IS1 Grade Four Instructional Segment 1: Car Crashes

In earlier grades, students developed models for how objects push or pull against one another, but grade four is the first time that students encounter the abstract concept of energy and the flow of energy within systems. In IS1, students explore energy transfer in a visual, tangible form: collisions.

GRADE FOUR INSTRUCTIONAL SEGMENT 1: CAR CRASHES

Guiding Questions

- Why do car crashes cause so much damage?
- What happens to energy when objects collide?

Performance Expectations

Students who demonstrate understanding can do the following:

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object. [Clarification Statement: **Examples of evidence relating speed and energy could include change of shape on impact or other results of collisions (CA).**] [*Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.*]

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide. [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

California clarification statements that are bolded and followed by **CA** *were incorporated by the California Science Expert Review Panel.*

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering)	PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer PS3.C: Relationship Between Energy and Forces	[CCC-2] Cause and Effect: Mechanism and Explanation [CCC-4] Systems and System Models [CCC-5] Energy and Matter: Flows, Cycles, and Conservation

CA CCSS for ELA/Literacy Connections: RI.4.1, 3, 9; W.4.2 a–d, 7, 8, 9 a–b

CA ELD Standards Connections: ELD.PI.4.6a, 11a, 10a

Students begin their study of motion by exploring movements and collisions with a set of materials such as toy cars, marbles, ramps, and other objects. In this way, they can test out their existing mental models of motion. Teachers can challenge students to get their vehicle to move faster or explore what happens when it collides with various objects. Students begin to ask their own **questions [SEP-1]**, predict outcomes of different combinations of motion and collision, and then try them out. From this spirit of free exploration, students record as many observations and questions as possible in their science notebooks. They can return to these questions again and reframe them in terms of energy after they have a better understanding of the energy of motion.

Teachers can focus students back on a toy car sitting on a table. Why isn't it moving? What will it take to get it to move? Students have investigated forces in kindergarten and grade three, and know that they need to push or pull the car to get it to move. A person gives energy to the car when he or she applies a force to it. Scientists like to use the phrase "transfer energy" rather than "give" because it emphasizes **flow of energy [CCC-5]** in the **system [CCC-4]**, where energy gained by one object always comes at the loss of energy from somewhere else. People do not usually feel the effects of losing energy when they push a small toy car, but pushing a real car would be exhausting. Clearly people must transfer more energy to a full-size car to get it to move than pushing a toy car. But what is energy?

Energy is a term commonly used in everyday language, but the concept of energy in science has a specific meaning and teachers need to draw attention to these differences. In science textbooks, energy is often formally defined as "the ability to do work," but an informal way to think about energy is "the ability to injure you." Table 4.3 presents a list of many different ways that a child could get injured. While a different verb describes each process, they all have the same result. In the same way, scientists have different words to describe the different forms by which energy can manifest itself. Each example of an injury in table 4.3 correlates with a different form of energy that a person absorbs, which **causes [CCC-2]** damage to the person's body. Each of these energy forms can be transformed into another by different processes—an electric stove transforms electricity into heat, an electric fan transforms electricity into motion, and a windmill does the reverse by transforming motion into electricity. Students explore many of these energy conversion processes in IS2 while IS1 focuses on the energy from motion and energy transfer.

Table 4.3. Analogies Between Injuries and Different Forms of Energy

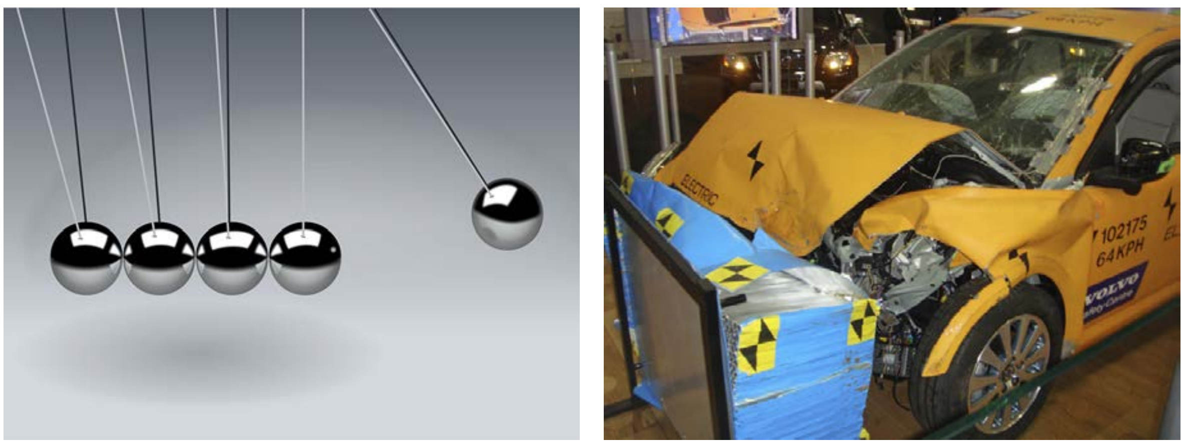
VERB PHRASE DESCRIBING AN INJURY	RELATED FORM OF ENERGY
Fell down	Gravity (gravitational potential energy)
Crashed into a wall on a bicycle	Energy of motion (kinetic energy)
Hit by a baseball	Energy of motion (kinetic energy)
Burned by touching a hot stove	Heat (thermal energy)
Electrocuted by touching an electrical outlet	Electricity (electrical energy)
Sunburnt	Light energy
Ruptured eardrums at a loud concert	Sound energy
Poisoned by accidentally drinking household cleaning products	Chemical energy (chemical potential energy)

In grade four, it is appropriate to use everyday language to describe common forms of energy (e.g., heat, electricity). In the middle grades and high school, students will label these concepts with more technical terms (shown in parentheses in the right-hand column).

Students next **plan and carry out energy investigations [SEP-3]** to explain the relationship between an object's speed and its energy. Students have an intuitive understanding of speed and can probably devise ways to measure it (e.g., the time it takes to travel a fixed distance), but energy is an abstract quantity. They need to compare the amount of energy, but in grade four the relative amounts are qualitative and not quantitative. In order to talk about amounts of energy, students also need to develop the idea that energy has **effects [CCC-2]**. Something with more energy has larger effects (e.g., does more damage when it hits a barrier or digs a bigger hole when it lands in a sand box). Which has more ability to cause damage, a moving car or a parked car? How about a car moving at five mph in a parking lot versus one traveling at 65 mph on the freeway? Students can explore the effect a rolling marble or toy car has when it hits a paper cup or another car. They can devise ways to increase or decrease the speed of their vehicle (e.g., roll it down ramps at different speeds) and then describe the effect on the paper cup (e.g., the distance the cup moved). Their measurements are evidence that they can use to **explain [SEP 6]** the relationship between an object's speed and its energy (4-PS3-1).

Students are now ready to ask more detailed questions about the effects of collisions in terms of energy and energy transfer. They can investigate what happens when different size cars collide (or tape together a stack of multiple identical cars to see the effect of a car with twice the mass) or the effects of adding a bumper of paper, clay, wood, or metal. They can compare these collisions with the collisions in a Newton's cradle where almost all the energy from one silver ball gets transferred to the other balls and a real car crash where some of the energy goes into deforming and squishing the car frame (figure 4.8). Their **investigations [SEP-3]** should be driven by student-generated **questions [SEP-1]**. Teachers can help students refine their questions in terms of energy transfer, for example: What determines the amount of energy in a collision? What determines the amount of energy that gets transferred during a collision? What happens to the energy in different types of collisions if it isn't transferred to the energy of motion? Where does the energy of motion go when a car crashes into a brick wall and stops? As they ask and refine each question, they can make and test specific predictions (4-PS3-3).

Figure 4.8. Energy Transfer During Collisions in a Newton's Cradle Versus a Car Crash



Source: Jarmoluk 2014; Duran Ortiz 2011
Long description of Figure 4.8.