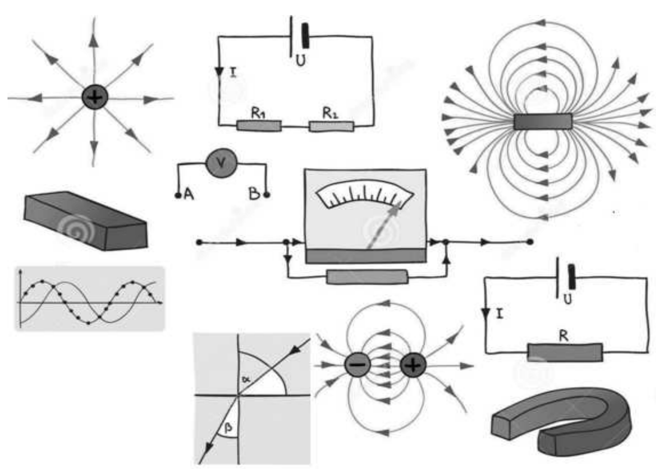
Palestine Technical University-Khadoorie

LABORATORY MANUAL

General Physics Lab II



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Contents

INSTRUMENTS FOR ELECTRICAL MEASUREMENT

In this laboratory most of the experiments are related to electricity and magnetism, so electrical power is used to operate the instruments in this laboratory, which are mainly of three types:

1. Instruments which deliver power as power supplies, batteries, signal generators.
2. Instruments which consume electric power as resistors, capacitors, coils.
3. Measuring instruments as ammeters, voltmeters, galvanometers, multitesters, oscilloscopes.

For all of these instruments, it is very important to know how to use them, because any mistake in their usage, either you damage the instrument or other instruments in the experiment. So we are going to explain how to use them in a safe way.

1- Power Supplies:

These are the main source of power in our laboratory. Usually, we are using

Figure 1:

simple power supplies which contains variable DC and AC output. To be more safe, you better start from lower value at the beginning and increase gradually until you reach the desired value.

DO NOT SWITCH ON THE POWER SUPPLY BEFORE ASKING YOUR INSTRUCTOR TO CHECK YOUR CIRCUIT 2- Signal generators: Usually used to produce signals with different shapes such as sine-wave, square-wave and sawtooth-wave with variable frequency and amplitude. So, you can select your signal with the desired frequency and amplitude from the equipment.

3- Resistors:

Figure 2:

1. The resistance of this type depends on the type of wire, cross-sectional area and the length of the wire.

2. Carbon resistors: The value of these resistors is defined by color bands on the resistor's body as shown in Fig. (1). The value of the resistor;

$$R(\Omega) = abX10^c \pm d \tag{1}$$

Where a.b.c and d are codes for 1 st, 2nd, 3rd and 4th color as given in table (1).

4-Resistance Box: A box containing a number of precision resistors connected to panel terminals or contacts so that a desired resistance value can be obtained by

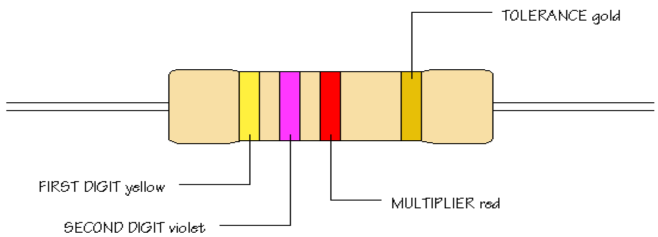


Figure 3:

withdrawing plugs (as in a post-office bridge) or by setting multicontact switches as shown in Fig(4). 5- Oscilloscope:An electronic instrument that produces an

Figure 4:

instantaneous trace on the screen of a cathode-ray tube corresponding to oscillations of voltage and current as shown in Fig(5).

Table 1: Collar Code Table

Number	*Collar*	*Tolerance*	*Collar*
0	*black*	± 1	*brown*
1	*brown*	± 2	*red*
2	*red*	± 5	*gold*
3	*orange*	± 10	*silver*
4	*yellow*		
5	*green*		
6	*blue*		
7	*violet*		
8	*grey*		
9	*white*		

Figure 5:

Error Calculations

When we measure a physical quantity, we do not expect to get the exact value which equals the true value. The accuracy of the measurement depends on how close the result is likely to be to the true value. Estimates of errors is very important to get a good conclusions from the experimental measurements.
The main sources of error comes either form the used system in the measurement or random errors. In the following paragraphs:

1. The error in one measured un repeated value is equal to $\pm\frac{1}{2}$ of the least scale in the tool of measurement.
   Example: x = 4.3 cm,
   $\Delta x = 0.5 * (0.1) = 0.05cm.$
   $x \pm \Delta x = 4.3 \pm 0.05cm$

2. If the measured quantity is repeated (n) times, it can written as:
   $x = \overline{x} = \pm\Delta\overline{x}$ where $\overline{x}$ is the mean value: $\overline{x} = \frac{\sum x_i}{n}$
   $and\Delta\overline{x}$ is the stander deviation:
   $\Delta\overline{x} = \frac{1}{n}\sqrt{(\Delta x_i)^2},\ where\ \ \Delta x_i = |x_i - \overline{x}|$

3. If a quantity Z depends on more than one variable like (x, y):

   (a) $Z = X \pm Y,$ so $(\Delta Z) = (\Delta X) + (\Delta Y)$
   (b) $Z = XY or Z = X/Y$ so $\left(\frac{\Delta Z}{Z}\right) = \left(\frac{\Delta X}{X}\right) + \left(\frac{\Delta Y}{Y}\right)$
   (c) $Z = x^n$, so we get Z=n Ln(X), $\frac{\Delta Z}{Z} = n\frac{\Delta X}{X}$.
   (d) $Z = Ln(X)$, $\Delta Z = \frac{\Delta X}{X}$

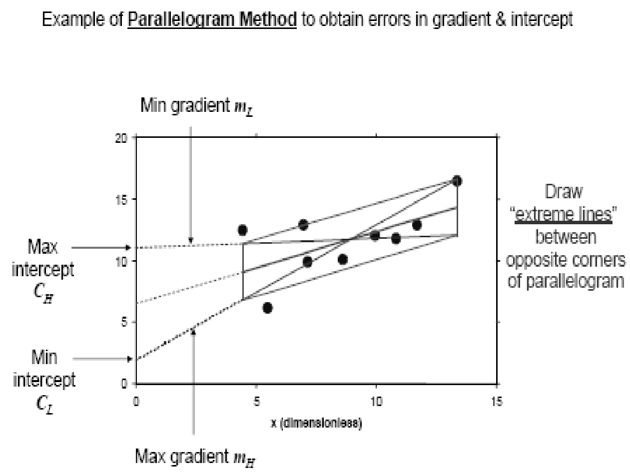


Figure 6:

(e) $Z = X^n * Y, \;\; Ln(Z) = n * Ln(X) + Ln(Y)$

$\frac{\Delta Z}{Z} = (n * \frac{\Delta X}{X} + \frac{\Delta Y}{Y})$

(f) $Z = sin(X), \;\; given : X \pm \Delta X \; \Delta Z = sin(X + \Delta X) - sin(X)$

Example: $Z = sin(45^o)$

$X \pm \Delta X = 45^o \pm 1^o$

$\Delta Z = |sin(46^o) - sin(45^o)| \;\; = |0.719 - 0.707| = 0.012$

4. The error in any measured quantity can be expressed by any of the following:

(a) Absolute error: $\pm \Delta X$

(b) Relative error: $\pm \frac{\Delta X}{X}$

(c) Relative percentage error: $\pm \frac{\Delta X}{X} * 100\%$

(d) Estimating Errors in Simple Straight-Line Graphs:

To obtain errors in gradient and intercept using the Parallelogram Method as shown in Fig(6)we use:

$\Delta m = \frac{m_H - m_L}{\sqrt{n}}, \;\; so \;\; Slope \;\; is \;\; m \pm \Delta m$

$\Delta c = \frac{c_H - c_L}{\sqrt{n}}, \;\; so \;\; intercept \;\; is \;\; c \pm \Delta c$

Experimental No. (1)

Equipotential surfaces

OBJECTIVE: The purpose of this lab is to explore the electric force per unit charge as a function of the distance from various charged electrode configurations.

Equipment: Multimeter, apparatus for mapping equipotentials, graph paper (provided).

Theory: The electric force per unit charge is called the electric field intensity or simply the electric field (E). The electric field is a vector quantity given by

$$\overrightarrow{E} = \frac{\overrightarrow{F}}{q_o} = k\frac{q_o}{r^2}\widehat{r} \tag{2}$$

Like all other vector quantities, it has both magnitude and direction. As discussed in the lecture, electric field lines flow from positively to negatively charged regions (positive to ground in this experiment). From the equation above (Coulomb's Law) you should also realize that the magnitude of the electric field decreases as the inverse square of the distance from the point source (in this experiment, the electrodes). This implies that the density of electric field lines (how close together they are) will decrease as you get further away from the source. the electrical potential is constant along equipotential surfaces, which are perpendicular to electric field lines. Thus, by mapping experimentally where the potential is constant, you can get a map of the electric field. That is the main point of this experiment.

Sketch two configurations of the electrodes on the graph paper. Connect the apparatus to the power supply. Turn the power supply on and set it to 6 volts as shown in the Fig(7) Connect the ground from the voltmeter to the ground from the power supply. Now, using the positive probe you will mark out some equipotential surfaces around the electrodes. Being careful to not touch the water with

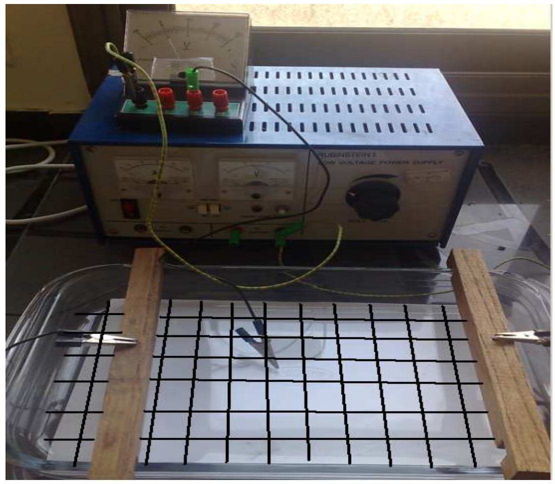


Figure 7:

anything other than the probe, locate 8 points each for the following voltages; 1, 2, 3, 4, 5 V. Make sure the points are spread out, so that you can get a good sampling of the space around each electrode. Connect the points of equal voltage (potential) with a smooth line and label them. These are equipotential surfaces. Now draw the corresponding electric field lines, with arrows to show the direction of the field. Repeat the same steps for three different electrodes.

Name: Grade:

Students No.: Date:

Data and Calculation

Table 2: Data sheet for point charge and line charge respectively

$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*	
x cm	y cm	x cm	y cm	x cm	y cm	x cm	y cm	x cm	y cm
$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*		$V = ...Volt$ *Potential*	
x cm	y cm	x cm	y cm	x cm	y cm	x cm	y cm	x cm	y cm

Table 3: Data sheet for two line charges

$V = ...Volt$ Potential		$V = ...Volt$ Potential		$V = ...Volt$ Potential		$V = ...Volt$ Potential		$V = ...Volt$ Potential	
x cm	y cm	x cm	y cm	x cm	y cm	x cm	y cm	x cm	y cm

Questions:

1. What is the angle between the equipotential surfaces and electric field lines.
2. In which case of the three performed setups we get uniform electric fields?
3. Where are regions of strongest and weakest electric fields located?
4. Can electric field lines ever cross? Explain. (Hint: Remember that the electric field is a vector.)

Experimental No. (2)

The Oscilloscope and AC Circuitry

OBJECTIVE

1. To gain experience with the operation of an oscilloscope for the observation and measurement of transient and periodic electrical phenomena.

2. To be able to use it to measure voltages.

3. To study simple AC circuitry.

Equipment

Oscilloscope, sine and square wave generator, terminal board with 0.0047 μF capacitor (ceramic) or close to that value, 47 mH inductance or close to that value, a 1.5 volt battery, a supply of coaxial cables, 3-cycle log-log and rectilinear graph paper (student-provided).

The cathode-ray oscilloscope is an instrument which can be used to display the magnitudes of rapidly changing electric currents, potentials, or pulses as a function of time. The information is displayed on the face end of a "cathode-ray tube" (CRT). This face appears as a circular or rectangular window usually with a centimeter graph superimposed on it. (The picture tube in your TV set and the display terminal of most computers are cathode ray tubes). The cathode-ray tube consists essentially of an "electron gun" for producing a beam of rapidly moving electrons called cathode rays, a fluorescent screen upon which a luminous spot is produced by the impact of the cathode rays, and a means for displacing the spot from its quiescent position as the result of current or voltage applied to the deflecting mechanism. Although the electron beam may be focused by means of magnetic fields, electrostatic focusing is usually used. Figure (5,8) shows the electrode structure of a typical cathode-ray tube having an electron gun with electrostatic focusing.

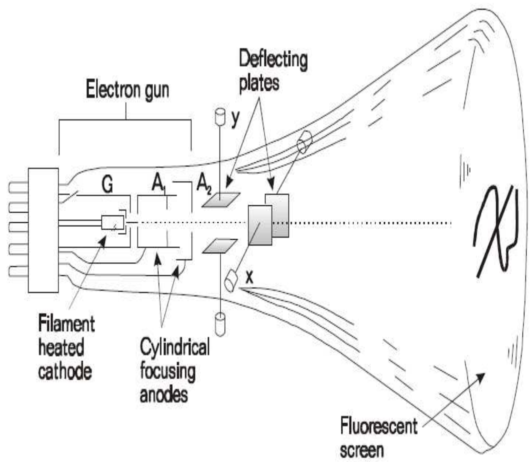


Figure 8:

The electron gun consists of an electron source (i.e., an electrically heated cathode which "boils off" electrons), a grid G for controlling the electron intensity of the beam and hence, the brightness of the luminous spot, and two anodes A1 and A2 . The final velocity with which the electrons leave the gun is determined by the potential of A2 , which is normally maintained constant. The electrostatic field between G and A1 and between A1 and A2 focuses the stream of electrons in a manner somewhat analogous to the focusing of light rays by lenses. Usually the focus control on the oscilloscope adjusts the potential of A1. After leaving the electron gun, the electron beam passes between a pair of horizontal plates. A potential difference applied between these plates deflects the beam in a vertical plane in direct proportion to the instantaneous voltage applied between the deflecting plates. This pair of plates provides the Y-axis or vertical movement of the spot on the screen. A pair of vertical plates provides the X-axis or horizontal movement of the spot on the screen.

The screen of a cathode-ray tube consists of a thin layer of a phosphor, which is a material that luminesces as the result of bombardment by rapidly moving electrons. The bombardment gives rise to both fluorescence and emission of light after bombardment. The phosphor is applied to the inside of the end of the tube by spraying, dusting, or precipitation from a liquid. Slow decay of phosphorescence makes possible the visual observation of nonrepeating transients and prevents flicker in the visual observation of periodic voltages of low frequency. However, if it is too slow it causes blurring whenever an image on the screen changes form.

Experimental Work:

Part I:Prepare the oscilloscope for operation by following the instructions for "First Time Operation" from the instructor.

Part II:Measurement of D.C. and A.C. Voltages using the Oscilloscope. Do the following and describe and explain all results in your report: Using Channel 1 (Ch.1) controls only:

1. Set the "DC-GND-AC" Switch on GND.

2. Adjust the vertical "position", knob so the horizontal trace is vertically centered on the screen.

3. Set the "DC-GND-AC" switch to DC.

4. Turn the variable, "VAR" dark gray knob, voltage control fully clockwise. The surrounding light gray knob, "VOLTS/DIV", can be adjusted to change the vertical scale calibration in volts per centimeter above and below the zero (central) or ground position. The calibration is correct ONLY when the dark gray knob is fully clockwise.

5. Measure the voltage of a 1.5 volt battery connected to the input of Channel 1. Voltages are measured on an oscilloscope by first counting the number of divisions of vertical deflection and then multiplying by the VOLTS/DIV setting.

   Measure the battery voltage for several settings of the VOLTS/DIV knob such as 5.0 V/DIV, 2.0 V/DIV and 0.5 V/DIV. What is the best setting of the V/DIV knob if you want to measure the voltage most accurately? Note what happens to your voltage measurement if the variable dark gray knob is not fully clockwise.

   Reverse the polarity of your battery and again measure the voltage. If you do not get the same value as before, your trace was probably not vertically centered when the DC-GND- AC switch was in the ground position. If such is the case, you can still get an accurate result by taking the average of the results for the two polarities. Why?

6. Set the DC-GND-AC switch to AC with the battery still connected. Explain what happens.

7. Attach the function generator to the horizontal input, set the DC-GND-AC switch to AC. With the "TRIGGER MODE" at AUTO, set the TRIGGER SOURCE" select switch to CH 1. You are now ready to measure an AC voltage from the function generator. Connect to the output of the generator and set the function selector to the sine wave position. Turn on the generator and set the frequency to 60 Hz. Adjust the 20 V peak-to-trough max control on the generator until you measure 4 Volts peak-to-trough on your oscilloscope. Adjust the TRIGGER LEVEL control knob if the wave displayed on the oscilloscope is not stationary. Ask your instructor to verify that you are observing this correctly. Note that the setting of the horizontal time scale, knob TIME/DIV affects how many cycles of the 60 Hz sine wave

is seen on the screen at one time. A setting of TIME/DIV at 10 ms/DIV (10 milliseconds per division) will cause several cycles of the 60 Hz wave to be displayed. (You will learn why this is so in the next section). Note also that by making peak-to-trough measurements of an AC voltage, you do not have to worry about whether the trace is perfectly centered vertically. Thus, this mode gives you the freedom to move the pattern up or down or left or right so that you can place a convenient part of the pattern such as one of the maxima or minima exactly on a scale division.

Part III: Measurement of the Period and Frequency of A.C. signals using the oscilloscope.

Take the pattern you just observed in step (7), part II, for the 60 Hz, 4 V peak-to-trough sine wave and adjust the TIME/DIV knob until only 1 or 2 cycles of the wave are displayed. Measure on the horizontal scale the time period, T, of 1 cycle of the voltage oscillation. This means determining the number of divisions constituting 1 cycle on the screen and multiplying by the setting of the TIME/DIV knob. Compare your result with $f = 1/T = 60$ Hz. Repeat the above for several frequencies from the function generator such as 100 Hz, 1000 Hz and 10,000 Hz. In each case adjust the TIME/DIV so that only 1 or 2 cycles are displayed. Compare your results for the generator frequency as given by the dial setting with what you measure with the oscilloscope. Neither the generator nor the oscilloscope have been calibrated to better than several percent so you cannot expect perfect agreement. What is the largest percent error you observe?

Name: Grade:

Students No.: Date:

Data and Calculation

Part II:

Battery Voltage:.............. Volt

Table 4:

	$0.5V/DIV$	$1.0V/DIV$	$2V/DIV$
positive voltage			
negative voltage			
Average Voltage			
percentage error			

Q1: Which division gives the best results?

....

Part III:

Table 5:

Signal Frequency(Hz)	*Nomber of divisions constituting onecycle*	T =(n*Time/Div) (s)	$1/T$ s^{-1}	*percentage error*

Q2 : Find the frequency of the electricity which comes from the electricity company(the same from the power supply-+) ,and at home too? ....

Experimental No. (3)

Ohom's Law

Introduction

In this experiment you will test Ohm's "law" for a carbon resistor. Then, using this "law", you will determine the equivalent resistance of 2 or more resistors connected in series and parallel.

Theory

Ohm's law states that for an ohmic conductor, the current I through the conductor is directly proportional to the voltage V applied across the conductor. That is,

$$V = I * R \tag{3}$$

Ohm's law, $V = I * R$ is only an approximation for the electrical behavior of certain materials under certain conditions. The resistance of many conductors such as metals increases with increasing temperature. When a current I flows through a resistance R, heat is generated at the rate, $I^2 * R$ (Joule heating). Thus, if enough current flows through a resistor to cause it to heat up appreciably, it will behave in a non-ohmic way and one cannot speak of the resistor as having a certain fixed resistance for all currents.

Procedure

1. **Part 1. Ohm's Law**

   Your instructor will discuss with you the use of ammeters and voltmeters. The main points to remember are that a voltmeter has a high resistance and is attached across the ends of a circuit element to measure the voltage between the ends of the element. An ammeter has a low resistance and is never placed across the ends of circuit element. It is always wired into a circuit so that it acts as a connecting wire to the circuit element whose current is to be measured.

Construct the circuit below to study Ohm's law for the resistor.

The element on the left is a power supply set at 5 VDC. The rheostat is

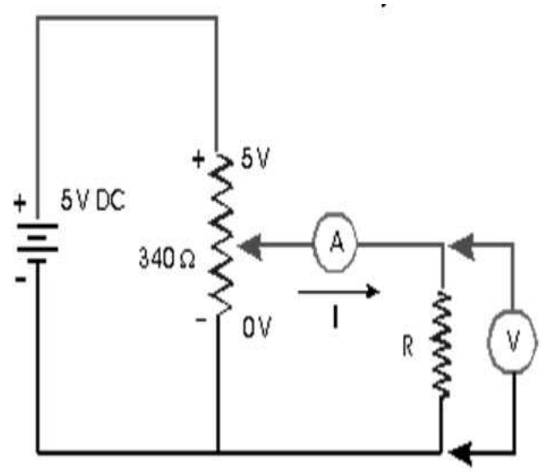


Figure 9:

connected as a voltage divider. By moving the rheostat wiper, the voltage across R can be varied from 0 to 5 V. Use one of the three carbon resistors on the board given you as R.

Note that the voltmeter V is connected across the ends of R. V and R are said to be connected in parallel. On the other hand, the ammeter A connects the rheostat to the resistor and is said to be in series with the resistor. Measure the current I through R for at least 5 voltages across R between 1 and 5 volts. Note that if you change to a new ammeter scale after you have set the voltage, you will need to reread or reset the voltage because the ammeter resistance changes with a change in scale.

Make a linear plot of V versus I. You may do this on the computer using the program Excel.

2. **Part II**

   The Equivalent Resistance of two or more Resistors connected in Series

   Wire the series circuit as shown in Figure (10-a) using two of the carbon

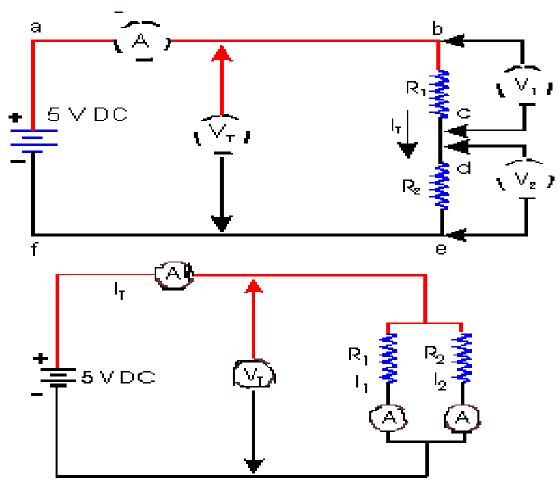


Figure 10:

resistors furnished. Measure the current along ab, cd and ef. Next measure the voltage across af (V_T), bc (V_1) and de (V_2).

Since you have measured V_T and I_T, you can determine the equivalent resistance, R_eq of your circuit from Ohm's law,

$$V_T = I_T * R_{eq} \tag{4}$$

Similarly from I_T, V_1 and V_2 you can determine R_1 and R_2. Compare the sum $R_l + R_2$ to R_eq as determined above. Does it appear that R_l and R_2 in series have an equivalent resistance $R_eq = R_1 + R_2$

3. **The Equivalent Resistance of two or more Resistors connected in Parallel**

   Wire the two resistors that you used above into parallel circuit as shown in Figure (10-b), both R_1 and R_2 have the same voltage V_T, across them. By definition, two in parallel have the same voltage across them. Insert the voltmeter to measure this voltage V_T. Adjust the power supply so that V_T = 5 V. Now measure the total current I_T and then the individual currents I_1 and I_2 through, R_1 and R_2. Does $I_T = I_1 + I_2$ within experimental error? Compare the values of $R_eq, R_1 and R_2$ with

$$\frac{1}{R_eq} = \frac{1}{R_1} + \frac{1}{R_2} \tag{5}$$

Name: Grade:

Students No.: Date:

Data and Calculation

R_1 colors are:

R_2 colors are:

Table 6:

$R_1 =$		$R_2 =$		$R_s =$		$R_p =$	
V	I	V	I	V	I	V	I
$Slope =$		$Slope =$		$Slope =$		$Slope =$	

Q1:Plot V(Volt) vs I (Amp.) for each resistance and the find the slope?

Q2:Find the percentage error in each resistance?

....

....

....

....

Q3:Show from your results that $R_s = R_1 + R_2$ and $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$.

Experimental No. (4)

THE POTENTIOMETER:

Internal Resistance of a Test Cell

OBJECTIVE:

To calibrate a one meter slide wire potentiometer using a standard cell and then to use this potentiometer to measure the emf of a test cell. The terminal voltage of the same test cell is then measured as different load resistors are connected across the test cell and these data are used to determine the internal resistance of the test cell.

THEORY:

The electromotive force (emf) of a cell is its terminal voltage when no current is flowing through it. The terminal voltage of a cell is the potential difference between its electrodes. A voltmeter cannot be used to measure the emf of a cell because a voltmeter draws some current from the cell. To measure a cell's emf a potentiometer is used since in a potentiometer measurement no current is flowing. It employs a null method of measuring potential difference, so that when a balance is reached and the reading is being taken, no current is drawn from the source to be measured.

In this method (refer to Figure (12)) a uniform, bare slide wire AB is connected across the power supply. If you were to connect a voltmeter between the + power supply terminal and point A you would measure essentially zero volts. If you were to now connect the voltmeter between the + power supply and point B you would measure a voltage equal to the terminal voltage of the power supply which is approximately 4.0 volts. The potential relative to

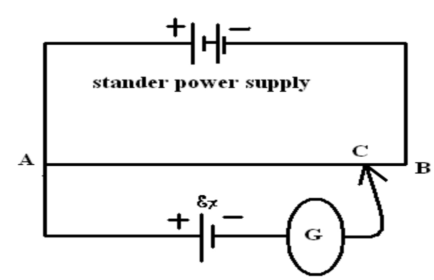


Figure 12: This is the basic circuit diagram for a potentiometer.

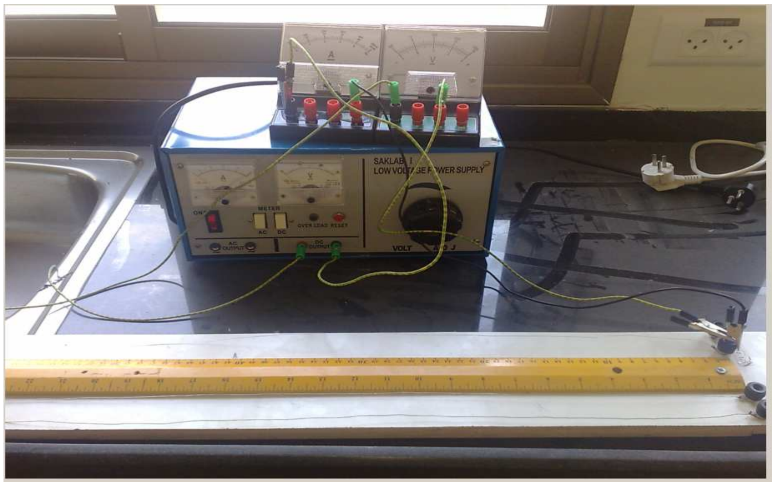


Figure 11:

point A then varies from zero at A to approximately

4.0 volts at B.

The cell whose emf is to be determined is then con-

nected so that its emf opposes the potential along the wire. At some point C the potential difference between A and C is exactly equal to the emf of the cell so that if the other terminal of the cell is connected to the point C, no current will flow. The calibration procedure is to locate this point C using a standard cell whose emf is accurately known (emf = will be assigned by instructor). You then know that at this point C the potential difference relative to point A is exactly the assigned one.

Since the wire is uniform, the length of wire spanned is proportional to the potential drop and the wire can now be calibrated in volts per cm. The emf of an unknown cell is then found by finding a new point C whose potential is exactly equal to the emf of the unknown cell and multiplying this new distance AC times the calibration factor determined using the standard cell.

It is crucial in this experiment that the current flowing through wire AB remain constant throughout the experiment. If the current varies then the potential at all points along the wire will vary and you cannot trust your calibration. An ammeter is included in series with wire AB so that you can monitor this current. The circuits used in this experiment are shown below in Figures (11,12).

Here E_s is the standard cell (emf which given by instructor), and E_x is the unknown cell whose emf is to be measured. G is the galvanometer and its simply a digital voltameter, you can simply find the position of the balance point C from the sign of the digital voltameter reading while the pin connected to C wire sliding from A to B. Once the potentiometer is balanced by adjusting point C until there is no deflection of G.

Since the electromotive force of the standard cell is equal to the potential drop in the length of wire spanned (measured from A) for a condition of balance and the same is true for the unknown cell, the emf of each cell is proportional to the lengths of wire spanned. Thus:

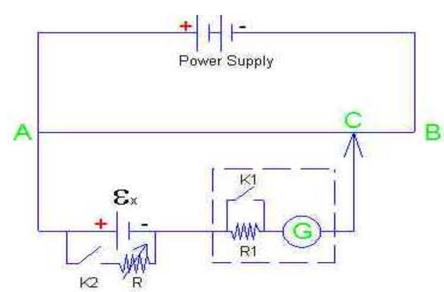


Figure 13:

$$\frac{E_x}{E_s} = \frac{L_x}{L_s} \tag{6}$$

and the unknown emf is given by

$$E_x = \frac{L_x}{L_s} * E_s \tag{7}$$

where E_x is the unknown emf and, E_s is the emf of the standard cell, L_x is the length of wire (AC) used for balancing the unknown cell, and L_s is the length of wire used for balancing with the standard cell.

If we have a test cell of emf, E_x and internal resistance r_{in} supplying current to a variable load resistor R (see figure 12), then we will measure a terminal voltage V which is a function of the load resistance R.

Since $V = E_x - I * r_{in}$, if you plot V versus I the negative of the slope of the graph will be the internal resistance of the cell r_{in}.

Calibration Use the experimental arrangement shown in Figure (13) for the calibration of the potentiometer wire, using the standard cell E_s. Start with your sliding contact C near the center of the bridge. Press the contact C. The galvanometer will probably deflect. Find a point C where there is no deflection. Now close switch K1 and again adjust C for no deflection. Pushbutton switch K1 (13) shorts out the protective resistance R1 and gives the galvanometer maximum sensitivity. Record the final setting of the contact point C and known value of the emf of the standard cell. Compute the calibration factor f in volts/cm. Electromotive force (emf) of a test cell Connect the test cell E_x into the circuit as shown in Figure(13). Determine the emf of this cell by again locating a point C where no galvanometer deflection occurs when contact C is pressed. Remember to close switch K1 for a finer adjustment of C. When no galvanometer deflection occurs with the switch K1 closed the potential drop along the wire from A to C exactly equals the emf of the test cell. Record the final balance position of the contact C and the emf of the test cell. Terminal Voltage of the test cell in use Now adjust the load resistor R to 150 ohms. You must hold switch K2 down in order for the circuit connecting R across the test cell to be complete. While holding K2 down again balance the bridge as described above. When balanced, again record the distance AC and compute the terminal voltage of the test cell. Repeat this procedure for R = 100, 60, 30, 15, 10, 8, 6, and 4 ohms. Using your measured value for the terminal voltage V and the resistance R, compute the current I being supplied by the test cell for each value of R used. Plot a graph with terminal voltage V on the vertical axis and current on the horizontal axis. Draw the best straight line through your data points. Determine the value of the internal resistance of the test cell from this graph.

Electromotive force (emf) of a test cell:

Connect the test cellE_x into the circuit as shown in Figure(12). Determine the emf of this cell by again locating a point C where no galvanometer deflection occurs when contact C is pressed. Remember to close switch K1 for a finer adjustment of C. When no galvanometer deflection occurs with the switch K1 closed the potential drop along the wire from A to C exactly equals the emf of the test cell. Record the final balance position of the contact C and the emf of the test cell.

Terminal Voltage of the test cell in use

Now adjust the load resistor R to 150 ohms. You must hold switch K2 down in order for the circuit connecting R across the test cell to be complete. While holding K2 down again balance the bridge as described above. When balanced, again record the distance AC and compute the terminal voltage of the test cell. Repeat this procedure for R = 100, 60, 30, 15, 10, 8, 6, and 4 ohms. Using your measured value for the terminal voltage V and the resistance R, compute the current I being supplied by the test cell for each value of R used. Plot a graph with terminal voltage V on the vertical axis and current on the horizontal axis. Draw the best straight line through your data points. Determine the value of the internal resistance of the test cell from this graph.

Name: Grade:

Students No.: Date:

Data and Calculation

Calibration

E_s = 5.0 V (which is given by instructor)

Calibration factor f = ...V/cm

Electromotive force (emf) of test cell:

Balance point C_x for test cell..............cm

E_x = ...V

Terminal voltage of test cell:

load resistance (R), slide position (AC), terminal voltage(V), and I(calculated)

R = 15Ω L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

R =............ L_{AC}=..............V_{AC}=............ I=$\frac{V_{AC}}{R}$............

Plot V_{AC} Vs. I.

Slope = - r_{in}, r_{in}=..................

Intercept= E_x, E_x=..................

Experimental No. (5)

VARIATION OF RESISTANCE WITH TEMPERATURE

OBJECTIVE:

1. To investigate the variation of the resistance of metals with temperature and to measure the temperature coefficient of resistance for copper.

EQUIPMENT:

Glass Beaker ,Metal resistor (Coil of fine long copper wire) ,Heating arrangement to heat the resistor ,Thermometer, 0 to 100 C^o ,Constant voltage power supply ,Ohmmeter ,Connecting leads.

Theory:

The electric resistivity of most materials varies as its temperature changes. In metallic conductors the resistivity usually increases as the temperature increases, but the resistivity of insulators decreases as the temperature increases. The electric Resistivity of a metal is due to impurities and irregularities in its structure and to the thermal vibrations of its atoms. As the free electrons flow through a metallic conductor in the circuit, their motion is impeded when they interact with the atomic ion-cores. When the metal is heated, its atoms increase their energy, and they vibrate with larger amplitudes. These vibrating atoms present greater obstacles in the path of any flowing free electrons, and effective interactions occur more frequently. Consequently, as the temperature of the metal increases, its resistivity also increases. If the temperature is not too great, the resistivity of metals varies in nearly linear fashion with temperature, according to the following expression:

$$\rho = \rho_o(1 + \alpha(T - T_o)) \quad (8)$$

where: ρ is the resistivity at any temperature T (in C), ρ_o is the resistivity at some reference temperature T_0, α is the temperature coefficient of resistivity.

α is defined as the fractional change in resistivity per degree change At wide temperature range, Eq.(8) is not adequate and terms proportional to the square and cube of the temperature are needed:

$$\rho = \rho_o(1 + \alpha T + \beta T^2 + \gamma T^3) \tag{9}$$

Where the coefficients β and γ are generally very small and we set $T_o = 0\ C^o$; but when T is large their terms become significant. Since the resistance of a conductor is proportional to the resistivity according to the equation:

$$R = \rho \frac{L}{A} \tag{10}$$

By combining expressions (8) and (10) the equation can be written as:

$$R = R_o(1 + \alpha(T - T_o)) \tag{11}$$

Where: R is the resistance at temperature T and R is the resistance at some reference temperature T_0. Equation (11) can be solved for α as:

$$\alpha = \frac{1}{R_o} * \frac{\Delta R}{\Delta T} \tag{12}$$

Where: $\Delta R = R - R_0$, $\Delta T = T - T_0$ Note that the value of α depends on the choice of the reference temperature T_o; it is not the same for all temperatures. The variation in electrical resistance with temperature is a "thermometric physical property" of materials. This property can be used to make precise temperature measurements. Finally, at very low temperatures, the resistivity of certain metals becomes essentially zero ($\alpha \approx 0$). Materials in such a state are said to be Superconductors. In our experiment, the reference temperature is selected to be To $= 0\ C^o$ .The resistance will be heated within the linear temperature range (0 to 100 C^o).

EXPERIMENTAL PROCEDURE:

1. Short-circuit the ohmmeter to check for its zero reading Measure the room temperature. Record these readings.

2. Measure the resistance of the coil at room temperature. Record these values in your data sheet.

3. Immerse the heater and the resistance coil in the beaker containing water enough to cover the oil. Connect the power supply to the heating element, and the thermometer probe to be in contact with the resistance coil, as shown in Figure 14.

4. Measure the resistance of the coil R (Ω), and the temperature of the water TC^o. Make the zero-reading correction for the resistance. Record your measurements in table-1

5. Slowly heat up the water and measure the resistance R at approximately 5C^o intervals of temperature T. Tabulate your results as in table -1.

6. As the resistance cools down, record the values of R and T. Record your measurements in table-1

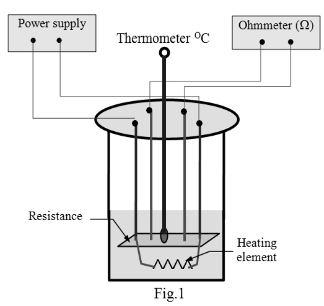


Figure 14:

Name: Grade:

Students No.: Date:
Reference Temperature $T^o = 0\ C^o$ *Room temperature* = ...

Table 7:

	$T(C^o)$	$R(\Omega)$
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

DATA ANALYSIS

(1) Plot a graph of R (Ω) versus T C^o. (Hint: Use a temperature scale that can be extended to -300 C^o) . From the graph :

- Determine the value of Resistance at T=0 , Ro ....

- Determine the value of temperature at R=0 , ...

- Calculate the %error in this temperature, given that its accepted value is 273 C^o.

....

....

....

- Determine the slope of the graph.

  ....

  ....

  ....

- Use equation (12) and your graph to calculate, the temperature coefficient of resistivity for copper.

  ....

  ....

  ....

  ....

- Calculate the % error in , given that the accepted value of is 0.0039 $1/C^o$

  ....

  ....

  ....

  ....

  ....

Experimental No. (6)

KIRCHHOFFS LAWS

OBJECTIVE:

To verify Kirchhoffs first and second laws

EQUIPMENT:

Breadboard, Resistor (3), Two power supplies, Voltmeter, Three ammeters, Connecting wires.

Theory:

Kirchhoffs rules are used in the analysis of electric circuits specially when there is more than a single loop. These rules are simple applications of the laws of conservation of charge and energy. (1) Kirchhoffs first rule or junction rule is based on the conservation of charge, it states that:

The Algebraic sum of the currents entering or leaving any junction in an electric circuit equal Zero

That is whatever currents enter a given point n a circuit must leave that point assuming no sinks or sources of currents at that point. This is due to the conservation of electric charge. The junction is any point in the circuit where the current can split. If we apply this rule to junction (a) in Fig.15, we get:

$$I_1 + I_2 + I_3 + ... = 0 \tag{13}$$

(2) Kirhhoffs second rule or loop rule is based on the conservation of energy, it states that:

The algebraic sum of voltages in a closed loop equals zero. That is, any charge moving in any closed loop in a circuit must gain energy as much as it loses. If we apply this rule to the left loop of the circuit in Figure (15) , we get: Closed Loop (1)

$$E_1 = V_1 + V_3 \tag{14}$$

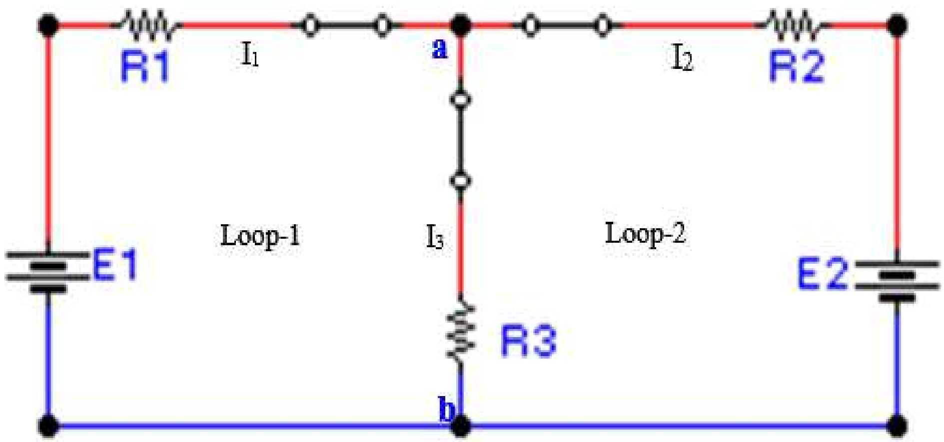


Figure 15:

$$E_1 = I_1R_1 + I_3R_3 \tag{15}$$

Closed Loop (2)

$$E_2 = V_2 + V_3 \tag{16}$$

$$E_2 = I_2R_2 + I_3R_3 \tag{17}$$

EXPERIMENTAL PROCEDURE:

1. **Connect the circuit as in Fig.15.**
2. **Determine the resistance of the three given resistors using their color code.**
3. **Measure the voltage of the two power supplies E_1 and E_2.**
4. **Measure the voltage drop across each resistor $R_1, R_2,$ andR_3 and record the polarities of $V_1, V_2,$ and V_3 on the circuit diagram.**
5. **Measure the current flow in each resistor $I_1, I_2$and I_3. Replacing one jumper at a time can do this by the ammeter.**

6. **Determine the direction of I_1, I_2andI_3. And record it on the circuit. Note that the ammeter reads with minus when the current is flowing in the opposite direction .**

7. **Record your data as shown in Table (I) below.**

Name: **Grade:**

Students No.: **Date:** **Lab Section:**

Data and calculation

$E_1 = ...$			$E_1 = ...$		
$R(\Omega)$		$V(volt)$		$I(mA)$	
		Measured	*Calculated*	*Measured*	*Calculated*
1					
2					
3					

DATA and ANALYSIS:

(1) Use the measured values of the currents to proof the junction rule

....

....

(2) Use the measured values of the voltages to proof the loop rule

....

....

....

(3) Calculate the values of V_1, V_2, V_3 , using the measured values of current ....

....

....

(4)Use the measured values of E_1 and E_2 and the three known resistors R_1, R_2 , and R_3 to calculate the currents I_1, I_2, and I_3, and the drop of voltages V_1, V_2, and V_3 across the resistors. (Write the detailed steps of calculations). Tabulate the results in table-1.

....

....

....

Experimental No. (7)

AC bridge meter

OBJECTIVE:

1. Measurement of unknown inductance or capacitance.
2. showing that impedance depends on frequency of the power source.
3. finding total impedance for parallel or serial connection.

Usually, the most precise means of measuring a complex impedance with an alternating current (A.C.) is to use some type of A.C. bridge. A generalized A.C. (Wheatstone) bridge is shown is figure (16).

For an unknown impedance to be determined, the bridge has to be balanced, the voltage across the detector has to be zero. This means that not only the voltages at both sides should have the same amplitude, but the same phase too. Once this is achieved, two separate conditions are satisfied, which respectively involve the real and imaginary parts of a complex impedance. It is now clear that there are two balancing conditions which must be satisfied simultaneously. Such a property means that the two balancing conditions must be independent of each other. This is an important influence in the design of bridge circuits for such use. For this, one would choose a bridge which had two variable impedances which were independent and exclusive of each other in both of the balancing conditions. With

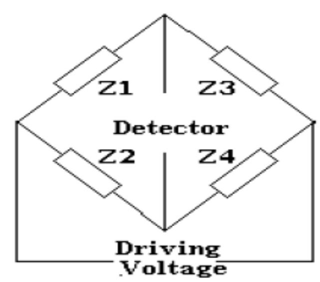


Figure 16: Wheatstone Bridge

such a bridge one of the impedances can be varied until a minimum reading on the detector is reached and the second variable impedance can be varied with until a new minimum is observed, then finer control can be achieved by returning to and varying the first impedance again. This process would be repeated as required.

Resistances and capacitances are the variable impedances used to reach the balanced state. The balance condition for the A.C. bridge shown in Figures (16,17) is similar to that of it's D.C. counter part

$$\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4} \tag{18}$$

Both of the balance conditions are contained in this complex equation. This makes sense when you consider that the real and imaginary conditions must be satisfied simultaneously. The A.C. bridge is particularly used to measure capacitance and the same general principals outlined above also apply to this circuit.

A diagram of a general bridge is shown in Fig. (17). The unknown capacitor (or condenser) is represented by the series grouping of C_x on the same arm of the bridge. C_s is a good standard condenser, whose magnitude should be will defined. R1 and R2 are a variable resistors, the value of these resistances depend on the length of the resistance, while the area of both resistances are the same. The balance condition can now be expanded to the following,:

$$V_{DC} = V_D - V_C = 0, \quad So \quad V_{AD} = V_{AC}$$

$$I_1 Z_{c_x} = I_2 R_{AC}$$

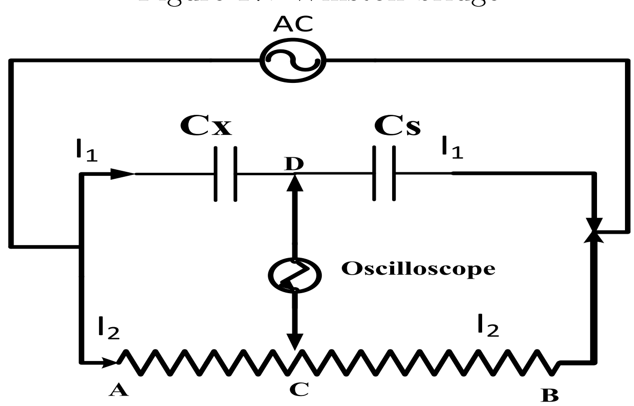
$$\frac{I_1}{\omega C_x} = I_2 \frac{\rho L_{AC}}{Area\ of\ the\ wire} \tag{19}$$

$$V_{BD} = V_{BC}, \quad So \quad I_1 Z_{c_s} = I_2 R_{BC}$$
$$\frac{I_1}{\omega C_s} = I_2 \frac{\rho L_{BC}}{Area\ of\ the\ wire} \tag{20}$$

Dividing the last two equation(19 over 20) at the balance (minimum amplitude at the oscilloscope screen) :

$$C_x = C_s \frac{L_{BC}}{L_{AC}} \tag{21}$$

Figure 17: Winston bridge



Name: **Grade:**

Students No.: **Date:**

Data and calculation

$C_s(\mu F)$	$L_{BC}(cm)$	$L_{AC}(cm)$	$\frac{L_{AC}}{L_{BC}}$	$C_s(\mu F)$	$L_{BC}(cm)$	$L_{AC}(cm)$	$\frac{L_{AC}}{L_{BC}}$
68				68			
100				100			
470				470			
1000				1000			
$Draw C_s Vs. \frac{L_{AC}}{L_{BC}}, Slope = C_{x1} =$				$Draw C_s Vs. \frac{L_{AC}}{L_{BC}}, Slope = C_{x2} =$			

$C_s(\mu F)$	$L_{BC}(cm)$	$L_{AC}(cm)$	$\frac{L_{AC}}{L_{BC}}$	$C_s(\mu F)$	$L_{BC}(cm)$	$L_{AC}(cm)$	$\frac{L_{AC}}{L_{BC}}$
68				68			
100				100			
470				470			
1000				1000			
$Draw C_s Vs. \frac{L_{AC}}{L_{BC}}, Slope = C_{series} =$				$Draw C_s Vs. \frac{L_{AC}}{L_{BC}}, Slope = C_{parallel} =$			

Questions:

Q1:What is the percentage error between $\frac{1}{C_s}$ **and** $\frac{1}{C_1} + \frac{1}{C_2}$**?**

....

Q2:What is the percentage error between C_p **and** $C_1 + C_2$**?**

....

Q3:What will happen if we replace C_1, C_2 **by coils** L_1, L_2

....

Experimental No. (8)

Earths magnetic field

OBJECTIVE:

The object of this lab is to measure the magnitude of the earth's total magnetic field in Palestine.

Theory:

The magnetic field produced by a circular coil (loop) of wire is given by:

$$B_m = \frac{\mu_o i N}{2R} \tag{22}$$

where B_m is the magnetic field, μ_o is the permeability constant ($\mu_o = 4\pi 10^{-7} T.m/A$), i is the current, N is the number of turns, and r is the radius of the circle.

The direction of this field is given by the right-hand rule. If the thumb of the right hand points in the direction of the current flow (from positive to negative) then the fingers curl in the direction of the magnetic field around the wire. This field can be used to measure an unknown magnetic field by the following manner. If the coil of the tangent galvanometer is aligned with an unknown field and the current is on, the two magnetic fields will add to give a resultant field. The needle of the tangent galvanometer will line-up with this resultant field. The deflection angle α can be measured and the horizontal component of the earth magnetic field B_{eh} can be calculated from:

Figure 18: experiment set

$$\frac{B_m}{B_{eh}} = \tan\alpha \qquad (23)$$

where B_{eh} is the horizontal component of the Earth's magnetic field. From figure(19) we see that the dip needle points in the direction of the resultant field. By calculating the horizontal component of the earth magnetic field and the azimuthal angle of palestine , the total magnetic field of the earth can be calculated.

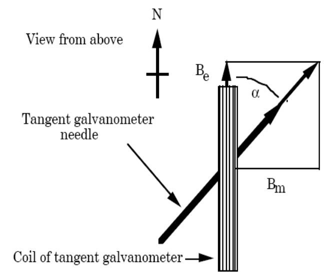


Figure 19: schematic diagram

Procedure:

1. **Measure and record the value of D = 2R, the diameter of the coil.**
2. **Wire the tangent galvanometer, the current limiting resistor, the Ameter , and the power supply together in a series circuit. (see Fig. (18) The tangent galvanometer has three places to connect wires. Where the wires are connected determines how many loops the current must pass through. Wire the circuit so that the current passes through 5 loops. Have your lab instructor approve your circuit before plugging in the power s u p p l y.**
3. **Align the tangent galvanometer coil so that it is parallel to the to the earth's magnetic field. (as shown in figure 19) Do this by rotating the dip needle so that it is horizontal and can act as a compass. The coil of the tangent galvanometer should be in line with the "compass" needle which points north-south.**

4. **Measure three different values for α by varying the current input. The values for α will be more accurate if they fall between 20^o and 70^0.**

5. **Repeat step three using 500 loops and again for 5 loops of current carrying wire, for a total of nine trials. Calculate the average horizontal field from these data.**

6. **Measure the dip angle of the total field with the dip needle. Make sure that the power supply to the tangent galvanometer is off.**

Name: **Grade:**

Students No.: **Date:**

Data and calculation

R=.............m **N=..............**

$forward\ \ \alpha$	$reverse\ \ \alpha$	$\overline{\alpha}$	$\tan\overline{\alpha}$	$i(mA)$

The slope of $\tan\alpha$ **vs. i, Slope=............,** $B_{eh} = \frac{\mu_o N}{2RS}$**=...........,** B_e**=............**

R=.............m **N=..............**

$forward\ \ \alpha$	$reverse\ \ \alpha$	$\overline{\alpha}$	$\tan\overline{\alpha}$	$i(mA)$

The slope of $\tan\alpha$ **vs. i, Slope=............,** $B_{eh} = \frac{\mu_o N}{2RS}$**=............,** B_e**=...........**

Experimental No. (9)

Current device

OBJECTIVE:

To measure the magnetic field strength of a solenoid for different solenoid currents, using a current balance.

Theory:

Figure (20) shows the essential components of a current balance. A source of emf (6.0 V D.C.) is connected to the large solenoid, with a variable resistance and an ammeter in the solenoid circuit.

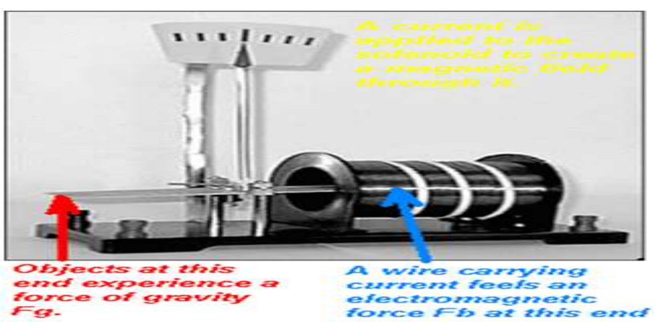


Figure 20: experiment set

A plastic 'teeter totter' is balanced at the opening at one end of the solenoid. A current is passed through a conducting strip that runs around one end of the teeter totter. The magnetic field of the solenoid exerts a net force on the portion of the strip that runs perpendicular with the solenoid's lines of force the segment on the diagram. Current direction in the strip is chosen so that the end of the balance arm (teeter totter) inside the solenoid is pushed downward. To measure the downward magnetic force on the strip, it is simply balanced by using the force of gravity on known masses added at the other end of the balance.

A section of a straight wire of length L, carrying a current (i) and placed in a magnetic field region of magnetic flux density B, experience a force given by:

$$\overrightarrow{F} = i\overrightarrow{L}X\overrightarrow{B} \quad (24)$$

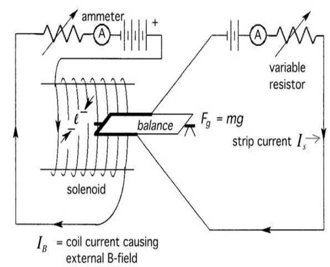


Figure 21: schematic diagram

If the wire is held horizontally in a uniform horizontal magnetic field perpendicular to the length of the wire, then the force experienced by the wire is directed either upwards or downwards depending on the direction of the current in the wire. The force is given by: $F = i\ L\ B$ As shown from fig.(21) magnetic force will make a torque on the balance, the other arm should be loaded by a mass to stabilize the balance, so it will keep the balance horizontally, $i\ L\ B\ d = m\ g\ d$, So $i = \frac{g}{LB}m$ and for long solenoid $B = \mu_o n i_{solenoid}$, where, $n = \frac{Number of turns of the soleniod}{length of the solenoid}$

Procedure:

1. Connect the circuit in Fig.(20) and consult with the instructor before turn power on.
2. use $i_{selonoid}$ =1 A.
3. make sure to balance the moving arm.
4. use full length of the wire L and register current i_m that will balance the hanged mass(20, 30, 40, 50, 60 mg).
5. repeat the previous step for L half length.

Name: **Grade:**

Students No.: **Date:**

Data and calculation

Number of turns of the solenoid=........., length of solenoid = ...,L= 4 cm, for full length check it?

$i(A)$					
$m(kg)$					

plot i vs m : Slope = ..., $B = \frac{g}{Slope * L} = ...,\mu_o = ...$

step two: L =2 cm, half the original length:

$i(A)$					
$m(kg)$					

plot i vs m : Slope = ..., $B = \frac{g}{Slope * L} = ...,\mu_o = ...$

Exercises:

Q1:a- A solenoid 15.0 cm long has 600 turns and carries a current of 5.0 A. What is the magnetic field strength inside this coil?

..

..

b- if 2.0 cm segment of a current balance arm is balanced inside the solenoid when the current in it is 3.0 A. What is the magnetic force on the segment?

...

Q2: The magnetic field strength inside a certain solenoid is 0.025 T. If a 3.2 cm conducting strip, which is perpendicular to the magnetic field inside the solenoid, experiences a force of $5.9X10^{-4}$ N, what is the current in the conducting strip?

Experimental No. (10)

CHARGING AND DISCHARGING OF A CAPACITOR

OBJECTIVE:

1) To study charging and discharging characteristics of a capacitor.

2) To find the time constant RC for an RC-circuit.

APPARATUS:

Capacitor, C = 100μF, Resistor R = 1MΩ, D.C. power supply, Voltmeter, Timer, Connecting wires.

THEORY:

Capacitance is created when two conductors are separated by a dielectric. The symbol for capacitance is C, and its unit is farad F, smaller units are: μF, nF, pF. In electric circuits, capacitors are used for many purposes. For example, they are used to store energy, to pass alternating current while blocking direct current, and to shift the phase relationship between current and voltage. Also used in filters and resonance circuits. In this experiment they will be used in timing circuits. A capacitor can store a charge of electrons over a period of time. When a voltage V is applied across a capacitor, electrical charges will be forced onto one plate and pulled off the other. The process of building up the charge of electrons in a capacitor is known as charging. The magnitude of the charge (Q) thus displaced from one plate to the other is proportional to the capacitance (C) and to the voltage V across the capacitor: $V = \frac{Q}{C}$

CHARGING A CAPACITOR:

The circuit in Figure(22), the capacitor is initially uncharged; the initial potential difference across it is zero ($V_c = 0$). At the instant the switch (S) is moved to position (a), the charge of electrons rush to the capacitor, but the resistor works to hold up this rush, and the entire input voltage appears across the resistor (V_R = V).

At this instant the current in the circuit is maximum and equal to I = V/R. As the capacitor charges, its voltage increases with time, opposing the source voltage, and the voltage across the resistance decreases, as a result, the current I decrease also. Finally, when the capacitor becomes fully charged, its voltage Vc is equal and opposite to the applied voltage V, i.e,(Vc = V , VR = 0 and I = 0).

At some time (t), after the switch has been moved to position (a), let Q represent the charge on the capacitor, and I the current in the circuit, thus, applying Kirchhoffs second low, we obtain:

$$V_o = V_R + V_c \qquad (25)$$

$$V_o = IR + \frac{Q}{C} \qquad (26)$$

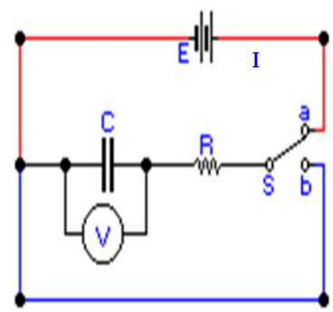


Figure 22:

The rate at which charge flows through the resistor: $I = \frac{dQ}{dt}$ is equal the rate at which the charge accumulates on the capacitor, thus we can write:

$$V_o = \frac{Q}{C} + R\frac{dQ}{dt} \qquad (27)$$

This equation can be solved, the solution is:

$$Q = Q_o(1 - e^{\frac{-t}{RC}}) \qquad (28)$$

$$V_c = V_o(1 - e^{\frac{-t}{RC}}) \qquad (29)$$

The charging current Ic in the circuit at any moment can be calculated by the derivative of the charge Q with respect to the time t in equation (30):

$$I_c = I_o e^{\frac{-t}{RC}} \qquad (30)$$

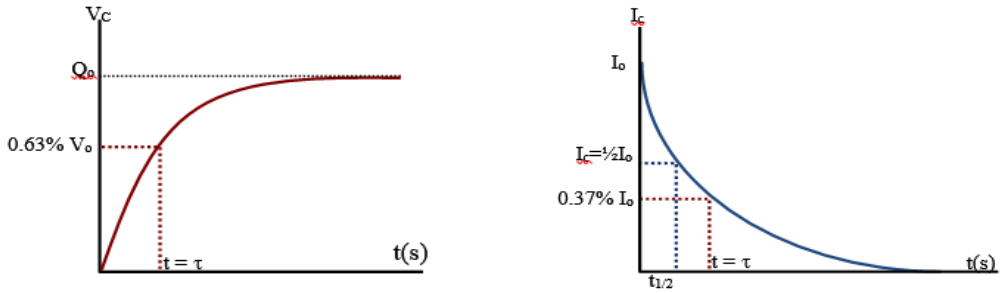


Figure 23:

From equation-28, Figure -23 is the plot of the charging voltage Vc versus time t . At t =RC , the value of Vc reach 63 % of its maximum value Vo, this quantity is called the time constant τ of the RC circuit. So at t = τ , the voltage across the capacitor has decreased to a value:

$$V_c = (1/e)V_o \approx 0.63V_o \tag{31}$$

Similarly, for equation-6, Figure-3 is the plot of the charging current Ic versus time t . So at:

$$t = RC = \tau, and I_c = 0.37I_o \tag{32}$$

A quantity, which is easy to measure experimentally, is the time required for the charge Q to become 1/2 of its original value Q_o. Denoting this time as $t_{1/2}$, we have from equation (28):

$t_{1/2}$ **= 0.693** τ

Thus the product RC is a measure of how quickly the capacitor gets charge. You can demonstrate that a capacitor does not charge instantaneously; it takes time to charge, because all circuits contain some resistance.

DISCHARGING A CAPACITOR:

As soon as the power source is disconnected, (switch S is at position b, Fig.24), the charge begins to flow from one plate of the capacitor towards the other, forming a current I through the resistance R until the capacitor is fully discharged. Applying Kirchhoffs second low, since there is no applied voltage, we obtain : VR + Vc = 0 , or $\frac{dQ}{dt}R + \frac{Q}{C} = 0$ **This equation has the solution:**

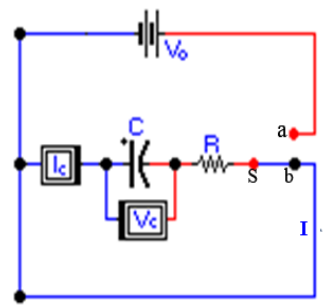


Figure 24:

$$Q = Q_o e^{\frac{-t}{RC}} \quad (33)$$

$$I_c = -I_o e^{\frac{-t}{RC}} \quad (34)$$

$$V_c = V_o e^{\frac{-t}{RC}} \quad (35)$$

After time t =RC= τ **the voltage across the capacitor has decreased**

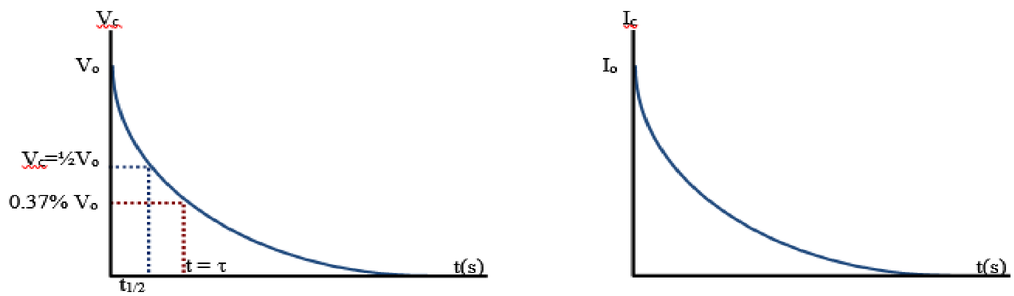


Figure 25:

to a value:

$$V_c = 0.37V_o \quad (36)$$

Figures (25) shows the discharging graphs Vc versus t and Ic versus t .

EXPERIMENTAL PROCEDURE:

1) Record the value of the capacitance C , the resistance R , the applied voltage Vo and the initial current Io in table (1). Connect the circuit as shown in Figure (22), have the instructor check your circuit before closing the switch. Short the capacitor. In order to be familiar with the procedure, close the circuit, (switch S is at position a), Dis-short the capacitor , note the voltage rise and the current decay in the capacitor during charging.

When the capacitor is fully charged ($V_c \approx V_o$, and $I_c \approx 0$), disconnect the power source, (switch S is at position b Figure.24), note the voltage and current decay as the capacitor discharges.

2) Now, simultaneously, close the circuit and, Dis-short the capacitor , start the timer. At regular time intervals of 10 seconds, read the current I(μA), and voltage Vc until the capacitor is nearly fully charged. Record your data in table (1). Reset the timer.

3) Simultaneously set the switch S at position (b), Fig.24, and start the timer. At regular time intervals of 10 seconds, read the current I(μA), and voltage Vc until the capacitor is nearly discharged (Vc≈0 , and I_c ≈0), . Record your data in table (2).

Name: **Grade:**

Students No.: **Date:**

Data and calculation

V_o=........., I_o=.........., **R=.............**, **C=.............**

Table 1 Charging

t(s)	**I(μA)**	V_c**(volts)**

Table 2 Discharging

t(s)	**I(μA)**	V_c**(volts)**	**Ln V**

Charging of a Capacitor.

1) Plot the charging voltage V_C versus t(s) . From the graph find the time constant τ .

....

....

....

-Use the graph to Calculate the value of Q_o as shown in Figure (22) .

....

....

....

-Compare With the theoretical value $Q_o = CV_o$

....

....

2) Plot the charging current I_C versus t(s). From the graph find the time constant τ

....

....

....

3) Calculate the value of the charge Q stored in the capacitor at t =τ

....

....

4) Calculate the value of$\frac{Q}{Q_o}$

....

....

5) From the graph, determine the value of $t_{1/2}$ and then calculate τ .

....

....

....

Discharging of a Capacitor.

6) From the data of the discharge current in table (2) plot ln I_C versus t for the discharging process. Draw the best straight line. Find the slope of this graph.

...

...

7)Using equation (34), where. $\tau = \frac{1}{slope}$, From the slope calculate the time constant τ,

...

...

8)You have already found τ by many methods, Find the mean value , and find the standard deviation of τ.

...

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