GENERAL PHYSICS
PART B: ELECTIRICITY AND MAGNETISM
EXPERIMENT-1

USES OF COMMON ELECTRIC LABORATORY INSTRUMENTS

1. PURPOSE

The purpose of this experiment is to show and demonstrate how and where some measuring devices are used.

2. THEORY

Meters used for electric measurements are delicate instruments and they are used in ac and dc circuits but they are constructed differently. A measuring meters used in ac circuit must not be used in a dc circuit.

Although laboratory test equipments vary with each laboratory situation, there are some basic equipments that common to all electric physics laboratories. These are: voltmeter, ammeter, ohmmeter, galvanometer, power supply, rheostat, resistance coil, and resistance box.

Instruments such as voltmeters, ammeters, and ohmmeters may be analog or digital. But today in many laboratories digital meters are most commonly used since the most accurate measurements can be done by means of these instruments.

2.1. The Voltmeter

The electronic Digital Multimeter (DMM) can be used to measure voltage as well as current and resistance. The voltmeter is a part of DMM which is designed to measure voltage that appears on any element of an electrical circuit. The internal resistance of a voltmeter must be very large to measure the voltage accurately. *A voltmeter is always connected in parallel with the any element of an electrical circuit across which one wishes to measure the potential difference* as shown in Fig. 1.1.
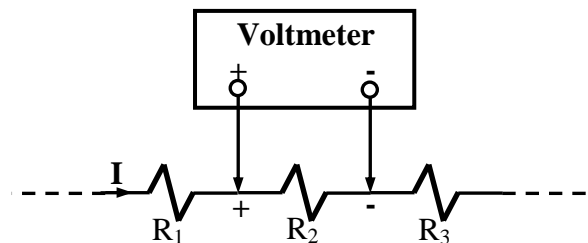

Figure 1.1: Connection of a voltmeter to an electrical circuit to measure the potential difference across resistor R_2.

Before connecting a dc voltmeter in an electrical circuit, find the terminal marked positive (+) and negative (-) and be sure that the positive terminal of your dc-voltmeter is connected to the current entering lead of the resistor.

2.2. The Ammeter

As name implies an ammeter is an instrument designed to measure the value of the current through a circuit element (i.e. a resistor). The internal resistance of an ammeter is very small. Thus it is no effect on the real value of current. The proper measurement of the current through a part of an electrical circuit requires that the part must be broken and the meter must be inserted in this portion, as indicated in Fig.1.2.
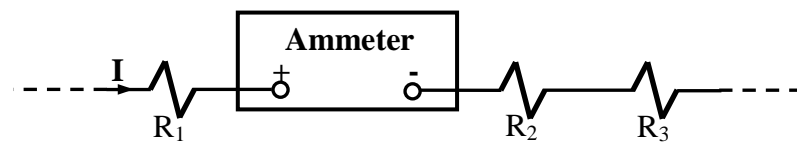

Figure 1.2: Connection of an ammeter to an electrical circuit to measure the current value
through a branch in this circuit.

An ammeter is connected in series in an electrical circuit. An ammeter must not be connected parallel with any other instruments or electrical circuit part. If an ammeter is connected parallel with an element of an electrical circuit or instruments, it may be destroyed. An ammeter has a small effect on the measurements because of its very low internal resistance ($R_i \cong 0$) when an ammeter is inserted to the any point on the electrical circuit. It must be very careful not to exceed a current that becomes intolerable of the range of the instrument.

WARNING: *An ammeter must never be placed across a voltage source; it must only be used in series with a load that does not draw more than the full scale current.*

2.3. The Ohmmeter

In general, an ohmmeter is designed to measure resistance in the low, mid or high range. The mid-range of an ohmmeter is most commonly used in applications. The resistance value of a resistor is measured placing the resistor ends to the terminals of the ohmmeter. **Any type of ohmmeter must never be used to measure the resistance value of any resistor without taking out the resistor from the energized circuit.** The additional potential introduced by an energized circuit may be enough to establish a current through the movement much greater in magnitude than its current sensitivity, which may result in the permanent damage of the meter.
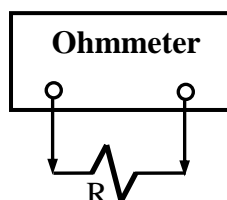
Figure 1.3: Connection of an ohmmeter across a resistor to measure its resistance value.

2.4. The Galvanometer

A galvanometer is an instrument used to detect the presence small electrical current and to determine the direction of current and also to find its relative magnitude. Since a galvanometer is not protected by a high resistance in series or by a shunt across its terminals, it may be used safely only with very small current. There are many types of galvanometer. Some of them are called such as the wall galvanometer, reflecting galvanometer, table type of galvanometer, ballastic galvanometer. Their current sensitivity is also different from each other.
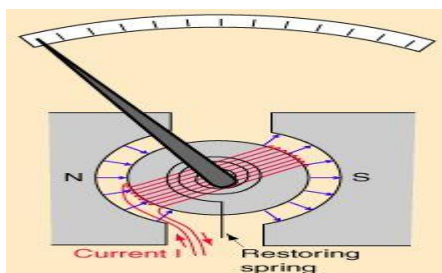

Figure 1.4: General scheme of a galvanometer.

2.5. The Rheostat and Resistance Box

There are two types of resistor that are called as fixed and variable type resistors. The fixed type resistors are the molded-carbon composition resistors. The variable type resistor are also in many forms, basically they can be separated into the linear and nonlinear types. The three point variable resistor may be called rheostat or potentiometer. The screw-drive rheostat is one of the type rheostat is determined by the position of the contact arm, which can be used with the movable hand wheel. The stationary terminal used with the movable contact determines whether the resistance increases or decreases with movement of the contact arm, as shown in Fig.1.5.
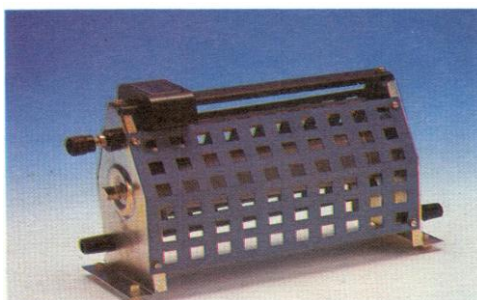

Figure 1.5: A screw drive type rheostat.

For fixed types of resistors, the resistance value of the resistors is only changed due to the temperature and the change in the value of the resistance is different from resistor to resistor. The resistance box, which is variable type resistor, is the combination of fixed types resistors and it has many dials on it. The required value of resistance can be obtained by turning the value of the dials.

Figure 1.6: A resistance decade box.

2.6. The Power Supplier

Device which produce electromotive force (emf) or current is called as power supplier. The dc voltage source and current source is the more familiar of two types of power supplies. Also there are two types of voltage sources; dc and ac voltage sources. Many laboratories are equipped with low voltage power supplies to furnish the needed direct current for student's use. The output voltage of a voltage source is usually varies from 0 to 30 volt. Some power supplies have meters or digital screen on the face of the instruments to indicate the applied voltage or current values while many of them do not have them. The primary purpose of these meters is to indicate the approximate value of the voltage and/or current supplied to the entire circuit. They also indicate the range of values likely to be encountered in the measurements in the various parts of the circuit.

3. EXPERIMENTAL PROCEDURE

Now, let see how common electrical circuit instruments are used in laboratory studies. Digital Multimeter (DMM) will be used in our measurements. This type of meter generally requires 220 volt, 50 Hz. The electrical specifications of DMM used in the Engineering of Physics Department Laboratories are:

a-) (±) DC voltage range from 200 mV to 1000 V.

b-) (±) DC current range from 200 μA to 20 Amper.

c-) Resistance range from 200 ohms (Ω) to 20 MΩ.

3.1. DC-Voltage (DCV) Measurement

To measure the voltage across a circuit element (i.e. a resistor) using a voltmeter,

1. Connect black test lead into "-" terminal,
2. Connect red test lead into "+" terminal,
3. If you are using a DMM, engage function push button DC and V on function scale,
4. Determine the highest anticipated voltage in the range scale and press the corresponding range push button,
5. Press power switch to ON position,
6. Adjust the power supplier to 5 volt and set up the following circuit (Fig.2.7)
7. Change the position of screw on the rheostat and read the display value on the voltmeter to five different values.
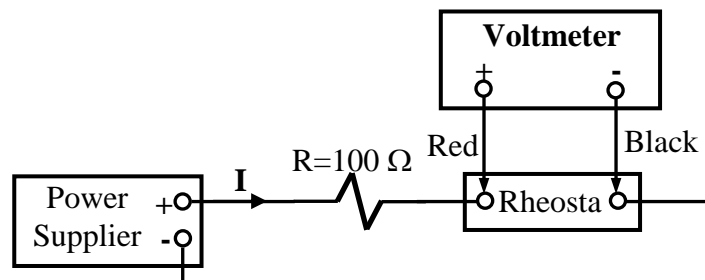

Figure 1.7: Experimental circuit for voltage measurement.

3.2. DC-Current (DCA) Measurement

1. Connect black test lead into COM (-) terminal,
2. Connect red test lead into A terminal for measurement up to 2 A for measuring current between 0 A and 2 A,
3. Engage function push button DC and A on function scale,
4. Determine the highest anticipated current on the range scale and press the corresponding range push button,
5. Press power switch to ON position,
6. Adjust the power supplier to 5 volt and set up the following circuit (Fig.1.8)
7. Change the position of screw on the rheostat and read the display value on the ammeter to five different values.
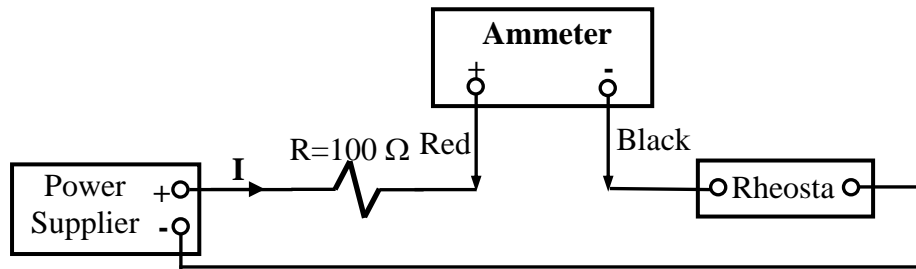
Figure 1.8: Experimental circuit for current measurement.

3.3. Resistance Measurements

1. Connect black test lead to COM (-) terminal,

2. Connect red test lead to "+"terminal,

3. Engage function push button Ω on function scale,

4. Determine the highest anticipated resistance on the range scale and press the corresponding range push button,

5. Press power switch to ON position,

6. Connect test leads of ohmmeter to measuring points (as shown in Fig.9) and read the display value of ohmmeter for at least five different values.
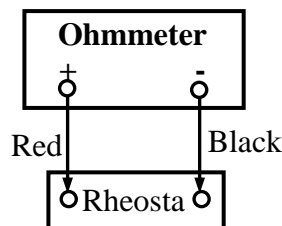

Figure 1.9: Experimental circuit for resistance measurement.

4. DISCUSSIONS and CONCLUSIONS

4.1-) Tabulate the all measured voltage, current, and resistance values.

5. QUESTIONS

5.1-) Explain the operational principle of a galvanometer.

5.2-) How is a voltmeter and ammeter connected in a circuit?

5.3-) What are the factors adversely affect on the accuracy of a meter?

5.4-) What does it really mean when it is said that a meter has 3% accuracy?

5.5-) Describe the basic operation of a voltmeter, ammeter and ohmmeter.

5.6-) Describe the differences between the types of galvanometers.

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1. PURPOSE

The purpose of this experiment is to investigate the force between charged objects and to show the variations of the electric force and fields according to the distance between charges.

2. THEORY

Coulomb charged two small pith balls (pith is a light, spongy material from the center of plant stems) and measured the force between them. Coulomb found that "the repulsive force between two small spheres electrified with the same type of electricity is inversely proportional to the square of the distance between the centers of the two spheres" and also verified the inverse-square distance law for the attractive force between unlike charges.

The electrostatic force also depends on the product of the charges. Thus, the magnitude of the force between two point charges is

$$F = k \frac{|q_1||q_2|}{r^2} \tag{2.1}$$

where q_1 and q_2 are the values of the two charges, r is the seperation between them, and k is a proportionality constant. The relationship of Eq.1 is known as Coulomb's Law. The force is directed along the line joining the two charges. There are two forces, one acting on one charges and another acting on the other charge. These two forces form an action reaction pair. Thus, the force $\vec{F}_{1,2}$ exerted on charge q_1 by charge q_2 is equal in magnitude and opposite in direction to the force $\vec{F}_{2,1}$ exerted on charge q_2 by charge q_1 as shown in Fig. 2.1. If both q_1 and q_2 are positive, the force is repulsive. Similarly, if both charges are negative, the force is again repulsive. However, if one charge is positive and the other negative, then the force is attractive.
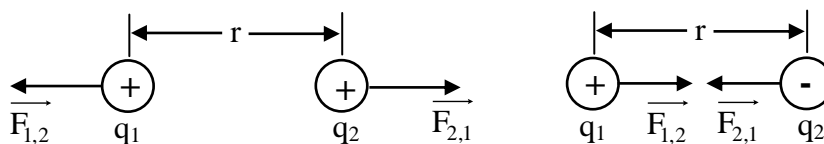

Figure 2.1: Force diagram between charges.

3. EXPERIMENTAL PROCEDURES

The Coulomb Balance and the included accessories are shown in Fig. 2.2. A stable kilovolt power supply for charging the spheres. Any electrostatic charger can be used to charge the spheres, but a power supply lets you replenish the charge to a fixed value throughout an experiment. Ideally the supply would have a momentary "power on" button so that you can conveniently turn it off whenever you are not charging the spheres.
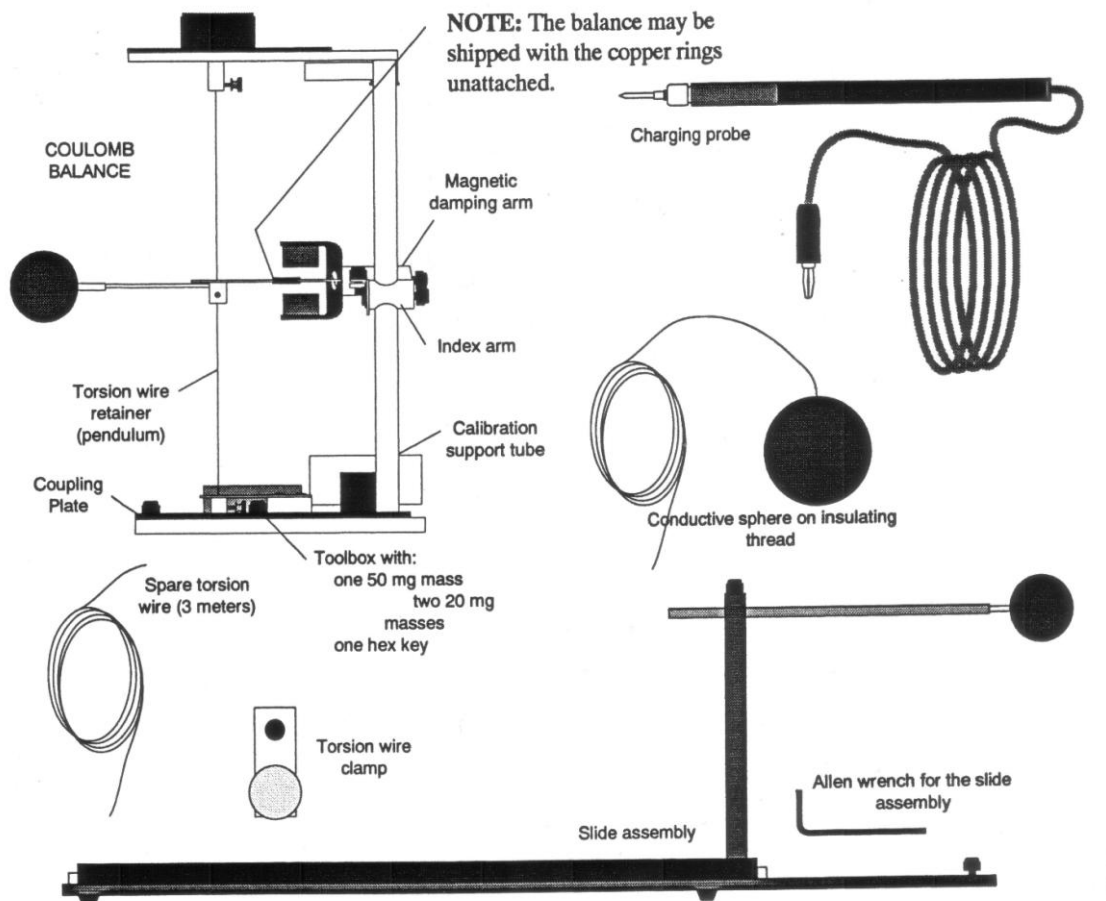
Figure 2.2: The Coulomb Balance

Tips for Accurate Results

1- Perform the experiment during the time of your when humidity is lowest.

2- Perform the experiment in a draft-free room.

3- The table on which you set up the experiment should be made of an insulating material-wood, masonite, plastic etc. If a metal table is used, image charges will arise in table that will significantly affect the results.

4- Position the torsion balance at least two feet away from walls or other objects which could be charged or have a charge induced on them.

5- Use a stable, regulated kilovolt power supply to charge the spheres. This will help ensure a constant charge throughout an experiment.

6- When charging the spheres, turn the power supply on, charge the spheres, then immediately turn the supply off. The high voltage at the terminals of the supply can cause leakage currents which will affect the torsion balance.

7- When charging the spheres, hold the charging probe near the end of the handle, so your hand is as far from the sphere as possible. If your hand is too close to the sphere, it will have a capacitive effect, increasing the charge on the sphere for a given voltage. This effect should be minimized so the charge on the spheres can be accurately reproduced when recharging during the experiment.

3.1. EXPERIMENTAL SET UP

1- One of the conductive spheres is not attached when the Coulomb Balance is shipped. To attach it, just slip the stem of the sphere over the fiber glass rod of the pendulum assembly.

2- Slide the copper rings into the counterweigth vane, as shown in the bottom of Fig. 2.3. Then release the packing clamp that holds the counterweigth vane, as shown in the top of Fig. 2.3. Adjust the position of the copper rings so the pendulum assembly is level.

3- Reposition the index arm so it is parallel with the base of the torsion balance and of the same heigth as the vane.

4- Adjust the heigth of the magnetic damping arm so the counterweigth vane is midway between the magnets.

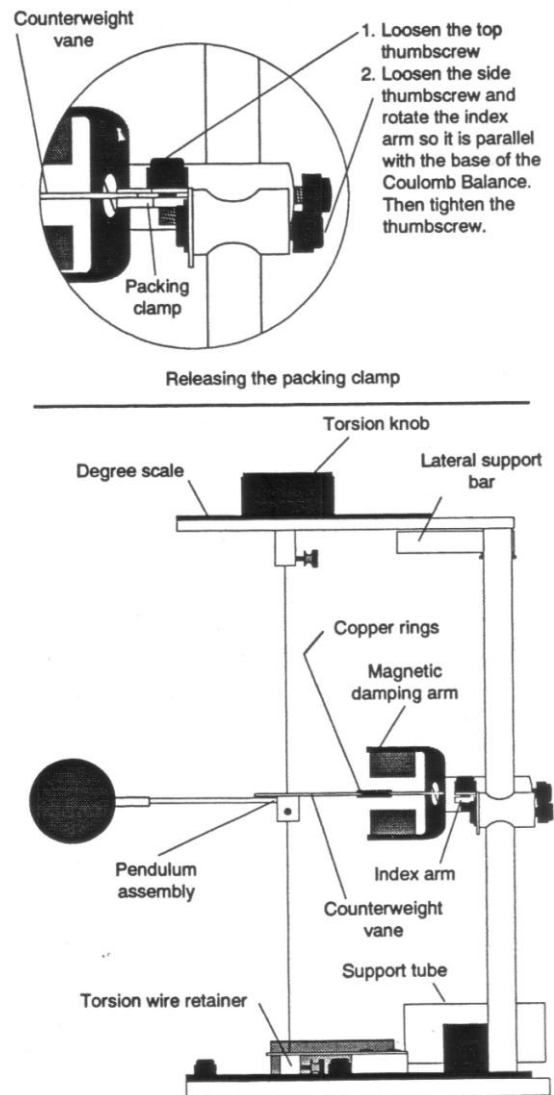5- Turn the torsion knob until the index line for the degree scale is aligned with the zero degree mark.

Figure 2.3: Experimental Setup

6- Rotate the bottom torsion wire retainer until the index line on the counterweigth vane aligns with the index line on the index arm.

7- Carefully turn the torsion balance on its side, supporting it with the lateral support bar, as shown in Fig. 2.4. Place the support tube under the sphere, as shown in Fig. 2.4.
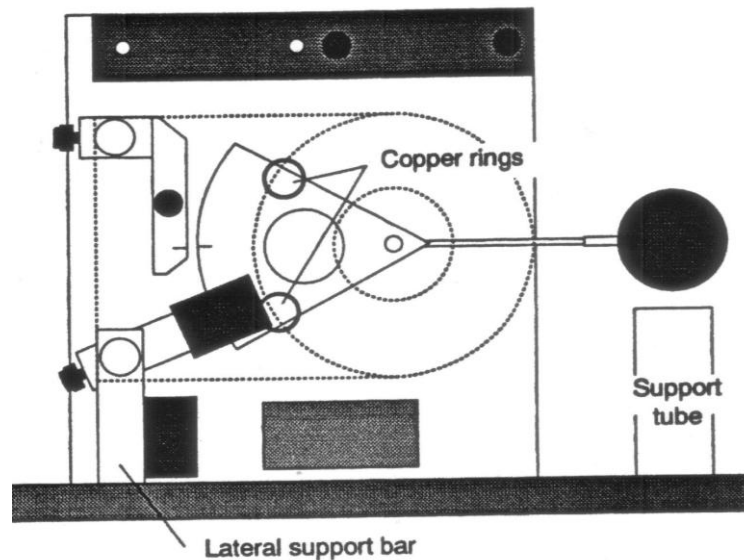

Figure 2.4: Torsion Balance

8- Adjust the positions of the copper rings on the counterweigth vane to realign the index line on the counterweigth with the index line on the index arm.

9- Move the sliding sphere as close as possible to the suspended sphere. The spheres should be at the same heigth.

3.2. EXPERIMENTAL PART A: Force Versus Distance

1- Set up the Coulomb Balance as described in the previous section, as shown in Fig. 2.5.

2- Be sure the spheres are fully discharged (touch them with a grounded probe) and move the sliding sphere as far as possible from the suspended sphere. Set the torsion dial to 0 ^{0}C. Zero the torsion balance by appropriately rotating the bottom torsion wire retainer until the pendulum assembly is at its zero displacement position as indicated by the index marks.

3- With the spheres still at maximum separation, charge both the spheres to a potential of 6-7 kV, using the charging probe. (One terminal of the power supply should be grounded). Immediately after charging the spheres, turn the power supply off to avoid high voltage leakage effects.
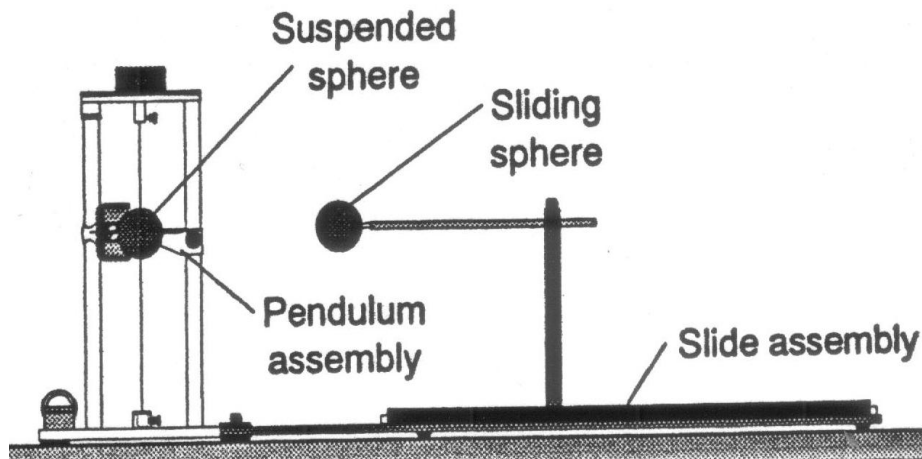
Figure 2.5: The Coulomb Balance set up for the experiment to show electric
force versus distance.

4- Position the sliding sphere at a position of 20 cm. Adjust the torsion knob as necessary to balance the forces and bring the pendulum back to the zero position. Record the distance (R) and the angle (θ) in using an appropriate table (see Table 1).

5- Separate the spheres to their maximum separation, recharge them to the same voltage, then reposition the sliding sphere at a separation of 20 cm. Remeasure the torsion angle and record your results again. Repeat this measurement several times, until your result is repeatable to within ±1 degree. Record all results.

6- Repeat steps 3-5 for 14, 10, 8, and 5 cm.

3.3. EXPERIMENTAL PART B:

Force Versus Charge

1. With sphere separation (R) held at a constant value (choose a value between 7 and 10 cm), charge the spheres to different values and measure the resulting force.

2. Keep the charge on one sphere constant and vary the charge on the other.

3. Graph angle versus charge to determine the relationship.

The charge can be varied using either of two methods:

Method 1

If your power supply is adjustable, simply charge the spheres to different potentials, such as 7, 6, 5, 4 and 3 kV. (When charging the spheres, they should always be at their maximum separation). The charge on the sphere is proportional to the charging potential.

Method 2

If your power supply voltage is not adjustable, the charge can be changed by touching one or both of the spheres with an identical sphere that is discharged. The charge will be shared

equally between the charged and discharged sphere. Therefore, touch the charged sphere once to reduce the charge by half, twice to reduce the charge by ¼, etc. Plot potential versus angle θ.

4. DISCUSSIONS and CONCLUSIONS

4.1. Corrections to the data

The reason for the deviation from the inverse square relationship at short distance is that the charged spheres are not simply point charges. A charged conductive sphere, if it is isolated from other electrostatic influences, acts as a point charge. The charges distribute themselves evenly on the surface of the sphere, so that the center of the charge distribution is just at the center of the sphere. However, when two charged spheres are separated by a distance that is not large compared to the size of the spheres, the charges will redistribute themselves on the spheres so as to minimize to electrostatic energy. The force between the spheres will therefore be less than it would be if the charged spheres were actual point charges. A correction factor B, can be used to correct for his deviation. Simply multiply each value of θ by 1/B, where $B = 1 - 4\dfrac{a^3}{R^3}$

1- Calculate the correction factor B for each of the separations R that you used. Record your results in Table 1.

2- Multiply each of your collected values of θ by 1/B and record your results as $\theta_{corrected}$.

3- Reconstruct your graphs relating force and separation, but this time use $\theta_{corrected}$ instead of θ. Make your new plot on the same graph as your original plot. How does the correction factor affect your results?

4.2. Calculations

4.1-) Determine the functional relationship between the force, which is proportional to the torsion angle (θ); and the distance (R). This can be done in the following ways:

4.2-) Plot logθ versus logR.

Note: If $\theta = bR^n$, where b and n are unknown constants, then logθ = nlogR+logb. The slope of the graph of logθ versus logR will therefore be a straigth line. Its slope will be equal to n and its y-intercept will be equal to logb. Therefore, if the graph is a straigth line, the function is determined.

4.3-) Plot θ versus R^2.

5. QUESTIONS

5.1-) Two charged particles attract each other with a force F. If the charge of one of the particles is doubled and the distance between them is also doubled, calculate the force.

5.2-) Two small spheres carry a total charge of 400 μC. When they are seperatde by a distance of 80 cm, the force one exerts on the other is 12 N and is repulsive. What are the charges carried by each sphere?.

5.3-) Why do electrostatic experiments not work well on humid days?

5.4-) If a metal object receives a positive charge, does the mass of the object increase, decrease, or stay the same? What happens to its mass if the object is given a negative charge?

5.5-) Does the Coulomb's law hold for all charged objects?

5.6-) What is the total charge in coulombs of 75 kg of electrons?

5.7-) How many megacoulombs of positive (or negative) charge are in 1 mol of neutral molecular-hydrogen gas (H_2)?

5.8-) An electron is in a vacuum near the surface of Earth. Where should a second electron be placed so that the electrostatic force it exerts on the first electron balances the weight of the first electron?

5.9-) How far apart must two electrons be if the magnitude of the electrostatic force acting on either one is equal to the electron's weight at Earth's surface?

5.10-) Discuss the similarities and differences between gravitational force between masses and the electric force between charges.

5.11-) Are the Coulomb forces between electrical charges conservative or nonconservative forces? Explain your answer.

Table 2.1. Force versus distance (Data and Calculation)

θ	R	θ_{avg}	$B(1-4a^3/R^3)$	$\theta_{corrected}$	$1/R^2$

1. PURPOSE

To study the nature of electric field and to map the equipotential lines and then determine the lines of force for a two-dimension electric field.

2. THEORY

The steady field of forces can be represented into two different ways such as an electric or magnetic field. The concept of a field is basic to the development of our knowledge of electric and magnetic phenomena. Thus the concept of field is very important in the understanding many of the phenomena of modern physics. In here, we will be explained briefly electric field phenomena.

2.1. Electric Field

Any charged object always gives rise to an electric field. If a test charge placed near the object will experience a force because of the object's charge and the electric field generated due to this point charge (called as test charge). The direction of the electric field is taken to be the direction of the electric force on the positive test charge. If we want to draw a diagram for the electric field near a positive point charge Q and a negative point charge –Q, the electric field lines become as shown in Fig. 3.1.

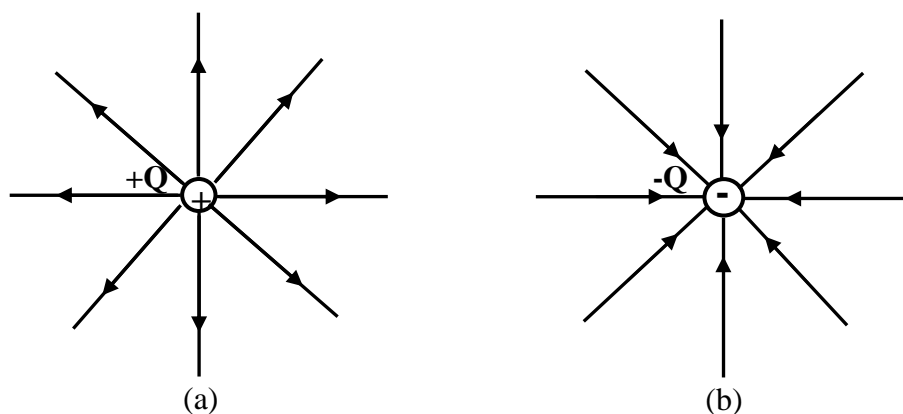(a)   (b)

Figure 3.1: Electric field lines outward from positive charges and inward from negative charges.

Fig. 3.2(a) and (b) show the two possible cases the lines of force for two equal unlike and like charges. To find the direction of the field lines, Michael Faraday introduced

the field lines close to the charges are directly radially outward from positive charges and radially inward toward negative charges.
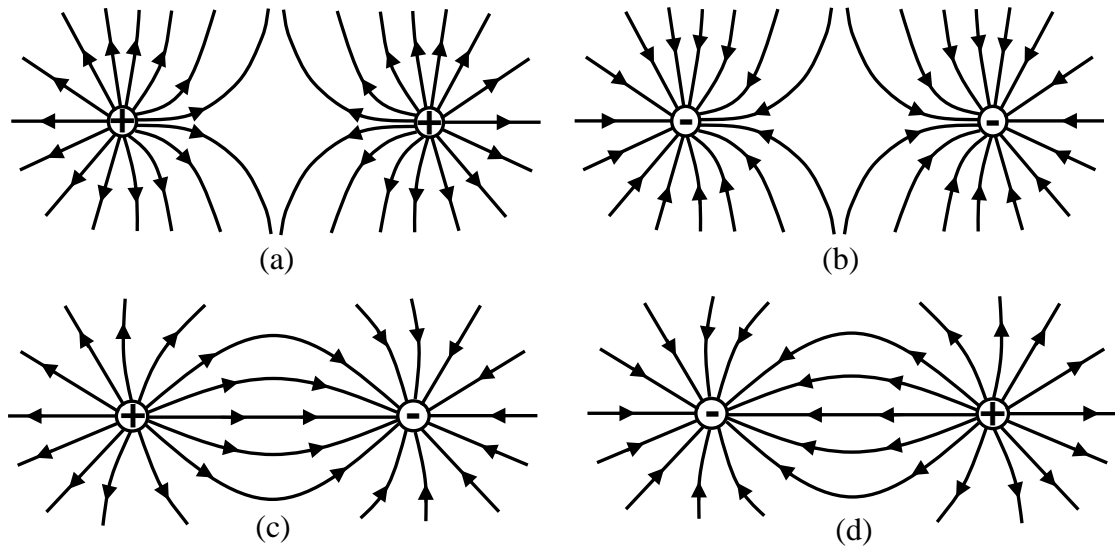

Figure 3.2: a; b-) Electric field lines of force for two equal positive and negative point charges, respectively. c; d-) Electric field lines of force for two equal unlike point charges.

To find the electric field strength $\vec{E}$ at a point, suppose a positive test charge q is placed at that point. The force on the test charge will be $\vec{F}$. We define electric field strength at that point to be

$$\vec{E} = \frac{\vec{F}}{q}$$ (3.1)

where E has the units Newton per coulomb in order that it to be the force per unit test charge. The field strength is a vector quantity whose direction is that of F.

2.b. Electric Potential

The electric field E and electric potential V is intimately related with each other. Since a free test charge would move in an electric field under the action of the present forces from one point to another the work (W) is done by the field in moving charges. If external forces act to move a charge against the electric field, then work is done on the charge by the external force. The work done against electrostatic forces in a moving charge q from point A to B is independent of the path taken. The electrostatic force is conservative. To find the electric potential difference between two points A and B in an electric field, the test charge q is now moved from A to B, work is again done, and the ratio of the work W to the test charge q is called the potential difference between the point A and B as shown in Figure 3.3. We represent the electric potential difference between two points A and B by V_B-V_A and it is defined as

$$V_B - V_A = \frac{\text{Work}}{q} = \frac{W_{AB}}{q} \qquad (3.2)$$

Its unit is work per charge, namely joules per coulomb. This unit is given a special unit, by Volt (V).
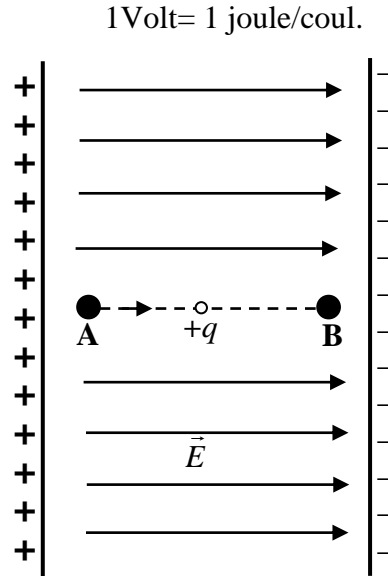
1Volt= 1 joule/coul.

Figure 3.3: Potential difference in an electric field.

Now consider Fig. 3.4 which shows the equipotential lines and surface in the field of a point charge. If a charge is moved along a path such as from M to N which is perpendicular to the lines of force, there is no force component along the path. Therefore, no work will be done in a moving test charge along the path from points N and M. Hence there is no difference in potential between these two points. Both M and N, also all points on the path are the same electric level. No work is done in moving a test charge on a circle centered on the point charge q. The difference in potential between these points and all similar points is zero. It can be said that each circle with different radius (r_A or r_B) have different equipotential (equal-potential) line.
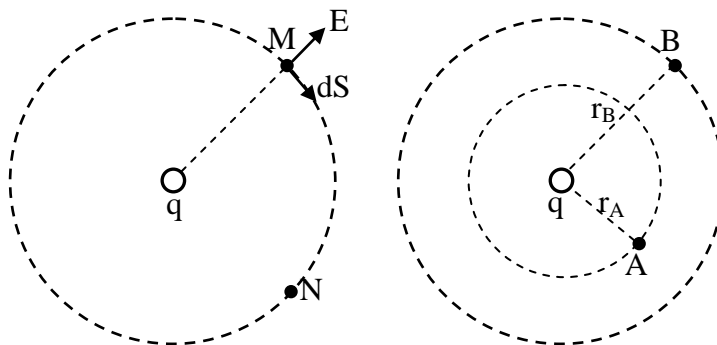

Figure 3.4: Description of equipotential lines and surfaces around a point charge.

3. EXPERIMENTAL PROCEDURE

Set-up the electric field-mapping apparatus circuit as shown in below Fig. 3.5.

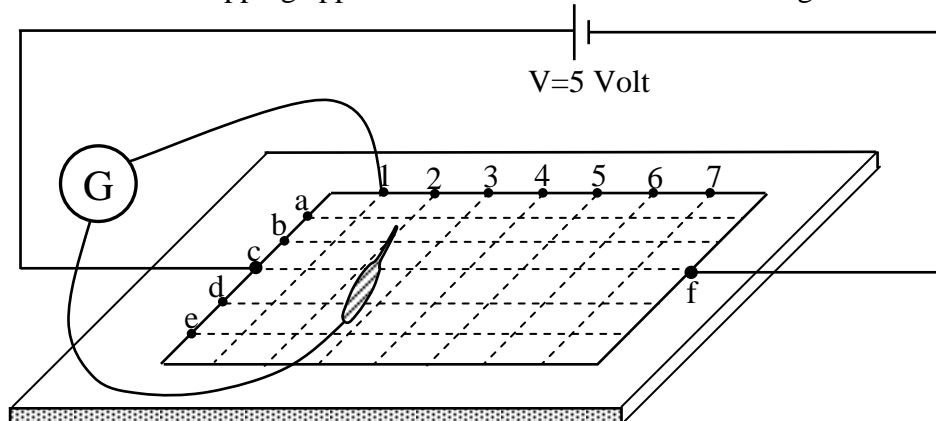

Figure 3.5: Electric field mapping apparatus circuit.

3.1-) Take the carbonized layer paper from your laboratory instructor.

3.2-) Carefully place it on the board.

3.3-) Adjust the power supply (DC-voltage source) to the 5 volt.

3.4-) Connect the end of the power supply to the point c and the other end the point F just opposite point c as shown in Fig. 3.5.

3.5-) Connect the one end of galvanometer to the point 1 and the other end of galvanometer is free. This free end can be clamped on the carbonized layer paper.

3.6-) Clamp the free end of galvanometer on the top of the paper if the needle of the galvanometer is shown zero, read this point from paper and record it. Read minimum five values in this position.

3.7-) Move the fixed end of galvanometer to the next point 2 and repeat step 3.6.

3.8-) Continue until you have a line for each of the seven possible galvanometer lead positions. Your plot should resemble Fig.3.6.
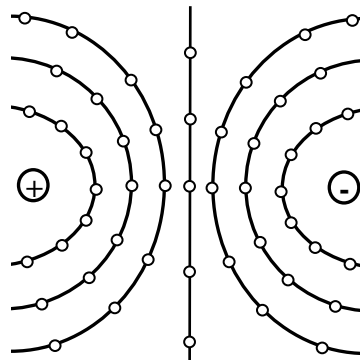

Figure 3.6: Sample plot of equipotential lines when the filed plate which simulates "two charged points" is used.

4. DISCUSSIONS and CONCLUSIONS

4.1-) Draw a sheet which is similar to the carbonized layer paper.

4.2-) Plot of your data on the sheet which was obtain from your experiment.

4.3-) Draw this lines with a different color of pencil.

4.4-) How can you expected the electric field lines and compare your result by the Fig. 3.6.

5. QUESTIONS

5.1-) Is it possible for two equipotential lines or two lines of forces to cross? Why?

5.2-) How can the conductivity of carbonized layer on the black board affect the equipotential and electrical force lines? Explain?

5.3-) If the conductivity of the carbonized layer on the black board were not uniform, what effect would this have on the nature of plotted patton.

5.4-) See Fig.3.2 a and b, in each case where is the electric field strong and weak?

5.5-) Describe the motion of a free charge in a constant electric field.

5.6-) What kinds of substances can electric field force exert?

5.7-) Explain briefly practical applications of electric fields on the technology.

5.8-) How are energy and work related to force fields.

5.9-) When the potential difference between two points is given, calculate the work you must do to transport charge q from one point to the other.

5.10-) A positive charge is released from rest. Will it move to values of higher or lower potential. Repeat for a negative charge.

1. PURPOSE

To measure the resistance of a resistor by voltmeter-ammmeter method (Ohm's Methods) and also to study the voltage and current variating in simple series and parallel circuits.

2. THEORY

1.1. Ohm's Law

A simple relationship exist between the current flowing in a circuit element, (i.e, a resistor) and potential difference (or voltage) across the circuit element. If the current is measured in amperes (A) and denoted by I, the resistance in ohm (Ω), and denoted by R and potential difference in volts (V) denoted by V, then Ohm's law may be written,

$$I = \frac{V}{R} \tag{4.1}$$

By simple mathematical manipulations, if voltage and current are know, then using ohm's law we can calculate the resistance or vica versa. If we relate Ohm's law to the straight-line equation in the following manner.

$$V = R.I + 0$$
$$y = m.x + b \tag{4.2}$$

We find that the slope (m) of the line is determine directly by the resistance, as show in Fig.4.1.
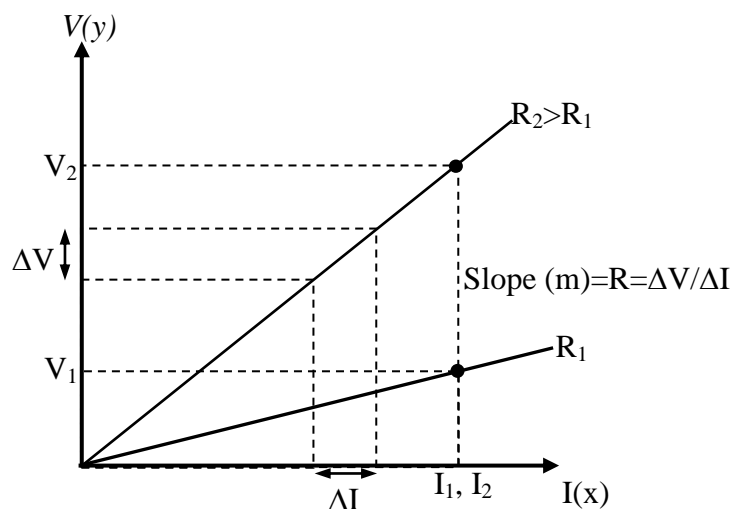

Figure 4.1: V-I graph.

Note that for a voltage (ordinate) versus current (abscicsa) plot, the closer the line to the vertical axis, the greater the resistance. The curve indicates that for a fixed current (I), the greater the resistance, the greater the voltage as determined by Ohm's Law.

2.2. Series Circuits

A circuit consists of at least two elements and they have only one point in common that is not connected to a third element. They are providing at least one closed path through which current can flows. Such as two resistors R_1 and R_2 in Fig. 4.2 are in series since they have only one common point b, there is no other branches connected to this point. The voltage source (V), R_1 and R_2 are therefore referred to as a series circuit.
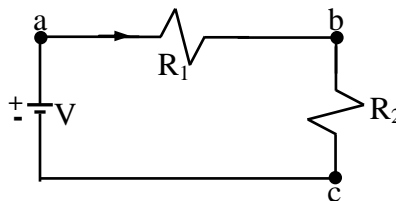

Figure 4.2: Series circuit

In series circuit to find the total resistance, simply add the values of the various resistors. If we assume there are N resistors in the series circuit, the total resistance R_T is given by the expression.

$$R_T = R_1 + R_2 + R_3 + ... + R_N \qquad (4.3)$$

where $R_1, R_2, R_3, ..R_N$ are the resistances of each resistors. The current in a series circuit is constant. The current flowing from and returning to the source is the same as that flowing through any one of the circuit components, this the same current flows through all the resistance since there is no alternate path for current flow.

$$I_T = I_1 = I_2 = I_3 = ... = I_N \qquad (4.4)$$

The voltage in a series circuit is equal to the sum at all the potential drops across each component of a series circuit. The total voltage:

$$V_T = V_1 + V_2 + V_3 + ... + V_N \qquad (4.5)$$

where V_1, V_2, V_3,...,V_N are the voltage across each resistor R_1, R_2, R_3,...,R_N, respectively.

2.3. Parallel Circuits

Two elements or branches are in parallel if they have two points in common as shown in Fig.4.3. The resistance R_1 and R_2 is parallel with each other. Since each circuit element is in parallel with every other circuit elements, it is called a parallel circuit. In Fig.4.3 R_1 and R_2 both have point a and b in common. Also voltage source is parallel to R_1 and R_2.
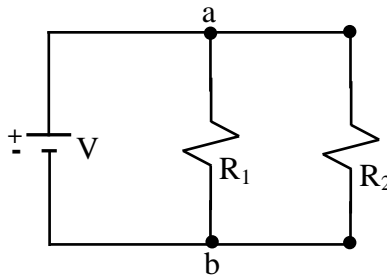
Figure 4.3: Parallel circuit

The total resistance of a parallel circuit is given by

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... \tag{4.6}$$

In words, the reciprocal of the total resistance of a parallel circuit is equal to the sum of the reciprocal of each resistor. In parallel circuit, the total resistance is always less than the resistance of any one of the alternate path. The total current in a parallel circuit is equal to the sum of the currents flowing in the each separate components.

$$I_T = I_1 + I_2 + I_3 + ... + I_N \tag{4.7}$$

where I_T total current flowing in a parallel circuit, I_1, I_2, I_3,...and I_N are component currents flowing through separate resistance R_1, R_2, R_3,... and R_N, respectively. Each component current is inversly propostional to the resistance of that component. In a parallel circuit, the voltage is always the same across parallel elements.

$$V_T = V_1 = V_2 = V_3 = ... = V_N \tag{4.8}$$

where V_1, V_2, V_3,...,V_N are the voltage across the each resistor R_1, R_2, R_3,...,R_N, respectively.

3. PROCEDURE

3.1. Resistance Measurement By Ohm's Method

1- Set up the circuit below Fig. 4.4

2- Connect any one resistor between points a and b.
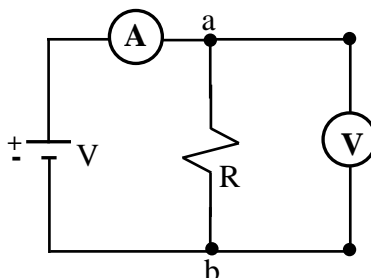
Figure 4.4: Connection of ammeter and voltmeter on an electric circuit

3- Change the value of voltage source to 0,2,4,6,8 and 10 volts and read the current (I) and also voltage across R_x in each cases.

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4- Remove R, connect another resistance and repeat step 3.

3.2. Series Circuit Measurement

Set up below circuit Fig. 4.5.
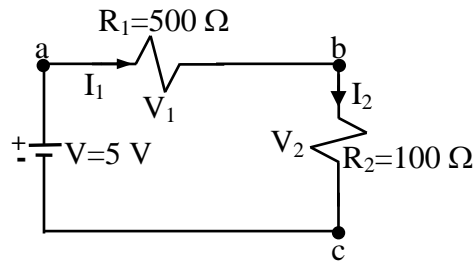
Figure 4.5: Series circuit measurement

1- Measure the current I_1 and I_2 flowing through each resistor as shown in Fig. 4.5.

2- Measure the voltage across each resistor, V_1 and V_2.

3- Remove voltage source and connect ohmmeter with respect to voltage source and read the value of total series resistance of Fig. 4.5.

4- Finally remove R_1 and R_2 measure the resistance of each resistor separately by using ohmmeter, respectively.

3.3. Parallel Circuit Measurement

Set up the circuit shown in below Fig. 4.6.

Figure 4.6: Parallel circuit measurement

1- Measure the currents, I_T, I_1 and I_2 flowing through each resistor.

2- Measure the voltages V_1 and V_2 across each resistor.

3- Remove voltage source and connect ohmmeter with respect to the voltage source and measure the total resistance.

4- Again separate R_1 and R_2 and measure resistance of each resistor using an ohmmeter.

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4. DISCUSSIONS and CONCLUSIONS

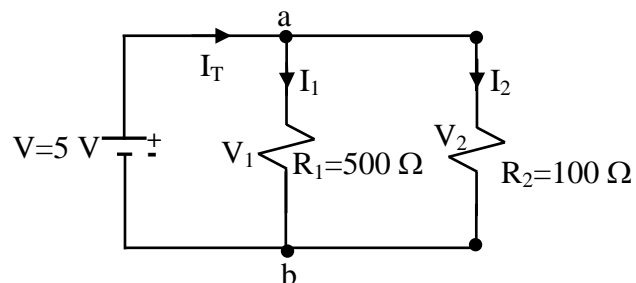4.1)- In part 3.1; plot the values of V and I on a graph paper respectively. Fit a straight-line to the plotted points (see Fig.4.1) and obtain the value of R from the graph by using Eq.4.2. Repeat this step for also other resistor.

4.2)- In part 3.2; tabulate the resistance value of total resistance, separately and also currents and voltages for each resistor into a table. Calculate the resistance of each resistor by using Eq.4.1 (Ohm's Law) and also calculate total resistance of circuit Fig.4.5 by using Eq.4.3.

4.3)- Repeat 4.2 for part 3.3 only calculate total resistance of circuit Fig.4.6 by using Eq.4.6.

5. QUESTIONS

5.1-) State in words the exact meaning of Ohm's Law. How were the units of voltage, current, and resistance chosen in order to make Ohm's Law true? Start by defining the coulomb. What are the units of the ampere, volt and Ohm?

5.2-) If you don't have ohmmeter, how can you measure the resistance of a resistor ? Explain.

5.3-) What kinds of electronic apparatus or machinary are ordinarily connected in series and in parallel?

5.4-) Are resistance values of resistors which measured by ohmmeter and Ohm's Law equal each other. Which of them are realiby than other. Explain.

5.5-) Why have each substance different amount of resistance?

5.6-) In part 3.2 (series circuit), are all currents I, I_1 and I_2 equal each other or not? If they are so, why or not?

5.7-) In part 3.3 (parallel circuit), are the all voltages V_1, V_2 equal each other or not? If they are so, why or not?

5.8-) In part 3.2., is the sum of V_1 and V_2 equal to power supply voltages or not?

5.9-) In part 3.3., is the sum of I_1 and I_2 equal to the I_T or not?

5.10-) Why given the direction of the current in a wire, state which end is at higher potential.

1. PURPOSE

The purpose of this experiment is to study the measurement of resistance and resistivity of a resistor or metal wire by using the Weatstone Bridge Method.

2. THEORY

In the previous examples; we were studied some methods to measure and calculate the electrical resistance of a resistor. These methods are ohmmeter and the voltmeter-ammeter methods (Ohm's Law). In addition to these methods, in this example we will study the Wheatstone Bridge method to measure also resistance and resistivity of resistor or metal wire.

2.1. The Weatstone Bridge Method

The Weatstone Bridge circuit measures the value of unknown resistance with a much higher accuracy than that obtainable from typical ohmmeter and voltmeter-ammeter method, it is a simple bridge circuit consisting of a voltage source, a galvanometer or ammeter and a network of four resistors as shown in Fig. 5.1.
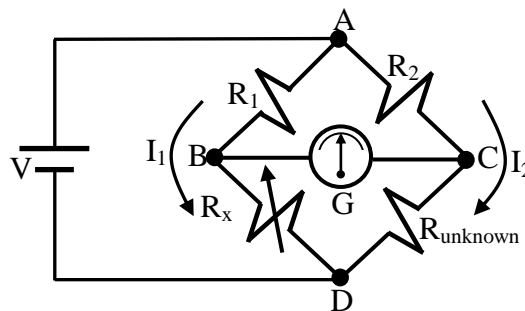
Figure 5.1: The Wheatstone Bridge Circuit.

If you use a Galvanometer for measuring current between the point B and C, and the values of R_1 and R_2 is known, than R_x (Resistor decade box) is adjusted for galvanometer shows zero deflection (or ammeter to zero amper reading), the $R_{unknown}$ can be found in terms of R_1, R_2 and R_x. The bridge circuit is said to be balance when galvanometer shows zero deflection. When the bridge is balanced, the voltage drop across $R_{unknown}$ must be equal to voltage across R_x, there can be no difference of potential between B and C. Thus the current I_1 and I_2 is equal each other.

Then

$$V_{AB}=V_{AC} \qquad \text{and} \qquad V_{BD}=V_{BC} \qquad\qquad (5.1)$$

$$I_1R_1=I_2R_2 \qquad \text{and} \qquad I_1R_x=I_2R_{unknown} \qquad\qquad (5.2)$$

Dividing these two equation side by side

$$\frac{R_1}{R_x}=\frac{R_2}{R_{unknown}} \qquad\qquad (5.3)$$

$$R_{unknown}=\frac{R_2R_x}{R_1} \qquad\qquad (5.4)$$

where R_x is measured from resistor decade box at just balance condition and $R_{unknown}$ is determine using Eq. 5.4.

2.2. Slide-Wine Wheatstone Bridge

The slide-wire Wheatstone Bridge is a length of uniform resistance wire such as 1 meter long and stretched along a meter rod. In the laboratory, form of a slide-wire Wheatstone Bridge is shown in Fig. 5.2.
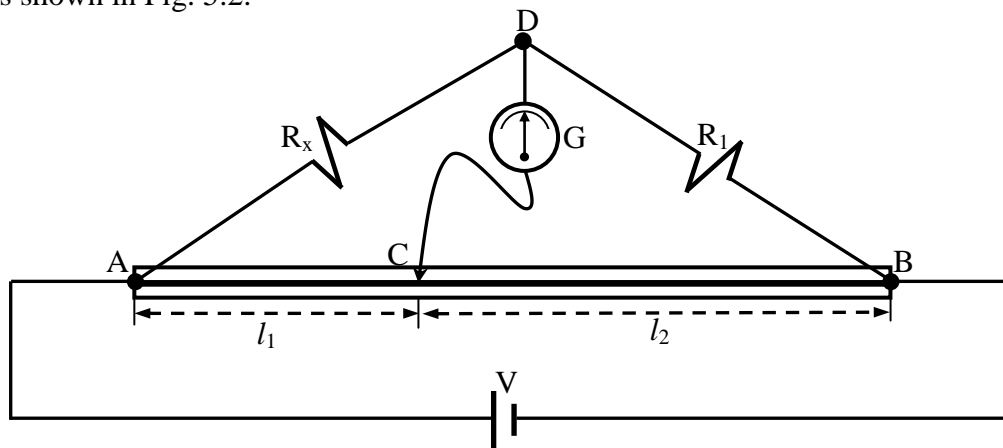
Figure 5.2: The wiring diagram for the slide-wire Wheatstone Bridge.

Let AB be the uniform wire, R_1 a known resistance derived on a resistance box, R_x the resistance which is to be measured and a slider makes contact with wire at C anywhere along AB.

When a voltage is applied to the circuit, current flows to A and divided at this point into two paths DB and CB flows to B. If the values of R_1 and R_x and the length of l_1 and l_2 are so chosen that the galvanometer shows zero deflection. Thus there can be no potential difference between points C and D. Under these conditions, the resistance of the uniform wire is directly proportional to its length.

$$\frac{\mathrm{Re}\,sis\,\tan ce \quad of \quad AC}{\mathrm{Re}\,sis\,\tan ce \quad of \quad CB} = \frac{l_1}{l_2} \tag{5.5}$$

Therefore

$$\frac{R_x}{R_1} = \frac{l_1}{l_2} \Rightarrow R_x = R_1 \frac{l_1}{l_2} \tag{5.6}$$

2.3. Resistivity

In calculating resistance of wires in industry it is a common practice to express its length and diameter. Also the resistance of any material with uniform dimensions is determined by the following four factors:

1- Material

2- Length

3- Cross-sectional area

4- Temperature

For two wires of the same physical size at the same temperature, the relative resistances will be determined only by material. An increase in length will result in an increase in the resistance. Increased area for remaning similar length will result in a decrease in resistance. Finally, increased temperature for metallic wires of identical construction and material will be result in an increased resistance which they will be explained in the next experiment in detail. Then the resistance is directly proportinal to the length of material and inversely proportional to its area.The resistance of a conductor at room temperature (20^0) is expressed as follows:

$$R = g\frac{l}{A} \tag{5.7}$$

where R is the resistance of conductor in ohms (Ω), l is the length of wire in cm, ρ is the resistivity constant in ohm centimeter and A is its cross-sectional area in cm^2.

3. EXPERIMENTAL PROCEDURE

3.1. Resistance Measurement By The Wheatstone Bridge

1-) Connect the circuit as shown in Fig.5.1.

2-) Change the resistance value of resistor decade box R_x which the galvanometer shows zero deflection. In this position read and note the resistance value of R_x.

3-) Measure the components currents and voltages on each resistance.

4-) Read the value of $R_{unknown}$ by using ohmmeter.

3.2. Resistance Measurement By The Slide-Wire Wheatstone Bridge

1-) Set up the circuit as shown in Fig.5.2.

2-) Connect the one terminal of galvanometer to the point D, the other terminal of the galvanometer is connect slide contact C by a wire long enough to permit the contact key to touch any point of the wire AC.

3-) Move the slider along the wire AB until the galvanometer needle shows zero deflection. Take measurement length l_1 and l_2 when galvanometer in the zero position.

4-) Repeat the above steps for another unknown resistance R_x.

3.3. Resistivity Measurement

1-) Note the length l, diameter d of the wire whose resistivity is to be measured.

2-) Set up the circuit as shown in Fig.5.3.

3-) Connect wire whose resistivity is to be measured instead of unknown resistance $R_{unknown}$ in Fig. 5.1.

4-) Again change the value of decade box (R_x) which galvanometer shows zero deflection. Note the R_x at this position.

5-) Measure the resistance value of wire with an ohmmeter.

6-) Note the material and actual resistivity wire asking your laboratory instructor.
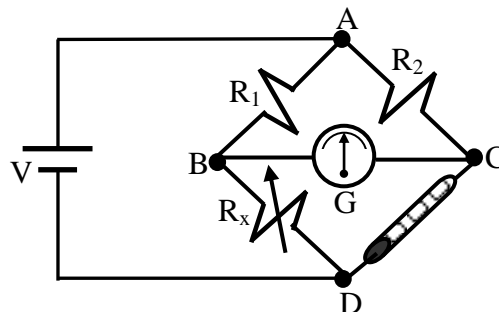
Figure 5.3: The Wheatstone Bridge Circuit.

4. DISCUSSIONS and CONCLUSIONS

4.1-) In part 3.1; using the known values of R_1, R_2 and R_x, calculate the unknown value of $R_{unknown}$ using Eq.5.4.

4.2-) Tabulate the all component current and voltages in part 3.1 for Fig.5.1.

4.3-) Find the percentage difference between the measured resistance by ohmmeter and the Wheatstone Bridge Method in part 3.1 for Fig.5.1.

4.4-) In part 3.2; using the known value l_1 and l_2, calculate the value of unknown resistance $R_{unknown}$ using Eq.5.6.

4.5-) In part 3.3; using the known value of R_1, R_2 and R_x (Decade Box), calculate the resistance value of wire and then using Eq.5.7 calculate the resistivity value of the wire.

4.6-) Using the measured resistance value of wire by ohmmeter, calculate the resistivity of wire using Eq.5.7. Compute the percentage difference between the Wheatstone Bridge circuit and ohmmeter method.

5. QUESTIONS

5.1-) Is there a difference between calculated and measured values of unknown resistance $R_{unknown}$ in part 3.1? Why? Explain.

5.2-) Which are results accuracy, measured values by ohmmeter or calculated value using the Wheatstone Bridge?

5.3-) Discuss the source of error in your experiment.

5.4-) In part 3.2 and 3.3, connection wires must be short wires. Why is it better to use short wires in circuit connections?

5.5-) If the length of a wire is doubled, what happens to its electrical resistance?

5.6-) Is the resistivity of a 1 mm thick copper wire less than the resistivity of a 5 mm thick wire? Why?

5.7-) If the diameter of a wire is doubled, what happens to its electrical resistivity.

5.8-) Calculate the resistance in ohms of a copper wire 100 ft long if its diameter is exactly 0.5 inch.

5.9-) How does the protective resistance in series with the galvanometer affect the balance position?

5.10-) Would there be any advantage in using a slide wire ten times as long as you used ? Explain.

5.11-) If the flowing current in the Wheatstone Bridge circuit is very large, what do you do?

5.12-) Why is different the resistivity of materials?

5.13-) What are the resistivity of a material depends on?

1. PURPOSE

The purpose of this experiment is to determine the temperature coefficient of resistance of a metallic conductor and also to study the effect of changes in temperature on the resistance of metallic conductors.

2. THEORY

In previous example, we were explained that the resistance of any material will depend on four factors; 1-) Material, 2-) Length, 3-) Cross-sectional area, and 4-) Temperature. The effect of length and cross-sectional area on the resistance of a conductor were also explained in previous experiment. In this experiment, we shall examine the forth factors which is temperature effect on the conductors.

In the case of pure metals and for most conductors, the resistance increases rapidly with increase in temperature, due to the increased molecular movement within the conductor which hinders the flow of charge. On the other hand, many nonmetals such as semiconductor materials; transistors, diodes and so on show decreases in resistance with increase in temperature. Also there are special alloys which their resistance are practically independent of temparture.
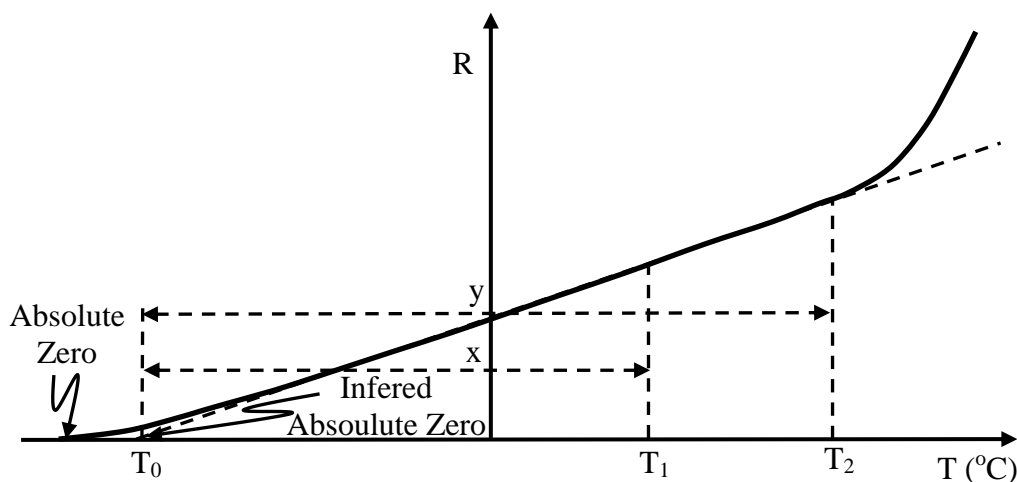

Figure 6.1: The effect of temperature on the resistance of copper.

Fig.6.1 indicates that for a metallic conductor the resistance increases almost linearly (in a straight-line relationship) with increase in the temperature. There is operating limits on the curve of Fig.6.1. The straight-line approximation is quite accurate for the normal operating temperature range. At two different temperatures, T_1 and T_2, the resistance of metallic conductor becomes R_1 and R_2, respectively. By using mathematical trigonometry from similar triangles,

$$\tan\frac{R_1}{x} = \tan\frac{R_2}{y} \tag{6.1}$$

then

$$\frac{R_1}{x} = \frac{R_2}{y} \tag{6.2}$$

If we put x and y instead of T_1 and T_2

$$x = |T| + T_1$$
$$y = |T| + T_2 \tag{6.3}$$

where $|T|$ indicates the inferred absolute temperature of the material and equation 6.2 can be written as

$$\frac{R_1}{|T| + T_1} = \frac{R_2}{|T| + T_2} \tag{6.4}$$

Another equation for the determining the resistance of a conductor at different temperatures is

$$R_1 = R_0\left[1 + \alpha(T_1 - T_0)\right]$$
$$R_2 = R_0\left[1 + \alpha(T_2 - T_0)\right] \tag{6.5}$$

or

$$R_1 = R_0\left[1 + \alpha\Delta T\right]$$
$$R_2 = R_0\left[1 + \alpha\Delta T\right] \tag{6.6}$$

where R_1, R_2 and R_0 are resistance of the given material at temperatures T_2, T_1 and T_0, respectively. T_1-T_0 or T_2-T_0 is the temperature differences between temperature at T_1 and T_0 or T_2 and T_0. ΔT is equal to T_1 or T_2, if T_0 is equal zero. The α (alpha) is called temperature coefficient of resistivity. The ratio of the change is resistivity due to a change of temperature of 1 ^{o}C to its resistivity at 0 ^{o}C is given as

$$\alpha = \frac{\Delta\rho / \Delta T}{\rho_0} \tag{6.7}$$

where $\Delta\rho$ is the change in resistivity between the temperature T_1 and $0\ ^{\circ}C$ and the ρ_0 is called of the resistivity a material at $0\ ^{\circ}C$, thus $\Delta\rho$ and ΔT in equation 6.7

$$\Delta\rho = \rho T_1 - \rho_0$$
$$\Delta T = T_2 - T_0 = T_2 - 0 = T_2$$

(6.8)

If we substitute equation 6.8 into equation 6.7,

$$\alpha = \frac{\rho T_1 - \rho_0}{\rho_0 T_1}$$

(6.9)

Thus α is the fractional increase per degree centigrade of the resistance at $0\ ^{\circ}C$, and has a magnitude of about 0.0038 per $^{\circ}C$ for pure metals. The α is directly proportional to the slope of the curve, so the greater the slope of the curve, the greater the value of α. It can be conclude that the higher the value of α, the greater the rate of change of resistance with temperature. At table 6.1, the values of α are indicated for different materials at temperature of $20\ ^{\circ}C$. From this table, we see that nickel is more sensitive to temperature variations than other metallic conductor. Also as indicated from this table, carbon has negative temperature coefficient. The resistance of this kind of materials will drop with increases in temperature or vice versa.

Table 6.1: The temperature coefficient some materials

Material	Temperature Coefficient ($\alpha(1/^{\circ}C)$)
Nickel	0.006
Iron	0.0055
Tungsten	0.005
Copper	0.00393
Aluminum	0.00391
Silver	0.0038
Gold	0.0034
Nichrome	0.000044
Constantan	0.000008
Carbon	-0.0005

If the temperature coefficient is extremely low, these kinds of materials can be very suitable for constructing standard resistance. Because of this, they are very slightly affected by a change in temperature.

3. EXPERIMENTAL PROCEDURE

Set up the circuit shown in Fig.6.2

3.1-) Connect the slide-wire wheatstone bridge circuit with a coil $R_{unknown}$ whose temperature coefficient is to be measured.

3.2-) Immerse the coil in a large beaker.

3.3-) Put a little ice in the beaker.

3.4-) Balance the bridge circuit after the coil temperature has adjusted to that of the ice water.

3.5-) At the balance position, measure l_1 and l_2 and temperature by means of thermometer at the same time.

3.7-) Add cold water to the ice and measure l_1 and l_2 when the temperature has risen $10\ ^{o}C$ at balance condition. **Be careful to exact value of temperature.**

3.6-) Heat the water and maintain it at a series of steady temperatures up to $80\ ^{o}C$ for several minutes at per $10\ ^{o}C$ record the $l_1,\ l_2$ and temperature at each balance conditions.

3.7-) Repeat above steps for another coil.
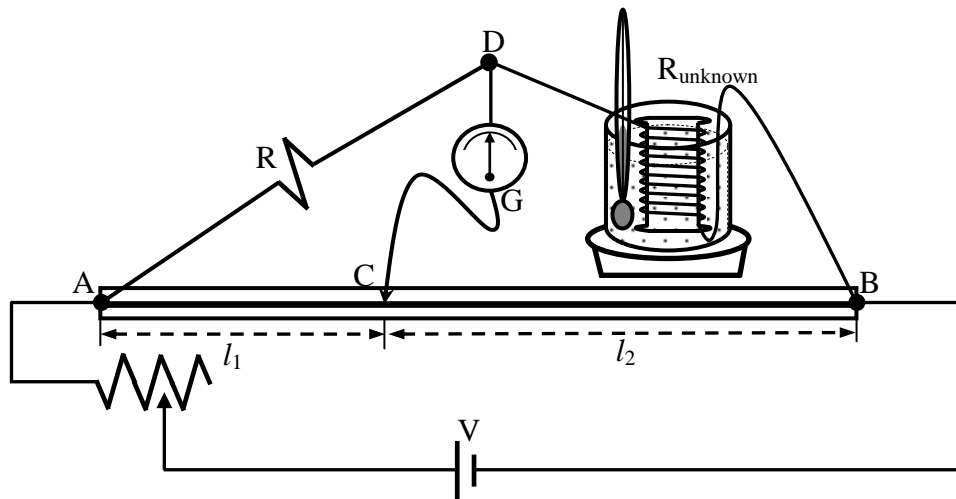
Figure 6.2: Connect the slide-wire wheatstone bridge circuit with a coil $R_{unknown}$

4. DISCUSSIONS and CONCLUSIONS

4.1-) Tabulate all measured values $l_1,\ l_2$ and temperature T in experimental measurements.

4.2-) Calculate the resistance of coil using below equation at each balance condition for each coils using

$$R_{unknown} = R\frac{\ell_1}{\ell_2}$$

4.3-) Plot a graph of the resistance R_t versus temperature T ^{o}C and draw a best straight-line as shown in figure 6.1 for each coils.

4.4-)Using plotted curve, determine the temperature coefficients α for each coils using Eq. 6.5 and 6.6.

5. QUESTIONS

5.1-) Discus the principal sources of errors and calculate the percentage errors α in this experiment.

5.2-) Compute the uncertainty in temperature coefficient. (Note: To find the error in the gradient; draw the line of greatest or least slope, which differs from that of the "best" line and remeasure the gradients).

5.3-) Explain why one would expect the temperature that effects the resistance of a conductor?

5.4-) What kind of relation does your graph show to exist between the resistance and temperature of a conductor? If the temperature changes from 40 ^{o}C to 80 ^{o}C, does the resistance becomes twice as much? Explain and then state another possible way of expressing a proportionality relation of temperature to resistance.

5.5-) If the resistance of a copper wire is 50 Ω at 20 ^{o}C. What is its resistance at 100 ^{o}C?

5.6-) The resistance of a conductor at 40 ^{o}C is 11.68 Ω; at 60 ^{o}C it is 12.52 Ω. What is its resistance at 0 ^{o}C and 100 ^{o}C? Calculate its temperature coefficient.

5.7-) What temperature coefficient of resistance would be desirable for a wire used to make the resistance coils of a resistance box?

5.8-) If the temperature coefficient of resistance remains the same for all temperatures, compute the temperature at which the resistance of your coil is zero. What is the significant of zero resistance?

5.9-) To what temperature would the coils used in this experiment have to be heated to double the value of the resistance it has at 20 ^{o}C?

GENERAL PHYSICS
PART B: ELECTIRICITY AND MAGNETISM
EXPERIMENT-7
RC CIRCUIT

1. PURPOSE

The purpose of this experiment is to study charging and discharging phases (transient phases) of a R-C circuit.

2. THEORY

When two metal plates are connected across to the terminals of a voltage source, electrical charges move from voltage source to the metal plate. The positive charges are provided by the positive terminal and negative charges are provided by negative charges. On each plate, the electrical charges are equal to each other as shown in Fig.7.1. They are important in the electronic industry since they can be used to store electrical charges. This type of circuit elements is called capacitor.
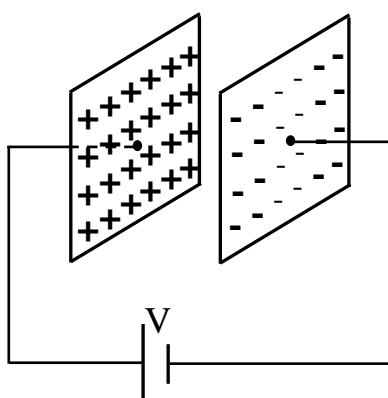
Figure 7.1: Parallel plate Capacitor

2.1. Types of Capacitors

Many types of capacitors are variable today. Some of the most common are the mica, ceramic, electrolytic, tantalum and polyester film capacitors.

2.2. Charging Phases

Fig.7.2 was designed charging phase and this circuit is called an RC circuit, because of this it involves a series resistance and capacitance combination. Assuming that at the initial case (t=0), the capacitor is uncharged. After the switch (S) is suddenly closed the circuit at the charging phases. The electrical charges will from the battery though resistor to the capacitor. The charges should flow until the capacitor full up. For find the potential and flow charges on the capacitor, we can use Kirchoff's circuit law (loop method).
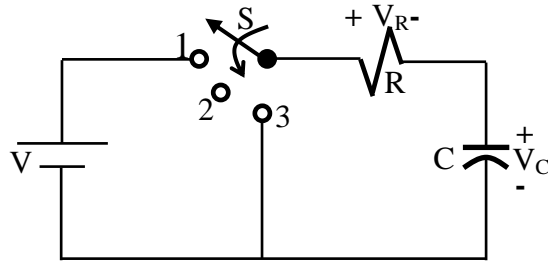
Figure 7.2: Charging phase of a RC circuit

$$V = V_R + V_C \qquad (7.1)$$

where $V_R = I_R.R$, then substituting this equation into Equ 7.1.

$$I_R R + V_c = V \qquad (7.2)$$

In the above paragraph, we said that charge should flow until the capacitor acquires.

$$Q = C.V \qquad (7.3)$$

where C is the capacitance, V_C is the potential difference between the plates of capacitor and Q is the electrical charge density on the capacitor. The current in the circuit is also written as

$$I = \frac{dQ}{dt} \qquad (7.4)$$

from equations 7.3 and 7.4

$$I_c = C\frac{dV_c}{dt} \qquad (7.5)$$

The current I_R and I_c is the same for the resistor and capacitor. The Equ.7.2 can be written as

$$C\frac{dV_c}{dt}R + V_c = V \qquad (7.6)$$

Equ.7.6 can be solved using the methods of calculus and V_c will be found that

$$V_c(t) = V(1 - e^{-t/RC})_{charging} \qquad (7.7)$$

Also the current in the charging phase is given as;

$$I_c(t) = \frac{V}{R}e^{-t/\tau}{}_{charging} \qquad (7.8)$$

The voltage across the resistor is determined by Ohm's law:

$$V_R(t) = V\,e^{-t/\tau}{}_{charging} \qquad (7.9)$$

In these equations, RC product is called time constant and its unit is seconds and is shown by simply τ.

$$\tau = RC \tag{7.10}$$

If the switch is moved to position 2 (Fig.7.3), the capacitor will retain its charge for a period of time determined by its leakage current. For capacitor such as the mica and ceramic, the leakage current is very small, so that the capacitor will retain its charge, and hence the potential difference across its plate, for a long period of time.
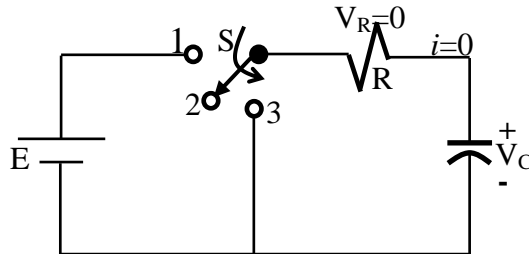
Figure 7.3: Transition phase of a RC circuit.

2.3. Discharging Phases

If the switch is then moved to position 3 which is shown in Fig.7.4, the capacitor will discharge through the resistor R. To find the current and potential as a function of time, again we will use Kirchoff's law (loop medhod) in which we proceed in the preceding section. The mathematical expression for the current I_c, potentials V_c and V_R can again be found by using mathematical methods for discharging phase. They are equal to:

$$V_c(t) = E e^{-t/\tau}{}_{discharging} \tag{7.11}$$

$$i_c(t) = \frac{E}{R} e^{-t/\tau}{}_{discharging} \tag{7.12}$$

$$V_R(t) = E e^{-t/\tau}{}_{discharging} \tag{7.13}$$
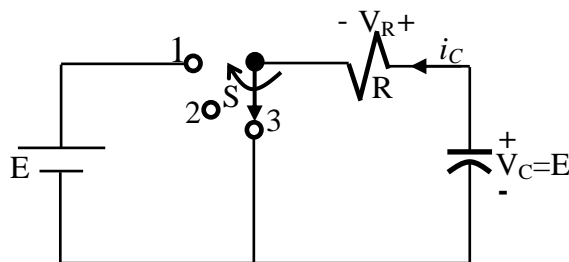
Figure 7.4: Discharge phase of a RC circuit.

If the switch of Fig.7.1 is moved between the various position every five time constant (5τ), the wave shapes will be as shown in Fig.7.5 for the current I_c and voltages V_c and V_R.
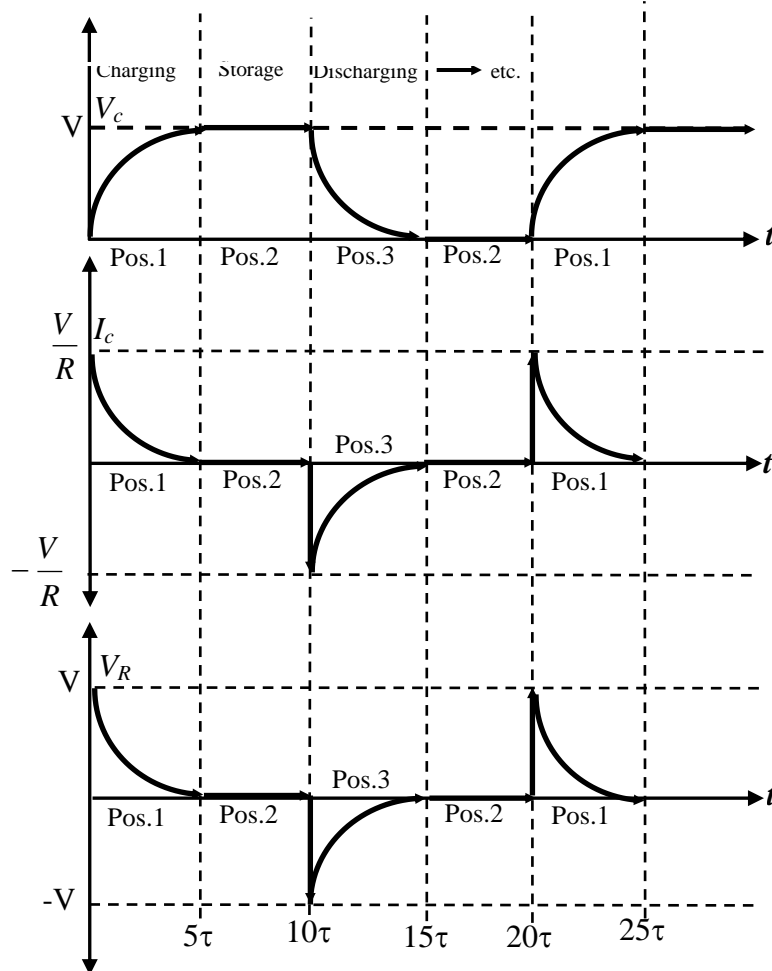
Figure 7.5: The wave shapes of a capacitor discharging and charging phases.

The total energy stored in a charge capacitor will be given as

$$W = \frac{1}{2}CV^2 \qquad (7.14)$$

3. EXPERIMENTAL PROCEDURE

3.1-) Set up the circuit below circuit (Fig.7.6) and and then closed the switch to position 1 and then record the $V_c(t)$ and $I_c(t)$ at appropriate time intervals.
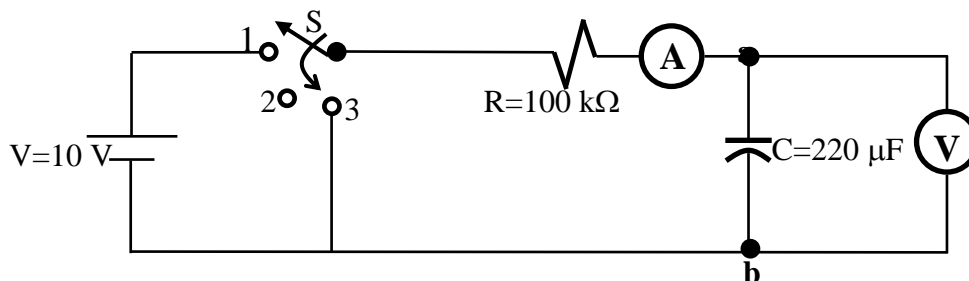
Figure 7.6: RC circuit

3.2-) After t=120 sec, change the switch position to 3 and again record the $V_c(t)$ and $I_c(t)$ at appropriate time intervals.

4. DISCUSSIONS and COCLUSIONS

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4.1-) Tabulate the all current and voltage values that you find in part 3.1 and 3.2.

5. QUESTIONS

5.1-) Find the expressions for $V_c(t)$ and $I_c(t)$ both charging and discharging phases.

5.2-) Draw the voltage and current wave shapes for both charging and discharging phases and compare your experimental results with theoretical results.

5.3-) Calculate the sotored energy on the used capacitors over the time intervals between 0 and ∞.

5-4-) Explain the physical meaning of the time constant $\tau=RC$.

5.5-) Write the possiple errors that occur in this experiment.

GENERAL PHYSICS
PART B: ELECTIRICITY AND MAGNETISM
EXPERIMENT-8

MAGNETIC FIELD

1. PURPOSE

To examine the mapping of magnetic field in two dimensional region.

2. THEORY

In the Exp.3, we have learned the electric field. In this experiment, we are concerned the other field called as the magnetic field. The phenomenon of magnetism has been observed and studied for about two thousand years. The knowledge of magnetism and magnetic fields has been developed by Coulomb and Oersted.

The most easily a magnet much of our qualitative terminology concerning magnetic fields in terms of bar magnets. A magnetic field in the space around a magnet in which its magnetic influence can be dedected. Therefore, we often speak of magnetic fields in terms of bar magnets. The other type of magnet is known as U magnet, as seen in Fig. 8.1. There are two poles of a bar and U magnets. These are defined as north pole and south pole. The north or south poles of magnets repeal each other.The south pole of a magnet is always attracted by the north pole of another magnet.
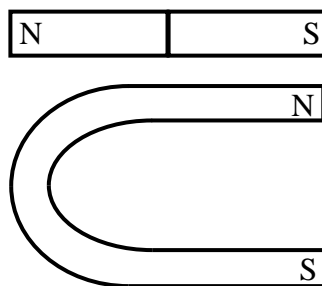
Figure 8.1: U and Bar Magnet.

The two most common detectors used for studying the nature of a magnetic fields are iron filings and the magnetic compass. The magnetic fields are easily ploted by means of compass needles and is capable of indicating the direction of a magnetic field. We can therefore determine the direction of the magnetic field at any point observing the orientation of a small compass needle placed at the point as the direction of compass in which shows the north pole of compass.

If one should move a small compass from point to point, by letting the north pole of the needle dictate the direction to be moved the path resulting from this motion would

reveal the direction of the field at all points along which it moved. A line which indicates the direction of a magnetic field at every point is called line of force. This is shown in Fig.8.2.

Notice that the field lines emerge from the north poles and enter south poles. The magnetic field of the earth is always present and also the earth acts like a huge magnet with the magnet's north pole being near the position of the earth's south pole. The earth's geographic north pole is near it's magnetic south pole.
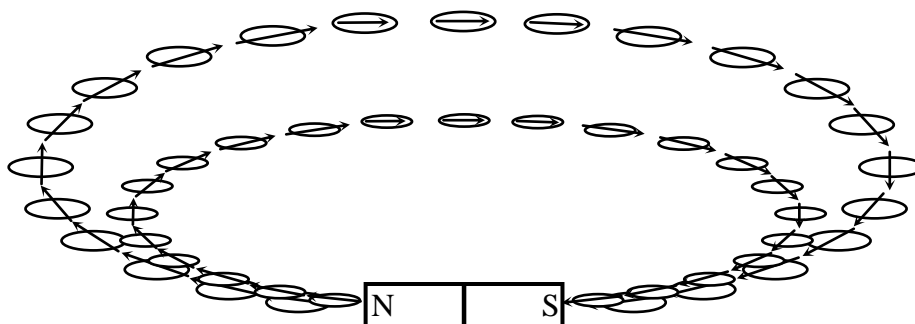
Figure 8.2: A compass needle points in the direction of magnetic field.

When more than one magnet is placed in a particular region, the individual magnetic fields are superimposed upon each other and a compass needle placed in the region will indicate the direction resulting from the interaction of the fields. Since a magnetic field has both magnitude and direction, the resulting field intensity at each point in the field is the vector sum of the components at that point.

In order to provide a magnetic field resulting from the interaction of two or more magnets, we shall improvise a magnet board by taping two or more magnets to the under side of a cardboard.

3. EXPERIMENTAL PROCEDURE

3.1-) Determine the north-south line of the earth's magnetic field by means of the magnetic compass needle. Be sure that bar magnet and all other pieces of iron are removed from near compass needle during this section of experiment.

3.2- a-) Place the slotted magnet board on the table.

b-) Replace the bar magnet to the slot of board. Attention that the slotted magnet board is parallel to the earth's field and also the long axis of the bar magnet is parallel to the diection of earth's fields in which the north pole of magnet directed toward the south.

c-) Cover a large sheet of paper on the board.

d-) Outline the position of the bar magnet on sheet. Identify polarities of bar magnet and write the north and south poles of bar magnet on the sheet. Also mark the position and direction of sheet. At this position; do not change the position of slotted magnet board, magnet and also sheet.

e-) Slowly sprinkle a little iron filings on the paper. Again be sure that there are no any other magnets near slotted board.

f-) You tick one end of the sheet to very well arrange of iron filings.

g-) Sketch very slowly lines of force with a pencil without touching iron filings which make up the magnetic fields lines as indicate by the shape of the iron filings.

4. DISCUSSIONS and CONCLUSIONS

4.1-) Make careful sketches of the field between the bar magnets (N to S) and also between the poles of U-magnet. Indicate the direction of the lines of force by arrowheads.

4.2-) After you have mapped the lines of force of the magnetic field, draw in the equipotential lines using another colored pencil.

5. QUESTIONS

5.1-) The magnetic field lines emerge from the north poles and enter south poles. Why is this always true?

5.2-) Define magnetic field lines.

5.3-) When a beam of electrons is shot into a certain region of space, the electrons travel in a straight line through the region. Can we conclude there is no electric and magnetic field in this region?

5.4-) Briefly sketch the general nature of the lines of force in a magnetic field between two unlike poles also between like poles.

5.5-) Examine your drawing and note whether or not lines of force ever intersect.

5.6-) What kinds of substances can magnetic field force exert?

5.7-) Explain briefly practical applications of magnetic fields on the technology.

1. PURPOSE

To study some of the phenomena of the electromagnetic induction.

2. THEORY

Magnetism plays an integral part in almost every electrical devices used today in industry, research, or the home. Generators, motors, transformers, circuit breakers, televisions, radios and telephones all employed magnetic effects induced by the flow of charge or current, electromagnetism. Many computers use magnetic tapes, disks or "bubbles" to store the numerous bits of data.

An important step in the understanding of the nature of magnetic fields occurred in 1820 when the Danish physicist Hans Christian Oersted discovered that the needle of a compass would deflect if brought near a current-carrying conductor. Oersted said that there is a relationship between electric current and magnetic field. In subsequent years, men such as Michael Faraday, Karl Friedrich Gauss and James Clerk Maxwell continued to experiment in this area and developed many of the basic concepts of electromagnetism. Furthermore, the converse effect-electricity from magnetism was discovered about eleven years later (1831) by Faraday. He showed that if a conductor is moved through a magnetic field so that it cuts magnetic lines of flux, a voltage will be induced across the conductor, as shown in Fig.9.1.
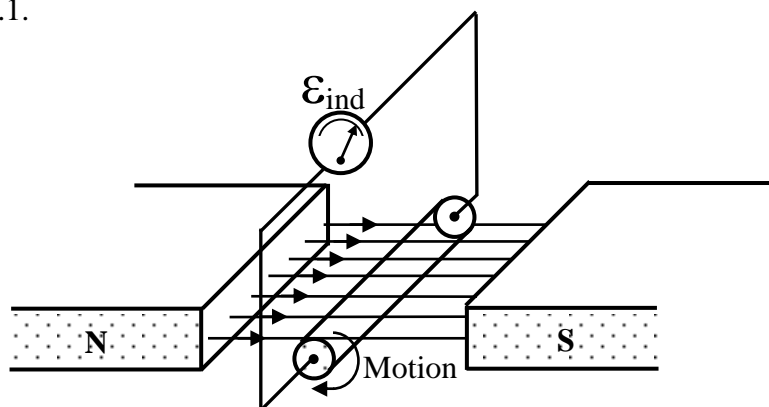

Figure 9.1:A basic configuration to show induced voltaj across a conductor

An electric current can be produced in a conductor by relative motion of the wire and the conductor or when a change occurs in a magnetic field passing through the area enclosed by wire loop as shown in Fig.9.2.
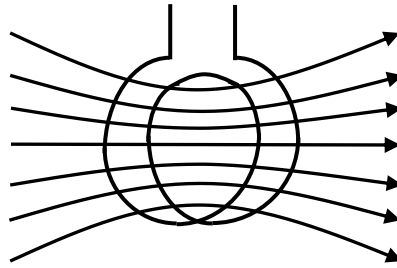
Figure 9.2: A current is induced in a coil of wire if it is "cut" by the lines of force of a magnet field.

Michael Faraday summarized his results in what is now called Faraday's law. His law relates the induced emf ε in a coil of N loops to the rate of change of the flux $d\Phi/dt$ through the coil Faraday's law is

$$\varepsilon = -N\frac{d\Phi}{dt} \tag{9.1}$$

If the number of coils time rate of change of the magnetic-flux linkage is increased the induced electromotive force is increased. If the magnetic flux is constant, there is no induced emf in the wire. The negative sing in above equation tell us the direction of the induced emf.

The polarity (direction) of the induced emf is given by Lenz's law. If magnetic flux is increasing with time, the emf induced will be in one direction; if decreasing with time, it will be in the other direction. Lenz's law explain that induced emf is in such a direction as to oppose the change in flux.

The direction of current can be illustrated easily by use of the apparatus shown in Fig. 9.3. A coil of wire is connected to a galvanometer. If a bar magnet is rest, there is no any deflection in the needle of galvanometer (Fig.9.3a). The bar magnet approaching the coil the magnetic flux is increased in the core, the galvanometer registers a current as long as the magnet is moving (Fig.9.3b). The direction of flowing current is showing in figure 9.3b. The moving magnet causes a source of emf to exist in the coil. As shown in Fig.9.3, the current flow only when the bar magnet is in the motion. The emf exists and the current flows only the change in the magnetic flux is occurring. Moreover, the induced emf reverse polarity depending upon the magnetic field is increasing or decreasing. If the bar magnet is moved away from the coil then the magnetic flux lines are deceased and current is flowing in the opposite direction. The direction of the magnetic field is important in the direction of induced current is the same for a bar magnet if it approaching or going away from the coil

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at the opposite direction, as shown in Fig.9.3d and 9.3e. If the magnet is held fixed but coil is moved toward the magnet or go away from the magnet, the above same effects occur.
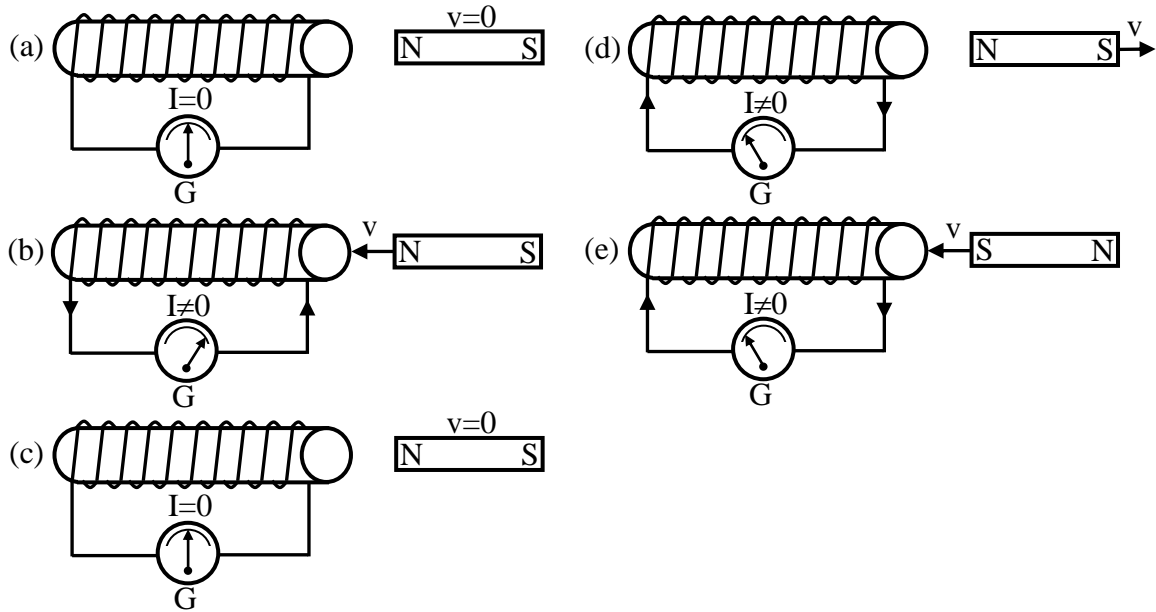
Figure 9.3: The illustration of the direction of current by using the a coil, galvanometer and bar magnet.

3. EXPERIMENTAL PROCEDURE

3.1. Direction of Galvanometer Deflection for a Known Current Direction

Remember that the galvanometer is used for very small currents. It should never be used with currents whose magnitudes are wholly unknown and should never be connected directly to a battery.

Set up the following circuit (Fig.9.4).
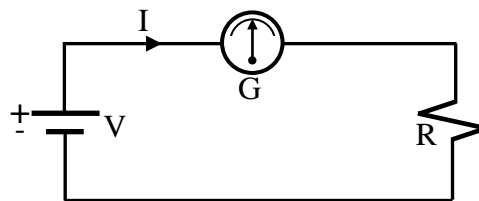
Figure 9.4: Connection of the galvanometer to a circuit.

1-) Connect the galvanometer a series combination with dc voltage source and a resistance of about 20 kΩ as shown above Fig.9.4.

2-) Keep the value dc voltage less than 5 volt.

3-) Since the direction of current furnished from dc voltage source is known, the direction of the current through the galvanometer and note the corresponding direction of galvanometer deflection and mark which is the + direction for the galvanometer and use this through the experiment.

3.2. Induction in a Coop Wire

3.2.A Orientation of Coils:

1-) Connect the terminals of the secondary coil to the galvanometer as shown in Fig.9.5 a.

2-) Connect another primary coil to the dc voltage source in which determine the direction of current as shown in Fig.9.5 b.

3-) Move the secondary coil quickly according to the primary coil forth and back along the same axis. If the galvanometer needle is very high deflect than reduce the value of dc voltage in the primary coil. Record the directions of the current in the primary and secondary coils under these two conditions. Repeat these processes, by moving primary instead of the secondary and again record directions of current and motions in this case.

4-) If the primary coil near the secondary coil make and break the current in the primary coil and observe and record the both direction of current and relative magnitude of the deflection. Determine the galvanometer throws while the primary current is made and broken when the primary and secondary coils are separated by 0, 1, 2, 3, 4, 5, and 10 cm and mark all of them.

Secondary Coil   Primary Coil

(a)   (b)
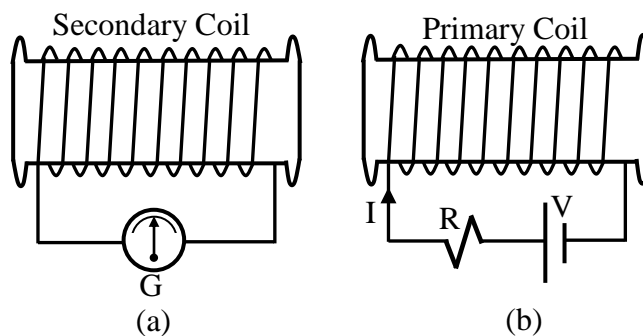
Figure 9.5: Orientation of coil

3.2.B Orientation of Coil and Bar Magnet

1-) Place only the secondary coil as shown in Fig.9.6.
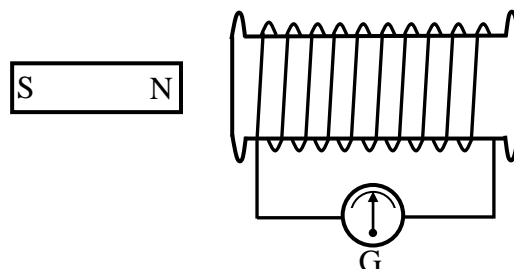
Figure 9.6: Orientation of coil and bar magnet.

2-) Now thrust the bar magnet into the coil. First with the N pole entering ahead and then the S pole ahead. Note the direction of the galvanometer needle deflection for each

case and then determine which way the current flows around the coil, clockwise or counterclockwise direction.

3-) Observe the effect of a change of speed of the moving magnet.

3.2.C Magnetic Coupling Variable Core

Set up the following circuit Fig.9.7.
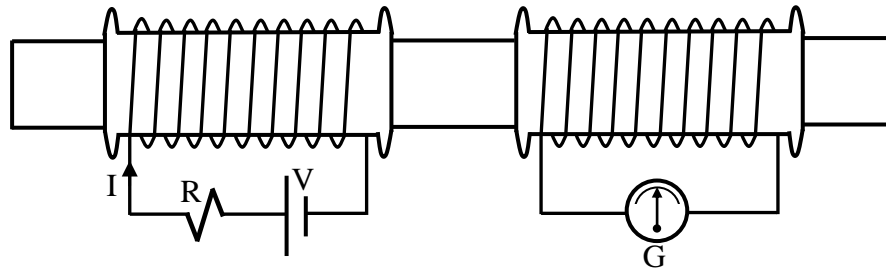
Figure 9.7: Magnetic coupling variable core.

1-) Insert beams (aluminum) rod through the cores of both coils when there is 2 cm distance between the ends of two cores.

2-) Repeat step 3.2 a and record of the results.

3-) Next replace the aluminium rod with an iron rod an repeat above step, record your results.

4. DISCUSSIONS and CONCLUSIONS

4.1-) Describe by carefully drawn sketches and briefly in words every step of the experimental procedure at outline above.

4.2-) State what you observed and explain why each effect happened as it did.

5. QUESTIONS

5.1-) Define; (a) induced emf, (b) magnetic flux, (c) Faraday's law, (d) Lenz's law, (f) primary and secondary coils, (g) magnetic induction.

5.2-) Find the direction of the induced emf in a loop when information about the flux change through it is given.

5.3-) Why is a dc actuated primary coil unsuitable for producing a useable output from a secondary coil?

5.4-) As a bar magnet is inserted into a coil of wire an electric current is induced in the wire. This current is actually electric energy. What is the source of that energy?

5.5-) Explain the effect of a change of speed of the moving magnet and effect of a change in polarity of the magnet.

5.6-) Consider the coil as an electromagnet, how can you determine the polarity from the direction of the induced current.

5.7-) From your experimental results, what things seem to influence the magnitude (or amount) of the induced current? What observations indicate these?

5.8-) Did you decide whether a magnetic force resulted from the motion of the magnet? If so write a statement which relates the direction (attraction or repulsion) of the force to the direction of the induced current.

5.9-) When two coil (one carrying a current) undergo relative motion with respect to each other, which one do you move to get the most induced current in the secondary? Explain.

1. PURPOSE

The purpose of this experiment is to study the basic main operational principles of simple dc and ac generators and motors.

2. THEORY

Today the electrical motors and generators are used in the all area of industries. Furthermore they are always used in home, at school or etc. The motors and generators are electromechanical device. A generator converts mechanical power (energy) to electrical power (energy) whereas a motor converts electrical energy to mechanical energy. Thus it has reverse bias function with respect to the generator. Both motors and generators have the same constraction and apparatus. Thus they are reversible. A generator can be run as a motor if electric power is supplied to it. But if mechanical power is supplied to it, it will produced electric power (energy). There are two main components of motor and generator. These are rotor (or armature) and the stator. The basic parts of motors and generators are given in below.

2.1. The Rotor and Stator

Electric generators and motors make use of coils which rotate in magnetic field. As the coil rotates, the flux through it changes, and therefore an electromotive force(emf) induced in it. The rotor rotates within the framework of the stator which is stationary part. When the rotor is caused to rotate by some mechanical power such as is available from the forces of rushing water (dams) or steam-turbine engines, the conductors on the rotor will cut magnetic lines or force established by the poles of the stator, as shown in Fig.10.1.

The length of conductor as shown in Figure 10.1 passing through the magnetic field will have an emf induced across it. Note that the induced emf across each conductor is additive, so the generated terminal voltage is the sum of the two induced emf's and it's given by following relation

$$\varepsilon = -N \frac{d\Phi}{dt} \tag{10.1}$$

where N is the loops on the coil, Φ is the magnetic flux lines through the loop and t is time. The induced emf is sinusoidal in time.
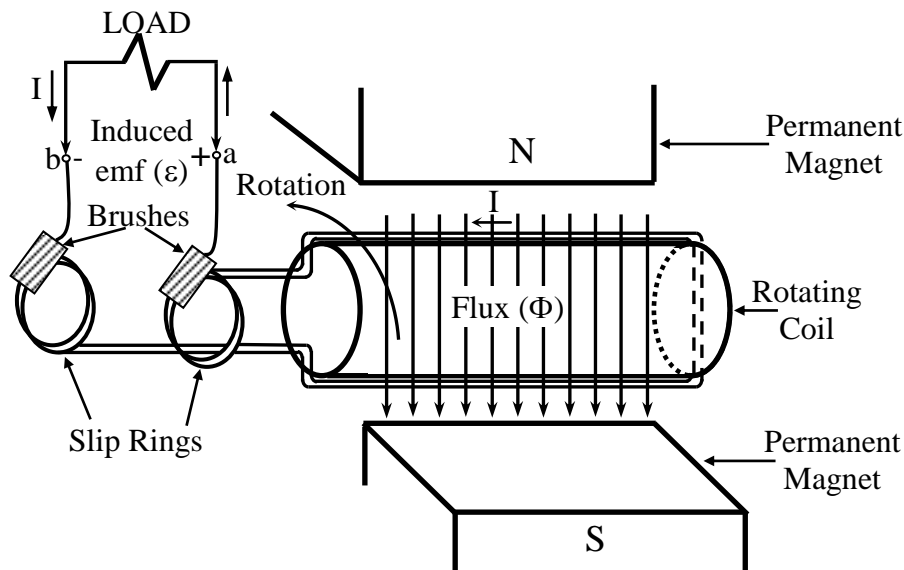
Figure 10.1: Basic generator.

2.2. Slip Rings

If rotor is rotating, the output terminal a and b are connected to some fixed external load, there is the necessity for the induced slip rings. The slip ring are circular conducting surfaces that provide a path of conduction from the generated voltage to the load and prevent a twisting of the coil at a and b when the coil rotates. The induced emf will have a polarity at therminal a and b and will develop a current I having the direction indicated in Fig.10.1. The direction of I is also the direction of increasing induced emf within the generator.

2.3. Brushes

Brushes are the sliding contact device to pick up the generated current from armature-rotor machines or to supply current to d-c motors which is shown in Fig.9.1.

Also there are the other basic equipment of motors and generators. The commutator is a device for collecting direct current from a d-c generator or for supplying direct current to the rotor of a d-c motor. The field winding is produce the magnetic field it may be on either stator or rotor, depending on the type of machine.

3. EXPERIMENTAL PROCEDURE

3.1. D-C Generator

1-) Set up the two-pole d-c generator apparatus.

2-) Use the d-c rotor and note that rotor turns freely.

3-) Set the bar magnets close to the rotor.

4-) Adjust brushes if required.

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5-) Connect the galvanometer to the binding post on top of the brush holder.

6-) Rotate the rotor by hand in one direction and note the direction of galvanometer deflection value.

7-) Rotate in opposite direction, and also note the galvanometer deflection value.

8-) Rotate the rotor different speeds in both direction and note effects of it.

9-) Move the bar magnets further away from rotor, then rotate the rotor and note the effect of induced electromotive force (emf).

10-) Sketch circuit diagrams, showing the direction of the magnetic field of the rotor coil winding, and of the rotation. Show the direction of induced current.

11-) Repeat above steps for a three-pole d-c generator.

3.2. D-C Motor

1-) Connect a d-c power supply (0-10 volt) in series with the armature rotor and switch.

2-) Set the brushes so that polarity of the armature changes at the right time to produce continuous rotation.

3-) Test effect on the speed of the motor of moving the magnets from the armature.

4-) How would you reverse the direction of rotation? Reverse armature current, magnetic field and both. Test all these possibilities.

3.3. A-C Generator

1-) Replace the d-c rotor with the a-c rotor and slip rings.

2-) Connect the galvanometer to the rotor.

3-) Rotate the rotor by hand observe the nature of a-c output.

3.4. A-C Motor

1-) Put the d-c rotor back in the machine.

2-) Connect the field magnet and rotor in series with a 6 volt a-c source from a transformer.

3-) Describe operation.

4. DISCUSSIONS and CONCLUSIONS

4.1-) Record all of the experimental values step by step.

5. QUESTIONS

5.1-) If a commutator is used on a d-c generator, the output function becomes sine wave. How can you change this output current to the direct current?

5.2-) What types of motor will run on either direct or alternating current?

5.3-) Describe the basic construction of a d-c motor.

5.4-) Describe how a rotating coil generator operates and derive the equation for its voltage output.

5.5-) Why an emf curve is a sine wave?

5.6-) Explain how an induction motor can operate without having any electric current supplied to its rotor.

5.7-) Explain the function a commutator on a small d-c generator and on simple d-c motor also slip ring on a small a-c generator?

5.8-) Discuss the differences between the d-c voltage sources batteries and generators.

1. PURPOSE

To study RC and RL a-c circuits and observe the effect of capacitance and inductance in a-c circuits. Also to determine the reactance of capacitors and inductor RC and RL circuits, respectively.

2. THEORY

In this experiment, phasor algebra will be examined for solving series a-c circuits. It must be also useful for parallel a-c circuits. In an a-c circuit the resistance of circuit element have more complexity than the ohmic resistance of d-c circuit. In the d-c circuit, the resistance of an inductance must be zero. But, in a-c circuits, there is an effecitve resistance of both capacitive and inductive circuit elements.

2.1. Response of capacitor to a-c

The series configuration of a capacitor with one electromotif force (emf) will be considered in Fig.11.1.
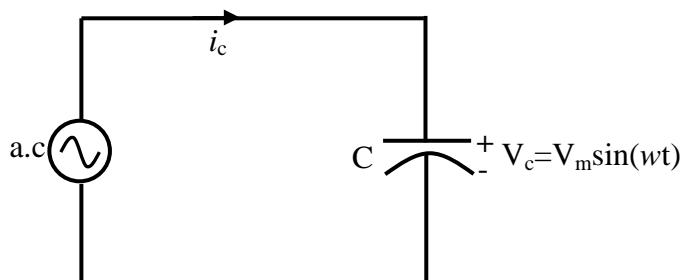
Figure 11.1: The series configuration of a capacitor with one electromotif force.

In the example-7 we said that the capacitive current should flow until the capacitor full up. If the value of capacitance greater and for greater particular charge in voltage across the capacitor, the resulting capacitive current will be greater. Thus an increase in frequency of alternating current voltage source (emf) corresponds to an increase in the rate of change of voltage across the capacitor and to an increase in the current of the capacitor. Therefore the current flow through the capacitor is related to the frequency (angular

velocity) and the capacitance value of the capacitor. If both these quantities are increased the current through the capacitor will increase.

The resistance (opposition) of a capacitor is directly related to the reciprocal of ωC. If the frequency of a-c and capacitance are increased, the opposition to the current will be less. By using some mathematical approach, the opposition will be given as;

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$
(11.1)

where f is the frequancy (Hz) of emfand C is the capacitance (Farads) of capacitor.

The quantity $1/\omega C$ is also called as the reactance of a capacitor and it is the resistance to electron flow caused by capacitance. It is measured by ohms (Ω).

If only capacitance is present in the circuit, the build up of voltage is delayed and the current leads the voltage by 90 electrical degrees. Thus the voltage and current are not in phase. There a 90^0 phase difference between then as shown in Fig.11.2.
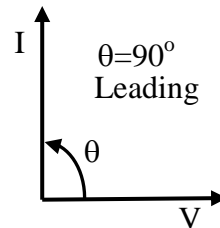
Figure 11.2: Current and voltage direction in an capacitor to a-c circuit.

2.2. Response of inductor to a-c

The voltage appearing across an inductor directly related to the rate of change of current through the coil. The series configuration of an inductor with one emf is shown in Fig.11.3.
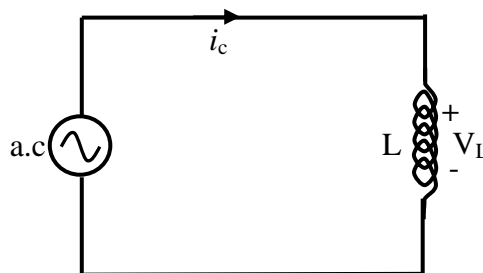
Figure 11.3. The series configuration of an inductor with one electromotiv force.

If the frequency (ω) of emf and inductance (L) of inductor are increased, the value of inductor voltage (V_L) should be increased. The product of frequency (ω) and inductance (L) represents an opposition to the current I_L. The value of V_L increased, the current I_L

should be decreased. The quantity ωL is also called as reactance of an inductor (inductive reactance). It is represent by X_L and measured by ohms (Ω).

$$X_L = \omega L = 2\pi f L \qquad (11.2)$$

If only inductor is present in the circuit, the voltage and current are not in the same phase. The built up of current delayed and voltage leads the current by 90^0 electrical degrees as shown in Fig.11.4.
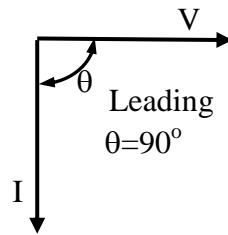
Figure 11.4: Current and voltage direction in an indicator to a-c circuit.

3. EXPERIMENTAL PROCEDURE

1.1. RC Circuit

Set up the circuit shown in Fig.11.5.
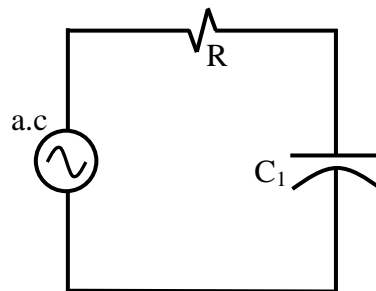
Figure 11.5: RC Circuit.

1-) Connect the voltmeter across the capacitance and also ammeter to the circuit with series both R and C.

2-) Apply 5 a-c volt to the circuit.

3-) Measure the circuit current I and the potential difference V across the capacitor C and record all of them.

4-) Substitude the capacitor C_1 with another capacitor C_2 and repeat above steps.

3-2. RL Circuit

Set up the circuit shown in Fig.11.6.
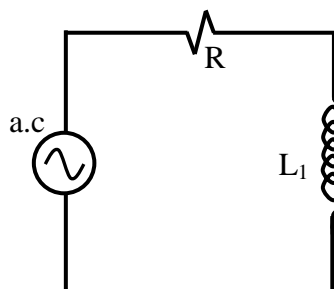
Figure 11.6: RL Circuit.

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1-) Measure the circuit current I and the potential difference V across the inductor L using an ammeter and voltmeter then record them.

2-) Substitute inductor L_1 with another inductor L_2 and repeat above step.

4. DISCUSSIONS and CONCLUSIONS

4.1-) For the RC circuit; plot the voltage phase diagram. Measure phase angle. Compute the values of R, C and X_c . What is the impedance value (Z) of this circuit and only capacitor?

{Phase angle $\Phi=\arctan(-X_L/R)$}

4.2-) For RL circuit; plot voltage phase diagram. Measure phase angle. Compute the values of R, L and X_L. What is the impedance value of this circuit and only inductor ?

{Phase angle $\Phi=\arccos(R/Z)$}

5. QUESTIONS

5.1-) Discuss the results and source of errors you obtained in the experiments.

5.2-) How does capacitive reactance vary with capacitance and with frequancy ?

5.3-) How could the impedence diagram be converted to a voltage diagram ?

5.4-) Define (a) sinusoidal current and voltage, (b) in phase, (c) 90^0, or $\pi/2$, out of phase (d) inductive reactance (e) capacitive reactance.

5.5-) Explaine why the impedance of a capacitor decrease with increasing frequancy.

5.6-) Explain why the impedance of an inductor increases with frequancy.

APPENDIX A

PRECISION TIMER
USER'S MANUAL

PRECISION TIMER allows you to use an IBM PC or IBM-compatible computer as an accurate and very flexible laboratory timer. There are 19 different timing modes. To use most modes you will need photogates. Times are accurately measured to the nearest tenth of a millisecond. In addition to acting as a timer, the computer can store or print the data table, do statistics, display the times in large block digits, save data tables on a disk, and graph the data. In certain modes the computer can even calculate and graph speeds, accelerations, and displacements.

A QUICK LOOK AT PRECISION TIMER
Starting the Program

Connect your TEL-Atomic photogate interface box to the computer's game port (15-pin socket in the back of the computer). Plug the photogates into the box.

Set up the computer as you norma]ly do using an MS-DOS disk. To start up the PRECISION TIMER program:

If your working copy of PRECISION TIMER is on a floppy disk: Place your normal **MS-DOS** startup disk in drive A:. This disk should include the **MS-DOS COMMAND.COM** file.

Place the working copy of the PRECISION TIMER disk in the B: disk drive and select the B: drive by entering: B: To start the program enter: PT

If you have PRECISION TIMER on your hard disk: Use the MS-DOS command CHDIR to change the current directory to the one that contains the PRECISION TIMER program. To start the program enter: PT

The program will first load a graphics logo and the essential files. Press <Enter> to proceed to the Main Menu:

Precision Timer — TEL-Atomic Copyright 1988—1992 Vernier Software

(MS—DOS Version)

Select Mode:

M — Motion Timer

G - Gate Timing Modes

P - Pulse Timing Modes

K - Keyboard Timing Modes

C - Collision Timer

T - Miscellaneous Timing Modes

D — Data Analysis Options

O — Other Options

S - Photogate Status Check

Q – Quit

The Main Menu allows you to select a timing mode for collecting data (using one of the first six selections). There are also several selections that are used to access other features of the program. The DATA ANALYSIS OPTIONS include displaying, graphing, saving, and loading data. The OTHER OPTIONS selection allows you to change the way the program operates or to recalibrate. The PHOTOGATE STATUS CHECK is a quick way to make sure your photogates are connected and working properly.

Using Menus in This Program

Menus are used in this program in the same way they are used in many other programs. One of the choices is initially highlighted. This is referred to as the *default* selection. You can make a selection from a menu in either of two ways:

(1) Type the letter that appears to the left of the menu item and then press <Enter> or

(2) Use the arrow keys to move through the selections until the one you want is highlighted and then press <Enter>. Either the <↓> or <→> key can be used to move down through the selections and either the <↑> or <←> key can be used to move up through the selections. The menu "wraps around" so that you can go "down" from the bottom back "up" to the top.

Pressing the <ESC> key at any time will cause the program to return to the Main Menu or to a previous menu. Some menus offer only a YES or NO choice. When presented with these menus, use the arrow keys, <Y>, <N>, or the <Space Bar> to select the choice, and then press <Enter>.

A Typical Timing Procedure

1. Select the S - PHOTOGATE STATUS CHECK option from the Main Menu to make sure the photogates are working properly. Block each of the photogates with your hand and make sure the program responds properly.

2. Position the appropriate photogates as required for the timing you plan to do. (If you do not have any photogates, you can still use the program in one of the KEYBOARD TIMING modes.)

3. Select the proper timing mode. The first six selections on the Main Menu contain the timing modes. In some cases, several different timing modes are grouped together. If

you select one of the groups of modes from the Main Menu, a submenu of those timing modes will appear. All of the timing modes are listed below (in their groups) along with a brief description of how they are meant to be used:

M- Motion Tinier (times between leading edges of a "picket fence" object passing photogate #1)

G- Gate Timing Modes (measures the interval of time that photogates are blocked)

        A-OneGate
        B-TwoGates
        C-ThreeGates
        D-FourGates
        G-Any Gate

P- Pulse Timing Modes (measures the time intervals between photogates)

        A -Pulse 1-2
        B -Pulse l-2 and 2-3
        C -Pulse l-2 and 2-3 and 3-4

K- Keyboard Timing Modes (measures the time between presses of the <Space Bar>)

        S - Simple Stopwatch
        M - Stopwatch Motion Timer

C- Collision Timer (measures the time that either of 2 photogates is blocked independently)

T- Miscellaneous Timing Modes

        P - Pendulum Timer (times the period of a pendulum)
        B - Bounce Timer (measures the speeds of a ball before and after a bounce)
        S - Strobe Timer (determines the time between strobe light flashes)
        D - Duration Of Flash (measures the duration of a flash of light)
        G - Gate And Pulse (2 Gates) (measures time blocked and time between gates)
        H - Gate And Pulse (3 Gates) (measures time blocked and time between gates)
        I - Gate And Pulse (*4* Gates) (measures time blocked and time between gates)

Select the timing mode you want to use from the Main Menu or submenu. For example, to time a pendulum, choose mode T - MISCELLANEOUS TIMING OPTIONS and then mode P - PENDULUM TIMER.

4. After you select a timing mode, you will usually be asked to specify how the time data should be displayed:

        N - Normal Time Display
        L - Times Displayed in Large Digits
        Q - Times Not Displayed

The N - NORMAL TIME DISPLAY selection will display the times in standard characters on the monitor as the times are measured.

The L - TIME DISPLAYED IN LARGE DIGITS selection will cause the times to be printed in large block digits on the screen as the times are measured. This is often useful because it allows many people to be able to see the results at once.

The Q - TIMES NOT DISPLAYED selection will cause the program to skip the displaying of times after each run. The times are stored in memory and can be displayed at the end of the complete timing sequence. The advantage of this selection is that it slightly speeds up the data gathering process, since no time is spent displaying the results before beginning another timing run.

5. The computer will now be ready for timing. Run the experiment (pass the objects through photogates, etc.). Normally a high-pitched sound will be emitted from the computer as the timing is taking place. If you do not like this sound, you can turn it off (see OTHER OPTIONS). However, the sound does serve a useful purpose: it provides an indication of exactly when the program is timing. In most modes, the times are displayed after each run[2]. Repeat the experiment as often as you like — up to 512 times. The timing data will be stored in the computer's memory. Press <Enter> when you are ready to stop timing.

6. The Data Analysis Options Menu is now displayed:

> T- Display Table of Data
> P- Print Table of Data
> L - Large Digit Data Table
> D- Delete Data
> S- Special Options
> F- File Options
> G- Graph Data
> X- Return to Main Menu.

These options provide you with a number of ways to view, graph, modify or save the time data that you have collected. Most of these options are self-explanatory, but each of these options is discussed in detail in the "Data Analysis Options" section.

To simply view the table of time data, choose option T - DISPLAY TABLE OF DATA. A complete table of time data, with statistics, will be displayed. Times are listed, with one run of the experiment per row. The times are listed across the row in the order in which they were measured.

THE FILE OPTIONS include saving data to disk, loading data files, and MS-DOS disk functions.

In some cases, a graph of the results may be useful. In any mode, the program will graph the times in any column of the data table vs. run number. In the MOTION TIMER or STOPWATCH MOTION TIMER modes, other types of graphs are possible. The data collected in these modes allow the program to calculate and graph displacement vs. time, velocity vs. time, acceleration vs. time, or time vs. run. The values that are graphed can be displayed, printed, or saved on a disk.

When you choose one of the Data Analysis Options, the operation will be performed, and the program will eventually return to the Data Analysis Options Menu. When you are ready to do some new timings, select the X - RETURN TO MAIN MENU option. You can then begin a new experiment. Remember, however, that when you collect new data, any timing data currently in memory will be overwritten.

7. To quit the program, select mode Q - QUIT from the Main Menu.

Entering Values

While using this program you will occasionally be asked to enter a numerical value. A standard format is used in these situations. A default entry is usually displayed. This entry is usually the most reasonable or likely choice. If you simply press <Enter>, the default entry will be used. If you wish to enter something different, type in the correct entry. The following keystrokes can be used:

KEY	ACTION
<←>	moves cursor left
<→>	moves cursor right
<Backspace>	deletes character to the left of the cursor
<Delete>	deletes character that the cursor is on
<ControL><X>	deletes all characters (start over from scratch)
<Control><Z>	restores the default entry (start over from the default entry)
<Control><Y>	deletes from cursor to end of line
<ES C>	exits what you are doing and returns to the previous menu (escape)

To use one of the "control" commands, hold the <Control> key down while pressing the other (letter) key. For example, if you want to completely erase the default entry and type in something else, hold down the <Control> key and then press the <X> key. The number of characters allowed is limited in some cases, and if you try to enter too many characters the computer will beep. When you have the entry the way you want it,

press <Enter>. Pressing the <ESC> key will cause the program to return to the Main Menu or to a previous menu.

M - MOTION TIMER

The MOT[ON TIMER mode uses only photogate #1, but allows for an extensive analysis of the motion of an object. This mode was designed for use with either TEL-Atomic's Rotogate or with a "picket fence" object made up of alternating opaque and ~and transparent bands:
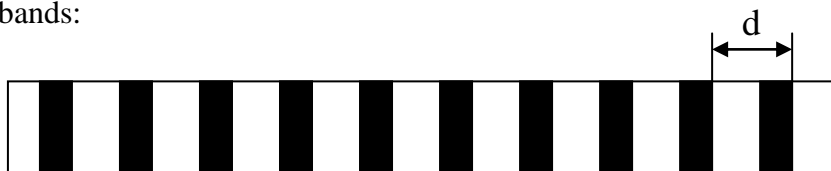
The width of each of the bands should be at least *0.5* cm. The distance between the leading edges (d in the figure above) should be at least 3 cm or larger if the picket fence is to be moving rapidly (for example in a free fall experiment). A closer spacing can be used if the object will be moving slowly; for example, on an air track glider. The timings are made as the object passes through photogate #1. The time between passing of the leading edges of the opaque bands is measured. These times are displayed in a data table.

More importantly, if you enter the distance between the leading edges of the opaque bands (d), the program can analyze the times, and calculate velocities, displacements, and accelerations.

To use this mode, select M - MOTION TIMER from the Main Menu. Pass the picket fence object through the photogate, and then press <Enter> to exit the timing routine. A table of data will be displayed. passing <Enter> again will display the Data Analysis Options Menu.

The G - GRAPH DATA option is especially useful with data collected in the MOTION TIMER mode. A sample velocity vs. time graph made from times collected in this mode is shown here. See the "Data Analysis Options" section for details on the procedures for graphing times collected in this mode.

D - DATA ANALYSIS OPTIONS

Immediately after completing a timing experiment, the Data Analysis Options Menu is displayed:

        T - Display Table of Data

        P - Print Table of Data

L - Large Digit Data Table

D - Delete Data

S - Special Options

F - File Options

G - Graph Data

X - Return to Main Menu

Notice that there is also a D - DATA ANALYSIS OPTIONS selection on the Main Menu. This selection lets you return to data you have collected previously using one of the timing modes. Remember that if you start a new timing, all data currently in memory is lost. This selection allows you to save, print, or graph useful data before collecting new data.

These options are explained below:

T - DISPLAY TABLE OF DATA

This option lets you examine the data table. When a long data table is displayed on the screen, the display stops at the bottom of the screen and waits for you to press one of the following keys:

<↓> moves down one more line in the table. By pressing <↓> repeatedly, you can move down through the data table one line at a time.

<↑> moves up one line in the table.

<Pg Dn> moves down one page (16 lines) at a time. <Pg Up> moves up one page (16 lines) at a time.

<Home> moves to the top of the data table. <End> moves to the end of the data table.

<ESC> causes the program to skip the display of the rest of the data table and return to the DATA ANALYSIS OPTIONS.

At the end of the data table, statistics on the number of data items, mean, standard deviation, standard deviation of the mean, minimum, and maximum of each column are displayed.

P - PRINT TABLE OF DATA

The "P" option allows you to make a paper copy of the data table if you have a printer. The complete data table, including the statistics, will be printed.

L - LARGE DIGIT DATA TABLE

The "L" option displays the data table column by column in large digits approximately one-fourth the height of the monitor. One row of the data table is displayed

on the screen at a time. The top time is from column one, the next lower one is from column two, etc. You can move though the table, row by row, using the $<\downarrow>$ and $<\uparrow>$ keys. If more than four times were collected in each row (possible only in some of the gate and pulse modes), a second screen may be used to display the second part of the row.

The times are identified at the bottom of the screen. To exit this option, press <Enter>. This option is designed to display the data to a large group.

D - DELETE DATA

This option allows you to get rid of "strange" data; for example, if you miss a photogate during a inn, you will want to throw out that line of data. In this mode, you will be asked the row number of the data to be deleted. If you do not know the row numbers of the lines you want to delete, use the DISPLAY TABLE OF DATA option (described above) to display the data table with the row numbers so that you can check them. The following patterns may be used to enter row numbers for deletion:

To Select	Enter
a single row	the row number
all rows from A to B (inclusive)	A-B
all rows from #l to line B	-B
all rows after row B (inclusive)	B-

In these examples, A and B can be any row number in the data table. Note that when you delete a row number from the middle of the table, all the rows of data below it are moved up and renumbered. This can lead to confusion. Before using the DELETE DATA function a time, you should look at the data table again to make sure you are deleting the correct rows of

There is one restriction placed on deletion of data collected using either the MOTION TIMER or STOPWATCH MOTION TIMER modes: Deleting times from the middle of a timing experiment made using these modes would lead to erroneous motion graphs. As a result, deletions from data collected in these two timing modes can only be made at the beginning or end of the data tables.

F - FILE OPTIONS

D - Contents of Current Directory

L - Load Data from a File

S - Save Data to a File

C - Change the Current Directory

M - Make a New Directory

E - Erase a Data File

X - Return to Data Analysis Options Menu

D-CONTENTS OF CURRENT DIRECTORY

This option lists the contents of the current MS-DOS directory. Use <Control><S> to stop and start the directory listing use <Control><C> to quit.

L - LOAD DATA FROM A FILE

This option asks you to enter the name of the file that you wish to load. Only data files saved by PRECISION TIMER can be used. If you enter just the file name, the current directory will be used. You can also load files from other directories and disks using any legal MS-DOS pathname.

S-SAVE DATA TO A FILE

This option asks you to enter the name of the file that you want to use as the data file. If you enter just the file name; the current directory will be used. You can also save files from other directories and disks using any legal MS-DOS path name. Some examples are shown below; these examples assume that the current disk is A: and the current directory is PT:

To save a file named DATA located:	Enter:
on the current disk and directory	DATA
in the subdirectory TEMP in the current directory	TEMP\DATA
in the March directory on the current disk	\MARCH\DATA
on the root directory of a disk in drive B:	B:\DATA

C - CHANGE THE CURRENT DIRECTORY

This option allows you to change the MS-DOS directory. It is similar to the MS-DOS command CHDIR.

M - MAKE A NEW DIRECTORY

This option is similar to the MS-DOS command MKDIR; it creates a new subdirectory within the current directory.

E - ERASE A DATA FILE

This option allows you to delete a file from the disk. Use it with caution.

G - GRAPH DATA

The " G " option allows you to make graphs of your experimental results. In any of the timing modes, a graph of time vs. data line # can be plotted. The time plotted can be any column of times you select This kind of graph can be useful, for example, to show the gradual change in the period of a pendulum as the amplitude of its swing changes. If you are graphing data taken in a mode that collects more than one column of times, you can select which of these columns of times is to be graphed.

The MOTION TIMER and STOPWATCH MOTION TIMER modes offer a variety of other graphing possibilities. The data collected in these modes allow the program to calculate and graph displacement, velocity, or acceleration vs. time. When you graph data taken in the MOTION TIMER and STOPWATCH MOTION TIMER modes, you will be asked to make the following choice:

D - Displacement vs. Time

V - Velocity vs. Time

A - Acceleration vs. Time

T - Time vs. Run

If you choose any of the first three choices, the program will assume that the moving object traveled equal distances during each of the time intervals measured. You will then be asked to identify the object from the following choices:

A – TEL-Atomic Picket Fence (Linear)

B - Other Picket Fence Device (Linear)

C – TEL-Atomic Rotogate (Linear)

D – TEL-Atomic Rotogate (Rotational)

E - Other Device (Rotational)

Select the one that matches the data you have collected. If you choose Other Picket Fence (Linear) you will be asked to specify the spacing of the bars. If you choose TEL-Atomic Rotogate (Linear) you will be asked to specify the number of spokes and the diameter of the pulley. The default values are the standard measurements. If you choose Other Device (Rotational) you will be asked to specify the number of spokes. If you are using the Stopwatch Motion Timer mode, the distance is the distance the object traveled between key presses.

Graph Style Options

Your first choices when graphing involve the style of the graph:

Graph Style Options:

Off P - Point Protectors

Of f E - Error Bars

Off G - Grid On The Graph

Of f L - Line Connecting Points

Off R - Regression Line

Of f S - Statistics

Of f B - Bar Graph

Of f T - Specify Graph Title

The simplest graph created by PRECISION TIMER will consist of labeled axes, a title at the top of the graph, and dots at each of the data points. The graph style selection gives you several options that you can add to this graph. The Graph Style Menu is different from the other menus used by this program. This menu allows you to activate a style option by moving to it and pressing <Space Bar>. The word "on' or "off' to the left of the option indicates its status. Any number of options can be turned on at any one time. As an example of using this menu, if you want to add a line between the points on the graph, move to L - LINE CONNECTING POINTS either by using the arrow keys or by pressing <L>. Now press <Space Bar>. The word "on" will appear, to the left of the L - LINE CONNECTING POINTS selection on the menu, indicating that it is turned on. You can then move to other options and turn them on if you wish. To turn off an option, move to it and press <Space Bar> again. When you have the graph style set as you want it, press <Enter>.

More information about each of the graph style choices is given below, along with sample graphs of a free fall experiment done using the MOTION TIMER mode:

P - POINT PROTECTORS

If this option is activated, each data point will be surrounded by small symbol to make it more visible. If you are plotting a large number of data points, you may want to turn off the point protectors to avoid cluttering the graph. On time vs. run number graphs, different shapes of point protectors are used, depending on which column of time data is being graphe&

column	symbol
1	triangle
2	square
3	circle
4	diamond
5	X
6	plus sign
7	minus sign

E - ERROR BARS

Both horizontal and vertical error bars can be added to the graph. When this option is turned on, you will be asked to error a size for the horizontal error bars and a size for the vertical error bars. You can enter a number to set an absolute size (in whatever units are being used) for the error bars. For example, if you enter *"5"* for the size of the vertical error bars, all vertical error bars will extend *5* units above and below the data point. You can also enter the size of an error bar as a percent by typing a number followed by a "%"

sign and then pressing <Enter>. This sets the size of the error bar relative to the data.

For example, if you enter" 10%" as the size of the vertical error bars, each vertical error bar will extend a distance that represents 10% of the vertical-axis value plotted. If you enter zero for the error bar size, no error bar will be drawn. In many cases, you will want to have only vertical axis error bars. The default sizes for error bars are 10% for the vertical bars and 0 for the horizontal bars (no horizontal error bars).

G - GRID ON THE GRAPH

This option produces a background grid of dots on the gray so that it looks more like graph paper. These dots are line up with the tick marks on the graph axes. If you activate this option, you probably will want to use point protectors 1 make the data points distinguishable from the grid dots.

L - LINE CONNECTING POINTS

This option will cause a point-to-point line to be drawn connecting the data points.

R - REGRESSION LINE

This selection causes the "best fit" straight line to be draw through the data. The position of this line is calculated using linear regression analysis.

S - STATISTICS

This option will add the statistics on the slope, y-intercept coefficient of correlation of the linear regression best-f line. These statistics are displayed at the top of the graph just below the title. Just below the slope and the y-intercept, di standard deviations of the slope and the standard deviation of the y-intercept are displayed. These statistics are labeled as follows:

M = slope of linear regression line
B = vertical-intercept of the linear regression line
R   = coefficient of correlation of the linear regression line (This is a measure of how well the data fits a straight line. If the data is a perfect fit4 the value will be +1.00 or-1.00. If the data is totally random, the value will be near zero. Refer to the *Teacher's Guide* for more information on correlation coefficients.)
+/-   used to indicate the standard deviation of the slope and the y-intercept.

B - BAR GRAPH

This option changes the appearance of the graph drastically. A bar graph of the data will be created, with the alternate bars shaded with different patterns. If you choose this on, you probably will not want to use point protectors or error bars. If the bar graph option is selected, you will be asked to enter the width of the bars on the graph. This width is specified in arbitrary units on the monitor. Each unit is 1/1000th the width of the screen. The default bar width chosen by the program will produce a fairly attractive graph. You

can adjust the width if you wish. The minimum width is 2 units. If you have a large number of data pairs, you will want to use narrow bars to prevent overlapping. If you have only a few points on the graph, you can use wide error bars. Try different sizes until you get the graph to look the way you want.

T - SPECIFY GRAPH TITLE

This option allows you to customize the title of the graph. If you do not turn this option on, the graph will automatically be titled using the vertical axis label vs. horizontal axis label; for example, DISPLACEMENT VS. TIME or TIME VS. RUN NUMBER. Using this mode you can add a title of your choice. The length of the title is limited to a maximum of 70 characters.

Axis Scaling

The next choices deal with the scale for the axes. The monitor will first display:

Select Horizontal Scaling:

A-Automatic Scaling, Axis Starts at 0

B-Automatic Scaling, Variable Origin

C -Manual Scaling

These scaling options are explained below:

A - AUTOMATIC SCALING; AXIS STARTS AT 0

The program will analyze the data table and choose the largest scale possible for the horizontal axis with the left edge of the graph starting at zero. At the same time, it follows standard graphing conventions. A value of 1,2,4,5 or one of these values times some power of 10 will be chosen as the value of the space between tick marks along the axis. This is the default selection and it should be used in most situations.

B - AUTOMATIC SCALING, VARIABLE ORIGIN

The computer will select the scale in a similar manner, but without the restriction that the left edge of the graph must represent zero.

C - MANUAL SCALING

Using manual scaling, you have control over the starting point and the value used at the major tick mark near the right side of the graph. The monitor will display the largest and smallest value to be graphed. You will then be asked to enter the starting value for the horizontal axis. The default answer is the minimum horizontal axis value, but any value may be entered. Next, you will be asked to enter the value to be used at the major tick mark near the right side of the graph. A default value is displayed. It represents the

smallest possible value that will allow all of the data to fit on the graph and still follow standard graphing conventions. Use this default value in most cases. If you want to expand the graph (possibly leaving some of the points off the graph) choose a smaller number. If you want to shrink the graph, choose a larger value.

Next, the scaling method for the vertical axis is selected:

Select Vertical Scaling:

A - Automatic Scaling, Axis Starts at 0

B - Automatic Scaling, Variable Origin

C - Manual Scaling

These scaling options are similar to the choices for the horizontal axis. The default choice is "B" scaling, which should be used in most cases. If you want to have the graph start at zero, choose "A" scaling. C - MANUAL SCALING gives you greater flexibility in setting up the graph, but requires more decision making. The best way to use type "C" scaling is to choose a good number for the value at the origin and then let the program decide the value to be used at the major tick mark on the graph. The graph will now be displayed on the monitor. The axes of the graph are labeled and the title is at the top. There are four major tick marks along the horizontal axis with their values indicated. There are three labeled tick marks along the vertical axis. The values at the lower-left corner of the graph are indicated. A line representing y =0 will be drawn if it should appear within the graph (rather than at the axis). The program will begin to plot the points on the graph. If it tries to graph a point that will not fit on the graph, it will sound a "beep" and skip that point. Press <Enter> when you have finished viewing the graph.

You are now presented with the Graph Follow-Up Options:

D - Display Previous Graph

R - Regraph - Same Scale

S - Change Scale and Regraph

0 - Print Graph

A - Alter Type of Graph *

A - Graph A Different Column of Times *

T - Display Table of Values *

P - Print Table of Values *

V - Save Values on Disk *

X - Return to Data Analysis Options Menu

(The selections marked with an "*" are not always displayed.)

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These options allow you to display, save, or print the previous graph, go back and make a new, slightly different graph, or return to the Main Menu. In the case of graphs made with the MOTION TIMER or STOPWATCH MOTION TIMER modes, you can also examine or save the values that were graphed.

D - DISPLAY PREVIOUS GRAPH

This choice displays the same graph with no changes.[7]

R - REGRAPH - SAME SCALE

This option will plot the graph again, with the same scaling, but you will have the opportunity to change the graph style options (point protectors, grid, point-to-point line, etc.)

E- CHANGE SCALE AND REGRAPH

This option redraws the graph but allows you to change the graph style and the scaling.

O- PRINT GRAPH

This option prints out an exact copy of the graph that was displayed on the monitor. Refer to the *Teacher's Guide* for details on the type of printer required to print graphs.

A - ALTER TYPE OF GRAPH *

This option is available only if you are graphing data collected in the MOTION TIMER or STOPWATCH MOTION TIMER modes. It allows you to choose a different type of graph and graph again; for example, if you have graphed velocity vs. time and want to try a displacement vs. time graph.

A - GRAPH A DIFFERENT COLUMN OF TIMES *

This option is available only if you are graphing data collected in a timing mode with several columns of times. It allows you to graph a different column of times.

T - DISPLAY TABLE OF VALUES *

Option T displays a table of the calculated values (displacements, velocities, accelerations or times) that were most recently graphed. It is displayed only if you are graphing data collected in the MOTION TIMER or STOPWATCH MOTION TIMER modes.

P - PRINT TABLE OF VALUES *

This option prints the table of the calculated values that were most recently graphed. It is displayed only if you are graphing data collected in the MOTION TIMER or STOPWATCH MOTION TIMER modes.

V - SAVE VALUES ON DISK *

This option saves the calculated values (displacements, velocities, accelerations, or times) on the disk. The file format is a simple ASCl ltext file. This file can not be used again by this program, but can be read by other programs, such as word processors or Lotus 1-2-3. This option is displayed only if you are graphing data collected in the MOTION TIMER or STOPWATCH MOTION TIMER modes.

S - SPECIAL OPTIONS

The 'S" option will do any special data analysis that is available in that particular mode. Examples are cafculations of speeds and accelerations. The special options of each mode are explained in "A Detailed Look at Each Timing Mode" above. Not all timing modes have special options.

O- OTHER OPTIONS

Several infrequently used options of the program are included under 0-OTHER OPTIONS:

S - Turn Sound On or Off

0 - Save Program Options

Z - Calibrate the Timer

S -TURN SOUND ON OR OFF

This allows you to specify whether the computer will make a sound as it times. The advantage of the sound is that it is an indication of when the program is actually timing. The disadvantage is that it may be irritating if you are doing a lot of timing. The sound status (on or off) can be saved, along with other program options, using 0- SAVE PROGRAM OPTIONS (described below).

O-SAVE PROGRAM OPTIONS

There are several options that can be specified from the Other Options Menu and then saved on disk. The 0- SAVE PROGRAM OPTIONS choice allows you to "customize" the program so that these options are set as you want them whenever the program is used. The options that are saved are:

- Sound on or off during timing
- Graphics mode (VGA, EGA, CGA or Hercules)
- Calibration data
- Computer I]) bytes
- Colors used for menu
- Colors used for graphs
- File specification string used for directories

Once these options are set as you want them, select SAVE PROGRAM OPTIONS to save them on the disk so that they will be set as specified each time you run the program.

Z - CALIBRATE THE TIMER

This program times by using the 8253 or 8254 programmable timer that is built into all IBM-compatible computers. The frequency of this timer is set by the program at what should be 10026.72 Hz for all timing modes except the KEYBOARD STOPWATCH modes (which use a much lower frequency). In most cases you will never need to recalibrate. The timer frequency is not directly related to the "clock frequency" used by the computer (4.77 MHz, 8 MHz, etc.). The CALIBRATE THE TIMER option allows you to adjust this frequency, if necessary.

To recalibrate you need a stopwatch and photogate #1. Follow this procedure:

1. Select CALIBRATETHE TIMER from the Other Options Menu. Proceed to where the monitor displays "Begin timing whenever you are ready."
2. Block photogate #1 and at the same time start the stopwatch.
3. Leave the photogate blocked for a long time interval — at least several minutes.
4. Unblock the photogate and at the same time stop the stopwatch.

The monitor will display the number of "counts" the tinier went through during the interval and the time as measured using the current calibration. You will then be asked to enter the actual elapsed time as measured by the stopwatch. Using this information, the computer will calculate the frequency that your new calibration yields. You will then be asked whether you actually want to change the calibration file. If you do, you will be asked to enter the date and your name so the calibration file can be properly updated. This new calibration file will be used each time the program is started.

S - PHOTOGATE STATUS CHECK

Mode S allows you to quickly check the operation of the photogates. When you select this mode, the screen will report on the status of each photogate as either "BLOCKED" or "UNBLOCKED". By passing an object through the gate you can make sure the gate is working.

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