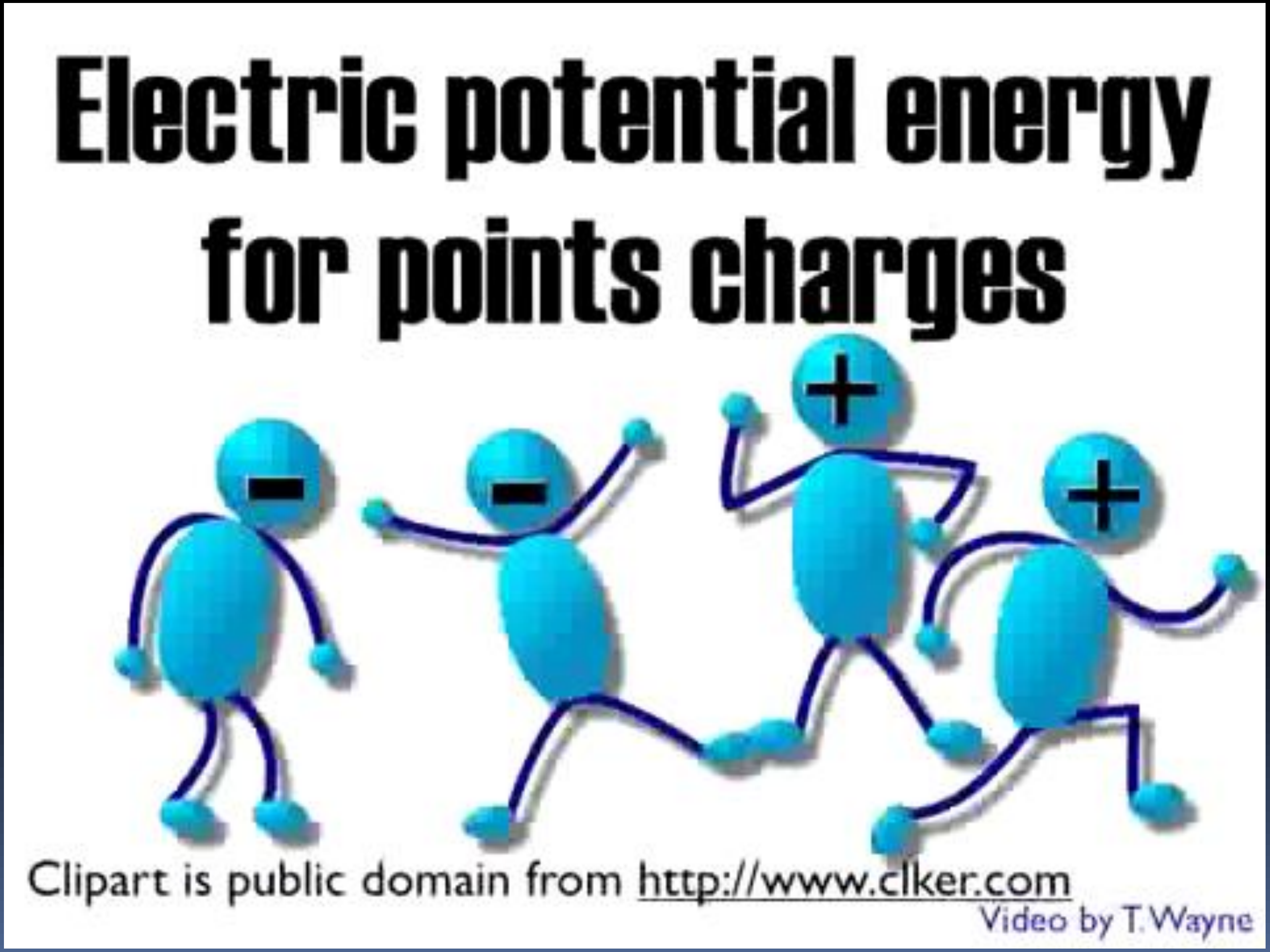
DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS

IB PHYSICS

LSN 5-3: ELECTRIC CELLS

Review Video: Electric Potential Voltage



In the last lesson we learned:

- The definition of electric current, $$I = \frac{\Delta Q}{\Delta t}$$
- The definition of electric resistance, $$R = \frac{V}{I}$$
- That metallic conductors at constant temperature satisfy Ohm's Law, $$I \propto V$$

In the last lesson we learned:

- That the potential drops as one moves across a resistor in the direction of the current
- That a resistor dissipates power, $P = VI$

Essential idea:

- Electric cells allow us to store energy in a chemical form.

International-mindedness:

- Battery storage is important to society for use in areas such as portable devices, transportation options and back-up power supplies for medical facilities

Theory of knowledge:

- Battery storage is seen as useful to society despite the potential environmental issues surrounding their disposal.
- Should scientists be held morally responsible for the long-term consequences of their inventions and discoveries?

Understandings:

- Cells
- Internal resistance
- Secondary cells
- Terminal potential difference
- Electromotive force (emf)

Applications and skills:

- Investigating practical electric cells (both primary and secondary)
- Describing the discharge characteristic of a simple cell (variation of terminal potential difference with time)

Applications and skills:

- Identifying the direction of current flow required to recharge a cell
- Determining internal resistance experimentally
- Solving problems involving emf, internal resistance and other electrical quantities

Guidance:

- Students should recognize that the terminal potential difference of a typical practical electric cell loses its initial value quickly, has a stable and constant value for most of its lifetime, followed by a rapid decrease to zero as the cell discharges completely.

Data booklet reference:

$$\varepsilon = I(R + r)$$

Aims:

- **Aim 6:** experiments could include (but are not limited to): investigation of simple electrolytic cells using various materials for the cathode, anode and electrolyte; software-based investigations of electrical cell design; comparison of the life expectancy of various batteries

Aims:

- **Aim 8:** although cell technology can supply electricity without direct contribution from national grid systems (and the inherent carbon output issues), safe disposal of batteries and the chemicals they use can introduce land and water pollution problems

Aims:

- **Aim 10:** improvements in cell technology has been through collaboration with chemists

Utilization:

- The chemistry of electric cells (see *Chemistry* sub-topics *9.2* and *C.6*)

Introductory Video: Why Charges Move

Emf (ε)

- Charges will not move in a conductor unless there exists an electric potential created by an *electromotive force (emf)* providing the energy
  - Resistance
  - Superconductors are an exception
- Since the electrons must be ‘pushed’ from the positive terminal to the negative terminal, work must be done on the electrons

Emf (ε)

- Emf sources
  - battery - converts stored chemical energy into electrical energy
  - generator – converts mechanical energy into electrical energy
  - thermocouple – converts thermal energy into electrical energy
  - photoelectric material – converts solar energy into electrical energy

Batteries: Practical Source of Electric Current

Emf (ε)

- Electromotive force (emf, **ε**) is equal to the total work done in moving a unit charge completely around a circuit

$$\varepsilon = \frac{W}{q}$$

- Unit for emf is the volt (V, J/C)

Emf (ε)

- Emf can also be defined as the total power generated by the voltage source per unit current

$$\varepsilon = \frac{W}{q}$$

$$P = \frac{W}{t}, Pt = W$$

$$\varepsilon = \frac{Pt}{q}$$

$$I = \frac{q}{t}, \frac{1}{I} = \frac{t}{q}$$

$$\varepsilon = \frac{P}{I}$$

Emf (ε)

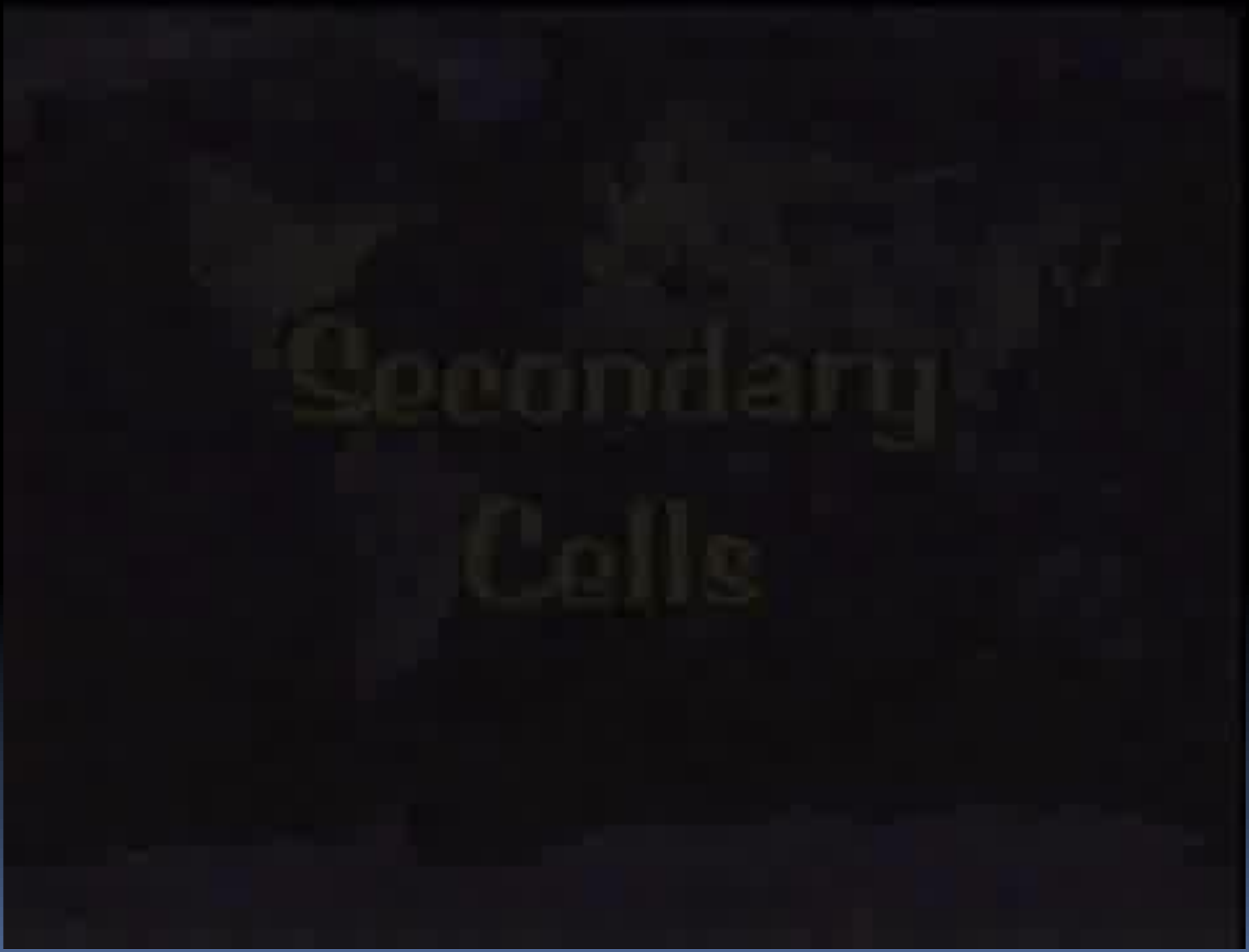
- Chemicals inside the battery create a small amount of resistance (*r*) which is the ***internal resistance*** of the battery
- The total emf is reduced by the internal resistance of the battery, thus the potential of the battery is

$$\varepsilon = IR + Ir$$

$$V = \varepsilon - IR$$

- Thus, the potential of a battery is always less than the emf of the battery

Secondary Cells

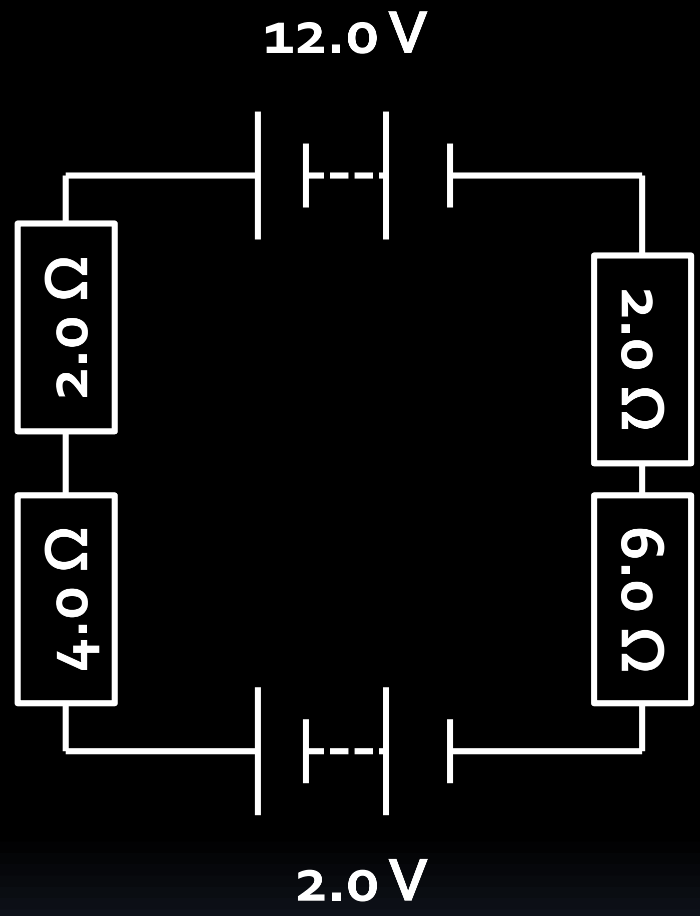


Secondary Cells

- Primary cells are those that can only be used once
- Secondary cells can be recharged
- In circuit analysis, the potential of a recharging cell is subtracted from the emf

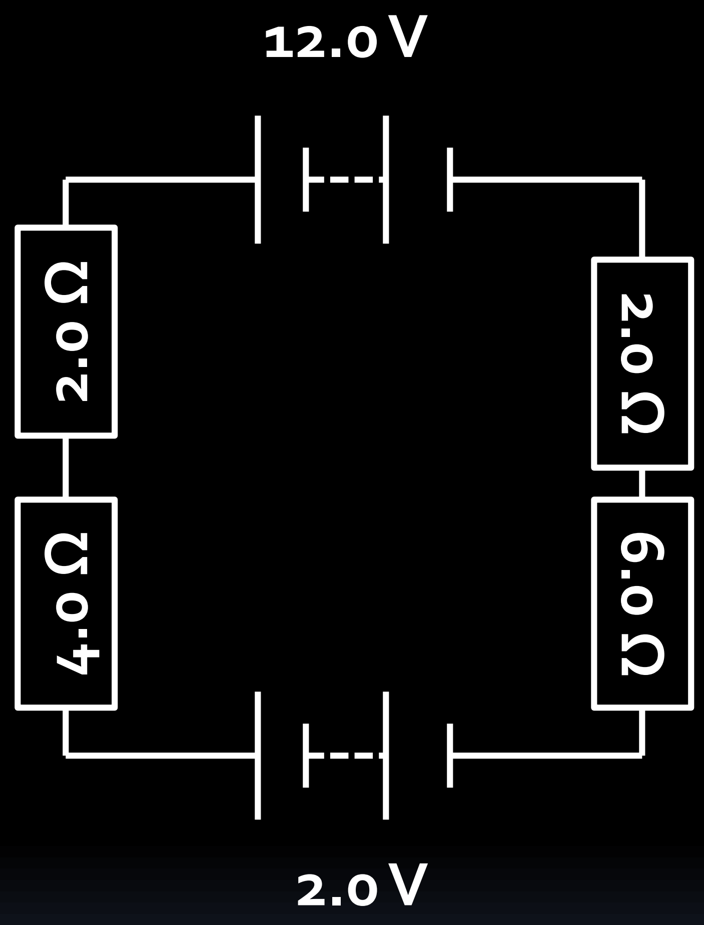
Secondary Cells

- *Is this circuit drawn correctly?*



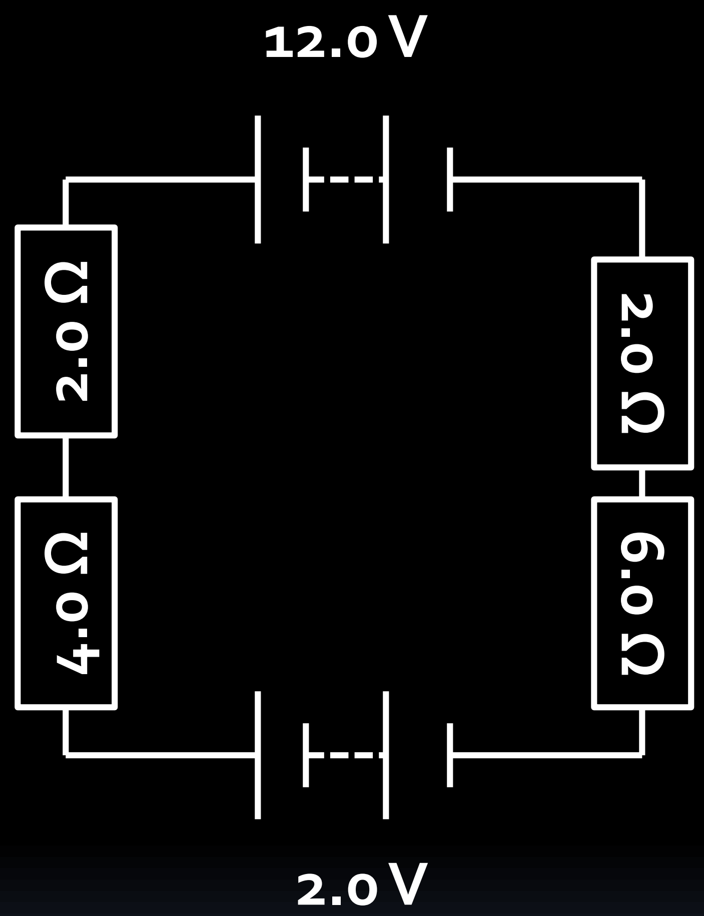
Secondary Cells

- *Is this circuit drawn correctly?*
  - *While it appears the currents from the two cells are flowing in opposite directions, the reality is that one cell is being used to recharge the other.*



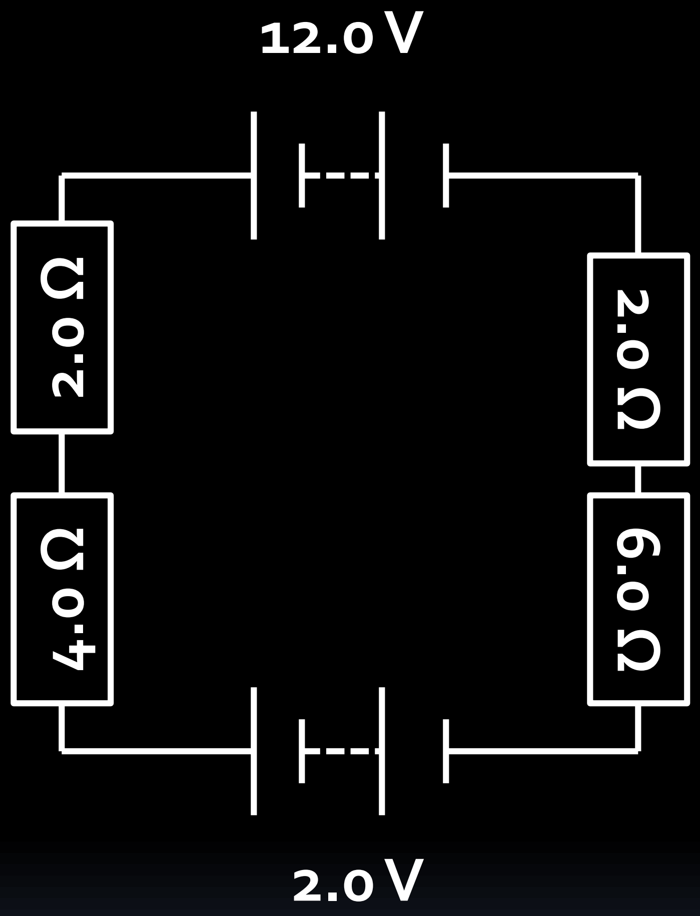
Secondary Cells

- *Which cell is being charged?*



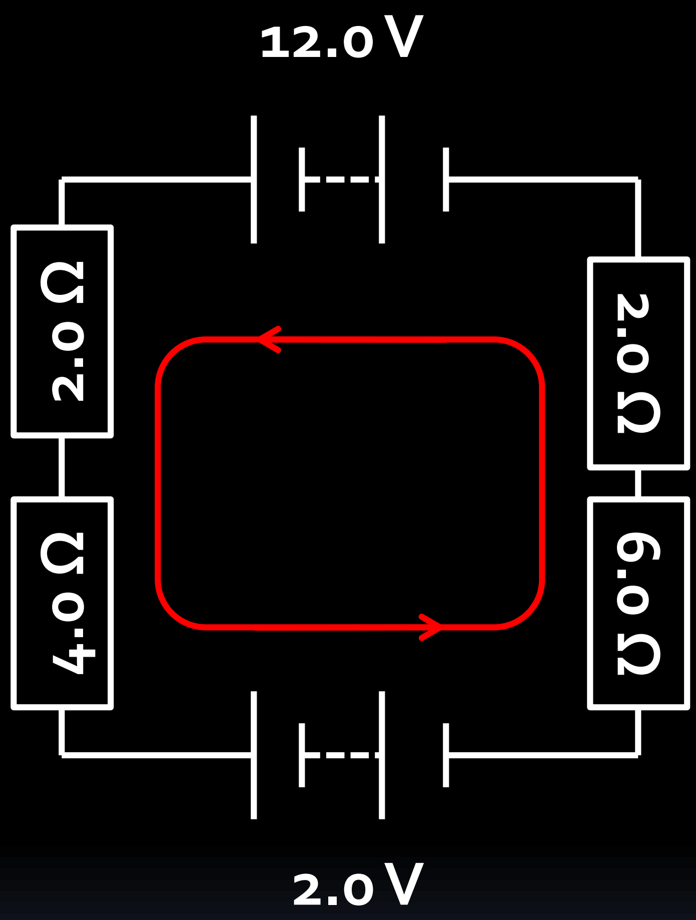
Secondary Cells

- *Which cell is being charged?*
  - *The 2-V cell*
- *What will be the direction of the current?*



Secondary Cells

- *Which cell is being charged?*
  - *The 2-V cell*
- *What will be the direction of the current?*
  - *Counter-clockwise*
- *What is the current in this circuit?*



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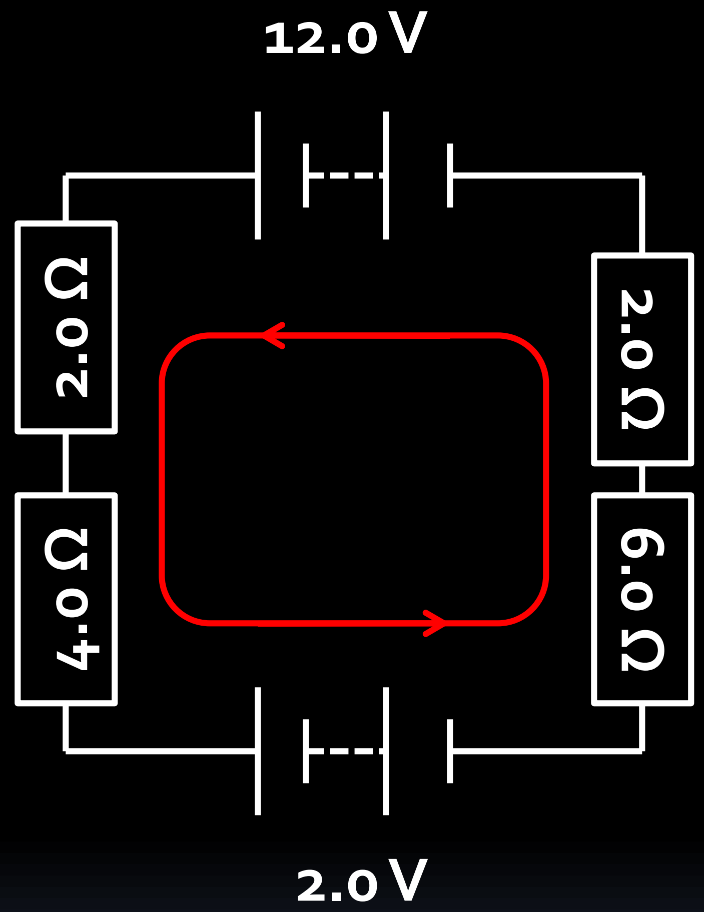


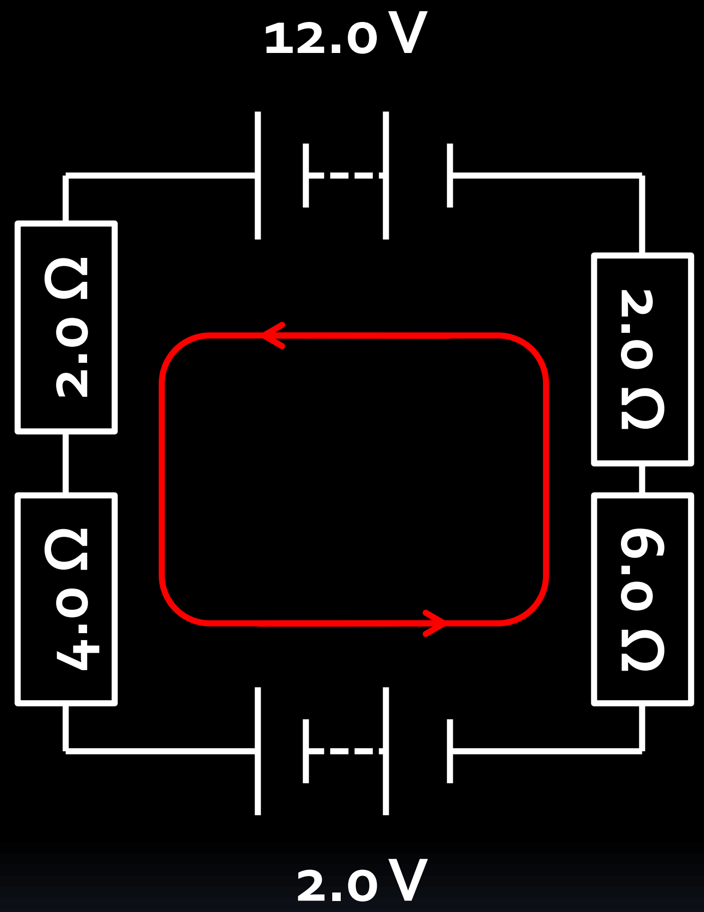
$$\Sigma V = +12 - 2I - 4I - 2 - 6I - 2I = 0$$

$$14I = 10$$

$$I = 0.71$$

Secondary Cells

- *How much power is being used to charge the 2.0 V cell?*



$$I = 0.71$$

Secondary Cells

- *How much power is being used to charge the 2.0 V cell?*

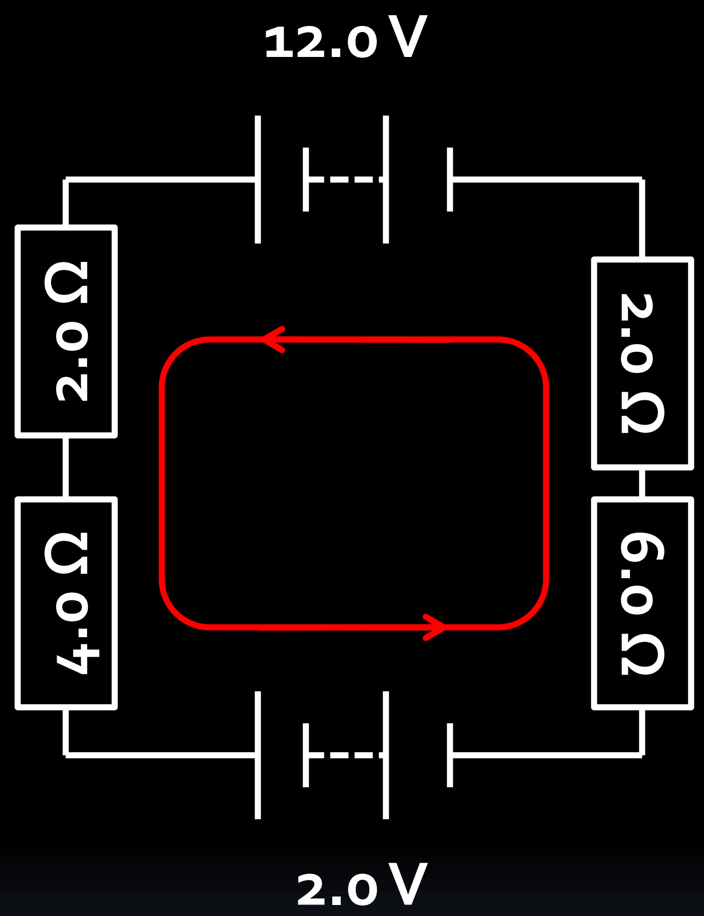
$$P_{tot} = \varepsilon I = (12)(0.71)$$

$$P_{tot} = 8.57W$$

$$P_{res} = R_{tot} I^2 = (14)(0.71)^2$$

$$P_{res} = 7.14W$$

$$P_{chg} = 8.57 - 7.14 = 1.43W$$

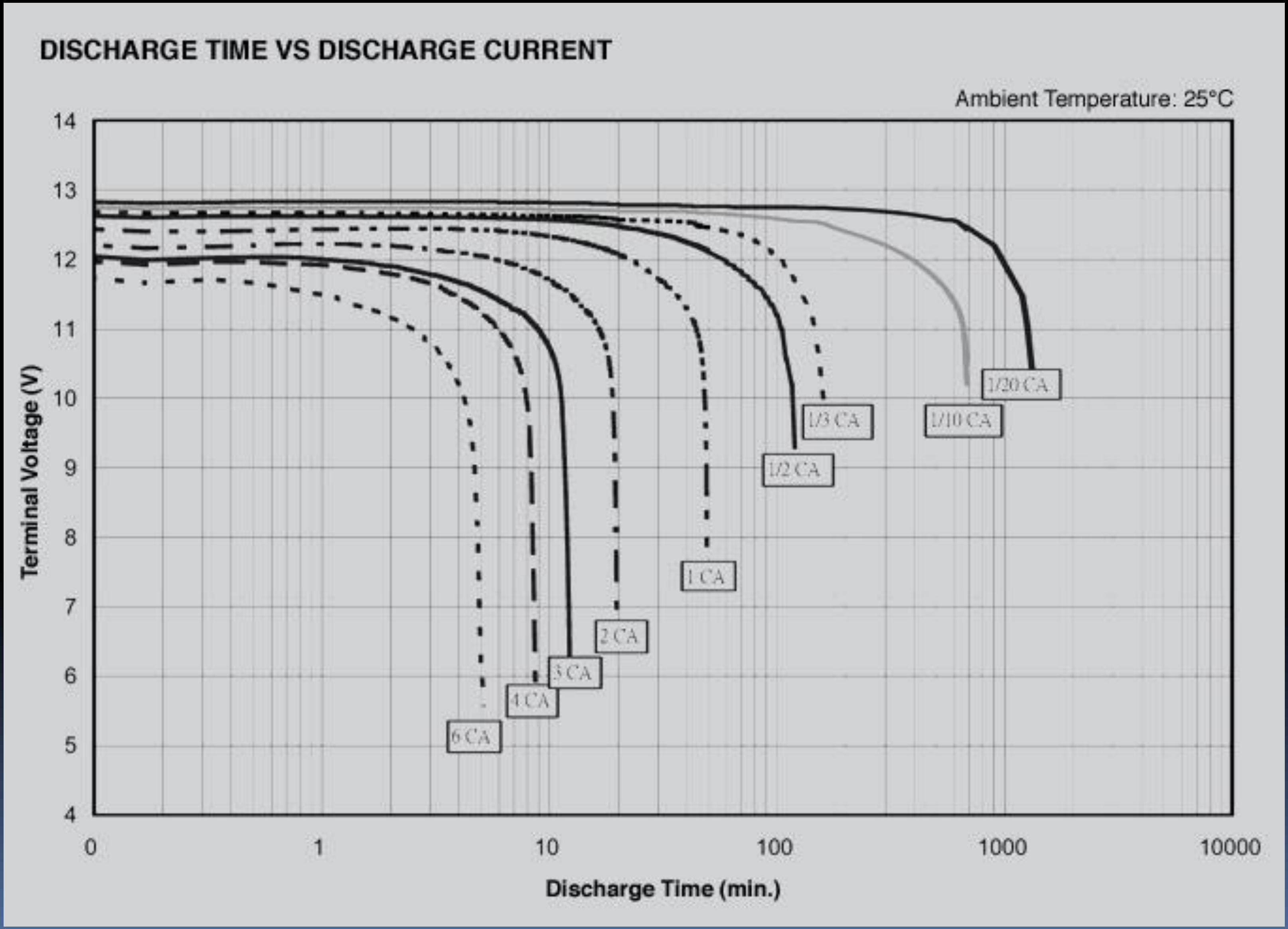


$$I = 0.71$$

Battery Discharge Rates

- Highly dependent on amount of current
- General trend in terminal voltage:
  - Initial drop
  - Generally constant
  - Quick drop-off

Discharge Rate – Car Battery



RadioShack Engineering Data Sheet

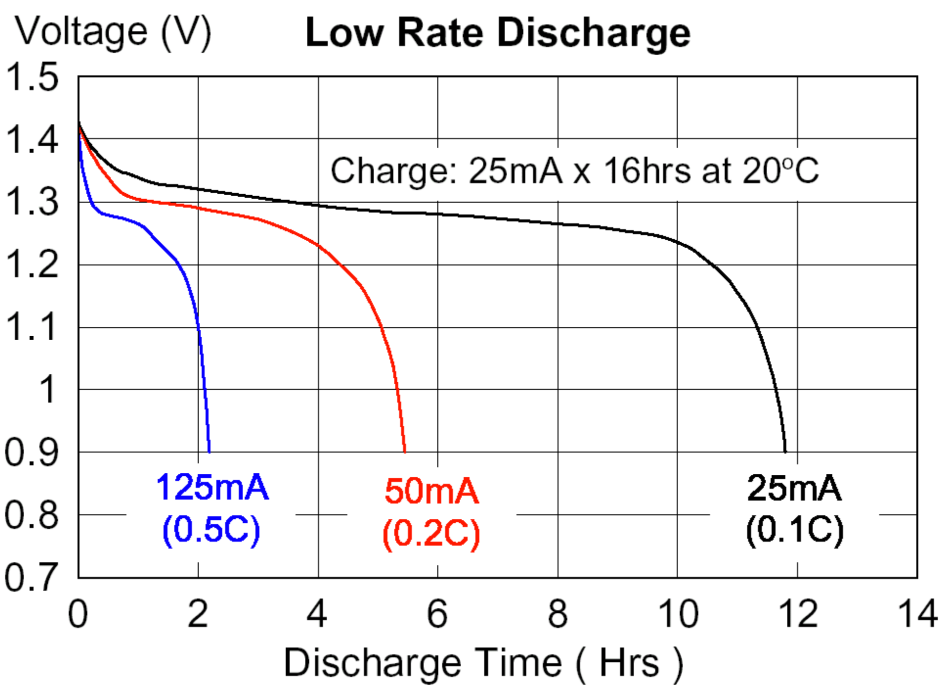
Standard Ni-Cd "AAA"
Catalog Number 23-127

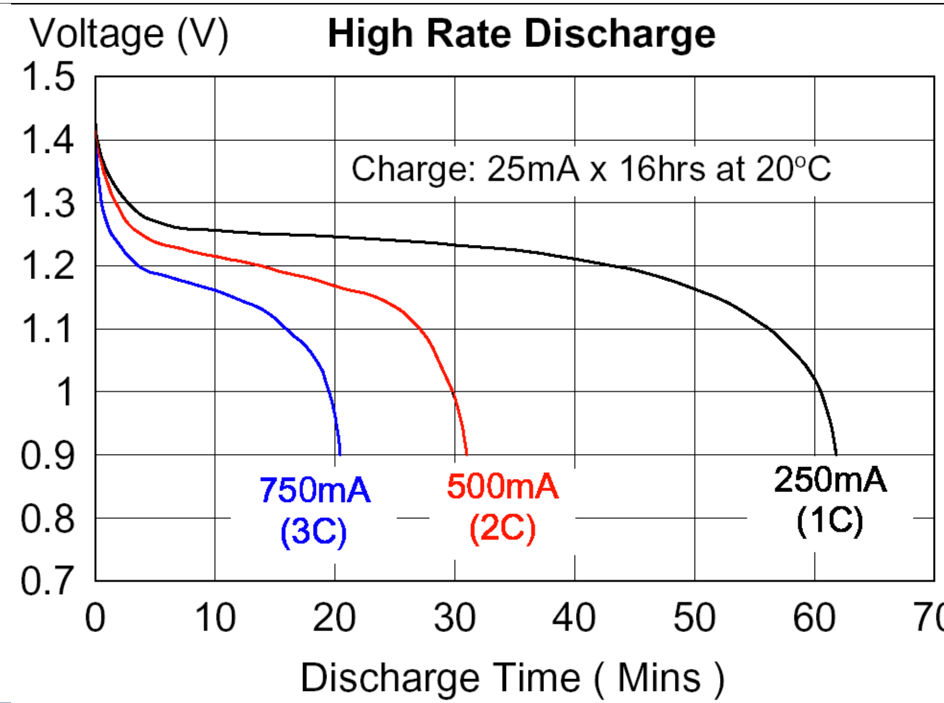
Chemical System: Nickel-cadmium
Designation: "AAA"
Battery Voltage: 1.2 Volts
Internal Impedance: <= 80 milliohms when fully charged
Capacity: 250 mAh (Minimum)
Average Weight: 10.0 grams (0.353 oz)
Service Life: >500 cycles
Temperature Range:
- **Standard Charging:** 32° to 114° F (0° to 45° C)
- **Fast Charging:** 50° to 113° F (10° to 45° C)
- **Discharging:** -4° to 122° F (-20° to 50° C)
- **Storage:** -4° to 95° F (-20° to 35° C)

Discharge Cut-off Voltage: 1.0 Volts
Maximum Discharge Current: 750 mAh (3 C)
Charge Retention: >= 187.5 mAh after 28 days
Charging Condition: 25 mA for 16 hours at 20° C
Max Charging Voltage: 1.5V at 25 mA charging
Continuous Overcharge: 25 mA maximum current for 1 year
Trickle Charge: 12.5 ma (0.05 C) - 25 ma (0.1 C)
Fast Charge: 125 mA (0.5 C) to 250 mA (1 C)

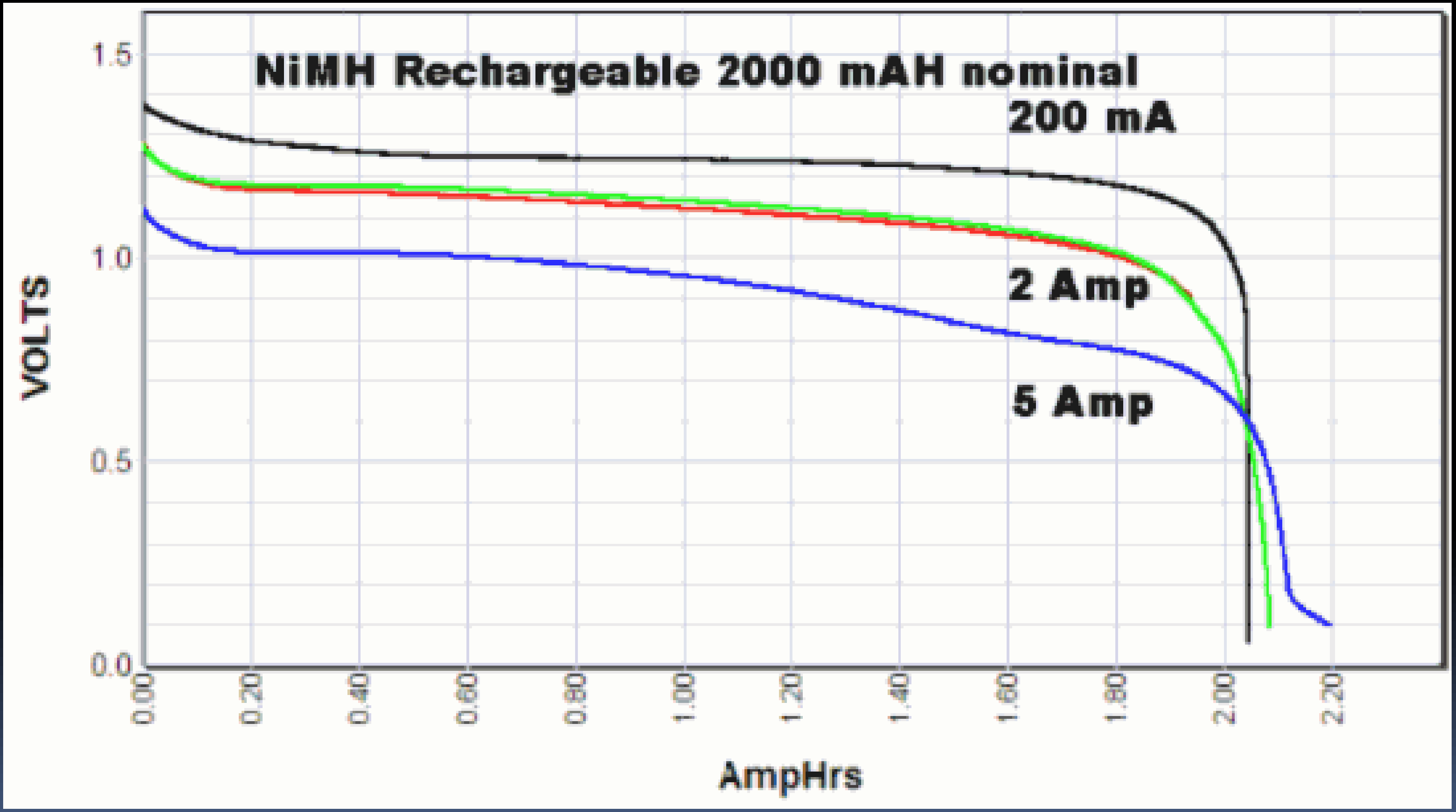
Requires charge termination control.
Recommended Control Parameters:

-delta V: 10 - 20 mV.
Timer: 120% nominal input





Discharge Rate – Secondary Cell



Nature of Science / TOK

- Consumers want:
  - Longer battery life
  - Quicker recharge rates
  - Longer batter longevity
- Battery hazards
  - Mercury, lead-acid, and cadmium are toxic
  - Lithium batteries can create intensely hot fires
  - Unused lithium batteries provide a convenient source of lithium metal for use as a reducing agent in methamphetamine labs

Nature of Science / TOK

- *How do we balance consumer desires with social and ecological responsibility?*

Applications and skills:

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Understandings:

- Cells
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- Electromotive force (emf)

Essential idea:

- Electric cells allow us to store energy in a chemical form.

QUESTIONS?

Homework

#30-36

STOPPED HERE 4/22/15