The Maker's Journey:
Powering Progress

OVERVIEW

This unit immerses students in the history of 19th-century manufacturing and guides them through the modern Engineering Design Process as they build, test, and refine model water wheels. Move through the unit sections at a pace that works for you. The planning, prototyping, and testing of the water wheels may take multiple classroom periods.

UNIT OUTLINE

Introduction & Energy Transfer	**Overview:** Understand the origin of water-powered factories and identify energy pathways. 1. Interactive slideshow on Robbins & Lawrence Armory 2. Energy Types & Energy Transfer Mapping a. Students label diagrams showing water's potential energy flowing into paddles, shaft, and lifted weight b. Students explore their environment for examples of different energy types and energy transfers in action. 3. Energy Transfer Card game Activity
Engineering Design Process Introduction	**Overview:** Learn about and practice the steps of the engineering design process. 1. Engineering Design Process Slideshow 2. Present the Water Wheel Challenge 3. In small groups, students begin planning process 4. Class discussion: What are the variables you can control for in the water wheel design? a. Size of paddles b. Number of paddles c. Angle of paddles d. Depth of paddles e. Alignment of paddles f. Speed of the release of ceramic beads.
Prototyping & Testing	**Overview:** Construct & test prototypes and collect comparison performance data. 1. Choose a design and build. 2. Focus on:

	a. strong connections – any slipping and unwanted movements of paddles indicates energy losses. b. Frequent testing
Final Build & Share Out	**Overview:** How long you spend on prototyping before the final build and testing is up to you. Allow all students an opportunity to reflect on and share about their process and what they learned.

HANDOUTS & SUPPORT DOCUMENTS

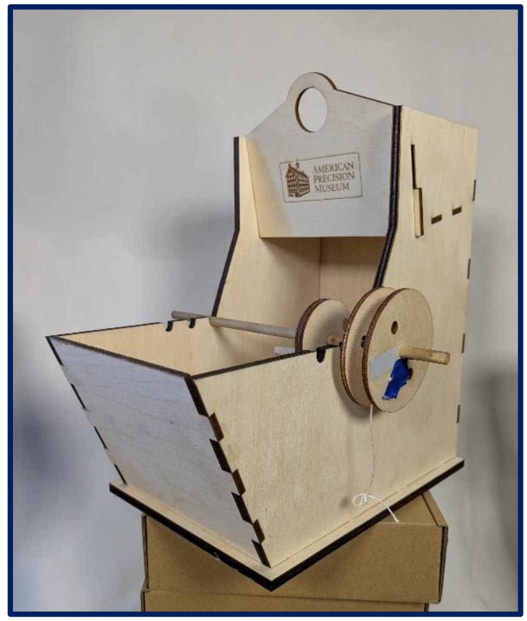
SECTIONS	TEACHER MATERIALS	STUDENT MATERIALS
INTRODUCTION & ENERGY TRANSFER	1. Powering Progress Introduction & History Slideshow 2. *Follow the Energy* Answer Key 3. *Sample Energy Transfer Categories*	1. *Follow the Energy* worksheet 2. *Energy Type Scavenger Hunt* cut-out cards 3. *Energy Transfer Scavenger Hunt* worksheet 4. Energy Transfer Card Game cards & handout
ENGINEERING DESIGN PROCESS INTRODUCTION	1. Engineering Design Slideshow	1. *Engineering Design Process* handout 2. *Water Wheel Planning Guide*
PROTOTYPING & TESTING	1. Water Wheel Troubleshooting Guide 2. Extra building supplies *(optional. feel free to use other materials in the water wheel designs)*	1. Individual Water Wheel building material boxes 2. **From classroom supplies**: Scissors, hole-punches, pencils, rulers, tape
FINAL BUILD & SHARE OUT	1. Water Wheel Challenge Rubric	

Kit Materials

Classroom Set (per 20-24 students)	QTY		Individual Boxes	QTY
Water Wheel Wooden Hooper	3		Wheels, cardboard	4
Ceramic Beads, 5lb container	1		Slats, cardboard	8
Ruler, 18”	3		Straw, paper	2
			Chipboard, white	4
Water Wheel Components Box			Chipboard, brown	4
Measuring Cup	3		Index card, color	4
Pulley	3		Binder clip	2
Ruler Stand	3		Tape, mini masking	1
Weight	3			
Axle, large wheel	3		**Extra Water Wheel Material Box**	
Axle, small wheel	3		Wheels, cardboard	10
String	1		Slats, cardboard	40
			Cardboard, thin sheets	25
Energy Transfer Card Set Box			Chipboard	25
Energy type Card Set	5		Straw, paper	bag
Object Card Set	5		Tape, masking	2
			Hole punch	1

WATER WHEEL SET-UP

Each water wheel hopper/base has 2 axles for attaching the student water wheel designs. Each axle needs a string attached that will reach from the table or desk where the water wheel is mounted down to the floor. The wooden wheels on each axle are surrounded by wooden guides to keep the string in place. There is a hole in each guide to thread the strings through and attach to the outside of the guide with tape. The other end of the string is tied to the hook on the weight.



Instead of water, each hopper uses white ceramic beads. This makes it easier to do multiple tests and fair tests as it allows you to use the same amount of beads (energy input) each time. One measuring cup full of beads will fit into the hopper. *Make sure the door is all the way down before adding the beads to the hopper*.

To measure how efficiently their designs use the energy from the falling beads to do work, students will measure how far off the ground the weight on the end of the strings is lifted each time. Start with 20g of weight on the string. Work = Force x distance. With a consistent force, a change in distance demonstrates more work being done. And by keeping the input (amount of beads) the same, a greater lift indicates a more efficient transfer of energy.

The individual boxes contain supplies for students to make at least 2 different prototypes. You do not need to be constrained by the materials in the boxes, especially for the final build designs. You may offer more classroom supplies and allow students to bring in their own supplies.

Tips & Tricks for prototyping:

1. To start: With 2 wheels together, push the slats through both wheels. Then slowly pull the wheels apart while keeping the slats in both wheels. Using a surface to stand the slats on and push the bottom wheel down is effective.
2. Straws can be used for building and bracing the water wheels. Hole-punch the cardboard wheels and the straw fits snuggly in the holes, providing a way to securely connect the wheels and attach the paddles.
3. Make sure students are changing one thing at a time between testing so they can say if that variable affects the efficiency of their design.
4. For the final design, you may want to use hot glue. The tape is good for prototyping but more securely fastening paddles for the final design may improve efficiency.

Unit Outline

Introduction & Energy Transfer	**1.** Introduction: Use the Lesson 1 Slideshow to share the history of the **American Precision Museum** and introduce the unit. The American Precision Museum (APM) originally opened as the Robbins & Lawrence Armory in 1846. The innovations that happened at APM helped launch a new era of manufacturing and defined a system that became known of the American System of Manufacturing. Hydropower was an essential element to the growth of industry. Many towns were formed along rivers to power the mills and factories. Energy comes in many forms and can be transformed from one type into another. The water wheel used the gravitational potential energy of the water behind the dam to power the machinery in the factory. The second to last slide prompts the use of the *Follow the Energy* worksheet. **Follow the Energy**. Hand out the worksheets and have students work in small groups to label the water wheel diagram and connect each of the 4 elements to the correct type of energy. The last slide introduces the concept of Energy Transfer and the scavenger hunt activities **2. Energy Scavenger Hunts**. The final slide leads to a discussion about energy. Then, students will explore their classroom/environment and find examples of different types of energy. First, students cut out the *Energy Type Scavenger Hunt Cards* and place them where they find each type. **a.** Could they find them all? **b.** Are some more common than others? Building on the Energy Type Scavenger Hunt and discussion, students next look for examples of energy transfer in action. Hand out the Energy Scavenger Hunt worksheet. If students need help getting started, a great place to begin is anything with a plug! Electrical energy is the input but what is the output? **Use the *Sample Energy Transfer Categories* Teacher guide for other prompts as needed.** **3.** Play the **Energy Transfer Game**

	Play in groups of 3 or 4. Each group gets one set of Energy Cards and one set of Object Cards. Use the *Energy Transfer Game* handout to explain the game set-up and rules. There are blank object cards so students can come up with their own objects to signify other energy transfers. ***Read through the game directions first so you can clearly explain the rules to the students.*** Reference: **APM** water wheel background
Engineering Design Process Introduction	**1.** Introduction to Engineering Design: Use the **Engineering Design and Manufacturing Slideshow** to introduce the lesson. Pass out the *Engineering Design Process* handouts for the students *The engineering design process is a creative, step-by-step way to solve problems and build solutions—just like real engineers do! Whether you're designing a water wheel, building a bridge, or inventing a new kind of game, this process helps you think critically, test ideas, and improve your work.* *Here's how it works:* • *Identify the problem: What problem are we trying to solve?* • *Build Understanding: Brainstorm lots of ideas—wild ones welcome!* • *Plan: Choose your best idea and sketch out a plan.* • *Prototype & Test: Build a prototype or model.* • *Adjust: Try it out, see what works, and make it better.* *It's not about getting it perfect the first time, it's about learning, experimenting, and improving. Every mistake is a clue, and every redesign brings you closer to a great solution.* The slideshow goes through the steps that the students will follow for the Water Wheel Challenge. There are also 2 examples of what the process looks like in action. **2.** Introduce the Water Wheel Challenge: For this challenge, the students will take on the roles of engineers and fabricators as they design and build multiple iterations of their water wheel models. Each student will make their own design but planning and evaluation between tests should be done in small groups.

	In this unit, you'll step into the shoes of 19th-century engineers who transformed rivers into power sources for factories. Just like them, you'll use the ***Engineering Design Process*** *to solve a real-world challenge:* ***Can you design a water wheel that lifts a weight as efficiently as possible?*** *Engineers follow a series of steps to turn ideas into working solutions:* • ***Identify the Problem:*** *What's the challenge? What are the limits (materials, time, goals)?* • ***Build Understanding:*** *Brainstorm water wheel designs—how will paddles, axles, and pulleys work together?* • ***Plan:*** *Sketch your best idea, list materials, and outline build steps.* • ***Prototype & Test:*** *Build your prototype and test how well it lifts a weight.* • ***Adjust & Test again:*** *Use data and observations to tweak your design and try again.* *Your water wheel will show how energy transfers from flowing water to rotating paddles, lifting weights—and how small design changes can make a big difference. You'll measure work, calculate efficiency, and reflect on how engineers balance creativity, constraints, and trade-offs.*
Prototyping & Testing	**Overview:** As students construct and test prototypes, it is helpful to limit the initial build times to 15 minutes or so. Stress that they should not be focused on making a perfect model to start, but you want to see them getting to test as quickly as possible. After the first build time, gather the whole class together for a discussion of what worked, what didn't, and emphasis learning from each other to move the process along as quickly and efficiently as possible. Encourage each student to share what they have done so far, what they think they will do next, and any things they have learned that may help others.
Final Build & Share Out	**Overview:** Engineering is all about the constraints we put on ourselves and the project. And time is usually the most restrictive and influential over what our final designs look like! Allowing students to bring in other materials or using hot glue and other more permanent adhesives for the final designs, will lengthen the amount of time you may what to spend building. A minimum of 2 class periods for building is needed, and others are often needed depending on your student's interest and the amount of time you have available.

VOCABULARY

Energy Transfer	Movement of energy from one system or object to another
Water Wheel	A machine that converts the energy of flowing water into rotational motion
Pulley	A simple machine that changes the direction of a force and can lift loads
Axle	A rod or spindle that passes through the center of a wheel
Iteration	The process of repeating and improving a design
Efficiency	A measure of how well energy is converted into useful work
Prototype	An early model built to test a concept or process
Design Process	Steps engineers follow to solve problems and create solutions
Constraints	Limitations or restrictions in a design challenge (e.g., time, materials)
Output	The measurable result of a system, such as lift height in this challenge