the circuit? Give your reasons.
7. Are the theorems applicable with presence of dependent sources in the circuit? Give your reasons.

(c) The Maximum Power Transfer

Aim:

- To verify the maximum power transfer theorem.

Introduction:

The maximum power transfer theorem states that a resistive load will receive maximum power when its total resistive value is exactly equal to the Thevenin's resistance of the network as "seen" by the load.

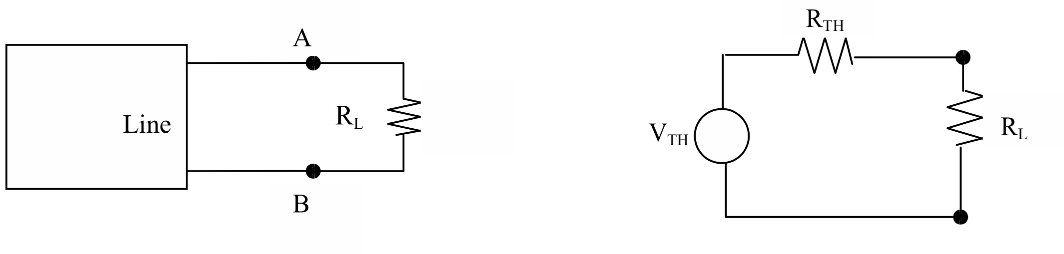


Figure 3-2

Figure 3-2 shows that any circuit A terminated with a load R_L can be reduced to its Thevenin's equivalent. Now according to this theorem the load R_L will receive maximum power when

$R_L = R_{TH}$

The efficiency of power transfer is defined as the ratio of the power delivered to the load P_{OUT}, to the power supplied by the source P_{IN}.

$$\%\eta = \frac{P_{OUT}}{P_{IN}} \times 100 = \frac{V_L}{V_{TH}} \times 100 = \frac{R_L}{R_L + R_{TH}} \times 100$$

The voltage regulation is defined as

$$\%VR = \frac{\text{Load voltage at no load} - \text{Load voltage at full load}}{\text{Load voltage at full load}} \times 100$$

$$= \frac{R_{TH}}{R_L} \times 100$$

At maximum power transfer condition, η= 50% & VR= 100%.
A relatively low efficiency of 50% can be tolerated in situations where power levels are relatively low such as in electronic & communications circuits for transmission & reception of signal where the Engineer's goal is to receive or transmit maximum amount of power.

However, if large power levels are involved, such as at generating stations, efficiencies of 50% would not be acceptable. The goal here is high efficiency and not maximum power. Power utility systems are designed to transmit the power to the load with the greatest efficiency by reducing the losses on the power lines. Thus the effort is concentrated on reducing R_{TH}, which would represent the resistance of the source plus the line resistance.

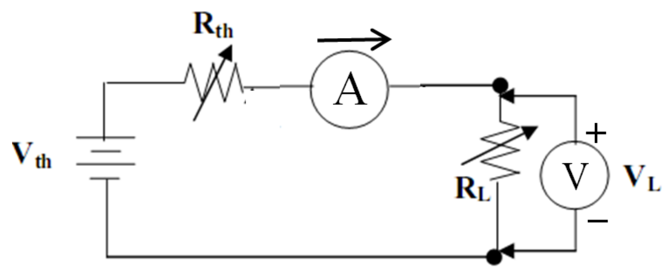


Figure 3-3

Method:

1. Set up the circuit as shown in **Figure 3-3**.
2. Apply 10V dc from the dc power supply.
3. Keep the Thevenin rheostat, R_{th} 5kΩ at maximum position.
4. Vary the load rheostat R_L from 0Ω to 10kΩ.
5. Measure the voltages V_L and I. Take 11 sets of reading.
6. Record all result in **Table 3-4.**

Analysis, deductions and conclusion:

1. Has the maximum power transfer theorem been verified from the experiment? What facts determined from the results support this decision?
2. Why high voltage transmission is used in case of transmitting electric power?
3. Where maximum power transfer is used?
4. Why instead of transmitting maximum power, power utility transmits power at maximum efficiency?
5. Deduce the condition for maximum power transfer.

Report:

Plot the following curves on the graph paper and attach them to your report:

1. % η vs R_L
2. % VR vs R_L
3. loss vs R_L
4. P_{OUT} vs R_L
5. I_L vs R_L
6. V_L vs R_L

Table of Results

Measured values						
V1	R1	R2	R3	R4	R5	RL

Table 3-1

Measured values			Theoretical values		
Thevenin's resistance	Thevenin's voltage	current in RL	Thevenin's resistance	Thevenin's voltage	current in RL

Table 3-2

Measured values			Theoretical values		
Norton's Resistance	Norton's current	current in RL	Norton's resistance	Norton's current	current in RL

Table 3-3

No	V_{TH}	V_L	I	$P_{IN} = V_{TH} I$	$P_{OUT} = V_L I$	$Loss = P_{IN} - P_{OUT}$	%η	%VR	$R_L = V_L / I$
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									

Table 3-1

2:28 How can ye reject the faith in Allah.- seeing that ye were without life, and He gave you life; then will He cause you to die, and will again bring you to life; and again to Him will ye return.

4:57 But those who believe and do deeds of righteousness, We shall soon admit to Gardens, with rivers flowing beneath,- their eternal home: Therein shall they have companions pure and holy: We shall admit them to shades, cool and ever deepening.

Experiment 4

Verification of Superposition Theorem

Aim:

- To verify experimentally the Superposition theorem which is an analytical technique of determining currents in a circuit with more than one emf source.

THEOREM:

In a circuit (network) made up of linear elements (e.g. resistors) and containing two or more sources of emf, the current in any particular branch when all the emf sources are acting simultaneously may be found by considering the sources of emf to act one at a time, then finding the current in the specified branch due to each source and then superimposing, or adding algebraically, these component currents.

Note regarding Superposition theorem:

While the current due to a particular source of emf is being found the other emf sources are rendered inactive and if any branch element is in series with those sources that remains intact.

Apparatus:

- Two DC power supplies of suitable voltage and current ratings.
- Three potentiometers each of 10KΩ rating.
- Three DC voltmeters (0-5 V).
- One multi-meter.
- Trainer board

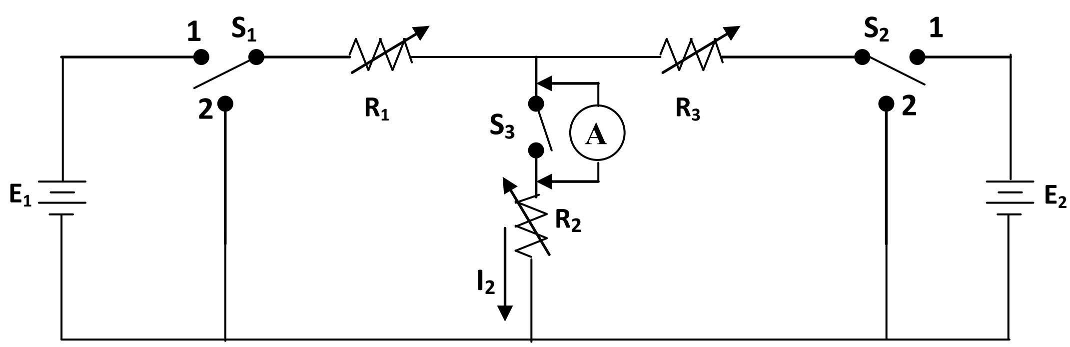


Figure 4-1

Procedures:

1. Set up the network (circuit) as in Figure 4-1.
2. Keep both sources active in the circuit by keeping the poles of SPDT s in proper position.
3. Apply 5 volts from E_1 and 10 volts from E_2.
4. Set the rheostats R_1, R_2, R_3 at such value so that none of the ammeter readings I_1, I_2, I_3 exceeds the power supplies (E_1 and E_2 current ratings and the rheostat current) ratings.
5. Measure the current I_2 and record it in Table 4-1.
6. Render E_2 inactive.
7. Measure the current $I_2^{'}$ in the branch R_2 and record it in Table 4-1.
8. Render E_1 inactive.
9. Measure the current $I_2^{''}$ in the branch R_2 and record it in Table 4-1.
10. Verify if $I_2 = I_2^{'} + I_2^{''}$ which would validate the superposition theorem for this particular circuit.
11. Repeat steps 4 to 10 by changing R_1, R_2, and R_3 and take a few more sets of readings.

Table of Results

Values of resistors (ohms)			I_2 with both E_1 and E_2 active (amps)	$I_2^{'}$ with only E_1 active (amps)	$I_2^{''}$ with only E_2 active (amps)
R_1	R_2	R_3			

Table 4-1

Report:

1. Show the table.
2. Comment on the obtained results and discrepancies (if any).
3. Find theoretically the current I_2 with reference to Figure 4-1 applying the superposition theorem considering E_1 = 15 volts, E_2 = 20 volts and R_1, R_2, R_3 at their values recorded in the first observation of the table shown.

Experiment 5

Transient Response of an RC Circuit

Aims:

- To study the transient response in storing an electrical charge on a capacitor in an RC circuit.
- Also to study the transient decay of an initial charge on a capacitor through a resistor.
- To understand the time constant in an RC circuit and how it can be changed.

Background & Theory:

A capacitor has the ability to store an electrical charge and energy. The voltage across the capacitor is related to the charge by the equation V=Q/C for steady state values, or expressed as an instantaneous value,
dv=dq/C

By definition i = dq/dt or dq = idt. Therefore

$$dv = \frac{1}{C} idt \quad or \quad v = \frac{1}{C}\int idt$$

The derivation of the transient responses of both the capacitor current and voltage in an RC circuit when a source voltage is suddenly applied to that circuit is shown below.
Note that the time constant (t = τ = RC).

The step response of an RC circuit can be analyzed using the following circuit:

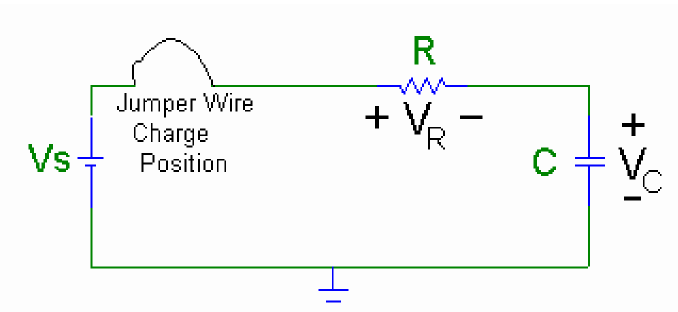


Figure 5-1

$$V_S = Ri + \frac{1}{C}\int_0^t idt + V_C(0)$$

Immediately after the switch closes, KVL requires that-
If we differentiate (1) with respect to t, we get

$$R\frac{di}{dt}+\frac{i}{C}=0$$

The other two terms drop out because they are constants. Now divide thru by R-

$$\frac{di}{dt}+\frac{i}{RC}=0 \quad \Rightarrow \quad \frac{di}{dt}=-\frac{i}{RC} \quad \Rightarrow \quad \int_{I_0}^{i(t)}\frac{di}{i}=-\frac{1}{RC}\int_0^t dt$$

The voltage across the capacitor at t = 0 (V_o) will be zero because there cannot be an instantaneous change in voltage across the capacitor. Therefore, the initial current in the circuit will be as follows:

$$\ln i-\ln I_0=-\frac{t}{RC}$$

$$\ln i\Big|_{I_0}^{i(t)}=-\frac{1}{RC}t\Big|_0^t$$

$$\frac{i(t)}{I_0}=e^{-\frac{t}{RC}} \quad \Rightarrow \quad i(t)=I_0e^{-\frac{t}{RC}}$$

$$i(0)=I_0=\frac{V_S}{R}$$

Substituting (8) into (7) and plotting Normalized current = $i(t)/I_o$,versus Normalized time = t/RC.

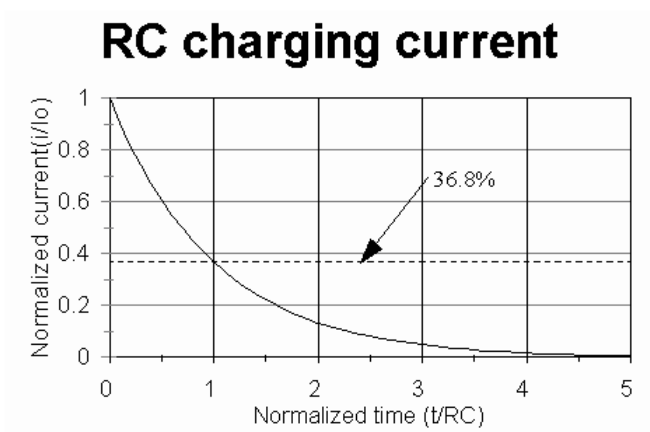


Figure 5-2

Note that the time constant (t = τ = RC) occurs at 36.8% of I_o or 0.368 V_s/R. We also know that

$$i_C(t)=C\frac{dV_C}{dt} \quad \Rightarrow \quad V_C(t)=\frac{1}{C}\int_0^t i_C(x)dx+V_C(0)$$

Substituting i from (7) and I_o from (8) into (9), Putting in limits and simplifying gives:

$$V_C(t) = \frac{V_S}{RC}\left[-RCe^{-\frac{t}{RC}} + RC\right] = V_S - V_S e^{-\frac{t}{RC}}$$

$V_C(t) = V_S\left(1 - e^{-\frac{t}{RC}}\right)$ Capacitor voltage at any time t when charging from zero

$V_C(t) = V_i e$ Capacitor voltage at any time t when discharging to zero

Plotting normalized voltage (V_c/V_S) versus normalized time (t/RC)

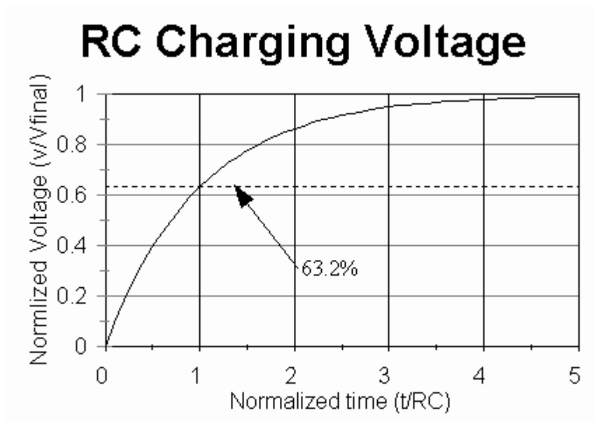


Figure 5-3

Note that the time constant (t = τ = RC) occurs at 0.632 V_S

Apparatus:

- Vdc = 12V
- Breadboard
- Digital Multi-meter (DMM)
- Fixed Resistors: 68kΩ, 100kΩ
- Electrolytic Capacitor 470 μF

Method:

(a) Transient Response of RC circuit when capacitor is single

1. Calculate time constant τ = RC for a series RC circuit having C = 470 μF for R = 68kΩ and R = 100kΩ to gain a perspective of how long the transients will take. A capacitor will be mostly charged or discharged after five time constants, 5τ. This is also called as transient period. Record in **Table 5-1**.
2. Construct the circuit of **Figure 5-4** using the values of R and C given in step1. You will use a jumper wire for the switch to connect the resistor either to the voltage source or to the reference node (ground). Be sure to connect the negative side of the electrolytic capacitor to ground.

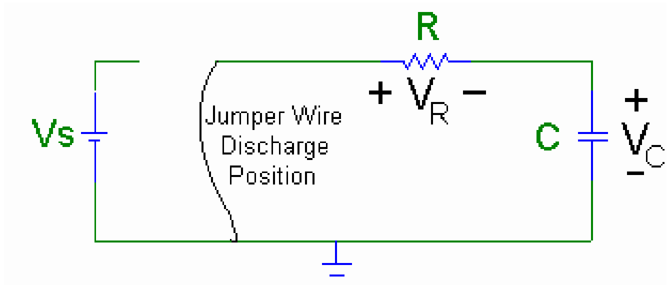


Figure 5-4

3. Set V_S at 12 volts. Leave the jumper wire in the discharge position until the voltage across the capacitor stabilizes at 0 volts. (Note that if the capacitor has been charged before, a wire temporarily shorting out the capacitor will speed up this process. Do not use your bare hands).

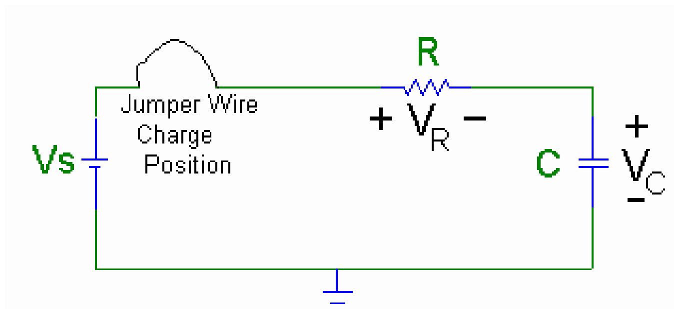


Figure 5-4

4. Then put the jumper wire in the charge position.
5. Record V_c every 20 seconds up to 4 minutes (240s). Then leave the switch in up position until the voltage V_c **stabilizes** at the maximum value (when the second digit of the multi-meter is no longer changing over 30 second period) and record that value in **Table 5-2.**

   Note: One person will need to call off time and the other person read the meter and write down voltage. You may need to practice and repeat the steps until you establish a good procedure for taking data.
6. Next put the jumper wire in the discharge position and record the capacitor voltage V_c at the same time intervals as in step 5.
7. Repeat items 3 to 6 with R = 100kΩ. Record the values in **Table 5-2.**

(b) Transient Response of RC circuit when capacitors are in parallel

1. Construct RC circuit of using one R = 100kΩ and two C = 470 µF. Now, the capacitors are in parallel.
2. Find the total capacitance. For **parallel capacitors**, the total capacitance is:

$$C_T = C_1 + C_2$$

   Calculate the transient period 5τ. The charging and discharging of the capacitor will stabilize at this period.
3. Repeat step 3 and 4 in the first experiment.
4. Repeat step 5 and record that value in **Table 5-3.**
5. Repeat step 6 and 7 and record that value in **Table 5-3.**

(c) Transient Response of RC circuit when capacitors are in series

1. Construct RC circuit of using one R = 100kΩ and two C = 470 μF. Now, the capacitors are in series.
2. Find the total capacitance. For **series capacitors**, the total capacitance is

   $$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$

   Calculate the transient period 5τ. The charging and discharging of the capacitor will stabilize at this period.
3. Repeat step 3 and 4 in the first experiment.
4. Repeat step 5 and record that value in **Table 5-4.**
5. Repeat step 6 and 7 and record that value in **Table 5-4.**

Table of Results

Time constant	R = 68KΩ	C =	τ =
	R = 100KΩ	C =	τ =

Table 5-1

Time interval(s)	Vc R = 68KΩ		Vc R = 100KΩ	
	Charge	Discharge	Charge	Discharge
0				
20				
40				
60				
80				
100				
120				
140				
160				
180				
200				
220				
240				
Maximum time				

Table 5-2

Time interval (s)	Vc		Time interval (s)	Vc	
	Charge	Discharge		Charge	Discharge
0					
20					
40					
60					
80					
100					
120					
140					
160					
180					
200					
220					
240					
Maximum time					

Table 5-3

Time interval (s)	Vc	
	Charge	**Discharge**
0		
20		
40		
60		
80		
100		
120		
140		
160		
180		
200		
220		
240		
Maximum time		

Table 5-4

11:85 "And O my people! give just measure and weight, nor withhold from the people the things that are their due: commit not evil in the land with intent to do mischief.

Experiment 6

AC Peak, RMS, and Phase Measurement

Aims:

- To become familiar with the oscilloscope and what it does.
- To learn how to use the various controls on the oscilloscope.
- To identify the characteristics of basic non-sinusoidal waveforms.

Background & Theory:

The Oscilloscope is a device for observing and taking measurements of electrical signals and waveforms.

The analog oscilloscope consists of a cathode ray tube (CRT) which displays a graph, primarily voltage versus time. It also has one or more amplifiers to supply voltage signals to the CRT and a time base system for generating the time scale. Some of the modern digital oscilloscopes use a liquid crystal display screen for the same purpose.

Sine Wave

The sine wave is a common type of alternating current (ac) and alternating voltage.

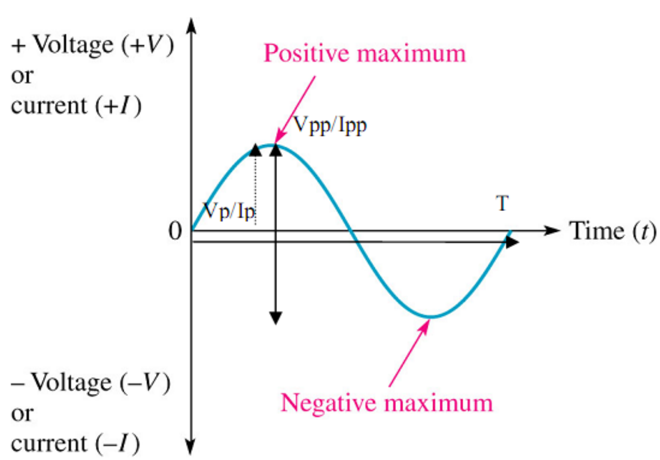


Fig 6-1: Graph of one cycle of a sine wave

For the wave in Figure 6-1:

- Time period = T
- Frequency f = 1/T
- $v = V \sin 2\pi ft = V \sin(2\pi / T)t$

Period of Sine Wave

The time required for a sine wave to complete one full cycle is called the period (T).

- A cycle consists of one complete positive, and one complete negative alternation.
- The period of a sine wave can be measured between any two corresponding points on the waveform by any of the three methods.
  - i) The period can be measured from one zero crossing to the corresponding zero crossing in the next cycle.
  - ii) The period can be measured from the positive peak in one cycle to the positive peak in the next cycle.
  - iii) The period can be measured from the negative peak in one cycle to the negative peak in the next cycle.

Frequency of a Sine Wave

Frequency (*f*) is the number of cycles that a sine wave completes in one second.

- The more cycles completed in one second. The higher the frequency.
- Frequency is measured in **hertz** (Hz)Relationship between frequency (*f*) and period (T) is: ***f* = 1/T**

Electronic Signal / Frequency Generators

In the lab, we usually use a signal generator to produce a variety of waveforms at a wide range of frequencies.

- An oscillator in the signal generator produces the repetitive wave.
- We are able to set the frequency and amplitude of the signal from the signal generator.

Instantaneous Values of Sine Waves

The instantaneous values of a sine wave voltage (or current) are different at different points along the curve, having negative and positive values.

Instantaneous values are represented as:
v and ***I***

Peak Values of Sine Waves

The peak value of a sine wave is the value of voltage or current at the positive or negative maximum with respect to zero.

Peak values are represented as:
V_P and I_p

Peak-to-Peak Values

The peak-to-peak value of a sine wave is the voltage or current from the positive peak to the negative peak.
The peak-to-peak values are represented as:

V_{pp} and I_{pp}

Where:

$V_{pp} = 2V_p$ and $I_{pp} = 2I_p$

Effective Value

Effective (rms) values of ac waveforms are given as:

$$V = \sqrt{\frac{1}{T}\int_0^T v^2 dt} = \frac{V_m}{\sqrt{2}}$$ (For sinusoidal wave)

$$I = \sqrt{\frac{1}{T}\int_0^T i^2 dt} = \frac{I_m}{\sqrt{2}}$$ (For sinusoidal wave)

These values are directly measured in ac voltmeter / ammeter and can be used in **power calculation** as:

True /Average Power $P = VI.Cos\theta$ **W** or $P=I^2R$ **W**

Apparent Power $P_A = VI$ **VA**

Reactive Power $P_R = VI.Sin\theta$ **VAR**

where θ is phase difference between voltage and current.

Average Value

Average values of ac waveforms are given as:

$$V = \frac{1}{T}\int_0^T vdt = 0$$ (For sinusoidal wave)

$$I = \frac{1}{T}\int_0^T idt = 0$$ (For sinusoidal wave)

Phase Difference:

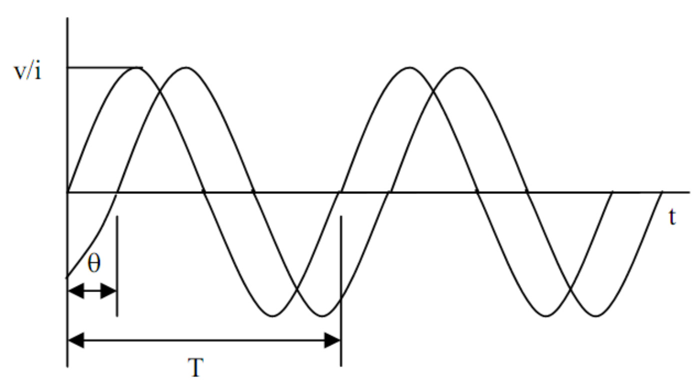


Figure 6-2. Two sinusoidal waves with phase difference

The phase of a sine wave is an angular measurement that specifies the position of a sine wave relative to a reference. When a sine wave is shifted left or right with respect to this reference, there is a phase shift or phase difference.

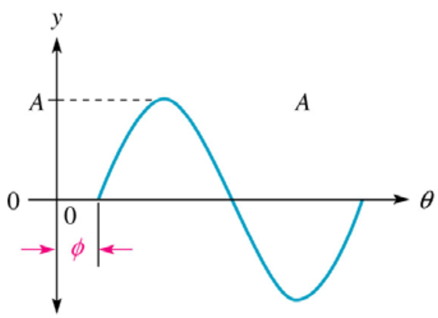
Phase difference between two ac sinusoidal waveforms is the difference in electrical angle between two identical points of the two waves. In **Figure 6-2**, the voltage and current equations are given as:

$$v = V_m Sin(2\pi/T)t$$

$$i = I_m Sin\left(\frac{2\pi}{T}\right)t - \theta$$

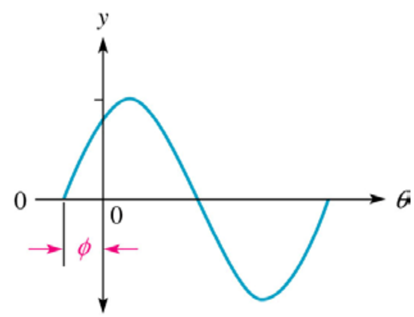
Expressions for Shifted Sine Waves

- When a sine wave is shifted to the right of the reference by an angle *f*, is is termed lagging.
- When a sine wave is shifted to the left of the reference by an angle *f*, is is termed leading.



(a) $y = A \sin(\theta - \phi)$

Figure 6-3(a)



(b) $y = A \sin(\theta + \phi)$

Figure 6-3(b)

Impedance:

Relation between the voltage across and the current through any component of an ac circuit is given by impedance. For the voltage and current waveforms in **Figure 6-2**, the corresponding impedance Z is given as:

$$Z = V_m / I_m \angle\theta) = V_{rms} / I_{rms} \angle\theta$$

RMS Value of a Sine Wave

The rms (root mean square) value of a sinusoidal voltage is equal to the dc voltage that produces the same amount of heat in a resistance as does the sinusoidal voltage.

$V_{rms} = 0.707V_p$

$I_{rms} = 0.707I_p$

Average Value of a Sine Wave

The average value is the total area under the half-cycle curve divided by the distance in radians of the curve along the horizontal axis.

$V_{avg} = 0.637V_p$

$I_{avg} = 0.637I_p$

Angular Measurement of a Sine Wave

A **degree** is an angular measurement corresponding to 1/360 of a circle or a complete revolution.
A radian (rad) is the angular measure along the circumference of a circle that is equal to the radius of the circle.
There are 2π radians or 360° in one complete cycle of a sine wave.

Ohm's Law and Kirchhoff's Laws in AC Circuits

When time-varying ac voltages such as a sinusoidal voltage are applied to a circuit, the circuit laws that were studied earlier still apply.
Ohm's law and Kirchhoff's laws apply to ac circuits in the same way that they apply to dc circuits.

Apparatus:

- Oscilloscope
- Function generation
- Digital Multi-meter
- Capacitor 1µF, 10µF
- Resistance 100 Ω,
- Breadboard

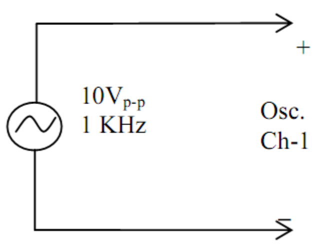


Figure 6-4(a)

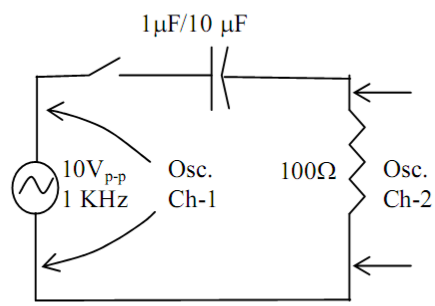


Figure 6-4(b)

Method:

1. Connect the output of the function generator directly to channel 1 of the oscilloscope as shown in **Figure 6-4(a).** Set the amplitude of the wave at $10V_{p\text{-}p}$ and the frequency at 1 kHz. Select sinusoidal wave shape.
2. Sketch the wave shape observed on the oscilloscope. Determine the time period of the wave and calculate the frequency.
3. Measure the ac and dc voltage.
4. Change the frequency to 500Hz and note what happens to the display of the wave. Repeat when the frequency is increased to 2 KHz with the increment of 500Hz.
5. Construct the circuit as shown in **Figure 6-4 (b)** considering 1µF capacitor.
6. Measure the input voltage and the input current with the oscilloscope. In order to measure current flowing through the circuit, measure the voltage across the resistor by using oscilloscope and then divide by resistor which gives the current flowing through the circuit. The ratio between the voltage and the current gives the magnitude of the impedance, Z. Record the results in **Table 6-1**.
7. Observe the wave shapes of oscilloscope channels 1 and 2 simultaneously. Find the frequency of both the waves and amplitude from the display. Determine the phase difference between the two waves. The phase difference is give by
   where "Δt" is the time delay between the two waves.
   Also observe which of the two waves lead. Note that the voltage in channel 2 is the voltage across a resistance and hence this is in phase with the current flowing in the circuit. Find the impedance of the circuit by oscilloscope.
8. Repeat step 5 to 7 for considering 10µF.
9. Repeat step 5 to 7 by changing frequency 1 kHz, 5 kHz and 10 kHz for 1µF capacitor. Record the results in **Table 6-2**.

Report:

1. Compare the frequency of the wave determined from the oscilloscope with the mentioned value on the function generator in step 2 of the procedure.
2. Calculate the rms value of the voltage observed in step 2 of the procedure and compare with that measured in step 3.
3. How does the time period vary when the frequency of the wave is changed in step 4?
4. Calculate the magnitude of the impedance from the readings taken in step 6.
5. Find the magnitude and the phase angle of the impedance from the readings taken in step 6 and 7.
6. Find the magnitude and the phase angle of the impedance from the readings taken in step 7.
7. Find apparent power, true/average power and reactive power for both the capacitive circuits using Volt-Ampere method and also by using oscilloscope.

Table of Results

	Nominal values	Meas. values	V_R (rms value)	V_S (rms value)	I (rms value)	Phase angle	Power Factor	P_A	P_T
1kHz 10 Vpp	R=0.1kΩ C=1μF	R= C=							
	R=0.1kΩ C=10μF	R= C=							

Table 6-1

	Nominal values	Meas. values	V_R (rms value)	V_S (rms value)	I (rms value)	Phase angle	Power Factor	P_A	P_T
5kHz 10 V_{pp}	R=0.1kΩ C=1μF	R= C=							
10kHz 10 V_{pp}	R=0.1kΩ C=1μF	R= C=							

Table 6-2

Note:

- $V_R=V_{p\text{-}p}$ Ch-2
- $V_S=V_{p\text{-}p}$ Ch-1
- $I=V_R/R$
- Phase angle=θ
- Power factor=cos θ
- $P_A=V_R I$
- $P_T=V_R I \cos\theta$

Ch-1 V/Div	Ch-2 V/Div	Time/Div	………..	……..