

POM - 3

CE - 2 (apply)

Lesson 1: Circuit of Inquiries – A Pre-assessment

Focus Questions: What do you know about energy and about forces?

Students perform eight exploratory activities, using items such as hand warmers, pulleys, levers, and ramps. They observe phenomena, suggest explanations and reasons for their observations, and relate what they observe to their own experiences.

Energy is the ability to cause change in objects and systems. It is not an object itself, but an object or a substance may be in a particular energetic state. Energy comes in many forms, including chemical, mechanical (potential and kinetic), and electromagnetic (electrical, light, and thermal). Energy is said to be *transferred* when systems interact or “do things” to each other. Energy is *transformed* when, during a transfer of energy, it changes from one kind of energy to another. During the transfer or transformation of energy, if one form of energy decreases, there is an increase in the other. *Energy is conserved in nature.*

Lesson 2: Making a Battery

Focus Questions: How do you make a battery? How do you know a battery works?

Students build a zinc-copper primary cell and observe that chemical reactions occur in the cell and that the cell produces enough electrical energy to light a small light bulb. They see evidence that the cell contains a limited amount of energy, which can be used up.

- 1.1 **Properties of Systems:** Energy Sources and Kinds
- 1.2 **Structure of Systems:** Systems, Energy Transfer and Transformation, Structure of Matter
- 1.3 **Changes in Systems:** Physical and Chemical Changes

Lesson 3: Rechargeable Batteries

Focus Questions: What evidence do we have that energy is stored in a battery? How can we change the amount of energy stored in a battery?

Students recharge a battery and learn about stored energy. They observe that the energy of the battery can be converted to different forms of energy, such as light, heat, and kinetic energy (energy of motion).

- AAAS ATLAS:
- Flow of Matter and Energy:** Flow of Energy in Ecosystems (p. 79)
- Energy Transformation:** Conservation of Energy Systems (p. 133)

Lesson 4: Storing and Using Energy in a Battery

Focus Question: How does charging time affect the stored energy in a rechargeable battery?

Students recharge batteries for different lengths of time and use them to light a flashlight. They use stopwatches to measure the time the flashlight bulb remains lit for the respective periods of battery-charging time.

There are many types of forces. Three that are investigated and measured include tension (elastic), gravitational, and friction. When objects stretch, bend, or change motion, forces are acting on them. An understanding of forces will help us understand the energy of motion. *Forces* are a push or a pull that arise out of the interaction between two objects.

Lesson 5: Introduction to Forces

Focus Questions: What is a force? How are mass and weight (force of gravity) related?

Students determine that the elastic force of a rubber band depends on the amount of stretch of the rubber band and that the weight of an object depends on its mass. They learn how to calibrate a measuring tool (a spring scale).

- 1.1 **Properties of Systems:** Motion of Objects, Energy Sources and Kinds
- 1.2 **Structure of Systems:** Systems, Energy Transfer and Transformation
- 1.3 **Changes in Systems:** Nature of Forces, Forces to Explain Motion

Lesson 6: The Force of Friction

Focus Question: What are the factors that affect the force of friction? How is pulling force related to the force of friction (when pulling at a steady speed)?

Students investigate how the force of sliding friction on a wooden block depends on the weight of an object as well as the kind of surface across which the block slides. They investigate the relationship of sliding friction to the surface area of the block.

- AAAS ATLAS:
- The Universe:** Gravity (p. 43)
- Motion:** Laws of Motion (p. 63)

Stored chemical energy of a battery can be transformed into electrical energy in a complete circuit. This electrical energy can be transformed into mechanical energy when a motor turns, exerting a force that allows a motor to overcome the force of gravity and lift a load. Energy and forces come together in describing work. *Work* is the ability to do something that would cause a change in an object, a substance or system. The motor lifting an object is an example of work. In order for work to be done, a force must be exerted through a distance. *Power* is a measure of the rate at which work is done or at which energy transformations take place.

Lesson 7: The Force Exerted by a Motor

Focus Question: What are the operating conditions that produce the maximum force from a motor?

Students design an experiment to determine which combination of variables will produce the maximum force from a small electric motor: number of batteries, how the batteries are connected, and how a string is attached. They determine what operating conditions yield the maximum load the motor can lift.

- 1.1 **Properties of Systems:** Energy Sources and Kinds
- 1.2 **Structure of Systems:** Systems, Energy Transfer and Transformation
- 1.3 **Changes in Systems:** Nature of Forces

Lesson 8: Work and the Motor

Focus Question: What is the relationship between forces applied and the work that is done?

Students are introduced to the scientific meaning of work by calculating the work done by a small electric motor when it lifts different loads. They build a sled with K'NEX™ pieces and try to lift it with a motor using the optimum lifting conditions identified in the previous lesson. They discover that even under the optimum conditions, the motor will not lift the sled, thus setting the stage for learning about the advantages of using machines to do a task.

- AAAS ATLAS:
- Flow of Matter and Energy:** Flow of Energy in Ecosystems (p. 79)
- Energy Transformation:** Conservation of Energy Systems (p. 133)
- Motion:** Laws of Motion (p. 63)

Lesson 9: Power of a Motor

Focus Question: How do scientists describe the term power?

Students learn how to calculate the power of a small electric motor. They then determine the relationship between the number of batteries connected in series and the power output of the motor as it lifts a load a standard distance.

Lesson 10: Assessing What You Know

Focus Question: What energy changes allow a falling body to light a bulb?

Students use equipment from previous lessons to investigate energy changes when washers (attached to the motor shaft by a string) fall, causing a small light bulb attached to the motor to light. They analyze a set of data and draw conclusions based on their data analyses. Students complete a series of higher-level thinking questions that address concepts covered in the energy unit.

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Machines are devices that make work easier. Work is done when a force is exerted over a distance. A machine makes tasks easier by reducing the exerted force (but increases the exerted distance and the amount of time exerting the force), changing the direction of the exerted force, or both. A *simple machine* is a device that does work with only one movement. When the small electrical motor was unable to lift a sled in lesson 8, the motor was working against gravity. The use of simple machines such as an inclined plane, a pulley, or a lever enables you to overcome gravitational resistance.

HBS - 3 (apply)

Lesson 11: The Inclined Plane
Focus Questions: What is a machine? Why is an inclined plane a machine?
 Students turn a K'NEX™ sled into a cart by adding wheels to it to observe how the friction is reduced. They pull the cart up an incline and measure the force needed to pull it at a steady rate. They design a procedure to determine how the angle of the incline affects the force needed to pull the cart up the incline. Students lift the cart a given vertical height and measure the effort force and effort distance needed to raise the sled the same height each time. They construct a definition of the term "machine."

1.2 **Structure of Systems:** Systems
 1.3 **Changes in Systems:** Nature of Forces

Lesson 12: The Pulley
Focus Questions: How do pulleys work? Why are pulleys machines?
 Students construct a pulley assembly system to lift a K'NEX™ sled a given distance, then use different pulley combinations, and ultimately determine the effort force and effort distance required to lift the load with each pulley assembly system. They refine their definitions of "machine" on the basis of what they've learned in this lesson.

Lesson 13: The Lever
Focus Questions: How do levers work? Why are levers machines?
 Students explore how to position weights (washers) to balance a given load placed on the arm of a lever. They make data tables and look for patterns in their data to determine a rule for how to balance a given load with a set number of washers. They investigate the relationship between effort force and effort distance with respect to the lever, and use their data to decide whether or not the lever functions as a machine.

AAAS ATLAS:
Systems (p. 133)
Motion: Laws of Motion (p. 63)

Two forces are involved when a machine is used to do work. The force applied *to* the machine is called the **effort force**. The force applied *by* the machine to overcome resistance due to gravity or friction is called the **resistance force**. You can never get more work out of a machine than you put in. The *mechanical advantage* of a machine is the number of times a machine multiplies the effort force (the force applied to it). Mechanical advantage can be calculated and compared.

Lesson 14: The Mechanical Advantage of Machines
Focus Questions: What is the difference between ideal and actual mechanical advantage? How are ideal and actual mechanical advantage calculated?
 Students use data from the three previous lessons to calculate and compare the mechanical advantages of the machines they have used.

1.2 **Structure of Systems:** Systems
 1.3 **Changes in Systems:** Nature of Forces

Lesson 15: The Efficiency of Machines
Focus Questions: What is machine efficiency? How is machine efficiency calculated?
 Students use data from three previous lessons to calculate and compare the efficiencies of the machines they have used.

AAAS ATLAS:
Systems (p. 133)

Lesson 16: Machines Assessment: A Technological Design Challenge
Focus Question: How can simple machines concepts (forces, work, and mechanical advantage) be used to enable a small motor to lift a load?
 Students use what they have learned about machines to design a system that will enable a small motor to lift a K'NEX™ sled. They work in teams to design a motor-and-machine combination that will lift the sled 0.10-meter. They who lift the sled through this distance using only these materials successfully complete the challenge.

Conceptual Story: STC/MS ENERGY, MACHINES, & MOTION

Applied Uses of Forces and Energy Transformations: Forces are required to do work in all parts of our daily lives. For every force that we employ to do work, it requires energy inputs and transformations.

Lesson 17: Introduction to the Anchor Activity

Focus Question: How are machines and energy transformations utilized in everyday devices?

Students select or build a device they use in their everyday life and investigate how it works; identifying the forces that make the device work and the energy changes that take place when it is used. They research its design and find out when it was invented (or explain how they built their own device) and how it meets human needs. Students design one change that would improve or expand the functioning of the device. They are expected to use a variety of research tools, for example textbooks, the library, the Internet, and CD-ROMs. They develop and present a working model of their modified device.

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| <p>1.1 Properties of Systems: Energy Sources and Kinds</p> <p>1.2 Structure of Systems: Systems; Energy Transfer and Transformation</p> <p>1.3 Changes in Systems: Nature of Forces</p> | <p>AAAS ATLAS: Systems (p. 133)</p> <p>Energy Transformations: Conservation of Energy (draft map)</p> |
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Lesson 22: The Anchor Activity

Focus Question: Why is sharing knowledge an important part of the scientific process?

Students present their investigations of the devices they selected during the "Introduction to the Anchor Activity." They apply what they have learned to a new situation, and share what they have learned with their classmates.

Forces to Explain Motion: Changes in motion occurs when an unbalanced force is exerted on an object. For constant motion, speed is the distance traveled in one second. What happens to an object's speed depends on the forces acting on the object. An object moving in a straight line will change its speed if an unbalanced force acts on it (i.e., fan car, mousetrap car). For a given object the greater the unbalanced force, the greater increase (or decrease) in speed over each interval. If an object is moving at a constant speed in a straight line, the forces acting on it are balanced). If an object is not moving, the forces acting on it are balanced. Gravitational potential energy is transformed into kinetic energy when a roller coaster moves down its track. The roller coaster changes motion over the course of its run due to unbalanced forces associated with friction and gravity.

Lesson 18: Motion of a Fan Car

Focus Questions: What is motion? What causes motion? What is speed and how is it calculated?

Students build a K'NEX™ fan car with a battery-powered fan attached. They investigate how constant unbalanced forces affect the motion of the fan car, and they learn to calculate speed using distance and time measurements. Students observe and describe the motion of the car with the fan turned off and then on. They discuss the forces on the car and begin to relate its motion to the forces identified.

- 1.1 Properties of Systems:** Motion of Objects; Energy Sources and Kinds
1.2 Structure of Systems: Systems; Energy Transfer and Transformation
1.3 Changes in Systems: Nature of Forces; Forces to Explain Motion

Lesson 19: Motion of a Mousetrap Car

Focus Questions: How does the size of the force affect the motion of an object? How does the duration of the force affect the motion of an object?

Students measure and observe the non-constant force exerted by a mousetrap car. They describe the energy changes in the car and the forces on it. Students quantify their observations by measuring distance and time to determine the speed of the car at different points along a track.

Lesson 20: The Roller Coaster

Focus Question: Why is teamwork a valued aspect of scientific investigation?

Students work cooperatively as a class towards a goal: building a 3-meter-long roller coaster with K'NEX™ pieces. They will use the roller coaster to study the effect of gravity on the motion of a roller coaster car, which they also put together.

- AAAS ATLAS: Motion:** Laws of Motion
Energy Transformation: Conservation of Energy (draft)

Lesson 21: Motion on a Roller Coaster

Focus Question: What energy transformations occur as a car moves along the track of a roller coaster?

Students investigate changing speed that results from the forces of gravity and friction. They learn about gravitational potential energy and observe how it changes to kinetic energy as the roller coaster car moves up and down the hills of the roller coaster. They measure the car's speed at different points along the roller coaster track.