Circuits and Capacitors

I. Current, Power, Resistance - resistivity

- II. Circuit Analysis
 - series and parallel
 - nodes, loops, switches
 - internal resistance
- III. Capacitance
 - parallel plate capacitor
 - capacitors in circuits

	The student will be able to:	HW:
1	Define electric current and the ampere and solve problems relating current to charge and time and to power and voltage.	1 – 3
2	Define resistance, resistivity, and the ohm and Ohm's Law and solve related problems.	4 – 10
3	Determine resistance for series or parallel combinations of resistors, state and apply Kirchoff's node and loop rules and solve related problems, including analysis circuits with multiple batteries, resistors, and switches.	11 – 15
4	Define and apply the concepts of internal resistance and emf to solve related problems with the standard model of the terminal voltage of voltaic cells.	16 – 21
5	Define capacitance and relate to charge, voltage, energy, and time constant to solve related problems involving capacitors in circuits at steady states of charge or discharge and qualitatively describe transitions of such states.	22-31
6	State the relation between capacitance, area, separation, and dielectric constant for parallel plate capacitors and solve related problems.	32 – 37

Definition of Resistance

For most materials it requires greater electric potential to produce greater current.

However, the resulting current also depends on resistance. The greater the resistance, the greater the potential required to produce a *certain level* of current.

Resistance is defined as the ratio of potential difference to current.

Definition of Resistance

$$R = \frac{\mathsf{D}V}{I}$$

where: R = resistance ΔV = electric potential "across" I = electric current "through"

More commonly written as:

(often referred to as Ohm' s Law)

$$V = IR$$

Units of Resistance

- The SI unit for electric resistance is the **ohm**.
- One ohm is equal to one volt per one ampere:

 $1 \Omega = 1 V/A$

The greater the number of ohms, the more volts it takes to achieve one ampere of current *– i.e.* "More volts per ampere means more resistance and therefore more ohms".

Which side of the resistor is at a higher potential?



The potential difference ΔV across a resistor (one side relative to the other) is often described as a potential drop because charge is losing energy that is dissipated by the resistor in the form of heat.

Ohm's Law

In the 1820's, Georg Ohm found that the ratio of voltage to current is constant over a wide range of conditions for metals and many other substances.

Such a substance has a **constant resistance** and is said to be **ohmic**.

However, there are materials and devices that do not have a constant resistance. These are said to be **nonohmic**.



Resistors



- A resistor is a device designed to have a particular amount of resistance.
- A resistor is designed to be ohmic and therefore has the same resistance over a wide range of operating conditions.

What determines the amount of resistance?

The type of substance has a great influence on resistance. In particular, electron orbitals and atomic bonding affect the potential difference required to produce a certain level of current.

The physical dimensions of an object will also greatly influence resistance.

Greater length and/or lesser cross sectional area will result in greater resistance (because there is less current for a given voltage).

Modeling Resistance in Ohmic Materials

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

where: R = resistance of wire (or other object) ρ = resistivity of the substance from which the wire is made L = length of wire

A = cross-sectional area of wire

Material	Resistivity $(\Omega \cdot m)$	Temp. Coeff. (K ⁻¹)
Silver	1.59×10^{-8}	3.8×10^{-3}
Copper	1.68×10^{-8}	6.8×10^{-3}
Aluminum	2.65×10^{-8}	4.29×10^{-3}
Tungsten	5.60×10^{-8}	4.25×10^{-3}
Nickel	6.84×10^{-8}	6.9×10^{-3}
Iron	9.71×10^{-8}	6.51×10^{-3}
Platinum	1.06×10^{-7}	3.93×10^{-3}
Nichrome	1.00×10^{-6}	4×10^{-4}
Carbon	3.5×10^{-5}	-5×10^{-4}
Silicon	2.5×10^{3}	-7×10^{-2}
Wood	$10^8 - 10^{11}$	
Glass	$10^{10} - 10^{14}$	

Dependence on Temperature

- Generally speaking resistance will increase as temperature increases.
- For the filament of an incandescent bulb this is a dramatic effect – the brighter the bulb, the higher the temperature of the filament, and the greater its resistance.
- Decreasing temperature in some materials results in resistance dropping to essentially zero. A material with zero resistance is called a **superconductor**.

Coil of Resistance Wire



Sliding Contact



The total resistance $(R_1 + R_2)$ between the two ends (red terminals) is constant. A certain part $(R_1 \text{ or } R_2)$ of the total resistance exists between either end and the point of contact (blue terminal) depending on the length of wire between.



If only the blue and one of the red terminals are connected the device becomes simply a variable resistor that can be controlled by turning a knob or otherwise sliding the point of contact along the resistance wire.

Potentiometers and variable resistors are useful for controlling current and/or voltage and are found in many different types of circuits.