# TEAM PROJECT REPORT

**Project 2: Synthesis and Characterization of Graphene for Energy Storage Devices**

### Submitted To

### The RET Site

### For

### “Challenge-Based Learning and Engineering Design Process Enhanced Research Experiences for Middle and High School In-Service Teachers”

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### Abstract

The group synthesized three-dimensional graphene foam (3DGF), in the form of sheets called three-dimensional graphene paper (3DGP) using chemical vapor deposition (CVD), milled it using a laser milling system to create interdigitated patterns (IP) with digits of thickness 25 µm and interdigital spacing, *d*, also of width 25 µm, and coated the IP with electrolyte solutions to form flexible micro-supercapacitors (µSC). 3DGF has been shown to be a good material for electrodes. This research focused on increasing the energy-density of µSCs to that of or above high-quality electrolytic storage devices (batteries) while maintaining the power-density and reusability of more traditional capacitors. Past techniques on the manufacture and characterization of supercapacitors were applied to reduced-scale IPs to manufacture and characterize µSCs. µSCs have noticeably better capacitance and energy-density, with minimal added internal resistance, than more traditional capacitors. Capacitors are limited to capacitances on the order of 100 pF and specific energies of no more than 0.1 Wh/L. µSCs can exceed each of those by 100 times. This research should help enhance the performance of µSCs further. The group’s µSCs will lead to general use electrical devices that are smaller, charge faster, and are more flexible than using any conventional technology. The porosity and flexibility of 3DGP scales down well to 25 µm and by modifying the electrolyte used and doping the carbon will yield further advantages in power- and energy-densities. The group will present in written, video, and oral form to the Research Experience for Teachers (RET) 2016 cohort, assistance, mentors, and administrators as well as publish it in journals.

### Key Words

Micro-supercapacitor, Graphene, Laser, Three-dimensional, Chemical Vapor Deposition

### Main Body

#### INTRODUCTION

Cell phones, computers, tablets and other portable electronic devices are common place today. Society is truly dependent upon these devices working. And since plugging them in all the time is not an option, the need for energy storage devices that will have the necessary power and long cycle life are required

Batteries have decreased in size, but have too short a cycle life to adequately handle the demands. Micro-supercapacitors (µSCs) have shown to demonstrate much greater cycle life and competitive energy density to batteries. They also happen to have flexibility as a characteristic, which makes them even more useful.

Graphene has been introduced as the electrode material for the µSCs. Graphene is highly conductive and when manufacturing graphene, chemical vapor deposition (CVD) allows the graphene to form as crumpled sheets in three dimensions.This allows for more surface area and so more energy storage.

When it comes to energy storage devices, the demands of society are incredible. Micro-supercapacitors made with 3D graphene should help society meet both the energy storage and the power usage demands in a package that can be bent to match the shape of most devices, even those that should be flexible.

#### LITERATURE REVIEW

Our society is awash in tiny electronics that can fit in a tight jean pocket and large, semi-autonomous devices like robots and cars that demand tremendous energy storage with increasingly urgency on reducing the time to charge the devices. One can find lists of specific devices throughout the literature, including papers by Chmiola, et. al., Niu, et. al., El-Kady and Kaner, Nery and Kubota, and others. Industry standard thin-film and polymer batteries serve the role of energy storage device for many of these devices, but they have short cycle life, are slow to charge, and have issues relating to overheating and starting fires (Long, et. al., 2004). There are further challenges integrating the batteries with the electronic circuits and miniaturizing the collective system (El-Kady and Kaner, 2013). In-plane µSCs show potential for replacing batteries in many instances as they may make integration and manufacture simpler as well as supply higher power densities due to the speed of capacitive charge transfer rates (Pech, et. al., 2010 and Beidaghi, et. al., 2012).

Electrodes for µSCs using electric dual-layer capacitance (EDLC) have been comprised of graphene oxide (GO) or reduced graphene oxide (rGO), as described in papers by Niu, et. al. (2013), Y. Wang, et. al. (2013), L.L. Zhang, et. al. (2012), C. Zhang, et. al. (2013), and El-Kady, et. al. (2015), among others. Drawbacks to these methods include complex electrode structure and binders that decrease the power density (Luo, et. al., 2012 and Suboja, et. al., 2013). Using simpler, monolithic 3D electrode structures created using a binder-free process should simplify fabrication and integration of µSCs. Capacitance, *C*, obeys a relationship that is proportional to cross-sectional area, *A*, and inversely proportional to distance between electrode plates, *d* (the same as our interdigital distance).

(1)

So, having monolithic 3D electrodes made of graphene paper yields very large surface areas relative to the mass of carbon used and the surface area of the IP. At the same time, using the micro-milling device allows *d* on the order of 25 µm for capacitance and on the order of the size of the ions in the electrolyte for the EDLC. (Balakrishnan and Subramanian, 2014)

By using chemical vapor deposition (CVD), electrodes can be created from 3D graphene that have high electrical conductivity and are monolithic in structure (M. Zhang, et. al., 2014, Miller, et. al., 2010, and Beidaghi, et. al., 2014). Traditionally, these are made using non-flexible hard metals as catalysts or silicon as a substrate. There is an additional challenge in transferring the 3D graphene to a more suitable substrate for manufacture or flexible use. There are further challenges matching electrolyte to electrode polarity so that performance is not reduced.

In this work, nickel catalyst particles are bound in a polymer to prepare 3D graphene by CVD. This makes a monolithic form of carbon structure referred to as three-dimensional graphene paper (3DGP), as previously reported. This method should lead to scale-up methods for production, according to previous work by the group (L. Zhang, et. al., 2015 and L. Zhang, et. al., 2016). The obtained 3DGP has high porosity, complex surface features, and is easily transferable in processing to virtually any substrate due to its high Van der Waals adhesion. It shows excellent electrical conductivity and flexibility compared to GO and rGO components. Surface polarity of the material has been shown to be easily tuned using plasma treatment and introduction of oxygen functional groups on the out-layer surface of the graphene. This increases the electrochemical relativity to aqueous-based electrolyte but maintains the low-defect structure of the inner layer of graphene and its correlate fast electron transfer. This is a critical concern as the research will attempt to use water-based, organic, and possibly other ionic materials between IPs, and this will require appropriate physical behavior of the 3DGP to the substance. The use of the substance is to introduce EDLC, which greatly enhances performance of the supercapacitor. Some ionic liquid electrolytes can handle higher potential differences without undergoing phase-changing redox reactions. This is an advantage, as the energy stored in a capacitor, *U*, is proportional to the square of the electrical potential difference, *V*,applied, as well as proportional to the capacitance, *C*, of the device.

(2)

(Balakrishnan and Subramanian, 2014)

Even a simple doubling of electric potential difference allowed before breakdown of the electrolyte should then yield a four-fold increased energy density.

#### GOALS AND OBJECTIVES

The participants intended to perform in-lab research to create 3DGP µSCs, improve the performance of the devices, and develop units appropriate for their classes. To these ends, they expected to learn to synthesize, process, characterize graphene paper and micro-supercapacitors, write this report, disseminate the information to the RET collaborators, their classes, and peers through professional development.

#### RESEARCH STUDY DETAILS

4.1 3D Graphene Paper Synthesis

4.1.1 Catalyst Preparation

Nickel powder and a poly-vinyl alcohol (PVA) solution were mixed, resulting in a wet slurry solution. This solution was allowed to dry for 24 hours and became a black flexible film-like substance. This substance was cut into strips that became the catalyst for this project.

4.1.2 Graphene Synthesis

The catalyst was placed into a tube chemical vapor deposition (CVD) furnace and heated to 1000 0C with Argon, Hydrogen and Methane gasses introduced during the heating process. Argon was used to create an oxygen free environment in the furnace. Hydrogen was used to reduce any metal catalyst oxide. Methane was the hydrocarbon that decomposed into carbon and hydrogen atoms, in which the carbon atoms were absorbed by the catalyst and formed a hexagonal graphene structure.

Then hydrochloric acid was used to remove the nickel, leaving a three-dimensional graphene paper (3DGP). The 3DGP was washed in alcohol to remove the acid residue.

4.1.3 3DGP on Flexible Substrate Preparation

3DGP was free-standing and could be transferred onto any substrate. Kapton was chosen because it was flexible and non-conductive, and therefore was used in our experiment. The 3DGP was fished out of the alcohol solution with the Kapton film and then dried at room temperature for 12 hours. A good adhesion was created between the 3DGP and the Kapton during the drying process thanks to Van Der Waals forces.

4.2 3DGP Characterization

4.2.1 Raman Spectroscopy

For testing the 3DGP on Kapton film, called “graphton,” Raman Spectroscopy was used. This procedure will give data that, when graphed, will show if the graphton had multi-layer structure. Raman also gives the information of the structural defects found in the graphene hexagonal structure.

4.2.2 Scanning Electron Microscopy (SEM)

SEM was used to study the morphology of the 3DGP. It yields information about the structure and the porosity of the 3DGP.

4.3 3DGP Micro-supercapacitor (µSC) Manufacturing

4.3.1 Laser Etching

Two-dimensional designs for interdigitated patterns (IP) were created using SolidWorks software. Two different designs were settled upon: one with 50-µm width digits and channels for testing different electrolytes and another with 25-µm width digits and channels for scaling down the size of the supercapacitors. Oxford Lasers Micro Machining System was then used to etch the patterns onto GP and to cut the parts free from the remaining Kapton film substrate.

4.3.2 Quality Control

Once the raw IP part was cut from the main Kapton sheet, it was characterized for quality using an optical microscope for visual inspection and a digital multimeter to insure there was no short across the channels in the IP.

4.3.3 3DGP Micro-supercapacitor Assembly

To complete the assembly of the µSC, electrolyte was applied to the IP. Because two different electrolytes, poly-vinyl alcohol and sulfuric acid mixture (PVA/H2SO4) and 1-ethyl-3-methylimidazolium tetrafluoroborate (EMIMBF4), were to be tested, two different sets of supercapacitors were manufactured. After the electrolyte-coated components had dried, copper tape was applied to the contact parts of the GP device that did not include the IP using silver paint, and then epoxy resin was used to bond the copper tape to the remaining Kapton substrate below the µSC. The copper tape was used as the primary contact region for macroscopic attachment to testing equipment. These steps were used to protect the actual µSC device from damage while undergoing final characterization.

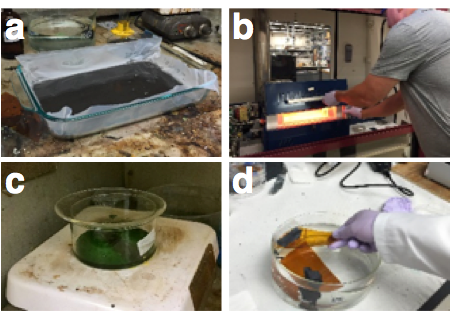
4.4 3DGP Micro-supercapacitor Characterization

A potentiostat system by Gamry Instruments was used to run characterization on the completed µSCs with attached copper contacts.

Cyclic Voltammetry (CV) tests vary the potential difference across a component while measuring the current the component drew. This was done repeatedly to the µSCs, using set potential difference intervals, with first charging then discharging cycles. Using CV graphs, the total areal charge and energy densities of the µSCs could be calculated based on the area inside the CV curves and the cross-sectional area of the µSC’s IP.

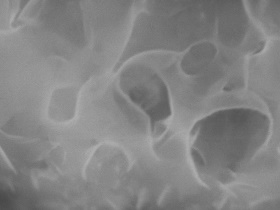
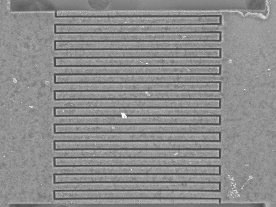
#### RESEARCH RESULTS

In order to study a micro-supercapacitor, they need to be manufactured. Nickel powder was used in our experiment as catalyst to synthesize graphene. To create a 3D catalyst template we use polymer as binders for Nickel powder (Figure 1a). Making the slurry with Nickel powder and a polymer is dangerous so masks had to be worn at all times. After the slurry dried, we transferred it into a CVD reactor to synthesize the graphene (Figure 1b). Heating the furnace to 1000°C was used to break the hydrocarbon into hydrogen and carbon atoms. The hydrogen atoms will form into hydrogen gas and escape into the atmosphere. The carbon atoms will be absorbed by the nickel catalyst and form graphene. After cooling, the graphene on nickel was transferred into an acid solution to remove the nickel (Figure 1c). Once the nickel was removed, the graphene paper was fished out with Kapton film (Figure 1d). The non-conductive Kapton film was used as a flexible substrate for the micro-supercapacitor.



**Figure 1.** (a) Nickel powder and polymer slurry; (b) CVD reactor for graphene synthesis; (c) Removing nickel using hydrochloride acid to get graphene; (d) Fishing graphene from water bath using Kapton film.

**a**

**c**

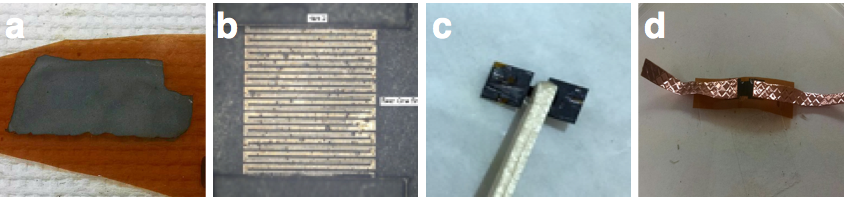
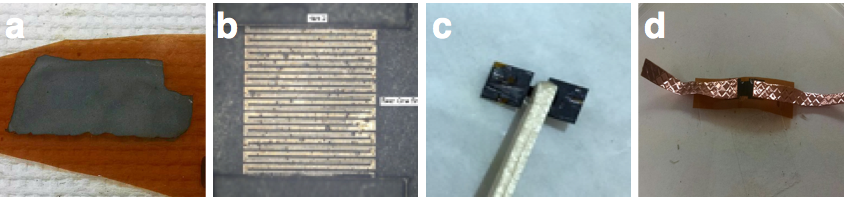
**b**

**Figure 2**. (a) Raman Spectroscopy of 3DGP sample; (b) SEM image of 3DGP sample; (c) IP laser-milled onto 3DGP sample.

Characterization of the graphene paper was an important step to understand the structure of the graphene before making into a micro-supercapacitor electrode. In our experiment, we used the Raman spectrum to study the quality of graphene paper. Figure 2a shows a typical Raman spectrum of graphene paper, in which the D peak (1300 cm-1) suggests defects in the structure and the ratio of the G peak (1580 cm-1) to the 2D peak (2700 cm-1) suggests the number of graphene layers. In our graphene paper we have a small D peak which means a high quality of graphene was created, that could potentially contribute to a high electrical conductivity. Based on the ratio of G to 2D, we have a crumpled, layered graphene structure in our graphene paper. We further studied the morphology of the graphene paper by using SEM. Figure 2b shows SEM image of our graphene paper suggesting a crumpled and porous graphene structure that could potentially contribute to a high specific surface area.

The two main areas of research that RET teachers did with this project were changing the formation of the interdigitation of the micro-supercapacitors (see Figure 2c) and the chemistry of the electrolyte that is applied to the interdigitation.

The first task for this project was to change the parameters to the final interdigitated pattern on the graphene paper. The graphene was cut interdigitally with the digits 25 µm in width, and the space between the digits also 25 µm. The parameters used were the percent power the laser would be cutting, the number of passes the laser would make and the cut speed of the laser. The pattern included the milling process to create the interdigitated pattern (IP) and the outside cutting process to cut through the substrate to free the graphene. (See Figure 3).



**Figure 3**. (a) Graphene paper on Kapton film before laser cutting; (b) Interdigitated pattern of graphene paper; (c) Applying PVA/H2SO4 electrolyte on graphene paper interdigitated pattern; (d) 3DGP µSC.

Table 1 shows the attempts that the RET teachers made so that the IP would have infinite resistance and could potentially contribute to a high capacitance for the µSC.

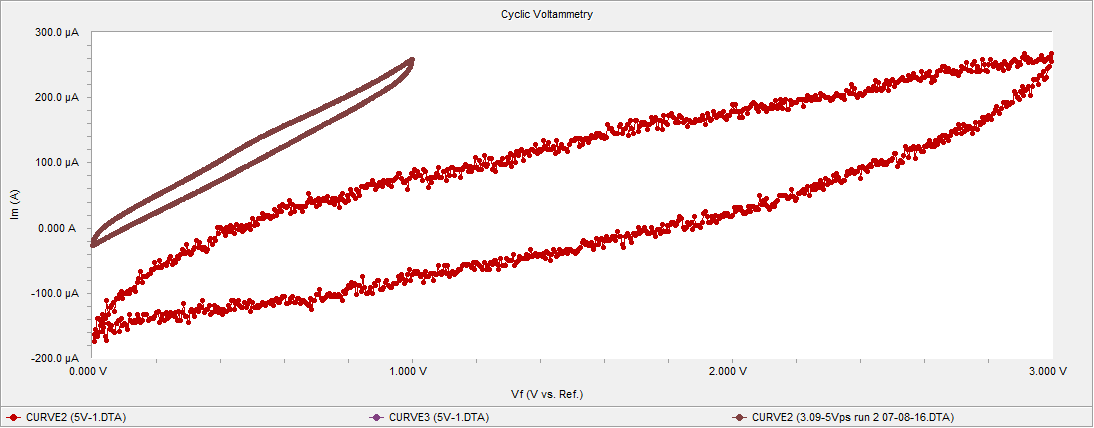
**Table 1: Effect of Different Laser Parameters to the Final Interdigitated Pattern**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sample | Inner  Power  (%) | # Passes | Cut Speed  (mm/s) | Outer  Power  (%) | Results |
| 1 | 0.5 | 1 | 1 | 3 | IP was good, outer cut was not strong enough and outside digits were greatly affected. |
| 2 | 0.4 | 2 | 1 | 5 | IP was good, outer cut was strong enough, but outside digits were greatly affected. |
| 3 | 0.4 | 2 | 1 | 0.5, 5 | IP was good, outer cut was strong enough and outside digits were not greatly affected. |
| 4 | 0.4 | 1 | 1 | 0.5, 5 | IP was not good, outer cut was strong enough and outside digits were not greatly affected. |
| 5 | 1 | 1 | 1 | 5 | IP was not good, outer cut was good, and outside digits were greatly affected |

Sample 3's process was the most successful in creating the pattern where the interdigitation was not touching each other, the outer digits were still intact, and the outer cut was through the substrate. While characterization using the Gamry demonstrated that energy density improved with 25 µm digit width and interdigital spacing over IPs designed at 50 µm, the improvement was below expectation.

The second task for this project was to apply several different types of electrolyte to the IP. The electrolyte provides the ions needed to make graphene micro-supercapacitors. Two electrolytes were tested. Since cutting at 25 µm was not very successful, 50 µm cutting was used to test the different electrolytes.

Poly Vinyl Alcohol (PVA) was placed on the IP and then allowed to dry. After attaching the copper to the outside graphene with silver paint, the copper was glued to the Kapton substrate with an epoxy. The Gamry tests were conducted to characterize the µSCs manufactured for the research. CV demonstrated clear improvement when 1-ethyl-3-methylimidazolium tetrafluoroborate (EMIMBF4) was used as an electrolyte, both in electrical potential range and overall charge capacity, over PVA. See Figure 4.



**Figure 4**. CV graph showing results for both PVA µSC (upper left loop) and EMIMBF4 µSC (entire lower loop).

#### CONCLUSIONS

The seven-week RET program teachers were very successful in finding several ways to increase the voltage and energy density in a micro-supercapacitor made from graphene paper. Along the way, the RET teachers learned the synthesizing process of the graphene paper. Then, the characterization of the graphene paper to analyze its properties, and the final step was to manufacture the micro-supercapacitor by etching the graphene paper into an interdigitated pattern and adding electrolyte to the IP.

One of the teachers' main emphasis for this research was the laser milling of the IP. Attempting to mill the IP at 25 µm had never been done before and the teachers discovered that the laser power was the most instrumental parameter. The first attempt was unsuccessful because the laser power was too high. After several more tries while lowering the power, the success rate increased. Decreasing the power too much also was not successful. There was also difficulty when it came to cutting the entire piece out of the graphene paper. If the laser was too strong, it would damage the outer digits of the IP and destroy the pattern. By cutting the graphene with a lower strength first, and then stronger, the digits were not destroyed and the piece was removed successfully. This set of parameters for the laser strength was the most successful in attaining a high resistance with the IP.

The second emphasis was on modifying the electrolyte placed on the IP to help increase the voltage and the energy density. PVA was used for most of the samples and was moderately successful. Using 1-ethyl-3-methylimidazolium tetrafluoroborate, however had a significant influence on the voltage and the energy density of the micro-supercapacitor (µSC).

This research project was very successful in teaching the RET teachers the methodology of research and its many failures and successes.

#### RECOMMENDATIONS

The manufacturing of successful micro-supercapacitors is a daunting task. By performing all the tasks that were given to us this past seven weeks, we feel a tremendous bond to the people that are working in this field. The future is extremely bright and unbelievably expansive for µSCs.

With our research concluded, the recommendations for this project continue on the path of improvement of the actual devices. This would include attempting to miniaturize the interdigital widths as well as the widths of the digits, finding more exotic electrolytes that would allow greater potential differences to be applied across the devices, and investigate high-rate pseudo-capacitive reactions that could be used with graphene or surface-treated rGO on the 3DGP. Further miniaturization should continue to improve the energy density of the µSCs, as well as increase the stored charge density, as it increases the capacitor surface area relative to the cross-sectional profile of the IP. It does appear, however, that the research is approaching the limit of the micro-milling machine to cleanly cut more fine patterns. Moving from PVA to EMIMBF4 increased energy density by about a factor of nine due solely to the three-fold increase in breakdown voltage and stored energy for capacitors being proportional to the square of the potential difference. If that potential difference could be increased by finding an even better ionic solution or compound, small changes would lead to large increases in energy density. So far, the research has not exploited the value of pseudo-capacitance. As has been stated previously, a possible channel for further research would be to use a plasma to activate surfaces on the 3DGP to allow a high-rate exchange of charge in redox reactions with the electrolyte, adding to the measurable capacitance and energy density of the µSCs. These are the three channels through which improvements will most likely happen.

The main other considerations would be to work on making the materials even more manageable so that the process can be scaled up to an industrial process and testing the limits of the flexibility of the components.

#### CLASSROOM IMPLEMENTATION PLANS

John D’Alessandro will introduce this research to his students in the third quarter (January to March) as a unit to integrate the concepts of electricity and magnetism. Learning objectives that will be met through the use of this unit are from *Course Outcomes for Regular Physics*, November 19, 2015: 4. Defend the use of 1st principles, assumptions, formulae, and graphs to accurately predict the outcome of a described physical phenomenon; 8. Analyze the current and future behavior of physical systems using the idea of kinetic and potential energy as well as the laws of conservation of energy and conservation of momentum; 10. Calculate the current, voltage and/or resistance in an electrical circuit; and 11. Design and build electrical circuits using a single power source and resistors. By taking the students on a “class trip” to the faculty parking lot to view an electric car in use, students will be prompted to think about energy and power usage in our modern age. The essential question will become “What are the most useful ways of storing electricity?” Students will develop questions to allow them to complete a challenge that requires them to make a toy car with an electrical power system that can complete a series of tasks in a fixed time. One of those tasks will be charging the power system. They will be scored based on a rubric for the final project and their teamwork and reporting skills. Please refer to Appendix III to see a unit plan for *Electrical Energy and Power Usage*.

This research will be introduced and implemented in Mike Day’s unit this fall by having students research about energy and how humans, plants, and mechanical types of machines use energy to move. Some machines need to be "plugged in". The hook is having students realize that machines that are not "plugged in" will eventually run out of energy. The essential question will be what are the parameters that make a good energy storage device? Students will be asking questions about how energy is captured and transported. Electricity runs many of the machines that we use and students will have an exercise in building circuit boards. Students will make both a battery and a capacitor. Since our research is about micro-supercapacitors the challenge will be making a capacitor that works the longest with a small budget of five dollars. The learning objectives that will be met from this unit are found in the engineering section of the Next Generation Science Standards. Students will design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Students will also analyze the global challenges that the lesson encounters. Please refer to Appendix IV to see a unit plan for *Energy, What is it good for*?.

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#### APPENDIX I: NOMENCLATURE USED

3D = Three-dimensional

3DGF = Three-dimensional graphene foam

3DGP = Three-dimensional graphene paper, a specially formulated 3DGF

*A* = cross-sectional area of electrode plates in an electrostatic capacitor

Capacitance is proportional to the cross-sectional area of and inversely proportional to the distance between the electrode plates

*C* = Capacitance of a device

CV = Cyclic voltammetry

CVD = Chemical Vapor Deposition

*d* = Interdigital spacing for µSCs, used similarly to the distance between electrode plates in an electrostatic capacitor

EDLC = Electric dual-layer capacitance

EMIMBF4 = 1-ethyl-3-methylimidazolium tetrafluoroborate

Gamry = Potentiostat system by Gamry Instuments used to perform electrochemical tests

GO = Graphene oxide

Graphton = Three-dimensional graphene paper bonded by Van der Walls forces onto Kapon film

IP = Interdigitated pattern

PVA = PVA/H2SO4 = poly-vinyl alcohol and sulfuric acid mixture

RET = Research Experience for Teachers

rGO = Reduced graphene oxide

SEM = Scanning electron microscopy

Energy stored in a capacitor is proportional to the capacitance of the device and to the square of the potential difference across the device

*U* = Energy stored in a device

µSC = Micro-supercapacitor

#### APPENDIX II: RESEARCH SCHEDULE

12.1 Week 1

RET participants received introduction to supercapacitor principles, education in use of the small furnace, prepared and presented information on supercapacitors. They had already started their literature review and continued it throughout the course of the RET summer.

12.2 Week 2

RET participants received training on and preformed the synthesis of 3DGP, received training on and characterized graphene using the Raman spectroscopy microscope and sensor, and received training on the Gamry electrochemical tests and the laser micro milling machine. They also began work on writing the report for the research.

12.3 Week 3

RET participants worked on creating 25 µm IP using the micro milling machine, cutting them free, coating the IPs with PVA, and attaching copper contacts to IP, and they manufactured µSCs. They also performed electrochemical tests on devices.

12.4 Week 4

RET participants were trained in the SEM and manufactured 50 µm IP µSCs with EMIMBF4.

12.5 Week 5

RET participants performed electrochemical tests on the new devices and wrapped up the report on the research.

#### APPENDIX III: UNIT PLAN FOR *Electrical Energy and Power Usage*

|  |  |  |
| --- | --- | --- |
| **Name:** John J. D’Alessandro | **Contact Info:** jdalessandro@stxavier.org | **Date:** 06/22/2016 |

|  |
| --- |
| **Unit Number and Title:** *Electric Power and Energy Usage* |

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| --- | --- |
| **Grade Level:** | 12 |

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| **Subject Area:** | Physics |

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| --- | --- |
| **Total Estimated Duration of Entire Unit:** | One quarter (approx. 2.5 months) |

**Part 1: Designing the Unit**

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| --- |
| 1. **Unit Academic Standards (**Identify which standards:NGSS, OLS and/or CCSS.Cut and paste from NGSS, OLS and/or CCSS and be sure to include letter and/or number identifiers.**):** |

From *Course Outcomes for Regular Physics*, November 19, 2015.

4. Defend the use of 1st principles, assumptions, formulae, and graphs to accurately predict the outcome of a described physical phenomenon.

8. Analyze the current and future behavior of physical systems using the idea of kinetic and potential energy as well as the laws of conservation of energy and conservation of momentum.

10. Calculate the current, voltage and/or resistance in an electrical circuit.

11. Design and build electrical circuits using a single power source and resistors.

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| --- |
| 1. **Unit Summary** |

The Big Idea (including global relevance): The world is undergoing climate change partially due to our use of fossil fuels. We will need to rely on other sources of energy and that will require storing it for use.

The (anticipated) Essential Questions: List 3 or more questions your students are likely to generate on their own. (Highlight in yellow the one selected to define the Challenge):

What are the most useful ways of storing wind energy?

What are the most useful ways of storing solar energy?

What are the most useful ways of storing electricity?

How can we generate electricity without fossil fuels?

What can we do reduce the loss of energy to the environment?

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| 1. **Unit Context** |

Justification for Selection of Content– Check all that apply:

☐ Students previously scored poorly on standardized tests, end-of term test or any other test given in the school or district on this content.

**X** Misconceptions regarding this content are prevalent.

**X** Content is suited well for teaching via CBL and EDP pedagogies.

**X** The selected content follows the pacing guide for when this content is scheduled to be taught during the school year. (Unit 1 covers atomic structure because it is taught in October when I should be conducting my first unit.)

**X** Other reason(s) Electricity is regularly a difficult topic for students due to it primarily being conceptual in nature.

The Hook: (Describe in a few sentences how you will use a “hook” to introduce the Big Idea in a compelling way that draws students into the topic.)

I drive a Chevy Volt, which is a Plug-in Electric Hybrid car. I will demonstrate it, running solely on electricity, to the students on a “field trip” to the main parking lot. I will then ask them questions about how fast they think it can go, the towing power, how long it takes to charge, how it stops, etc…

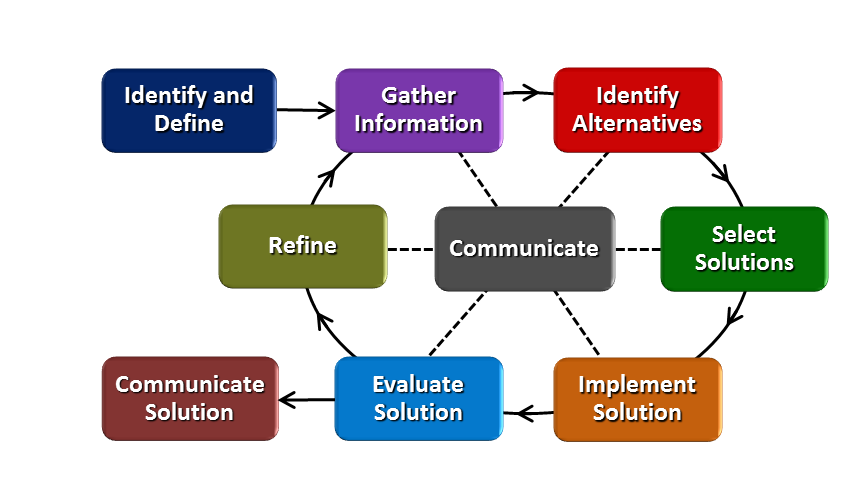
The Challenge and Constraints:

**X** Product **or** ☐ Process (Check one)

|  |  |
| --- | --- |
| Description of Challenge (Either Product or Process is clearly explained below): | List the Constraints Applied |
| **Students will build an electric toy car and, more importantly, one or more energy storage devices, so that it can complete an “Amazing Race,” as a set of challenges, including race and pull a load, in a fixed amount of time.** | **\* All have the same car kit and can only use the parts provided (with approved exceptions).**  **\* All cars will have recharging as part of their testing time.**  **\* Can work with limited variety of electricity storage devices as power supply.**  **\* Must complete tasks between start of quarter and exams.** |

Teacher’s Anticipated Guiding Questions (that apply to the Challenge and may change with student input.): Can we modify the car (Variety of questions)? Can we supply our own batteries/storage devices? Are we limited to one battery/storage device at a time? Does the car have to carry the storage device? What is the resistance of the car’s circuits? How much energy can each storage device store? What is the power output of each storage device? How long does it take to charge each storage device? How much energy does each task require?

|  |
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| **4. EDP: Use the diagram below to help you complete this section.** |

****

How will students test or implement the solution? What is the evidence that the solution worked? Describe how the iterative process from the EDP applies to your Challenge.

The students will actually run their cars in a time-trial for the “Amazing Race” competition, which includes a few events. Everyone will be able to charge their device “race” and “truck-pull,” but they will get different results. They will have documented multiple trials at home. Given time, we will have an early set of in-school trials, also.

How will students present or defend the solution? Describe if any formal training or resource guides will be provided to the students for best practices (e.g., poster, flyer, video, advertisement, etc.) used to present work.

Students will video-tape their project and post it. They will have a rubric to score their devices with success based on having solutions to both tasks. They will have multiple lessons on circuits throughout the term. They will also have to write a short comparison of their solutions to the other teams.

What academic content is being taught through this Challenge?

The Challenge should really allow the students to differentiate power and energy as well as reinforce their understanding of basic circuits, particularly electrical potential difference, charge, and current.

Assessment and EDP:

Using the diagram above, identify any places in the EDP where assessments should take place, as it applies to your Challenge. Describe below what kinds of assessment are most appropriate.

Formative assessment should take place at the first and second lessons. These relate to **Identify and Define** as well as **Gathering Information** and lead to **Select Solution**. So, lessons 1.1.1 and 1.1.2 are closely related to EDP.

Summative assessment should take place once items have been created by the students. This seems most natural after the video, once the students run their actual “Amazing Race,” and after they have evaluated their peers’ work. These relate closely to the EDP on **Implement Solution**, **Evaluate Solution**, and **Communicate Solution**. Since the students are going to have to meet criteria to successfully solve a challenge, this Lessons 1.2.3 and 1.2.4 also closely relate to the CBL.

|  |  |
| --- | --- |
| What EDP Processes are ideal for conducting an Assessment? (List ones that apply.) | List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative. |
| Gather Information  Select Solution  Implement Solution 1  Implement Solution 2  Communicate Solution | Have them form Guiding questions **X**  formative ☐ summative  Submit plans for storage device(s) **X**  formative ☐ summative  Video of early-stage RUBRIC ☐ formative **X**  summative  Cars “race” and “truck-pull” RUBRIC ☐ formative **X**  summative  Evaluate other teams cars RUBRIC ☐ formative **X**  summative |

Check below which characteristic(s) of this Challenge will be incorporated in its implementation using EDP. (Check all that apply.)

**X**  Has clear constraints that limit the solutions

**X**  Will produce than one possible solution that works

**X**  Includes the ability to refine or optimize solutions

**X**  Assesses science or math content

**X**  Includes Math applications

☐ Involves use of graphs

**X**  Requires analysis of data

**X**  Includes student led communication of findings

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| **5. ACS (Real world applications; career connections; societal impact):** |

Place an X on the continuum to indicate where this Challenge belongs in the context of real world applications:

|  |  |  |
| --- | --- | --- |
| **Abstract or Loosely Applies to the Real World** | **|--------------------------------------|-------------------------------------X-|** | **Strongly Applies to the Real World** |

Provide a brief rationale for where you placed the X**:­­­­­­­­­­­­­­** Electric cars are becoming more common and need to both move quickly for a long time and accelerate well. This merely simulates the much more complex reality, though.

What activities in this Unit apply to real world context? Teamwork overall, the car race and pull, and peer evaluations are all related to working and living in the real-world.

Place an X on the continuum to indicate where this Challenge belongs in the context of societal impact:

|  |  |  |
| --- | --- | --- |
| **Shows Little or No Societal Impact** | **|-------------------------------------|-------------------------X--------------|** | **Strongly Shows Societal Impact** |

Provide a brief rationale for where you placed the X**:** While batteries have pervasive use, and energy conservation is important, this specific challenge doesn’t seem to get the students to interact with the community in a positive way. However, I am requiring they communicate their results publicly through a video.

What activities in this Unit apply to societal impact? The students will work with energy storage device and will post videos so others can see them.

Careers: What careers will you introduce (and how) to the students that are related to the Challenge? (Examples: career research assignment, guest speakers, fieldtrips, Skype with a professional, etc.)

Electrical Engineering; Physicist; Industrial Designer – require to interview with a professional about their career path; GRA/Choose Ohio First Scholar interactions with class for Chem/other engineering program at UC.

|  |
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| **6. Misconceptions:** |

Students come to class believing… batteries make electricity; “charges” don’t really relate to “electricity”; “static” and “wall outlet” electricity are different things completely; batteries’ quality of manufacture is really only key difference in energy storage device

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| **7. Unit Lessons and Activities: (**Provide a tentative timeline with a breakdown for Lessons 1 and 2. Provide the Lesson #’s and Activity #’s for when the Challenge Based Learning (CBL) and Engineering Design Process (EDP) are embedded in the unit.) |

**Lesson 1: Storing Energy is Necessary to Control When It’s Used** – (2-3 days)

This will focus on leading students into the Challenge by engaging them in asking questions about energy and power usage.

Activity 1: Apply the Hook and Brainstorm “Essential Questions”… **(1 day)**

Activity 2: Introduce the Challenge and then Use KWL to help students formulate “Guiding Questions”… **(1-2 days)**

**Lesson 1.1.1 and 1.1.2 are good examples of the early stages of the EDP**

**Lesson 2: Amazing Race** – (3-4 days after building… 2-3 Weeks after Lesson 1: Activity 2)

Lesson 2 will have students build and test power-supplies and electric toy cars in a time-trail, multiple-challenge event.

Activity 3: Run the storage challenges while having student apply the rubric to each other’s devices. (This will be the second iteration run for all students.) **(2-3 days** after builds are complete**).**

**Lesson 1.2.3 is a good example of CBL and nears the culmination of the EDP with significant Refinement, Implementation, and Communication.**

Activity 4: Have students share their ideas for improving their device, or the “best one,” in writing. **(1 day).**

**Lesson 1.2.4 is an extension of Evaluation and Refine steps of the EDP**

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| **8. Keywords:** |

Energy, Power, Battery, Supercapacitor, Challenge-Based Learning

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| **9. Additional Resources:** |

* Carolina STEM Challenge®: Solar Car Design Kit, Item # 18096, 8 per kit so need 3-4 kits at $145 each.
* Supercapacitors, capacitors, and small, rechargeable Li-Ion batteries (TBD)
* Students will have to supply wires and connecting methods
* Power supplies to charge devices
* Racing, pulling, and ramp-climbing tasks (TBD)

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| **10. Pre-Unit and Post-Unit Assessment Instruments:** |

1.0.0a Electric Power and Energy Usage\_PrePostQuiz\_JDAlessandro\_070116.docx

|  |  |
| --- | --- |
| **11. Poster** | **12. Video (Link here.)** |

**If you are a science teacher, check the boxes below that apply:**

| **Next Generation Science Standards (NGSS)** | |
| --- | --- |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| **X** Asking questions (for science) and defining problems (for engineering) | **X** Patterns |
| **X** Developing and using models | **X** Cause and effect |
| **X** Planning and carrying out investigations | **X** Scale, proportion, and quantity |
| **X** Analyzing and interpreting data | **X** Systems and system models |
| **X** Using mathematics and computational thinking | **X** Energy and matter: Flows, cycles, and conservation |
| **X** Constructing explanations (for science) and designing solutions (for engineering) | **X** Structure and function. |
| **X** Engaging in argument from evidence | **X** Stability and change. |
| **X** Obtaining, evaluating, and communicating information |  |

**If you are a science teacher, check the boxes below that apply:**

| **Ohio’s Learning Standards for Science (OLS)** |
| --- |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| **X** Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| **X** Demonstrating Science Knowledge **(D)** |
| **X** Interpreting and Communicating Science Concepts **(C)** |
| **X** Recalling Accurate Science **(R)** |

**If you are a math teacher, check the boxes below that apply:**

| **Ohio’s Learning Standards for Math (OLS) or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| --- | --- |
| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

**Part 2: Post Implementation- Reflection on the Unit**

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| **Results: Evidence of Growth in Student Learning - A**fter teaching the Unit, present the evidence below that growth in learning was measured through one the instruments identified above. Show results of assessment data that prove growth in learning occurred.  **Please include**:   * Any documents used to collect and organize post unit evaluation data. (charts, graphs and /or tables etc.) * An analysis of data used to measure growth in student learning providing evidence that student learning occurred. (Sentence or paragraph form.) * Other forms of assessment that demonstrate evidence of learning. * Anecdotal information from student feedback. |

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| **Reflection:** Reflect upon the successes and shortcomings of the unit. Refer to the questions posed on the Unit Template Instruction sheet. Describe how the actual Engineering Design Process was actually used in the implementation of the Unit. |

## Quiz Over Electric Power and Energy Usage

### For each question, please select the best choice. If you do NOT know the correct answer, please select the most clearly incorrect.

1. Which of these answers best describes a battery?
   1. A way of storing and retrieving electrical potential energy using chemical energy.
   2. A source of electrons to be used by a device.
   3. A device that creates electricity from burning a fuel in a controlled manner.
   4. A way of storing and retrieving electrical potential energy using static electric fields.
   5. A magical device containing fairies that push capacities through other devices.
2. Which of these answers best describes a capacitor?
   1. A way of storing and retrieving electrical potential energy using chemical energy.
   2. A source of electrons to be used by a device.
   3. A device that creates electricity from burning a fuel in a controlled manner.
   4. A way of storing and retrieving electrical potential energy using static electric fields.
   5. A magical device containing fairies that push capacities through other devices.
3. Which of the following is the best item to use to power an electronic device?
   1. A battery is best.
   2. A capacitor is best.
   3. A supercapacitor is best.
   4. It really depends on the needs of the device. Sometimes, one of the above items may be better and other times may require a different one or a combination.
   5. A steam engine is best, particularly for pocketable devices.
4. What is the difference between “energy” and “power?”
   1. “Power” is a source of “energy.”
   2. “Energy” is a source of “power.”
   3. “Power” is a capability to do work and “energy” is a stored amount of work.
   4. “Power” is a quantity of how fast work is completed and “energy” is a quantity of how much work can be done.
   5. “Power” is what makes Superman and Wolverine different from other people and “energy” is what makes Beyoncé present differently from Hillary Clinton.
5. What is an electrical circuit?
   1. A system of components that can be connected together minimally needing a source of potential, a device to be run, and wires connecting the device to the source in a continuous series from highest potential to lowest potential.
   2. A system of components that can be connected together minimally needing a source of electricity, a device to be run, and wires connecting the device to the source in a continuous series so that the electricity can run to the device.
   3. A path that electricity can run through from high to low electrical field.
   4. A path that electricity can run through from high to low electrical current.
   5. A running path that electrons use to keep fit, frequently involving areas for specific cross-training exercises.
6. What is a resistor?
   1. A component that can reduce the flow of electrical potential.
   2. A component that can reduce the flow of electrical field.
   3. A component that can reduce the flow of electrical chemistry.
   4. A component that can reduce the flow of electrical charge.
   5. A person that can reduce the flow of government actions.
7. What does it mean for two electrical components to be “in series”?
   1. They are in series if they are both connected in the same circuit.
   2. They are in series if they are both connected to the same electrical energy storage device.
   3. They are in series if the same electrical current flows through both component at the same time.
   4. They are in series if both electrical components have the same electric potential difference at the same time.
   5. They are in series if they are part of a story that takes place over multiple episodes and you either have to wait a week to see what happens or you have to binge-watch them.
8. What does it mean for two electrical components to be “in parallel”?
   1. They are in parallel if they are both connected in the same circuit.
   2. They are in parallel if they are both connected to the same electrical energy storage device.
   3. They are in parallel if the same electrical current flows through both component at the same time.
   4. They are in parallel if both electrical components have the same electric potential difference at the same time.
   5. They are in parallel if they frequently have the same thought at the same time and sometimes finish each other’s sentences.

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| **Name:** John J. D’Alessandro | **Contact Info:** jdalessandro@stxavier.org | **Date:** 06/27/2016 |

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| **Lesson Title :** Storing Energy is Necessary to Control When It’s Used | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **1** |
| **Activity Title:** Apply the Hook and Brainstorm “Essential Quesitons” |

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| **Estimated Lesson Duration:** | 3 Days |
| **Estimated Activity Duration:** | 1 Day |

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| **Setting:** | St. Xavier HS faculty parking lot and room 1556 |

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| **Activity Objectives:** |

Given the topic of Energy Use without Fossil Fuels, students will develop the primary “Essential Question” through brain-storming.

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| **Activity Guiding Questions:** |

1. How fast do they think a 2015 Chevy Volt can go?
2. How quickly do they think it can accelerate?
3. What do they think its towing power is?
4. How long do they think it takes to charge?
5. How far do they think a charge takes a person?
6. How does it stop?
7. Why is there a gasoline engine?

| **Next Generation Science Standards (NGSS)** | |
| --- | --- |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| Asking questions (for science) and defining problems (for engineering) | Patterns |
| Developing and using models | Cause and effect |
| Planning and carrying out investigations | Scale, proportion, and quantity |
| Analyzing and interpreting data | Systems and system models |
| Using mathematics and computational thinking | Energy and matter: Flows, cycles, and conservation |
| Constructing explanations (for science) and designing solutions (for engineering) | Structure and function. |
| Engaging in argument from evidence | Stability and change. |
| Obtaining, evaluating, and communicating information |  |

| **Ohio’s Learning Standards for Science (OLS)** |
| --- |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| Demonstrating Science Knowledge **(D)** |
| Interpreting and Communicating Science Concepts **(C)** |
| Recalling Accurate Science **(R)** |

| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| --- | --- |
| **Standards for Mathematical Practice (Check all that apply)** | |
| Make sense of problems and persevere in solving them | Useappropriate tools strategically |
| Reason abstractly and quantitatively | Attendto precision |
| Construct viable arguments and critique the reasoning of others | Look for and make use of structure |
| Model with mathematics | Look for and express regularity in repeated reasoning |

|  |
| --- |
| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

From *Course Outcomes for Regular Physics*, November 19, 2015.

4. Defend the use of 1st principles, assumptions, formulae, and graphs to accurately predict the outcome of a described physical phenomenon.

8. Analyze the current and future behavior of physical systems using the idea of kinetic and potential energy as well as the laws of conservation of energy and conservation of momentum.

10. Calculate the current, voltage and/or resistance in an electrical circuit.

11. Design and build electrical circuits using a single power source and resistors.

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| --- |
| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

stxavier.instructure.com (Canvas Discussion will be used)

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| **Teacher Advance Preparation:** |

Create the Canvas Discussion. Make sure car will have enough charge to get through day.

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| **Activity Procedures:** |

1. Take students on “class trip” to faculty parking lot.
2. Explain how Volt gets power and powertrain differences.
3. Demonstrate driving on electric.
4. Present **Activity Guiding Questions** to them and have them right them down.
5. Return to class and have them brainstorm potential **Essential Questions** dealing with storing and using energy using the Canvas discussion board.

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

Observe classroom discussion to encourage full participation.

Make certain everyone gets a voice and that they are thinking on-track.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

All students can participate in brainstorming. They can work to their own level, asking more basic or more constructed and detailed questions as they feel comfortable.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

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| **Name:** John J. D’Alessandro | **Contact Info:** jdalessandro@stxavier.org | **Date:** 06/27/2016 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Lesson Title :** Storing Energy is Necessary to Control When It’s Used | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **2** |
| **Activity Title:** Introduce the Challenge and then use KWL to help students formulate “Guiding Questions.” |

|  |  |
| --- | --- |
| **Estimated Lesson Duration:** | 3 Days |
| **Estimated Activity Duration:** | 1-2 Day |

|  |  |
| --- | --- |
| **Setting:** | Room 1556 |

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| **Activity Objectives:** |

**The Challenge:** Students will build an electric toy car and, more importantly, one or more energy storage devices, so that it can complete an “Amazing Race,” as a set of challenges, including race and pull a load, in a fixed amount of time.

Students will self-assess what they know about energy storage. Students will generate a list of guiding questions about Challenge.

Constraints they will need to hit:

\* All have the same car kit and can only use the parts provided (with approved exceptions).

\* All cars will have recharging as part of their testing time.

\* Can work with limited variety of electricity storage devices as power supply.

\* Must complete tasks between start of quarter and exams.

|  |
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| **Activity Guiding Questions** (sample of possible student-generated Guiding Questions)**:** |

1. Can we modify the car (Variety of questions)?
2. Can we supply our own batteries/storage devices?
3. Are we limited to one battery/storage device at a time?
4. Does the car have to carry the storage device?
5. What is the resistance of the car’s circuits?
6. How much energy can each storage device store?
7. What is the power output of each storage device?
8. How long does it take to charge each storage device?

How much energy does each task require?

| **Next Generation Science Standards (NGSS)** | |
| --- | --- |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| Asking questions (for science) and defining problems (for engineering) | Patterns |
| Developing and using models | Cause and effect |
| Planning and carrying out investigations | Scale, proportion, and quantity |
| Analyzing and interpreting data | Systems and system models |
| Using mathematics and computational thinking | Energy and matter: Flows, cycles, and conservation |
| Constructing explanations (for science) and designing solutions (for engineering) | Structure and function. |
| Engaging in argument from evidence | Stability and change. |
| Obtaining, evaluating, and communicating information |  |

| **Ohio’s Learning Standards for Science (OLS)** |
| --- |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| Demonstrating Science Knowledge **(D)** |
| Interpreting and Communicating Science Concepts **(C)** |
| Recalling Accurate Science **(R)** |

| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| --- | --- |
| **Standards for Mathematical Practice (Check all that apply)** | |
| Make sense of problems and persevere in solving them | Useappropriate tools strategically |
| Reason abstractly and quantitatively | Attendto precision |
| Construct viable arguments and critique the reasoning of others | Look for and make use of structure |
| Model with mathematics | Look for and express regularity in repeated reasoning |

|  |
| --- |
| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

From *Course Outcomes for Regular Physics*, November 19, 2015.

4. Defend the use of 1st principles, assumptions, formulae, and graphs to accurately predict the outcome of a described physical phenomenon.

8. Analyze the current and future behavior of physical systems using the idea of kinetic and potential energy as well as the laws of conservation of energy and conservation of momentum.

10. Calculate the current, voltage and/or resistance in an electrical circuit.

11. Design and build electrical circuits using a single power source and resistors.

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

Paper for KWL or use of Canvas discussion board

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| --- |
| **Teacher Advance Preparation:** |

Set up plan for Challenge and Canvas discussion board.

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| **Activity Procedures:** |

1. Ask students to write down everything they know about electrical energy storage.
2. Ask them to write down what they would need to know if they were to make their own device to store electricity.
3. Submit the Challenge to them… possibly with modifications to fit student-generated ideas, specifications, or requests. The constraints of the Amazing Race must use a challenging amount of energy and that means they need to be fashioned to meet available charge-storing devices.
4. Ask them to write down what they need to learn to successfully fulfil the challenge… specify that they should write these in question form. These should be similar to the **Activity Guiding Questions** above.

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

Make certain students are participating by having them think-pair-share their KWL and group share their Guiding Questions.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

All students can participate on this assignment at their level. Grouping student in pairs based on their extroversion level may be beneficial to make certain all voices are heard.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

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| **Name:** John J. D’Alessandro | **Contact Info:** jdalessandro@stxavier.org | **Date:** 06/27/2016 |

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| --- | --- | --- | --- |
| **Lesson Title :** The Amazing Race | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **3** |
| **Activity Title:** The Amazing Race Happens |

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| **Estimated Lesson Duration:** | 3-4 Days (in class… 2-3 weeks overall) |
| **Estimated Activity Duration:** | 2-3 Days (in class… 2-3 weeks overall) |

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| **Setting:** | Room 1556 |

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| **Activity Objectives:** |

Students will video-tape their project and post it. They will have a rubric to score their devices with success based on having solutions to both tasks. They will have multiple lessons on circuits throughout the term. They will also have to write a short comparison of their solutions to the other teams.

The students will actually run their cars in a time-trial for the “Amazing Race” competition, which includes a few events. Everyone will be able to charge their device, “race” and “truck-pull,” but they will get different results. They will have documented multiple trials at home. Given time, we will have an early set of in-school trials, also.

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| **Activity Guiding Questions:** |

1. Is it better to have a device that can store more energy?
2. Is it better to have one that can charge faster?
3. What is the trade-off between the two?
4. What is the limiting factor on timing with the varioius stages… the car’s use of energy or the storage device’s power output?

| **Next Generation Science Standards (NGSS)** | |
| --- | --- |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| Asking questions (for science) and defining problems (for engineering) | Patterns |
| Developing and using models | Cause and effect |
| Planning and carrying out investigations | Scale, proportion, and quantity |
| Analyzing and interpreting data | Systems and system models |
| Using mathematics and computational thinking | Energy and matter: Flows, cycles, and conservation |
| Constructing explanations (for science) and designing solutions (for engineering) | Structure and function. |
| Engaging in argument from evidence | Stability and change. |
| Obtaining, evaluating, and communicating information |  |

| **Ohio’s Learning Standards for Science (OLS)** |
| --- |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| Demonstrating Science Knowledge **(D)** |
| Interpreting and Communicating Science Concepts **(C)** |
| Recalling Accurate Science **(R)** |

| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| --- | --- |
| **Standards for Mathematical Practice (Check all that apply)** | |
| Make sense of problems and persevere in solving them | Useappropriate tools strategically |
| Reason abstractly and quantitatively | Attendto precision |
| Construct viable arguments and critique the reasoning of others | Look for and make use of structure |
| Model with mathematics | Look for and express regularity in repeated reasoning |

|  |
| --- |
| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

From *Course Outcomes for Regular Physics*, November 19, 2015.

4. Defend the use of 1st principles, assumptions, formulae, and graphs to accurately predict the outcome of a described physical phenomenon.

8. Analyze the current and future behavior of physical systems using the idea of kinetic and potential energy as well as the laws of conservation of energy and conservation of momentum.

10. Calculate the current, voltage and/or resistance in an electrical circuit.

11. Design and build electrical circuits using a single power source and resistors.

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

* Carolina STEM Challenge®: Solar Car Design Kit, Item # 18096, 8 per kit so need 3-4 kits at $145 each.
* Supercapacitors, capacitors, and small, rechargeable Li-Ion batteries (TBD)
* Students will have to supply wires and connecting methods
* Power supplies to charge devices
* Racing, pulling, and ramp-climbing tasks (TBD)

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| **Teacher Advance Preparation:** |

Make sure the energy and power requirements of the tasks meet the capacity of the devices to make this not too easy nor difficult. Acquire parts. Perform other Activities first. Present information on electric potential, current, and resistance.

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| **Activity Procedures:** |

Students need to submit first iteration attempts of their work at home on video at least a week before trials are run in school.

On the day(s) of timed trial, have the students run their trials one group at a time while timing the trial runs. Actually take the best of three runs, to accommodate flaws in construction quality and vagaries of apparatus. Also, have the students peer-review using the rubric, as they will be using the evaluation for the next lesson.

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

Students will submit a video of early, home-test events that will be scored with a rubric.

Students have to overcome challenge; make certain partners have worked in the group and understand underpinnings of their work. They will score each other’s work with rubrics and they themselves will receive a score based on a rubric.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Score the device and car with a rubric (TBD)

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

With this being a project experience, it allows for implicit differentiation. Make certain rubric allows students with challenges to excel yet has enticement for strongest students to push themselves.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

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| **Name:** John J. D’Alessandro | **Contact Info:** jdalessandro@stxavier.org | **Date:** 06/27/2016 |

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| **Lesson Title :** TheAmazing Race | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **4** |
| **Activity Title:** Final revision plans |

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| **Estimated Lesson Duration:** | 3-4 Days (in class… 2-3 weeks overall) |
| **Estimated Activity Duration:** | 1 Day (in class… 2-3 weeks overall) |

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| **Setting:** | Room 1556 |

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| **Activity Objectives:** |

Have students submit ideas in writing for improving either their device or the device that they deemed “best” (of the ones they peer-assessed with rubrics the day before).

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| **Activity Guiding Questions:** |

1. Where did your car have the most trouble?
2. What was your limiting factor in time?
3. What could you do “the next time” to make an even better energy storage device?
4. How does that improve on the device?

| **Next Generation Science Standards (NGSS)** | |
| --- | --- |
| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| Asking questions (for science) and defining problems (for engineering) | Patterns |
| Developing and using models | Cause and effect |
| Planning and carrying out investigations | Scale, proportion, and quantity |
| Analyzing and interpreting data | Systems and system models |
| Using mathematics and computational thinking | Energy and matter: Flows, cycles, and conservation |
| Constructing explanations (for science) and designing solutions (for engineering) | Structure and function. |
| Engaging in argument from evidence | Stability and change. |
| Obtaining, evaluating, and communicating information |  |

| **Ohio’s Learning Standards for Science (OLS)** |
| --- |
| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| Demonstrating Science Knowledge **(D)** |
| Interpreting and Communicating Science Concepts **(C)** |
| Recalling Accurate Science **(R)** |

| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
| --- | --- |
| **Standards for Mathematical Practice (Check all that apply)** | |
| Make sense of problems and persevere in solving them | Useappropriate tools strategically |
| Reason abstractly and quantitatively | Attendto precision |
| Construct viable arguments and critique the reasoning of others | Look for and make use of structure |
| Model with mathematics | Look for and express regularity in repeated reasoning |

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| --- |
| **Unit Academic Standards (NGSS, OLS and/or CCSS):** |

From *Course Outcomes for Regular Physics*, November 19, 2015.

4. Defend the use of 1st principles, assumptions, formulae, and graphs to accurately predict the outcome of a described physical phenomenon.

8. Analyze the current and future behavior of physical systems using the idea of kinetic and potential energy as well as the laws of conservation of energy and conservation of momentum.

10. Calculate the current, voltage and/or resistance in an electrical circuit.

11. Design and build electrical circuits using a single power source and resistors.

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

Online submission form in Canvas.

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| **Teacher Advance Preparation:** |

Make online submission form and open to classes. Make certain all classes had adequate access to devices and rubric.

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| **Activity Procedures:** |

Deliver the **Activity Guiding Questions.**

Have them take notes for approximately 5-10 mins. This is there draft.

Have them review rubrics that THEY SCORED from the day(s) before… for about 5-10 mins.

Have them go online to find and write answers to the Canvas worksheet (the **Summative Assessment**). I am allotting 20-30 mins for this.

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

Students will have to analyze rubrics they have used to judge other energy devices, in comparison with their own, too. They would have scored their classmates devices, and their own, in the previous lesson. Today, they will focus on making evaluative decisions based off of those rubrics. For **EDP**, this would be part of the **REFINE** step, even though there is no time left to implement the design refinements. Also, the students will **COMMUNICATE SOLUTION** to me, as the review. Given time, I may bring in a guest engineer to discuss best choices.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Short answer document will be scored based on reasonableness of answers to guiding questions. They should be crafting a short work where they:

1. Answer the Activity Guiding Questions.
2. Choose a device design they would modify (their own or their chosen “best” of their classmates).
3. Explain their choice of device with at least three supporting statements.
4. Explain at least three improvements they could make.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

All students will have an opportunity to discuss improvement methodologies, even if they do not appreciate their own car/storage unit systems. This means that students with weaker building skills can either focus on that aspect of their own for improvement or choose a stronger-built but theoretically weaker design. Similarly, a student who struggles with the math/theory may select that as their own weakness for improvement.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

#### APPENDIX IV: UNIT PLAN FOR *Energy, What is it good for?*

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| --- | --- | --- |
| Name:Mike Day | Contact Info:513-543-0479 | Date: |

|  |
| --- |
| Unit Number and Title: 1 Energy, What is it Good For |

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| --- | --- |
| Grade Level: | 11-12 |
| Subject Area: | Mathematics-Engineering |

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| --- | --- |
| Total Estimated Duration of Entire Unit: | 7 days |

**Part 1: Designing the Unit**

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| 1. Unit Academic Standards (Identify which standards: NGSS, OLS and/or CCSS. Cut and paste from NGSS, OLS and/or CCSS and be sure to include letter and/or number identifiers.): |

## NGSS: [HS-ETS1-1 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-1-engineering-design)

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

## NGSS: [HS-ETS1-2 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-2-engineering-design)

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

## NGSS: [HS-ETS1-3 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-3-engineering-design)

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

## NGSS: [HS-PS1-6 Matter and its Interactions](http://www.nextgenscience.org/pe/hs-ps1-6-matter-and-its-interactions)

Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium

## NGSS: [HS-PS3-3 Energy](http://www.nextgenscience.org/pe/hs-ps3-3-energy)

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy

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| 2. Unit Summary |

The Big Idea (including global relevance):

*Things that move using cordless energy*. Can we make energy storage devices more efficient? This has tremendous global relevance because the more efficient the storage device the less waste there will be, and the more work can be achieved.

The (anticipated) Essential Questions: List 3 or more questions your students are likely to generate on their own. (Highlight in yellow the one selected to define the Challenge):

1. What are the expectations for an energy storage device?
2. What are the variables we can control in producing an efficient energy storage device?

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| 3. Unit Context |

Justification for Selection of Content– Check all that apply:

☐ Students previously scored poorly on standardized tests, end-of term test or any other test given in the school or district on this content.

X Misconceptions regarding this content are prevalent.

X Content is suited well for teaching via CBL and EDP pedagogies.

X The selected content follows the pacing guide for when this content is scheduled to be taught during the school year. (Unit 1 covers atomic structure because it is taught in October when I should be conducting my first unit.)

☐ Other reason(s) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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The Hook: (Describe in a few sentences how you will use a “hook” to introduce the Big Idea in a compelling way that draws students into the topic.)

Students will fly a drone, then talk on a cell phone, and then walk around. Meanwhile, a power point will be playing showing things that use energy and are mobile.

The Challenge and Constraints:

**X** Product **or** ☐ Process (Check one)

|  |  |
| --- | --- |
| Description of Challenge (Either Product or Process is clearly explained below): | List the Constraints Applied |
| Build a capacitor that charges quickly and discharges slowly. Time in minutes how long their capacitor takes to charge to 9 volts. Then time how long it takes until the capacitor discharges to 3 volts by running a fan. The test is a combination of the two variables. | Time  Materials from home to create capacitor  Budget of $5  9 Volt battery to charge capacitor. |

Teacher’s Anticipated Guiding Questions (that apply to the Challenge and may change with student input.):

1. What types of energy are there?
2. What do you use energy for?
3. What are different ways of generating energy?
4. What different types of Energy Storage Devices are used?
5. What characteristics are there for each energy storage devices?
6. What is the difference between a battery and a capacitor?
7. How do capacitors store energy?
8. How do we make capacitors charge quickly and discharge slowly?

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| 4. EDP: Use the diagram below to help you complete this section. |

How will students test or implement the solution? What is the evidence that the solution worked? Describe how the iterative process from the EDP applies to your Challenge.

Testing the capacitor will be done in several parts.

1. After hooking the capacitor to a 9 volt battery, measure how long it takes to charge to 9 volts?

2. How long does the discharge take to get to 3 volts while running a fan?

The evidence will be recorded using a volt meter and recording the time it takes to charge and to discharge. The faster to charge is better and the slower to discharge is better so to find the best capacitor we will use the formula: Time to discharge (Td) minus time to charge (Tc).

Maximimize: Td - Tc

The engineering design process applies because students will research capacitors, design several types, select their best design, build that capacitor, test it, and then refine the design and do it all over again.

How will students present or defend the solution? Describe if any formal training or resource guides will be provided to the students for best practices (e.g., poster, flyer, video, advertisement, etc.) used to present work.

Students will present their solutions to a panel of teachers. Students may use videos, posters or power points to convince the panel that their capacitors are the best. Our students all take IT classes as part of their curriculum to help with projects like this.

What academic content is being taught through this Challenge?

## NGSS: [HS-ETS1-1 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-1-engineering-design)

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

## NGSS: [HS-ETS1-2 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-2-engineering-design)

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

## NGSS: [HS-ETS1-3 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-3-engineering-design)

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Assessment and EDP:

Using the diagram above, identify any places in the EDP where assessments should take place, as it applies to your Challenge. Describe below what kinds of assessment are most appropriate.

|  |  |
| --- | --- |
| What EDP Processes are ideal for conducting an Assessment? (List ones that apply.) | List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative. |
| \_\_\_Gather Information\_\_\_\_\_  \_\_\_Identify Alternatives\_\_\_\_  \_\_\_Select Solution (Prototype)\_\_  \_\_\_Evaluate Solution\_\_\_\_\_\_\_ | \_\_\_\_Checklist\_\_\_\_\_\_\_­­\_\_\_\_\_\_\_\_\_\_\_\_\_ **X** formative ☐ summative    \_\_\_\_Checklist\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **X** formative ☐ summative  \_\_\_\_Model\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative **X** summative  \_\_\_\_Rubric\_\_\_\_\_\_\_\_\_­­\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative **X** summative |

Check below which characteristic(s) of this Challenge will be incorporated in its implementation using EDP. (Check all that apply.)

**X** Has clear constraints that limit the solutions

X Will produce more than one possible solution that works

X Includes the ability to refine or optimize solutions

X Assesses science or math content

X Includes Math applications

X Involves use of graphs

X Requires analysis of data

X Includes student led communication of findings

|  |
| --- |
| 5. ACS (Real world applications; career connections; societal impact): |

Place an X on the continuum to indicate where this Challenge belongs in the context of real world applications:

|  |  |  |
| --- | --- | --- |
| Abstract or Loosely Applies to the Real World | |--------------------------------------|---------------------------------X-----| | Strongly Applies to the Real World |

Provide a brief rationale for where you placed the X**:­­­­­­­­­­­­­­\_Energy storage has a major impact on our society, from cars to mobile devices, and especially our environment.\_\_\_\_\_\_**

What activities in this Unit apply to real world context? \_Every activity because of the implications of energy and how it impacts our lives.\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Place an X on the continuum to indicate where this Challenge belongs in the context of societal impact:

|  |  |  |
| --- | --- | --- |
| Shows Little or No Societal Impact | |-------------------------------------|----X-----------------------------------| | Strongly Shows Societal Impact |

Provide a brief rationale for where you placed the X**: ­­­­­­­­­­­­­­\_\_\_\_\_Creating home-made capacitors using everyday materials is not going to help society in itself, but understanding how to increase the storage of energy will.**

What activities in this Unit apply to societal impact? \_The entire activity has societal impact because of the issue of energy and how our world uses it. This unit highlights the fact that we need to store energy more efficiently. If that can happen then our world can become a safer place to live.

Careers: What careers will you introduce (and how) to the students that are related to the Challenge? (Examples: career research assignment, guest speakers, fieldtrips, Skype with a professional, etc.)

This activity would require chemical engineers, electrical engineers, and mechanical engineers. Engineering technologists would be involved also. Business and manufacturing careers would be involved.

Students will be doing a research project on the many types of engineering disciplines, and the differences between engineering and engineering technologies before this unit. Our business teacher will be involved, helping students decide what their manufacturing costs will be.

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| 6. Misconceptions: |

Where does energy come from? How does it work? Electricity, and how it works.

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| 7. Unit Lessons and Activities: (Provide a tentative timeline with a breakdown for Lessons 1 and 2. Provide the Lesson #’s and Activity #’s for when the Challenge Based Learning (CBL) and Engineering Design Process (EDP) are embedded in the unit.) |

Unit 1: Capacitors and how they can make your life better.

Lesson 1: What is energy and how is it stored? After stating the big idea about cordless energy, the discussion will find its way to the essential question about energy storage devices. Electricity is a big part of this project so there will be an activity about volts and amperes and how electricity flows. (3 Days[[WU1]](file:///C:/Users/UC%20Engineering/Desktop/RET%202016/RET%20Unit%20and%20Lessons/2016%20RET%20Unit%20Mike%20Day_TrackingON(4)_7.12.16%20(1).docx) )

Activity 1: Discussion about things that use energy. Why do we need it? A video plays about machines that use energy. Including humans, animals, plants and sea life. (<https://docs.google.com/a/readingschools.org/viewer?a=v&pid=sites&srcid=cmVhZGluZ3NjaG9vbHMub3JnfG1yZGF5MjAxNnxneDo1ODU2YjVhMDQ3YjZkYmNi>)

The hook is introduced here and it is about things that use energy to move, but are free to roam. Students will see that machines that are “tied up” have limitations. Point out machines that are in the room that use any type of energy. Students will be asked to generate essential questions about these machines and their energy. After listening to their ideas and writing them on a board, the primary essential question is introduced: What are the variables we can control in producing an efficient energy storage device? From this question, they are asked to come up with challenges that stem from this concept. Collect them and, hopefully one of them is the true challenge. (1 Day)

Activity 2: Students generate guiding questions to explore types of energy, and ways to generate it. Another guiding question is how to store energy. The type of energy that is used the most is electricity. This activity will contain information about how electricity works. Watch a Bill Nye video about electricity. (<https://www.youtube.com/watch?v=gixkpsrxk4Y>) Complete lesson with circuit boards and how electricity flows. (2 Days)

Lesson 2: Students will explore energy storage devices. Specifically, the differences between batteries and capacitors. This will generate more questions about the challenge and will be more specific about using capacitors in the challenge. They will be building a basic battery and for the challenge, efficient capacitors. They will be using the engineering design process to build the most efficient capacitors. (5 Days)

Activity 3: The first part of this activity is comparing batteries and capacitors. Each group will present to the teacher their findings. They will build a battery using potatoes. Explore why this works and how to make this battery generate more energy. The second day they may bring in other vegetables or materials to see if they generate more electricity. (2 Days)

Activity 4: The students will revisit challenge, which is to build a capacitor that can increase the quickness of the charge and the length of the discharge. They will be charging with a 9 volt battery and the discharge will be running a small fan. They may use different materials, depending on what their research states. They will have a budget of $5. (3 Days[[WU2]](file:///C:/Users/UC%20Engineering/Desktop/RET%202016/RET%20Unit%20and%20Lessons/2016%20RET%20Unit%20Mike%20Day_TrackingON(4)_7.12.16%20(1).docx) )

CBL (Lesson 2, Activity 4)

EDP (Lesson 2, Activity 4)

|  |
| --- |
| 8. Keywords: |

Capacitor, Energy, Battery, Electricity, Energy Storage Device, Fuel Cells,

|  |
| --- |
| 9. Additional Resources: |

|  |
| --- |
| 10. Pre-Unit and Post-Unit Assessment Instruments: |

Pre-Unit will be a 10 question multiple choice quiz.

Post-Unit will be a 10 question multiple choice quiz.

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| 11. Poster | 12. Video (Link here.) |

**If you are a science teacher, check the boxes below that apply:**

|  |  |
| --- | --- |
| Next Generation Science Standards (NGSS) |  |
| Science and Engineering Practices (Check all that apply) | **Crosscutting Concepts (Check all that apply)** |
| X Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| X Developing and using models | X Cause and effect |
| X Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | X Systems and system models |
| ☐ Using mathematics and computational thinking | X Energy and matter: Flows, cycles, and conservation |
| X Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| X Engaging in argument from evidence | ☐ Stability and change. |
| X Obtaining, evaluating, and communicating information |  |

**If you are a science teacher, check the boxes below that apply:**

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| Ohio’s Learning Standards for Science (OLS) |
| Expectations for Learning - Cognitive Demands (Check all that apply) |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☐ Demonstrating Science Knowledge (D) |
| ☐ Interpreting and Communicating Science Concepts (C) |
| ☐ Recalling Accurate Science (R) |

**If you are a math teacher, check the boxes below that apply:**

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| --- | --- |
| Ohio’s Learning Standards for Math (OLS) or  Common Core State Standards -- Mathematics (CCSS) |  |
| Standards for Mathematical Practice (Check all that apply) |  |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

**Part 2: Post Implementation- Reflection on the Unit**

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| Results: Evidence of Growth in Student Learning - After teaching the Unit, present the evidence below that growth in learning was measured through one the instruments identified above. Show results of assessment data that prove growth in learning occurred.    Please include:   * Any documents used to collect and organize post unit evaluation data. (charts, graphs and /or tables etc.) * An analysis of data used to measure growth in student learning providing evidence that student learning occurred. (Sentence or paragraph form.) * Other forms of assessment that demonstrate evidence of learning. * Anecdotal information from student feedback. |
| Reflection: Reflect upon the successes and shortcomings of the unit. Refer to the questions posed on the Unit Template Instruction sheet. Describe how the actual Engineering Design Process was actually used in the implementation of the Unit. |

[[WU1]](file:///C:/Users/UC%20Engineering/Desktop/RET%202016/RET%20Unit%20and%20Lessons/2016%20RET%20Unit%20Mike%20Day_TrackingON(4)_7.12.16%20(1).docx)Explicitly state **in the Activities** where the student generate EQs and Challenges.

[[WU2]](file:///C:/Users/UC%20Engineering/Desktop/RET%202016/RET%20Unit%20and%20Lessons/2016%20RET%20Unit%20Mike%20Day_TrackingON(4)_7.12.16%20(1).docx)Is this where you’ll introduce the challenge? **I understand that this is where they are doing the challenge. What is not clear is where you have the students come up with challenges on their own and when they are told which one was selected. That could be in Activity 2 - but you need to explicitly state that in the Activity itself.**

**Also below you’ll need to clearly tell where the CBL and EDP take place – in which Activities**.

**See the sample for guidance.**

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| Name: Mike Day | Contact Info: [mday@readingschools.org](mailto:mday@readingschools.org) | Date:7/15/16 |

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| Lesson Title : The Big Idea: Energy Driven Devices | Unit #:  1 | Lesson #:  1 | Activity #:  1 |
| Activity Title: Are You Tied Up With Cords |  |  |  |

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| Estimated Lesson Duration: | 3 Days |
| Estimated Activity Duration: | **1 Day** |

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| Setting: | Foundations of Engineering Class, 11-12 Grade |

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| Activity Objectives:   1. Students will be able to describe types of energy 2. Students will be able to describe different uses for energy 3. Students will be able to cite examples of how energy is generated 4. Students will be able to identify energy storage devices 5. Students will be able to identify capacitors and batteries as storage devices |

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| Activity Guiding Questions:   1. What types of energy are there? 2. What do you use energy for? 3. What are different ways of generating energy? 4. What different types of Energy Storage Devices are used? 5. What characteristics are there for each energy storage devices? 6. What is the difference between a battery and a capacitor? 7. How do capacitors store energy? 8. How do we make capacitors charge quickly and discharge slowly? |

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| Next Generation Science Standards (NGSS) |  |
| Science and Engineering Practices (Check all that apply) | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☒ Systems and system models |
| ☐ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☒ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| Ohio’s Learning Standards for Science (OLS) |
| Expectations for Learning - Cognitive Demands (Check all that apply) |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☐ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☐ Recalling Accurate Science (R) |

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| Ohio’s Learning Standards for Math (OLS) and/or  Common Core State Standards -- Mathematics (CCSS) |  |
| Standards for Mathematical Practice (Check all that apply) |  |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| Unit Academic Standards (NGSS, OLS and/or CCSS): NGSS: [HS-ETS1-1 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-1-engineering-design) Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.   NGSS: [HS-ETS1-2 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-2-engineering-design) Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.   NGSS: [HS-ETS1-3 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-3-engineering-design) Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. |

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| Materials: Video to watch:    [Machines that move](https://docs.google.com/a/readingschools.org/viewer?a=v&pid=sites&srcid=cmVhZGluZ3NjaG9vbHMub3JnfG1yZGF5MjAxNnxneDo1ODU2YjVhMDQ3YjZkYmNi) |

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| Teacher Advance Preparation: For this activity the teacher will need an understanding of energy, electricity, capacitors and batteries. |

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| Activity Procedures:   1. Play the video and ask what do these items have in common? 2. Look at the “machines” around you and ask if these things have anything in common with things in the video. 3. Students generate ideas about these items 4. Students generate questions about the items and they are written on a board 5. From this list narrow it down to one essential question 6. Students generate challenges that society would need from the questions they posed. |

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| Formative Assessments:  Big Idea worksheet for students to use:  [Big Idea Worksheet](https://docs.google.com/a/readingschools.org/viewer?a=v&pid=sites&srcid=cmVhZGluZ3NjaG9vbHMub3JnfG1yZGF5MjAxNnxneDo3Njg4OTU5NDI1YTUyODNk) |

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| Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit. |

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| Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

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| Reflection: Reflect upon the successes and shortcomings of the lesson. |

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| Name: Mike Day | Contact Info: | Date:7/18/16 |

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| Lesson Title : The Big Idea: Energy Driven Devices | Unit #:  1 | Lesson #:  1 | Activity #:  2 |
| Activity Title: Electricity |  |  |  |

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| Estimated Lesson Duration: | 3 Days |
| Estimated Activity Duration: | **2 Days** |

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| Setting: | Foundations of Engineering Class, 11 -12 Grade |

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| Activity Objectives:   1. Students will cite examples of how electricity is generated 2. Students will explain how electricity flows 3. Students learn the definitions of voltage, ampere, and wattage 4. Students will build a circuit board to demonstrate knowledge of electricity flows |

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| Activity Guiding Questions:   1. How does electricity work? 2. What does electricity flow using electrons? 3. What are volts, amps, and watts, and how do we measure the flow of electricity? 4. Why do people get shocked? |

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| Next Generation Science Standards (NGSS) |  |
| Science and Engineering Practices (Check all that apply) | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☒ Systems and system models |
| ☒ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☒ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| Ohio’s Learning Standards for Science (OLS) |
| Expectations for Learning - Cognitive Demands (Check all that apply) |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☒ Interpreting and Communicating Science Concepts (C) |
| ☐ Recalling Accurate Science (R) |

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| Ohio’s Learning Standards for Math (OLS) and/or  Common Core State Standards -- Mathematics (CCSS) |  |
| Standards for Mathematical Practice (Check all that apply) |  |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| Unit Academic Standards (NGSS, OLS and/or CCSS): NGSS: [HS-ETS1-1 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-1-engineering-design) Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.   NGSS: [HS-ETS1-2 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-2-engineering-design) Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.   NGSS: [HS-ETS1-3 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-3-engineering-design) Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. |

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| Materials:  Circuit Boards from the science department    Bill Nye the Science Guy video about electricity:  [Bill Nye: Electricity](https://www.youtube.com/watch?v=gixkpsrxk4Y) |

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| Teacher Advance Preparation: Knowledge about electricity, and Ohm’s Law |

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| Activity Procedures:   1. Students are asked to generate questions about electricity and circuitry 2. Watch video of Bill Nye the science guy about electricity 3. Students build a circuit board from a kit 4. Explain how voltage, amperes, and wattage work and how they are measured 5. Students fill out worksheet about Ohm’s Law |
| Formative Assessments:  Ohm’s Law Worksheet:  [Worksheet: Ohm’s Law](https://docs.google.com/a/readingschools.org/viewer?a=v&pid=sites&srcid=cmVhZGluZ3NjaG9vbHMub3JnfG1yZGF5MjAxNnxneDo2NzhmNWRjZTIwMTQ4YmZj%20.) |

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| Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit. |

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| Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

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| Reflection: Reflect upon the successes and shortcomings of the lesson. |

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| Name: Mike Day | Contact Info: [mday@readingschools.org](mailto:mday@readingschools.org) | Date:7/18/16 |

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| Lesson Title : Energy Storage Devices | Unit #:  1 | Lesson #:  2 | Activity #:  3 |
| Activity Title: Batteries |  |  |  |

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| Estimated Lesson Duration: | 5 Days |
| Estimated Activity Duration: | **2 Days** |

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| Setting: | Foundations of Engineering Class, 11-12 Grade |

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| Activity Objectives:   1. Students will be able to describe how batteries work 2. Students will be able to build a basic battery using potatoes and other vegetables |

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| Activity Guiding Questions:   1. What makes a battery work? 2. How can you make a battery have more voltage? |

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| Next Generation Science Standards (NGSS) |  |
| Science and Engineering Practices (Check all that apply) | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☒ Systems and system models |
| ☐ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☒ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| Ohio’s Learning Standards for Science (OLS) |
| Expectations for Learning - Cognitive Demands (Check all that apply) |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☒ Demonstrating Science Knowledge (D) |
| ☐ Interpreting and Communicating Science Concepts (C) |
| ☐ Recalling Accurate Science (R) |

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| Ohio’s Learning Standards for Math (OLS) and/or  Common Core State Standards -- Mathematics (CCSS) |  |
| Standards for Mathematical Practice (Check all that apply) |  |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| Unit Academic Standards (NGSS, OLS and/or CCSS): NGSS: [HS-ETS1-1 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-1-engineering-design) Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.   NGSS: [HS-ETS1-2 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-2-engineering-design) Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.   NGSS: [HS-ETS1-3 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-3-engineering-design) Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. |

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| Materials: Video to watch about how a battery works:  [How a battery works](https://www.youtube.com/watch?v=u4FpbaMW5sk&index=2&list=PLkyBCj4JhHt8DFH9QysGWm4h_DOxT93fb) |

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| Teacher Advance Preparation: For this activity, the teacher needs to understand how a battery generates electricity. |

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| Activity Procedures:   1. Research batteries on the internet 2. Groups fill out a worksheet and present their findings individually to the teacher 3. Build a battery using potatoes that lights an LED light 4. Test other vegetables as batteries, fill out the table provided |

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| Formative Assessments:  WS on information about batteries:  [Worksheet: How a Battery Works](https://docs.google.com/a/readingschools.org/viewer?a=v&pid=sites&srcid=cmVhZGluZ3NjaG9vbHMub3JnfG1yZGF5MjAxNnxneDo2ODZkODk3N2I4ZTlkZDUx)    Table about batteries and how they worked, along with other materials.  [Table: Battery Results](https://docs.google.com/a/readingschools.org/viewer?a=v&pid=sites&srcid=cmVhZGluZ3NjaG9vbHMub3JnfG1yZGF5MjAxNnxneDo2NTk4ZTdkZGM4MmYzZjRh) |
| Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit. |

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| Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

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| Reflection: Reflect upon the successes and shortcomings of the lesson. |

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| Name: Mike Day | Contact Info: [mday@readingschools.org](mailto:mday@readingschools.org) | Date:7/18/16 |

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| Lesson Title : Energy Storage Devices | Unit #:  1 | Lesson #:  2 | Activity #:  4 |
| Activity Title: Batteries |  |  |  |

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| Estimated Lesson Duration: | 5 Days |
| Estimated Activity Duration: | **3 Days** |

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| Setting: | Foundations of Engineering Class, 11-12 Grade |

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| Activity Objectives:   1. Students will be able to explain how capacitors work 2. Students will be able to build capacitors out of household materials for under $5, and test them |

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| Activity Guiding Questions:   1. What makes a capacitor work? 2. What is the difference between a capacitor and a battery? 3. How can you make a capacitor charge faster and discharge slower? |

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| Next Generation Science Standards (NGSS) |  |
| Science and Engineering Practices (Check all that apply) | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☒ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☒ Systems and system models |
| ☐ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☒ Engaging in argument from evidence | ☒ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

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| Ohio’s Learning Standards for Science (OLS) |
| Expectations for Learning - Cognitive Demands (Check all that apply) |
| ☐ Designing Technological/Engineering Solutions Using Science concepts (T) |
| ☐ Demonstrating Science Knowledge (D) |
| ☐ Interpreting and Communicating Science Concepts (C) |
| ☐ Recalling Accurate Science (R) |

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| Ohio’s Learning Standards for Math (OLS) and/or  Common Core State Standards -- Mathematics (CCSS) |  |
| Standards for Mathematical Practice (Check all that apply) |  |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| Unit Academic Standards (NGSS, OLS and/or CCSS): NGSS: [HS-ETS1-1 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-1-engineering-design) Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.   NGSS: [HS-ETS1-2 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-2-engineering-design) Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.   NGSS: [HS-ETS1-3 Engineering Design](http://www.nextgenscience.org/pe/hs-ets1-3-engineering-design) Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. |

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| Materials: Video to watch about how a capacitor works:  <https://www.youtube.com/watch?annotation_id=annotation_1160083969&feature=iv&src_vid=u4FpbaMW5sk&v=f_MZNsEqyQw> |

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| Teacher Advance Preparation: For this activity, the teacher needs to understand how a capacitor generates electricity. |

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| Activity Procedures:   1. Watch the video on capacitors 2. Groups present their findings individually to the teacher 3. Revisit the challenge and its parameters 4. Build a capacitor that will charge 9 volts at the quickest rate, and discharges the 9 volts by running a fan at the slowest rate. 5. Test the design and then try to improve it using the engineering design process. |

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| Formative Assessments:  Student involvement in the discussion about capacitors |
| Summative Assessments:  Journal observations throughout this whole lesson  Engineering Design Process packet filled out  Final Rubric to score testing iterations and model design. |

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| Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

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| Reflection: Reflect upon the successes and shortcomings of the lesson. |