STEM Curriculum Planning Guide

This instructional design guide serves as the template for the design and development of STEM units of instruction at the Dayton Regional STEM Center in Dayton, Ohio. The guide is anchored to the *STEM Education Quality Framework* also developed at the Dayton Regional STEM Center.

STEM Unit Title	**Up, Up and Away: Making Motion with Magnets**
Economic Cluster	Power & Propulsion
Targeted Grades	8th
STEM Disciplines	Science, Technology, Engineering and Math
Non-STEM Disciplines	English Language Arts and Fine Arts

Section I: STEM Unit Overview

Unit Overview

The newest Ford class aircraft carriers will utilize Electromagnetic Aircraft Launch System (EMALS) to launch their aircraft. EMALS is a far more efficient and green system than the current steam system. In this series of investigations, students will develop an understanding of how magnets can be used to move large payloads such as an airplane. The unit will begin with a career connection activity. Next, students will investigate the properties of magnetism through station activities. Data collection and analysis software will be used to investigate the increase in force with the increase of magnets. Linear functions will be used to document and interpret data. Engineering design teams will develop a system using forces to move a payload a specified distance. It will be essential for teams to collect accurate data in order to make informed decisions to modify designs. Finally, teams will present their findings to a panel of stakeholders with interest in future launch systems.

Essential Question

How can unseen forces aid in the efficient transportation of large payloads?

Enduring Understanding

Magnetic forces can act at a distance. Magnetic fields exist around magnetic objects. If a second magnetic object is placed in the field, the two objects experience magnetic forces that can attract or repel them, depending on the objects involved. Electric current produces magnetic fields.

Unbalanced forces will cause an object's motion to change. Changes in motion depend upon the size and direction of the total unbalanced force exerted on the object.

Energy takes many forms. These forms can be grouped into types of energy that are associated with the motion of mass (kinetic energy), and types of energy associated with the position of mass and with energy fields (potential energy).

Patterns of association can be found in bivariate data, specifically positive linear association. Straight lines are use to model relationships between two quantities.

Knowledge gained can be expressed through organization and refinement of style for an appropriate audience using technology tools, visual displays and content appropriate language.

Engineering Design Challenge

Students will work in engineering design teams and engineer a system to move a payload a distance of 2.5 meters. Students must include magnetic force in their designs. Students will make informed decisions and redesign their system using the data collected during the design process.

Time and Activity Overview

Day	Time Allotment	Actvities
1	45 minutes	Pre-Test Video Hook Form Teams/EMALS Articles Introduce Peer Evaluation Sheet
2	45 minutes	Review the Engineering Design Process Introduce Engineering Design Challenge Introduce Team Roles Assign Career Concept Map
3	45 minutes	Magnetic Inquiry Stations
4	45 minutes	Magnetic Inquiry Stations

5	45 minutes	Graphing Linear Functions
6	45 minutes	Revisit Engineering Design Challenge Finish Design Brief Decision Analysis Matrix
7	45 minutes	Design, Build, Test and Rebuild
8	45 minutes	Design, Build, Test and Rebuild
9	45 minutes	Final Design Prepare Presentations
10	45 minutes	Presentations
11	45 minutes	Post-Test

Pre-requisite Knowledge & Skill

Students should know the definition of a linear function and be familiar with examples of linear vs. non-linear functions.
Students should have an understanding of the basics of forces and motion, including friction, gravity, mass, speed and weight.
Students should understand that forces exist that have the ability to move objects with them touching.
Students should be able to use presentation software to create a multimedia presentation.

Academic Content Standards

Add Standard	Mathematics	Ohio
Grade/Conceptual Category	CCSS.MATH.CONTENT.8.SP.A.1	
Domain	Statistics and Probability	
Cluster	Investigate patterns of association in bivariate data.	
Standards	Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.	

Add Standard	Mathematics	Ohio
Grade/Conceptual Category	CCSS.MATH.CONTENT.8.SP.A.2	
Domain	Statistics and Probability	
Cluster	Investigate patterns of association in bivariate data.	
Standards	Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.	

Add Standard	Mathematics	Ohio
Grade/Conceptual Category	CCSS.MATH.CONTENT.8.SP.A.3	
Domain	Statistics and Probability	
Cluster	Investigate patterns of association in bivariate data.	
Standards	Use the equation of a linear model to solve problems in the context of bivariate measurement data, interpreting the slope and intercept. For example, in a linear model for a biology experiment, interpret a slope of 1.5 cm/hr as meaning that an additional hour of sunlight each day is associated with an additional 1.5 cm in mature plant height.	

Add Standard	English Language Arts	
Grade	SL.8.1	
Strand	Speaking and Listening	
Topic	Comprehension and Collaboration	
Standard	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.	

Add Standard	English Language Arts	
Grade	SL.8.4	
Strand	Speaking and Listening	
Topic	Presentation of Knowledge and Ideas	
Standard	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.	

Add Standard	English Language Arts	
Grade	SL.8.5	
Strand	Speaking and Listening	
Topic	Presentation of Knowledge and Ideas	
Standard	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.	

Add Standard	English Language Arts
Grade	SL.8.6
Strand	Speaking and Listening
Topic	Presentation of Knowledge and Ideas
Standard	Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. (See grade 8 Language standards 1 and 3 here for specific expectations.)

Add Standard	English Language Arts
Grade	RI.8.4
Strand	Reading: Informational Text
Topic	Craft and Structure
Standard	Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the impact of specific word choices on meaning and tone, including analogies or allusions to other texts.

Add Standard	English Language Arts
Grade	RI.8.1
Strand	Reading: Informational Text
Topic	Key Ideas and Details
Standard	Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences drawn from the text.

Add Standard	Social Studies	Ohio
Grade		
Theme		
Strand (pk-8 only)		
Topic		
Content Standard		

Add Standard	Science	Ohio
Grade	8	
Theme	Order and Organization	
Topic	Forces and Motion	
Content Standard	Forces between objects act when the objects are in direct contact or when they are not touching. Magnetic, electrical and gravitational forces can act at a distance.	

Add Standard	Science	Ohio
Strand		
Course Content		
Content Elaboration		

Add Standard	Fine Arts
Grade	8
Subject	Visual Art
Standard	Producing/Performing (PR)
Benchmark	Generate, create, realize, use & master skills
Indicator	Use critical thinking and visual literacy to communicate a specific idea.

Add Standard	Technology
Grade	8
Standard	Nature of Technology
Benchmark	Benchmark A: Analyze information relative to the characteristics of technology and apply in a practical setting.
Indicator	1. Design technological solutions to problems generated by individual or collective needs. 2. Interpret the interrelationship between technology, creativity and innovation. 4. Apply multiple factors when developing products and systems to solve problems.

Add Standard	Technology
Grade	8
Standard	Nature of Technology
Benchmark	Benchmark B: Apply the core concepts of technology in a practical setting.
Indicator	1. Demonstrate how technological systems can be connected to one another. 2. Examine parameters and constraints in the design of a product or system. 4. Indicate ways a system malfunction may affect the function and quality of the system. 5. Recognize that trade-offs are the result of the decision-making process, involving careful compromises among competing factors.

Add Standard	Technology
Grade	8
Standard	Technology and Social Interaction
Benchmark	Benchmark E: Assess the impact of technological products and systems.
Indicator	1. Design and use appropriate instruments to gather data (e.g., design, fabricate and use a balance scale). 2. Interpret and evaluate the accuracy of the information obtained during a test or experiment and determine if it is useful.

Add Standard	Technology
Grade	8
Standard	Technology for Productivity Applications
Benchmark	Benchmark B: Select appropriate technology resources to solve problems and support learning.
Indicator	1. Solve problems using all available technologies for inquiry, investigation, analysis and presenting conclusions.

Add Standard	Technology
Grade	8
Standard	Technology and Information Literacy
Benchmark	Benchmark B: Use technology to conduct research and follow a research process model which includes the following: developing essential question; identifying resources; selecting, using and analyzing information; synthesizing and generating a product; and evaluate both process and product
Indicator	8. Evaluate final product for its adherence to project requirements (e.g., recognize weaknesses in process and product and find ways to improve).

Add Standard	Technology	
Grade	8	
Standard	Design	
Benchmark	Benchmark A: Evaluate the aesthetic and functional components of a design and identify creative influences.	
Indicator	3. Categorize the requirements for a design as either criteria or constraints. 4. Document compromises involved in design (e.g., cost, material availability). 5. Apply a design process to solve a problem in the community (e.g., identify need, research problem, develop solutions, select best solution, build prototype, test and evaluate, communicate, redesign).	

Add Standard	Technology	
Grade	8	
Standard	Design	
Benchmark	Benchmark B: Recognize the role of engineering design and of testing in the design process.	
Indicator	1. Explain how design involves a set of steps that can be performed in different sequences and repeated as needed (e.g., plan - do - study - act; problem analysis - design - coding and debugging - integration - testing and validation; define problem - identify options - identify best solution - plan how to achieve best solution - evaluate results). 2. Identify how modeling, testing, evaluating and modifying are used to transform ideas into practical solutions.	

Add Standard	Technology	
Grade	8	
Standard	Designed World	
Benchmark	Benchmark A: Develop an understanding of, and be able to, select and use physical technologies.	
Indicator	1. Solve a problem involving energy and power systems (e.g., build a roller coaster for marbles, solar vehicles or solar cookers).	

Assessment Plan

What evidence will show that students have acquired the enduring understandings for this STEM unit?

Performance Task, Projects	Engineering Design Challenge with Rubric (Appendix F) Final Presentation Final Presentation Video or Live Demonstration Presentation Directions and Rubric (Appendix R)
Quizzes, Tests, Academic Prompts	Pre/Post Test (Appendix A)
Other Evidence (e.g. observations, work samples, student artifacts, etc.)	Design Process Notes (Appendix P) Data Records
Student Self- Assessment	Magnet Station Reflection Questions (Appendix M) Design Process Reflection Questions (Appendix Q)

Technology Integration

ADISC Technology Integration Model*

	Type of Integration	Application(s) in this STEM Unit
A	Technology tools and resources that support students and teachers in ***adjusting, adapting, or augmenting*** teaching and learning to meet the needs of individual learners or groups of learners.	Career Connections Video Related Articles (Appendix C)
D	Technology tools and resources that support students and teachers in ***dealing effectively with data***, including data management, manipulation, and display.	Data recording table Design Process Notes (Appendix P) Calculators LoggerPro Software
I	Technology tools and resources that support students and teachers in conducting ***inquiry***, including the effective use of Internet research methods.	Magnets Meter sticks Stopwatches SloPro Application
S	Technology tools and resources that support students and teachers in ***simulating*** real world phenomena including the modeling of physical, social, economic, and mathematical relationships.	EMALS videos
C	Technology tools and resources that support students and teachers in ***communicating and collaborating*** including the effective use of multimedia tools and online collaboration.	Slide Presentation Optional Video Presentation and/or Working Design
	**The ADISC Model was developed by James Rowley PhD, Executive Director of the Institute for Technology-Enhanced Learning at the University of Dayton*	

Career Connections

Career Description

The Aerospace Systems Directorate (AFRL/RQ) was formed by combining the Propulsion (AFRL/RZ) and the Air Vehicles Directorates (AFRL/RB) together. This directorate is responsible for developing better aircraft engines, alternative fuels, structural testing, rocket testing, hypersonic/supersonic/subsonic speeds, wind tunnel testing and flight simulation. Some of the technologies developed include scramjet engines, alternative fuels, unmanned vehicles, hypersonic vehicles, collision avoidance, and aircraft energy optimization. This directorate could use the technology developed using electromagnetic energy to propel or lift objects off the ground such as drones, unmanned air vehicles, and remotely piloted aircraft. The Navy is currently looking at using this technology to catapult airplanes off aircraft carriers using electromagnetic energy as a Electromagnetic Aircraft Launch System (EMALS) Other areas of interest might include batteries with larger storage capacity and longer life spans. Potential career field applications include aerospace engineers, mechanical engineers, electrical engineers, materials engineers, physicists, and chemists.

The Munitions Directorate (AFRL/RW) is responsible for developing precision conventional munitions technologies to neutralize potential threats. This research and development directorate can use this technology as kinetic energy to propel objects to destroy targets. Potential career field applications include physicists, statisticians, electrical engineers, mechanical engineers, aerospace engineers, material engineers, and chemists.

The Space Vehicles Directorate (AFRL/RV) is responsible for developing and transitioning space technologies for more effective and affordable products. This directorate and NASA can use this technology to deliver heavy payloads into space resulting in lower fuels costs. Potential career field applications include aerospace engineers, mechanical engineers, electrical engineers, material engineers, physicists, and chemists.

The Materials & Manufacturing Directorate (AFRL/RX) is responsible for developing materials, processes, and advanced manufacturing technologies for aircraft, spacecraft, missiles, rockets, and ground-based systems. This directorate can work on different materials that are good conductors of electricity and/or better magnetic properties. Other properties to consider are materials with good thermal management capabilities, extended service life, and high structural strength. Potential career field applications include material engineers, physicists, chemists, electrical engineers, mechanical engineers, and aerospace engineers.

The Information Directorate (AFRL/RI) is responsible for developing and integrating affordable information technologies for air, space and cyberspace. This directorate can use this technology to develop better computer hard drives, speakers, generators, and electrodynamic bearings. Potential career field applications include computer scientists, electrical engineers, mechanical engineers, aerospace engineers, material engineers, physicists, and chemists.

The Directed Energy Directorate (AFRL/RD) is responsible for developing high power microwaves and laser technologies. This directorate and the Department of Energy (DOE) can use the non-lethal portion of this technology to subdue violence, riots, and border protection. Potential career field applications include electrical engineers, chemical engineers, mechanical engineers, aerospace engineers, material engineers, physicists, and chemists.

Section II: STEM Lesson Plan

Title of Lesson

Day #1 - Pretest and Background Information

Time Required

45 minutes

Materials

Pretest (Appendix A) - copy for each student
Career video https://www.youtube.com/watch?v=27k6pH5sZ5M and/or https://www.youtube.com/watch?v=e-V0dKwyu6E
Related Articles (Appendix C) - one copy for each student (optional)
Computer or tablet - one for each student or one for each pair (optional)
Career Concept Map (Appendix D) - one for each student

Objectives

Students will be able to identify careers associated with EMALS technology, and explain how an electromagnet works.

Instructional Process

1. Administer pretest to each student
2. Show career connection video(s) https://www.youtube.com/watch?v=27k6pH5sZ5M and/or https://www.youtube.com/watch?v=e-V0dKwyu6E
3. Give each student an article about the use of electromagnetic energy based on the approximate lexile reading level and article length. Each student will be responsible for reading and summarizing the information from their article for the class.
4. Assign Career Concept Map (Appendix D) as homework.

Differentiation

Testing accommodations for pretest as needed.
Instead of having students read the articles individually, students can work in partners or engineering design teams.
Allow student to find their own articles that apply to this content.

Assessments

Pretest (Appendix A)
Article Summaries
Career Concept Map (Appendix D)

Section II: STEM Lesson Plan

Title of Lesson	**Day #2: Introduction of the Engineering Design Challenge and Formation of Groups**
Time Required	45 minutes
Materials	Engineering Design Process Graphic (Appendix E) - for class display or one copy for each student Engineering Design Challenge with Rubric (Appendix F) - one copy for each student Engineering Design Challenge Roles (Appendix G) - one copy for each student Design Brief (Appendix H) - one copy for per design team Peer Evaluation Sheet (Appendix I) - one for each student Envelope - one for each student
Objectives	Students will understand the engineering design challenge and the engineering design process. Students will form into engineering design teams and acquire roles. Students will begin to form ideas about their engineering design by completing a portion of the Design Brief (Appendix H).
Instructional Process	1. Introduce the class to the Engineering Design Challenge (Appendix F). 2. Divide students into engineering teams of approximately four (double the Research Scientist role if more than four students are in a group). Hand out a copy of Engineering Design Challenge Roles (Appendix G) to each student and assign roles or have students choose roles. They will work in these teams throughout the lessons. 3. Introduce the class to the Engineering Design Process Graphic (Appendix E). 4. Each group should work together to complete the Design Brief (Appendix H). "Design Description" and "Deliverables" columns may be left blank until knowledge is gained through the magnetic stations. 5. At the end of the class, hand out the Peer Evaluation Sheet (Appendix I) to each student. Each student should complete the "Team Formation/Design Brief" column of the handout. These are confidential and will only be seen by the student filling it out and the teacher. When finished, students should put the evaluation in an envelope and return it to the teacher until the next day.
Differentiation	Students may choose roles depending on personal strengths and abilities. Design Brief (Appendix H) can be completed as a class.
Assessments	Design Brief (Appendix H) Engineering Design Challenge Roles (Appendix G) Peer Evaluation Sheet (Appendix I)

Section II: STEM Lesson Plan

Title of Lesson

Days #3 and #4 - Magnetic Stations

Time Required

45 minutes

Materials

Magnetic Station Task Cards (Appendix J) - Place printed (you may want to laminate) card at each station.
Magnetic Stations Answer Document (Appendix K) - one copy for each student
Magnet Station Reflection Questions (Appendix M) - one copy for each student
Peer Evaluation Sheet (Appendix I) - one for each student (same copy from previous day)

Station Materials:

Station 1: Electromagnet
Iron nails (various lengths and sizes)
3 ft of thin coated copper wire (one length per team)
D battery (approximately one per team)
Paper clips (approximately 100)
Wire cutter/stripper
1 roll electrical tape

Station 2: Magnetic Linear Accelerator
2 wooden rules with grooves
1 roll Scotch tape
5 1/2 inch neodymium cube magnets
12 steel ball bearings - (should be about the same height as 1/2 inch neodymium cube magnets)
Hot Wheel tracks (approximately 5 lengths)

Station 3: Magnetic Fields 2-D
2 bar magnets
Film canister filled with iron filings with a small hole poked in lid
Petri dish with lid
Compass

Station 4: Magnetic Fields 3-D
2 bar magnets
Horseshoe magnet
Jar of iron filings in oil

Station 5: Spring Scale
Spring scale
Various classroom objects to hang from scale

Station 6: Which Way is North?
One pair of donut magnets
String (approximately 2 feet)
Tape
Compass

Objectives

Students will be able to hypothesize how different types of magnets work.

Instructional Process

1. Prior to the lesson set-up each of the six stations. Each station will need its materials and Magnetic Station Task Cards (Appendix J) that accompany it.
Note: Setting up the magnetic linear accelerators for station 2 can be difficult. Neodymium magnets are very strong, difficult to pull apart and brittle. Depending on student ability, this station may be set-up by the teacher in advance.
2. Group students in their engineering teams.
3. Students should complete each of the stations with their teams by following Magnetic Station Task Cards (Appendix J) directions and completing Magnetic Stations Answer Document (Appendix K). They will complete 2-3 stations on the first day and 3-4 stations on the second day.
5. At the end of each day working in stations, student should complete the "Magnetic Stations" column of their Peer Evaluation Sheet (Appendix I). When finished, students should put the evaluation in an envelope and return it to the teacher until the next day.
6. Assign Magnet Station Reflection Questions (Appendix M) as homework.

Differentiation

Limit questions if needed.
Have students to design their own magnetic station with information, material list, and questions.
Stations can be completed as class-guided experiments.

Assessments

Magnet Stations Reflection Question (Appendix M)

Section II: STEM Lesson Plan

Title of Lesson

Day #5: Graphing Linear Functions

Time Required

45 minutes

Materials

1-magnet linear accelerator
4-magnet linear accelerator
Hot Wheels style track (approximately 2.25 meters in length)
SloPro application or other recording device
LoggerPro free 30-day demo
LoggerPro data and graph - one copy of each for each student
How Does the Number of Magnets Affect the Speed of a Magnetic Linear Accelerator? (Appendix N) - one copy for each student

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Objectives

Students will draw a line of best fit and calculate slope to determine how the number of magnets on a linear accelerator affects the speed of a ball bearing.

Instructional Process

1. Prior to the lesson, use the SloPro application to record a video of 1-magnet linear accelerator launching a ball bearing a distance of approximately 2.25 meters. The fast-moving ball bearing can be difficult to detect on video, so follow the recording tips listed below.
Video Recording Tips:
• Place linear accelerator set-up on a high contrast surface.
• Launch the ball bearing along a closed track (i.e. Hot Wheels track).
• Place the recording device as close to the linear accelerator/track set-up as possible in order to enlarge the appearance of the ball bearing.
2. Prior to the lesson, use Logger Pro (free 30-day demo available online) data-analysis software to create a distance versus time graph of the launched ball bearing. Use the following YouTube video for detailed directions: https://www.youtube.com/watch?v=nmKuPz5O2KM
Note: In the "Movie Options" settings, the frames per second (fps) rate will need to be changed to 60 if the SloPro app was used to record the linear accelerator video.
3. Prior to the lesson, repeat steps 1-2 with a 4-magnet linear accelerator.
4. As a class, review students' findings during magnetic stations using the Magnetic Station Reflection Questions (Appendix M). Conduct a whole-class debrief reviewing the reflection questions, specifically Station 2: Magnetic Linear Accelerator.
5. Display and hand out printed copies of the data and graphs created using Logger Pro.
6. Hand out Appendix N: How Does the Number of Magnets Affect the Speed of a Magnetic Linear Accelerator?
7. Work with students to complete the hand out by drawing a line of best fit, describing the linear association and finding the slope for each graph.
8. Compare the information from each graph and determine how the number of magnets affects the speed of a magnetic linear accelerator. By finding the slope of the line, students should recognize that the speed of the 4-magnet linear accelerator is greater than the speed of the 1-magnet linear accelerator. For example, a 1-magnet linear accelerator may have a slope/speed of 1.87 meters per second while a 4-magnet linear accelerator may have a slope/speed of 2.62 meters per second.

Differentiation

Advanced students may use the LoggerPro software to complete the data collection and graphing process.
Students can be guided through Appendix N as a whole class or work individually.
Students can be challenged to sketch a graph that would should the velocity of each ball bearing over time.

Appendix N: How Does the Number of Magnets Affect the Speed of a Magnetic Linear Accelerator?

Section II: STEM Lesson Plan

Title of Lesson — **Day #6 - Decision Analysis Matrix**

Time Required

45 minutes

Materials

Design Brief (Appendix H) - one copy for per design team
Decision Analysis Matrix (Appendix O) - one copy per design team
Peer Evaluation Sheet (Appendix I) - one for each student (same copy from previous day)

Objectives

Students will be able to will be able to describe their design plan.

Instructional Process

1. Review the engineering design challenge and have teams finish completing the Design Brief (Appendix M).
2. Next, instruct each student should complete their own design. Remind students to apply their newfound knowledge of magnets to their design.
3. Hand out a copy of the Decision Analysis Matrix (Appendix O). Review the example of an analysis matrix. Students should then add the required and important elements to their team's matrix (i.e. design goals and weight).
4. The group will use the Decision Analysis Matrix (Appendix O) to make decisions about final team design. Teams can choose one member's individual design or decide to use components of different designs for their team's initial design.
5. Final designs should be submitted to the teacher and approved before building begins.
6. At the end of the lesson, each student should complete the "Design Proposal" column of their Peer Evaluation Sheet (Appendix I). When finished, students should put the evaluation in an envelope and return it to the teacher until the next day.

Differentiation

Students may draw their final design plan in Google Sketch-Up at www.sketchup.com
Tutorial videos for Google Sketch-Up at http://www.sketchup.com/learn/videos/58
Printable Sketch-Up reference cards available at https://www.sketchup.com/content/quick-reference-cards-0

Assessments

Engineering Design Challenge with Rubric (Appendix F)
Peer Evaluation Sheet (Appendix I)

Section II: STEM Lesson Plan

Title of Lesson

Days #7 and #8 - Engineering Design Challenge

Time Required

45 minutes

Materials

Design Process Notes (Appendix P) - one for each team and have more copies available
Design Process Reflection Questions (Appendix Q) - one for each student
Peer Evaluation Sheet (Appendix I) - one for each student (same copy from previous day)

Engineering Design Challenge Building Materials:
meter sticks - six per design team
bar magnets - 10 per design team
wand magnets - 5 per design team
masking tape - one roll per design team
duct tape - one roll for class use
tin foil - one roll for class use
felt - 8x11 sheet per design team
stop watches - one per design team
rulers - six per design team
wax paper - one roll for class use
ball bearings (various sizes) - one of each size per design team
cylindrical magnets - ten per design team
1/2 inch neodymium cube magnets - ten per design team
graph paper - five sheets per design team
sand paper - 8x11 sheet per design team
bubble wrap - 8x11 sheet per design team
other materials that students can use for their engineering design

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Objectives

Students will be able to evaluate and analyze their design plan.

Instructional Process

1. Engineering Design Teams will begin to build and test their initial design. Teams will continue to build, test, and redesign as they work through Day #7 and Day #8. Since teams will be making many changes throughout the design process, each team will need to keep Design Process Notes (Appendix P) to record the changes they made to their design and the effect of the changes.
2. At the end of Day #7 and #8 each student should complete column "Build, Test and Redesign" of their Peer Evaluation Sheet (Appendix I). When finished, students should put the evaluation in an envelope and return it to the teacher until the next day.
3. After Day #8 assign Design Process Reflection Questions (Appendix Q) for homework.

Differentiation

Students may make design changes to their Google Sketch-Up drawing.
You may choose to limit the reflection questions, divide them between days, or ask students to answer them after both building days.

Assessments

Design Process Reflection Questions (Appendix Q)
Peer Evaluation Sheet (Appendix I)

Section II: STEM Lesson Plan

Title of Lesson **Day #9 - Team Presentation Design**

Time Required 45 minutes

Materials

One computer or tablet per team
Slide presentation software (Google Slides, PowerPoint, Prezi, etc.)
Presentation Directions and Rubric (Appendix R) - one copy for each student
Peer Evaluation Sheet (Appendix I) - one copy for each student (same copy from previous day)

Objectives

Students will be able to defend and justify their design based on analysis of data collected from prototype.

Instructional Process

1. Teams will first need to finalize their design on this day and begin to prepare their design presentations.
2. Hand out the presentation requirements to each engineering design team. Each team will get 5-8 minutes to present their design and data. Each team will need a 3-slide presentation, a 1-page handout that must include at least one data table, and either a live demonstration or a video in their presentation of their working design.
3. At the end of the lesson, each student should complete the "Presentation Preparation" column of their Peer Evaluation Sheet (Appendix I). When finished, students should put the evaluation in an envelope and return it to the teacher until the next day.

Differentiation

Students may make design changes to their Google Sketch-Up drawing.
Poster boards or presentation boards may be used in place of technology if needed.

Assessments

Presentation Directions and Rubric (Appendix R)
Peer Evaluation Sheet (Appendix I)

Section II: STEM Lesson Plan

Title of Lesson	**Day #10 - Presentations**
Time Required	45 minutes
Materials	Computer or tablet for presentation Slide presentation software (Google Slide, PowerPoint, Prezi, etc.) Peer Evaluation Sheet (Appendix I) - one for each student (same copy from previous day) Presentation Directions and Rubric (Appendix R) - one copy for each student
Objectives	Students will be able to summarize and report their design plan and all their findings with others.
Instructional Process	1. Each engineering design team will present their team's final design presentation. 2. At the end of the lesson, each student should complete the "Presentation" column of their Peer Evaluation Sheet (Appendix I). When finished, students should put the evaluation in an envelope and return it to the teacher until the next day.
Differentiation	In lieu of oral presentations engineering teams may write a technical report with diagrams and/or illustrations.
Assessments	Presentation Directions and Rubric (Appendix R) Peer Evaluation Sheet (Appendix I)

Section II: STEM Lesson Plan

Title of Lesson	**Day #11 - Post-Test**
Time Required	45 minutes
Materials	Post Test (Appendix A) - one copy for each student Peer Evaluation Sheet (Appendix I) - one for each student (same copy from previous day)
Objectives	Students will be able to demonstrate their understanding of magnetic forces through formal assessment.
Instructional Process	1. If needed, complete any presentations. 2. Each student should complete the Post-Test (Appendix A). 3. At the end of the lesson, each student should turn in their completed Peer Evaluation Sheet (Appendix I) to the teacher in its envelope.
Differentiation	Testing accommodations for students as needed.
Assessments	Post-Test (Appendix A)

Section III: Unit Resources

Materials and Resource Master List

Engineering Design Challenge Materials Available to Students:
meter sticks - two per design team
bar magnets - 10 per design team
wand magnets - 5 per design team
masking tape - one roll per design team
duct tape - one roll for class use
tin foil - one roll for class use
felt - 8x11 sheet per design team
stop watches - one per design team
rulers - six per design team
wax paper - one roll for class use
ball bearings (various sizes) - one of each size per design team
cylindrical magnets - ten per design team
1/2 inch neodymium cube magnets - ten per design team
graph paper - five sheets per design team
sand paper - 8x11 sheet per design team
bubble wrap - 8x11 sheet per design team
other materials that students can use for their engineering design

Other materials needed:
calculators
three different sized iron nails - one set per design team
3 feet of THIN COATED copper wire - 3 feet for each design team
new size D battery - one for each design team
variety of magnetic objects - for station set-up
electrical tape- one roll
wooden rulers with groove - two for station set-up
5 neodymium 1/2 inch cube magnets - for station set-up
adhesive tape - one role
twelve steel ball bearings - (should be about the same height as 1/2 inch neodymium cube magnets)
measuring tape
2 bar magnets - one set for station set-up
film canister of iron filings - one for station set-up
iron filings in jar of oil-one for station set-up
petri dish - one for station set-up
compass - two needed for station set-up
spring scale - one for station set-up
various objects to hang from spring scale
pair of donut magnets - one set for station set-up
string - about two meters for each design team
masking tape - one roll needed for station set-up

computer or tablet access - one per design team

Other video resources for teacher:

https://www.youtube.com/watch?v=FehUCQKKRwo
https://www.youtube.com/watch?v=XiHVe8U5PhU
Rail Gun Naval Test Shot: http://www.youtube.com/watch?v=y54aLcC3G74
US Navy Unveils High speed Rail Gun: http://www.cbsnews.com/videos/us-navy-unveils-high-speed-rail-gun/
Naval Rail Gun: http://specialized-weapons.wonderhowto.com/how-to/build-miniature-version-navys-electromagnetic-railgun-weapon-0122973/
Miniature Version of Navy Rail Gun: http://specialized-weapons.wonderhowto.com/how-to/build-miniature-version-navys-electromagnetic-railgun-weapon-0122973/

Key Vocabulary

Acceleration- the measure of how fast velocity is changing, so we can think of it as the change in velocity over time. The most common use of acceleration is acceleration due to gravity which can also appear as the gravitational constant (9.8 m/s2).

Balanced forces- forces acting so they do not cause a change in motion. They are equal in size and opposite in direction.

Coulomb's Law- a law of physics describing the electrostatic interaction between electrically charged particles.

Current- the rate of charge flow past a given point in an electric circuit, measured in Coulombs/second, which is named Amperes.

Drag- the forces acting opposite to the relative motion of any object moving with respect to a surrounding fluid. This can exist between two fluid layers or a fluid and a solid surface.

Electrical force- the attractive or repulsive interaction between any two charged objects is an electric force.

Electricity- is the set of physical phenomena associated with the presence and flow of electric charge.

Electromagnet- a type of magnet in which the magnetic field is produced by electric current. The magnetic field disappears when the current is turned off.

Electromagnetic energy- a form of energy that is reflected or emitted from objects in the form of electrical and magnetic waves that can travel through space.

Electromagnetic Aircraft Launch System (EMALS)

Field models- form the foundation of traditional, compass-based navigational systems. These models provide a picture of the Earth's magnetic field and how it varies from one point on the Earth's surface to another.

Force- a dynamic influence that changes a body from a state of rest to one of motion or changes its rate of motion. The magnitude of the force is equal to the product of the mass of the body and its acceleration.

Friction- the surface resistance to relative motion, as of a body sliding or rolling.

Generator- a machine that converts one form of energy into another, especially mechanical energy into electrical energy.

Ground state- the state of least energy of a particle, as an atom, or of a system of particles.

Inertia- the tendency to resist changes in their state of motion.

Linear acceleration- the acceleration caused by a moving body with uniform acceleration in a straight line.

Lodestones- a special type of the mineral magnetite that possesses distinctly north-south polarity.

Magnetic domain- a region in which the magnetic fields of atoms are grouped together and aligned.

Magnetic field- a mathematical description of the magnetic influence of electric currents and magnetic

Magnetic force- the attraction or repulsion that arises between electrically charged particles.

Magnetic poles- the region of a magnet toward which the lines of magnetic induction converge (south pole) or from which the lines of induction diverge (north pole).

Magnetism- a physical phenomena arising from the force between magnets, objects that produce fields that attract or repel other objects.

Magnitude- a term for the size or length of a vector.

Motor- a device that creates motion. It usually refers to an engine of some kind.

Net force- the overall force acting on an object.

Newton (symbol: N) is the International System of Units (SI) derived unit of force. It is named after Isaac Newton

Technical Brief

Technical Brief for Electromagnetic Aircraft Launch System (EMALS)

Electromagnetic energy refers to the energy that comes from a mixture of electrical fields and magnetic fields combined together. The waves from electromagnetic radiation cause the flow of electricity to make things work. [1] So what exactly is electrical energy and magnetic energy? From our chemistry class we know that atoms are composed of protons, neutrons and electrons. The protons and neutrons are bound together in the center of the atom to form the nucleus, whereas the electrons float on the outer shell of the atom. Because electrons are small and light, they can move about more easily than the protons or neutrons. Electricity is described as the movement of electrons from one atom to another. As the electrons move from one atom to the next, they create a current of electricity that flows along each atom. Remembering that like charges repel each other, the electrons that move from one atom to the next creates a force that repels the nearest electron to the next atom and so on. It's the motion or movement of the electrons from one atom to the next that creates a current. Some atoms hold on to their electrons very tightly, so they don't move from one atom to the other. These materials are commonly referred to as insulators because they resist the movement of electrons. Plastic is a good example of an insulator and is usually wrapped around copper wire to prevent electrical shock. In contrast, there are other atoms that hold on to their electrons very loosely with little resistance and these materials are commonly referred to as conductors. Copper, aluminum and steel are good examples of conductors.[2]

Magnets are materials that produce an area of magnetic force called a magnetic field. They have both a magnetic north and a magnetic south pole. When a magnetic north pole is moved close to a magnetic south pole, the magnets will attract each other. However, when a magnetic north pole is moved close to a magnetic north pole, the objects will repel each other. It is this magnetic field that surrounds the magnet that provides enough force to attract or repel objects. These magnetic fields can attract certain types of metals such as iron, nickel, or cobalt while other metals such as aluminum, copper and gold are not attracted at all.[3]

A Electromagnetic Aircraft Launch System (EMALS) is an electrically powered electromagnetic projectile launcher. In a classroom model of EMALS, magnets are placed on a platform and electricity is used to help propel a force field down the aluminum rails which in turn propels an armature. To create the proper force field, magnets are laid side-by-side on a platform with their magnetic north poles facing up. Since these like poles repel each other, the magnets are first attached to the platform using double sided tape and then secured with duct tape to ensure they stay in place. Next, aluminum rails are aligned on each side of the magnets to act as the conducting rails when an electrical current is applied. (Remember, aluminum is not magnetic but it is a good conductor of electricity). When electricity is applied to the aluminum rails it helps push the magnetic force field down the rails. These magnetic fields (created by high electrical currents) accelerate a sliding metal aluminum conductor, or armature, between two rails to help launch the projectiles. Experiments could be conducted using different types of batteries, armatures and aircraft to determine strength, conduction, and distance. Another experiment might involve using stronger magnets made from rare earth materials.

Safety and Disposal

Magnetic casings are delicate and can break easily. Remind students to be careful with magnets.
Magnets are very strong and can pinch fingers. In the case of the ingestion of a magnet seek medical attention immediately.

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Curriculum Developers

Karen Blair - Contributing Author
Monica Brouwer- Contributing Author
Laura Drager - Editor
Eric Heinrich - Contributing Author
Brandon Kirby - Contributing Author
Suzanne Loudner - Contributing Author
Jeff Morris - Contributing Author
Daniel Powers, PhD. - Contributing Author
Benjamin Seibert - Contributing Author
Jill Weaver - Contributing Author
Vicki Wissel - Contributing Author

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