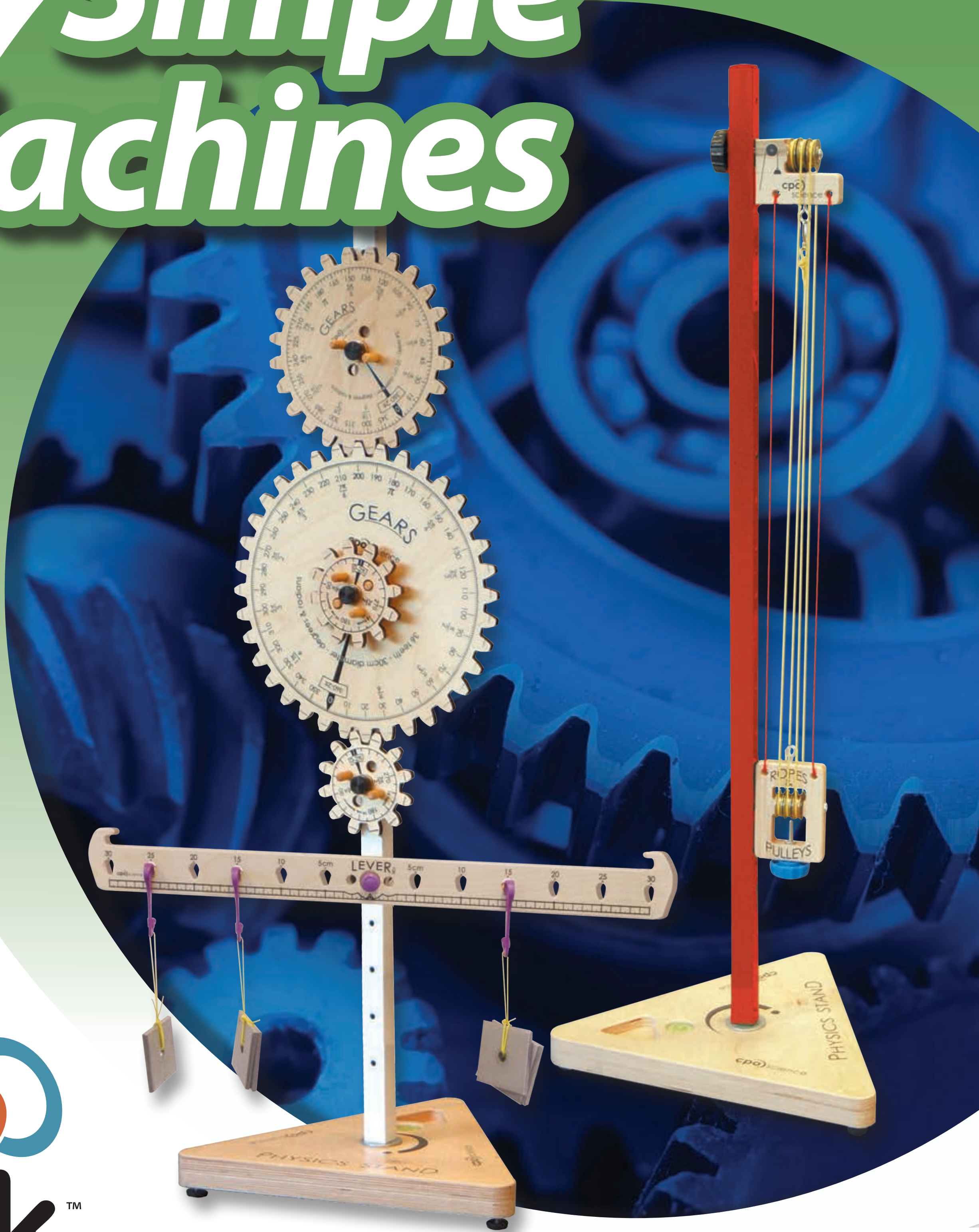
Work and Energy

Simple Machines



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CPO Science

Real Investigations in Science and Engineering

Overview Chart for Investigations–Simple Machines

	Investigation	Key Question	Summary	Learning Goals	Vocabulary
A1	**Ropes and Pulleys** Pages 1–8 50 minutes	How can ropes and pulleys be used to lift large weights with small forces?	Students define force, identify input and output forces in a simple machine, and discover how a rope-and-pulley machine can multiply force.	• Develop an understanding of force and how it can be measured. • Identify input and output force on a simple machine. • Discover how a simple machine can be used to multiply force.	force gravity input force newton output force rope-and-pulley system simple machine weight
A2	**What Is Work?** Pages 9–16 50 minutes	How can a simple machine multiply forces?	Students measure the length of string that they must pull in order to lift the bottom block a certain height when using one or more pulleys. Students learn the scientific definition of work, calculate input and output work in their rope-and-pulley system, and discover that output work cannot exceed input work.	• Discover the relationship between the number of pulleys utilized in a simple machine and the distance the string is pulled to lift the load. • Define work as force (newtons) multiplied by distance (meters). • Calculate and compare input work and output work in a rope-and-pulley machine. • Explain why output work can never exceed input work.	friction input distance input work joule output distance output work work
A3	**The Lever** Pages 17–24 50 minutes	How does a lever work?	Students work together to balance levers using various combinations of weights placed at different distances from the fulcrum. Through this process, they discover the relationship between the input arm, input force, output arm, and output force.	• Describe how a lever works. • Identify the relationship between input force, output force, input arm, and output arm on a lever. • Learn the difference between speed and acceleration.	fulcrum input arm lever output arm
A4	**Levers and the Human Body** Pages 25–32 50 minutes	How does the human arm work?	Students explore how the human arm acts as a lever. They learn how to find the mechanical advantage of a lever, and discover that the lever system in the human arm has a mechanical advantage of less than 1.	• Define *mechanical advantage*. • Explain the relationship between lever arm length and mechanical advantage. • Show how the arm acts as a lever with a mechanical advantage of less than 1.	mechanical advantage
A5	**Gears** Pages 33–38 50 minutes	How do gears work?	This investigation introduces students to gears and gear ratios. Students work with pairs of gears and determine the rule that relates the number of turns of one gear to the number of turns of another.	• Discover the relationship between number of teeth on a pair of gears and the number of turns each gear will make. • Express gear ratios in different forms.	gear gear ratio input gear output gear

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	Investigation	Key Question	Summary	Learning Goals	Vocabulary
A6	**Gear Machines** Pages 39–44 50 minutes	How can you build machines with higher gear ratios?	Students discover that placing a third gear between a pair of gears does not change the original gear ratio. Next, students experiment with stacking two gears on a single axle, creating an inner pair of gears and an outer pair of gears. Finally, they build their own complex gear machine and find its gear ratio.	• Build compound gear machines. • Calculate gear ratios for compound machines.	compound gear machine
A7	**Designing Gear Machines** Pages 45-52 100-150 minutes	How can you design machines with different gear ratios?	Students begin with a simple number theory exercise to determine which gear ratios are possible using the CPO gears. Next, they design their own gear machines using mathematical principles. Finally, they build and test their own gear machine that will launch a ping pong ball.	• Use number theory to determine which gear ratios are possible using CPO gears. • Design and test a compound gear machine. • Use the engineering cycle to design a ping pong ball launcher using CPO gears.	criteria constraints engineering cycle prototype
B1	**Forces in Machines** Pages 53–60 50 minutes	How do simple machines work?	Students build a simple machine using rope and pulleys. They measure the input force required to lift a weight as the number of pulleys over which the string passes is increased. Students develop a mathematical rule based on their observations. Finally, students learn to calculate the mechanical advantage of their simple machine for each arrangement of the string.	• Identify input and output forces on a simple machine. • Measure input and output forces on a rope-and-pulley machine. • Calculate the mechanical advantage of the rope-and-pulley system with different arrangements of the string.	input force mechanical advantage output force rope-and-pulley system simple machine
B2	**Work and Energy** Pages 61–68 50 minutes	What happens when you multiply forces in a machine?	Students will measure input and output distance as well as input and output force for various arrangements of the rope-and-pulley system. They use their data to calculate input and output work for the machine.	• Calculate the amount of work done by simple machines. • Analyze the effect of changing force or distance in a simple machine. • Describe the relationship between work and energy.	energy friction input distance input work joule kinetic energy output distance output work potential energy work

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	Investigation	Key Question	Summary	Learning Goals	Vocabulary
B3	**Levers, Torque, and Mechanical Advantage** Pages 69–78 100 minutes	How do levers work?	Students learn to calculate torque for levers with multiple forces on the input and/or output side. Next, they learn how to apply the concept of mechanical advantage to the lever, and distinguish between theoretical and actual mechanical advantage. They learn about the three classes of levers and construct a model of each one.	• Build and test three types of levers. • Define and calculate torque for each arm of a lever. • Develop a rule relating input force, output force, input length, and output length. • Define and calculate theoretical and actual mechanical advantage for each class of lever.	first-class lever fulcrum input arm lever output arm second-class lever third-class lever torque
B4	**Gears and Rotating Motion** Pages 79–84 50 minutes	How do simple gear machines work?	Students are introduced to simple gear machines. They learn to measure input and output rotation using degrees and radians. They build gear machines with input and output gears of various sizes. As they measure and record input and output gear rotation, students discover the relationship between number of teeth and number of turns of the gears. This relationship is known as the law of gearing.	• Practice using rotations, degrees, and radians to measure rotational motion. • Demonstrate the law of gearing.	angle degree gear law of gearing radian rotation
B5	**Compound Gear Machines** Pages 85–94 150 minutes	How can you evaluate the performance of a gear machine?	Students learn to evaluate the performance of a gear machine by calculating the mechanical advantage and the gear ratio. They build compound gear machines and calculate the gear ratios. Next, they design and test their own gear machines.	• Explain how mechanical advantage and gear ratios are used to evaluate gear machines. • Design and test a compound gear machine. • Use the engineering cycle to design a Rube Goldberg-type device using a minimum of three different simple machines.	criteria compound gear machine constraints engineering cycle gear ratio prototype
B6	**Machines with Gears and Levers** Pages 95–100 50 minutes	How does a bicycle work?	In this investigation, students explore combinations of gears and levers to help them understand how a bicycle works. They build machines using two gears and two levers, and develop a mathematical rule for making the two levers balance.	• Build complex machines with gears and levers. • State the rule that relates force, distance, and number of teeth on a gear for their machines. • Explain the value of multiple gears on a bicycle.	crankset freewheel

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	Investigation	Key Question	Summary	Learning Goals	Vocabulary
C1	**Simple and Complex Pulley Systems** Pages 101–110 100 minutes	How can different types of pulley systems be used to move objects?	Students review the three classes of levers and compare them with three types of pulley systems. They build each type of pulley system and calculate its ideal and actual mechanical advantage. They learn to use a pulley system in an unconventional manner to increase output distance without increasing input distance.	• Construct and test various types of pulley systems. • Calculate the ideal and actual mechanical advantage of various types of pulley systems. • Evaluate the types of tasks that each type of pulley system can accomplish.	actual mechanical advantage ideal mechanical advantage of a lever ideal mechanical advantage of a rope-and-pulley system
C2	**Rotational Motion** Pages 111–118 50 minutes	How is the speed of a rotating object measured?	Students use a timer and photogates to measure the angular speed of a rotating gear. They practice expressing angular speed in rotations, degrees, and radians per unit time. Next, they find the formula for linear speed of a rotating object and calculate the linear speed of two different points on the gear.	• Measure angular speed and express the speed in rotations, degrees, and radians per unit time. • Calculate linear speed of a point on a rotating object. • Describe the relationship between angular and linear speed of a rotating object.	angular speed linear speed pitch circumference
C3	**Center of Gravity and Equilibrium** Pages 119–126 50 minutes	How can the weight of a lever be determined using the principle of rotational equilibrium?	Students use their understanding of rotational equilibrium to solve a problem. They identify forces contributing to clockwise and counterclockwise torque in the lever. Next, they write an equation relating clockwise and counterclockwise torque that will allow them to solve for the weight of the lever.	• Find a lever's center of gravity. • Set up a lever so that rotational equilibrium is achieved. • Access prior knowledge about calculating torque to find the weight of a lever. • Compare the calculated weight with the lever's weight found experimentally.	center of gravity equilibrium rotational equilibrium torque

Next Generation Science Standards Correlation

CPO Science *Link* investigations are designed for successful implementation of the Next Generation Science Standards. The following chart shows the NGSS Performance Expectations and dimensions that align to the investigations in this title.

NGSS Performance Expectations	Simple Machines Investigations
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.	A1, A3, A4
MS-PS3-5. Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.	A2, C2
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	A5, A6, A7, C1
HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.	B1, B2, B3, B4, B5, B6
HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	C3

NGSS Science and Engineering Practices	Simple Machines Investigations
Constructing Explanations and Designing Solutions	B1, B2, B3, B4, B5, B6, C1
Developing and Using Models	A1, A3, A4
Engaging in Argument from Evidence	A2, A5, A6, A7, C2
Using Mathematics and Computational Thinking	C3

NGSS Disciplinary Core Ideas	Simple Machines Investigations
ETS1.A: Defining and Delimiting an Engineering Problem	B1, B2, B3, B4, B5, B6
ETS1.B: Developing Possible Solutions	A5, A6, A7
ETS1.C: Optimizing the Design Solution	C1
PS2.B: Types of Interactions	C3
PS3.A: Definitions of Energy	A1, A3, A4, B1, B2, B3, B4, B5, B6
PS3.B: Conservation of Energy and Energy Transfer	A2, C2
PS3.C: Relationship Between Energy and Forces	A1, A3, A4

NGSS Crosscutting Concepts	Simple Machines Investigations
Systems and System Models	A1, A3, A4, A5, A6, A7
Energy and Matter	A2, B1, B2, B3, B4, B5, B6, C1, C2
Patterns	C3

Common Core State Standards Correlation

CCSS-Mathematics		Simple Machines Investigations
MP.2	Reason abstractly and quantitatively.	A2, A5, A6, A7, C3
MP.4	Model with mathematics.	B1, B2, B3, B4, B5, B6, C1, C2, C3
RP.A.2	Recognize and represent proportional relationships between quantities.	A2, A3, A4, A5, A6, A7
7.EE.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.	A5, A6, A7
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.	B1, B2, B3, B4, B5, B6, C1, C2, C3
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling.	B1, B2, B3, B4, B5, B6
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	B1, B2, B3, B4, B5, B6, C3
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context.	C1, C2, C3
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.	C3

CCSS-English Language Arts & Literacy		Simple Machines Investigations
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.	A1, A3, A4
RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.	A2, A5, A6, A7
WHST.6-8.1	Write arguments focused on discipline content.	A2
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	A5, A6, A7
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research.	A5, A6, A7
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.	B1, B2, B3, B4, B5, B6