

# Module Overview

Daily life provides students with many experiences—for example, riding in cars, participating in sports activities, doing household chores—through which they can see evidence of forces and energy changes as well as the use of machines to make work easier. In *Energy, Machines, and Motion*, students investigate energy and the different forms it can take, how forces do work to change energy from one form to another, how machines reduce the effort force needed to do work, and how forces change the motion of objects. By engaging in inquiries that provide opportunities to explore these relationships and concepts, students begin constructing a knowledge base of their own. Reading selections reinforce these concepts by focusing on such diverse applications as battery-powered devices, cars, sports, engineering, and amusement park rides.

Each lesson builds on skills and concepts presented in previous lessons. As students progress through the module, they take greater responsibility for their own learning, eventually planning and conducting their own procedures, devising their own data tables, and analyzing the results they obtain. Therefore, the module should be taught as a complete unit. It should not be used as a sourcebook of occasional experiments.

The module's 22 lessons are organized in three parts—Part 1: Energy, Part 2: Machines, and Part 3: Motion. Each part offers a series of inquiries that develop the concepts and physical principles related to its overall theme. A conceptual outline for *Energy, Machines, and Motion* appears on page xxix.

## **PART 1 ENERGY**

Part 1 of the module, consisting of Lessons 1 through 10, focuses on energy, the nature of various forces, and the work done when forces

act on an object. Part 1 begins with a preassessment for the entire module: Lesson 1 introduces students to the kinds of materials they will use and the types of activities they will be engaged in throughout the module. During this lesson, students perform eight short activities in which they observe phenomena, suggest explanations and reasons for their observations, and relate what they observe to their own experiences. As students perform the activities, the teacher can assess the knowledge they bring to the classroom and the misconceptions they may have.

In Lessons 2 through 4, students investigate energy in batteries and how that energy can be converted to other useful forms. In Lesson 2, they 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 lightbulb. They also see evidence that the cell contains a limited amount of energy, which can be used up.

In Lesson 3, students work with a rechargeable alkaline battery and learn how to charge the battery and store energy in it. They observe that the energy of the battery can be converted to different forms of energy, such as light and mechanical energy. In Lesson 4, students investigate how the amount of energy stored in a rechargeable battery is related to the amount of time it is charged. Students charge two D-cell rechargeable alkaline batteries for different lengths of time and use them to light a flashlight. Using stopwatches, students measure the time the flashlight bulb remains lit for the respective periods of battery-charging time. Lesson 4 also serves as a model for experimental design and data analysis, skills that students will develop and refine as they progress through the module.

Lessons 5 and 6 introduce students to several different forces and the nature of each. In

Lesson 5, they 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 also learn how to calibrate a measuring tool, in this case a spring scale.

Lesson 6 has three inquiries on the nature of sliding friction. In the first inquiry, students investigate how the force of sliding friction on a wooden block depends on the kind of surface across which the block slides. In the second inquiry, they find out that the force of sliding friction also depends on the weight of the object, and in the third inquiry they investigate the relationship of the force of sliding friction to the surface area of the block that is in contact with the surface. Emphasizing the collaborative nature of much scientific effort, this lesson is designed to allow students to research strategies as a class as they carry out some of their investigations. For example, in the second inquiry, students investigate the relationship of weight to frictional force on different surfaces.

In Lesson 7, students design and execute an experiment to determine which combination of variables will produce the maximum force from a small electric motor. Specifically, they investigate how the number of batteries and the way they are connected affect the load a motor can lift. They also investigate how the way a piece of string is attached to the motor shaft affects the load the motor can lift. Students will use the information they learn from Lesson 7 about force and the motor during Lessons 8 through 10 and in the technological design challenge in Lesson 16.

Lesson 8 introduces students to the scientific meaning of work. They calculate the work done by the small electric motor when it lifts different loads. Students build a sled with K'NEX™ pieces and try to lift it with the motor using the optimum lifting conditions identified in Lesson 7.

They find that even under the optimum conditions, the motor will not lift the sled. This activity sets the stage for students to learn about the advantages of using machines to do a task.

Lesson 9 is a brief lesson on power in which students learn how to calculate the power of the small electric motor. They then determine the relationship between the number of batteries connected in a series and the power output of the motor as it lifts a load a standard distance.

Lesson 10 is an assessment for the first part of the module. The assessment has three components. The first is a performance component in which students use equipment from previous lessons to investigate energy changes when washers attached to the motor shaft by a string fall and light a small lightbulb attached to the motor. In the second component, students analyze a set of data and draw conclusions based on their analysis of the data. The third component is a set of multiple-choice and short-answer questions.

## **PART 2 MACHINES**

Part 2, consisting of Lessons 11 through 16, focuses on how simple machines work. In this part of the module, students investigate the inclined plane, the pulley, and the lever. They apply what they have learned about work, force, and distance to develop an understanding of how simple machines make work easier by reducing the effort force needed to do work. They determine the mechanical advantage and the efficiencies of the machines they study. Part 2 culminates with a technological design challenge in which students apply what they have learned about motors and machines.

Part 2 begins with two inquiries in Lesson 11. Students first turn the K'NEX™ sled they assembled in Lesson 8 into a cart by adding wheels to it to observe how the friction is

reduced. They pull the cart up the incline and measure the force needed to pull it at a steady rate. They then design a procedure to determine how the angle of the incline affects the force needed to pull the cart up the incline. In the second inquiry, 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. To reinforce what they observed, students are asked to construct a definition of the term “machine.”

In Lesson 12, students work with pulleys. They construct a pulley assembly system to lift the K'NEX™ sled a given distance, then use different pulley combinations and determine the effort force and effort distance required to lift the load with each pulley assembly system. Students then refine their definitions of “machine” on the basis of what they learned in Lesson 12.

Lesson 13 provides a third set of investigations into the nature of machines. In the first of two inquires in the lesson, 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. In the second inquiry, students again investigate the relationship between effort force and effort distance—this time with respect to the lever—and use their data to decide whether or not the lever functions as a machine.

Lessons 14 and 15 introduce mechanical advantage and efficiency of machines. Students use data from Lessons 11 through 13 to calculate and compare the mechanical advantage and the efficiencies of the machines they have used.

In Lesson 16, the assessment for Part 2, students are asked to use what they have learned about machines to design a system that will

enable the small motor to lift the K'NEX™ sled. Students work in teams to design a motor-and-machine combination that will lift the sled 0.10 meter. When students have lifted the sled through this distance using only these materials, they have successfully completed the challenge.

### **PART 3 MOTION**

In Part 3, consisting of Lessons 17 through 22, students are first introduced to the extended research project that they will carry out. The next four lessons then concentrate on motion—on how unbalanced forces affect the motion of objects. In these four lessons, students build three different types of cars and study their motion when various forces act on them. During the final lesson of the module, students present the results of their research projects to the class.

Part 3 opens with Lesson 17, which introduces the Anchor Activity, a research project that takes place over several weeks and that culminates in Lesson 22 with student presentations. The Anchor Activity is designed to link the different conceptual threads of the module by having students investigate a device they use in their daily lives. Students select (or build) an appropriate device 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. They are also asked to design one change that would improve or expand the functioning of the device. In addition to traditional textbook and library resources, students are expected to use a variety of resource tools, including electronic resources such as the Internet and CD-ROMs. Students develop and present a working model of their modified device.

In Lesson 18, students build a fan car—a K'NEX™ car with a battery-powered fan attached. During the lesson, they investigate how constant unbalanced forces affect the motion of the fan car, and they learn to calculate speed using distance and time measurements. In the first inquiry, they observe and describe the motion of the car with the fan turned off. They then describe the force they feel while holding the car with the fan turned on and predict the car's motion when it is released on the floor with the fan on. Then they test their prediction. Students discuss the forces on the car and begin to relate its motion to the forces they identified. In the second inquiry, students measure the speed of the fan car as it moves along the floor with the fan on.

Lesson 19 continues the study of forces and motion with a mousetrap-powered K'NEX™ car that students build. Students measure and observe the nonconstant force exerted by the mousetrap. They set the trap by winding a string attached to it around the axle of the car; they observe the motion of the car when the trap is released. Students are asked to describe the energy changes in the car and the forces on it. This activity gives them an opportunity to use their knowledge of stored energy, energy transformations, and frictional forces to describe the motion. They quantify their observations by measuring distance and time to

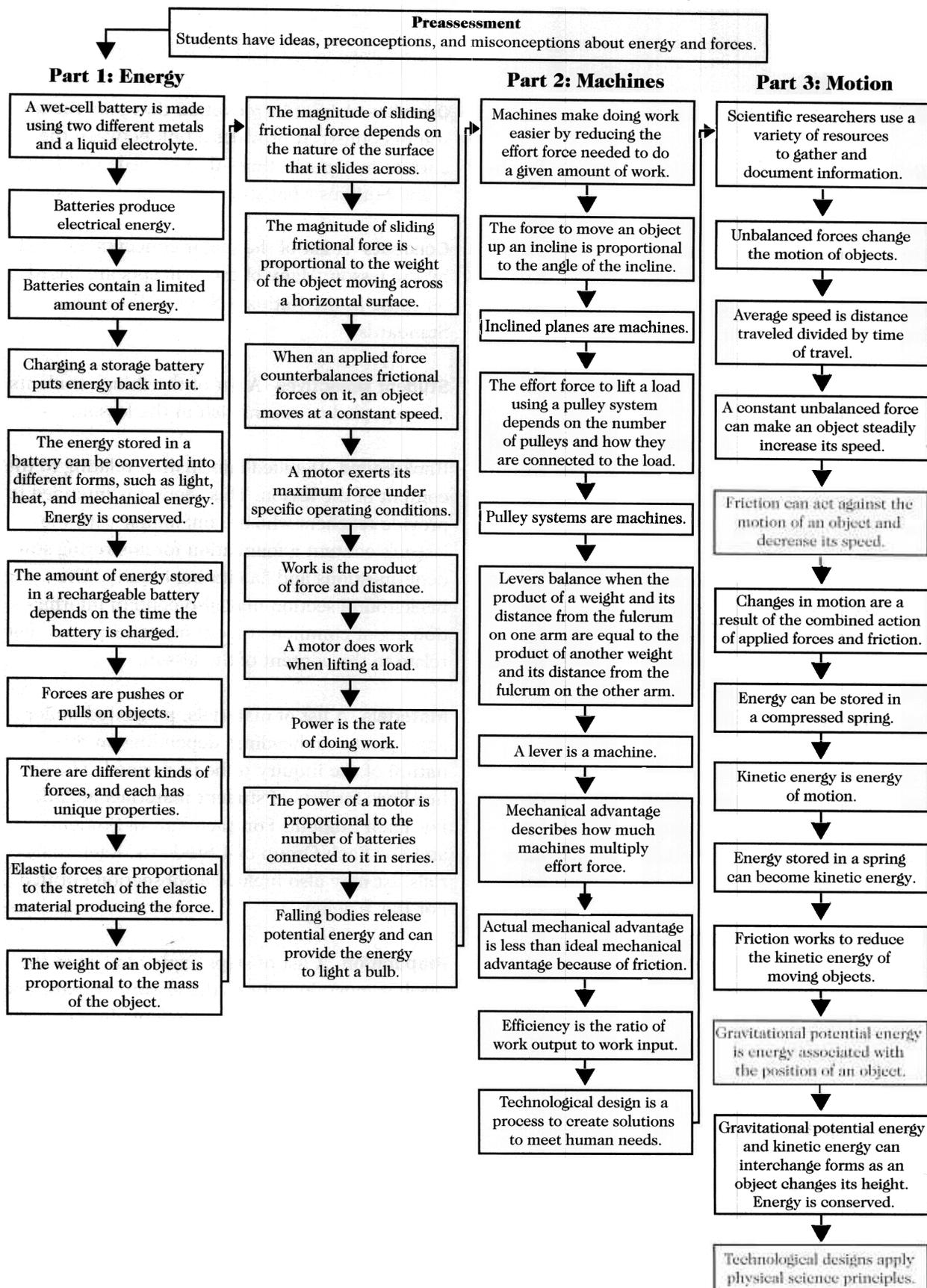
determine the speed of the car at different points along a track.

In Lesson 20, students work as class to build a 3-meter-long roller coaster with K'NEX™ pieces to study the effect of gravity on the motion of a roller coaster car, which they also put together. They use this roller coaster in Lesson 21 to investigate changing speed that results from the forces of gravity and friction. This lesson gives students an opportunity to work cooperatively toward a goal.

In Lesson 21, the last lesson on motion, students 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. In addition, students measure the car's speed at different points along the roller coaster track. By this lesson, students should be skilled in observing and describing motion and in using the language of energy and energy transformations. They recognize that energy is transferred in many ways—one of the central concepts of the module.

Lesson 22 concludes *Energy, Machines, and Motion* as students present their investigations of the devices they selected in Lesson 17 for the Anchor Activity. This lesson gives students an opportunity to apply what they have learned to a new situation and to share what they have learned with their classmates.

# Conceptual Sequence for *Energy, Machines, and Motion*



## Module Structure

*Energy, Machines, and Motion* includes a Teacher's Guide, a Student Guide, and a materials and equipment kit. Following are brief descriptions of the major components in the Teacher's Guide and in the Student Guide. The master list of materials and equipment for the module begins on page xxxviii.

### TEACHER'S GUIDE

The Teacher's Guide for *Energy, Machines, and Motion* includes 22 lessons. The shortest lesson can be completed in one 45-minute class period, and the longest takes three periods. Lessons may be taught in 45-minute class periods or in back-to-back periods to accommodate block scheduling. Block scheduling requires less time for materials management and allows more time for class discussion and work on the extensions. For lessons that are more than 45 minutes long, suggestions for appropriate breaking points may be given.

The Teacher's Guide contains general information on teaching the module. It includes information about the science concepts that apply to each lesson, materials and their management, assessments, homework assignments, and extension activities. It also contains information about the Anchor Activity, a major research project that students begin in Lesson 17 and continue to work on through the rest of the module.

The following components appear in each lesson of the Teacher's Guide:

#### Lesson Number and Title

#### Number of Inquiries and Periods in the Lesson

One period is assumed to be 45 minutes.

**Overview** A brief introduction that puts the lesson in context. It provides a link between the current lesson and those that precede and follow it and outlines what students do in the lesson.

**Concepts** A list of the major concepts covered by the lesson. Many of the concepts are based on those in the National Science Education Standards.

**Student Objectives** A list of the things students are expected to accomplish in the lesson.

**Background** Detailed information relating to the content of the lesson. This section is intended to provide teachers who are unfamiliar with the lesson's content a foundation for answering student questions and facilitating inquiry. The Background section may also contain information about common student misconceptions that relate to the content of the lesson.

**Materials** A list of materials, presented under appropriate subheadings depending on the nature of the inquiry to be performed. The subheadings for lists of student materials include For Each Student, For Each Pair of Students, and For Each Group of 4 Students. Each materials list may also include a subsection entitled For the Teacher.

**Preparation** A list of steps explaining what the teacher must do prior to the lesson. Preparation may include photocopying student sheets, preparing transparencies or newsprint, collecting additional items of equipment not included in the kit, preparing solutions, assembling lab equipment, or setting up audiovisual equipment. It is assumed that the teacher will refill containers of chemicals and replace other consumables when necessary.

**Getting Started** A brief exercise or activity that introduces students to or provides the context for the lesson. In some cases, they first brainstorm what they already know about the topic. This encourages students to begin thinking about the topic of the lesson and allows the teacher to assess their pre-existing ideas.

**Inquiry Number and Title** Lessons may contain more than one inquiry. Each inquiry has its own number, title, and procedure.

**Procedure** A step-by-step guide for facilitating the inquiry. This section provides a carefully planned route through the lesson and complements the Procedure in the Student Guide.

**Reflections** A list of steps presenting guidance on how to provide closure for the lesson. Students may be asked to reflect on their inquiry results and discuss how the concepts encountered in the lesson can be applied to situations outside the classroom.

**Homework** Homework assignments that relate to either the current or the next lesson. Many of the assignments involve the reading selections that appear in the Student Guide. Additional homework can be assigned from the extensions (see below).

**Extensions** Activities designed to extend students' experience of the topic into other fields of science and other content areas. These activities provide the opportunity for science teachers to collaborate with colleagues from other content areas to ensure a more integrated curriculum.

**Assessment** A section that suggests methods for assessing students for each lesson. Teachers may wish to assign point values in keeping with

their customary grading schemes. When a lesson itself is designed as an assessment, scoring rubrics are provided.

**Preparation for [a subsequent lesson]** Brief mention of preparation and/or materials needed for an upcoming inquiry when they must be prepared by the teacher in advance. It is suggested that teachers check materials requirements before each lesson is to be taught.

**Inquiry Masters** Reproducible sheets that include keys to the types of answers students may give in response to questions posed in an inquiry, transparency masters, suggested data tables and graphs, and scoring rubrics. These are generally for teacher use only. (See Appendix A for a complete list of inquiry masters.)

**Student Sheets** Reproducible worksheets that students use to record their ideas and interpret their data and to answer questions about the concepts covered in the inquiries. Student sheets may also be used for homework assignments, reviews, and assessments. Many lessons have at least one student sheet; some have several. Masters for these sheets appear at the end of each lesson in the Teacher's Guide. Teachers must photocopy sufficient quantities of them before each lesson. (See Appendix A for a complete list of student sheets.)

## STUDENT GUIDE

The Student Guide is intended to be used in conjunction with the Teacher's Guide. The components in the Student Guide complement those in the Teacher's Guide. For example, both guides contain lists of student objectives, but the wording may differ slightly between the two volumes, as appropriate for teachers and for students. The materials lists are less detailed in

the Student Guide than in the Teacher’s Guide. Some sections are unique to each guide; for example, Homework and Extensions are not included in the Student Guide, while reading selections do not appear in the Teacher’s Guide. The two volumes are designed to be complementary, and the teacher needs both guides to facilitate inquiry.

Each lesson in the Student Guide contains the following sections:

#### **Lesson Number and Title**

**Introduction** A brief section of text that places the concepts included in the lesson in context with those that have preceded it and with the students’ own experiences. It may also provide a brief preview of the lesson. Some introductions include background information to draw students into the topic to be investigated.

**Objectives for This Lesson** A list that outlines what the students are expected to accomplish by the end of the lesson.

**Materials** A list that specifies the size of the group in which the students will be working as well as the materials they will require.

**Getting Started** A brief exercise or activity that introduces students to the topic of the lesson. It may include a brainstorming session on what students already know about the topic or a series of questions or experiences that form the basis for a brief group or class discussion.

#### **Number and Title of Inquiry**

**Procedure** Step-by-step instructions that students follow to complete an inquiry or to explore the concepts of a lesson more fully. This section often contains questions that students discuss in their groups.

**Reflecting on What You’ve Done** A closing section that provides students an opportunity to think about and discuss what they have learned in the lesson and to begin to apply what they have learned to new situations.

**Reading Selections** Readers—frequently accompanied by photographs and illustrations—that pertain to the content of the module or, more specifically, to that of a lesson. Most lessons in this module have one or more reading selections. A reading selection may provide background information that helps apply the concepts addressed in the lesson or it may introduce additional concepts from other areas of the National Science Education Standards. Most reading selections develop these concepts in the context of the world outside the laboratory. They are also intended to increase students’ awareness of the history of science and technology.