Resistivity

Resistivity of a material at a given temperature is defined as the resistance of a unit length and unit cross-section of the material. It has units of Ωm. Resistivity increases with increase in temperature for metals. It is dependent on the material of a conductor and temperature only.

Factors affecting resistivity

Resistivity is affected by:

Nature of material: Metals and alloys have low resistivity ($\approx 10^{-8}\ \Omega m$) while insulators have very high resistivity ($>10^{8}\ \Omega m$).
Temperature:
Metals- Increases with increase in temperature.
Semiconductors- Decreases with increase in temperature.
Alloys- Doesn't change much on change

Material of a wire

The choice of material of wire is dependent on the application.

Copper and aluminium for electrical connections and power transmission due to low resistivity.
Magnanin and constantan are used as standard resistors because of less effect of temperature change in its resistance.
Alloy of lead and tin for fuse wire because of low melting point and high resistivity.
Tungsten wire for filament of electrical bulb because of high melting point and resistivity.
Nichrome wire as heating element because of high resistivity and increase in resistivity with temperature.

Resistivity of common resistors

Resistivity of some common materials at room temperature are listed below:

Silver: $1.63\times10^{-8}\ \Omega m$
Copper: $1.73\times10^{-8}\ \Omega m$
Aluminium: $2.63\times10^{-8}\ \Omega m$
Iron: $9.8\times10^{-8}\ \Omega m$

Steel: $20\times10^{-8}\,\Omega m$
Brass: $6.6\times10^{-8}\,\Omega m$
Magnanin: $44\times10^{-8}\,\Omega m$
Silicon: $2.3\times10^{-5}\,\Omega m$

Wire bound and carbon resistors

Wire bound resistor	Carbon resistor
Withstand unusually high temperatures of up to 450^0C	Very temperature sensitive
Made by winding a metal wire, usually nichrome, around a ceramic, plastic, or fiberglass core	Made of carbon clay composition covered with a plastic case
tolerance range: 0.01 % to 1 %	Tolerance range: 5% to 20 %

Colour coding of resistors

To distinguish left from right there is a gap between the C,and D bands.
Band **A** is the first significant figure of component value (left side)
Band **B** is the second significant figure (some precision resistors have a third significant figure, and thus five bands).
Band **C** is the decimal multiplier
Band **D** if present, indicates tolerance of value in percent (no band means 20%)

Variation of conductivity of conductor, insulator and semiconductor with temperature
Conductivity

Electrical conductivity is the reciprocal of electrical resistivity, and measures a material's ability to conduct an electric current.
σ=1ρ
where σ is the conductivity, and ρ is the resistivity.

Analogy of electric current to other phenomenon

Flow of electric current occurs only in the presence of potential difference and it flows from higher potential to lower potential. This is similar to:

Heat Transfer: It flows from body at higher temperature to a body at lower temperature.
Water flow: It flows from high pressure to low pressure.
Free fall: A body falls from point of higher gravitational potential to a point of lower gravitational potential.

Verifying Ohm's Law
Let resistance used for verification be R. Make a circuit of R, voltmeter and ammeter measuring voltage and current through R, rheostat (variable resistor), and a cell. Connect the components properly. Note down values of voltage and current shown by voltmeter and ammeter. Repeat the above for different values of Rheostat. Record data in a tabular format and calculate *VI*for each case. Its should be approximately same. Plot V v/s I on a graph paper. A straight line is obtained whose slope equals resistance.

Ohmic and Non-ohmic resistors

S.No.	Ohmic Resistor	Non-ohmic Resistor
1	Obeys Ohm's Law	Does not obey Ohm's Law
2	Graph of V v/s I is a straight line	Graph of V v/s I is not a straight line
3	Slope of V-I graph is constant	Slope of V-I graph changes
4	Examples: Metals	Examples: Semiconductors, inductor, etc

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Primary cells v/s secondary cells

S.No	Primary cell	Secondary Cell
1	Chemical reaction is irreversible.	Chemical reaction is reversible.
2	Chemical energy is converted into electrical energy.	Chemical energy is converted into electrical energy during energy supply & electrical energy is converted into chemical energy during charging.
3	Cannot be recharged	Can be recharged
4	Internal resistance is high.	Internal resistance is low.
5	Can supply weak currents only.	Can supply weak and high currents.
6	Light and cheap.	Heavy and costly.
7	Example: Simple voltaic cell, Dry cell	Example: Lead (or acid) accumulator, Ni-Fe

Electro-motive force

The potential difference between the terminal of a cell when no current is drawn from it is called electromotive force (ε). Its unit is volt (V).

Factors affecting e.m.f.

E.m.f. of a cell depends upon the material of electrodes and electrolyte used in the cell. It is independent of shape of electrodes, distance between electrodes and the amount of electrolyte.

Voltage drop in a cell

When current is drawn through a circuit, the voltage supplied by the battery is not equal to the emf but actually decreases. This decrease in potential across the ends of the battery is known as voltage drop. Voltage drops is undesired in circuit elements like conductors,contacts,connectors and internal resistances of the source as the supplied energy is lost but it is desired in loads and across other active circuit elements as the energy given is converted into work.

Factors affecting internal resistance
The internal resistance of a cell depends on:

Surface area of electrodes (more surface area → less resistance)
Distance between the electrodes (more distance → more resistance)
Nature and concentration of electrolyte (higher concentration → more resistance)
Temperature of electrolyte (more temperature →more resistance)

Equivalent emf/resistance of cells in series and parallel

Again assume emf of each cell is E and internal resistance of each cell is r. As n numbers of cells are connected in each series, the emf of each series as well as the battery will be nE. The equivalent resistance of the series is nr. As, m number of series connected in parallel equivalent internal resistance of that series and parallel battery is nr/m.

The junction law

The sum of all the currents directed towards a point in a circuit is equal to the sum of all the currents directed away from the point.

The loop law

The algebraic sum of all the potential differences along a closed loop in a circuit is zero.

Sign convention of current and voltage

The terminal voltage at higher potential is positive whereas the terminal at lower potential is negative.
If the current is flowing from higher potential to lower potential, then the current is a positive value. If the current instead is flowing from lower potential to higher potential, then the current is a negative value.

Basic electric circuit

Basic electrical circuit consists of an electric cell, key, conducting wires and an electrical gadget (say bulb). When switch is closed, current flows through the circuit and the bulb glows.

Galvanometer

Galvanometer is an instrument used to check the presence of electric current and find its direction in a circuit. It is connected in series to the device through which current is to be checked. Ideal galvanometer has zero resistance.

Ammeter and Voltmeter

Ammeter is a device used to measure the current in a circuit. It is connected in series to the element through which the current flows. Resistance of an ideal ammeter is zero. Sometimes a resistance is connected in parallel to the ammeter to increase the range of an ammeter. Voltmeter is a device used to measure the potential difference in the circuit. It is connected in parallel to the element through which potential drop is to be measured. Resistance of an ideal voltmeter is infinite.

Shunt

In an ammeter, a resistor having a small resistance is connected in parallel with the coil. This resistor is called shunt. It allows electric current to pass around another point in the circuit by creating a low resistance path.

Galvanometer as a voltmeter

To convert a galvanometer into a voltmeter it must be connected in parallel with the circuit across which the voltage is to be calculated. Moreover a negligible amount of current should be drawn from it such that it doesn't disrupt the original set up by a large amount and well below one per cent. To ensure this, a large resistance R is connected in series with the galvanometer.

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Precautions while using a potentiometer

1. Jockey should not be dragged along the wire.
2. The current value should be as small as possible.
3. Current should be passed only while taking the readings.

Potentiometer vs voltmeter

Voltmeter	Potentiometer
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.
Measures emf of cell approximately	Measures emf of cell very accurately
Sensitivity is low	Sensitivity is high

Identify the appliances without heating coil

Microwave oven and induction cooker are appliances which do not use a heating coil. In a microwave oven, microwaves are used and induction cooker uses eddy currents.

Sign convention of electrical power

The power will be a positive if energy is leaving the circuit(energy is absorbed) by way of the element. In this case, energy is being converted to a non-electrical form, such as heat, light, motion, chemical energy, an electric field, or a magnetic field.
The power will be negative if energy is entering the circuit (energy is supplied). Energy is being converted from a non-electrical form to electrical current.

Seebeck effect

Two metallic strips made of different metals are joined at the ends to form a loop. If the junctions are kept at different temperatures, there is an electric current in the loop. This effect is called the Seebeck effect and the emf developed is called the Seebeck emf or thermo-emf.

Neutral and inversion temperature

The temperature of the hot junction at which the thermo-emf is maximum is called the **neutral temperature** and the temperature at which the emf changes its sign (current reverses) is called the **inversion temperature.**

Working of a thermocouple

The working principle of thermocouple is based on three effects - Seebeck Effect, Peltier Effect and Thomson Effect.
It comprises of two dissimilar metals, A and B, joined together to form two junctions, p and q, which are maintained at the temperatures T1 and T2 respectively which generates the Peltier emf within the circuit and it is the function of the temperatures of two junctions.The total emf or the current flowing through the circuit can be measured easily by the suitable device.Now, the temperature of the reference junctions is already known, while the temperature of measuring junction is unknown. The output obtained from the thermocouple circuit is calibrated directly against the unknown temperature. Thus the voltage or current output obtained from thermocouple circuit gives the value of unknown temperature directly.

Thomson effect

If a metallic wire has a nonuniform temperature and a current is passed through it, heat may be absorbed or produced in different sections of the wire. This heat is over and above the Joule heat i^2Rt and is called Thomson heat. The effect itself is called the Thomson effect.

Voltage rating of a bulb

The voltage rating of an incandescent bulb is the voltage that bulb is designed to operate in the circuit measured at the base of the bulb and in which published data watts, amps, lumens, colour temperature and life hours are measured.

Power rating of a bulb

The power rating on a light bulb indicates how much power it would dissipate when it is hooked up to the standard household voltage of 120V.

Difference between breaking voltage and voltage rating of a bulb

Voltage rating of a bulb is the voltage at which the bulb operates.

If an excess voltage is applied to the bulb, a dangerously high electric field is induced which may damage the bulb. The minimum value of voltage at which breakdown occurs is called the breakdown voltage of the bulb.

Non-ideal capacitor

If the dielectric material between the plates of a capacitor has finite resistivity as opposed to infinite resistivity in case of an ideal capacitor then there will be a small amount of current flowing between the plates of the capacitor.Lead resistance and plate effects also exist in non-ideal capacitor.

Sudden change in voltage s forced across a capacitor

If a source of voltage is suddenly applied to an uncharged capacitor, the capacitor will draw current from that source, until the capacitors voltage equals that of the source. Once the capacitor voltage reached this charged state, its current decays to zero.

Domestic electrical circuits

The major components of domestic electrical circuits are:

Supply lines: Live wire (red), earth wire (green) and neutral wire (black). Potential difference between live wire and neutral wire is 220 V.
Earth wire is connected to a metal plate deep inside the ground for safety purpose.
Live wire and neutral wire enter electricity meter via a main fuse (used for protection).
Two separate circuits of different current ratings (5A and 15 A) are used.
All components are used in parallel and hence are supplied by same potential difference of 220 V. Currents in the loads vary according to requirement. Also, this allows to separately handle each load. It also reduces the overall resistance of the load.
Fuses are used in the circuit for protection in the circuit against huge current values due to short circuit and overloading.

Unit of current

The unit of current is *coulomb* S^{-1} or *Ampere*

Electricity as flow of charges

An electric current is a flow of charges. In electric circuits this charge is often carried by motion of electrons. It can also be carried by ions in an electrolyte, and in plasma it is carried by both by ion and electrons.

Importance and need of electricity

Electricity has made living easy,it is used in the woking of household appliances like a fan,refrigerator, water purifier,induction stoves etc.
Electricity is used to run big machines in factories and industries.
Modern computers and large technological development are flourished in the presence of electricity only.
Modern means of transport and communication like an electric train and mobile phones use electricity.
Electricity is the important source of energy for working of ECG and X-ray machines in medical and surgery field.

Types of Electric Circuits

Simple Circuit: A circuit made up of a cell, a switch and

a bulb is known as a simple circuit.
Series Circuit: A circuit where bulbs are connected end to end. This type of circuit is known as series circuit.Here the current can flow only in one direction and the same amount of electric current flows through all the bulbs.
Parallel Circuit:Here each bulb is connected to the battery terminals by separate wires. This type of circuit is known as parallel circuit.In this circuit, different amount of current passes through the bulbs.

Steady current

An electric current that does not change with time is known as steady current. An example would be closing or opening a switch to add or remove a battery, current may initially change, but then reach a final ``steady-state" value after a long time, or go to zero, depending on the situation.

Current through a wire

S.No.	Conductor	Insulator
1	Substance which allows electricity to pass through them is called conductors	Substance which does not allow electric current to pass through it is called insulators.
2	Metals like copper,iron,aluminium etc are conductors.	Plastic,wood,rubber glass etc are insulators.
3	Resistance of conductors is very low.	Resistance of insulator is high.
4	Energy band gap is zero.	Energy band gap is widest of 10 eV.

Examples of conductors

Conductors have electrons which are free to move. These electrons are the outer shell electrons of an atom. They are not so tightly bound to the nucleus. Such electrons are present in metals such as **silver, copper, gold**.
Hence most of the metals are good conductors of electricity.

Conductors and insulators

Substances which allow electric charges to flow through them easily are called good conductors of electricity. They have a large number of free electrons.
Substances which do not allow any electric charges to flow through are called bad conductors of electricity or insulators. They have a very small number of free electrons or no free electrons.