### **Electrical Connections**

Series and Parallel

## 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

### Series Connections

Current passes through each device in a particular order. There is only one path for current to follow.



The **current** is the same through each device. The **voltage** across any set of devices is equal to the sum of the individual voltages.

### **Parallel** Connections

Current passes through the devices simultaneously. There are multiple paths for current to follow.



The **voltage** is the same across each device. The **current** through any set of devices is equal to the sum of the individual currents.

### Equivalent Resistance of Series Resistors



### Equivalent Resistance of Parallel Resistors



The equivalent resistance is *less* than that of any single resistor in the set. © Matthew W. Milligan

### An example circuit...







### Kirchhoff's Laws

• Loop Rule: The sum of the potential differences across all elements around any loop equals zero.

Because energy is conserved!

A "loop" is any pathway through a circuit that starts and ends at the same point. It can have any shape.







## Kirchhoff's Laws

- Loop Rule: The sum of the potential differences across all elements around any loop equals zero.
- Node Rule: The sum of currents entering a node equals the sum of currents exiting a node.

Because charge is conserved!

A "node" is any junction in a circuit where two or more wires or other current pathways connect.

































## Circuits and Capacitors

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## Cells & Batteries

- A voltaic (or galvanic) cell is a single container of chemicals with two electrodes: an anode and a cathode.
- Properly speaking a "battery" is a collection of multiple cells connected in series.
- Energy is "stored" in chemical form until a current is drawn from the battery, at which point oxidation occurs at the anode and reduction occurs at the cathode.

# EMF

- The energy associated with the chemical reaction can be quantified by *EMF* ("electromotive force"), which is a measure of energy per charge.
- For a given chemical reaction there is a characteristic *EMF*, which is independent of the quantity of reactants and can be determined by standard electric potentials of the corresponding half-reactions.



image credit: Wikipedia, Ohiostandard

The potential or *EMF* (electromotive force) is the sum of the half-potentials of the reactions taking place – 0.762 + 0.337 = 1.099V in this particular example.

### Terminal Voltage and Internal Resistance

- A battery's voltage has a *tendency* to be *relatively constant*. However it is the EMF of the chemical reaction that should be constant.
- The voltage measured at the terminals of the battery is variable depending on the current. The greater the current, the less the terminal voltage.
- The variance in terminal voltage is a result of internal resistance associated with the flow of charge through the battery.

### Modeling the Behavior of a Cell or Battery



### Modeling the Behavior of a Cell or Battery



The terminal voltage is the "useable" potential difference between the positive and negative terminals of the battery.

$$V_{term} = \mathcal{E} - Ir$$