Sudan University of Science Technology

College of Graduate Studies

Determination of Temperature Coefficient of Resistivity for some Metal Wire

تحديد المعامل الحرارى للمقاومة لبعض اسلاك المعادن

Athesis submitted for fulfillments partial of the requirement of the degree of Science master in physics

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الآية

قال تعالى:

(قُلْ لَوْ كَانَ الْبَحْرُ مِدَادًا لِكَلِمَاتِ رَبِّي لَنَفِدَ الْبَحْرُ قَبْلَ أَنْ تَنْفَدَ كَلِمَاتُ رَبِّي وَلَوْ جِئْنَا بِمِثْلِهِ مَدَدًا)

صدق الله العظيم

سورة الكهف

Dedication

I dedicate to my parents

And to my family

Acknowledgment

My praise and thanks to Allah, who give me the strength to conduct such work

I am greatly indebted to my supervisor

Thanks are also due to all those who helped and encouraged me to do this work.

Abstract

Resistance is the quality of a conductor which hinders the flow of electrons and the resistance a wire offers to a current depends on its material, its cross-sectional area, and length.

However resistance also depends on the temperature, which increases with increasing temperature. Other than choosing an efficient materials there are a couple of simple thing that can be done to reduce the resistance of a conductor. Conductors have lower resistance at low temperatures. Keeping a conductor cool will help keep resistance low and reduces the amount of power lost conductor heating.

Tow metal wires (AL,Cu) has been prepared to study the thermal effect on this wire and the thermal coefficient has been calculated, also their resistances was calculated under variation oftemperature and concluded that the resistance increase with increasing temperature as considered in theoretical consideration.

The Thermal conductivity was calculated to be 0.73(cal/cm.k.sec) for Al and 2.95 (cal/cm.k.sec) for cupper respectively which in agreement with the theoretical consideration that calculate by Handbook of Chemistry and Physics.

المستخلص

المقاومة صفة نوعية للموصل وتعبر عن اعاقة مرور الالكترونات فيه، وتعتمد مقاومة السلك لمرور التيار علي نوعية مادة السلك و مساحة مقطعة و طوله.

وتعتمد المقاومة ايضا علي درجة الحرارة حيث تزيد بزيادة درجة الحرارة. بجانب اختيار المادة الفعالة وبمراعاة عاملين بسيطين يمكن تقليل مقاومة الموصل. الحفاظ علي الموصل في وسط منخفض الحرارة فبارتفاع درجة حرارة الموصل تزيد مقاومته،و بتقليل كمية القدرة المفقودة بالتسخين .

تم استخدام أسلاك نوعان من المعادن لدراسة تأثير درجة الحرارة علي مقاومتهما وتعين المعامل الحراري لهما .

حيث تم حساب المقاومة والمقاومة النوعية لكل سلك وذلك برفع درجة حرارة العينتين ووجدت أن قيمتها تتزايد بارتفاع درجة الحرارة في اتفاق تام مع الافتراضات النظرية .

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Chapter One
Introduction

1.1 The electrical Resistivity

Is related to the resistance through ohms low, and it was expected to change as a function of temperature.

Ohms law states that the current passes through a Conductor across any two points at constant temperature is directly proportional to the potential difference [1].

First one looks over the definition of electrical resistivity and how it is related to resistance. It was include a discussion about how the resistance might be expected to change as a function of temperature. Second, one talks briefly about the technique developed by Bean and collaborators which uses Faraday's law of induction to measure the resistivity of a sample.

starting with the assumption that Ohm's law is valid, that is, V=IR , where resistance is independent of voltage or current. Consider the idealized resistor. The resistor has a length and a cross sectional area.

A voltage drop is applied across the ends of the resistor. A current an idealized resistor of electrons flows from one end to the other, against a resistance *R* which is due to the electrons interacting somehow with the atoms of the material.

Consider Ohm's law on a microscopic level. The electric field set up across the ends of the resistor is just multiplied of voltage by length. The electrons which carry the current will be spread out over the area A, so at any point within the resistor you expect a current density passes through the area [2].

And the resistivity is a property of the material which is independent of the dimensions of the resistor.

The resistivity comes from collisions between the electrons and the atoms of the material, which specify will be a metal. In a metal, the electrons are essentially free, so without any collisions they would continually accelerate under and applied field with an acceleration a equals multiplied of field and electrons divide by electrons mass; However, the collisions cause the electrons to stop and then start up again, until the next collision [2].

1.2 The Problem

The linear coefficient of resistance indicates the amount by which the resistance increases by increasing temperature that may be subject to it during its work in the electric or electronic circuits.

Through the circuit will reduce, beside yields of thermal energy that appears as heat in the electronic device and cause destructive of this device.

1.3 The Objective

- To determine temperature coefficient of resistivity for different material.
- To avoid destructive of electric device
- To compare results obtained with theoretical consideration.

1.4 The Methodology

Experiment carried out using different type of wire (AL ,Cu) results were taken as a data by using voltmeter and ammeter by aid of DC power supply under temperature variation, the data will lend it self to analysis using some of curve. Fitting formulas in order to see whether this result is agree theoretical consideration.

1.5 Literature Review

A.Maria (2004) study the effect of temperature and photon energy on electrical conductivity for some metal (experimental study) it was found that the conductivity decrease as temperature increased. and also decrease as light frequency increase while it increase as light intensity increase [3].

1.6 Thesis layout

This thesis consist of four chapters, Chapter introduction, chapter two Electrical properties of metals, Chapter three electrical field and charge distribution and Chapter four material and method.

Chapter Two

Electrical Properties of Metals

2.1 Electrical Conduction

Is the passage of electricity through a conductor.

Ohm's law state that

V=IR (2.1)

Where:

I ≡ current (Ampere).

V ≡ voltage (Volts).

R ≡ the resistance (Ohms or Ω) of the conductor.

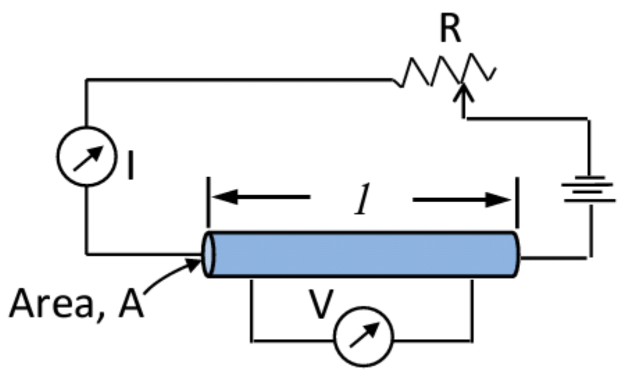

Figure (2.1): Ohm circuit.

2.2 Resistivity

Is the material's opposition to the flow of electric current; measured in ohms.

Resistivity ρ = RA/l (Ω-m) (2.2)

Where A is the area and l is the length of the conductor [1].

2.3 Electrical conductivity

Is ability of electric current to flow through a material conductor.

Conductivity, $\sigma = 1/\rho = l/RA \ (\Omega - m)^{-1}$ (2.3)

2.4 Band Theory

Electrons occupy energy states in atomic orbital. When several atoms are brought close to each other in a solid these energy states split in to a series of energy states (molecular orbital).The spacing between these states are so small that they overlap to form an energy band.

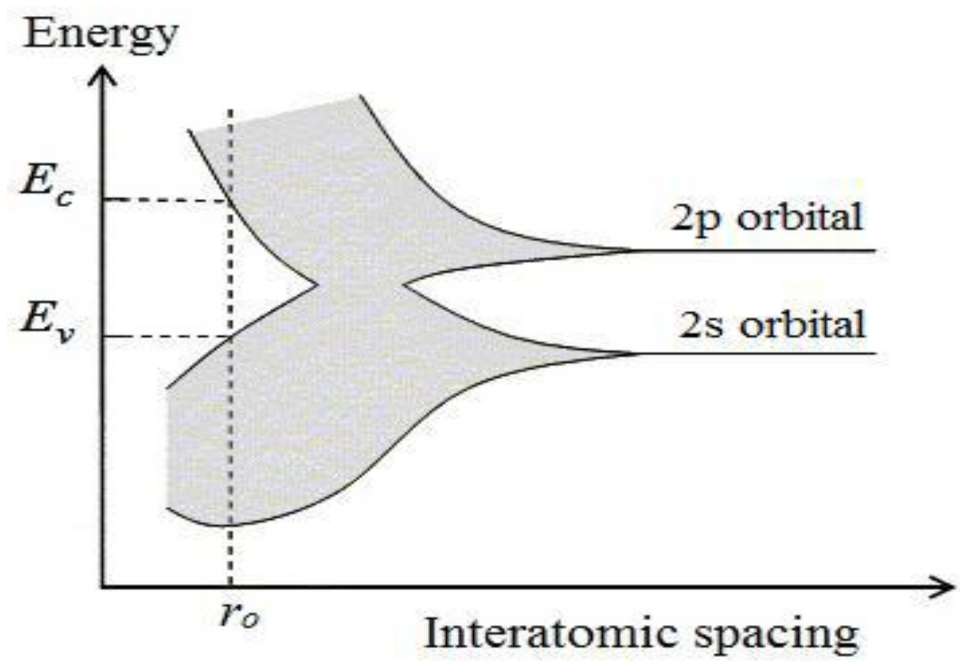

Figure (2.2): shows band theory energy versus interatomic spacing.

The furthest band from the nucleus is filled with valence electrons and is called the valence band. The empty band is called the conduction band. The energy of the highest filled state is called Fermi energy. There is a certain energy gap, called band gap, between valence and conduction bands. Primarily four types of band structure exist in solids [4].

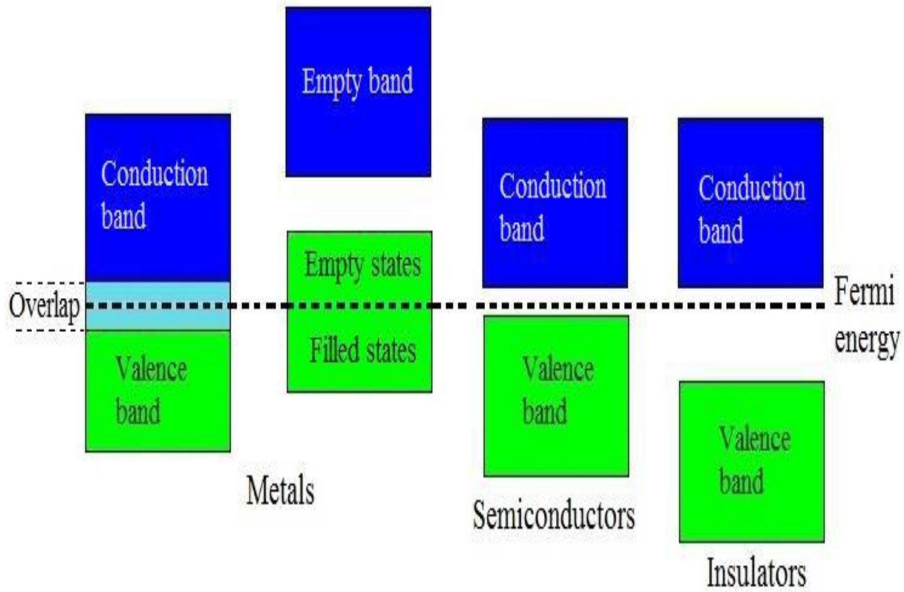

Figure (2.3): shows the overlaps of different types of band structure for metal, semiconductor and insulator Fermi energy.

In metals the valence band is either partially filled (Cu) or the valence and conduction bands overlap (Mg).

Insulators and semiconductors have completely filled valence band and empty conduction band. It is the magnitude of band gap which separates metals, semiconductors and insulators in terms of their electrical conductivity.

The band gap is relatively smaller in semiconductors while it is very large in insulators [4].

2.5 Conduction Mechanism

An electron has to be excited from the filled to the empty states above Fermi level (E_f) for it to become free and a charge carrier.

In metals large number of free valence electrons is available and they can be easily excited to the empty states due to their band structure. On the other hand large excitation energy is needed to excite electrons in Insulators and semiconductors due the large band gap. Empty states filled states conduction in metals E_f [4].

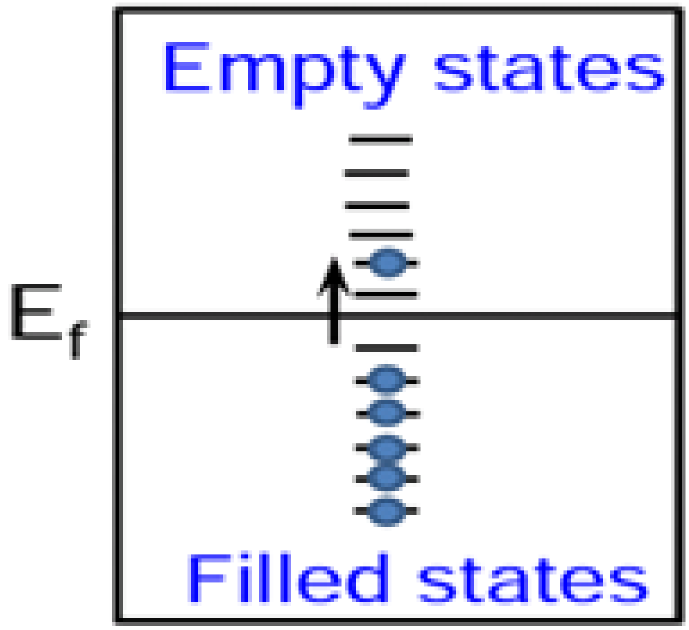

Figure (2.4) Conduction in Metals

2.6 Intrinsic Conductivity

Electrical conductivity of a conductor primarily depends on two parameters – charge carrier concentration n, and carrier mobility μ,

Conductivity, $\sigma = n\,|e|\,\mu$ is absolute charge (1.6 x 10^{-19} C).

Intrinsic semiconductors have two types charge carriers, namely electrons and holes

$$\sigma = n\,|e|\mu_e + p\,|e|\,\mu_h \qquad (2.4)$$

Where n and p are concentration of electron and hole charge carriers respectively and μ_e and μ_p are their mobility [5].

Since each electron excited to conduction band leaves behind a hole in the valence band, n = p = n_i

$$n\,|e|(e+h) = p|e|(e+h) = n_i|e|(e+h) \qquad (2.5)$$

2.7 Extrinsic Conductivity

Large number of electrons can be excited from the donor state by thermal energy in n-type extrinsic semiconductors.

Hence, number of electrons in the conduction band is far greater than number of holes in the valence band, i.e. *n* >>*p* and

$$\sigma = \mathrm{n}\,|\mathrm{e}|\mu_{\mathrm{e}} \qquad (2.6)$$

In p-type conductors, on the other hand, number of holes is much greater than electrons (*p* >>*n)* due to the presence of the acceptor states.

$$\sigma = \mathrm{h}\,|\mathrm{e}|\mu_{\mathrm{h}} \qquad (2.7)$$

2.8 Effect of Temperature

Increasing temperature causes greater electron scattering due to increased thermal vibrations of atoms and hence, resistivity, (reciprocal of conductivity) of metals increases (conductivity decreases) linearly with temperature.

The resistivity of metals depends on two other factors namely, impurity level and plastic deformation as these generate scattering centers for electrons.

Increase in impurity level results in more scattering centers and decreases the conductivity.

Similarly plastic deformation introduces more dislocations which act as scattering centers and increase the resistivity.

$$\rho_{Total} = \rho_t + \rho_i + \rho_d \qquad (2.8)$$

2.9 Temperature Coefficient of Resistivity

Resistance of any material varies with temperature. For temperature range that is not too great, this variation can be represented approximately as a linear relation

$$R_T = Ro\,[1 + \alpha\,(T - To)] \qquad (2.9)$$

Where R_T and Ro are the values of the resistance at temperature T and To, respectively. To is often taken to be either room temperature or 0^0 C. α is the temperature coefficient of resistivity [5].

Pure metals have a small, positive value of α, which means that their resistance increases with increasing temperature. From temperature measurements of R you can find α. To do this you will plot resistance values versus T, and approximate the results with a straight line.

The Intercept of this line with the resistance axis is Ro, and the slope divided by Ro is the values of thermal coefficient.

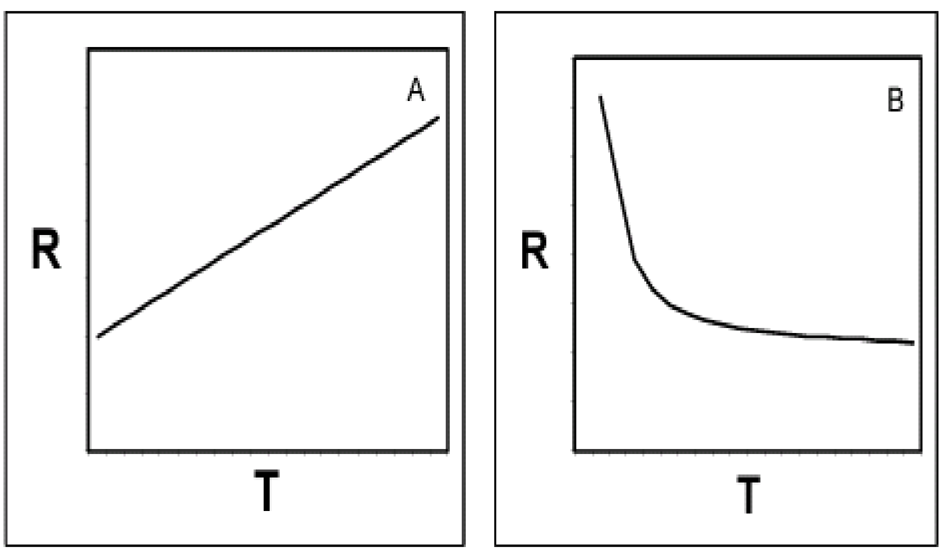

Figure (2.5): Variation of resistivity with temperature of a metal (A) and a semiconductor (B).

There are materials in which resistance decreases with increasing temperature. Athermistor is an example of such a material. It is made of semiconductors, such as oxides of manganese, nickel and cobalt mixed in the desired proportion with a binder and pressed into shape. Thermistors are very sensitive to even small changes of temperature, therefore they are often used as thermometers. The change of resistance of a thermistor caused by temperature change is a nonlinear function and can be approximated by the following formula:

$$R_T = R_0 \exp [\beta (1/T - 1/T_o)] \quad (2.10)$$

Where R_T and Ro are the resistance values at absolute temperatures T and to (on the Kelvinscale), β is a constant over a limited temperature range and characterizes a property of material.

The unit of β is degree Kelvin. Equation (2.10) can be expressed as

$$\text{Ln} (R_T/R_0) = \beta (1/T - 1/T_0) \quad (2.11)$$

2.10 Basic Concepts of Electrical Conduction

Electrical conduction occurs through transport of electric charge in response to an applied electric field. Electric charge is carried by electrons, electron holes, and ions.

Electrical conductivity σ and its reciprocal, electrical resistivity, $\rho = 1/\sigma$, are physical properties of a material. While the range of values is somewhat arbitrary, electrical conductivity is very low in insulators, $\sigma < 10^{-15}$ S/cm ($\rho > 10^{21}$ Ωcm), intermediate in semiconductors, $\sigma = 10^{-5}$ to 10^{3} S/cm ($\rho = 10^{3} - 10^{11}$ Ωcm), very high in conductors, $\sigma = 10^{4}$ to 10^{6} S/cm ($\rho = 1$ to 10^{2} μΩcm), and infinite in superconductors.

Electrical conductivity, σ, is defined as the product of the number of charge carriers, *n*, the charge, *e*, and the mobility of the charge carriers μ.

$$\sigma = n \cdot e \cdot \mu \quad (2.12)$$

For electronic conductors the electron charge, $e = 1.6 \times 10^{-19}$ coulombs, is constant and independent of temperature. The mobility, μ, usually decreases with increasing temperature due to collisions between the moving electrons and phonons, i.e., lattice vibrations.

The number of charge carriers n remains constant for metallic conductors with increasing temperature, but increases exponentially for semiconductors and insulators. Thus at very high temperatures some insulators become semiconducting, while at low temperatures some semiconductors become insulators [5].

2.11 Conductive in material

2.11.1 Conduction in pure metals

The charge transport in pure metals is caused by the drift of free electrons (or "electron gas"). (In some metals like beryllium and zinc, the movement of charge is considered to be due to electron holes.) Free electrons have comparatively high velocities and relatively long mean free paths until they collide with ions constituting the crystal lattice. This process is called scattering.

In a perfect periodic lattice structure, no Collisions would occur and the resistivity would be zero (not to be confused with superconductivity). Mean free paths of the electrons are limited by:

- Ionic vibrations due to thermal energy,
- The crystal defects, such as vacancies, dislocations, grain boundaries, Frenkel and Schottky defects,
- The random substitution of impurity atoms for pure metal atoms on the pure metal lattice sites.

As the temperature increases, the amplitudes of the ionic vibrations grow larger and scattering of the electrons increases.

This offers more resistance to the flow of electrons. Resistivity increases roughly linearly with temperature at high temperatures. At low temperatures, where electron scattering becomes the dominating scattering process, aT5 dependence is predicted. Common pure metals have a resistivity of Common pure metals have a resistivity of 1.5 to 150 μΩ-cm at room temperature.

2.12 Common Elemental Conductors

Copper smelting operations have been traced back to at least 7000 years before present today, electrical and electronic uses dominate the copper markets. The advantages of copper are its high thermal and electrical conductivity, which is only surpassed by pure silver. The grade and quality of copper is very important with regard to its intended application.

For instance, conductivity is greatly influenced by impurities and mechanical working. The International Annealed Copper Standard (IACS) assigns a 100% to copper with the resistivity of 1.724 μΩ-cm at 20 °C. For electrical applications high conductivity copper is used which easily exceeds these 100%.

Copper is easily soldered to and has good mechanical temperatures up to 300 °C. There is not enhanced 'bimetallic' corrosion at defective areas of the coating as sometimes seen with silver. Nickel plating is also often used as a barrier coating under the final gold plating on electronic conductors.

Aluminum is the second most abundant metal after silicon and is second only to iron measured in quantity or value of production. At 20 °C commercial, hard-drawn corrosion in many environments is due to aluminum has a conductivity of 61 % that of copper while being a third as dense. This makes it useful for the production of lightweight shielding cans, component mounts/chassis, power line conductors, heat sinks, mechanical fixtures, etc.

Aluminum is also a basic integrated circuit metallization element. Its excellent resistance to the protective, highly adherent native oxide film. Aluminum can be 'anodized' to give an artificial oxide film for increased corrosion protection.

Historically, silver has been used for jewelry and as a basis for monetary systems [5].

Primary source of silver is its recovery as a byproduct of copper, gold, lead, or zinc production. Today the most important use for silver is in the manufacture of photographic materials. Silver is also an excellent conductor. Since it is a very soft metal, it is not normally used in its pure state, but is alloyed with a hardener, usually copper. Silver is malleable and ductile and does not oxidize in air at room temperature.

Silver does, however, absorb considerable amounts of oxygen at elevated temperature and is tarnished by sulfur compounds. Its major electric applications are as contacts on relays for currents less than 20 A, and in instruments rated for small currents. In presence of humidity and electric fields silver will migrate to form fine silver threads or dendrites between conductors eventually causing electric shorts. If used in microelectronic circuits, silver migration needs to be contained by diffusion barriers such as tungsten, palladium or nickel.

Pure gold has unsurpassed resistance to oxidation and suffixation. However, its softness and susceptibility to erosion limits its use in electrical contacts to currents below 0.5A.

Gold sometimes forms a carbonaceous deposit in presence of volatile organic compounds increasing contact resistance. The low hardness of gold can be increased by alloying with copper, silver, palladium, or platinum. Gold is used for fine wire connections and as a contact surface in integrated and hybrid circuits.

The refractive platinum metals (Pt, Pd, Rh, Ir, Os, Ru) are highly resistive to corrosive environments. Stable thermoelectric behavior, high resistance to spark erosion, tarnish resistance, and broad ranges of values of electrical resistivity and temperature coefficient of electrical resistance make platinum metals useful for a number of electrical applications such as thermocouples or contacts for telephone relays.

Tungsten is stronger than any common metal at temperatures over 2000 °C and has the highest melting point of all metals, 3380 °C. The electrical resistivity is about three times as high as that of copper, but better than that of platinum or nickel. The high temperature stability of tungsten is exploited in lamp filaments and electronic filaments in which it serves as a light- or

Electron-emitting cathode material, Tungsten is used as a wear-resistant material for contacts.

Graphite is a crystalline, allotropic form of carbon of very high melting point (3700 °C).

The electrical conductivity of graphite is slightly less than that of metals and their alloys. Pure carbon, in contrast, is a semiconductor with a negative coefficient of resistance.

Carbon and graphite are used also as sliding electrical contacts because of their ability to withstand temperatures up to 3000 °C, low density, ability not to weld to metals, self lubrication properties and inexpensive production. Graphite fibers have a very high thermal conductivity, far greater than that of copper, and are being used for lightweight, heat-management applications [5].

2.13 Induced Charges in a conductor

The above properties of a conductor influence the behaviour of a conductor placed in an electric field. Consider, for instance, what happens when a charge $+q$is brought near an uncharged conductor. The conductor is placed in the electric field of the point charge. The field inside the conductor should however be zero. His is achieved by a charge separation within the conductor which creates its own electric field which will exactly compensate the field due to the charge$+q$. The separate charges must necessarily reside on the surface.

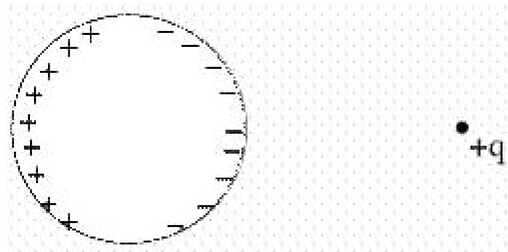

Figure (2.6): show a charge$+q$is brought near an uncharged conductor.

Another way of looking at what is happening is to think of the free charges in the conductor being attracted towards (or repelled from) the external charge. Thus the surface of the conductor towards the external charge is oppositely charged. To keep the charge neutrality, the surface away from the external charge is similarly [6].

2.14 Electrostatic Potential

Electrostatic force is a conservative force, i.e., the work done by the force in moving a test charge from one point to another is independent of the path connecting the two points [1].

Chapter Three

Electric Charge Distribution

3.1 Conductors

For much of the rest of this class, we will be concerned with processes that involve conductors:

Materials in which it is easy for charges to move around, we will discuss conductors in some depth when we discuss currents; for now, we will just summarize a few of their properties.

Among the best conductors are metals - silver, gold, copper, aluminum, etc. The atoms of these metals form a crystalline structure in which electrons can easily hop around from atom to atom. Although a chunk of metal is neutral overall, we can visualize it as being made of lots of positive charges that are nailed in place, paired up with lots of negative charges (electrons) that are free to move around. In isolation, the negative charges will sit close to the positive charges, so that the metal is not only neutral overall, but also largely neutral everywhere (no local excess of positive or negative charge). Under the influence of some external field, the electrons are free to move around [7].

Some materials conduct OK, but are not as good as metals. For example, salty water has lots of charges that are free to move around under the influence of an $\vec{E}$ field. However, since these charges _usually sodium and chlorine ions | are far more massive than an electron, and they do not flow in a crystalline structure, salty water is not a very high quality conductor. Another example is graphite: the somewhat unusual bond structure of graphite makes it a fairly good conductor, but only in certain directions.

At the opposite end of the spectrum are insulators: materials in which the electrons are bound quite tightly to the constituent molecules and hence have essentially no freedom to move. Insulators are typically made from organic materials such as rubber or plastic, or from crystals formed from strong covalently bounded molecules, such as quartz or glass.

The effectiveness of a substance as a conductor is quantified by its resistivity, a number that expresses how well it resists the flow of current. We will revisit this quantity in about a week when we discuss currents in detail; for now, suffice to say that small resistivity means a good conductor. In SI units, resistivity is measured in "Ohm-meters" (usually written (Ω -m); in cgs units, resistivity turns out to be measured in seconds.

As you can see, the resistivity of ordinary materials varies over an enormous range, reflecting the very different electronic properties of materials around us.

3.2 Electrics fields and conductors

For the rest of this class it will assume that conductors are materials that have an infinite supply of charges that are free to move around. (This of course just an idealization; but, it turns out to be an extremely good one. Real conductors in fact behave very similar to this limit.) From this, one can deduce a few important facts about conductors and electrostatic fields:

- The there is no electric in field side a conductor. Suppose which bring a plus charge near a conductor. For a very short moment, there will be an electric] field inside the conductor. However, this field will act on and move the electrons, which are free to move about. The electrons will move close to the plus charge, leaving net positive charge behind. The conductor's charges will continue to move until the "external" $\vec{E}$ -field is cancelled out | at that point there is no longer than $\vec{E}$ −field to move them, so they stay still [7].

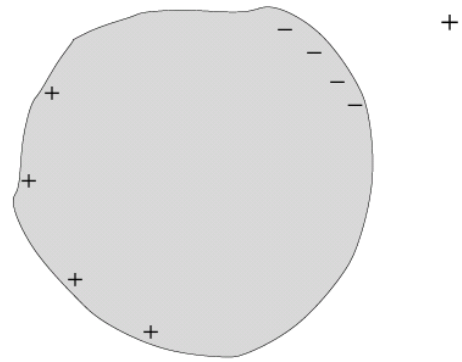

Figure (3.1): Conductor near an external charge. The charges in the conductor very quickly rearrange themselves to cancel out the external field.

A more accurate statement of this rule is "After a very short time, there is no electric field inside a conductor". How short a time is it? Recall that in cgs units, resistivity (which tells us how good/bad something conducts electricity) is measured in seconds. It turns out that the time it takes for the

charges to rearrange themselves to cancel out the external $\vec{E}$ field is just about equal to this resistivity. For metals, this is a time that is something like 10^{-16}-10^{-17} seconds. This is so short that we can hardly complain that the original statement isn't precise enough!

- The electric potential within a conductor is constant. Proof: the potential difference between any two points $\vec{a}$ and $\vec{b}$ inside the conductor is

$$\emptyset_a - \emptyset_b = -\int_{\vec{a}}^{\vec{b}} \vec{E} \,.\, d\vec{S} = 0 \qquad (3.1)$$

Since $\vec{E}$= 0 inside the conductor. Hence for any two points $\vec{a}$ and $\vec{b}$ inside the conduction $\emptyset_a = \emptyset_b$,

- Net charge can only reside on the surface of a conductor. This is easily proved with Gauss's law: make a little Gaussian surface that is totally contained inside the conductor. Since there is no $\vec{E}$field inside the conductor, $\oint \vec{E}\,.\,d\vec{A}$clearly zero for your surface. Since that is equal to the charge the surface contains, there can be no charge.

We will discuss the charge on the conductor's surface in a moment.

- Any external electric field lines are perpendicular to the surface. Another way to put this is that there is no component of electric field that is tangent to the surface. We prove this by contradiction: suppose that a component of the $\vec{E}$ −field were tangent to the surface. If that were the case, then charges would flow along the surface.

They would continue to flow until there was no longer any tangential component to the $\vec{E}$ field Hencethis situation cannot exist: even if it exists momentarily, it will rapidly (within 10^{-17} seconds or so) correct itself.

The conductor's surface is an equipotential. This follows from the fact that the$\vec{E}$ field is perpendicular to the surface. We do a line integral of $\vec{E}$on the surface; the path is perpendicular to the field; so the deference in potential between any two points on the surface is zero.

A few important corollaries follow from these rules.

- Corollary 1: Consider a conductor with a hollowed out region. If there is no charge in this hollow, then the potential$\emptyset$ there is constant. It follows that the electric field $-\vec{\nabla}\emptyset$inside the hollow is zero.

The prove of this carefully shortly. For now, it can motivate this proof by noting that the surface of the conductor must be an equipotential. Since there is no charge anywhere on the inside, the interior potential must obey Laplace's equation $\nabla^2\emptyset = 0$.

Solutions to Laplace's equation can have no local maxima or minima. The only solution that has some proscribed constant value on an exterior boundary and has no local maxima or minima is one that is constant.

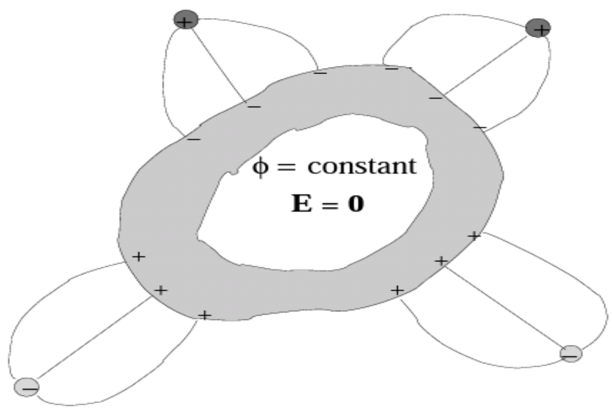

Figure (3.2): conductor with a hollowed out region.

By putting things inside a conducting box, it is shielded from any external electric field such an arrangement is known as a Faraday cage. Although it is beyond the scope of this course to prove this, Faraday cages work pretty well even when the external fields vary in time, as long as they don't vary too quickly.

- Suppose we put a charge q inside this hollow. There must be an induced layer of surface charge on the wall of the hollow; the total amount of induced charge in this layer is $q_{ind} = -q$.

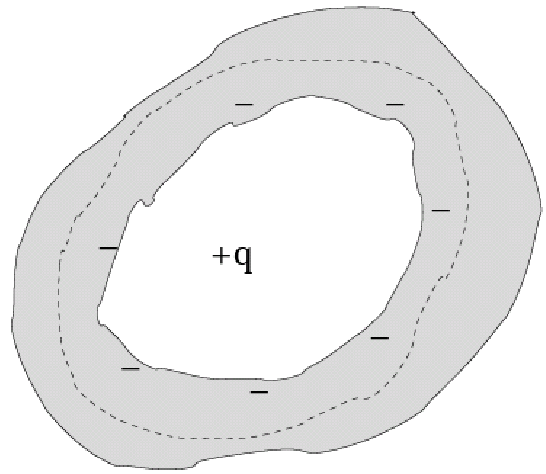

Figure (3.3): Gaussian surface: dashed line enclosing hollow and induced negative charge.

To prove this, use Gauss's law. We draw a Gaussian surface that lies inside the conductor. The $\vec{E}$ field there is zero, so the total electric flux must be zero. This flux equals 4π times the total charge contained by the surface, which is q plus the induced charge:

$$\oint \vec{E}.d\vec{A} = 0 = 4\pi(q + q_{ind}) \qquad (3.2)$$

$$\rightarrow q_{ind} = -q \qquad (3.3)$$

You should be able to prove with another well chosen Gaussian surface that the conductor has another layer of charge on its outer surface with total magnitude +q.

Corollary 3:

The induced charge density on any surface is given $|E|\ /4\pi$, where is the electric field right next to the surface. This follows from the rule that whenever there is a surface charge layer, the electric field changes with $\Delta E = 4\pi\sigma$. Since the field inside the conductor is zero, $\Delta E = \left|\vec{E}\right|$ [8].

3.3 The Uniqueness Theorem

Suppose we know that some region contains a charge density $\rho(\vec{r})$. Suppose we also know the value of the electrostatic potential $\emptyset(\vec{r})$ value on the boundary of this region. The uniqueness theorem then guarantees that there is only one function $\emptyset(\vec{r})$ which describes the potential in that region. This means that no matter how we figure out $\emptyset$'s value | guessing, computer aided numerical computation, demonic invocation | the function Á we find is guaranteed to be the one we want[].

We prove this theorem by assuming it is not true: we assume that two functions, $\emptyset_1(\vec{r})$ and $\emptyset_2(\vec{r})$, both satisfy Poisson's equation:

$$\emptyset_1(\vec{r}) = -4\pi\rho(\vec{r}) \qquad (3.3)$$

$$\nabla^2 \emptyset_2(\vec{r}) = -4\pi\rho(\vec{r}) \qquad (3.4)$$

Both of these functions must satisfy the boundary condition: we must $\emptyset_1(\vec{r}) = \emptyset_2(\vec{r}) = \emptyset_B(\vec{r})$on the boundary of our region.

By the principle of superposition, any combination of the potentials$\emptyset_1(\overrightarrow{r}) and \emptyset_2\overrightarrow{(r)}$ must be a perfectly valid potential. (It's not the potential that describes our region, but it still is valid as far as the general laws of physics are concerned.) Let's look in particular at $\emptyset_3(\vec{r}) = \emptyset_2(\vec{r}) - \emptyset_1(\vec{r})$. First, what is the boundary condition for $\emptyset_3$?since$\emptyset_1 = \emptyset_2$ on boundary,we must have $\emptyset_3 = 0$:

$$\nabla^2\emptyset_3 = \nabla^2(\emptyset_1 - \emptyset_2) \qquad (3.5)$$

$$= \nabla^2\emptyset_{2\_}\nabla^2\emptyset_1 \qquad (3.6)$$

$$= 4\pi\rho - 4\pi\rho = 0 \qquad (3.7)$$

The potential Á3 thus satisfies Laplace's equation. This means that it can have no local maxima or minima inside its boundary. But, on the boundary, its value is zero! The only function which is zero on a boundary and has no local maxima or minima is one which is zero everywhere in the region $\emptyset_3(\vec{r}) = 0$. This means that $\emptyset_1(\vec{r}) = \emptyset_2(\vec{r})$ | our initial assumption, that at least two potentials satisfied

Poisson's equation in the region with the given boundary condition, was wrong. Hence the solution for $\emptyset(\vec{r})$ is unique. Putting it concisely, we have proved the uniqueness theorem: An electrostatic potential ($\vec{r}$) is completely determined within a region once its value is known on the region's boundary [8].

Chapter Four

Materials and Method

4.1 Introduction

The ability of materials to conduct electric charge gives us the means to invent an amazing array of electrical and electronic devices, especially considering the extraordinarily wide range of conductivity available, with insulators on one end and superconductors on the other. (Semi-conductors, thermoelectric materials, opto-electronic materials and magneto resistive materials are whole other matters) Between these extremes are materials which offer as mall degree of resistance to flow of electrons, such as ordinary copper wire used in household wiring, and many other useful materials.

This experiment focuses on the resistance of wires made of materials such as copper and aluminum more specifically, the resistivity of copper and aluminum as functions of temperature [8].

4.2 Material and method

4.2.1 Material

Cupper wire (length 97cm), aluminum wire (42cm), Thermometer, voltmeter, ammeter, DC power supply and sand.

Figure (4.1): shows apparatus and material setup in experiment without heating.

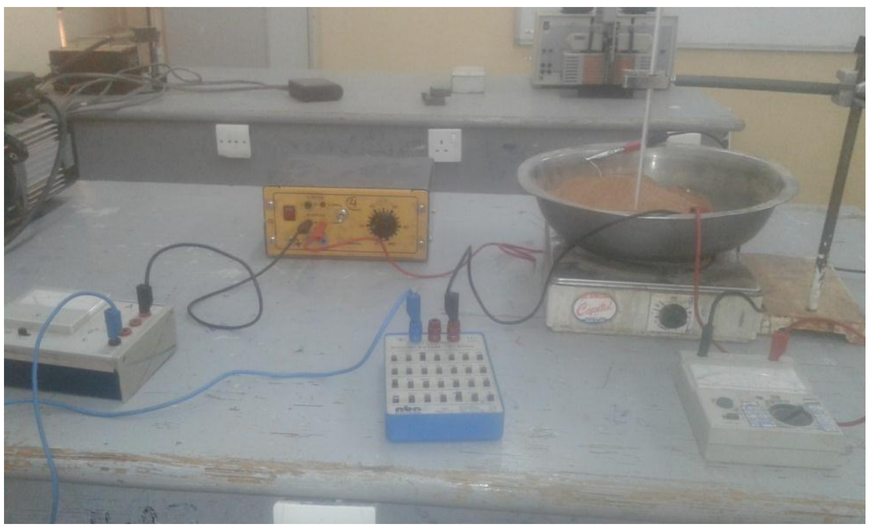

Figure (4.2): shows apparatus and material setup in experiment with heating.

4.2.2 Methods

Experiment carried out using different type of wire (AL ,Cu) results were taken as a data by using voltmeter and ammeter by aid of DC power supply under temperature variation, the data will lend it self to analysis using some of curve. Fitting formulas in order to see whether these results in agreement with theoretical consideration.

4.3 Theory

The power dissipated in wires can be calculated using

$$p = IV = KA\frac{dT}{dx} \qquad (4.1)$$

Where K is the Thermal Conductivity (cal/cm.k.sec), dx is length and A is area section.

While the variation of its resistance with temperature can be calculated using:

$$R = R_0(1 + \alpha\Delta T) = R_0 + R_0\alpha\Delta T \qquad (4.2)$$

Where α is the temperature coefficient, ΔTdegreeof difference temperature

$$T_n = \frac{\mathrm{T}}{\theta_{\mathrm{D}}} \qquad (4.3)$$

T_n is the Normalized temperature,$\theta_D$is the Debye Temperature[2];

$$(\theta_D)_{AL} = 359K^{\circ}$$

$$(\theta_D)_{Cu} = 333K^{\circ}$$

Table (4.1) shows the relation between current and potential difference for Al wire without heating

V_T/V $\pm 1\ V$	I/A ± 0.025A	$R_c = {V_T}/{I} - 12$ ± 1 ohm
1	0.025	28
2	0.05	28
3	0.075	28
4	0.1	28
5	0.125	28
6	0.15	28
7	0.175	28
8	0.2	28
9	0.225	28
10	0.25	28
11	0.275	28
12	0.3	28
13	0.325	28

Table (4.2) shows the relation between current and potential difference for cupper wire without heating.

V_T/V $\pm$ 1V	I/A $\pm$0.02A	$R_c = {V_T}/{I} - 12$ $\pm$1 ohm
2	0.07	16.6
3	0.11	15.3
4	0.14	16.57
5	0.18	15.77
6	0.21	16.57
7	0.25	16
8	0.29	15.58
9	0.33	15.27
10	0.37	15.07
11	0.41	15.82
12	0.45	14.67
13	0.49	14.53

Table (4.3) shows the relation between current and potential difference for Al wire with heating:

T/c° $\pm 1\ c^{\circ}$	V/v $\pm 1\ V$	I/A $\pm 0.1 A$	p/watt ± 0.01 watt	R/ohm ± 1 ohm
40	10.83	0.2	2.16	42.15
50	13.8	0.25	3.45	43.5
60	17.44	0.3	5.23	46.1
70	19.21	0.3	5.61	52.03
80	21.19	o.3	6.36	58.63

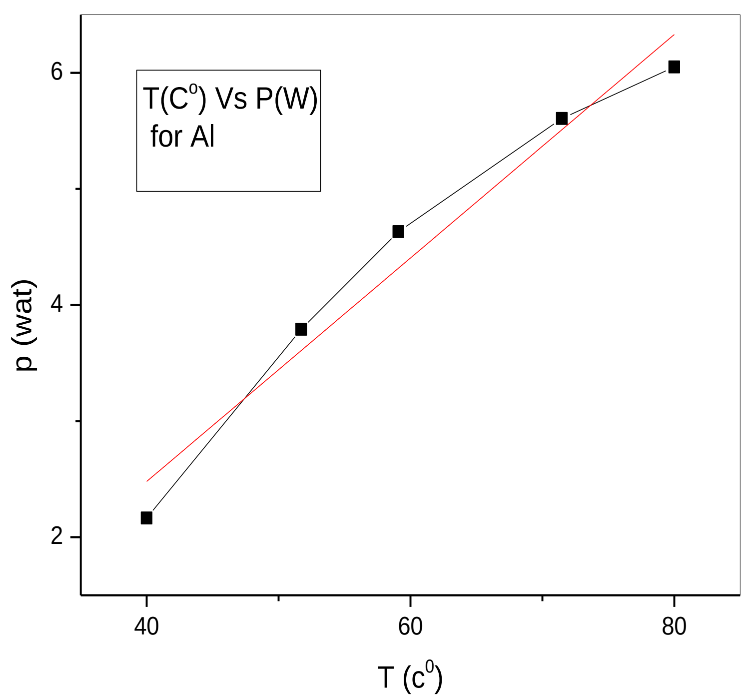

Figure (4.3): shows the relation between temperature and power for Al wire.

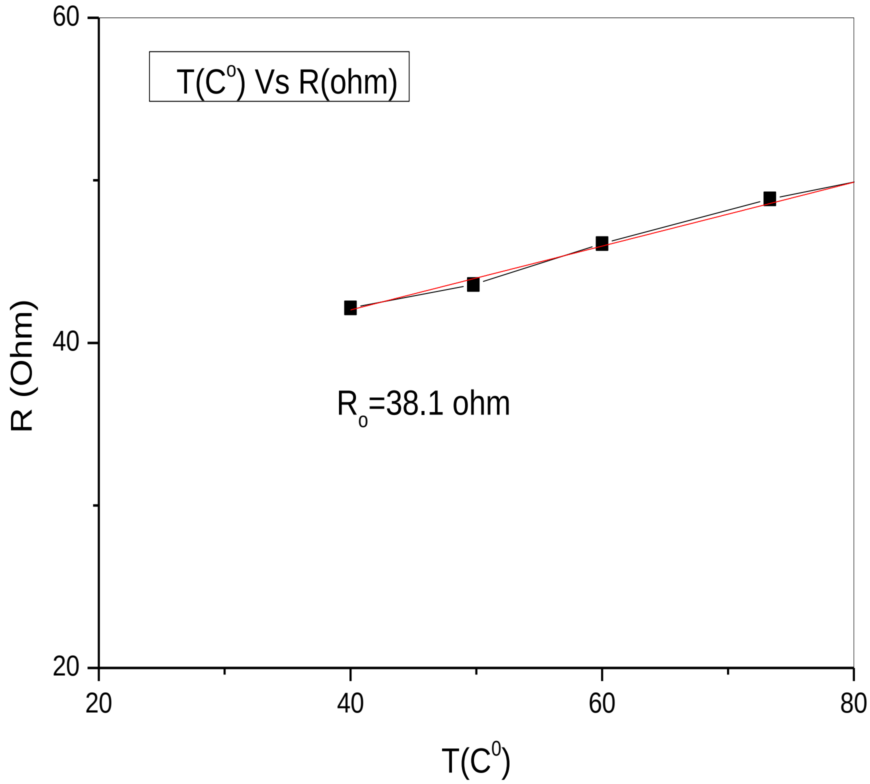

Figure (4.4): shows the relation between temperature and resistance for Al wire.

Table (4.4) shows the relation between current and potential difference for Cu wire with heating:

T/c° $\pm 1\ c^{\circ}$	V/v $\pm 1\ V$	I/A $\pm$1 A	R/ohm $\pm$1 ohm
200	3.8	0.4	9.5
210	3.9	0.4	9.75
220	3.9	0.4	9.75
270	4.0	0.4	10
280	4.0	0.4	10

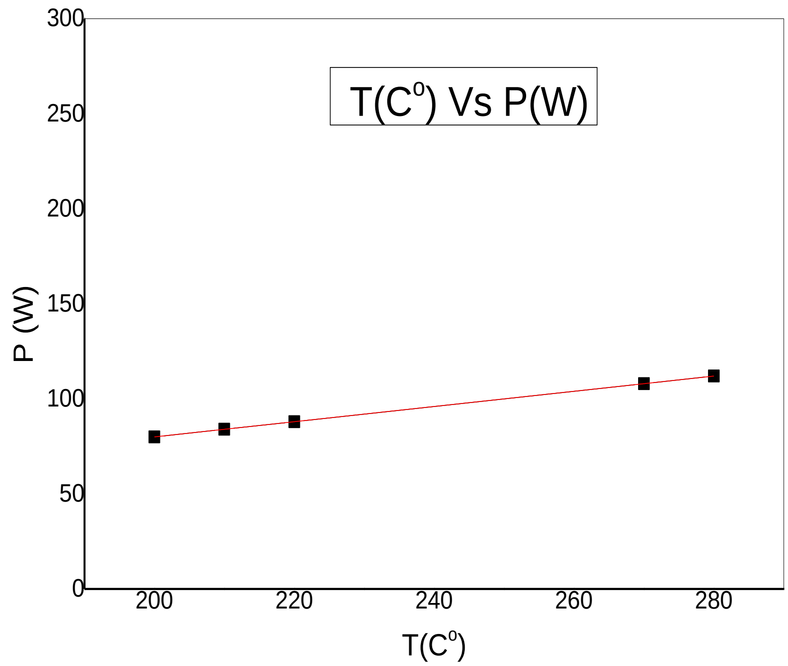

Figure (4.5) shows the relation between temperature and power for cu wire.

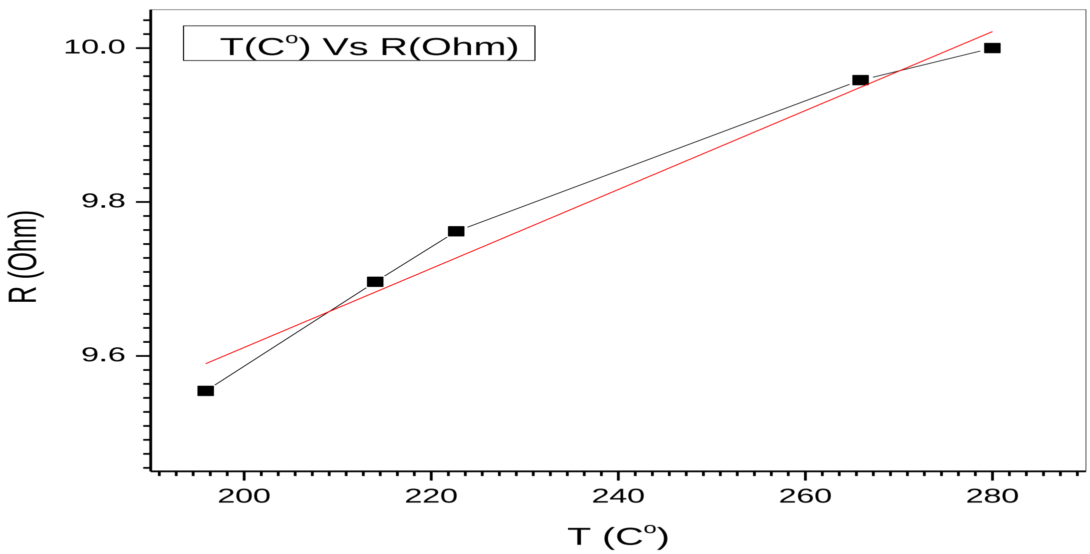

Figure (4.6) shows the relation between temperature and resistance for cu wire.

Table (4.5) shows the relation between temperature and normalized temperature for Al wire.

T/c° $\pm 1\ c^{\circ}$	$T/k^{\circ} \pm 1\ k^{\circ}$	$T_n = \frac{T}{\theta_D}$
40	313	0.79
50	323	0.82
60	333	0.84
70	343	0.87
80	353	0.89

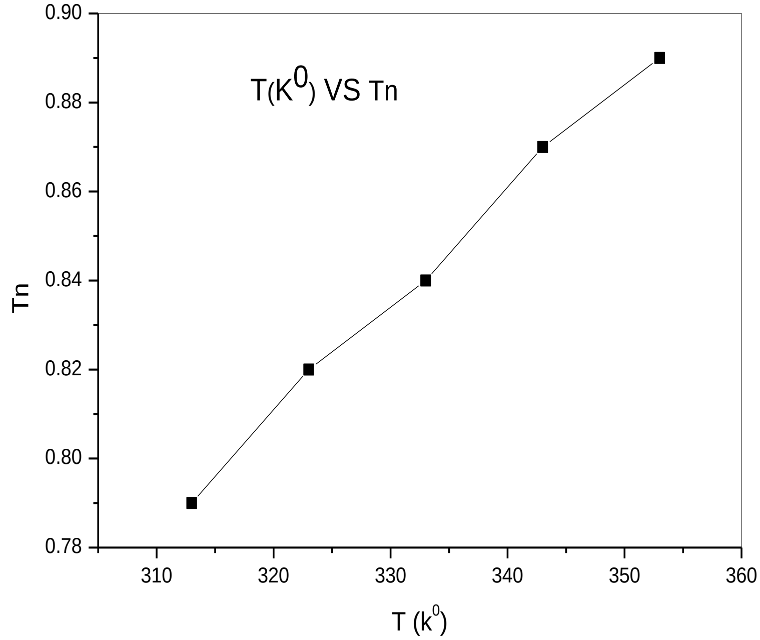

Figure (4.7): shows the relation between temperature and normalized temperature for Al wire.

Table (4.6): shows the relation between temperature and normalized temperature for Cu wire.

T/c° $\pm 1\ c^{\circ}$	T/k° $\pm 1\ k^{\circ}$	$T_n = \frac{T}{\theta_D}$
200	473	1.42
210	483	1.45
220	493	1.48
270	543	1.63
280	553	1.66

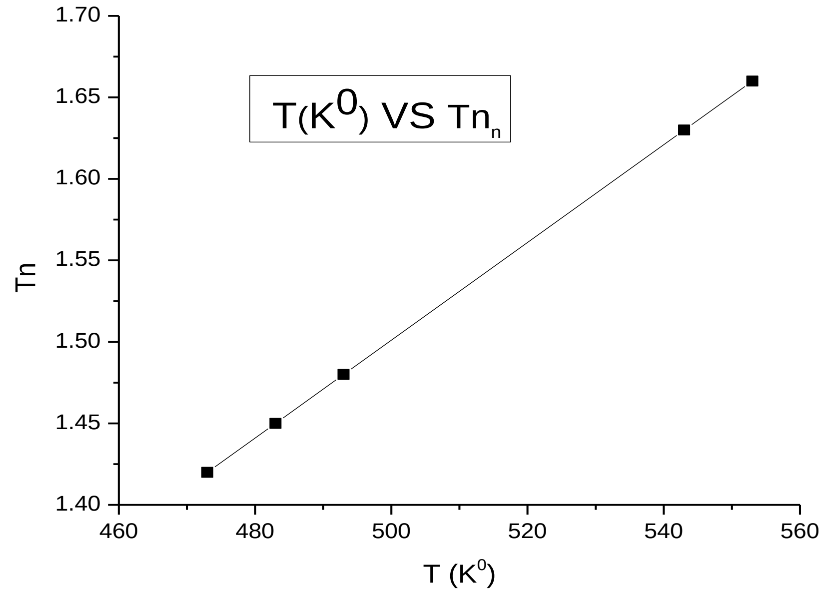

Figure (4.8): shows the relation between temperature and normalized temperature for Cu wire.

4.5 Calculation

From figure (4.1):

The slope of Al power dissipated versus temperature one can get the slope of the curve from which thermal conductivity k was calculated

$$slope = \frac{p}{dT} = \frac{KA}{dx}$$

$K = (0.0023 \times 42)/(3.14 \times (0.01) \times 4.18) = 0.73$(cal/cm.k.sec)

From figure (4.4): shows the relation between temperature and the resistance to calculate the thermal coefficient

$$\alpha = slope/R_0$$

=0.19/38.1=0.0049=4.9 ($10^{-3}/K$)

From figure (4.5): shows The slope cu power versus temperature is = 0.004 w\k □°

The thermal conductivity was calculates as w\km

$$\mathrm{slope} = \frac{\mathrm{p}}{\mathrm{dT}} = \frac{\mathrm{KA}}{\mathrm{dx}}$$

Where A is area of the wire and dx is the length

$K = (0.004 \times 97)/(3.14 \times (0.01) \times 4.18) = 2.95$(cal/cm.k.sec)

From figure (4.6): shows the relation between temperature and the resistance to calculate the thermal coefficient

$$\alpha = slope/R_0$$

α =0.0571/8.4=0.00680 ($10^{-3}/K$)

4.6 Discussion

From Table (4.1) shows the relation between current and potential difference for Al wire without heating and table (4.2) shows the relation between current and potential difference for cu wire without heating

For both aluminum and copper wire it is clear that the resistance remain constant without heating. That current proportional to potential difference in full agreement with theoretical consideration.

From table (4.3) shows the relation between current and potential difference for Al wire with heating and table (4.4) shows the relation between current and potential difference for Cu wire with heating and their figures (4.3),(4.4),(4.5) and (4.6) was used to calculate thermal conductivity and the temperature coefficient of resistance is known as (α) constant and symbolizes the resistance change factor per degree of temperature change. Just as all materials have a certain specific resistance (at 20°C), they also change resistance according to the temperature by certain amounts. For pure metals, this coefficient is a positive number, meaning that resistance increases with increasing temperature.

From table (4.5) shows the relation between temperature and normalized temperature for Al wire and table (4.6) shows the relation between temperature and normalized temperature for Cu wire and their figures, it was clear that the normalized temperature roughly linear for temperatures greater than certain temperature for both aluminum and cupper.

4.7 Conclusions

Resistance is the quality of a conductor which hinders the flow of electrons and the resistance a wire offers to a current depends on its material, its cross-sectional area, and length.

However resistance also depends on the temperature, which increases with increasing temperature. Other than choosing efficient materials there are a couple of simple thing that can be done to reduce the resistance of a conductor. Conductors have lower resistance at low temperatures. Keeping a conductor cool will help keep resistance low and reduces the amount of power lost conductor heating.

From results obtained the temperature coefficient for aluminum wire was found to 6.44 ($10^{-3}/K$) while in copper it was found to be 6.80 ($10^{-3}/K$) with full agreement with theoretical value which calculated by the \CRC Handbook of Chemistry and Physics" to be 4.29 ($10^{-3}/K$) and 6.80 ($10^{-3}/K$) respectively.

Also the thermal conductivity for both wires were calculated and found to be

0.73 (cal/cm.k.sec) and 2.95 (cal/cm.k.sec) respectively, Then graph of the Normalized temperature T_n versus the resistivity R reveals linear relation.

4.8 Recommendation

Further studies must be carried out in this field of study in such experiment by using more sensitive apparatus required to avoid mistakes made during the carry out the results and pure metal wires must be used.

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