TEAM PROJECT REPORT

Optimizing Graphene for Use in Na Batteries

Submitted To

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For

“Engineering Design Challenges and Research Experience for Secondary and Community College Teachers”

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ABSTRACT

Graphene is already a highly desirable electrode material in lithium chemistry batteries. The high porosity and conductive properties make graphene an ideal candidate for use in sodium chemistry batteries as well, however due to atomic differences between sodium and lithium graphene needs to be optimized to work within sodium batteries. Sodium batteries could be cheaper to produce and easier to dispose of after use than the current lithium models. To optimize graphene for use in sodium batteries multiple catalyst structure methods, reaction times and temperatures, as well as nitrogen doping have been tested. The graphene resulting from these tests were analyzed for improved structural and electrochemical properties.

Key Words : Graphene, nitrogen doping, energy storage, sodium battery, nanomaterials, Electrical conductivity

1. INTRODUCTION

As the use of renewable energy rises and the electric car industry grows batteries have become more important than ever. The need to store energy in a space and cost effective way is essential to many of these industries success. Research into sodium batteries has expanded as these batteries could be much cheaper to produce than the current industry standard of lithium batteries. These batteries could also make battery disposal process simple and more efficient. While lithium batteries have undergone many rounds of testing and optimization sodium batteries are still undergoing this process of standardization and optimization.

To move sodium batteries closer to large scale industrial feasibility the standardization and optimization of graphene must occur. This process includes many sub optimizations, such as reaction temperature, reaction time, catalyst structure and synthesis methods, as well as doping methods and amounts. The Nanoworld lab has moved forward in all of these aspects of graphene optimization.

2. LITERATURE REVIEW

Graphene is already a substance used for supercapacitor electrodes, but the production and properties of it can be further refined. In the 2015 paper Beyond graphene foam, a new form of three-dimensional graphene for supercapacitor electrodes a new production method of graphene synthesis is put forth. This paper outlined the transition and improvements made from moving from graphene foam to graphene pellets. The graphene pellet was not only more economical - as shown in the figure below - but also produced better surface area, pore measurement, and electrochemical properties (*J. Mater. Chem. A*, 2016,4, 1876-1886) .

The synthesis process of graphene is shown below, this graphene was an improvement from the previously synthesised graphene foam.

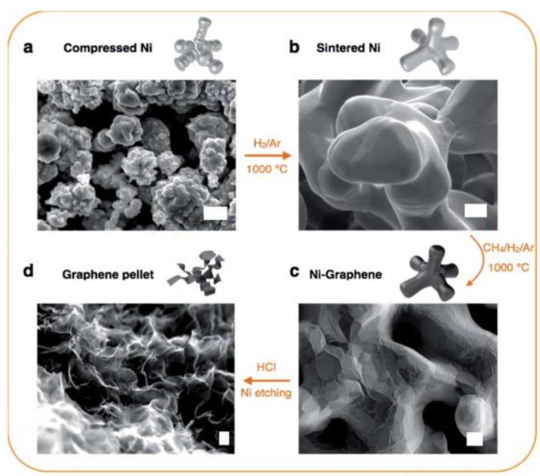

Figure 1: Graphene pellet synthesis process

This new process of graphene pellet catalyst structure results in a marked improvement in electrical conductivity as seen below. The graph below also shows how the variation in methane used in the CVD process resulted in varying improvements of electrical conductivity. Peak electrical conductivity results in a methane concentration of 1.9% (*J. Mater. Chem. A*, 2016,4, 1876-1886).

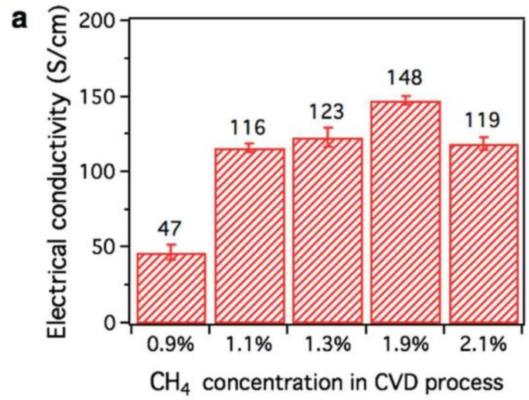

Figure 2: Optimization of methane concentration in CVD process

Further improvement in graphene was made in current density. Pristine graphene pellets are seen in the graph below. There is a clear increase in storage capacity with all versions on the graphene pellets.

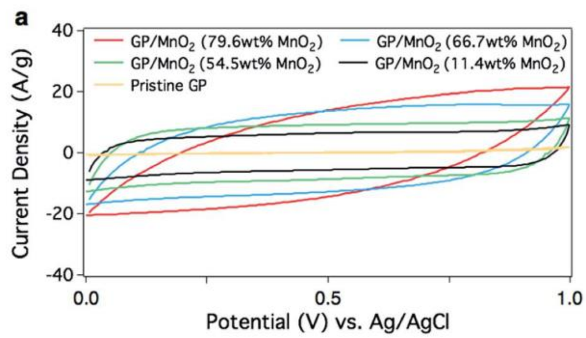

Figure 3: Increase in capacity of graphene pellets

One of the concerns for scalability of sodium batteries is their energy density. Due to sodium's larger atomic size their ability to compete with the energy density of lithium batteries requires optimization. As seen below the graphene pellets are another step forward in this optimization process, increasing both the energy density and power density compared to other graphene research (*J. Mater. Chem. A*, 2016,4, 1876-1886).

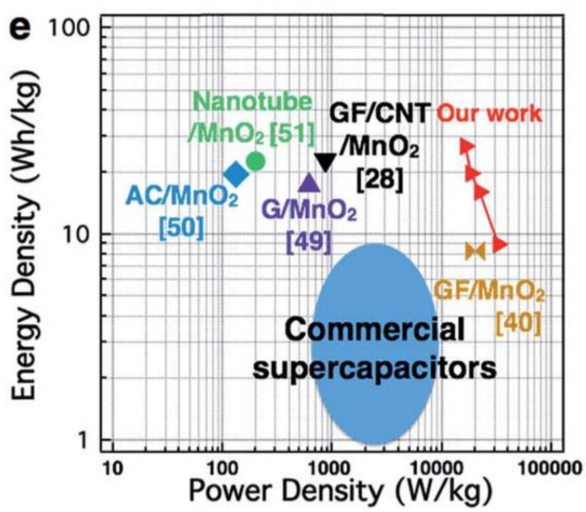

Figure 4: Improvements in energy density and power density

3. GOALS AND OBJECTIVES

The goals of this research include the creation of a stable nitrogen doped graphene sample. After determining feasibility nitrogen doped graphene samples are to be optimized for use in Na batteries. Lastly, this research strives to standardize the creation and testing methods used in Na batteries.

4. RESEARCH STUDY DETAILS:

1. Nickel Slurry Synthesis

To create the Nickel slurry used as a catalyst in the CVD process we combined melted polystyrene and Nickel powder in a 1.1:8 gram ratio. In the Nickel slurry 1.6 mL of Diglyme is added to allow for Na intercalation. Toluene is used as a viscosity manager. One the slurry is created it is spread evenly in a thin layer.

2. CVD Process

To dope the graphene with Nitrogen and react the Nickel catalyst with the carbon doner a chemical vapor deposition (CVD) system is used. The doping is done in situ with the graphene growth process. The nickel slurry is heated to 1000 degrees C in a tube furnace under Ar. Hydrogen is utilized during to reduce any metal catalyst oxide. Acetonitrile serves as our carbon source, and is introduced for 10/15/20 minutes. The sample is cooled to room temperature. A diagram of the CVD process is shown below(“Queen's Advanced MicroEngineering Centre.”). For our purposes the substrate is the nickel slurry, and the gases being transported are hydrogen and methane primarily.

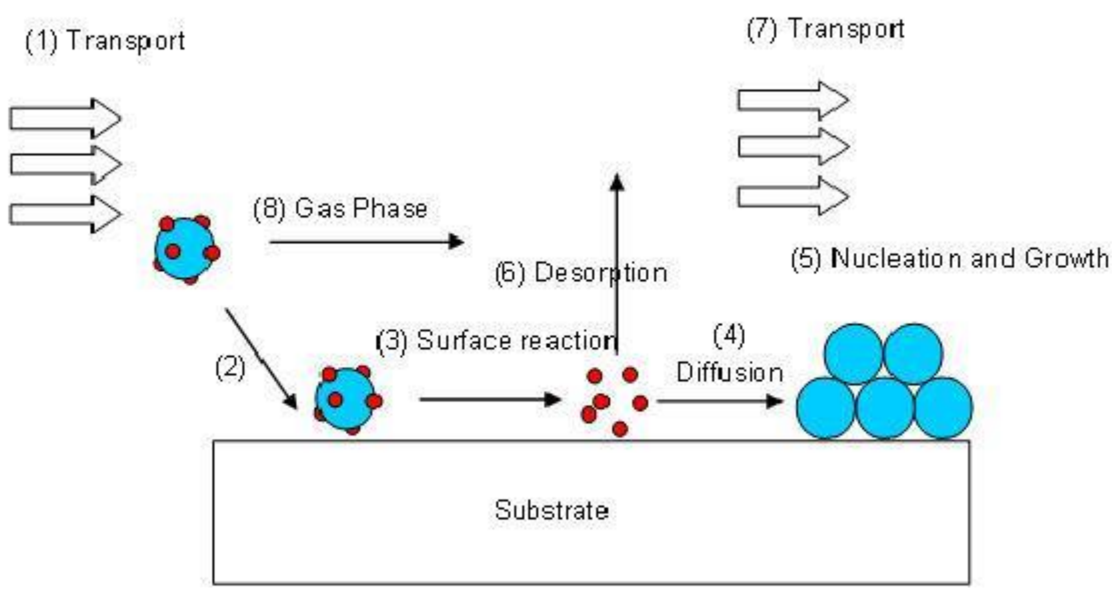

Figure 5: The CVD Process

3. Acid wash and cleaning

The 3D graphene structure removed from the CVD is produced by using HCl to etch away the nickel. This graphene then goes through 2 water baths, followed by an ethanol bath. It is dried in an oven at 75 degrees Celsius.

4. Half cell creation process

For EDLC testing a graphene half cell was manufactured. This cell was made on a glass slide. Kapton tape is used to secure the graphene to the slide. Another section of graphene is used as an extender to connect the tested graphene to a copper strip. The copper is secured to the graphene using a silver paste. All samples were normalized by area of graphene tested. Na_2SO_4 was used as the electrolyte for these tests.

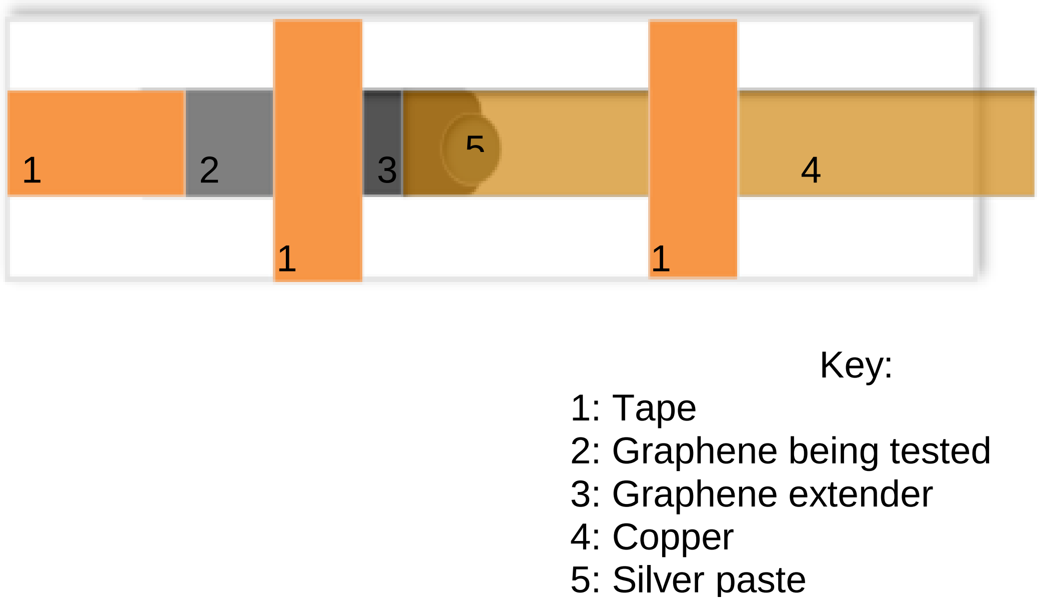

Figure 6: Diagram of a half cell used for EDLC testing

5. Electrochemical analysis - follow paper Sathya sent for this section and name of machines

5. RESEARCH RESULTS

The change in catalyst improved not only the cost effectiveness of the sodium battery but also increased the electrochemical and surface properties desired. The nickel slurry catalyst process is both more uniform and more scalable than the previous nickel foam and nickel pellet process.

As seen below improvements in graphene performance in sodium batteries were made not only with the use of diglyme, but also with nitrogen doping. While diglyme alone improved performance, adding nitrogen doping and diglyme resulted in the best results.

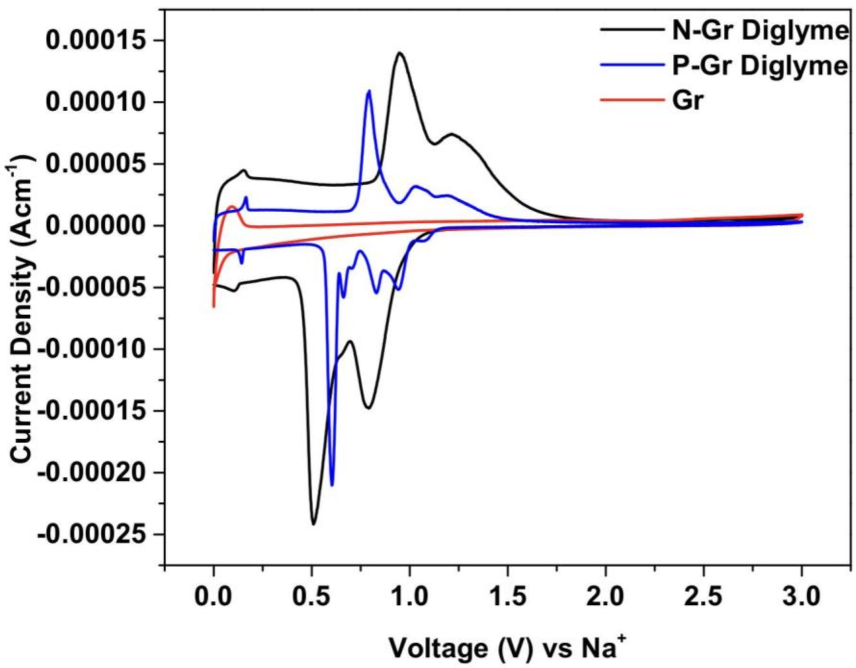

Figure 7: The effect of diglyme and nitrogen doping on graphene performance

Temperature optimization on the nitrogen doping method also showed significant improvements in capacity. Nitrogen doping performed at 750 degrees Celsius had a significantly larger capacity that graphene doped at 850 degrees Celsius or pristine graphene.

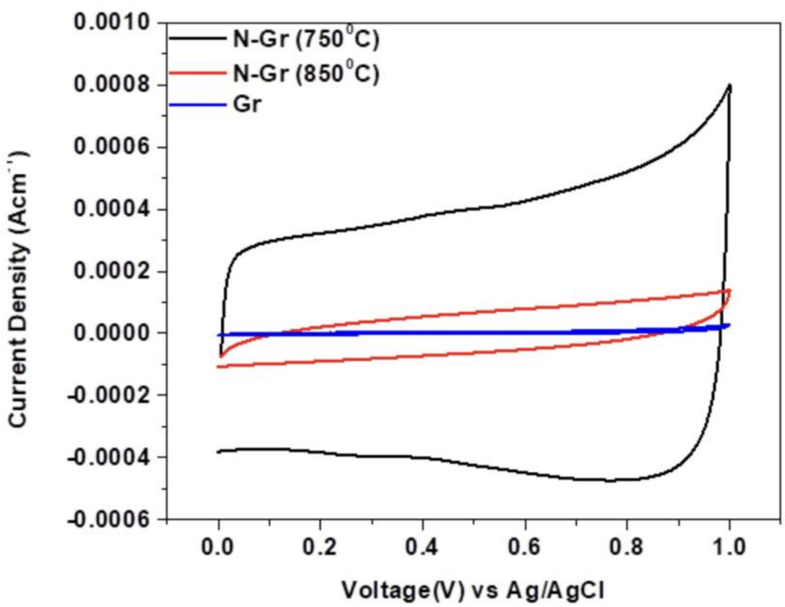

Figure 8: The effect of temperature on the performance of doped graphene

The effect of temperature on performance was also shown in the cyclic voltammetry tests, seen below. The highest performance was given by the graphene that experienced 20 minutes at 750 degrees celsius.

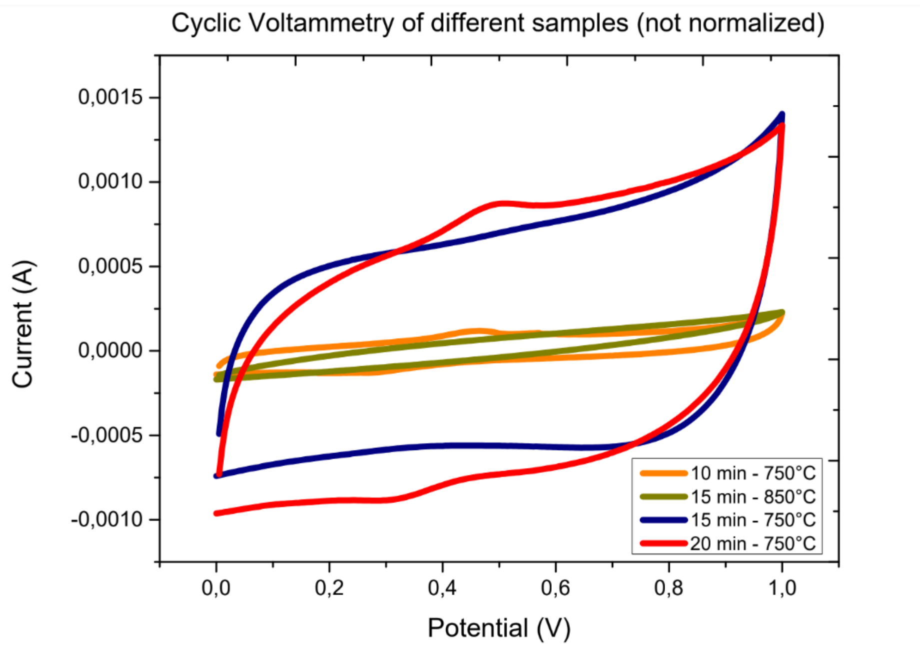

Figure 9: The changes in capacity for different temperatures and reaction times

Another quality of graphene that if of interest if the layering structure. To determine the layering structure Raman Spectroscopy is used. The ratio between the peaks presented below indicate the bonding structure, and thus the layering structure of the graphene sample. Single layer graphene is the most desired for use in batteries.

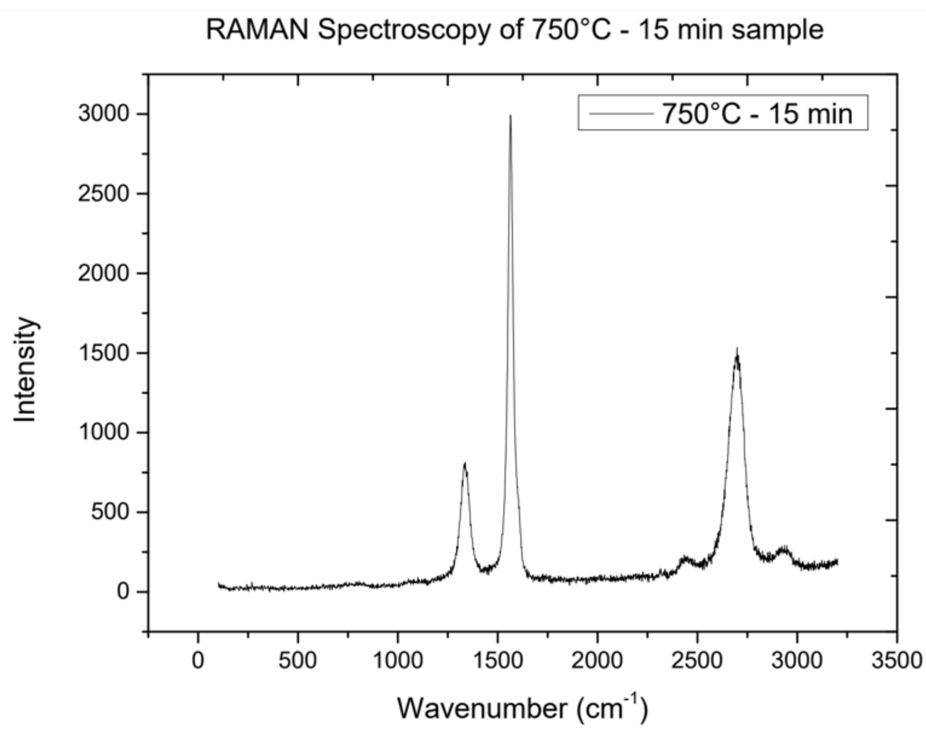

Figure 10: Spectroscopy data from a graphene sample

6. RESEARCH CONCLUSIONS

Nitrogen doping significantly improved the performance of graphene as an electrode in the EDLC testing environment and the full cell tests. There was a peak in doped graphene performance after which more concentrated or longer doping amounts actually decreased electrode performance.

Temperature and reaction time also significantly affected the performance of the graphene. The best performing graphene was achieved by reacting for 15 or 20 minutes at 750 degrees celsius.

The changes made to the nickel catalyst process directly impact the potential scalability. By moving from the nickel foam, to nickel pellets, to the final nickel slurry the batteries produced and will be less expensive to produce and also easier to produce in larger quantities. Improvements in scalability, electro data

7. RECOMMENDATIONS FOR FUTURE RESEARCH

For next steps to further optimize graphene the Inclusion of transition metal oxides for higher energy density should be tested. These metal oxides are already being used in more traditionally battery structures, but need testing and refinement for the Na battery chemistry.

Another area for future development is that of finding candidates for cathode materials in Na chemistry full cell batteries. While phosphorous appears to be a good choice, testing of different materials could yield new solutions for full cell battery creation.

8. CLASSROOM IMPLEMENTATION PLAN:

Victoria Implementation Plan:

The unit created revolves around battery optimization. Activity 1 uses physical models to allow students to develop an understanding of battery and electricity basics - specifically focusing on voltage. In this activity the big idea - Battery Optimization - is introduced by having students select pairs of ions in their model that maximize and minimize voltage. Activity 2 further cements students understanding of battery function. In this activity students will be electroplating a copper key. This activity will also help students to visualize the internal components and process within batteries. Students will then use this activity to create an engineering diagram of a battery. Activity 3 combines students knowledge of batteries and optimization. In activity 3 students will be optimizing an electrolyte for battery uses. Students will be in lab groups and must brainstorm and test different electrolyte options. Students will then analyze their results and create a scientific write up. Activity 5 allows students to optimize batteries in a different scope. Students will be optimizing batteries in series versus batteries in parallel. Students will use this activity to further explore how engineers approach optimization while also gaining knowledge of different circuit types. In the final activity - the challenge - students will use their knowledge of electrochemistry and the engineering design process to optimize a motorized car's battery set to fit differing criteria. The challenge will include designing the battery storage device via 3D printing and also designing the battery network that powers the car. Students will go through the EDP to complete this challenge.

Ramya Implementation Plan:

This unit gives students the opportunity to optimize an everyday structure(staircases) using essential coordinate geometry concepts. In the lab, the RET Fellows participated in the optimization of battery designs. The purpose of this unit design is to show students that anyone, regardless of background, can be an engineer and have a hand in designing the world around them. First, students will be introduced to the engineering design process. Next, students will be shown examples of public staircases that do not function as intended. Students will brainstorm possible solutions to the malfunction. For the challenge, students will be given “blueprint” paper, height and length requirements, and money. The students will be asked to design an optimized staircase using coordinate geometry concepts (distance, slope, and transformation) to work within the dimensional and monetary constraints. Once the staircase designs are complete, student teams will take turns presenting their designs and reflecting on possible improvements to their models. Throughout this process, students will use the engineering design process and discuss the relevant engineering career pathways that are available and accessible to them.

ACKNOWLEDGEMENTS:

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Zhang, Lu & DeArmond, Derek & Alvarez, Noe & Zhao, Daoli & Wang, Tingting & Hou, Guangfeng & Malik, Rachit & R Heineman, William & Shanov, Vesselin. (2015). Beyond Graphene Foam, a New Form of Three-Dimensional Graphene for Supercapacitor Electrode. J. Mater. Chem. A. 4. 10.1039/C5TA10031C.

“Queen's Advanced MicroEngineering Centre.” *Queen's University Belfast | CVD Tungsten*, www.qub.ac.uk/research-centres/QAMEC/ResearchActivities/Metallisation/CVDTungsten/.

APPENDIX I: NOMENCLATURE USED

GF: Graphene Foam
GP: Graphene Pellet
CVD: Chemical Vapor Deposition
RET: Research Experience for Teachers
SEM: Scanning Electron Microscope
EIS: Electrochemical Impedance Spectroscopy
EDP: Engineering Design Process

APPENDIX II: UNIT TEMPLATE OF TEACHER # 1

Name: Victoria Jones	**Contact Info: vpj2103@gmail.com**	**Date: 6/18/19**

Unit Number and Title: Unit 3 Electrochemistry

Grade Level:	10th
Subject Area:	Chemistry

Total Estimated Duration of Entire Unit:	6 weeks

Part 1: Designing the Unit

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

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

2. Unit Summary

The Big Idea (including global relevance): How can we design transportation that is effective and eco friendly using battery technology?

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):

How do we use chemistry to design batteries?

How do we test batteries to determine their abilities?

How and why do we store chemical and electrical energy?

What are the advantages of electric vehicles as opposed to gasoline vehicles?

What are the pros and cons of different battery types and arrangements?

3. Unit Context

Justification for Selection of Content– Check all that apply:

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

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

Tesla video

The Challenge and Constraints:

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

Description of Challenge (Either Product or Process is clearly explained below):	List the Constraints Applied
Students will be designing a battery powered car that meets 3 challenges - one based on speed, a distance, regular course.	**Weight limit** **Speed of car** **Distance travelled** **Cost - solution must be cost effective** **Time limits**

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

How do we mount batteries to a car?

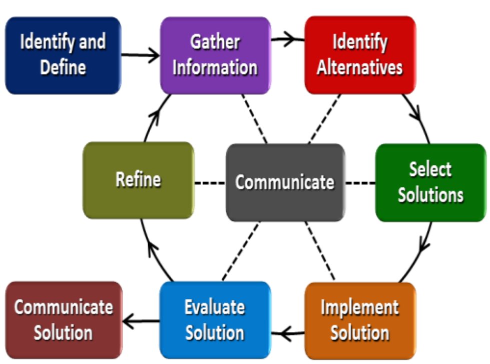
How can we minimize weight on our car?

How do we mix series and parallel batteries?

What size and type of batteries best suite our build?

What's the difference between a series and a parallel circuit?

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 designs during 3 differing challenges. Students will be able to redesign their car battery system and holder in between each of the challenges.

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

Students will be writing a summary report of their design and any future changes they would make. Students may also make a fake commercial for their car that informs consumers about its power and limitations.

What academic content is being taught through this Challenge?

Redox Reactions

Balancing Reactions

Voltage and current

Parallel versus Series

Renewable energy versus fossil fuels

Battery design

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

What EDP Processes are ideal for conducting an Assessment? (List ones that apply.)	List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative.
Gathering information Implement Solution Refine Communicate solution	_______Rubric__________ ☐ formative ______Rubric_________________ ☐ formative ______Checklist______________________ ☐ formative ____Rubric_________________ ☐ summative

Check below which characteristic(s) of this Challenge will be incorporated in its implementation 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**

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 challenge is about a topic that is currently very applicable to the real world. Climate change and dependence on fossil fuels are pushing the automotive industry towards electric vehicles. Designing and optimizing these cars and the batteries that power them are a huge field.**

What activities in this Unit apply to real world context?

Student use batteries on a daily basis. Disposing of phones and old batteries.

Activity 1 - Communicating information in different methods

Activity 3 - making choices to optimize a product or solution

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**:**

Process of students making the choices to optimize specific aspects of the car is something that they'll need to do often in life. Electric vehicles support different industries and encourage different consumer behavior than fossil fuel vehicles.

What activities in this Unit apply to societal impact?

Societal attitudes towards energy and reusability are addressed in multiple activities. Activities 3 and 4 address the trade off between performance and price/time, which is something that shows up in society in a variety of ways.

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.)

Chemical, Materials, Environmental, Electrical engineering

Guest speaker from Nanotechnology coming in to speak

6. Misconceptions:

Energy is only electricity. Battery charging mechanisms and methods - it's best to fully charge a battery/never fully charge the battery etc.

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.)

Order of how the unit will progress - list out here

The first activity in the unit is centered around giving students an understanding of voltage as a concept and a number. Students will create and use a physical model to better understand voltage, as well as optimize voltage.

The second activity is focused on allowing students an inside look into batteries. While most students have seen batteries before they don't know or understand the internal mechanisms. The electroplating copper activity will help students learn how batteries work and how to create detailed diagrams.

The third activity revisits optimization, asking students to optimize an electrolyte for a given battery. Students will have several attempts to select and optimize the electrolyte and must then explain their rational and results.

The fourth activity combines battery knowledge and optimization. Students will be designing and optimizing batteries in parallel and in series to determine output properties. Students will present their findings and a scientific explanation explaining them.

The challenge activity has students design a car battery system. Students design and 3D print a battery compartment to hold their design. Students will have multiple design processes to optimize their battery and car design to meet 3 challenges - speed, distance, and trip.

8. Keywords: Electrochemistry, Batteries, Energy, Storage

9. Additional Resources/Materials: N/A

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

Students will take a pre-unit test to determine their base knowledge and an end of unit test to determine growth.

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

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

Next Generation Science Standards (NGSS)	
Science and Engineering Practices (Check all that apply)	**Crosscutting Concepts (Check all that apply)**
☐ 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 Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**
☐ Interpreting and Communicating Science Concepts **(C)**
☐ Recalling Accurate Science **(R)**

Part 2: Post Implementation- Reflection on the Unit

Results: Evidence of Growth in Student Learning - After the Unit has been taught and the Post-Unit Assessment Instrument has been used to assess student growth in learning, the teacher must analyze the data and determine whether or not student growth in learning occurred. Present all documents used to collect and organize Post- Unit evaluation data such as graphs or charts. Provide a written analysis in sentence or paragraph form which provides the evidence that student growth in learning took place. Please present results and, if applicable, student work (as a hyperlink) used as evidence after the Unit has been taught.

Please include:

- Any documents used to collect and organize post unit evaluation data. (charts, graphs and /or tables etc.)
- An analysis of data used to measure growth in student learning providing evidence that student learning occurred. (Sentence or paragraph form.)
- Other forms of assessment that demonstrate evidence of learning.
- Anecdotal information from student feedback.

Reflection: **Reflections: Reflect upon the successes of teaching in this Unit in 5 or more sentences in the form of a narrative. Consider the following questions:**

1) Why did you select this content for the Unit?
2) Was the purpose for selecting the Unit met? If yes, provide student learning related evidence. If not, provide possible reasons.
3) Did the students find a solution or solutions that resulted in concrete meaningful action for the Unit's Challenge? Hyperlink examples of student solutions as evidence.
4) What does the data indicate about growth in student learning?
5) What would you change if you retaught this Unit?
6) Would you teach this Unit again? Why or why not?

Name:Victoria Jones	**Contact Info:vpj2103@gmail.com**	**Date: 7/17/19**

Lesson Title : What is voltage?	**Unit #:**	**Lesson #:**	**Activity #:**

Activity Title: Modeling Voltage	3	1	1

Estimated Lesson Duration:	2 class periods
Estimated Activity Duration:	1 class period

Setting:	General classroom - Beechwood High School

Activity Objectives: Students will be able to

- **Refine and build a physical model to help them understand and explain the concept of voltage.**
- **Test 3 pairs of ions and state the "strength" of their pull**

Activity Guiding Questions:
Why do we use physical models?
How do we evaluate the effectiveness of models?
What are some examples of models why use?
What are ions?
What is the difference between cations and anions?
What is the difference between a positive and negative ion?
What is voltage?
How is voltage created?

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

Ohio's Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**

☐ Interpreting and Communicating Science Concepts **(C)**	
☐ Recalling Accurate Science **(R)**	

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

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

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)
Student Worksheet

Teacher Advance Preparation:
Print student worksheets

Foam board, rubber bands, thumb tacks, markers

Activity Procedures:

1. **Student will be given a set of supplies and will be creating and evaluating a model for understanding voltage.**
2. **Students must create a model that allows others to place thumb tacks into the board at the correct location to represent an ions charge. The ion can then be paired with an opposite charge ion and a runner band is placed around the thumbtacks.**
3. **Students' models must be able to accurately show 4 example ion pairs, then students will allow another student to test their design by having them use it to model 4 new pairs.**

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

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.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners. Refer to Activity Template for details.
Activity instructions are scaffolded to include design sketches for students that struggle to follow directions.

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

Name: Victoria Jones	Contact Info: vpj2103@gmail.com	Date: 7/17/19

Lesson Title : What Happens Inside Batteries?	Unit #:	Lesson #:	Activity #:
Activity Title: Electroplating with Copper - get old keys from locksmith	1	1	2

Estimated Lesson Duration:	3 days
Estimated Activity Duration:	1 days

Setting:	General classroom and lab - Beechwood High School

Activity Objectives:Students will be able to

- **Students should be able to understand the essential parts of a battery and their role.**
- **Students will be able to write or describe what a half-reaction is**
- **Students will communicate why some ions are switching when electroplating.**

Activity Guiding Questions:

1. **How do batteries work?**
2. **What makes-up a battery?**
3. **Why do batteries degrade over time?**

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

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

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

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

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

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

Student handout

Teacher Advance Preparation:
1.5-volt D battery with battery holder
Two alligator clip leads or insulated wire
Beaker or glass
Copper sulfate
Copper electrode (or coil of copper wire)
Brass key
Safety equipment

Activity Procedures:

https://www.homesciencetools.com/article/electroplating-science-project/

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

Exit Ticket

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.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.

Refer to Activity Template for details.

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

Name: Victoria Jones	**Contact Info: vpj2103@gmail.com**	**Date: 7/17/19**

Lesson Title : Optimizing a Battery	**Unit #: 3**	**Lesson #: 2**	**Activity #: 3**
Activity Title: Battery Optimization Lab - Finding the best electrolyte			

Estimated Lesson Duration:	**5-6 class days**
Estimated Activity Duration:	**3-4 class days**

Setting:	**Chemistry Lab and Classroom - Beechwood High School**

Activity Objectives: Students will be able to

- Create and optimize a Two Cell Battery.
- Justify their optimization using data collected during experiments.

Activity Guiding Questions:

From where does electricity come? (Possible answers: A wall outlet, power plant, photovoltaic/solar cells, batteries, etc.)

What is inside batteries that helps produce current electricity? (Possible answers: Chemicals, paste, or a bunch of electrons.)

What are examples of electrolyte that we could use?

What is an electrolyte?

What makes a good electrolyte?

What is the role of the electrolyte in a battery?

Next Generation Science Standards (NGSS)	
Science and Engineering Practices (Check all that apply)	**Crosscutting Concepts (Check all that apply)**
☐ Asking questions (for science) and defining problems (for engineering)	☐ Patterns
☐ Developing and using models	☐ Cause and effect
☐ Planning and carrying out investigations	☐ Scale, proportion, and quantity
☐ Analyzing and interpreting data	☐ Systems and system models

☐ Using mathematics and computational thinking	☐ Energy and matter: Flows, cycles, and conservation
☐ Constructing explanations (for science) and designing solutions (for engineering)	☐ Structure and function.
☐ Engaging in argument from evidence	☐ Stability and change.
☐ Obtaining, evaluating, and communicating information	

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

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

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

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

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

Handout for students

Students must create their own data table for the lab

Teacher Advance Preparation:

Cut two 8 in x 12 in (20 cm x 30 cm) pieces of aluminum foil for each team.

Cut one 12 in (30 cm) piece and two 31.5 in (80 cm) pieces of wire for each team. Note that insulated wire can be used, as long as it is stripped at the ends.

Decide which electrolytes to use. (Suggestion: For a class of 27 students working in nine teams of three students each, use three different electrolytes [vinegar, citrus juice, salt] in three different strengths [weak, medium, strong].)

Prepare the electrolyte solutions, making about 400 mL of each solution. Make sure to label them. The whole class can use the same type of solution at different strengths, or different teams can have different types of solutions at a range of strengths (see examples below):

Weak solution: 5 ml (~1 teaspoon) of [vinegar or citrus juice or salt] for every 100 ml water

Medium solution: 15 ml (~1 tablespoon) of [vinegar or citrus juice or salt] for every 100 ml water

Strong solution: 40 ml (~2.5 tablespoon) of [vinegar or citrus juice or salt] for every 100 ml water

If the number of teams is not a multiple of three (one team using the weak solution, one using the medium solution, and one using the strong solution), prepare more electrolyte solutions for the remaining teams, making them incrementally stronger.

Prepare a Battery Testing Station for the entire class to use: 3 pairs of goggles, a DC ammeter, graduated cylinders, all the containers of prepared electrolyte and paper towels.

Set up a Cleaning Station.

Make copies of the Two-Cell Battery Worksheet, one per team.

Activity Procedures:

Before the Activity

1. **Cut two 8 in x 12 in (20 cm x 30 cm) pieces of aluminum foil for each team.**
2. **Cut one 12 in (30 cm) piece and two 31.5 in (80 cm) pieces of wire for each team. Note that insulated wire can be used, as long as it is stripped at the ends.**
3. **Decide which electrolytes to use. (Suggestion: For a class of 27 students working in nine teams of three students each, use three different electrolytes [vinegar, citrus juice, salt] in three different strengths [weak, medium, strong].)**
4. **Prepare the electrolyte solutions, making about 400 mL of each solution. Make sure to label them. The whole class can use the same type of solution at different strengths, or**

different teams can have different types of solutions at a range of strengths (see examples below):

5. **Weak solution: 5 ml (~1 teaspoon) of [vinegar or citrus juice or salt] for every 100 ml water**
6. **Medium solution: 15 ml (~1 tablespoon) of [vinegar or citrus juice or salt] for every 100 ml water**
7. **Strong solution: 40 ml (~2.5 tablespoon) of [vinegar or citrus juice or salt] for every 100 ml water**
8. **If the number of teams is not a multiple of three (one team using the weak solution, one using the medium solution, and one using the strong solution), prepare more electrolyte solutions for the remaining teams, making them incrementally stronger.**
9.
10. **Prepare a Battery Testing Station for the entire class to use: 3 pairs of goggles, a DC ammeter, graduated cylinders, all the containers of prepared electrolyte and paper towels.**
11. **Set up a Cleaning Station.**
12. **Make copies of the Two-Cell Battery Worksheet, one per team.**

With the Students

Have each team construct its two-cell battery at a desk. After all the groups have finished, gather the class around the battery testing station to observe what happens when electrolyte is added to each team's battery.

Constructing the Battery:

1. **Put a piece of tape on each glass container. Label one container A and the other B.**
2. **Have students roll each piece of foil so the long side of the roll is about 12 in (30 cm). Crumple about 1/4 of one end on each roll.**
3. **Place one aluminum foil roll in each container, placing the crumpled end on the bottom of the container. Carefully flatten the rolled part of the foil against the side of each container.**
4. **Place a paper cup bottom (or milk cap) on top of the crumpled foil in each container; the aluminum foil column should go up and around the side of the paper cup (or milk cap) (see Figure 1).**
5. **Carefully wind one end of the 12 in (30 cm) piece of copper wire around the top of the foil roll in container A. Make a couple winds with the wire to get a good connection. Leave the other end of the wire free.**
6. **A photograph shows the bottom of a glass jar containing a rolled aluminum foil column bent at a 90-degree angle across the bottom of the jar. Past the bend, some of the foil is crumpled against the bottom of the glass jar. On top of the crumpled aluminum foil is an upside down paper cup bottom.**
7. **Figure 1. The aluminum foil column (anode) crumpled at the bottom and covered by a paper cup bottom.**
8. **copyright**
9. **Coil about 22-24 in (55-60 cm) of the 31.5 in (80 cm) piece of wire into a ball. Place this ball on top of the paper cup bottom in container B. Make sure the copper wire is not touching the aluminum foil.**
10. **Coil about 22-24 in (55-60 cm) of the second 31.5 in (80 cm) piece of wire into a ball. Place this ball on top of the paper cup bottom in container A. Make sure the copper wire is not touching the aluminum foil.**
11. **Carefully wind the free end of the third piece of copper wire (the 31.5 in wire in container A) around the top of the foil roll in container B. Again, make a couple winds with the wire to get a good connection.**
12. **A photograph of the activity set up. On the left, a glass container marked "A" holds a rolled aluminum foil column with a 90-degree angle and the part of the foil after the angle crumpled against the bottom of the glass jar. On top of the crumpled piece of aluminum is an upside down bottom of a small paper cup. A coiled piece of copper wire sits on top of the paper cup bottom. The other side of the copper wire is connected to the top of the aluminum foil column that is situated in a second glass container, labeled "B," located to the right of container "A." Container B has the same setup described for container A,**

however, the coiled copper wire on top of the paper cup leads out of the container and is not connected to anything.

13. **Figure 2. Activity set up: A completely assembled battery ready for testing.**
14. **copyright**
15. **Testing the Battery. Repeat steps 9–15 for each team.**

Have students wear goggles when they test their batteries.

1. **Connect the free end of the wire from container A to one of the ammeter connections.**
2. **Connect the free end of the wire from container B to the other ammeter connection.**
3. **Obtain an electrolyte solution. Pour about 50 ml of the electrolyte solution into container A and about 50 ml of the same solution into container B. The solution should cover the wire coils in both containers completely; if not, carefully add more of the solution.**
4. **Measure the current produced by the battery using a DC ammeter. Have one student from each team record the electrolyte concentration and current.**
5. **A photograph displays the completed battery (described in Figure 2) being tested with a lemon juice/water electrolyte solution. Container A and container B are filled with just enough of the electrolyte solution to cover the coiled copper wire. An ammeter is connected to the two copper wires that are wrapped around the top of the aluminum foil columns. The ammeter reads 0.06 Amps.**
6. **Figure 3. The current generated by an approximate 4mL/100mL solution of lemon juice.**
7. **copyright**
8. **Disconnect the wires from the ammeter.**
9. **Pour the electrolyte solution back into its correct source container.**
10. **After all students have tested their batteries, have teams disassemble their batteries. Have one member of each team take its materials to the Cleaning Station. Students should gently rinse containers A and B with a small amount of water. Pour this water in the sink or into a container provided for this purpose.**
11. **Have teams report the electrolyte concentration and current produced by their batteries on the classroom board.**

In teams, have students complete the Two-Cell Battery Worksheet.

As a math exercise, using the chart on the Two-Cell Battery Worksheet, have students construct graphs of current as a function of concentration and use the graphs to predict what the current might be at intermediate electrolyte concentrations.

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

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.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners. Refer to Activity Template for details.
For the analysis section some students will get a scaffolded data google sheet, so that they don't have to create the data tables and the graphs individually.

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

Name: Victoria Jones	Contact Info: vpj2103@gmail.com	Date: 7/17/19

Lesson Title : Circuits	Unit #: 3	Lesson #: 2	Activity #: 2
Activity Title: Exploring parallel and series circuits			

Estimated Lesson Duration:	2 days
Estimated Activity Duration:	1 day

Setting:	General classroom

Activity Objectives: SWBAT:
-optimize a set of batteries to increase the brightness of a lightbulb
-defend their optimization using both data and scientific principles

Activity Guiding Questions:
What are series and parallel batteries arrangements?
What changes about battery output when you change the arrangement?

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

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

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

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

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

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

Student worksheet

Teacher Advance Preparation:

Teacher will need to prep materials for activity - including batteries and light bulbs, light bulbs should all be the same size and wattage.

Activity Procedures:

Students will be given the goal of the activity of maximizing the brightness of a lightbulb. They will then get 3 timed iterations of brainstorming and designing to attempt to maximize their design. Designs will be judged and students will write a paragraph explaining why their design resulted in the level of brightness it did and what future changes they would make.

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

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.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.

Refer to Activity Template for details. Students will be put into differentiated groups for this activity based on writing level. Groups will receive different scaffolds for their explanations and future changes depending on their writing level.

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

Name: Victoria Jones	**Contact Info: vpj2103@gmail.com**	**Date: 7/17/19**

Lesson Title : Designing an electric car	**Unit #: 3**	**Lesson #: 2**	**Activity #: 5**
Activity Title: Optimizing an electric car			

Estimated Lesson Duration:	**5-6 class days**
Estimated Activity Duration:	**3-4 class days**

Setting:	**Classroom - Beechwood High School**

Activity Objectives: Students will be able to

- Design a 3D printed battery case for their car
- Optimize their battery arrangement for 3 different challenges
- Justify their optimization using scientific concepts

Activity Guiding Questions:

How do we design cars to meet human needs?

How does battery structure affect car performance?

How can we 3D print a case with minimum weight but sound structure?

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

☐ Obtaining, evaluating, and communicating information	

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

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

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

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)
RC cars
3D printer and supplies
Computers
Batteries

Teacher Advance Preparation:
Order batteries, take apart cars for battery structure, resource 3D printers

Activity Procedures:
Optimization:
Students will be given the challenges in order and must design their battery arrangement first. Once they've finalized their first battery design they may design and print a 3D case that attached to the car while also holding the batteries. The final challenge will have 3 iterations where students are allowed to alter their designs.

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

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.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners. Refer to Activity Template for details.
A basic 3D print of a battery holder will be available for students to look at. Select students will also receive a scaffold sheet reminding them of important relationships. Students will receive a calander of work and a checklist for organizational purposes.

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

APPENDIX III: UNIT TEMPLATE OF TEACHER # 2

Name: Ramya Ravindrababu	**Contact Info:** ramya.ravindrababu@floyd.kyschools.us	**Date:7/9/19**

Unit Number and Title: Unit 2 – Coordinate Geometry

Grade Level:	10

Subject Area:	Geometry

Total Estimated Duration of Entire Unit:	4 weeks

Part 1: Designing the Unit

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

KY.9-12.G.SC.18 Coordinate Geometry: Students will find the distance between two points using their coordinates and the Pythagorean theorem or the distance formula
KY.9-12.G.SC.11 Shapes and Relationships: Students will draw and construct representations of two-dimensional figures and three-dimensional objects using a variety of tools
G.GPE.5 Prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems (e.g., find the equation of a line parallel or perpendicular to a given line that passes through a given point).
G.GPE.6 Find the point on a directed line segment between two given points that partitions the segment in a given ratio.

2. Unit Summary

The Big Idea (including global relevance):

People encounter staircases every day. Some make you huff and puff, some are a breeze, and still others are designed in such a way that you will trip on them every single day. Optimizing the usability, costs, and materials used in building public stair cases is an important aspect of optimizing day-to-day life for many people around the world.

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):

- How can we build stairs that will fit subway dimensions without causing people to trip?
- What is the optimal slope of a set of stairs?
- What is the optimal height/distance ratio of stairs?
- How can we maximize the ease of use while minimizing the bulk of materials and cost of stair case implementation?
- What are the criteria of a “user-friendly” stair case experience?
- What makes stairs cumbersome? How can we reduce these issues?
- What are the constraints of stair case design?

3. Unit Context

Justification for Selection of Content– Check all that apply:

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

x Misconceptions regarding this content are prevalent.

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

☐ 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) ____

____

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

Everyday, millions of people use the New York Subway system. At several Subway exists, there are stairs that have gone viral for causing an inordinate number of accidents. Students will watch one such viral video and asked to consider why people trip over these stairs. How can the stair case design be improved to provide safer passage?

The Challenge and Constraints:

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

Description of Challenge (Either Product or Process is clearly explained below):	List the Constraints Applied
Students will design staircase blueprints to replace the current New York Subway stairs. Students will use distance calculations, slope calculations, and ratios to design the optimal stair case experience. Students will present their blue prints offering solutions to the tripping stair case issues. For a final activity, students will consider idea refinement in a written report.	Time Consistent ratios of distance and slope must be achieved to traverse a certain overall distance Students will be given "money" and will only be able to "purchase" a certain amount of materials for their staircase

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

- How can we traverse a certain distance/height using steps of uniform size?
- What can we do if we don't have enough money to create a sufficient number of stairs?
- What do we do if the distance/height does not divide evenly for step creation?
- What math can be used to optimize our staircase design?
- What shapes, figures, and mathematical concepts can be used to optimize our staircase design?

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 sketch the blueprint for their staircase solution on a large piece of chart paper. Other teams, and myself, will be able to evaluate the evenness of the steps and whether or not the criteria have been met. All students will be given the opportunity to see other groups' solutions and will write a reflection describing further iterations they could make to their design.
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.
Each team will do a 3-5-minute presentation describing their solution and promoting it as the best solution. Teams will receive rubrics outlining expectations and criteria for their presentations. Students will be allotted half of a class period to rehearse their presentations.
What academic content is being taught through this Challenge?
The purpose of Geometry is to encourage students to be thinking critically about how shapes fit into certain criteria or constraints. Students are expected to be able to manipulate the tools of geometry to achieve the goals of a given problem. This challenge directly encourages this type of student growth by providing real world context for this type of thinking.

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

What EDP Processes are ideal for conducting an Assessment? (List ones that apply.)	List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative.
Gather information Select Solution Implement Solution Implement Solution Communicate Solution	Q&A x formative ☐ summative Checklist x formative ☐ summative Quiz over slope & distance ☐ formative x summative Blueprint of final solution(rubric) x formative ☐ summative Presentation of final solution(rubric) ☐ formative x summative

Check below which characteristic(s) of this Challenge will be incorporated in its implementation using EDP. (Check all that apply.)
x Has clear constraints that limit the solutions
x Will produce than one possible solution that works

☐ Includes the ability to refine or optimize solutions
x Assesses science or math content
x Includes Math applications
☐ Involves use of graphs
☐ Requires analysis of data
x Includes student led communication of findings

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

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

Provide a brief rationale for where you placed the X**: Stair cases are an important part of infrastructure and day-to-day life for most people. Students will be introduced to the connections between real life construction challenges and mathematics. This Challenge is an introduction to the application of civil engineering and mathematics.**

What activities in this Unit apply to real world context? **Activity 2: The Hook, Activity 3: Creating the Blueprint, Activity 4: Presenting the Solution**

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

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

Provide a brief rationale for where you placed the X**: --------------While there is a clear potential for social impact with a project such as this one, there is not enough time to take students to the point where they will be able to pitch an real-life construction project.**

What activities in this Unit apply to societal impact? **Activity 3: Creating the Blueprint**

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.)

Possible careers: civil engineer, structural engineer, mechanical engineer, construction management, architectural engineer, possibly inviting a guest speaker.

6. Misconceptions:

· There are not many applications of mathematics that are important to me.
· There is only one correct way to build a staircase
· Structures like staircases, batteries, devices we use in day to day life have already been optimized be people who are much fancier. There is no way for us (students/laypeople) to be a part of those conversations.

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: **Introducing the Engineering Design Process**
Students will engage with the engineering design process for the first time. They will be encouraged to see engineering as a highly accessible process and career.
Activity 1: **Engineering a Duck** (25 minutes)
· Think Pair Share: what are the features that make up a duck?

· Here are some Legos – Build a Duck

· Between your duck and your partners duck, present and quickly choose your favorite. Between your team and the team behind you, choose your favorite duck.

· Introduce the Engineering Design Process, discuss which parts of the EDP we just engaged in.

Activity 2: **The Hook – When Staircases Fail** (25 minutes)

· Watch video about the NY Subway

· Full group discussion – Why do you think that is happening? How would you build a better stairway? What tools have we been learning about that may be useful to that end?

Lesson 2: **Connecting Stairs and Coordinate Geometry**

Activity 3: **Modeling Real World Solutions with Slope & Distance** (2 days)

· Students will use slope & distance to build an even staircase within their materials and cost constraints.

Activity 4: **Presentation & Reflection** (1 day)

· Students will present in teams. After seeing all of the presentations, students will write a reflection including future iterations on their designs, and the importance of math in real life as an exit ticket.

8. Keywords: structural design, slope, distance, ratios, criteria, constraints, usability

9. Additional Resources:

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

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

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

Next Generation Science Standards (NGSS)	
Science and Engineering Practices (Check all that apply)	**Crosscutting Concepts (Check all that apply)**
☐ 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 Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**
☐ Interpreting and Communicating Science Concepts **(C)**
☐ Recalling Accurate Science **(R)**

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

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

Part 2: Post Implementation- Reflection on the Unit

Results: Evidence of Growth in Student Learning - After the Unit has been taught and the Post-Unit Assessment Instrument has been used to assess student growth in learning, the teacher must analyze the data and determine whether or not student growth in learning occurred. Present all documents used to collect and organize Post- Unit evaluation data such as graphs or charts. Provide a written analysis in sentence or paragraph form which provides the evidence that student growth in learning took place. Please present results and, if applicable, student work (as a hyperlink) used as evidence after the Unit has been taught.

Please include:

- Any documents used to collect and organize post unit evaluation data. (charts, graphs and /or tables etc.)
- An analysis of data used to measure growth in student learning providing evidence that student learning occurred. (Sentence or paragraph form.)
- Other forms of assessment that demonstrate evidence of learning.
- Anecdotal information from student feedback.

Reflection: Reflections: Reflect upon the successes of teaching in this Unit in 5 or more sentences in the form of a narrative. Consider the following questions:

1) Why did you select this content for the Unit?

2) Was the purpose for selecting the Unit met? If yes, provide student learning related evidence. If not, provide possible reasons.

3) Did the students find a solution or solutions that resulted in concrete meaningful action for the Unit's Challenge? Hyperlink examples of student solutions as evidence.

4) What does the data indicate about growth in student learning?

5) What would you change if you re-taught this Unit?

6) Would you teach this Unit again? Why or why not?