

**ABSTRACT**:

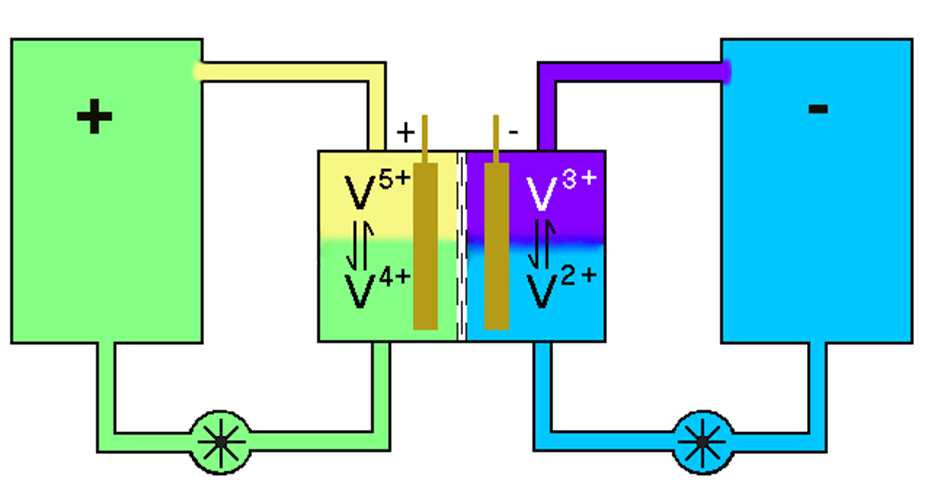
The intermittent nature of alternative energy sources such as solar and wind power requires an energy storage system for times when the supply exceeds the demand. Vanadium Redox Flow Batteries (VRFBs) show potential to fill this need because they are efficient, flexible, and scalable. Further research and scale-up of these batteries depends upon a fast, simple, and inexpensive means of monitoring the vanadium state of charge. This project evaluated the use of UV-Vis spectroscopy to assess state of charge in VRFBs. The method first involved analysis of known concentrations of each vanadium species to establish a calibration plot. The resultant calibration plot exhibited a linear relationship between absorbance and concentration that allowed for extrapolation or interpolation to determine specific concentrations of vanadium species in unknown samples. Confirmation of this method provides researchers working on the optimization of VRFBs a means of obtaining state of charge data. Furthermore, the potential application to alternative energy sources relates to a current societal issue, which teachers can connect to a variety of classroom lessons.

**Keywords: Beer-Lambert Law, redox flow battery, state of charge monitoring, UV-Vis spectroscopy, vanadium redox flow battery.**

1. **INTRODUCTION**

Vanadium reduction-oxidation flow batteries (Fig. 1) have great potential to support renewable energy sources such as solar and wind power. Since these energy sources are intermittent, meaning their energy production does not always coincide with energy usage, a storage system is required. VRFBs have the potential to fill this need and level out supply needs. VRFBs provide a number of advantages. They are flexible in their application and design so they can be installed almost anywhere and easily scaled up. They have a very high storage capacity and power rating. VRFBs also have a very long life cycle and are environmentally friendly and safe to use. However, additional research is needed before use of VRFBs become widespread, in particular expense and efficiency require further study.

VRFBs store electrical energy through the use of chemical reactions. Specifically, they use solutions of vanadium in sulfuric acid and reduction and oxidation reactions to store the energy. Vanadium can exist in several oxidation states including V(II), V(III), V(IV), and V(V). The electrical energy is stored by converting vanadium between the various oxidation states.



**Figure 1.** Schematic diagram of Vanadium Redox Flow Battery

(<https://en.wikipedia.org/wiki/File:Vanadium_battery.png>)

Since the storage of energy is contingent upon the oxidation state of the vanadium, it is critical that a method be developed to determine the state of charge of the batteries to support research and implementation of the batteries. One method of measuring the state of charge is to measure the concentration of the various vanadium species. Each oxidation state of vanadium appears as a different color; V(V) - yellow, V(IV) – blue, V(III) – green, and V(II) - violet. (Fig. 2) This characteristic provides an ideal scenario for the use of UV-Vis measurements. The light absorbed in UV-Vis occurs at different wavelengths for each vanadium species. In addition, the concentration of each species can be detected by how much light they absorb at those wavelengths. This is explained in the Beer Lambert Law which shows the mathematical relationship of the absorption to the concentration of the species being measured. The Beer-Lambert equation states the absorptivity is a product of the absorptivity extinction coefficient (, the distance the light travels through the sample (*l*), and the species concentration (*c*).

Beer-Lambert Equation: (1)



**Figure 2.** Vanadium species and corresponding colors

http://www.reddit.com/r/chemistry/comments/2n37us/transition\_metal\_rainbow/

This project studies the use of the UV-Vis to monitor the concentration of the vanadium species which in turn would provide needed information for the state of charge monitoring of VRFBs to support research, development, and implementation of VRFBs.

**2. LITERATURE REVIEW**

Starting in 1973 NASA researched and reported developments in redox flow batteries (RFBs) at their Lewis Center, based in Cleveland, Ohio.(Thaller 1979) Testing included a number of transition metal pairs, specifically titanium (Ti(III)/Ti02+), iron (Fe(II)/Fe(III)), chromium (Cr(II)/Cr(III)). The iron-chromium system, emerged as the most worthy candidate for further development. A trio of patents were granted in 1980 for various aspects of RFBs. De Nora Electrochemical Plants in Milan, Italy; National Electrotechnical 222 Laboratory in Tokyo, Japan and NASA in the USA (Bartolozzi 1989) Also in Ohio, reports of investigation on three varieties of RFBs were made by Savinell (1981) at the University of Akron in OH. Ford Motor Co made a foray into RFBs with one solution being Vanadium and trying in turn Cu, Fe, and Sn as the other. (Oei 1982) The pioneering work on the vanadium version occurred at the University of New South Wales in Australia. Under Kazacos and Kazacos, the VRFBs were led from concept in 1984 to prototypes for electric vehicles during the late 1980s and 1990s. In early 1988, new features of an all-vanadium redox flow battery were communicated by Rychcik. (1988)

More recently researchers have revisited the potential of RFBs, particularly as a storage solution for renewable energy such as solar and wind, when the supply exceeds the demand. Although the initial cost of Vanadium is greater than iron/chromium combinations, VRFBs are advantageous because cross-contamination is not an issue (Ding 2013). For VRFBs to be viable in the field, it is necessary to monitor state of charge (SOC). The distinct colors of V (II III, IV, and V) in acid solution point to visible spectroscopy as a possible instrument for analysis (Buckley 2014). As part of their ongoing work on VRFBs, Kazacos and Skyllas-Kazacos (2011) explored SOC monitoring by both conductivity and UV-vis spectroscopy. They concluded that UV-vis spectroscopy could be used by placing a detector which monitors absorbance at 750 nm. Given the tendency for V(II) to oxidize to V(III), researchers at Yonsei University experimented with sealed electrolyte reservoirs to look at how dissolved O2 influenced the capacity of a VRFBs (Choi 2013). In contrast to the V(II) exposed to O2, the V(II) in sealed vessels could be analyzed via UV-vis spectroscopy provided the samples were less than 0.15M to avoid detector saturation and permit application of the Beer-Lambert Law.

**3. BACKGROUND INFORMATION**

The allotted time for research during the teachers’ participation in Research Experience for teachers (RET) limited the scope of this project. The Area Coordinator chose this area of inquiry, in part, because he envisioned multiple opportunities for classroom connections. The teaching standards which correspond to students’ grade levels promoted teachers to focus on energy transformations as the big idea for their unit plans for the upcoming term. However, future teaching assignments may open opportunities to connect this research to lessons related to the electromagnetic spectrum, color, wavelengths, light or vision.

Conducting research afforded the teachers opportunities to reacquaint themselves with good laboratory practices. Of particular note, recording daily entries in a permanently bound notebook with numbered pages, highlighted the value of historical record keeping unlike the common classroom practice of using worksheets for lab activities. Both time and the simplicity of the set-up precluded the opportunity to work in an atmosphere which would limit the oxidation of V(II) to V(III). Research focused on confirming the suitability of visible spectroscopy as a method for identifying and quantifying various vanadium species in sulfuric acid solution (the electrolyte currently used in the Area Coordinator’s laboratory).

**4. GOALS AND OBJECTIVES**

The goal of this project was to research the use of UV-Vis to determine if this method is viable to determine the concentration of vanadium species in sulfuric acid-based VRFBs. The objective of the project was to establish Calibration Plots for each of the vanadium species. The calibration plots consist of graphs of absorption versus concentration. These calibration plots could then be used to determine the concentrations for each the vanadium species in samples from VRFBs based on their absorbance spectra.

**5. RESEARCH STUDY DETAILS**

Members of the research team were trained using a UV-Vis spectrometer and supporting computer program called SpectraSuite. The instruction provided on the operation of the UV-Vis spectrometer included sample preparation requirements for the sample, use of the computer program SpectraSuite supporting the UV-Vis spectrometer, start up and calibration of the instrument, and performance of the analysis for the samples. Included in the training was the wearing and usage of appropriate personal protective clothing. The primary safety concern for this operation was the 2 Molar (M) sulfuric acid that each of the samples were in solution. Handling of the samples required wearing nitrile gloves, lab coats and safety glasses.

The samples which were analyzed came from another VRFB research project. Each sample had a sum total concentration of 0.100M for all vanadium species and were in solution with 2.0M sulfuric acid. Samples were delivered to the lab as needed. This lab providing the samples was capable of reducing or oxidizing the vanadium to provide the specific species to be analyzed.

**5.1 Vanadium(IV) Analysis**

The first set of analysis occurred on a series of samples of known concentrations of vanadium (IV) [V(IV)]. The known concentrations were 0.100M, 0.070M, 0.050M, and 0.025M. Each concentration was analyzed three times for statistical purposes. Details regarding sample numbers and data were recorded in the laboratory notebook. The data collected by the supporting computer software program, SpectraSuite, provided a visual display of the graph comparing absorption to wavelength for the samples and specific data points for the absorption at each wavelength. This data was transferred to Excel for storage and management.

The collected data was processed by determining the maximum absorption. The maximum absorption for the three analyses at each concentrations was averaged and the standard deviation calculated. The result of the average absorbance for each concentration with its corresponding standard deviation was plotted to develop a graph of Absorbance versus Concentration or a Calibration Plot. All calculations performed were recorded in the laboratory notebook.

**5.2 Vanadium(V) Analysis**

The process described above was duplicated for V(V) samples at the following concentrations; 0.100M, 0.075M, 0.050M, and 0.025M. The maximum absorption peaks were not selected for the development of the Absorption to Concentration graphs for the V(V). This was due to the difficulty in observing a consistent maximum absorption peak. Each spectrum dropped off gradually so a wavelength was chosen along this slope to use as a common comparison to related absorbance and concentration. This wavelength provided a relationship of absorption to concentration for V(V) allowing for the establishment of the Calibration Plot. The final steps of data management and plotting were the same as those stated for V(IV).

**5.3 Vanadium(III) Analysis**

Analysis on V(III) was performed using the same concentrations as V(V) 0.100M, 0.075M, 0.050M, and .025M. However, V(III) is susceptible to oxidation causing it to oxidize into V(IV) when exposed to the surrounding air. Therefore, when the V (III) sample was analyzed, a peak for the V(IV) was also present. To adjust for the presence of the V(IV), the V(IV) Calibration Plot, developed earlier, was used to quantify the V(IV) present in the sample. This concentration was then subtracted from the total vanadium concentration in the sample. This provided the V(III) concentration which was used to develop the V(III) Calibration Plot.

**5.4 Vanadium (II) Analysis**

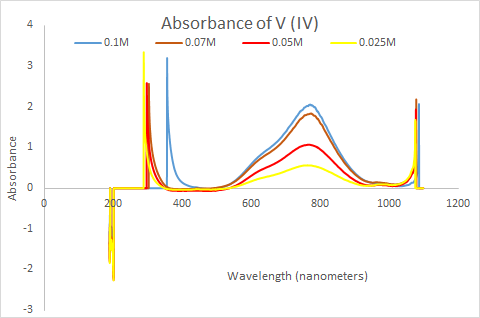
The final series of tests was to determine the Calibration Plot for V(II). The V(II) species is extremely susceptible to oxidation, so the sample concentrations of V(II) also needed to be adjusted based on the presence of other vanadium species in particular V(III). The approach was similar to that of V(III). The Calibration Plot for V(III) was used to establish the concentration of V(III) and which was subtracted from the total vanadium concentration in each sample. For this series of analysis a 0.100M sample was received and concentrations of 0.075M, 0.050M, and 0.025M were made through dilution of the 0.100M sample. The adjusted concentrations were then to be used to develop the final Calibration Plot for V(II). Care was taken minimize the time the samples were exposed to oxygen by keep caps on the samples when not in use.

**6. RESEARCH RESULTS AND CONCLUSIONS**

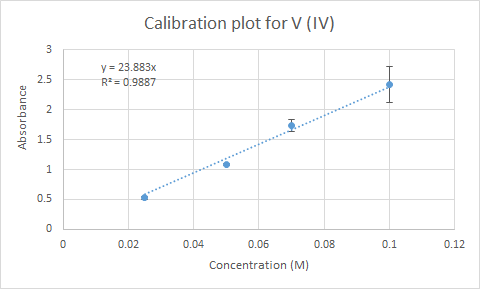
**6.1 V(IV) Calibration Plot**

The analysis for the Calibration Plot for V(IV) was successfully developed. A direct relationship of concentration is readily observable from the data. The Calibration Plot appears to be very usable to assist in determining V(IV) concentrations.

Figure 2 displays an overlay of the absorption graphs of each concentration of V(IV) as it relates to wavelength. This readily demonstrates Beer-Lambert Law relating relative concentration to absorbance. The maximum absorbance peak is located in the 765-775 nm range.



**Figure 2**. Absorbance spectra for various concentrations of V(IV)

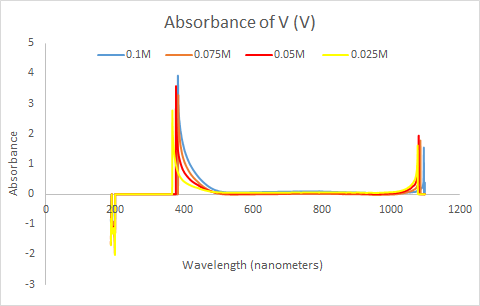


**Figure 3.** Calibration Plot for V(IV) – Absorbance vs Concentration

The Calibration Plot for V(IV) (Figure 3) shows the linear relationship of Absorbance to concentration. Also displayed is the equation relating the x (concentration) and y (absorbance) values.

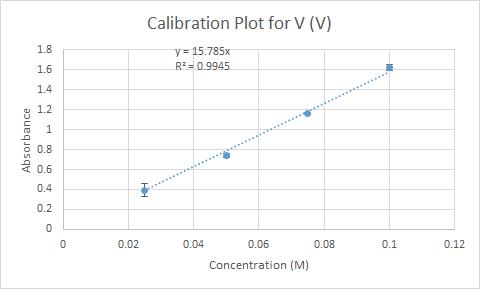
The final calculation performed was the determination of the absorptivity extinction coefficient as established using the Beer-Lambert Law.For the V(IV) in 2 M sulfuric acid, the absorptivity extinction coefficient is 23.883 L mol-1 cm-1.

**6.2 V(V) Calibration Plot**

The analysis for the Calibration Plot was successfully developed with relatively small error. A direct relationship of concentration is readily observable from the data. The Calibration Plot appears to be very usable to assist in determining V(V) concentrations.

**Figure 4**. Absorbance spectra for various concentrations of V(IV)

Figure 4 displays an overlay of the absorption graphs of each concentration of V(V) as it relates to wavelength. This readily demonstrates Beer-Lambert Law relating relative concentration to absorbance. Because of the location of the observed maximum peak for each concentration was not at the same wavelength, the 400 nm wavelength was selected for this calibration plot.



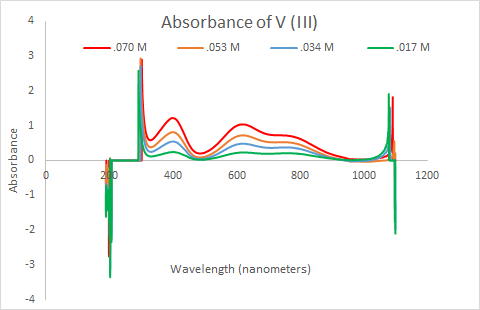
**Figure 5**. Calibration Plot for V(IV) – Absorbance vs Concentration

The Calibration Plot for V(V) Figure 5 shows a linear relationship of Absorbance to Concentration. Also displayed is the equation relating the x and y axis values. By using the equation, the measured absorbance of a sample can be converted to a concentration. Also evident from the equation is the absorptivity extinction coefficient which for the V(V) species is calculated as 15.785 L mol-1 cm-1.

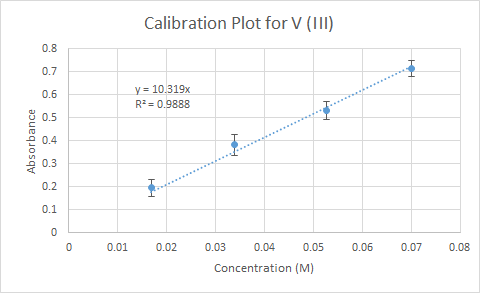
**6.3 V (III) Calibration Plot**

The analysis for the Calibration Plot was successfully developed with relatively small error. A direct relationship of concentration is readily observable from the data. The Calibration Plot appears to be very usable to assist in determining V(III) concentrations.

Figure 6 displays an overlay of the absorption graphs of each concentration of V(III) as it relates to wavelength. This readily demonstrates Beer-Lambert Law relating relative concentration to absorbance. The peak of interest here is the peak located in the 610 nm range. Note that concentration values are different from those typical of the V(IV) and V(V) Calibration Plot, the concentration values listed here required the removal of V(IV) concentration known to be in the sample due to the V(III) species susceptibility to oxidation. The V(IV) is observable by the peak in the 765 nm range. To compensate for the presence of the V(IV), the Calibration Plot for V(IV) was used to establish the concentration of V(IV). The total concentration of the vanadium species in the samples was 0.100 M. The adjusted concentrations for the V(III) are listed in the Absorbance graph.



**Figure 6**. Absorbance spectra for various concentrations of V(IV)



**Figure 7.** Calibration Plot for V(IV) – Absorbance vs Concentration

The Calibration Plot for V(III) (Figure 7) shows a linear relationship of Absorbance to Concentration. Also displayed is the equation relating the x and y axis values. By using the equation, the measured absorbance of a sample can be converted to a concentration. Also evident from the equation is the absorptivity extinction coefficient which for the V(III) species is calculated as 10.319 L mol-1 cm-1.

**6.2 V (II) Calibration Plot**

The performance of the calibration plot for V(II) was to have been the final and most complex of the species. Due to its high susceptibility for oxidation, it was expected that there would be the presence of V(III) species from the oxidation of the V(II). The initial approach for the V(II) was to use the V(III) Calibration Plots to determine the concentration of the oxidized vanadium species and remove that concentration from the total vanadium concentration. The remaining vanadium would be considered V(II). From that information a V(II) Calibration Plot could be constructed.

The measurement of the 0.100M sample provided the following results. Measured absorption showed a concentration of 0.045M V (III). By subtracting the concentration of V(III), the concentration of the V(II) was determined to be 0.055M V(II).

The 0.075M sample was shown to have a concentration of 0.029M V (III) and therefore a concentration of 0.046M V (II). As analysis continued with the diluted samples of 0.050M and 0.025M the concentration of V (II) became undetectable. This is believed to be due to the high susceptibility to oxidation of the V (II) and the exposure to air caused by the dilution process and handling of the samples.

Due to the high level of susceptibility of the sample to oxidation, it is evident that creation of a Calibration Plot for V(II) was not feasible. The V(II) oxidation occurred so quickly that the results obtained were not usable. However, concentrations for V(II) could still be identified indirectly through use of the Calibration Plots for the other vanadium species by difference. Another area of difficulty arose from the presence of the absorbance peaks located in the 400 nm range. Both V(V) and V(III) contain peaks in this region so identifying concentrations using these peaks when both V(V) and V(III) are present may be rather complex.

**7. RECOMMENDATIONS FOR FUTURE RESEARCH**

Use of UV-Vis to measure absorbance and determine the concentration of vanadium species is useful and a feasible process for V(III), V(IV), and V(V). Additional studies can be done in this area to refine the Calibration Plot and reduce error.

Use of this method for identifying V (II) concentration will require further research. Verification needs to be made to show that removal of the other vanadium species can accurately identify the V (II) and issue related to the overlap of the V (V) and V (II) peaks are addressed to assure results are accurate. Furthermore, research may be conducted on testing methods for performing UV-Vis on the samples to reduce exposure to air. These modification could provide an accurate and usable Calibration Plot for V(II).

However, limitations do exist in Beer-Lambert Law and the linear relationship between Absorbance and Concentration breaks down at concentrations as exceeding 1M for V(III) and greater than 2M for V(V) and V(IV).

**8. CONCLUSION**

The use of UV-Vis spectrometry to measure concentrations of vanadium in VRFBs is an affective and achievable through the development of Calibration Plots for V(III), V(IV), and V(V). Calibration Plot showed a very linear relationships for concentrations below 0.1M for these species. Using UV-Vis for V(II) proved very difficult primary due to how susceptible it is to oxidation into the other vanadium species.

**9. CLASSROOM IMPLEMENTATION PLANS**

**9.1 Marie Inanli’s Classroom Implementation Plan**

The title of Marie Inanli’s unit “Beyond Basic Batteries “is meant to convey multiple meanings. Many students are familiar with batteries labelled “alkaline” so may think that that most if not all batteries are “basic” as in non-acidic or neutral pH. Another point to emphasize is that words which sound familiar to students often still need to be defined because they have a specific meaning in the context of science or engineering. Classic examples include the words ‘law’ and ‘theory’. Team activities also benefit from a common language so that students need not refer to an important part as thingamajig or doo-hickey. Therefore lessons include vocabulary activities.

Students will complete the unit during the beginning of the second semester for a total of ten class periods of 50 minutes each. The big idea for students to contemplate is that energy can be transformed. Engineers often design equipment and processes to transform energy into a useable form for the benefit of humans. So, too, will the students participate in a challenge to convert chemical energy into electrical energy. Specifically they will select one of several produce items to make a battery with available materials such as copper wire, pennies, galvanized nails etc. What differentiates this lesson from the classic build a lemon battery activity? First of all students can build their batteries multiple ways.. Secondly the students will measure the output of their batteries, compare their data with that obtained by other students and then improve upon their design.

Guiding questions include:

What is a battery?

How do batteries work?

What is a circuit?

What is a conductor?

What is an insulator?

What energy transformation occurs when battery power allows a lamp to glow?

Aside from the fact that this unit connects to summer research, the topic was chosen because battery power is valued by most middle-school students insofar as it keeps their precious electronic devices operating.

The first activity after introducing the unit will be a pretest of a dozen questions to assess prior knowledge, address misconceptions, and evaluate growth. The students will the do a flipped lesson from TED-Ed on how batteries work. The next day I will address misconceptions and build vocabulary via Marzano methods and interactive games. On the following day students will build circuits using pHet simulations and complete a worksheet that as probing questions and provides a place for students to sketch circuit diagrams. At the end of the week I will use a video clip describing a power outage as a hook to introduce the challenge. The students will be guide to ask essential questions and define the problem. One of the first steps in the solution is for students to go home and conduct an inventory of essential devices their family would operate by an alternate source if the power was out. Student will need to record pertinent information on a data table such as amps, volts, watts.

The students will consider this information when they design their batteries because one of the constraints is that their battery should be able to power a selected device for three days. After students finalize their designs and evaluate how well the batteries function, they will share their best battery. The vehicle for this will be the creation of an advertisement which can take many forms: billboard, jingle, video etc. The students will complete a rubric for their own work as well as their classmates. The fact that students use produce as an energy source will provide a nice segue to life science.

**9.2 Larry Honigford’s Classroom Implementation Plan**

Larry Honigford’s unit is titled “Transforming Energy with Style”. It will be used in 6 sections of ninth grade Physical Science in the January-February timeframe during the 2015-16 school year.  The big idea is that energy is never “used up” but is conserved. Energy “usage” is really just a transformation of energy to an alternative form. Energy is a very critical topic both for its importance to with world’s economy, but also to the environmental health of Earth. The use of certain energy sources, such as fossil fuels, leads to societal issues regarding pollution and long term environmental impacts such as global warming. Other energy sources such as solar and wind power which are “renewable” have far less negative impact.

The essential question to be addressed in this unit is “What happens to energy when it is “used”? To address this essential question, students will be given the challenge of designing a Rube Goldberg Device consists of a series of contraptions to complete a very simple task. The students will have to create a device with at least five energy exchanges, and include vertical (up or down movements of the process) and horizontal movements (left to right movements of the process). Students will have the opportunity to redesign and retest their device in order to incorporate refinements. Students will also need to present their device, and describe the sequential energy transformations in the device and included a discussion on energy that is lost to the surrounding environment and no longer useful to the device.

The guiding questions for this challenge include:  What is energy? For what purpose is energy used? Where do we get our energy from? What issues are we challenged with regarding energy today? How can potential energy be converted into kinetic movement through twists and turns as well as gravity? How can potential and kinetic energy be calculated? What is meant by the conservation of energy? How does energy transform from one kind to another? How can energy be quantified within a system to demonstrate conservation of energy? What is the relationship of potential to kinetic energy? How can potential and kinetic energy demonstrate the Law of Conservation of energy?

The unit was selected because students do not readily identify that total energy of system does not change. They have the misconception that energy is “used up”. In addition, there is a rising need to establish alternative forms of energy which are not detrimental to the environment. Finding alternative energy sources requires resourceful and creative thinking. The use of the Engineering design process to create multiple solutions is very important to the establishment of alternative energy sources.

Lesson one, called “What Lost, Not Energy!”, will address the idea that energy can come in many forms, but is conserved. If we were capable of quantifying all energy in any system we would find that no energy is lost. Activity one will start with the application of a pre-assessment consisting of 12 questions. Following the pre-assessment a music video by OK Go! “This too shall pass” will be shown. The video shows a very complex Rube Goldberg device. This will spark conversations about the energy and where goes is, and how the device continue to operate without another push. The students will also be given time to visit websites in which they can develop their own virtual Rube Goldberg device. From this activity the student will be providing ideas for a challenge regarding energy. The outcome will be the Rube Goldberg device challenge. The following day the challenge will be introduced along with constraints and required steps and deliverables. In the second activity under lesson 1 the students will explore the concept of the Law of Conservation of Energy. They will explore different forms of energy and show the transformation that occurs within a given situation. Included in this activity they will perform experiments using kinetic and potential energy tracks to visually observe the conservation of energy and begin quantifying potential and kinetic energy.

Lesson two, called “Energy Transformations”, will address quantification of energy (specifically potential and kinetic energy) and the implementation of the Rube Goldberg device. The first activity in this lesson will start by introducing the potential and kinetic energy equations and will include opportunities to practice using those formulas and when each formula applies. The students will also have the opportunity to quantify the relationship of potential and kinetic energy through the softball toss activity which includes graphing results of a softball being tossed in the air. The final part of this activity will be the creation of a roller coaster. This is a mini-challenge in which they will need to create a Rollercoaster which will include specific criteria including a vertical loop, and a 90 degree turn. The students will not only have to meet time constraints for this mini-challenge, but also cost constraints in this challenge. The second activity in this lesson will be the testing, refining and presentation of the Rube Goldberg devices. Students will be assessed using a rubric to determine whether they met the challenge criteria.

The Engineering Design Process (EDP) can be found throughout the unit.  The steps of EDP and details of where it is found in the unit are outlined below:

* Identify the problem:  After teacher introduces the big idea, students will identify the problem of how to create a Rube Goldberg device during the first activity.
* Identify criteria and constraints: The device must include 5 energy transformation and include vertical and horizontal direction changes in the device. It must also start with only the potential energy from the first step and finish with no additional help.
* Brainstorm possible solutions: After student teams have been established time will be provided for team members to provide ideas about the parts of the device.
* Generate ideas: Student teams will continue to generate ideas as the unit progresses through the Law of Conservation of energy, types of energy, and energy calculations.
* Explore possibilities: Student groups will test different combinations of materials see if they can effectively transform the energy in the device.
* Select approach:  From the evaluation of alternatives the student teams will select a combination of materials to incorporate into their device that meets the constraints of the challenge.
* Build model, prototype, or design process: Students will be given time in class to put together and actively test their device.
* Communicate ideas: Student teams will communicate information and test results throughout the design process. They will keep an engineering portfolio in which they will they maintain documentation of the EDP throughout the project.
* Refine the process: Student teams will redesign or tweak their devices during the test day to assure that all steps adequately work. Refinement will be made as needed to assure a working device is created.

During the unit, progress and understanding will be monitored using the students’ engineering portfolio.  The students will be provided a list of items that they will need to include in their portfolio including lists and sketches from brainstorming, selection of solutions, draft drawings, a lab journal.

The final presentation of the devices will occur on the last day. The students will need to present their devices to the class and include energy transformation descriptions in their presentations. The Summative Assessment will be a 12 question posttest which is identical to the pretest to measure growth in student learning.

It is expected that this unit will impact between 150-160 students, or six sections of Physical Science, in the 2015-2016 school year.  By including the student developed challenge approach, where the student are asked to develop the challenge, the students should have a greater ownership of the project. The expected outcome is a greater level of student learning and project ownership. As the year progresses, it is expected that the use of the Engineering Design Process and Challenge Based Learning will have already been used to some extent. So students will have some familiarity of the process.  This priming will give the students a better opportunity to immerse themselves in the challenge.

**10. ACKNOWLEDGEMENTS**

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**12. APPENDIX I: NOMENCLATURE USED**

A – Absorbance

*c* – Concentration

Calibration Plots - Graphs which plotted Absorbance versus Concentration

CBL – Challenge Based Learning

- Absorptivity extinction coefficient

EDP – Engineering Design Process

*l –* Distance light travels through the sample

M - Molarity, concentration measure in moles per liter of solution

nm – nanometers

RFBs – Redox Flow Batteries

SOC - State of charge

UV-Vis - Ultraviolet-Visible spectroscopy

V (II) – Vanadium +2 oxidation state

V (III) – Vanadium +3 oxidation state

V (IV) – Vanadium +2 oxidation state

V (V) – Vanadium +3 oxidation state

VRFBs - Vanadium Redox Flow Batteries

**13. APPENDIX II: UNIT TEMPLATE OF MARIE INANLI**

|  |  |  |
| --- | --- | --- |
| **Name: Marie Inanli** | **Contact Info: marie.c.inanli@gmail.com** | **Date: July 2015** |

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| **Unit Number and Title: Unit 1 Beyond Basic Batteries** |

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| --- | --- |
| **Grade Level:** | Middle School |
| **Subject Area:** | Physical Science |

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| --- | --- |
| **Total Estimated Duration of Entire Unit:** | **10 x 50 min classes** |

**Part 1: Designing the Unit**

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

NGSS MS-PS3.CC.3.1.

ELF 4.1 Humans transfer and transform energy from the environment into forms useful for human endeavors.

ELF 4.6 Humans intentionally store energy for later use in a number of different ways.

ELF 4.7 Different sources of energy and the different ways energy can be transformed, transported and stored each have different benefits and drawbacks.

ONLS

PS.68.7a Identify an energy transfer (e.g., electricity to heat in a circuit).

PS.68.7c Demonstrate energy transfer by completing a circuit (e.g., switch to activate a mechanical item).

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| 1. **Unit Summary** |

The Big Idea (including global relevance): Energy Transformations

Progress in the development of electric cars and improving the battery life of portable electronic devices depend on engineering better batteries. Understanding how energy is transformed is important in developing alternative energy sources which is of global importance to the health and wealth of people throughout the world.

With the increased intensity of storms and ageing infrastructure, the likelihood of a power outage increases.

Are there alternate ways to supply energy to essential devices?

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. How do batteries work?

2. How long do batteries last?

3. Can we make a battery instead of buying one?

4. What makes a battery rechargeable?

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| **Unit Context – Select all that apply.** |

Justification for Selection of Content:

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

☐ Misconceptions regarding this content are prevalent.

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

☐ 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: Be a hero: prevent panic by providing portable power

<https://www-ssl.intel.com/content/www/us/en/corporate-responsibility/better-future/eesha-khare-cell-phone-battery.html>

The Challenge and Constraints:

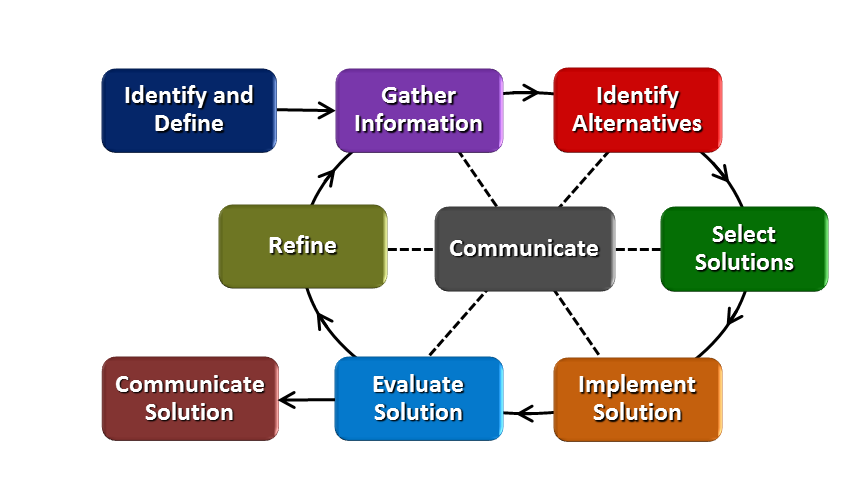
x Product **or** ☐ Process (Check one)

|  |  |
| --- | --- |
| Description of Challenge (Either Product or Process is clearly explained below): | List the Constraints Applied |
| A major storm knocks out power. Your local power company predicts it will be out for a few days. All the stores are out of batteries. Build the best battery for your needs. . Evaluate battery by determining if it can light a bulb for 3 days (during the school day | Complete Challenge during 7 class periods.  Use supplied materials:  Alligator clips  Aluminum foil  Cans of cheap soda pop  Cardboard  Copper wire  Galvanized nails  apples, bananas, cucumbers, grapefruit, kiwi, kumquats, lemons, limes, mangoes, nectarines, oranges, papayas,  peaches, plums, or potatoes,  Pennies  Table salt  Vinegar  micro-ammeter/multimeter |

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

1. What is in a battery?
2. How does a car battery differ from a phone battery?
3. Do you use the same type of battery in all your electronic devices?
4. How is a battery’s capacity measured?
5. What makes a battery last?

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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.*

Students will test their batteries qualitatively by whether or not an LED bulb lights. They will quantitatively test their batteries with a voltmeter. Students will have the opportunity to improve their batteries.

*How will students present or defend the solution?*

Students will provide photographic evidence of their batteries in operation.

*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 create advertisements for their product. They can choose whether they create a poster, video, or jingle to sell their “product”. Resource guides will be available for reference. Unless a student is new to the class, s/he would have prior exposure to various modes or presentation

*What academic content is being taught through this Challenge?*

The academic content includes: energy transformations eg from chemical to electrical; energy storage eg batteries, dry cells, fruit; energy transfer by completing a circuit; cost/benefit analysis for parallel vs. series circuits.

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. |
| communicate solutions  identify alternatives  pre-/post-test  implementation | Rubric\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative ☐ summative  sketch/checklist\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative ☐ summative  Q/A\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative ☐ summative  product\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ☐ formative ☐ summative |

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

☐ Has clear constraints that limit the solutions

☐ Will produce than one possible solution that works

☐ Includes the ability to refine or optimize solutions

☐ Assesses science or math content

☐ Includes Math applications

☐ Involves use of graphs

☐ Requires analysis of data

☐ Includes student led communication of findings

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

**Real world applications-**the use of household materials to solve a problem builds competence and confidence in their ability to deal with a variety of challenges both at home and at work.

**Career connections**-to this unit include a variety of STEM careers including but not limited to chemical and electrical engineering, trades such as electricians and HVAC technicians

**Societal impact-**as result ofunderstanding how energy, electricity, and batteries work students can become more conscientious citizens, better equipped to deal with energy choices individuals, corporations and communities will need to make as consumption grows.

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**:\_**Providing power during an outage is a real need. However, produce power is neither particularly portable or nor powerful.

What activities in this Unit apply to real world context? \_Students are likely to have many of the supplies used in the challenge, such as produce, pennies, vinegar etc. at home when an outage occurs.The apparent increase in the duration and intensity of storms means that students will likely see more power outages in the future.

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**: \_\_**Battery technology is a limiting factor in scaling up electric cars as well as renewable energy such as solar and wind

What activities in this Unit apply to societal impact? \_\_Building a battery empowers students to problem solve and encourages both self-sufficiency and cooperation .Batteries and battery technology are an integral part of modern technology. Their efficient use and disposal/recycling are an important aspect of proper environmental care.

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

I will introduce the careers of chemical engineering and electrical engineering by having our Graduate Research Assistant, speak to my students, either in person or via the Internet, depending on scheduling.

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| **6. Misconceptions:** |

One common idea, the “source-consumer” model, reveals that some students believe batteries send out a substance that gets “used up”. Students often show this by sketching a single wire attached to one (usually the top) terminal of the battery and the other end attached to the bulb. A similar model involves using two wires, each attached to each end of the battery and the bulb – each with wire carrying energy from the battery to the light bulb. (Driver et al. 1994) When dry cells“die” they do not “run out of electricity” Instead, the battery’s chemical reaction fails to fuel the movement of electrical charge.

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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 *Beyond Basic Batteries* timeline

Lesson 1 *Energy on the Move* introduces students to concepts around the Big Idea i.e. Energy and its transformations. Students will investigate the basics of batteries and circuits. A video hook will lead students to develop essential questions.

Activity 1 *How Batteries Work* Day 1 Includes CBL

Activity 2 *Complete the Circuit* Day 2

Lesson 2 *Survive a Storm* invites students to consider a scenario in which a storm leads to a prolonged power outage. They consider how they can apply scientific principles to engineer a solution by building a battery. Students work in teams through multiple iterations and communicate results via a choice of media.

Activity 3 Little Lights Day 3

Activity 4 Build a Battery Day 4-10 Includes CBL and EDP

* CBL begins in Lesson 1, Activity 1, because the students start down the path towards the challenge .Both a class video and an interactive online activity plant seeds leading to essential questions about energy, especially power disconnected from the grid such as batteries. The actual challenge is carried out in Lesson 2, Activity 4, through the design, creation and presentation of batteries
* Students follow the EDP during Lesson 2, Activity 4. Students will share the output of their initial batteries with the class. Teams can then apply their learnings through personal experience and date from classmates to improve upon their original design. This is the iterative portion of the EDP.

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| **8. Additional Resources:** |

Why batteries die:

<http://ed.ted.com/lessons/why-batteries-die-adam-jacobson>

Teacher written resources to align with pHET simulation:

<https://ratsgymnasium-pe.de/PhET/en/contributions/view/3121.html>

Volts Amps Watts:

<https://www.youtube.com/watch?v=SAB4YKfIGQM>

What is voltage and current?

<https://www.youtube.com/watch?v=l8JS8BbrVOg>

Bonus activity:

<http://www.bbc.co.uk/bitesize/ks2/science/physical_processes/circuits_conductors/play/>

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| **9. Pre-Unit and Post-Unit Assessment Instruments:** |

The pre/post unit assessments will include a dozen question that target middle school science standards related to energy.

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| **10. Poster (Link here.)** | **11. 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)** |
| ☐ 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 |  |

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

|  |
| --- |
| **Ohio’s New Learning Standards for Science (ONLS)** |
| **Expectations for Learning - Cognitive Demands (Select 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:**

|  |  |
| --- | --- |
| **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. |

To be completed after implementation of Unit during winter 2015-16

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| **Name: Marie Inanli** | **Contact Info: marie.c.inanli@gmail.com** | **Date: July 2015** |

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| --- | --- | --- | --- |
| **Lesson Title : Energy on the go** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **1** |
| **Activity Title: How Batteries Work** |

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| **Estimated Lesson Duration:** | **2 x 50 min class periods** |
| **Estimated Activity Duration:** | **1 x 50 min class period** |

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| **Setting:** | **Classroom or computer lab** |

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| **Activity Objectives:** |

Students will begin to explore the Big Idea-that energy can be transformed.

Teacher will facilitate discussion, leading students to ask Essential Questions

Student will be able to Student will be able to:

1. Define volt, reversible, energy.
2. Describe how energy is not destroyed, only transformed.
3. State Law of Conservation of Energy

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| **Activity Guiding Questions:** |

What causes electricity to flow?

What role do electrons play?

What happens when a battery is recharged?

Why do batteries stop working?

How did the volt get its name?

| **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 New Learning Standards for Science (ONLS)** |
| --- |
| **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)** |

| **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, ONLS and/or CCSS):** |

NGSS MS-PS3.CC.3.1.

ELF 4.1 Humans transfer and transform energy from the environment into forms useful for human endeavors.

ELF 4.6 Humans intentionally store energy for later use in a number of different ways.

ELF 4.7 Different sources of energy and the different ways energy can be transformed, transported and stored each have different benefits and drawbacks.

ONLS

PS.68.7a Identify an energy transfer (e.g., electricity to heat in a circuit).

PS.68.7c Demonstrate energy transfer by completing a circuit (e.g., switch to activate a mechanical item).

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

Pencil /paper or computers depending upon available technology

If computers are available create assessments in Google forms

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| **Teacher Advance Preparation:** |

Have multiple versions of the assessment available: A and B order, Spanish, others as needed

Before lesson ensure that all students have TED Ed accounts so that responses are recorded and shared with teacher.

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| **Activity Procedures:** |

1. Give pre-assessment to gauge students understanding of energy concepts
2. Collect completed assessment
3. Students will begin to explore the Big Idea-that energy can be transformed.
4. Show the video
   1. <https://www.youtube.com/watch?v=6K0Olvyqsmc> or
   2. <https://youtu.be/9M-AZVeyFyI> or
   3. <https://www.youtube.com/watch?v=YMYhMgr9R0A>
5. Students will think pair share with shoulder partner to share questions that arise from watching power outage video and thinking about the video focusing on their personal concerns in such a situation
6. Tell students that big idea for unit is energy transformations
7. How can we use the idea of energy transformations to help us in power outages?
8. What do we need to learn to understand the connection?
9. Students generate a list of Essential Questions
10. Capture student questions via sticky notes real or virtual
11. Teacher facilitates combining similar questions with student input; follow up to clarify questions; focus on the ENERGY related ones to develop the Essential Questions(EQs).
12. Teacher asks students as think pair share what challenge class can do to answer the EQ?
13. Teacher will collect responses, telling students she will use info to create a challenge for class to complete
14. Next Students will go to website for a mini lesson with questions following it

<https://ed.ted.com/lessons/why-batteries-die-adam-jacobson#watch>

* 1. Have students use earbuds/headphones as appropriate

1. After playing the ~ 4 min video, the screen will automatically transition to the “THINK” portion of the lesson. Students will answer 7 questions; 5 multiple choice and 2 free response. The students get immediate feedback on the MC questions. In case of an erroneous response, the lesson offers the option of revisiting the specific section of the video that addresses the question before allowing students to try again to answering correctly. Early finishers and interested students can complete an optional “Dig Deeper “section”
2. If students do not have individual access to computers at school, the lesson could be flipped if they have access at home. Alternatively, the video could be projected for everyone to watch. Then students could answer the questions on paper

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

<https://ed.ted.com/lessons/why-batteries-die-adam-jacobson#watch>

**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. Have multiple versions of the assessment available: A and B order, Spanish, others as needed. TED Ed lessons can be customized  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 Marie Inanli:** | **Contact Info: marie.c.inanli@gmail.com** | **Date: July 2015** |

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| **Lesson Title : Energy on the move** | **Unit #**  **1:** | **Lesson**  **#1:** | **Activity #**  **2:** |
| **Activity Title: Complete the circuit** |

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| **Estimated Lesson Duration:** | **2 x 50 min class periods** |
| **Estimated Activity Duration:** | **1 x 50 min class period** |

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| **Setting:** |  |

Classroom or computer lab

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| **Activity Objectives:** |

Students will be able to:

1. Identify the components of a circuit
2. Build virtual series and parallel circuits
3. Distinguish between insulators and conductors

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| **Activity Guiding Questions:** |

1. What is needed to complete a circuit?
2. What is a “short” circuit?
3. What is the difference between circuits built in series vs in parallel?

| **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 New Learning Standards for Science (ONLS)** |
| --- |
| **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)** |

| **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, ONLS and/or CCSS):** |

NGSS MS-PS3.CC.3.1.

ELF 4.1 Humans transfer and transform energy from the environment into forms useful for human endeavors.

ELF 4.6 Humans intentionally store energy for later use in a number of different ways.

ELF 4.7 Different sources of energy and the different ways energy can be transformed, transported and stored each have different benefits and drawbacks.

ONLS

PS.68.7a Identify an energy transfer (e.g., electricity to heat in a circuit).

PS.68.7c Demonstrate energy transfer by completing a circuit (e.g., switch to activate a mechanical item).

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

<https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc>

pHET circuit activity worksheet (including directions for running the simulation**)**

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| **Teacher Advance Preparation:** |

Download activity to computers if appropriate. (pHET is in the process of updating some simulations to run HTML5. If this sim is updated, downloading will no longer be necessary).

If school policy precludes download of the simulation an alternative website is

<http://www.andythelwell.com/blobz/guide.html> Covers same material but is cuter and more gamified.

Adapt worksheets as needed for ELLand SPED students

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| **Activity Procedures:** |

1. First students will pick up individual worksheets.
2. Then students will go to assigned computer stations.
3. Next students will read and follow instructions to access pHET simulation.
4. Students will build virtual circuits and complete the corresponding part of the worksheet.
5. Teacher will circulate among students to assess progress and provide assistance as needed.

This simulation shows students which parts are necessary to complete a circuit.

They can also experiment with various items to see if they act as conductors or insulators.

\*This simulation could be run with 2 or 3 students using one computer. Ideally each student would take a turn actually building virtual circuits and complete an individual worksheet

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

The worksheet will be used as a formative assessment.

**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. |

Students can partner heterogeneously at the computers. Worksheets will be adapted as needed.

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

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| **Name: Marie Inanli** | **Contact Info: marie.c.inanli@gmail.com** | **Date: July 2015** |

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| --- | --- | --- | --- |
| **Lesson Title : Survive a Storm** | **Unit #:**  **1** | **Lesson #**  **2** | **Activity #:**  **3** |
| **Activity Title: Little Lights** |

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| --- | --- |
| **Estimated Lesson Duration:** | **8 x 50 min periods** |
| **Estimated Activity Duration:** | **1 x 50 min periods** |

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| **Setting:** |  |

Classroom/lab

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| **Activity Objectives:** |

Students will

1. Recall information from activities in previous lesson
2. Students will apply knowledge from previous lesson
3. Students will collaborate to complete an inquiry activity
4. Students will determine that batteries can be acidic

|  |
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| **Activity Guiding Questions:** |

1. What are the essential parts of a circuit?
2. What are the essential parts of a battery?
3. Is copper a conductor or an insulator?
4. What does “galvanized” mean?
5. How do electrons flow?

| **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 New Learning Standards for Science (ONLS)** |
| --- |
| **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)** |

| **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, ONLS and/or CCSS):** |

NGSS MS-PS3.CC.3.1.

ELF 4.1 Humans transfer and transform energy from the environment into forms useful for human endeavors.

ONLS

PS.68.7a Identify an energy transfer (e.g., electricity to heat in a circuit).

PS.68.7c Demonstrate energy transfer by completing a circuit (e.g., switch to activate a mechanical item).

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

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Distilled white vinegar

50 pieces of copper wire

50 galvanized nails

10 Ice tray

10 LED light

Paper towels

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| **Teacher Advance Preparation:** |

Prepare mini-lesson on safety concerns ie safe handling of pointy objects such as nails and wi Strip wire as needed

Prepare trays with 5 pieces of Cu wire, 5 galvanized nails, 1 LED light and 1 ice tray per group

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| **Activity Procedures:** |

1. Review learning about how electrons flow
2. Solicit input to identify the essential parts of a circuit
3. Solicit input to identify the essential parts of a battery
4. Correct any misconceptions
5. Students will form teams
6. Students will discuss how they might assemble the provided parts to cause electricity to flow as indicated by the bulb lighting
7. Students may review “How batteries work”, Worksheet from pHET simulation, or other class room resources.
8. Students will share plan with teacher. Teacher will distribute vinegar
9. Students will experiment with assembling components until bulb lights
10. Students will dispose of vinegar down the drain and rinse out ice trays
11. Students will dry off metal parts and return them to tray

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

Team check-in to share assembly plan

Absence or presence of lit bulb

**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. |

Create and distribute adapted versions of handouts-both instructions and worksheets.

Create a climate of cooperation that fosters peer support. Prepare extension activities including instructions and supplies for early finishers. Consult ELL and SPED specialists as needed.

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

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| **Name: Marie Inanli** | **Contact Info: marie.c.inanli@gmail.com** | **Date: July 2015** |

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| **Lesson Title : Survive a Storm** | **Unit #:**  **1** | **Lesson #**  **2** | **Activity #:**  **4** |
| **Activity Title: Build a Battery** |

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| --- | --- |
| **Estimated Lesson Duration:** | **8 x 50 min periods** |
| **Estimated Activity Duration:** | **7 x 50 min periods** |

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| **Setting:** |  |

Classroom/lab

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| **Activity Objectives:** |

Students will be able to

1. Sketch a design for a battery
2. Create a materials list
3. Budget for and “buy” materials
4. Build a battery
5. Test the battery
6. Share data re: battery output with the class
7. Improve the battery based on aggregated data, class discussion, and $ left to buy more materials.
8. Test the redesigned battery
9. Record sketches, design decisions, budget calculations, and testing data, in project notebook.
10. Identify important features of their design
11. Decide which medium best suits their message, style and strengths
12. Share their creation with classmates

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| **Activity Guiding Questions:** |

1. What components does my battery need to “work”?
2. What factors make a particular produce item a good candidate for a battery?
   1. Acidity
   2. Color
   3. Density
   4. Juiciness
   5. Shape
   6. Size
   7. Skin thickness
   8. Texture
3. How much $ should be held back for improvements?
4. What are the constraints?
5. What is the most important feature?
   1. Maximum output
   2. Maximum longevity
6. What features contribute to the value of your product?
7. How do you want to convey this information?
   1. Medium?
   2. Message?
8. How do you want to share tasks within your team?

| **Next Generation Science Standards (NGSS)** | |
| --- | --- |
| **Science and Engineering Practices (Check a**  **ll 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 New Learning Standards for Science (ONLS)** |
| --- |
| **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)** |

| **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, ONLS and/or CCSS):** |

NGSS MS-PS3.CC.3.1.

ELF 4.1 Humans transfer and transform energy from the environment into forms useful for human endeavors.

ELF 4.6 Humans intentionally store energy for later use in a number of different ways.

ELF 4.7 Different sources of energy and the different ways energy can be transformed, transported and stored each have different benefits and drawbacks.

ONLS

PS.68.7a Identify an energy transfer (e.g., electricity to heat in a circuit).

PS.68.7c Demonstrate energy transfer by completing a circuit (e.g., switch to activate a mechanical item).

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

**Supplies:**

Alligator clips

Aluminum foil

Cans of cheap soda pop

Cardboard

Copper wire

Galvanized nails

Knives to pierce produce

Pennies

Assorted produce:

Apples, bananas, cucumbers, grapefruit, kiwi, kumquats, lemons, limes, mangoes, nectarines, oranges, papayas, peaches, plums, +/or potatoes

Table salt

Vinegar

micro-ammeter/multimeter

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| **Teacher Advance Preparation:** |

Inspect circuit building kits, if available

Replace any damaged/missing items

Buy circuit building supplies as needed

Strip wire

Prepare price list for student materials

Determine realistic budget to provide $ constraint

Decide whether to share price list, project constraints etc. electronically or via paper printouts.

If paper, prepare photocopies

Decide whether to let students select project partners

Decide whether to provide all the produce or have students bring in items from home or get donations of past date/blemished/discarded items from cafeteria/commissary/local store

Provide safety training

Decide whether to share rubric with students digitally or by paper printout. If by paper, photocopy.

Obtain art supplies, distribute at stations

|  |
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| **Activity Procedures:** |

Day 1

Have students view news clip of power outage

Facilitate discussion of problems that result from a power outage

Have students consider

* 1. which items are most important to power during an outage
  2. how much energy those devices require to operate
  3. what options exist when battery power runs out

Send students home with an assignment to inventory essential electronic items that are battery powered (for example, flashlights and phones, not refrigerators and water heaters) Students will complete a data table including pertinent info such as # batteries, voltage, type if accessible as in a flashlight. If batteries are sealed in a device, students can obtain information online for batteries sealed in devices.

Day 2

Students will use information obtained from home inventory to determine home much energy their battery needs to produce in order to power their selected device.

Students will brain storm will brainstorm potential solutions to the problem of not having power to provide energy to devices or recharge batteries.

Teacher will facilitate discussion of solutions

Introduce challenge based on student input

Students will research their potential solution for 20 min to the problem of not having power to provide energy to devices or recharge batteries and report 1 soln.

From selected website

Students will use price list to create budget for project

Students will create a labelled sketches of battery and circuit design

Day 3

Students will form a team with other students who selected the same produce item.

Students will adopt team roles and fulfill appropriate function

Accountant will “buy” materials and maintain spreadsheet Team leader will keep track of time and communicate with teacher. Produce will be cut in pieces so each individual will “build’ a separate battery.

Students will use multi-meters to test batteries by measuring the voltage and current produced.

Students will submit data to shared Google Sheet.

Teacher will lead discussion to help students interpret data and consider what factors contribute to a “successful” design.

Day 4

Students will make new and improved battery

Students from the same team will collaborate to complete a series circuit, test it with multi-meter, and get completion checked by teacher.

Students will then collaborate to complete a series a parallel circuit, test it with multi-meter, and get completion checked by teacher.

Students will take photos of their batteries.

Students will determine whether they could power chosen device with their battery.

Student will write a reflection paragraph.

Since one of the constraints of the challenge is that the batteries last 3 days,

Students will check daily to see if their battery is still working and add observation to project notebook.

Day 5

Distribute assignment and rubric.

Give students a few minutes to review them.

Provide opportunity for students to ask questions.

Give students 10 minutes to discuss ad with teammate(s)

Announce when it is time for students to switch to production mode

Set a timer so students stop production early enough to put supplies away.

Day 6

Students continue working on their advertisements during first 20 min of class.

Set a timer so students stop production early enough to put supplies away.

Pass out rubrics for peer evaluation.

Use random number generator to select teams to begin presenting 2-3 minute ad.

Day 7

Distribute post test

Students take assessment

Check portfolios for correct sequencing and completeness

Students create a table of contents and submit portfolio.

Clean up any remaining batteries

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

Design documents including labelled sketches and circuit diagrams

**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.

Project portfolio including home inventory data table, vocabulary worksheet, energy forms worksheet, design plans with sketches-original and new & improved versions, pHET worksheet, budget sheet, results data table, reflection paragraph, and photos.

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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. |

Worksheets will be adapted as needed. Teacher will spend more time with students who benefit from extra support.

Consult ELL and SPED specialists as needed. Create and distribute adapted versions of handouts-both instructions and worksheets.

Create a climate of cooperation that fosters peer support. Prepare extension activities including instructions and supplies for early finishers.

Early finishers can make liquid batteries as an extension activity

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

**14. APPENDIX III: UNIT AND ACTIVITY TEMPLATE OF TEACHER LARRY HONIGFORD**

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| --- | --- | --- |
| **Name: Larry Honigford** | **Contact Info: larry.honigford@lakotaonline.com** | **Date: July 30, 2015** |

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| **Unit Number and Title: 1. Transforming Energy With Style** |

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| --- | --- |
| **Grade Level:** | 9th grade |

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| **Subject Area:** | Physical Science |

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| **Total Estimated Duration of Entire Unit:** | 10 days |

**Part 1: Designing the Unit**

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

**Ohio’s New Learning Standards: Science Standards: Physical Science**

• Conservation of energy

• Quantifying kinetic energy

• Quantifying gravitational potential energy

• Energy is relative

• Transfer and transformation of energy (including work)

**Next Generation Science Standards**

PS3.A: Definitions of Energy

PS3.B: Conservation of Energy and Energy Transfer

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| 1. **Unit Summary** |

The Big Idea (including global relevance): Generation of energy is really not an accurate statement. Energy is available all around us, it is just a matter of finding how to transform the energy into a means by which the energy becomes useful to us. The current search for renewable and sustainable sources of energy and reduction of carbon footprint is a critical issue in light of global warming.

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 is energy?

What happens to energy as it is “used”?

In what forms can energy be found?

What forms of energy are primarily used by us?

What is the purpose of energy in our lives?

How can we quantify energy?

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| 1. **Unit Context – Check all that apply.** |

Justification for Selection of Content:

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

Misconceptions regarding this content are prevalent.

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

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: The Hook will also introduce the challenge. The musical group OK-Go! produced a music video called “This too shall pass” using a Rube Goldberg Device <https://www.youtube.com/watch?v=qybUFnY7Y8w> which will be shown in class. Then the students will be introduced to the challenge stating that they will develop their own Rube Goldberg device and the requirements and constraints associated with the device. The student will also be given time to investigate the concept of the devices in the virtual world from the following websites

<http://makezine.com/2011/03/17/top-10-rube-goldberg-machines/> and <http://www.infinitecat.com/games/tom-n-jerry.html>.

The Challenge and Constraints:

Product **or**  Process (Check one)

|  |  |
| --- | --- |
| Description of Challenge (Either Product or Process is clearly explained below): | List the Constraints Applied |
| **Design and construct a Rube Goldberg device to complete a circuit to turn on a light bulb.** | **Device must have at least 5 energy transformations.**  **Device may start with assistance, but must continue and complete its flow on its own.**  **Device must complete a circuit to turn on a light bulb.**  **Must have both vertical and horizontal motions.**  **Students must calculate greatest potential energy and be prepared to explain transfers of energy through the device.**  **Students will need to provide materials for the device on their own.**  **Students need to have a working device within 2 weeks.**  **Students will be given one testing day to work on the device in class along with small amount of time during the unit to plan and discuss the construction of their device.** |

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

**How do I “create” the energy to start my device?**

**How do I keep the process going?**

**What will complete an electric circuit?**

**How can energy be quantified?**

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

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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 will be performed in the classroom. Students will be given a set amount of time to setup their device and then test it. Previous to that day, time will be allotted experimental testing and modifications. Lighting the bulb by using the device within the constraints will be the proof that the solution worked.

The process will require that the students test and modify their devices as they move through the design and implementation of their device. The students will need to work cooperatively to design their device. It is expected that the students will need to revise/modify their device as they move through the EDP to find a workable solution. Students will be given time in class to construct, experimentally test and modify their devices prior to final testing.

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.

Solution will be implement in the classroom and witnessed in person by the instructor. Students will need to verbally describe their device and how it will work, then they will physically test the device. Students must be prepared to answer questions regarding the operation of their device, how energy related to the starting of the device and where the energy went, when the device completed its task. Bonus point will be provided to devices that incorporate liquids and those which have the smallest change in height from the start to the finish.

What academic content is being taught through this Challenge?

• Conservation of energy

• Quantifying kinetic energy

• Quantifying gravitational potential energy

• Energy is relative

• Transfer and transformation of energy (including work)

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.

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| --- | --- |
| 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. |
| KE and PE Calculations  Law of Conservation of Energy  Operation of Roller Coaster  Operation of Rube Goldberg Device | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_­­\_\_\_\_\_\_\_\_\_\_\_\_\_  formative  summative  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_­­\_\_\_\_\_\_\_\_\_\_\_\_\_  formative  summative  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_­­\_\_\_\_\_\_\_\_\_\_\_\_\_  formative  summative  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_­­\_\_\_\_\_\_\_\_\_\_\_\_\_  formative  summative |

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

Has clear constraints that limit the solutions

Will produce more than one possible solution that works

Includes the ability to refine or optimize solutions

Assesses science or math content

Includes Math applications

Involves use of graphs

Requires analysis of data

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**:­­­­­­­­­­­­­­ The Rube Goldberg devices themselves are not a needed commodity when thinking of real world application. However, the concept of conservation of energy is an extremely important concept when considering issues such as global warming and environmental conservation.**

What activities in this Unit apply to real world context? The concept of conserving energy and that application or usage of energy is contingent upon the energy form, rather than simply the fact that energy is available. In other words, energy is not always in a form that is easily usable but it is available.

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**: The establishment of the device, again has limited direct societal impact, but rather an indirect link to the idea that our imagination and technology are the limiting factors for establishing usable energy sources.**

What activities in this Unit apply to societal impact? Discussions on energy transformations such as wind and solar power, fossil fuels, how they affect the environment. What their limitations are (i.e., wind and solar power are inconsistent power sources (therefore use of storage devices such as Vanadium Redox Flow Batteries are important.

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.)

Careers include engineers in various fields working to develop new energy and more environmentally energy sources including renewable energy sources such as wind and solar power. Also the need for supporting infrastructure for these types of energy sources for the use of storage and delivery on an as needed basis.

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| **6. Misconceptions:**  **- Energy is used up or lost in a system.**  **- We are running out of energy.**  **- An object at rest has no energy.** |

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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:** During this lesson the students will work on the concept of the Law of Conservation of Energy, forms of energy and energy transformation.

**Activity #1:** (2 days) includes the Hook, leading activity for the Big Idea and introduction for the challenge.

**Activity # 2:** (2 days) Introduces types of energy, Law of Conservation of Energy, and energy transformations.

**Lesson # 2:** During this lesson the students will learn to quantify energy with respect to kinetic and potential energy. They will also learn how the two related to each other in a system. Math application of the kinetic energy and potential energy formulas will be included. A mini-challenge will also be performed requiring the students to design rollercoasters.

**Activity # 3:** (5 days) The students will be practicing application of the kinetic and potential energy formulas using real-life examples. They will also be working with systems in which they will relate potential and kinetic energy to each other. They final 2 days will be the mini-challenge of designing and building a rollercoaster.

**Activity # 4:** (2 days) Includes testing and final presentation for student solutions. One day allows student refinement under the EDP.

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| **8. Additional Resources:** |

Activity # 1 would require presentation of videos and access to computers to run the virtual site.

Activity # 2 requires several worksheets and PE & KE Tracks and large marbles.

Activity # 3 requires worksheets to practice calculation for kinetic and potential energy. Softball toss package and graphing packet. For Roller coaster mini-challenge foam piping insulation cut in half lengthwise, masking tape, small marbles.

Activity # 4 most materials will need to be acquired at home by the student to complete the Rube Goldberg device. It is anticipated the many household items which are readily available will be used. This activity does not require any purchasing.

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| **9. Pre-Unit and Post-Unit Assessment Instruments:** |

A pre and posttest will be used that includes 12 questions on the energy topic.

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| **10. Poster (Link here.)** | **11. 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)** |
| 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 |  |

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

| **Ohio’s New Learning Standards for Science (ONLS)** |
| --- |
| **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:**

| **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. |

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| **Name: Larry Honigford** | **Contact Info: larry.honigford@lakotaonline.com** | **Date: July 6, 2015** |

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| --- | --- | --- | --- |
| **Lesson Title : What’s Lost, Not Energy!** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **1** |
| **Activity Title: What is a Rube Goldberg?** |

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| **Estimated Lesson Duration:** | **4 days** |
| **Estimated Activity Duration:** | **2 day** |

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| **Setting:** |  |

Classroom, or if available computer lab.

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| **Activity Objectives:** |

Define energy.

Describe how energy is not destroyed, only transformed.

Describe current issues associated with energy in modern times.

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| **Activity Guiding Questions:** |

What is energy?

What happens to energy when it is “used”?

For what purpose is energy used?

Where do we get our energy from?

What issues are we challenged with regarding energy today?

| **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 New Learning Standards for Science (ONLS)** |
| --- |
| **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)** |

| **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, ONLS and/or CCSS):** |

• Conservation of energy

• Energy is relative

• Transfer and transformation of energy (including work)

**Next Generation Science Standards**

PS3.A: Definitions of Energy

PS3.B: Conservation of Energy and Energy Transfer

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

<https://www.youtube.com/watch?v=qybUFnY7Y8w>

<http://www.infinitecat.com/games/tom-n-jerry.html>

<http://makezine.com/2011/03/17/top-10-rube-goldberg-machines/>

Pre-assessment

Brainstorming Handout

Rube Goldberg Challenge Packet/Handout

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| **Teacher Advance Preparation:** |

Assure that web links will work with your school’s devices and network limitations. Many schools have blocks on certain types of sites. The design of a Rube Goldberg through the Infinitecat website may require some instructional guidance for the students. Students should have access to the internet, preferably on computers or some device with screens larger than a phone.

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| **Activity Procedures:** |

Day 1

* Give pre-assessment on understanding of energy concepts and collect completed assessment.
* Give “This Too Shall Pass” handout and work through based on instructions. Collect when finished.
  + Show the video of OK GO! “This too shall pass” on the following link. <https://www.youtube.com/watch?v=qybUFnY7Y8w>
* Have the students go to the websites <http://www.infinitecat.com/games/tom-n-jerry.html> and/or <http://makezine.com/2011/03/17/top-10-rube-goldberg-machines/>.
* Students will address the following questions from the handout which is to be turned in at the end of class.
  + “What do you know about energy?”
  + “What questions do you have about energy?”
  + “What ideas do you have for a project or challenge that we could do for class that is related to energy?”
* This will provide student generated input on the Big Idea and essential questions.
* Allow students the remaining time to investigate these websites to generate ideas regarding a challenge project.

Day 2

* Discuss with students their input regarding ideas for a project or challenge regarding energy.
* Introduce the Rube Goldberg challenge using the Rube Goldberg Packet.
* Have the student break up into groups of 4. Each student shall take on a role and record their responsibility on their packet.
* Allow the student’s time to begin fleshing out some ideas regarding their Rube Goldberg Device. Roam the room to help answer questions.

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

Formative assessments will be performed based on conversations stemming from the leading questions starting the activity and student responses. Instructor will need to make sure subsequent lessons adequately focus on areas where current student understanding needs assistance.

**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.

The summative assessment will be the pre-assessment.

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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. |

Students are given a choice to either watch videos of other Rube Goldberg Devices or to participate in a virtual Rube Goldberg challenge.

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

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| **Name :Larry Honigford** | **Contact Info:** [**Larry.honigford@lakotaonline.com**](mailto:Larry.honigford@lakotaonline.com) | **Date: July 6, 2015** |

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| **Lesson Title : What’s Lost, Not Energy!** | **Unit #:**  **1** | **Lesson #:**  **1** | **Activity #:**  **2** |
| **Activity Title: Kinetic and Potential Energy Ramps** |

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| **Estimated Lesson Duration:** | **4 days** |
| **Estimated Activity Duration:** | **2 day** |

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| **Setting:** |  |

Classroom

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| **Activity Objectives:** |

1. Describe and identify real-life scenarios of Law of Conservation of Energy
2. Identify multiple types of energy.
3. Define potential and kinetic energy.
4. Describe and identify energy transformations.
5. Describe how potential and kinetic energy relate to one another within the context of the Law of Conservation of Energy

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| **Activity Guiding Questions:** |

What happens to energy as it is used?

What is the relationship of potential to kinetic energy?

How can they demonstrate the Law of Conservation of energy?

| **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 New Learning Standards for Science (ONLS)** |
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| **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)** |

| **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, ONLS and/or CCSS):** |

**Ohio’s New Learning Standards: Science Standards: Physical Science**

• Conservation of energy

• Quantifying kinetic energy

• Quantifying gravitational potential energy

• Energy is relative

• Transfer and transformation of energy (including work)

**Next Generation Science Standards**

PS3.A: Definitions of Energy

PS3.B: Conservation of Energy and Energy Transfer

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

Energy PowerPoint.

Energy Conversion Worksheet

Bowling Ball Pendulum kit (demonstration, optional)

Potential and Kinetic Energy Tracks and Large Marbles <https://www.sargentwelch.com/store/catalog/product.jsp?catalog_number=CP33578-00>

Landing pads such as cardboard, which may also be written upon.

KE and PE Tracks – Lab Packet

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| **Teacher Advance Preparation:** |

Need to have ramps which all start at the same height, but have different pathways and slopes leading to the bottom of the track. Sargent Welch has an ideal track for this (see link above), others may be substituted. Requires large marbles to roll down the ramps.

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| **Activity Procedures:** |

Day 1

* In preparation for the ramp activity students will need to have an understanding of the types of energy there are (specifically kinetic and potential energy). Use the PowerPoint to discuss with the students these ideas and concepts of: What is Energy? What is the Law of Conservation of Energy? And some types of Energy that are available.
* Give the student “Energy Conversions” worksheet. Student may work together to complete the worksheet. The worksheets will require them to demonstrate how energy transformation will occur in various situations. This will require them to use their knowledge of the various types of energy. Review the student answers in class.
* Perform Bowling ball pendulum demonstration.

Day 2

* Handout the PE-KE Ramp packets.
* Students will follow the guidelines on the lab packets. They will roll marbles down the tracks to first test which tracks the marbles will roll down the quickest. They will see the marbles do not roll down the track and arrive at the bottom at the same time. The students will then test each track to determine the distance the marbles fall. Students will observe that the marbles all land at relatively the same distance from the base of the tracks. This demonstrates to the students that the height of the marble (all start at the same height) determines the marble’s energy, Not the pathway they take down the ramp. This will connect the relationship of potential and kinetic energy relative to one another.

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

The formative assessment will be performed as the results of the “Energy Conversion” worksheets are reviewed. During the PE-KE Ramp activity walks throughs will be performed observing discussions and viewing student results.

**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.

Summative assessment will be based on student’s answers from the KE-PE lab packet questions.

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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. |

Results from the energy transformations may have multiple answers that are correct, the primary point of the exercise will be to give the student the opportunity to assess various situations and see that energy transformations are occurring. It will be less important that everyone have the same steps.

When comparing observations to mathematical formulas for kinetic and potential energy additional personal assistance may be required to evaluate the formulas qualitatively as students as students tend to find this challenging when no numbers are provided.

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

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| **Name: Larry Honigford** | **Contact Info:** [**Larry.honigford@lakotaonline.com**](mailto:Larry.honigford@lakotaonline.com) | **Date: July 6, 2015** |

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| **Lesson Title : Energy Transformations** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **3** |
| **Activity Title: Rollercoaster Mania** |

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| **Estimated Lesson Duration:** | **7 days** |
| **Estimated Activity Duration:** | **5 days** |

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| **Setting:** |  |

Classroom

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| **Activity Objectives:** |

To incorporate visual and manipulative activities related to transformation of potential to kinetic energy through an open ended challenge with constraints and instruct on the use of the kinetic and potential energy equations to calculate energy.

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| **Activity Guiding Questions:** |

How can potential energy be converted into kinetic movement through twists and turns as well as gravity?

How can potential and kinetic energy be calculated?

| **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 New Learning Standards for Science (ONLS)** |
| --- |
| **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)** |

| **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, ONLS and/or CCSS):** |

**Ohio’s New Learning Standards: Science Standards: Physical Science**

• Conservation of energy

• Quantifying kinetic energy

• Quantifying gravitational potential energy

• Energy is relative

• Transfer and transformation of energy (including work)

**Next Generation Science Standards**

PS3.A: Definitions of Energy

PS3.B: Conservation of Energy and Energy Transfer

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

PE KE Calculation PowerPoint

Potential Energy Worksheet

Kinetic Energy Worksheet

Potential and Kinetic Energy Worksheet

Potential and Kinetic Energy Worksheet - 2

Softball toss paper.

Piping insulation tubing.

Small marbles.

Masking tape.

Other materials around the room may be used as needed.

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| **Teacher Advance Preparation:** |

The pipe insulation for the rollercoaster mania challenge will need to be cut in half lengthwise to create the rollercoaster track. Teacher must also select an area in which the student may create and make their tracks. The classroom may be a suitable location for the activity.

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| **Activity Procedures:** |

**Day 1:**

* Review PowerPoint for performing calculations using potential and kinetic energy formula.
* Perform practice examples in class for potential energy calculations then provide example problems using the following worksheet:
  + Potential Energy
* Perform practice examples in class for kinetic energy calculations then provide example problems using the following worksheet:
  + Kinetic Energy

Day 2

* Review Completed Potential Energy and Kinetic Energy Worksheets from Day 1.
* Handout homework practice problems using mixed problem set of potential and kinetic energy. These will require the student to first identify which equation must be used in the scenario and then complete the calculations.
  + Potential and Kinetic Energy
* Provide final worksheet combining problems which may use either Kinetic or Potential energy formulas.
  + Potential and Kinetic Energy – 2

Day 3:

* Review Potential and Kinetic Energy – 2 worksheets identified in the items above
* Hand out Softball Toss exercise which requires the students to assess a simulated situation. Complete calculations for potential and kinetic energy and graph each in relationship to speed and height. The students will then assessed the graphs and identify the relationship of potential and kinetic energy. This will be turned in and assessed.

**Day 4:**

* Assessment on performing calculations on potential and kinetic energy.
* Handout the Rollercoaster mini-challenge. Explain the challenge and related constraints. Students will have the first day to test and experiment with their tracks. On the second day the students will finalize their tracks and have them tested. They will also be required to perform calculations and relate potential and kinetic energy to the movement of the marble down their track.

**Day 5:**

* Demonstrate and assess Rollercoasters.

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

Will be performed using homework and in class discussion during review of the homework. Evaluation of completed tracks will also be used in the assessment.

**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.

Summative Assessments will performed through a quiz to be administered on the last day of the activity. Evaluation will also occur through the assessment of written response to questions on the Rollercoaster Mania, mini-challenge.

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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. |

Additional help may be required to assist those that are challenged performing mathematical computations. The Rollercoaster Mania mini-challenge provides numerous options for construction.

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

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| **Name: Larry Honigford** | **Contact Info:** [**Larry.honigford@lakotaonline.com**](mailto:Larry.honigford@lakotaonline.com) | **Date: July 16, 2015** |

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| **Lesson Title :** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **4** |
| **Activity Title: Rube Goldberg Challenge** |

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| **Estimated Lesson Duration:** | **7 days** |
| **Estimated Activity Duration:** | **2 days** |

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| **Setting:** |  |

Classroom

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| **Activity Objectives:** |

Model the Law of Conservation of Energy

Describe the relationship to energy transformation in a system.

Create and refine models defining scientific principles.

Communicate and describe models relaying scientific principles.

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| **Activity Guiding Questions:** |

What is meant by the conservation of energy?

How does energy transform from one kind to another?

How can energy be quantified within a system to demonstrate conservation of energy?

| **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 New Learning Standards for Science (ONLS)** |
| --- |
| **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)** |

| **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, ONLS and/or CCSS):** |

**Ohio’s New Learning Standards: Science Standards: Physical Science**

• Conservation of energy

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• Quantifying gravitational potential energy

• Energy is relative

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**Next Generation Science Standards**

PS3.A: Definitions of Energy

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

Materials to build the Rube Goldberg devices will be provided by the student. Some miscellaneous materials may be made available to students in the classroom.

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| **Teacher Advance Preparation:** |

Areas must be identified in which the students may store and test their devices.

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| **Activity Procedures:** |

* Students will need to bring in the materials they have selected to use in their Rube Goldberg Device.
* On the first day they will be allowed to set up, test and modify their device as needed.
* On the second day they will be tested and evaluated by the instructor. Students must present their device and describe how it will work prior to its final test in front of the instructor.

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

Formative assessments will be provided during in class student work time. A checkpoint will be performed to assure student progress as follows.

Day 3 Idea selected.

Day 5 Initial drawings and material list

Day 8 Update draws and materials acquisition

Day 11 Final drawings and implementation/testing

**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.

Completion of the portfolio for the Rube Goldberg Challenge and completion of questions from the Rube Goldberg Challenge packet.

Documentation to be kept in portfolio:

\_\_\_\_\_\_\_ **Brainstorming:** List of Initial Brainstorming session with ideas. (Gathering Information)

\_\_\_\_\_\_\_ **Selection:** Short list of ideas you will include in your device and brief explanation as to why you selected them. (this may consist of multiple documents including scratch outs).

\_\_\_\_\_\_\_ **Drawings:** All drawings you make should be included in the portfolio, including drawings which are no longer to be used (indicate on the drawing that is no longer being used). Note: It is OK to change what you originally decided upon.

\_\_\_\_\_\_\_ **Journal entries:** Provide short journal entries describing what you did each day regarding your device. Place a date before each entry. This will include any test, material received, changes, results, decisions, and any other critical items related to your device.

\_\_\_\_\_\_\_ **Report:** Description of your final device along with final drawing. Must include how it met the criteria. The final drawing should be very clear.

\_\_\_\_\_\_\_ **Presentation:** You must present your device to the instructor. You must include description of how your device will work and how the energy is transferred.

\_\_\_\_\_\_\_ Packet Completion along with questions and description of Energy Transformations.

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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. |

The presentation and creation of the challenge allowed for many approaches and learning styles based on its limited constraints and ability to develop multiple correct devices.

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