How could Electricity be taught in the context of Next Generation Science Standards?

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Organization of Talk

I. About NGSS Physics content
   Responses expressed by AAPT Feb 2013 and July 2013

II. Active Physics lead by Arthur Bisenkraft
   Example: Electric circuits (Section 1 & 2)

III. Discussions (electric circuits)
As you are aware, this February, the State of North Dakota will adopt NGSS.

So far, ten states have adopted it, including ND.

AAPT (American Association of Physics Teachers) and APS (American Physical Society) have supported NGSS.

Are we ready?

How to implement it?
I. About NGSS Physical Sciences

- Final version April 2013
- AAPT is one of organizations, that carefully read the content and contributed extensive inputs.

Physical Sciences core ideas: basically from kindergarten to grade 12 there is a gradual build up of performance expectations in four areas.

I. Matter and interaction  II. Motion and stability

III. Energy

IV Waves and their applications in technologies for information transfer
Core Idea PS1: Matter and Its Interactions
   PS1.B: Chemical Reactions
   PS1.C: Nuclear Processes

Core Idea PS2: Motion and Stability: Forces and Interactions
   PS2.A: Forces and Motion
   PS2.B: Types of Interactions
   PS2.C: Stability and Instability in Physical Systems

Core Idea PS3: Energy
   PS3.A: Definitions of Energy
   PS3.B: Conservation of Energy and Energy Transfer
   PS3.C: Relationship Between Energy and Forces
   PS3.D: Energy in Chemical Processes and Everyday Life

Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer
   PS4.A: Wave Properties
   PS4.B: Electromagnetic Radiation
   PS4.C: Information Technologies and Instrumentation
At first glance you will notice that the several critical things are missing from the standard introductory physics.

How about electric circuits?

Geometrical optics?
AAPT’s responses to NGSS

Shortly after the second draft of NGSS became available, AAPT issued the seven page-long letter of response. Basically AAPT was disappointed with the draft. The executive summary is posted at http://www.aapt.org/Resources/policy/upload/AAPT_Summary_of_NGSS_Response_1_February_2013.pdf

Words I can find in that response is “unclear”, “scientifically in accurate”, .. And so on so on. Please read it if you are interested.

One of the comment in that letter was:
“We are concerned that there seem to be almost no standards relating to electric circuits.”
In July 2013 after the final draft became available AAPT issued a letter of support for adopting NGSS.

The American Association of Physics Teachers (AAPT) supports the adoption and implementation of common, nationwide science education standards to provide a coherent science and engineering education program for all K-12 students, not just those aiming for science, technology, engineering and mathematics (STEM) careers. The Association supports the NGSS as a guide for the development of assessments for student performance in...
In its second paragraph AAPT says

“We emphasize, however, that the Science Standards are not meant to be a guide for curriculum development. Further work will be required to develop curricula to support students as they prepare for the assessments built on the Science Standards ...”

Important point of the AAPT letter is that NGSS is not yet a guide for the curriculum development. In other words, we need to work further.

Is there any work already done so that teachers can use it?
II. Active Physics: Physics for All

Active Physics: Physics for All (Time to change.com)
A project based inquiry Approach
Arthur Eisenkraft

Textbook organization
There are 9 chapters
Each Chapter consists of 6-10 sections
CH 1 Driving the Roads (Measurement, Motion in 1D, Circular Motion)
CH 2 Physics in Action (Newton’s Laws of Motion, Projectile Motion, Friction, Energy)
CH 3 Safety (Inertia, Newton’s Second Law, Momentum and Impulse)
CH 5 Let Us Entertain You (Waves & Sound, Geometrical Optics)

CH 6 Electricity for Everyone (DC electricity and Thermal Physics)

CH 7 Toys for Understanding (Electricity and Magnetism, Motors, AC Circuits, Electromagnetic Waves, Spectrum)
CH 8 Atoms on Display (Electrostatics, Nucleus, Hydrogen Atom, Wave-particle Model, Nuclear Force, Radioactive Decay, Nuclear Fission and Fusion)
CH 9 Sports on the Moon
<table>
<thead>
<tr>
<th>Electricity</th>
<th>Heat</th>
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<tbody>
<tr>
<td>Conservation of Energy</td>
<td>Heat Energy</td>
</tr>
<tr>
<td>Electrical Efficiency</td>
<td>Heat Energy and Specific Heat</td>
</tr>
<tr>
<td>Energy (E = Pt)</td>
<td>Heat Transfer</td>
</tr>
<tr>
<td>Power (P = VI)</td>
<td>Entropy</td>
</tr>
<tr>
<td>Fuses</td>
<td>Thermodynamics</td>
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<tr>
<td>Generators</td>
<td>Utility bills</td>
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<tr>
<td>Load Limits</td>
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<tr>
<td>Ohm’s Law</td>
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<tr>
<td>Series Circuits</td>
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<tr>
<td>Parallel Circuits</td>
<td></td>
</tr>
<tr>
<td>Resistance, Voltage, Current</td>
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<tr>
<td>Switches</td>
<td></td>
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</tbody>
</table>
Each chapter begins with a description of a scenario and a project.

1. Scenario
2. Your Challenge
3. Criteria for Success
4. Engineering Design Cycle
5. Physics Corner (terms)
Chapter Organization  (Active Physics Chapter 6)

Section format

1. What Do You See?
2. What Do you Think?
3. Investigate
4. Physics Talk
5. Active Physics Plus*
6. What Do You Think Now?

7. Physics Essential Questions
   What does it mean? (articulating physics concepts)
   How do you know? (experimental evidence)
   Why do you believe? (it connects with other physics concepts, understanding physics world)

8. Physics to Go (Homework)
Chapter Organization (Active Physics Chapter6)

Review plus at the end of chapter

1. Physics You Learned (Chapter summary)
2. Physics Chapter Challenge on projects
3. Physics Connections to Other Sciences
4. Physics at Work
5. Physics Practice Test
**Physics Corner**

- Conservation of energy
- Electrical efficiency
- Energy $E = Pt$
- Entropy
- Fuses
- Generators

- Heat energy and specific heat
- Heat transfer
- Load limits
- Ohm’s law
- Parallel circuits
- Power $P = VI$

- Resistance, voltage, and current
- Series circuits
- Simple circuits
- Switches
- Thermodynamics
- Utility bills
Scenario
Imagine you and your team members are part of international group called Homes for Everyone (HFE).

The source of electricity chosen for the project is a 2.4 kW wind generator. Average month energy output is 90KWh (3KWh/day) DC-AC converter needed.

Your Challenge
- Decide which electrical appliances can/should be included to meet the basic needs.
- Making educational instruction how to stay within the power and energy limits.
- Make a wiring diagram.

Standard for Excellence
Engineering Design Cycle
Section 1 Generating Electricity

What Do You Think?

– How is the electricity that you use generated?
– Oil can be used as a source of energy to generate electricity. What other sources of energy can you identify?

Investigate

– Part A: What Electrical Appliances Do you Really Need?
– Part B: Investigating a Closed Circuit
Physics Talk  Generating Electricity

Electrical Circuit

Energy Transformation

Essential Questions, Reflecting on the Section and the Challenge

Physics To GO
Battery voltage is one volt which equals one joule of energy for each coulomb of charge.

One coulomb of charge just received one joule of energy.

I just received one joule of energy from that coulomb of charge.
Voltage (volts)
Joule of energy /Coulomb
Current (ampere)

**Round 3**: (vary voltage, current = 1A)
**Round 4**: (voltage = 1V, vary current)
<table>
<thead>
<tr>
<th>Electron Shuffle</th>
<th>Electrical Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>bag of pretzels</td>
<td><strong>battery</strong></td>
</tr>
<tr>
<td>students delivering pretzels</td>
<td><strong>charges</strong></td>
</tr>
<tr>
<td>students receiving pretzels</td>
<td><strong>light bulb</strong></td>
</tr>
<tr>
<td>number of pretzels</td>
<td>voltage (1 V = 1 J/C)</td>
</tr>
<tr>
<td>number of students passing a point every second</td>
<td>current (1 A = 1 C/s)</td>
</tr>
<tr>
<td>number of pretzels per second received by the student(s)</td>
<td><strong>Power-brightness of bulb</strong></td>
</tr>
<tr>
<td></td>
<td>(1 W = 1 J/s)</td>
</tr>
</tbody>
</table>
What Do you Think Now?

- What is electricity and how does it move through a circuit?
- Reflecting on the section and the Challenge
- Physics to GO

Section 3 Series and parallel Circuits
Section 4 Ohm’s law: Putting up a Resistance
Section 5 Electric Power: Load Limit
Section 6 Current, Voltage, and Resistance in Parallel and Series Circuits: Who is in Control?
Section 7 Laws of Thermodynamics: Too Hot, Too Cold, Just Right

Section 8 Energy Consumption: Cold Shower

Section 9 Comparing Energy Consumption: More for Your Money
III. Discussions

- Quick Review on CASTLE (Capacitor Aided System for Teaching & Learning Electricity) Basics Section 1 through 4 (Series circuit)

- CASTLE vs. the approach by Active Physics Chapter 6
  ---Advantages and disadvantages of the two models
III. Discussions

Quick Review on CASTLE
(Capacitor Aided System for Teaching & Learning Electricity)

1. What is moving in the wire?

A series circuit

What is moving?
Which direction is it moving?
Circuit (unbroken loop of electrical components)
Quick Review: CASTLE

2. What do the bulbs do to moving charge? (series circuit)

Flow rate (electric current) and number of bulbs (resistors)

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Figure 2.2a
ONE ROUND BULB

Figure 2.2b
TWO ROUND BULBS

Figure 2.2c
THREE ROUND BULBS
Quick Review: CASTLE

3. Where does the moving charge originate?

Fluid model

Capacitor charging and discharging

Figure 3.9a NORMAL AIR CAPACITOR

Figure 3.9b CHARGED AIR CAPACITOR
Quick Review: CASTLE

How is charge different from energy?
Quick Review: CASTLE

4. What makes charge moving in a circuit?

Potential Difference Across a capacitor
Quick Review: CASTLE

4. What makes charge moving in a circuit?

How can we visualize potentials (pressure level) in a circuit?

Color coding for electric potential in a circuit

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Highest, Battery (+)</td>
</tr>
<tr>
<td>Orange</td>
<td>Normal (not zero) pressure</td>
</tr>
<tr>
<td>Yellow</td>
<td>Lowest, Battery (−)</td>
</tr>
</tbody>
</table>

[Diagram showing color coding and a simple circuit diagram]
Quick Review: CASTLE

4. What makes charge move in a circuit?

How can we visualize potentials (pressure level) in a circuit?

Color coding for electric potential in a circuit

Figure 4.14a

Figure 4.14b

Figure 4.14c

Figure 4.14d
CASTLE vs. approach by Active Physics  Electron Shuffle

How are they different in terms of approaches?

CASTLE: Systematic.
   In-line to traditional physics
1. What is moving in the wire? (charge is moving in the wire)
2. What do the bulbs do to the moving charge? (flow rate and number of light bulbs)
3. Where does the moving charge originate? (capacitor, genecon, energy transfer)
4. What makes charge move in a circuit? (pressure difference pushes charges to move)

Electron Shuffle (Round 2)
“Battery voltage is one volt which equals one joule of energy for each coulomb of charge”
“Please move along, one coulomb per second is one ampere of current”
Terms and concepts are given as needed. Meaning is developed later and redefined.
Energy and energy transfer first.
CASTLE vs. approach by Active Physics  Electron Shuffle

How are they different in terms of approaches?

The brightness of light bulbs is closely related to the power dissipated
Energy transferred/time. This is clear in the electron shuffle model
Electron Shuffle (Round 2).

In CASTLE the brightness of the bulb is related to flow rate (current) and
pressure difference separately. This may give students the impression
the brightness is related to the pressure difference or flow rate.

Electron shuffle model may be difficult for students to act out in the
model when current is introduced. Also the model may introduce
confusions.

Who gets tired? Charges, light bulbs or battery?

Other thoughts?
Conclusions

- **How can we implement CASTLE under NGSS?**

- **Active Physics** is exciting but drastically different from traditional mode of teaching physics. Under the constraints, is it worth implementing it? There are lots of unknowns. Will the project-type approach work for average classes? We need some sort of pilot study. Is anyone interested? If so, I would love to cooperate.

- **If North Dakota adopts NGSS, we have to work a lot, and cooperation and communication among physics teachers and AAPT is essential.**
Thank you!