Pulley

Introduction
This Kid Spark lesson is designed to introduce students to one of the six simple machines: the pulley. Students will become familiar with how a pulley works by learning key information about pulleys, building and modifying a pulley teaching model, and then designing and engineering a custom pulley system to solve a challenge.

Click here to explore the entire Kid Spark Curriculum Library.

NGSS Learning Dimensions
This Kid Spark lesson engages students in the following learning dimensions of the Next Generation Science Standards:

Scientific/Engineering Practice:
Planning and carrying out investigations

Crosscutting Concept:
Cause and effect: Mechanism and explanation

Learning Objectives

- Understand the basic elements of a pulley.
- Understand how a pulley redirects motion and creates mechanical advantage.
- Calculate the mechanical advantage in a pulley system.
- Modify a pulley system to increase mechanical advantage.
- Design and engineer a custom pulley system.

Learning Steps
This lesson will use the following steps to help students learn about the pulley.

1. Learn
   - Elements of a pulley
   - Purpose of a pulley system
   - Real-world applications
   - Creating mechanical advantage with pulleys

2. Build & Modify
   - Build a fixed pulley system
   - Build a movable pulley system
   - Modify a pulley system from 2:1 to 3:1 mechanical advantage

3. Design & Engineer
   - Design & engineer a custom pulley system to solve a challenge

Activity Time: 180 Minutes
Target Grade Level: 6-8

Educational Standards

NGSS
3-5-ETS1-4 Engineering Design
MS-ETS1-4 Engineering Design

ITEEA
STL8- Attributes of Design
STL9- Engineering Design
STL10- Invention and Innovation
STL11- Apply Design Process

STEM Concepts Covered

- Force
- Effort
- Load
- Work
- Motion
- Distance
- Simple Machines
- Mechanical Advantage
- Prototyping
- Critical Thinking
- Multiplication
- Division
- Units of Measurement

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Levels of Learning

<table>
<thead>
<tr>
<th>Lower Level: Content Knowledge</th>
<th>Middle Level: Skills and Application</th>
<th>Higher Level: Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identify:</strong> Elements of a pulley system</td>
<td><strong>Design:</strong> A custom pulley system that creates mechanical advantage</td>
<td><strong>Describe:</strong> How pulleys create mechanical advantage</td>
</tr>
<tr>
<td><strong>Research:</strong> Real world applications of pulleys</td>
<td></td>
<td><strong>Recognize:</strong> How much mechanical advantage is in a pulley system</td>
</tr>
<tr>
<td><strong>List:</strong> Two purposes of a pulley</td>
<td></td>
<td><strong>Understand:</strong> How simple machines work and how to use them to solve problems</td>
</tr>
</tbody>
</table>

Resources

The following resources will be used to complete this lesson.

1. **Kid Spark STEM-Maker Curriculum**
   - Pulley
     - a. Teacher Lesson Plan
     - b. Curriculum Packet (1 per team)
     - c. Student Engineering Workbook (1 per team)

2. **Kid Spark Mobile STEM Lab (Pictured Right)**

Prerequisite Knowledge

Before participating in this activity, students should have a basic understanding of the following concepts:

1. How to use step-by-step graphic instructions to assemble a design.
2. How to use the metric system.
3. Using basic multiplication and division skills to solve a problem.
4. Fundamental communication skills including reading and writing.
5. How to use the design and engineering process to solve a problem.

Assessment

Students will be graded on the following for this lesson.

1. **Student Engineering Workbook** (Written Worksheet- 23 Points)
2. **Design & Engineering Challenge** (Performance Assessment/Rubric- 30 Points)
Procedure
Complete the following steps to teach students about the pulley. Teaching time will vary depending on grade level. Younger students may require more time to understand certain concepts. Instructor should thoroughly review content in curriculum packet prior to class instruction.

1. Grouping
Create differentiated groups before class, with students arranged in teams of up to four per module.

2. Disperse Materials (5 Minutes)
Provide teams with correct Kid Spark Mobile STEM Lab, curriculum packet, and student engineering workbook. Instruct students to fill out appropriate information in student engineering workbook as they progress through the lesson.

3. Review Learning Objectives (2 Minutes)
Review learning objectives with students.
(Curriculum Packet - Page 1)

4. Review Key Terms (10 Minutes)
Instruct students to review key terms in curriculum packet and write definitions in student engineering workbook.
(Curriculum Packet - Page 1)
(Student Engineering Workbook - Page 1)

5. Present Content (15 Minutes)
Instructor and students work together to learn about the pulley. (elements, purpose, real-world examples). Students should fill out appropriate information in student engineering workbook.
(Curriculum Packet - Page 3)
(Student Engineering Workbook - Page 2)

   Tip: Instructor should review content on page 3 in the pulley curriculum packet to prepare for lesson.

6. Build Model (15 Minutes)
Teams will follow step-by-step graphic instructions to assemble a Pulley System.
(Curriculum Packet - Pages 4-6)
(Student Engineering Workbook - Page 2)

   Tip: It is highly recommended for instructor to build and understand teaching model prior to instruction.

7. Test Pulley System (10 Minutes)
Review both sides of pulley system with students (fixed and movable).
(Curriculum Packet - Page 7)
(Student Engineering Workbook - Page 3)

   Tip: Start out reviewing the fixed pulley system. Demonstrate how the two equal weights balance each other out. Next, test the movable pulley system. Point out to students that the two weights are of equal mass, even though they look slightly different. Ask students why they think Weight 1 (Effort) is able to raise Weight 2 (Load), even though they are the same mass.
8. Understanding Mechanical Advantage (15 Minutes)
Work with students to make calculations of mechanical advantage on teaching models.
(Curriculum Packet - Page 8)
(Student Engineering Workbook - Page 3)

Tip: The movable pulley system is creating mechanical advantage by trading increased distance for reduced effort. Point out to students how Weight 1 (Effort) is traveling a total distance of 10 blocks (20cm), while Weight 2 (Load) is being raised a total of 5 blocks (10cm). This demonstrates how using a pulley system with a movable pulley can make work easier by creating mechanical advantage.

9. Modify Pulley Model (15 Minutes)
Challenge students to modify movable pulley system from 2:1 to 3:1 mechanical advantage.
(Curriculum Packet - Page 8)
(Student Engineering Workbook - Page 3)

Tip: Students may struggle on this step. Ask them to review the formula for movable pulley systems. The current pulley system is 2:1 in which two strings are connected to the movable pulley. To increase the mechanical advantage to 3:1 then there should be three strings connected to the movable pulley. If necessary, show students an image of a 3:1 pulley system (pictured right). After they have it correctly modified, have them observe the distance the effort travels compared to the load. The effort should now travel three times the distance of the load. (3:1 mechanical advantage).

10. Design & Engineering Challenge (60 Minutes)
Review design brief challenge and specifications with students. Instruct students to work through the Kid Spark Design & Engineering process to develop, test, refine, and explain a working prototype. Teams will present their designs to the rest of the class.
(Curriculum Packet - Pages 9-10)
(Student Engineering Workbook - Pages 4-5)

Tip: Briefly review the Kid Spark Design and Engineering process with students.

Tip: Have teams hand in completed student engineering workbooks while they are presenting. Use the challenge grading rubric on page 5 in the student engineering workbook to evaluate team projects.
11. Cleanup (10 Minutes)
Instruct students to disassemble all builds and correctly pack all components back in labs.

12. Lesson Review (5 Minutes)
Use the last five minutes of class to review the lesson.

Guiding Questions:
1. What are the two purposes of a pulley?

2. How does a pulley system create mechanical advantage?
Team Members:

1. ____________________  3. ____________________
2. ____________________  4. ____________________

Total Points

- Workbook: ........... /23 pts
- Challenge: ........... /30 pts

Key Terms
Write the definitions of each key term in the space provided.

1. Simple Machine: A device that transmits or modifies force or motion.

2. Pulley:  A simple machine consisting of a wheel with a grooved rim in which a pulled cable can change the direction of the pull and thereby lift a load.

3. Mechanical Advantage: The amount a machine multiplies force.

4. Force: A push or a pull.

5. Work: Using a force to move an object a distance.

6. Effort: A force applied to a machine to do work.

7. Load: The object or weight being moved or lifted.
Elements of a Pulley
There are three basic elements in a pulley. Identify the correct element in the spaces provided.

Purpose of a Pulley
A pulley is used for two different purposes. Fill in each purpose in the blank below.
11. Fixed Pulley System: Redirect Motion
12. Movable Pulley System: Create Mechanical Advantage

Real World Application
Research some real world applications of pulleys. Write two examples, not found in the curriculum packet, in the spaces below.
13. Various Answers
14. Various Answers

Build and Modify
Place a check in the boxes below as the team completes each step.
15. Build Pulley System
16. Test/observe Fixed Pulley System
17. Test/observe Movable Pulley System
Understanding Mechanical Advantage
Fill in the blanks in the statements below.

18. Mechanical Advantage exists when the _____output______ force of a machine is _____greater_______ than the _____input______ force that was applied to it.

19. For a machine to create mechanical advantage, it must trade increased time or _____distance_____ for reduced effort.

Calculating Mechanical Advantage
Use the formulas for calculating mechanical advantage to solve the problems below.

20. In Example 1, if the effort travels 40cm and the load travels 20cm, what is the mechanical advantage?

\[
\text{Mechanical Advantage: } \frac{\text{Distance of Effort}}{\text{Distance of Load}} = \frac{40\text{cm}}{20\text{cm}} = 2:1
\]

21. Determine the mechanical advantage of the pulley system in example 2.

\[
\text{Mechanical Advantage: } \frac{\text{Effort}}{\text{Load}} = \text{# of strings connected to movable pulley}
\]

Modify Pulley System
Place a check in the box below as the team completes each step.

22. \(\times\) Modify Movable Pulley System from 2:1 to 3:1 Mechanical Advantage.

23. \(\times\) Teacher confirms modification is correct.
Design & Engineering Challenge

Follow each step in the design & engineering process to develop a solution to the challenge. Place a check in the box as each step is completed. Fill in the blanks when necessary.

1. Identify The Challenge
   - Challenge: Design & engineer a pulley system to raise a go-cart
   - Sub-Challenge: Pulley system must lift cart at least 18 cm off ground
   - Sub-Challenge: Pulley system must be able to carefully lower cart
   - Sub-Challenge: Build a locking pin to secure cable in place
   - Sub-Challenge: Pulley system must create mechanical advantage
   - Review specifications.

2. Brainstorm Ideas & Solutions
   - Discuss design ideas.
   - Consider building components and cost.

3. Build A Prototype
   - Build a working prototype of the design.

4. Test & Improve The Design
   - Test & improve the design for performance and consistency.
   - New challenge discovered: Various new challenges discovered during testing
   - Review grading rubric and design specifications.
   - Consider ways to reduce cost.

5. Explain The Design
   - Prepare to demonstrate and present the design to others.
   - Review project grading rubric.
   - Explain any unique design features that were included.
   - Describe at least one new problem/challenge discovered during Step 4 (Test and Improve The Design) and how the team redesigned a new solution.
Challenge Evaluation
When teams have completed the design & engineering challenge, it should be presented to the teacher and classmates for evaluation. Teams will be graded on the following criteria:

- **Specifications**: Does the design meet all specifications as stated in the design brief?
- **Performance**: How well does the design work? Does it function consistently?
- **Team Collaboration**: How well did the team work together? Can each student describe how they contributed?
- **Design Quality/Aesthetics**: Is the design of high quality? Is it structurally strong, attractive, and well proportioned?
- **Material Cost**: What was the total cost of the design? Was the team able to stay on or under budget?
- **Presentation**: How well did the team communicate all aspects of the design to others?

### Grading Rubric

<table>
<thead>
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<th></th>
<th>Advanced (5 Points)</th>
<th>Proficient (4 Points)</th>
<th>Partially Proficient (3 Points)</th>
<th>Not Proficient (0 Points)</th>
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</thead>
<tbody>
<tr>
<td>Specifications</td>
<td>Meets all specifications</td>
<td>Meets most specifications</td>
<td>Meets some specifications</td>
<td>Does not meet specifications</td>
</tr>
<tr>
<td>Performance</td>
<td>Design performs consistently well</td>
<td>Design performs well often</td>
<td>Design is partially functional</td>
<td>Design does not work</td>
</tr>
<tr>
<td>Team Collaboration</td>
<td>Every member of team contributed</td>
<td>Most members of team contributed</td>
<td>Some members of team contributed</td>
<td>Team did not work together</td>
</tr>
<tr>
<td>Design Quality/Aesthetics</td>
<td>Great design/aesthetics</td>
<td>Good design/aesthetics</td>
<td>Average design/aesthetics</td>
<td>Poor design/aesthetics</td>
</tr>
<tr>
<td>Material Cost</td>
<td>On Budget ($120 or Less)</td>
<td>Slightly Over Budget ($120-130)</td>
<td>Over Budget ($130-140)</td>
<td>Significantly Over Budget ($141+)</td>
</tr>
<tr>
<td>Presentation</td>
<td>Great presentation/well explained</td>
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<tr>
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