Cornell Center for Materials Research
Research Experience for Teachers 2002

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CURRICULUM PROJECT

SUMMARY

Regents Physics
A Material Science extension to the *Electricity and Magnetism* unit of the Regents Physics curriculum will be described. This course is mandatory for all 11th grade students at Nardin Academy, although, typically, most schools offer the course as a senior elective.

Current Electricity
Topics will include:
- The discovery of the electron
- Scanning electron microscopes
- Television and computer monitors
- The light bulb
- Current electricity
- Series and Parallel Circuits

Process Skills
These will be cover the New York State Standards listed below:
- Analysis, Inquiry and Design (*standard 1*)
- Information Systems (*standard 2*)
- The Physical Setting (*standard 4*)
- Interconnectedness and Common Themes (*standard 6*)
- Interdisciplinary Problem Solving (*standard 7*)

Support for Cornell Center for Materials Research is provided through NSF Grant DMR-0079992

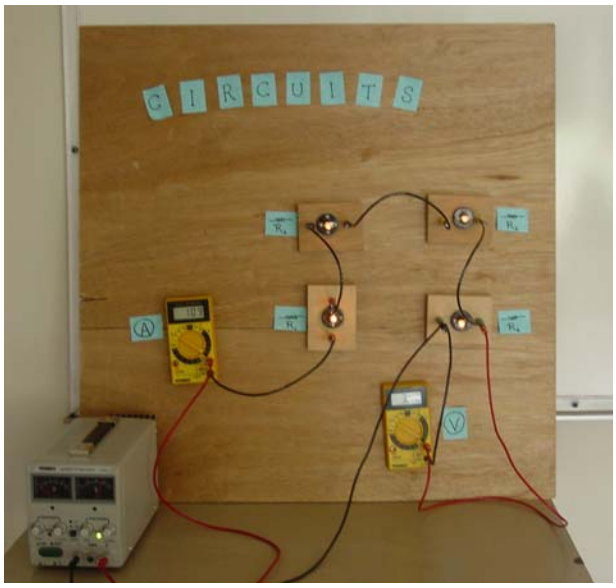
Equipment for demonstrations, activities, and labs

**** FIRE!!**
Steel wool
Wires with alligator clips attached
6- or 9-volt battery
Flame-resistant working surface

**** Making a light bulb**
6-inch piece of braided picture wire, with individual wires separated
Play-doh
Paper clip
connecting wires
6- or 9-volt battery

**** Conservation of Energy**
Miniature light bulbs in sockets
Connecting wires
Hand-cranked generators (2 per group) ("Genecons")

**** Circuit Boards**
(built during RET)



-3 foot square sheet of plywood

-Miniature lamps mounted on velcro-backed blocks of wood

-voltmeter (velcro-backed)

-ammeter (velcro-backed)

- leads with banana plugs

- power supply

** Lie Detector Test
Galvanometer for overhead projector
Two D-cells
Wires

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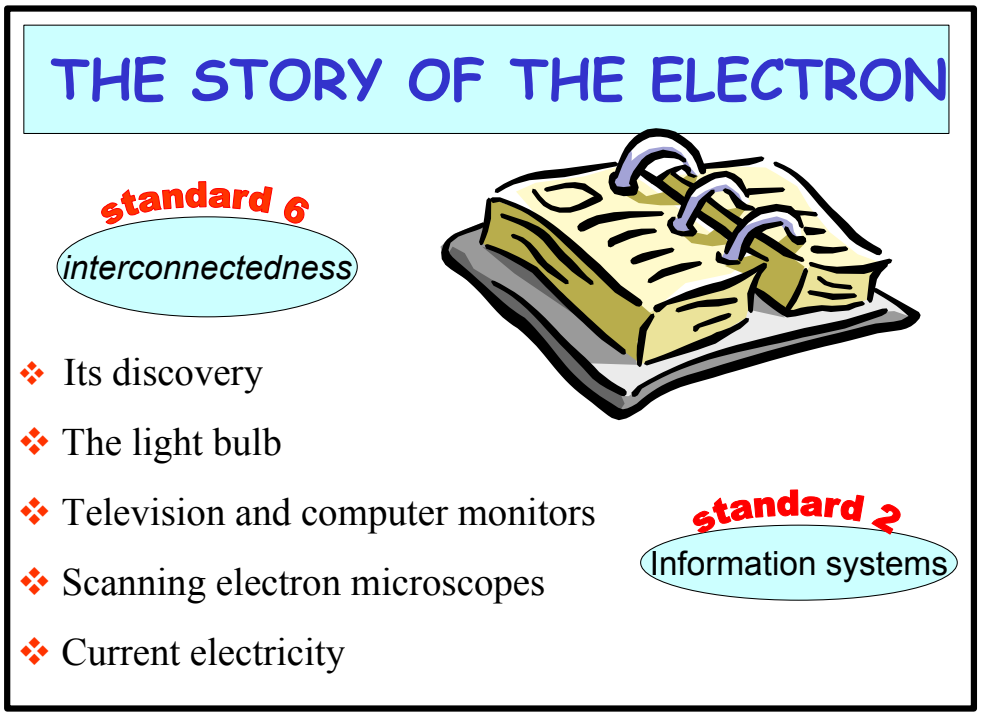
Students will have prior knowledge of the following topics:
Forms of energy
Static electricity and transfer of charge
Unit of charge
Elementary charge
Conductors and insulators
Electric fields
Electric potential
Potential Difference

This project begins with:



1. The Discovery of the Electron (1857)

- J.J. Thomson investigates mysterious glow in cathode ray tube
- Proposes rays are negative "corpuscles" of which atoms are composed
- Plum-pudding model of atom

Homework:
Bake plum pudding…or raisin or blueberry muffins
Internet research on Thomson

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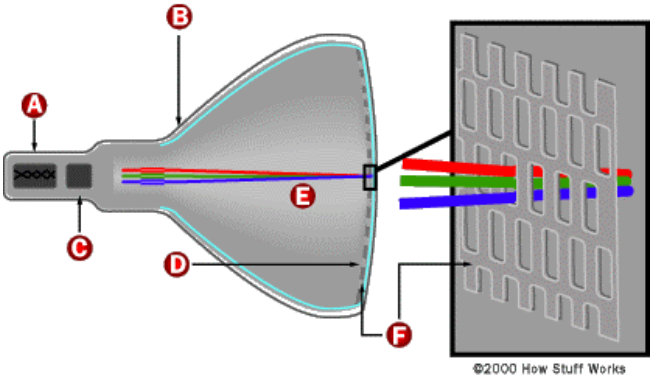
2. Invention of Television

- 14-year old Philo T. Farnsworth inspired while plowing field
- Visualized capturing and steering light line by line across a screen
- Used cathode ray tube (similar to that used by Thomson)
- Electrons boiled off cathode, beam scanned by magnetic field



http://www.howstuffworks.com/tv2.htm

3. Scanning Electron Microscopes

- Same technology of electron scanning as used in television
- Electromagnetic field acts as lens to focus electron beam
- FAR greater detail seen than with optical microscopes
- Due to tiny wavelength of electron *(Note: will learn in Modern Physics unit)*
- Electrons interact with sample (*Note: learnt in Modern Physics unit)*
- Interactions detected and turned into micrograph

Homework:
Internet research on SEM; bring in micrograph

4. The Incandescent Light Bulb

- Ability to light up the night had profound effect on civilization
- Light filament similar to cathode in cathode ray tube
- Invented by Thomas Edison (USA) and Sir Joseph Wilson Swan (U.K.)
- Energy transformations: electrical to heat to light
- Review concept of conservation of energy *(see Demo below)*
- *Materials Science connection:* what is used for filament? Why?

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**Demo: Conservation of Energy

Procedure

1. Attach light bulb to Genecon (hand-cranked generator)
2. Turn handle: lamp glows
3. Turn faster: lamp glows brighter
4. Disconnect lamp, connect two Genecons together
5. Turn handle of one: other handle rotates
6. Assign half of class to count number of times teacher turns handle. The rest of the students count number of times handle of second Genecon turns in response.

Observations

Fewer rotations of the attached Genecon

Conclusions

Work must be done to create electricity; energy seems to get lost; discrepancy due to friction; electricity has heating effect

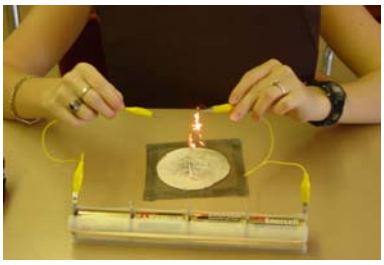
**Activity: FIRE!!

CAUTION: do not have anything flammable nearby.

Equipment: see list on p. 2

Procedure:

1. Connect a short length of steel wool to a 6- or 9-volt battery, using connecting wires with alligator clips.



2. Describe what happens.
3. Why do you think it happened?

Lab: The Light Bulb

Equipment: see list on p. 2

Procedure:

1. Form Play-Doh into 8 cm diameter disk to serve as lamp base
2. Wrap skinny metal wire tightly around paper clip to form filament
3. Remove filament and connect each end to 10 cm connecting wires, stripped at both ends, which serve as the filament supports
4. Push other end of supports through Play-Doh base
5. Cover with jelly jar

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6. Connect supports to 9-volt battery
7. Describe and explain observations

Extensions (Inquiry based)

How could the filament burn brighter? Longer?
Try varying metal properties: thickness, length, type of material, etc.

5. Current Electricity

- Primarily talk about current through metals
- Model microstructure of metals, using marbles in water *(Internet search: micrographs of metal crystals)*
- Metallic bonding *(Chemistry review: "sea" of electrons)*
- Batteries and generators push electrons *(analogy: hair dryer pushes air):* source of potential difference
- Current defined here as rate of flow of electrons through conductor
- Resistance reduces current
- Examine factors affecting resistance
- LABS on: resistance vs. length
  and resistance vs. cross-sectional area
- Ohmic resistors and Ohm's Law: relationship between V, I and R.
- LAB on dependence of current on potential difference
- Electrical power
- Calculate monthly cost of operating any particular electrical appliance
- EXTENSION: semiconductors *(Material Science connection)*
- EXTENSION: superconductivity *(Materials Science connection)*

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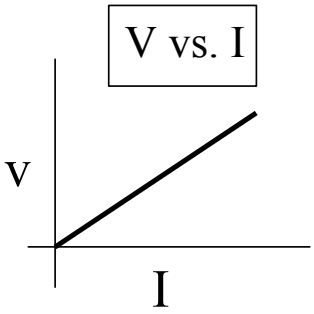
Resistance in Metals

Resistance and Current are Inversely Proportional



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

standard →

Analysis, Inquiry, Design

Wire resistance depends on

- resistivity (ρ)
- length, **L**, of the wire
- cross-sectional area, **A**

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

Resistivities at 20°C	
Material	**Resistivity** (Ω•m)
Aluminum	2.82×10^{-8}
Copper	1.72×10^{-8}
Gold	2.44×10^{-8}
Nichrome	$150. \times 10^{-8}$
Silver	1.59×10^{-8}
Tungsten	5.60×10^{-8}

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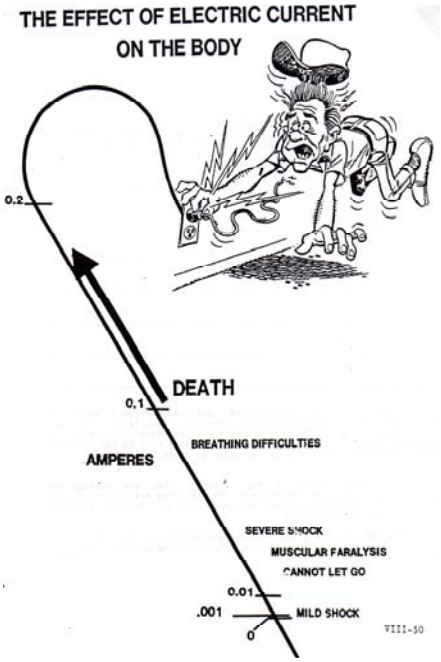
Resistance in People

- Lie detector
- Safety precautions
- Body's resistance



standard >

Address real-life problems

- Measure and compare body's resistance, both dry and wet

Demo: Lie Detector Test

1. Wire volunteer in series with galvanometer (set up on overhead) and one or two D-cells; she must face away from galvanometer
2. Class-mates ask her questions and watch needle on galvanometer
3. Students research polygraphs

- Safety precautions around electricity

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6. Circuits

- Definitions of series and parallel circuits
- Drawing schematic diagrams
- Equations for V, I and R in both series and parallel circuits
- Kirchoff's Laws for charge and voltage
- Household wiring: why parallel?
- Short circuits
- Overloading circuits
- Fuses, circuit breakers, and ground fault interrupters
- Use Circuit Board (*built during RET*) as indicated below
- Students design other labs making use of circuit board
- EXTENSIONS: research Integrated Circuits *(Materials Science connection)*

Activities with Circuit Board

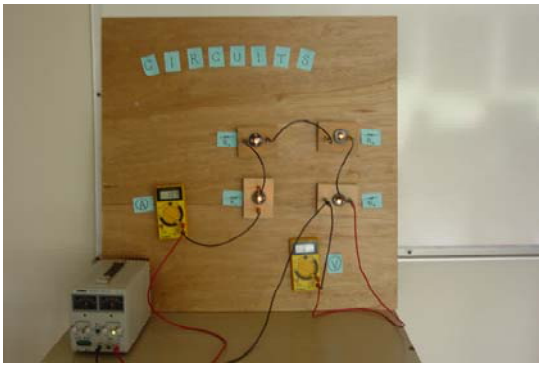
Physics Lab

Demonstrations:

✓ simple circuit, single lamp

✓ lamps in series or in parallel

✓connecting ammeter and voltmeter



White Board Activities

✓ Connect four identical lamps so that two are bright and two are dim

✓ Connect resistors to give desired effective resistance

✓ Add fuse or potentiometer

Lab: Resistors in series and parallel

standard 1

Analysis, Inquiry, Design

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RESOURCES

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- Zitzewitz, Paul, Robert Neff, Mark Davids and Kelly Wedding. *Physics: Principles and Problems.* Columbus: Glencoe McGraw Hill, 1995
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- http://www.matse1.mse.uiuc.edu/~tw/home.html
- http://www.aip.org/history/electron/jjhome.htm
- www.discovery.com/stories/deadinventors/dead980709/deadinventors.html
- http://www.howstuffworks.com/tv2.htm
- http://www.uq.edu.au/nanoworld/semicond.html

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