Electrical Circuits

I. **Current** and Resistance
- Ohm's Law

II. Resistivity
- resistance factors
- conductivity
- drift velocity & current density

III. Electrical Power

IV. Circuits
- series and parallel
- Kirchoff's Laws

V. Batteries and Meters
- internal resistance

	The student will be able to:	HW:
1	Define current and the ampere, conventional positive current flow, and solve related problems, including those with both positive and negative charge carriers.	1 – 3
2	Define resistance and the ohm, state Ohm's Law, and solve related problems involving ohmic and/or nonohmic devices.	4 – 7
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8	Model a cell or battery as an ideal voltage source or as an EMF with internal resistance and a certain terminal voltage, and solve related problems.	39 – 43
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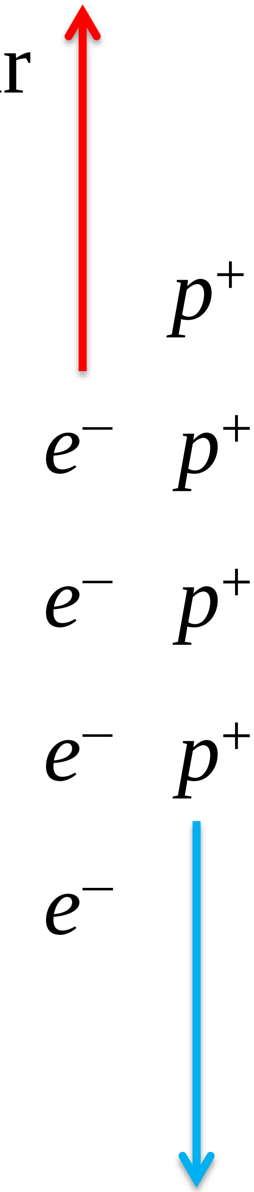
What is Current?

A **current** is the organized flow of a particular substance – for example a river is a water current and wind is an air current.

An **electric current** is the flow of charged particles.

Most often this involves a flow of electrons, however positive particles can also sometimes flow – for example ions in solution. In almost every way the flow of negative particles is equivalent to a flow of positive particles in the opposite direction.



Electric current is the rate at which charge passes through a certain cross section. (*i.e.* the *flux* of charge)

$$I = \frac{dq}{dt}$$

where: q = amount of charge crossing an imaginary plane

t = time

Units of Electric Current

- The SI unit for electric current is the **ampere**.
- One ampere is equal to one coulomb of charge per one second:

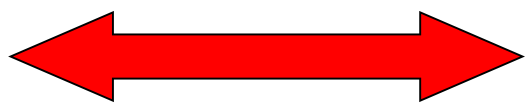
$$1\ \text{A} = 1\ \text{C/s}$$

- Although current is not a vector, it is taken to be positive in the direction that positive charges flow (or *would* flow).

AC versus DC

There are two common types of current: AC and DC.

AC stands for **Alternating Current** and means that charge oscillates and travels in alternating directions.



DC stands for **Direct Current** and means that charge travels in only one direction.

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What is Electrical Resistance?

When we speak of electrical resistance we mean resistance to the flow of charge (*i.e*. resistance to current).

Accordingly, conductors have very low resistance and insulators have very high resistance.

Some materials, such as semiconductors, have a resistance that varies depending on certain conditions.

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.

Resistance Quantified

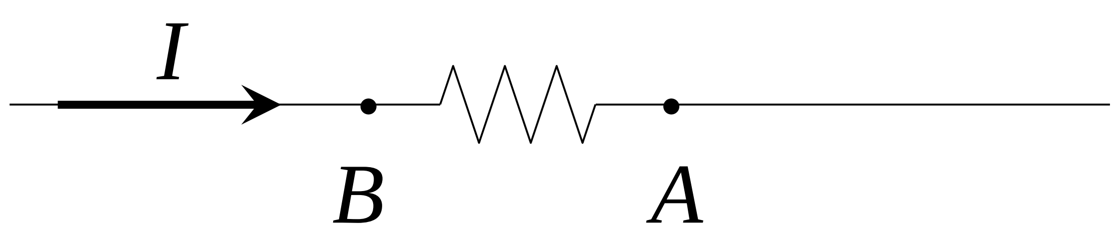
resistance defined:

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

often written and referred to as Ohm's Law:

$$V = IR$$

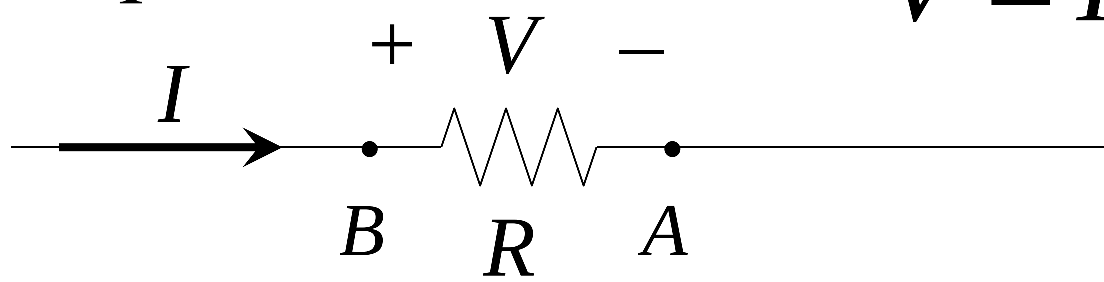
where: R = resistance
V = potential difference "across"
I = electric current "through"



<u>Note</u>: $V = V_B - V_A$ in this context

"Potential Drop"

$$V = IR$$



The voltage in the context of Ohm's Law is often referred to as a "drop" in potential. The logic in this is that in order for current to flow from *A* to *B* there must be an electric field pointing in that direction and therefore the potential at point *A* is greater than the potential at point *B* ($V_B > V_A$). As current flows through a resistor the potential "drops" by the amount $V = IR = V_B – V_A$. Note this is true whether the current consists of negative or positive particles (or both); the "drop" is in the direction of conventional positive current as shown.

Units of Resistance

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

$$1\ \Omega = 1\ \text{V/A}$$

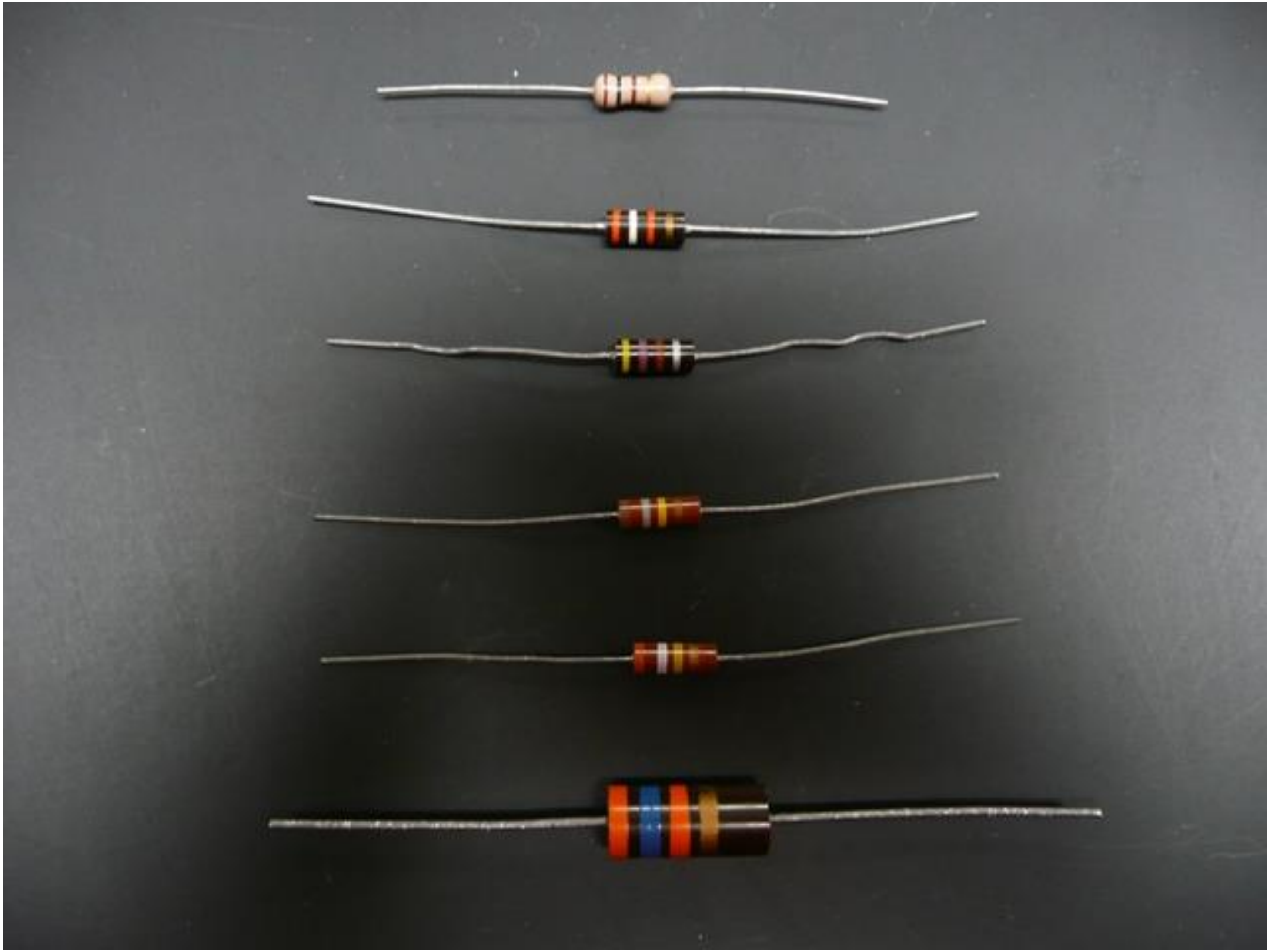
- The greater the number of ohms, the more volts it takes to achieve one ampere of current – *i.e.* "More volts per ampere means more resistance and therefore more ohms".

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.

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**.

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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	$10^{10} - 10^{14}$	

Modeling Resistance in Ohmic Materials

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

where: R = resistance of wire (or other object)

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Material	Resistivity ($\Omega \cdot m$)	Conductivity $(\Omega \cdot m)^{-1}$
Silver	1.59×10^{-8}	6.30×10^{7}
Copper	1.68×10^{-8}	5.96×10^{7}
Aluminum	2.65×10^{-8}	3.77×10^{7}
Tungsten	5.60×10^{-8}	1.79×10^{7}
Nickel	6.84×10^{-8}	1.46×10^{7}
Iron	9.71×10^{-8}	1.03×10^{7}
Platinum	1.06×10^{-7}	9.43×10^{6}
Nichrome	1.00×10^{-6}	1.00×10^{6}
Carbon	3.5×10^{-5}	28600
Silicon	2.5×10^{3}	4.00×10^{-4}
Wood	$10^{8} – 10^{11}$	$10^{-8} – 10^{-11}$
Glass	$10^{10} – 10^{14}$	$10^{-10} – 10^{-14}$

American Wire Gauge & Resistance of Copper Wire

AWG value	Diameter (mm)	Ohms per km
10	2.58826	3.276
12	2.05232	5.209
14	1.62814	8.282
16	1.29032	13.173
18	1.02362	20.943
20	0.81280	33.292
22	0.64516	52.939
24	0.51054	84.198
26	0.40386	133.857
28	0.32004	212.872
30	0.25400	338.496