

## THE FORCE OF A SOLENOID

### Performance Standards 12D/11B/13A/13B.J

Students will apply the concepts, principles and process of technological design to explore the nature of forces.

- *Knowledge*: understand electromagnetic forces and their relationship to application in industrial technologies.
- *Application*: calculate the electromagnetic force variables associated with solenoids in various settings.
- *Communication*: explain the scientific principles of electromagnetic forces and their industrial applications.

### Procedures

1. ***In order to know and apply concepts that describe force and motion and the principles that explain them (12D); the concepts, principles and processes of technological design (11B); the accepted practices of science (13A); and concepts that describe the interaction between science, technology and society (13B),***

students should experience sufficient learning opportunities to develop the following:

- Formulate a design innovation proposal to test the electromagnetic force of solenoids in various applications in industrial technologies in the real world.
- Generate ideas for design tests and applications, appropriate variables and tolerances for error.
- Identify design constraints due to access to tools, materials, time and precision.
- Research applicable scientific principles, concepts and applications of electromagnetic forces associated with solenoids in multiple applications.
- Design and conduct safe testing process to determine the specifications of variables affecting the action of a solenoid's moving a given mass of metal.
- Develop the sequence of the process with visualizations.
- Incorporate appropriate safety, available technology and equipment capabilities into construction of testing process and manipulation of solenoid devices.
- Repeat procedural steps for multiple trials.
- Collect and record data accurately, using consistent measuring and recording techniques and media with necessary precision.
- Document data accurately in selected format.
- Graph data appropriately to show relation to variables in design solution proposal.
- Interpret and represent results of analysis to produce findings.
- Compare data sets to design criteria for suitability, acceptability and applicability to application needs.
- Analyze/critique explanations of success or errors between similar investigations.
- Identify limitations of investigation methods, sample sets, technologies or procedures.
- Generate additional design modifications which can be tested later.
- Propose economic values associated with the use of the electromagnetic forces associated solenoid applications in the real world.

Note to teacher: This activity relates to knowledge associated with Standard 12D, while addressing the Performance Descriptors for Stage J within Standards 11B, 13A and 13B. This activity could be incorporated directly in a curricular study of electromagnetic devices. This activity will be beneficial to the student's understanding of the electromagnetic forces tapped in devices in their environment. Specifically, students will be able to determine and test the variables that affect the operation of the solenoid and relays.

2. Have students review and discuss the assessment task and how the rubric will be used to evaluate their work.
3. Introduce students to the basic scientific principles associated with electromagnetic forces demonstrated in solenoids. Question their background understanding of how solenoids work, where they are found and variety of industrial applications. Internet research may be a good option for most current resources. Students should brainstorm ways to test the strength of the force of a solenoid, how to measure the strength and which factors make a difference. Determine the class process of testing single variables, whether all teams will test all, multiple or single variables. It is suggested that they test a single variable only and then build to combinations of 1-2 additional variables. Teams should generate preliminary plans for their testing processes, request necessary materials and equipment, and identify safety precautions and data collection/analysis procedures. Students should conduct their single- and multiple-variable tests and present their findings for group presentations, comparisons and discussion. Discuss the limitations of the classroom study. After preliminary testing process and group discussion, each student (or team) should apply the basic findings about the variables

(current, wire size, number of turns, mass, distance, etc.) to assigned or chosen common devices in the real world which depend on the strength of solenoids. They should present their explanations of the applications of electromagnetic forces to the class. As an extension, they can research examples of solenoids which are not available for classroom use.

4. Evaluate each student's work using the Science Rubric as follows, and add the scores to determine the performance level:
  - *Knowledge:* The explanations of electromagnetic force variables and correlations to industrial applications were complete and expressed a correct understanding of the process for determining the strength of the force.
  - *Application:* The investigation was designed, conducted and analyzed to express correct applications of electromagnetic force strength and the appropriate variables precisely and accurately.
  - *Communication:* The team testing process, as well as the individual or team application study was well organized, well detailed and thoroughly explained the analysis of the force and its variables and the design process sequence and limitations with visualizations (as applicable).

#### **Examples of Student Work**

- [Meets](#)
- [Exceeds](#)

#### **Time Requirements**

- Approximately 3-5 class periods

#### **Resources**

- Equipment: solenoid, 12 volt source, ammeter, metric ruler, scales, etc.
- Classroom solenoids
- Examples of industrial solenoids (car ignition, heating/cooling valves, etc.)
- The Force of a Solenoid Student Worksheet
- Access to Internet
  - <http://www.howstuffworks.com/electromagnet.htm>
  - <http://www.wpiinstruments.com/Solenoids/theory.htm>
- Science Rubric

## **THE FORCE OF A SOLENOID**

### **Student Worksheet**

**Design a test to determine the strength of the electromagnetic force of a solenoid. Your team must consider the possible variables that make a difference in the operation of a solenoid and then limit your preliminary test to only one variable. Figure out:**

- **How to test the strength...**
  - **What are the variables that make a difference?**
  - **What is the impact of the combinations of different variables?**
  - **What are the classroom design constraints?**
  - **What are the limitations to these kinds of investigations?**
- **How to record and analyze the important data...**
  - **What is the important variable you will test?**
  - **How can you measure it?**
  - **What needs to be shown on your data table?**
- **How to display a visualization of your plan...**
- **What materials and equipment you will need...**
  - **What safety precautions need to be handled?**
  - **What preparation, operation and clean-up procedures apply?**
- **Which scientific principles or laws apply to how the solenoid works?**
- **How do solenoids in the real world work?**
  - **What factors or variables are affected in your solenoid application?**
  - **How?**
  - **What applicable mathematical specifications are involved?**

**Record the necessary procedural steps and the associated safety precautions:**

**Data table with appropriate factors and units identified:**

## SCIENCE RUBRIC

Exceeds - must receive no more than one 3 and the rest 4s in the other areas of the rubric.

Meets - may receive no more than one 2 and a combination of 3s and 4s in the other areas of the rubric.

Approaches - may receive no more than one 1 and a combination of 2s, 3s or 4s, in the other areas of the rubric.

Begins - must receive at least a 1 in all 3 areas of the rubric.

	<b>KNOWLEDGE</b>	<b>APPLICATION</b>	<b>COMMUNICATION</b>
	Knows and understands scientific terms, facts, concepts, principles, theories and methods.	Applies scientific knowledge, skills and methods to manipulate, analyze, synthesize, create and evaluate.	Communicates scientific knowledge and applications through writing, speech and visual displays.
<b>4</b>	<ul style="list-style-type: none"> <li>• Descriptions of scientific terms, facts, concepts, principles, theories and methods are complete and correct.</li> </ul>	<ul style="list-style-type: none"> <li>• Applications are thorough, appropriate and accurate.</li> </ul>	<ul style="list-style-type: none"> <li>• Written, oral and/or visual communication is well organized and effective.</li> </ul>
<b>3</b>	<ul style="list-style-type: none"> <li>• Descriptions of scientific terms, facts, concepts, principles, theories and methods are mostly complete and correct.</li> </ul>	<ul style="list-style-type: none"> <li>• Applications are mostly thorough, appropriate and accurate.</li> </ul>	<ul style="list-style-type: none"> <li>• Most of the written, oral and/or visual communication is well organized and effective.</li> </ul>
<b>2</b>	<ul style="list-style-type: none"> <li>• Descriptions of scientific terms, facts, concepts, principles, theories and methods are somewhat complete and correct.</li> </ul>	<ul style="list-style-type: none"> <li>• Applications are somewhat appropriate and accurate.</li> </ul>	<ul style="list-style-type: none"> <li>• Some of the written, oral and/or visual communication is organized and effective.</li> </ul>
<b>1</b>	<ul style="list-style-type: none"> <li>• Descriptions of scientific terms, facts, concepts, principles, theories and methods are minimally present or correct.</li> </ul>	<ul style="list-style-type: none"> <li>• Applications are minimally appropriate and accurate.</li> </ul>	<ul style="list-style-type: none"> <li>• Little of the written, oral and/or visual communication is organized and effective.</li> </ul>
<b>0</b>	<ul style="list-style-type: none"> <li>• All descriptions of scientific terms, facts, concepts, principles, theories and methods are missing and/or incorrect.</li> </ul>	<ul style="list-style-type: none"> <li>• All applications are missing and/or incorrect.</li> </ul>	<ul style="list-style-type: none"> <li>• All of the written, oral or visual communication is missing and/or lacks organization.</li> </ul>
<b>Score</b>			