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MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

Class 09 – Batteries

1

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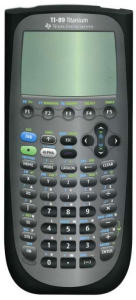
MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Batteries
  - Charge separation for work & play



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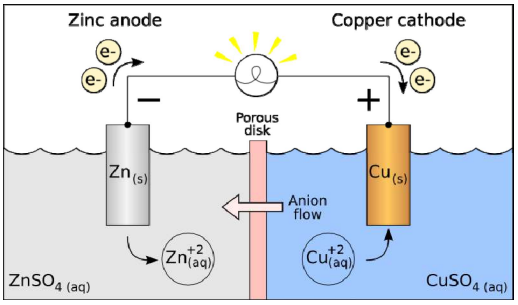
- Batteries
  - One or more electrochemical cells that convert stored chemical energy into electrical energy



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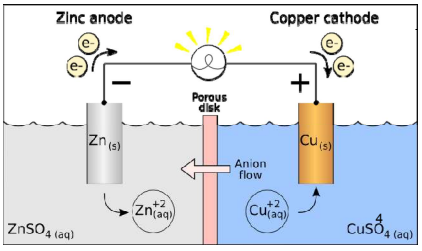
- Batteries
  - Redox – reduction oxidation reaction
    - Reduction – gains electrons, loses oxygen
    - Oxidation – loses electrons, gains oxygen
  - Potential difference
    - Chemistry dependent
      - 1.2V to 3.8V



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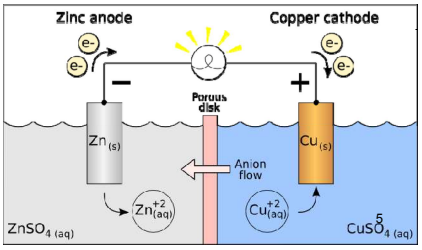
- Batteries
  - Chemistry
    - *Standard Electrical Potential*
      - *Copper +0.52V*
      - *Zinc -0.76V*
    - *Maximum Voltage*
      - *0.52V – (-0.76V) = 1.28V*



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- Batteries
  - Primary cell – one time use, not rechargeable, voltage on initial construction
    - Zinc-carbon, alkaline-manganese
  - Secondary cell – many times use, rechargeable, charge required on initial construction
    - Nickel-cadmium, nickel-metal hydride, lithium-ion cobalt, lithium-ion manganese, lithium-ion phosphate

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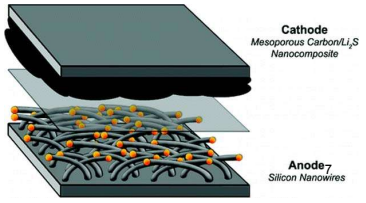
- Batteries
  - Specific Energy
    - Energy per unit mass
      - Mega joules per kilogram (MJ/kg)
      - Watt hours per kilogram (Wh/kg)
  - Energy Density
    - Energy per unit volume
      - Mega joules per liter (MJ/l)
      - Watt hours per liter (Wh/l)



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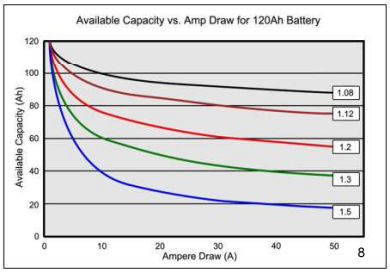
- Batteries
  - Capacity
    - The amount of charge the battery produces at a given discharge rate
      - Amp-hours (A-H)
      - Milli amp-hours (mA-H)



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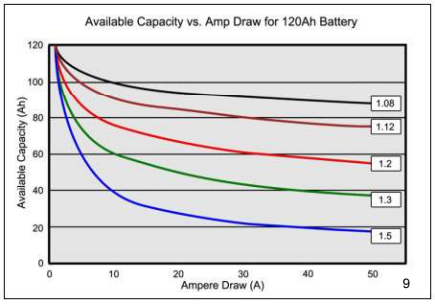
- Batteries
  - Capacity
    - C-Rate – the charge / discharge rate required to achieve battery capacity rating
    - Capacity = 1000mAh @ 25mA
      - 1C-rate = 25mA
      - 2C = 50mA
      - 0.5C = 12.5mA



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- Batteries
  - Internal Resistance
    - The resistance within a source to current flow, resulting in a voltage drop across the source.
    - Increased at high currents
  - Measurement
    - Full load voltage minus no load voltage divided by full load current

$$R_{CI} = \frac{V_{NL} - V_{FL}}{I_{FL}}$$

Where;
R_{CI} = cell internal resistance
V_{NL} = no load voltage
V_{FL} = full load voltage
I_{FL} = full load current

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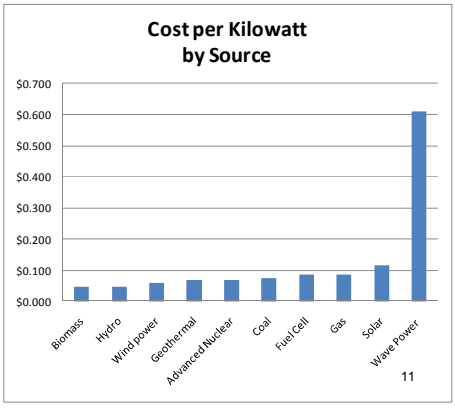
- Batteries
  - Energy Cost
    - Cost per unit power
      - Dollars per megawatt ($/MW)
      - Dollars per kilowatt ($/kW)
      - Cents per watt ($/W)



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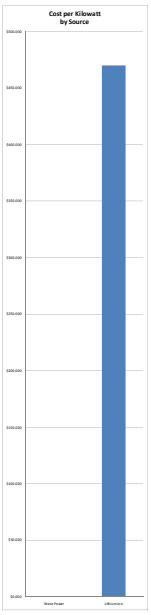
- Batteries
  - Energy Cost
    - Cost per unit power
      - $470,000 per megawatt
      - $470.00 per kilowatt
      - 47 cents per watt



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- Batteries
  - Chemistry
    - *Zinc-carbon* – primary cell, 1.5V/cell, 36 Wh/kg, low cost, high internal resistance at high current
    - *Alkaline-manganese* – primary cell, 1.5V/cell, 160 Wh/kg, internal resistance 150mΩ

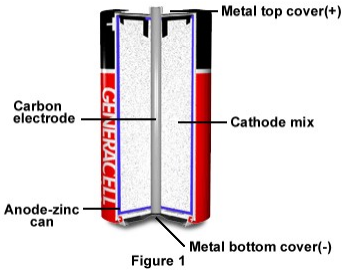

Figure 1

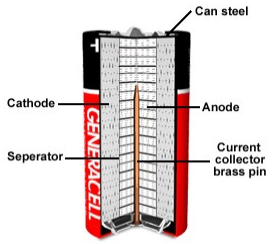

Figure 1

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- Batteries
  - Chemistry
    - *Lead* Acid – secondary cell (300 cycles) , 2V/cell, 50 Wh/kg, 100mΩ internal resistance, excellent specific power (cold cranking amps), low cost, ***highly toxic waste***!

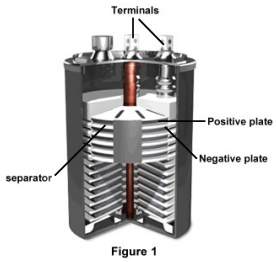

Figure 1

Figure 2

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- Batteries
  - Chemistry
    - *Nickel cadmium* – secondary cell (1000 cycles), 1.2V/cell, 80 Wh/kg, 200mΩ internal resistance, 1000+ charge cycles, memory effect, ***highly toxic waste!***

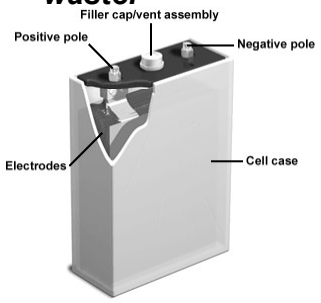
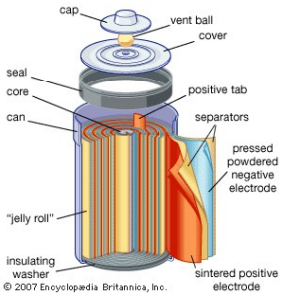


Figure 1



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- Batteries
  - Chemistry
    - *Nickel-metal-hydride* – secondary cell (500 cycles), 1.2V/cell, 120 Wh/kg, 300 mΩ internal resistance, poor high load performance, reduced memory effect, ***low toxicity!***

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- Batteries
  - Chemistry
    - *Lithium-ion Cobalt* – secondary cell, 3.6V/cell, 190 Wh/kg, 300 mΩ internal resistance, poor high load performance, no memory, over current protection mandatory

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- Batteries
  - Chemistry
    - *Lithium-ion Manganese* – secondary cell (1000 cycles), 3.8V/cell, 135 Wh/kg, 75 mΩ internal resistance, excellent high load performance, no memory, over current protection mandatory

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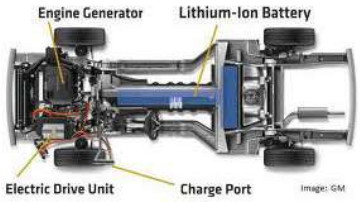
Mechatronics
Real Skills Real Jobs

- Batteries
  - Chemistry
    - *Lithium-ion Phosphate* – secondary cell (2000 cycles), 3.3V/cell, 120 Wh/kg, 50 mΩ internal resistance, superior high load performance, over current protection mandatory



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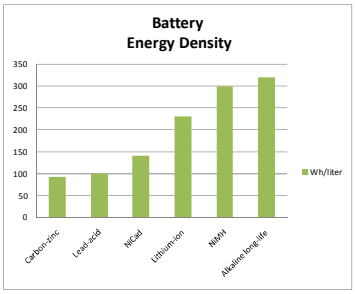
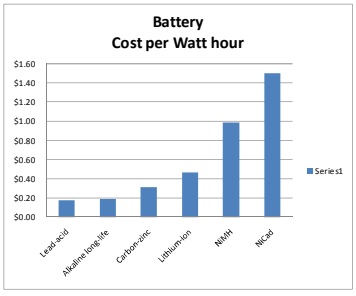
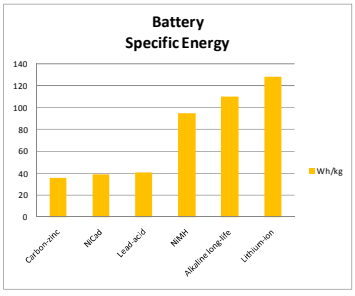
- Batteries
  - Selection
    - Cost per Watt Hour
    - Energy per Kg
    - Energy per Liter







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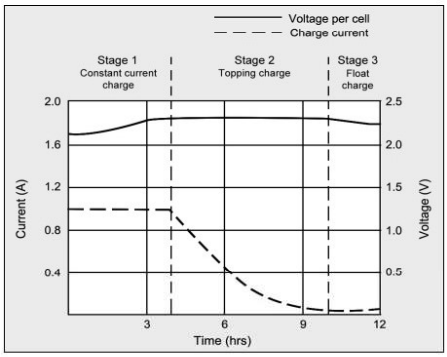
- Batteries
  - Lead Acid Charging
    - 12-16 hour charge time
      - Stage 1 – 1C constant current charge with voltage sensing
      - Stage 2 – topping charge, voltage controlled current reduction
      - Stage 3 – float charge, self-discharge loss



Stage 1
Voltage rises at constant current

Stage 2
Voltage peaks, current decreases

Stage 3
Float charge compensates for self-discharge. Voltage is lowered

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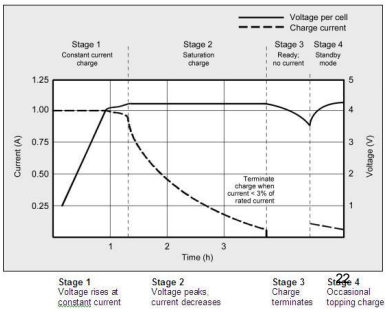
- Batteries
  - Lithium Charging
    - 3 hour charge time
      - Stage 1 – 0.5C constant current with voltage rise to cell max voltage
      - Stage 2 – saturation charge, voltage controlled current reduction
      - Stage 3 – charge terminates
      - Stage 4 – standby topping



Stage 1
Voltage rises at constant current

Stage 2
Voltage peaks, current decreases

Stage 3
Charge terminates

Stage 4
Occasional topping charge

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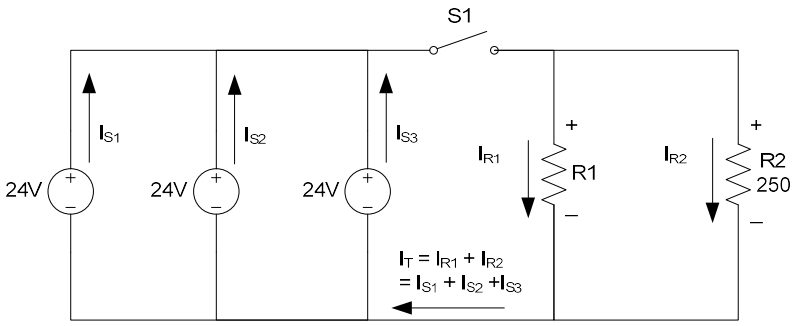
- Parallel Circuits
  - **Sources in Parallel** – parallel connected power sources are current adding



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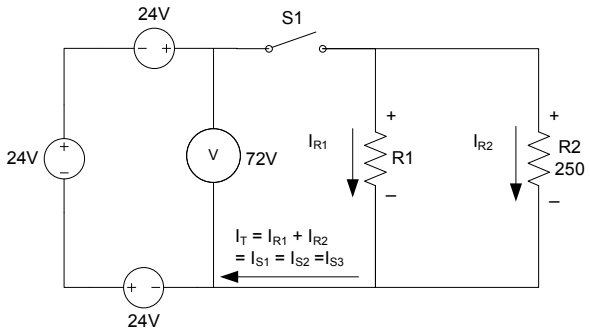
- Parallel Circuits
  - **Sources in Series** – series connected power sources are voltage adding



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Real Skills Real Jobs

- Uninterruptible Power Supplies
  - **Emergency power –** to critical loads
    - Computers, PLC's, bio-medical, telecommunications
  - **Equipment protection**
    - Over / under voltage
    - High frequency noise
    - Harmonic distortion

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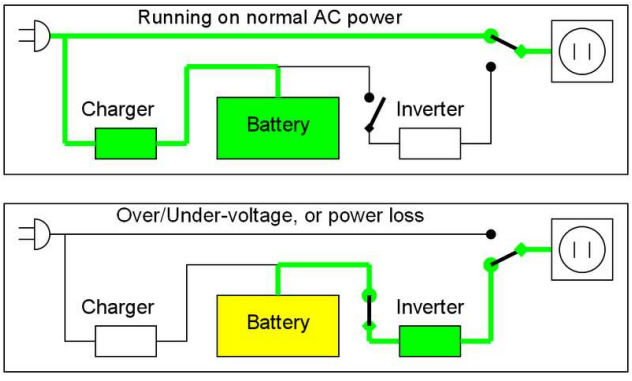
- Uninterruptible Power Supplies
  - **Offline**



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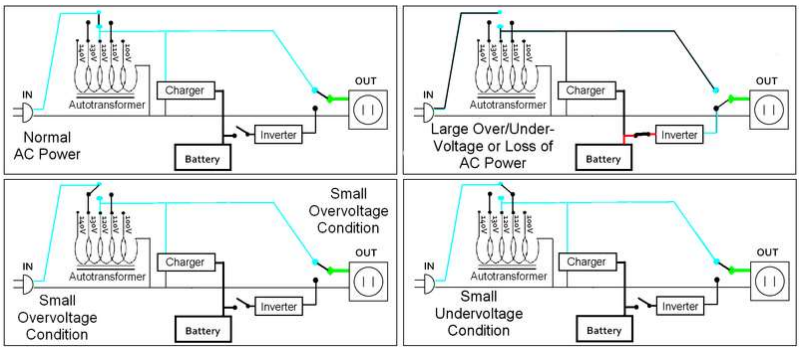
Real Skills Real Jobs

- Uninterruptible Power Supplies
  - **Line interactive** – over / under voltage protection



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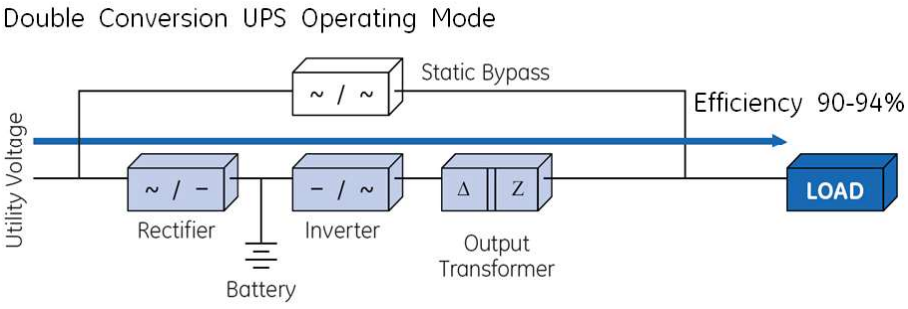
- Uninterruptible Power Supplies
  - **Online / Double conversion** – electrical isolation



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- Lab 09 – Batteries

Learning Objectives

- Build a wet cell battery from dissimilar metals and electrolyte
- Connect batteries in voltage adding and current adding configuration
- Measure electrical values using a digital voltmeter
- Use Ohm's Law to calculate cell internal resistance

Determine battery current capacity with a load test

		Points Possible
Documentation	Quality of documentation (neatness, clarity, spelling, grammar), Expected and measured values recorded on schematic diagram	**10**
Wet Cell	Voltage data points recorded in data table	**5**
	Voltage and load resistance data shown on scatter plot	**5**
Dry Cell	Voltage and current data points recorded in data table	**10**
	Voltage, current and load resistance data shown on scatter plot	**10**
Conclusions	Questions answered completely & accurately	**10**
	Total	**50**

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