Unit Plan

Unit Title: Energy and Electricity

Curriculum Objectives:

Science Understanding

Science Understanding:Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems (ACSSU155)
Science knowledge can develop through collaboration and connecting ideas across the disciplines of science (ACSHE226)

Science as a Human Endeavour

Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world (ACSHE134)

Science Inquiry

•Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS139)
•In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (ACSIS141)
•Use scientific knowledge and findings from investigations to evaluate claims (ACSIS234)

Key Understandings:	Higher Level Ideas:
•Differentiation of force (Newtons), energy (Joules) and power (Joules/s and Watts). •Conservation of energy in systems involving transfer and transformation of energy and its application in electric circuits. •Differentiation and conceptual understanding of voltage, current, and power (as energy x time) in circuits.	•Knowledge of electromagnetic field theory, e.g right hand rule, Kirchoff's Law, Ohm's Law ($I=V/R$), Resistance and conductivity relationships (e.g. $R=pL/A$, calculation of resistance in series and parallel), power relationships ($P=IV=V^2/R=RI^2$). Capacitance and Inductance , diodes, AC circuits. •Familiarity with various mental models of electric and magnetic phenomena, and the advantages and disadvantages of each. •Knowledge of microscopic perspective of charge. •Higher level understandings of Maxwell relationships between electric and magnetic fields.
Outcomes: •Students can describe and interpret energy transformations of various processes. •Students can identify, describe, analyse and design electrical circuits both physically and with circuit diagrams with schematic symbols. •Students perform fair tests and experimentally derive relationship between voltage, current, and resistance (Ohm's law) •Students apply their knowledge to predict behaviour in DC circuits, and theorise on energy transfer in circuits.	**Context & Prior Learning:** Students will likely have basic notions of electricity. Year 6 curriculum concepts: Electrical circuits provide a means of transferring and transforming electricity (ACSSU097) Energy from a variety of sources can be used to generate electricity (ACSSU219) In math, students should have covered plotting linear relationships on the Cartesian plane ... without the use of digital technologies (ACMNA193) **Duration (number of lessons, time, location):** 12 lessons in Clarence High School Science lab. Class meets three times per week.

Formal Assessment Strategies:

The lesson begins with diagnostic assessment and contains formative assessments throughout. Three lessons have summative assessments with criteria and rubrics. In lesson 2, a summative assessment task is presented to introduce students to typical criteria and rubric (and to formatively assess their capability for assignments). Lesson 10 assesses the fair test and experimental derivation of Ohm's Law. The final project (Lesson 11-12) summarises the unit with a design project that applies circuit knowledge, and an energy flow analysis based on power consumption of components.

LESSON 1. Force, Energy, Power	Resources

OUTCOMES: (Diagnostic Assessment)
-- identify and differentiate between force, energy, and power; and recognise the centrality of energy.
--Identify the need for a unit of energy--and recognise the Joule
--Reflect on the higher power needed to run vs. walk qualitatively then quantitatively.

ANTICIPATORY SET
Hook: Begin with “magic” trick light bulb which light with no apparent power source.
Key Question: What is energy?
Explain unit: Energy and Electricity (initially fundamentals).

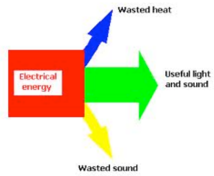
CONTENT
Concepts:
•Concept of Newton as the amount of gravitational force on an 100g apple.
•Concept of Joule as a unit of energy (lifting a Newton 1m, Heartbeat 1J).
•Concept of Watt as unit of power (Joules/second).
1. *Who can tell me what they know about energy?*
Elicit kinds of energy and record on board.
How much energy does it take to walk a kilometer?
How much energy does it take to run a kilometer?
Scaffold need for a unit for energy. Examine chocolate bar-->550KJ/25g. *What's 550KJ mean?* (Scaffold prefix kilo). Scaffold the Joule is a unit of energy. Provide definition as the amount of energy of a force of 1 newton 1 meter. Heartbeat 1J/beat. *How many joules per hour?*
Provide human energy consumption chart and ask to determine what work can be done with consumption of candy bar. Work in pairs. Then, whole class, compare power of walking and running by estimating time for each.
2. Next, compare chocolate bar with energy in AA battery (typically 10KJ). *What has more energy?* Have students look up battery energies and report. Discuss energy density and quality.
3. KWL. Hand out cards with student photos. Questions to write on back:
•What is the meaning of the word energy?
•What do you know about energy? (write at least three things).
•What do you want to know about energy?

PLENARY
Collect KWL cards. Review concepts Newton, Joule, Watt.
Describe subsequent lesson on energy sources and uses.

RESOURCES:

Trick light bulb.
Chocolate Bar.
AA Battery.
Human energy consumption chart.
Student computers.

(Just for fun:)

LESSON 2. Classification of energy, potential and "active" energy	**Resources**
OUTCOMES: (Explore) Brainstorm different types of energy and classify. Students create energy flow diagram for a energy transferring phenomena.	
ANTICIPATORY SET Hook: Flash Paper flame. Key Question: How is energy transferred and transformed? Explain lesson: Consider types of energy. Activate: Popup toys. Have students play, then describe (elastic potential-->kinetic-->gravitational potential-->kinetic.) Heat and sound transformations. Discuss concepts and formative assessment.	Flash paper, lighter. Popup toys and/ or flip-flaps. Global flow diagram.
CONTENT ***Concepts:*** •Energy can transform from one type to another. •Energy can transfer from one place to another. •Some energy degrades or dissipates when transferred or transformed but is still conserved. Efficiency (heat). •Energy Quality and Density concepts. •Energy is the ability to do work (evidence of change). 1. *Today let's brainstorm on types of energy.* Elicit types of energy and record on board, e.g. thermal, electrical, fossil fuel, petrol, solar, elastic, kinetic, acoustic, gravitational, chemical. Scaffold categorising of types of energy--"stored" or "active"--students write in pairs. Next, have students pick one type of energy and draw two cartoons showing the energy transforming into another form--show and describe to class. 2. Introduce concept of energy flow diagrams. Draw simple one on board and ask (example right) and ask what it could be representing. Next, show global flow diagram. Students then pick one of their "stored" energy examples and draw flow diagram of it being transformed. 3. *"Has anyone ever seen a perpetual motion machine?" Why not?* Discuss version of laws of thermodynamics. •First: You can't win.•Second: You can't break even.•Third: You can't quit the game. Show video(s) on perpetual motion (5 min). Discuss frictional and heat losses.	 Video(s) on perpetual motion. Handouts for homework Note: the summative assignment serves two purposes: 1. to prepare students for rubric based summative assessment, and 2. 2. to scaffold the likely choice of an electrical appliance later in unit.
PLENARY Review energy. Announce homework--energy flow diagram of object at home. Scaffold Criteria and Rubric. Questions? Everyone able to do this? Etc.	

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LESSON 3. Energy in Australia	Resources
OUTCOMES: (Explore) General understanding of relative energy generation, transportation, and transformation in Australia and compare relative amounts for household, commercial, mining, and transportation. General idea of MW (e.g. Gordon Dam 430MW capacity). Power vs. Energy. Developments in renewable energy types and overall production. Potential for future renewable sources. Distinction between "energy conservation" and "conservation of energy".	
(Note: draft lesson) This will cover energy use in Australia with facts and figures from the Department of Resources Energy and Tourism. •Discussion on renewables, including an insolation calculation of a large area of inland Australia (and compared to location of grid). Geothermal, hydropower, ocean energy and solar energy discussed. Perhaps a in-class debate. •Discussion of voltage of energy production and transmission. Hints at efficiency (mention future learning of Ohm's Law and idea of $P=IR^2$). Links to electrical consumption and cost of kW, and understanding of how much energy a kW per unit time provides(e.g. 220V toaster).	**Resources:** http://www.ret.gov.au

LESSON 4. Review of basic electricity and multimeter basics.	Resources
OUTCOMES: (Engage) Check student understanding of open vs. closed circuits. Introduction to multimeter for measuring voltage, current, and resistance.	
ANTICIPATORY SET Hook: LED light. Key Question:How does a torch work? (Energy perspective). Explain lesson: Simple circuits and functions of multimeter.	LED light. Video on Electricity (source: http://www.essentialenergy.com.au/content/school-resources)
CONTENT 1.Intro video on Electricity (2.5 min.) Assign groups of 3 and provide groups with battery, wires, resistive bulbs, switch. Allow experimentation. Scaffold completion of circuit (if necessary). 2.Powerpoint on Multimeter use. Prior to handing out multimeters, check for understanding and discuss safety. Parallel for voltage, series for current, range settings and proper inputs, e.g. *Can we measure current of your closed circuit? How?* Formative assessment on Multimeter use. 3. Back to circuit. Students experiment with voltage and current and sketch circuit diagram. Begin scaffolding energy transformations of simple circuits, e.g. *why will the battery eventually run out*? (not "charge"--chemical processes).	Powerpoint presentation on use of multimeter (source: www.technology.heartland.edu) Multimeters per group.

<table>
<tr><th>LESSON 5. Static Electricity and voltage</th><th>Resources</th></tr>
<tr><td colspan="2">OUTCOMES: (Explain)
Voltage as potential difference of charges--”tension” of opposite charges.
Understanding of static electricity and relationship to kinetic electricity.</td></tr>
<tr><td>ANTICIPATORY SET
Hook: Van de Graaff Generator quick demo.
Key Questions:What is “static” electricity?. What is “kinetic” electricity? What are the common features?
Explain lesson: Today we will look at the properties of static electricity.
Activate: why does the sound of lightning occur after flash?</td><td rowspan="3">Van de Graff generator.

More background at http://courses.physics.northwestern.edu/Phyx103/static.html

Examples: lighting strikes 50 times a second (up to 300K A and billion V).

Review lightning safety basics. Story of almost getting hit--dispelling notion of hitting only once.

Sample Leyden design: http://www.wikihow.com/Build-a-Capacitor Containers, aluminum foil, wire, batteries, multimeters.

Van de Graaff how it works: http://www.youtube.com/watch?v=EsZQS2GOMQE</td></tr>
<tr><td>CONTENT
Concepts: Static electricity becomes kinetic when sparked!
Intro Questions: What causes static electricity?
What causes lightning?
How is lightning related to static electricity?
1. Students build Leyden Jar. Charge with battery and measure voltage.
2. Experiment with Van de Graaff generator (e.g.Faraday cage with tinsel). As it’s charging,Is there any current now? Is there voltage?
Video on how Van de Graaff generator works, and Mythbusters video showing 60,000V.
3. Students draw a diagram illustrating the negative and positive charges that occur in a lightning storm and/or when a balloon is rubbed against wool. What happens to the energy when it sparks?</td></tr>
<tr><td>PLENARY
Review students understanding of common static electricity phenomena. Reinforce voltage and charges as “static” but will become kinetic when moving through medium when dialetric (conductor) present.</td></tr>
</table>

<table>
<tr><th>LESSON 6. Voltage in circuits</th><th>Resources</th></tr>
<tr><td colspan="2">OUTCOMES: (explain)
Understanding of voltage across components and its relationship to energy transfer.
Power defined as P=VI (noting oddness of ‘I’ for amperage).
Build circuits from schematic drawings.</td></tr>
<tr><td>ANTICIPATORY SET
Hook: TBD
Key Question: How does voltage change over a component?
Explain lesson: Today we will focus on voltage.
Activate: Ask students what they know about voltage--household, car, computer transformer, etc. What does it mean? Why are they different?</td><td rowspan="3">Video Electric Vocabulary at http://www.youtube.com/watch?v=MBRTR2dlwvA

Additional lesson ideas at http://stelr.org.au

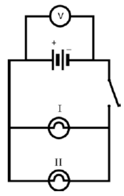


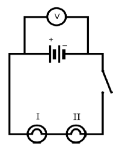
Figure 7.


Figure 5.

Materials for circuits.

Data sheet.

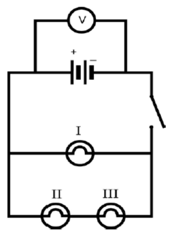


Figure 8.</td></tr>
<tr><td>CONTENT
•What is voltage?
• How is voltage measured?
1. Video on electric vocabulary.
2.Activity: provide two circuit diagrams and ask students to predict which bulbs will burn brighter.
Next, provide materials to build physical circuits and measure voltage at across each bulb and record on data sheet. Scaffold understanding of voltage drops.
3. Provide third circuit diagram (at right and in appendix) and discuss predictions for voltage and brightness of bulbs. Students then test their voltage predictions.
Emphasise energy transfer which can be identified by voltage drops.</td></tr>
<tr><td>PLENARY
Review student data sheets and draw circuit with one bulb but two batteries in circuit. Check for understanding. Link to power (P=VI) and energy (E=VIt), and Watt as Joules/s)
Quiz on circuits (Appendix).</td></tr>
</table>

<table>
<tr><th>LESSON 7. Current in circuits.</th><th>Resources</th></tr>
<tr><td colspan="2">OUTCOMES: (explain)
Current is constant along a given pathway and is conserved at nodes.
Current has a greater tendency to flow along paths of least resistance.
Source current in a circuit is dependent on components of system.
Understanding of light globe as resistor affecting current flow.
Introduce Ohm’s Law as I=V/R and applications in determining current series and parallel circuits.</td></tr>
<tr><td>ANTICIPATORY SET
Hook: TBD.
Key Question:What is electrical current?
Explain lesson: Current</td><td rowspan="3">Video source: http://www.youtube.com/watch?v=apHkG4T6QHM

Additional lesson ideas at http://stelr.org.au

Data sheet.

Materials for circuits, steel wool, heat matts.

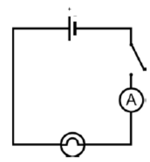


Figure 3.

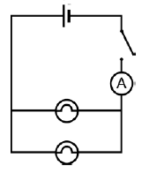



Figure 4.</td></tr>
<tr><td>CONTENT
Video: series and parallel circuits
1. Announce activity: provide two circuit diagrams and ask students to predict which circuit has greater current from the battery.
Next, provide materials to build physical circuits and measure current at critical points and record on data sheet.
2. Provide third circuit diagram and discuss predictions for current. Students then test their predictions.
3. Discuss safety. Students make fuse of steel wool and put in 1.5V circuit, measuring current when battery is first connected. Whole class scaffold connection to household 15A fuses (give example of many items on one plug and introduce Ohm’s law as I=V/R).
4. Discuss relationships of resistance and conductance (and insulators), and further scaffold intuitive meaning of Ohm’s Law and current’s inverse relationship with resistance.</td></tr>
<tr><td>PLENARY AND PRODUCT
Reiterate now we have two equations to help understand circuits (P=VI, and I=V/R)--the first helps us understand energy transfers, and the second helps us understand circuit (as system!) behaviour.
Challenge Activity--(see appendix) to test understanding of current effects. Check for understanding by asking effects of circuit if bulb was replaced by higher wattage bulb (with greater resistance).
Encourage students to examine light globe in detail to see it as a resistor.
If extra time, give quick quiz on circuit symbols (appendix).</td></tr>
</table>

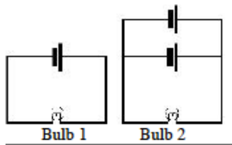
<table>
<tr><th>LESSON 8. Electricity as EMF</th><th>Resources</th></tr>
<tr><td colspan="2">OUTCOMES: (explore)
Introduction to orthogonal associations of electrical and magnetic fields.
Teacher knowledge: Moving magnetic fields generates current, current produces magnetic field, etc.(Maxwell eqns.)</td></tr>
<tr><td>ANTICIPATORY SET
Hook: Lenz Law demo--magnet in metal tube.
Key Question: What are the forces of electricity and magnetism?
Explain lesson: We will explore various EMF concepts.</td><td rowspan="3">Electric jumprope source: http://cse.ssl.berkeley.edu/segwayed/lessons/exploring_magnetism/magnetism_and_electromagnetism/guide_activity3.pdf

50’ extension cord, multimeters.

MIT videos at http://www.youtube.com/playlist?list=PL860B6886A47E5490

Materials for simple motor.
</td></tr>
<tr><td>CONTENT
1. Assign groups of four and provide one multimeter and worksheet (appendix) per group, and go outside to perform electric jumprope experiment in Earth’s magnetic field.
2. Back in class, discuss experiment.
3. MIT videos on EMF. Discuss.
4. Build simple motor (battery, magnet, AA battery) and/or electromagnet.</td></tr>
<tr><td>PLENARY
(note: this lesson is intended as a break from the more cognitively demanding analysis of voltage, current, etc.).

Review concept of current in magnetic field results in physical force (and other EMF relationships of Maxwell’s equations). Discuss induction motors and resource issues with rare-earth magnets and electric cars. Latest developments, (e.g. http://www.plugincars.com/rare-earth-elements-arent-actually-necessary-evs-or-hybrids-107194.html, issues with resource: http://www.economist.com/blogs/babbage/2012/03/rare-earths-and-high-performance-magnets).</td></tr>
</table>

LESSON 9. Batteries in series and parallel. Power concepts.	Resources
OUTCOMES: Comparison of power sources in parallel and in series. Analysis of power consumption (P=VI) based on energy source.	
ANTICIPATORY SET Hook: TBD Key Question: What delivers more electrical power for a given circuit – connecting batteries in series or in parallel? Explain lesson: Experimental investigation.	Lesson informed by lesson plans from http://stelr.org.au 
CONTENT •*Why do most battery-operated electrical devices need more than one battery to work?* • *When batteries are connected together, does the way they are connected make a difference to the voltage or current or power that they deliver?* Sketch circuit on board. Ask, will bulb 2 shine more, less, or equally as bright as bulb 1 (all other components similar). Will it be different if the batteries were hooked up in series? Students perform experiment and provide power calculations for bulbs in each scenario. Discuss. *Did the brightness of the globe seem to relate more to the power or the voltage or the current delivered to it?*	
PLENARY AND PRODUCT Review main topics of unit. P=VI, I=V/R. Scaffold sketching of energy flows when two batteries are hooked up in series and in parallel (students also draw energy flows in notebooks). Remind them that analysis of power and energy flow diagram will be required for final project.	

<table>
<tr><th>LESSON 10. Derivation of Ohm’s Law.</th><th></th></tr>
<tr><td colspan="2">OUTCOMES: Students experimentally derive linear relationship between voltage and current for two different resistors and a bulb.</td></tr>
<tr><td>ANTICIPATORY SET
Hook: TBD
Key Question:Can we derive the mathematical relationship between voltage, current, and resistance?
Explain lesson: Investigation with summative assessment.</td><td rowspan="3">Lesson informed by: www.tryengineering.org/ohmslaw.pdf

Per group: breadboard, 47 and 100 ohm resistors, 6V bulbs, 4 AA batteries and holder, wires.

Graph handout.</td></tr>
<tr><td>CONTENT
Review fair test. Cows Moo Softly--> change, measure, keep the same. How can we test the relationship between voltage, current, and resistance?
Introduce resistor, breadboard, and other equipment. Scaffold options for experiment--which variable can be changed (voltage) and correspondingly, what will we measure (current). Review maths plotting of linear relationships y=mx. Remind students that we will be doing three separate experiments for two resistors and bulb. (Provide graph handout).</td></tr>
<tr><td>PLENARY AND PRODUCT
Summative Assessment of fair test and analysis.</td></tr>
</table>

<table>
<tr><th>LESSON 11-12 Final Project</th><th>Resources</th></tr>
<tr><td colspan="2">OUTCOMES: Students investigate voltage divider, and design circuit for LEDs.</td></tr>
<tr><td>ANTICIPATORY SET
Key Question:How can we design a LED flashlight.
Explain lesson: We will investigate LED (light emitting diodes) and design a circuit to efficiently optimise power and light.</td><td rowspan="3">Lesson plan at http://www.tryengineering.org/lesson_detail.php?lesson=90

Breadboard, 9V batteries, LEDs, resistors.</td></tr>
<tr><td>CONTENT
1.Guided instruction on design of voltage divider (lesson plan from www.tryengineering.com.)
2. Investigation of LED. Explain diodes and history.
3. Student’s investigate LEDs mA and voltage requirements and design circuit to optimise power and light output with 9V source.</td></tr>
<tr><td>PLENARY AND PRODUCT
Students will be provided with project criteria and rubric (appendix) and will be scaffolded on requirements.</td></tr>
</table>

Lesson 1 resources (source: www.abdn.ac.uk/rowett/documents/.../energy_expenditure.pdf)

Table 2.0 Energy required for a variety of activities

Everyday Activities	KJ/min
Sitting	6
Standing	7
Washing, dressing	15
Walking slowly	13
Walking moderately quickly	21
Walking up and down stairs	38
Work and Recreation	
Light (most domestic work, golf, lorry driving, carpentry, bricklaying)	10-20
Moderate (gardening, tennis, dancing, jogging, cycling, digging)	21-30
Strenuous (cross-country running, football, swimming [crawl])	>30

The formula for determining cell energy is:

$$E = P{\cdot}t = V{\cdot}I{\cdot}t$$

Where:

I = Current Expressed in amperes
V = Electromotive force expressed in volts
P = Power expressed in watts
t = Time expressed in hours
E = Energy in joule

For example:

Product Number	Size	Nominal Voltage (volts)	Rated Capacity* (ampere-hours)
MN13OO	D	1.5	15.000
MN14OO	C	1.5	7.800
MN15OO	AA	1.5	2.850
MN24OO	AAA	1.5	1.150
MN91OO	N	1.5	0.800

```
  D: (15.0 Ah) x (1.5 V) x (3600 s) = 81,000 J
  C: (7.80 Ah) x (1.5 V) x (3600 s) = 42,120 J
 AA: (2.85 Ah) x (1.5 V) x (3600 s) = 15,390 J
AAA: (1.15 Ah) x (1.5 V) x (3600 s) = 6,210 J
  N: (0.80 Ah) x (1.5 V) x (3600 s) = 2,700 J
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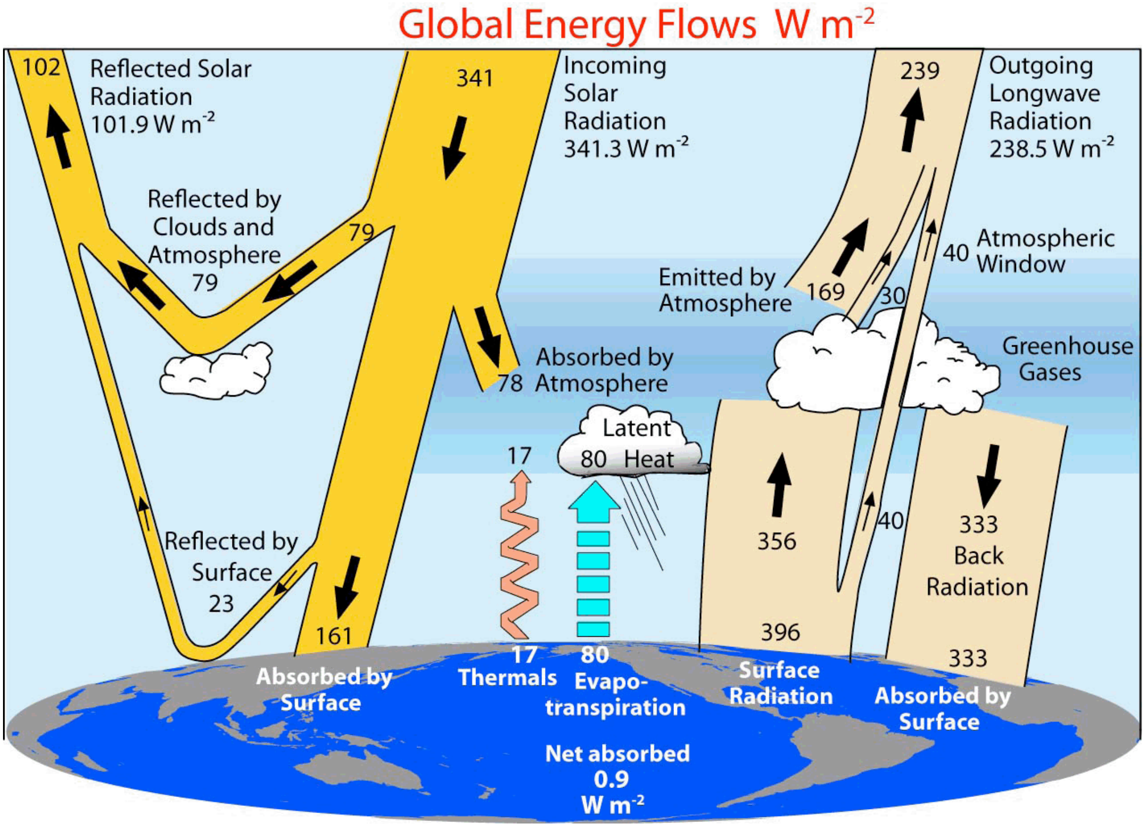
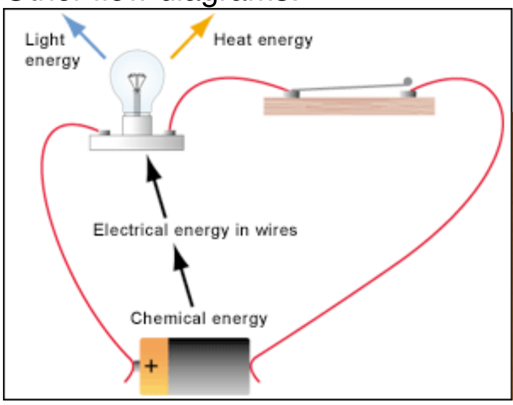
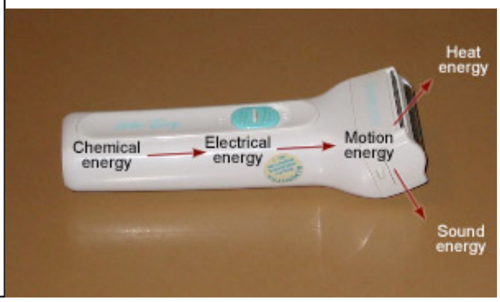
Lesson 2 Resources: (source http://www.ret.gov.au)

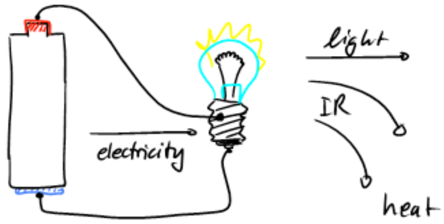


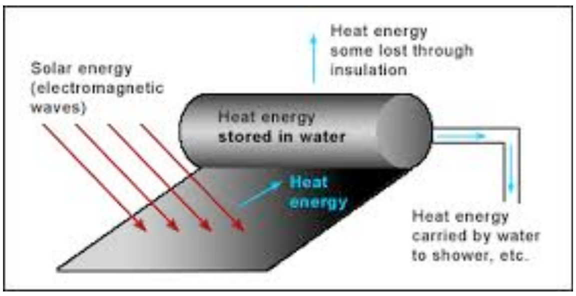
Other flow diagrams:



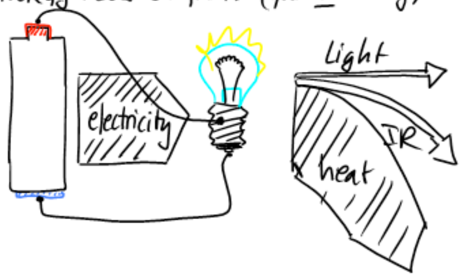


1) ENERGY FLOW DIAGRAM (qualitatively)





2) ENERGY FLOW DIAGRAM (quantitatively)



Lesson 2 Assignment

Energy transformations at home
Pick an object using energy at home and sketch it below. Additionally, draw an energy flow diagram using a format similar to the one at right. Label all types of energy and provide as much information as you can.

Criteria for assignment:
1. The student can visually describe using an energy flow diagram the transformation of energy.

Rubric:

Criteria	*Exceptional*	*Proficient*	*Pass*
1	As per proficient, AND student illustrates the relative amounts of energy transformed and transferred.	As peer pass, AND student identifies ALL types of energy transferred and transformed (e.g. sound, light, heat).	Student provides a energy flow diagram with energy types labeled.

Lesson 5 resources (source: http://www.studyphysics.ca/2007/30/06_forces_fields/12_voltage.pdf)

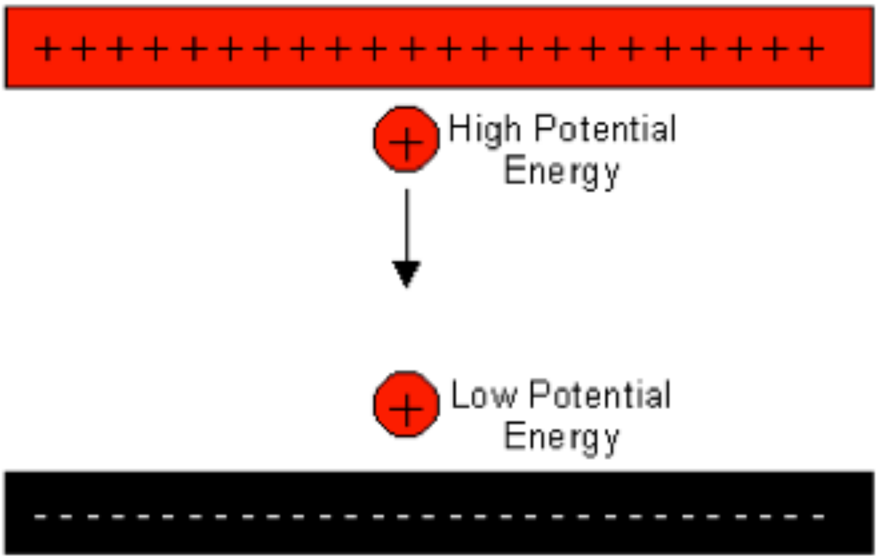


Illustration 2: Electric potential energy

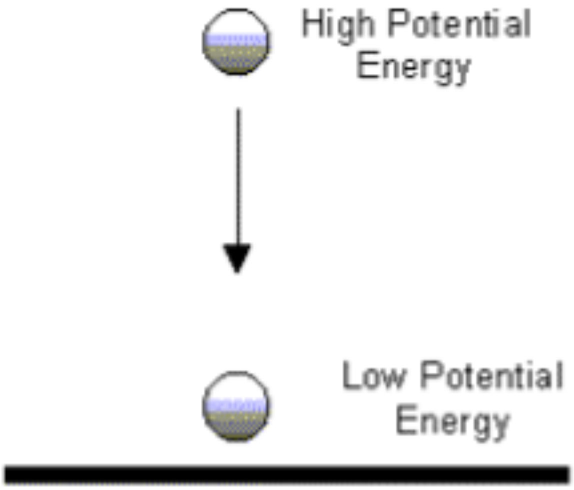


Illustration 1: Gravitational potential energy

Lesson 6 resources for voltage lesson (Source: Stelr).

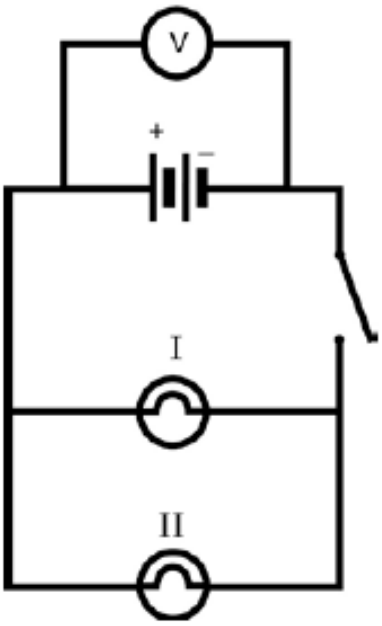


Figure 7.

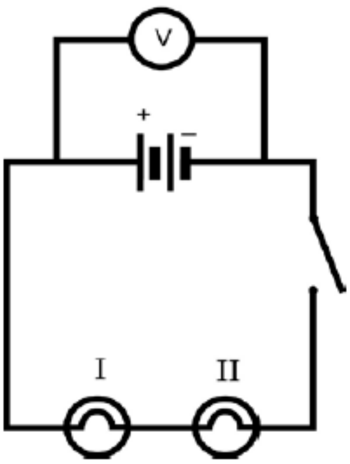


Figure 5.

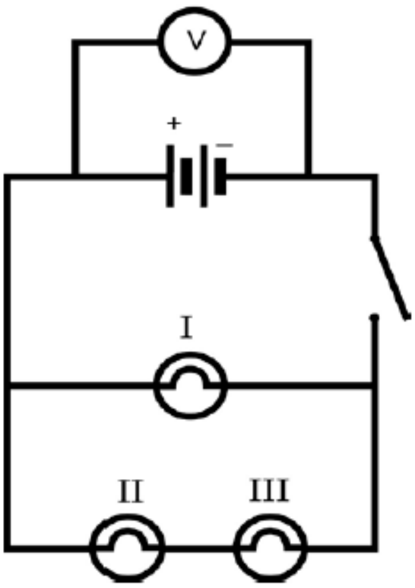


Figure 8.

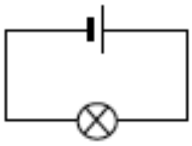
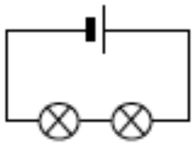
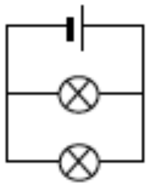
Lesson 6 Quiz (source: http://www.orbeducation.com.au/Samples/Sc/1/Previews/ScP014%20Circuits.pdf)

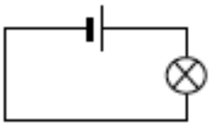
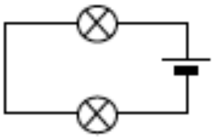
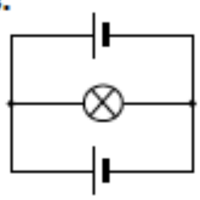
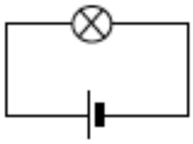
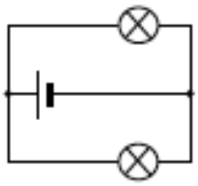
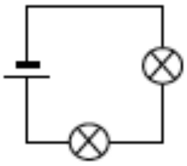
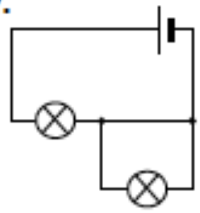
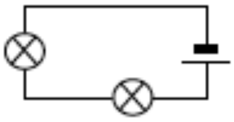
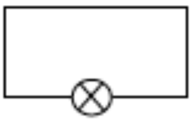
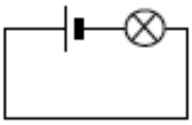
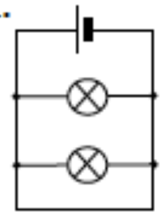
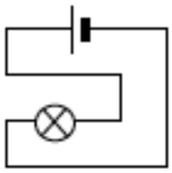
Electric Circuits

Identical Circuits

Instructions

Which of the 12 circuits below would be identical to circuits A, B and C if built? There may be several identical circuits in each case.

	A.	B.	C.
Circuit diagram			
Identical Circuits			

1. 	**2.** 	**3.** 	**4.** 
5. 	**6.** 	**7.** 	**8.** 
9. 	**10.** 	**11.** 	**12.** 

Further task

In which circuits would no lamps light?

Lesson 7--resources for current lesson. (source: Stelr)

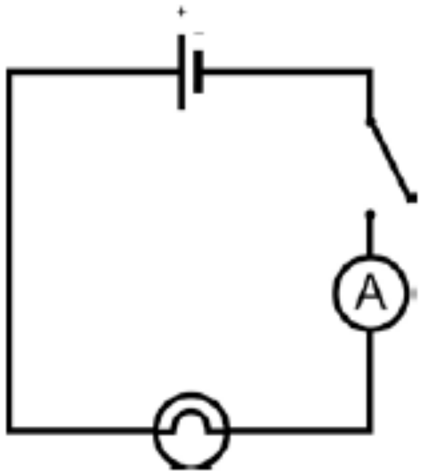


Figure 3.

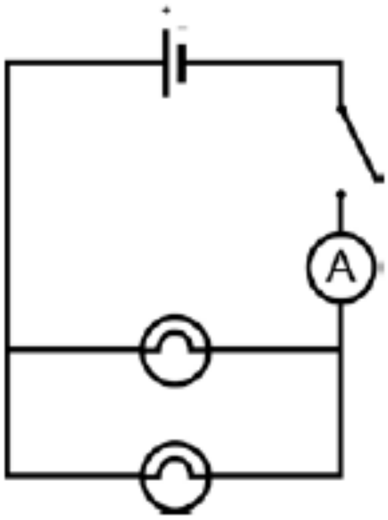


Figure 4.

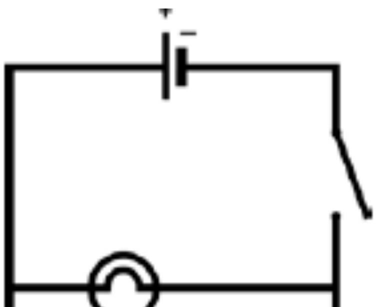


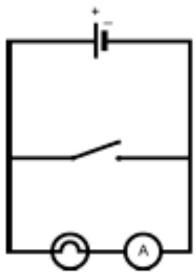
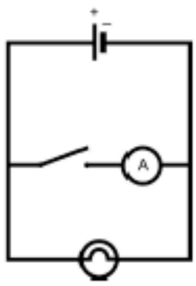
Figure 5.

Lesson 7 Challenge Activity.(source Stelr)

STELR PROJECT

PART C: Challenge activity

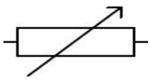
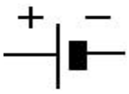
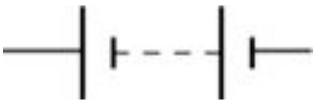
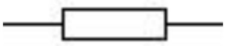
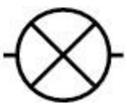
Table 6. Instructions for Part C

Step	What to do
1	Suppose you set up the circuit in **Figure 6**. Note that the ammeter is in the path containing the globe.  **Figure 6.** Based on your results from Parts A and B, predict what the current reading will be when the switch is opened and when it is then closed. Switch open: ____________________ Switch closed: ________________ Explain why you think this. ____ ____
2	Now suppose you set up the circuit in **Figure 7**. Note that the ammeter has been moved to the path containing the switch.  **Figure 7.** Predict what the current reading will be this time, when the switch is open and when it is closed. Switch open: ____________________ Switch closed: ________________ Explain why you think this. ____ ____

Lesson 7 Quick Quiz.(Source: TES http://www.tes.co.uk/mypublicprofile.aspx?uc=452473)

Circuit symbols

Match the symbol to the electrical component it represents.

Symbol	Component
	ammeter
	cell
	battery
	voltmeter
	variable resistor
	motor
	bulb
	switch
	resistor

Lesson 8 resources: (source: Electric jumprope source: http://cse.ssl.berkeley.edu/segwayed/lessons/exploring_magnetism/magnetism_and_electromagnetism/guide_activity3.pdf)

Student Name ___________________________ *Date* _______

Jump Rope Generator: Observations

Fill out the table with your measurements of greatest deflection on the galvanometer in each of the four cases. Then answer the questions below the table.

	Cord aligned east-west	Cord aligned north-south
Slow		
Fast		

1. What effect does the rotational speed of the cord have on the deflection of the galvanometer?

2. Describe the conditions in which you had the maximum voltage (or current) through the galvanometer.

3. Describe the conditions in which you had the minimum voltage (or current) through the galvanometer.

4. Explain why the galvanometer needle moves when you play jump-rope with the extension cord.

5. Explain why the the orientation of the jump rope to Earth's magnetic field effects the galvanometer reading.

Lesson 9 Sample Results (source: Stelr)

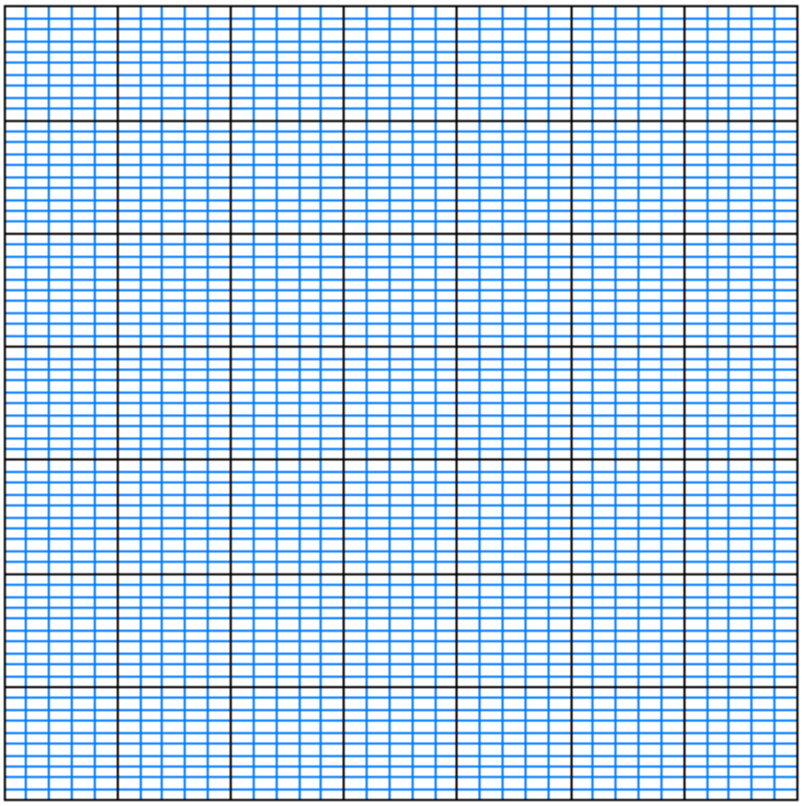
Results and calculations for Part B

Battery arrangement	Brightness of globe	Voltage *V* (final steady value) (V)	Current *I* (final steady value) (mA)	Electrical power *P* (mW) $P = V \times I$
Single battery	Dim	2.91	32.5	94.6
Two batteries in series	Bright	5.90	48.0	283
Two batteries in parallel	Dim	2.99	33.0	98.7

Lesson 10 Graph (source:www.tryengineering.org)

Student Worksheet
Step By Step Procedure (continued)

E in volts vs. I in milliamps.



Data for 6.3 volt, 150 mA, no. 40 light bulb

I, current, mA 0.0 ____ ____ ____ ____ ____

E, emf, volts 0.0 ____ ____ ____ ____ ____

Data for resistor 1 47 Ohms

I, current, mA 0.0 ____ ____ ____ ____ ____

E, emf, volts 0.0 ____ ____ ____ ____ ____

Data for resistor 2 100 Ohms

I, current, mA 0.0 ____ ____ ____ ____ ____

E, emf, volts 0.0 ____ ____ ____ ____ ____

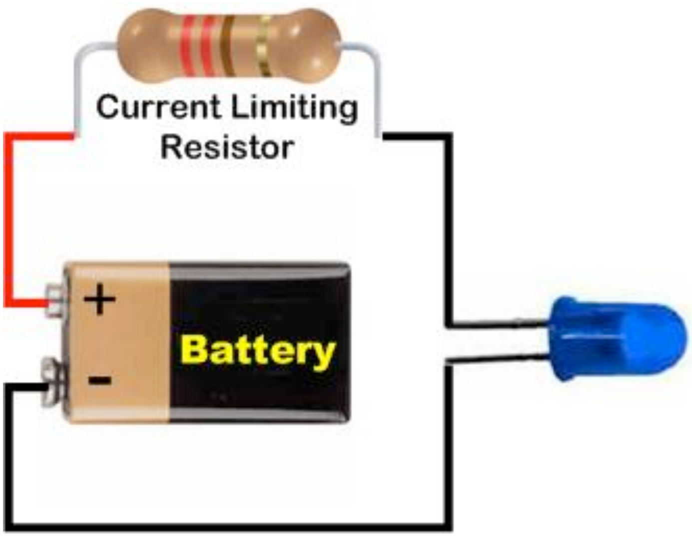
Lesson 10 Rubric:

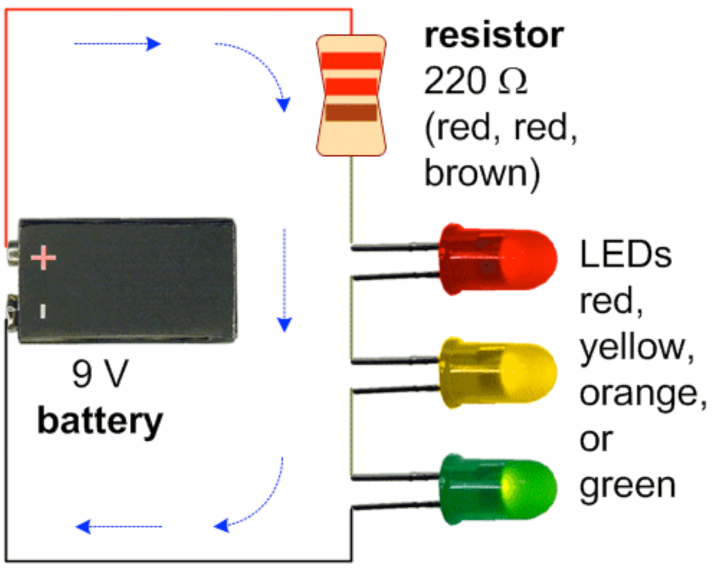
SUMMATIVE ASSESSMENT RUBRIC			
Derivation of Ohm's Law Students are to work in small groups to design and implement a fair test to generate relationship of Ohm's Law and the relationship between voltage, current, and resistance in a circuit. **Criteria for assignment:** The student can: 1. Design and perform fair test and create graph of experimental data. 2. Derive and describe relationship between voltage, current, and resistance. **Rubric:**			
Criteria	*Exceptional*	*Proficient*	*Pass*
1	As per proficient, AND student presents clear, clean plot and demonstrates clear relationship to recorded data.	As per pass, AND student shows evidence of data repeatedly measured and verified.	Student identifies variables to change, measure and keep the same. Student provides plotted data with title, labeled axes and units clearly marked.
2	As per proficient, AND student generalises implications of result by extending concept to hypothetical situations (e.g. what would the graph look like for a resistor of higher value).	As per pass, AND student justifies variations in measured data with reasonable scientific explanations.	Student recognises and describes linear relationship of variable in scientific language.

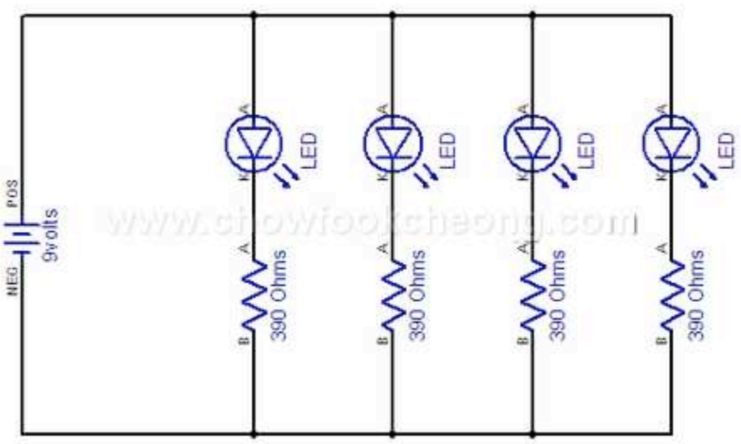
Lesson 11-12

SUMMATIVE ASSESSMENT RUBRIC			
Final Project Design of LED lighting system. Students are to work in teams of two or three to design a LED circuit, and provide individual reports. **Criteria for assignment:** 1. The student can design and construct a LED circuit with the proper additional resistance to optimise power aspects of the circuit. 2. Student can analyse circuit in terms of energy transfer, and formulate energy flow diagram that accurately reflects energy transformations in circuit. 3. Student presents all data, design and analysis in report form. **Rubric:**			
Criteria	*Exceptional*	*Proficient*	*Pass*
1	As per proficient, AND design has innovative features while maintaining efficiency of circuit.	As per pass, AND design has multiple LEDs and/or resistors to efficiently optimise light and/or power consumption.	Student designs LED circuit with appropriately chosen resistive components and explains design using Ohm's Law.
2	As per proficient, AND , student justifies choice of components by comparing and contrasting with alternate design scenarios.	As per pass, AND student qualitatively illustrates energy transformations using energy flow diagram.	Student provides circuit diagram and clearly identifies power requirements of EACH component of the circuit.
3	As per proficient, AND report is concise, highly detailed and ready for publication in *Australian Science Innovations.*	As per pass, AND report is well presented (typed) with labeled illustrations and diagrams.	Students work is complete (circuit diagram, power analysis, and discussion) and each section is identified clearly. Group members are listed.

Lesson 11-12 examples (minimum satisfactory circuit and more advanced circuits).
(Source: robotroom.com, ngineering.com)







Introduction

This unit is designed for a Year 8 Science class of students of mixed range of abilities. The unit is a series of lessons that begins with the concept of force, energy, and power, and segues into an extended series of lessons on electric phenomena. Objectives include scaffolding student understandings to the scientific understandings of circuits as a system, and emphasises energy transfer in circuits, with a pedagogical intent to enhance intuitive notions of voltage (as electromotive force), current (as kinetic charges), and power. The unit is constructively aligned(Biggs, 2003); outcomes inform criteria which in turn inform the learning activities, which include three summative, criteria and rubric based assessments.

Rationale

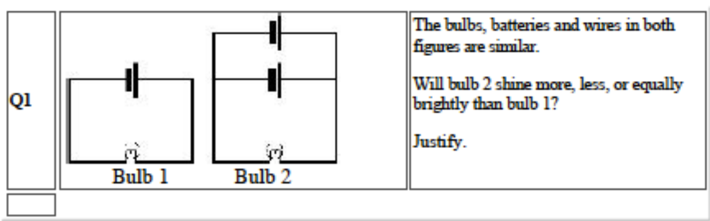
Force, Energy, and Power have both everyday and scientific meanings. An initial intended learning outcomes of the Energy and Electricity Unit is to facilitate scientific differentiation and identification of these concepts, with an emphasis on energy due to its centrality to both force and power. The scientific conception of energy, the capacity to do work, will be reinforced throughout the lessons, as well as conservation of energy concepts though the ongoing formative assessment of student-drawn energy flow diagrams.

Because this unit is designed for Year 8, quantitative analysis will be kept to a minimum but two equations will be utilised (the power definition $P=VI$, and Ohm's law $I=V/R$) to experimentally connect cognitive relationships. The unit will derive "rule-of-thumb" understandings of the units of measurement defined in physics, for example, the conceptual grasp of the Newton as the gravitational force exerted on an 100g apple on Earth, or the Joule as the amount of energy transformed by a single heartbeat in the human body. The focus will be on conceptual understanding with broader outlines of the mathematics, while retaining and emphasising the relative scale of energy transfers and transformations.

Specific to electricity, differentiation of the concepts of current, voltage, and power (as a quantitative representation of energy transferred over a period of time) is generally not well acquired by students by the end of their secondary education (Psillos, 1998). Psillos (1998) outlines four major difficulties:

•*Developing systematic reasoning.* Students view circuits as a linear model in which effects of components are considered linearly, in contrast to the understanding of the electrical circuit “as a closed system in which all components interact with each other and any disturbance extends in all directions” (section E4, p.1).
•*Conceptual differentiation.* Students confuse the concepts of electricity, current, and energy, i.e. current as a property of voltage (vs. resistance) indicating voltage “strength”.
•*Establishing relations.* Students do not link the relationship between electrostatics and electrokinetics; for example, students do not see common features between the attraction/ repulsion of electrified bodies and the lighting of a bulb. In contrast, the cognitive linkage between electrostatics and electrokinetics can, for example, enhance a broader scientific understanding of voltage potential.
•*Linking different models.* Students lack cognitive linkages between various mental models of electric and magnetic phenomena, including the link between qualitative and quantitative models.

Cognitive conflict with simple examples is employed frequently in the questioning segments of the unit. For example, in the diagram and question below, a common alternate conception is that the two batteries will result in a brighter bulb; however through the experimental design of circuits and measurement of voltage and current, scaffolding of the understanding of the bulb as a resistor--and thus being a primary determinant of the current in a circuit--will be reinforced (the teacher should prepare by performing a quantitative analysis of thought experiments to ensure proper scaffolding). Students will be encouraged to develop non-quantitative heuristics to predict behaviour of circuits prior to any calculations.



(Source: Psilos, 1998)

The general teaching strategy and approach will be concept first, followed by terminology, then experimentation and calculation. For example, prior to the introduction of the quantitative version of Ohm’s law as I=V/R, students will first be exposed to both thought and real-world experiments that lead to an understanding that current in a circuit increases with voltage, but decreases with increased resistance, as Ohm’s law quantitatively indicates. Historical discoveries and connections with real-world applications and experiences are integrated, and the final project, the design of a LED circuit, is intended to engage students with an authentic, yet reasonable, learning activity. Specific concepts such as Kirchoff's Law (conservation of current at nodes) will also be scaffolded based on a progression of mental models outlined below.

Mental Models

It is informative to consider the mental models likely to occur in the introductory study of electricity. Borges (2010) discusses two simple models, the unipolar model (energy can transferred over a single wire), where the bipolarity of both the battery and the bulb in a simple circuit are not acknowledged, and the "two-component" model ('plus' and 'minus' currents clash into a bulb and produce energy). Neither of these models are expected in secondary school (Karrqvist, as cited in Borges, 2010), and they are easily progressed by observation, experimentation and measurement. Additional mental models are outlined below, each offering clues on pedagogical questioning.

•*Current consumption model*--current circulates in the system, but is consumed as it passes through components (i.e.. only part of the current returns to the battery).

•*Constant current source model*--the battery is considered a source of constant current, irrespective of components. It is recognised that the battery drains, but only then does current change. This model is exposed with conceptual considerations of series and parallel circuits.

•*Ohm's model*--current "flows" (like a fluid) around a circuit under pressure (voltage), transmitting energy. This model is considered an acceptable circulatory model for secondary students, but it does not adequately represent the scientific notion of electricity, as resistors can still be considered consumers of charge rather than hindrances to its flow (Cosgrove, 1995). In other words, this view integrates the conservation of energy but assumes that energy is somehow delivered to components by the current instead of being a consequence of the field effects of the moving charges.

A variety of models can be employed to create specific analogies, for example the continuous circulating rope model (with a point of friction to represent a load), or the "electrons as billiard balls in a tube" model to represent the near instantaneous effects of electrical circuits, but Stefani (2008) warns against developing a singular simple model as it can inhibit subsequent university level comprehensions. Similarly, Stefani (2008) identifies the lack of incentive for students tasked with quantitative problems to "embark on the cognitively demanding task of developing more sophisticated mental models" (p. 126), (he also recommends restructuring study around the concept of the electromagnetic field). This unit will focus on cognitive models applicable to a reasoned qualitative understanding of circuits appropriate at this stage. Borges (2010) recommends introducing the appropriate vocabulary, defining individual entities involved in producing a system's behaviour, and highlighting the inter-relationships among the entities.

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