# Mathematics Lessons for Grades 9-12

## "Designing Attraction to Engineering Concepts"

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**Discipline**: Mathematics or Science
**Grade**: 9 to 10, 11 to 12

**Standards**
Number and Operations Standard - Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.
Algebra Standard – i) Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior. ii) Interpret representations of functions of two variables. Draw reasonable conclusions about a situation being modeled. iii) Approximate and interpret rates of change from graphical and numerical data.
Data Analysis and Probability Standard – i) Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. ii) Understand and apply basic concepts of probability.
Problem Solving Standard - Solve problems that arise in mathematics and in other contexts.
Communication Standard - Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
Connections Standard - Recognize and apply mathematics in contexts outside of mathematics.
Representation Standard – i) Use representations to model and interpret physical, social, and mathematical phenomena. ii) Create and use representations to organize, record, and communicate mathematical ideas.

**Purpose/Goal**
The students will be able to:

- Follow procedures to collect data while changing more than one variable.
- Plot data on a graph and generate equations of lines to represent data.
- Interpret data to predict overall behavior of multiple variables.
- Demonstrate deep comprehension while providing final design recommendations.

Goals:

- Math competency: Skills and appreciation for data collection used in real life.
- Quantitative literacy: Ability to follow procedures and provide recommendations.
- Engineering applications: Flow of electricity, electromagnets and solenoids, material selection and cost considerations.
- Cultural relevancy: How to follow procedures, collaborative work in small groups, applications for electricity, and hands-on activities.

**Context**
Most commonly recognized magnets are referred to as "permanent magnets". These magnets have two polar ends (positive and negative or North and South) and they are attracted to iron or steel. Some typical examples include compass and refrigerator magnets but magnets can also be found in VHS or audio tapes, computer hard drive, and on the back of credit or ATM cards. If a magnets is powerful enough it can temporarily "magnetize" a secondary object (for example a paper clip can be temporarily magnetized by rubbing it along a bar magnet). These are referred to as "temporary magnets."

This leads us to the third type of magnet known as "electromagnets." Electromagnets can be found in many everyday applications including automatic car widows, automatic doors, and junkyard cranes; other examples include particle accelerators. Electromagnets are unique because they must be connected to a power source; when they are connected to power they act like permanent magnets, but when disconnected they loose their magnetism. Therefore, they can be turned on and off. The most basic electromagnets consist of a coil of wire connect to a battery.

The strength of an electromagnet depends on the number of coils in the wire, the voltage flowing through the electromagnet, the material being used and the direction of flow. Electricity flows from negative to positive so the strongest magnetism will be felt at the negative end of the electromagnet.

**Preparation**

- Acquire necessary materials to include (for each group of four students): two 4inch nails, one 4inch section of a straw, two dixie cups, one 4inch x6inch strip of aluminum foil, four AA batteries, one box of 100 lock washers, four 30 inch sections of doorbell wire, and one battery holder. (Specifics given in activity documentation.)
- Pre-assemble battery holder according to instructions and diagrams given.
- Review introduction material and copy student worksheets.

**Motivation**

This activity was designed to elicit students' thinking about engineering, and that the students' can already do many of the same things that engineers do. A connection is specifically made to Electrical Engineering in this activity by demonstrating both an application for electromagnets and a real-world problem that would face a team of engineers in a car company. The key engineering aspects are: teamwork, hypothesis and testing, data collection, and communicating recommendations based on material performance and cost. In a low stress environment students can explore engineering, how electricity and electromagnets work, and how to communicate their results to peers, teachers and others.

**Description**

Students are presented with a real world example of engineering and become electrical engineers which must explore and use basic engineering problem solving principles. Students in small groups (4 students/group) use batteries, wire, and various materials to create their own electromagnets and test for magnetic strength. They collect data of magnetic strength while varying battery power, number of coils, and materials to determine the trends. Students use calculators, scatter plots, and knowledge of linear and non-linear data to make recommendations of the best electromagnet. Students will be generating/collecting their own data and then using it to analyze different electromagnets and make recommendations based on cost and performance. During this activity students use mathematical skills and learn about how electromagnets work while being transported into a real-world scenario of working as an Engineer in industry.

**Assessment**

The student worksheet can be used as an assessment tool of how well they followed procedures and answered questions. Additionally, their final recommendations can be assessed for higher level thinking. Using a Student Reflective Assessment can also produce opportunity for assessing students learning.

- Strengths: What was something that was really good about this activity? Explain why this was important?
- Improvements: What is something you would do differently if you had to do this activity again or something you would like to work on after this activity? Explain how you would do this?
- Insights: What is something significant that you learned from this activity? What was something that surprised you in this activity?

**Follow-Up Activities**

Depending on the skill level of students the activity can be preceded by having the students following the directions to make their own battery holder. In this extension students would be responsible for following directions correctly so that their holder works correctly. Faulty assembly may also result in holders breaking, further providing an opportunity for students to be responsible for fixing the holder. This extension will strengthen students' understanding on electrical systems (positive versus negative terminals, how power units are put in electrical series or parallel). It is also another real world experience in engineering, where engineers need to understand how testing equipment works to fully understand the data.

Some extension questions after the main activity could be having students hypothesize the effect of temperature on strength or the effect of the wire gauge (on the doorbell wire used) on strength. These predictions could then be tested (caution thinner gauge wire will also heat up more quickly so care is recommended).