Power Grid Reliability

LESSON OVERVIEW
In this lesson students will be introduced to the concept of inertia and will begin to understand the role that inertia plays in maintaining the reliability of the power grid. Students will listen to and read multimedia resources from *Inside Energy* and will then explore rotational inertia by building and playing with different types of tops/spinners. Finally, they will put all their learning together to design a reliable power source solution that minimizes coal usage. The lesson is organized using [the 5E Instructional Model](). While each section builds upon the previous, educators may find that they only need to use one or two sections to meet their teaching goals.

LEARNING OBJECTIVES
Students will:
- Explore the concept of inertia.
- Understand that inertia plays a role in power production and is important to the power grid.
- Connect the physics concept of Newton's first law of motion to the real-world case of the power grid.
- Apply an understanding of energy and force concepts to design a project that provides a solution to power production.

GRADE LEVELS: 6-8

KEY VOCABULARY/CONCEPTS
- Inertia
- Newton's First Law of Motion
- Energy
- Energy conservation
- Friction
- Power grid
- Fossil fuels
- Coal

CREDITS: Lesson developed by Tiffany Kapler. Multimedia developed by Inside Energy.

MULTIMEDIA RESOURCES
Keeping Lights On Key Issue In Coal Vs. Renewable Battle [5-minute audio]
IE Questions: What is Inertia? And What's Its Role in Grid Reliability? [Web Post]

SUGGESTED TIME: 3 days

- Day 1: Engagement and Exploration
- Day 2: Exploration and Explanation
- Day 3: Elaboration

MATERIALS

Per group:

- 3 cereal box weight cardboard cut into circles (~CD size)
- Extra cardboard for cutting additional shapes
- 4-6 sharpened pencils (golf pencils work well)
- 8-12 small rubber bands
- Pair scissors
- Black marker
- 12 pennies

LESSON PREP

Cut out cardboard circles and organize lab materials ahead of time.

THE LESSON

<table>
<tr><td>Engagement</td><td>Listen to the IE audio clip, <u>Keeping Lights On Key Issue In Coal Vs. Renewable Battle</u>

Discuss the following:
What are the benefits of coal power?
What are some of the reliability problems with clean energy sources (solar, wind)?
Who are some of the players who claim that the Clean Power Plan is a bad idea? Who are some of the Clean Power Plan proponents? Can you think of any motivations for the proponents? The opponents?
Power production has been slowly shifting away from coal power since the 1990's. Why are some people concerned about the Clean Power Plan now?
Given that coal power may be more reliable or predictable, from your previous understanding, why is there a push to move away from coal power?
What is one of the solutions proposed in the audio clip that would allow the power grid to move away from coal power AND provide reliable power?
Evaluate the discussion for current understanding as well as misconceptions. Use these points to focus and redirect during the Exploration and Explanation phases.</td></tr>
<tr><td>Exploration</td><td>Part of the reason that coal is reliable is that it can be (and is) stockpiled right next to the power plant. With the exception of coal shortages brought on by excessive demand and lack of coal transportation, as referenced in the audio clip, coal can be counted on to be present when needed. In addition to a generally ample supply, coal also contributes to inertia in the grid.

<u>Day 2:</u>

Have students read the IE Questions: What is Inertia? And What's Its Role in Grid Reliability? web post. Then allow students to explore rotational inertia by experimenting with "spinners" (homemade tops). As students experiment, encourage them to consider how the tops are similar to spinning turbines powered by coal</td></tr>
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	combustion in power plants* (or natural gas powered turbines, or wind powered turbines, etc.). ***Step 1:*** Build two spinners using two identical circular objects (container lids or cardboard cut into circles) and two pencils. 1. Poke the first pencil through the center of one of the circles. Don't go too far. You want a short tip and a long handle. Wrap a rubber band around the pencil on either side of the circle to hold it securely in place. 2. Build the second spinner in a similar fashion, but poke the pencil through *away* from the center of the circle. 3. Use a black marker to make a mark on both of the circles. 4. Spin the first top and using the black mark on the circle, count how many times it spins around within 10 seconds. Try this at least three times and record all three counts. 5. Repeat with the second top. Record any observations about the motion of this lop-sided top as compared to the first top. ***Step 2***: Build a third top like the first one (with the pencil poked through a center hole). 1. Add some weight to the two identical tops by taping 6 pennies to the circle. In the first top, tape the pennies in a small circle close to the pencil. In the other top, tape the pennies evenly around the outer edge of the circle. 2. Spin both of the tops and count the number of rotations in 10 seconds. Repeat at least 3 times for each top. Time the spinning to determine if one top remains spinning for longer than the other. 3. Record your results and compare the two tops. How are the results the same or different? ***Step 3***: Build tops of different shapes using cardboard. Try triangles, squares, etc. 1. Use the same basic top-building instructions from Step 1. 2. Test the different tops to see how long each shape continues to spin. Repeat at least three times and record your results. ***Step 4:*** If time permits, allow students time to experiment with additional variables (diameter, etc.) Teacher can use lab time to observe and converse with students to **evaluate** their understanding of inertia, as well as their understanding of their results. *If students are unfamiliar with how power plants use turbines to transform heat/kinetic energy into electricity, you may need to give them a general overview. Alternatively, pair this lesson with the Inside Energy lesson, "Wasted Heat into Power."
Explanation	In a class discussion and/or lab write-up students should be able to explain their results. Guiding questions and discussion prompts might include: • What is inertia? • Why do the tops continue spinning even after you let go of them? • If an object in motion tends to stay in motion unless acted upon by a force, why do the tops eventually stop spinning? What happens to the kinetic energy? • How are the tops similar to a fan-like turbine powered by steam in a coal combustion power plant or the fan-like turbine of a windmill? • If coal combustion suddenly stops in a coal power plant, how does the plant

	continue to produce power (at least for a little bit)? Would the same be true for other power sources? Which ones? Or why not? • Which factors appear to affect how long a top remains in motion? (Shape? Weight? Weight distribution? Center?) Could these results be transferred to engineering a turbine that remains in motion for the longest span of time? Why or why not? • Besides the factors explored here, what else might affect how long a turbine remains in motion after initial force is applied? What happens to the energy? *If students are unfamiliar with how a power plant works, it may be helpful to think of the turbine like a pinwheel or windmill.* • How is inertia important to keeping the power grid reliable? • Is coal the only way to have a reliable power grid? Teacher and students should **evaluate** student understanding of the concepts with a specific focus on inertia, energy, and power production.
Elaboration	Challenge students to design a power supply solution that reduces coal use (and ultimately, carbon emissions) while still providing reliability. Students should work in small groups and consider all of the information provided in the unit (multimedia resources and concepts learned in the ***Exploration*** phase). You may also encourage students to conduct additional library and/or internet research to further inform their design. While students will not actually construct their solutions, their designs should be complete and include appropriate diagrams and/or a prototype along with explanations of their choices. Possible extensions and alternatives: 1. Combine this lesson with the Inside Energy lesson, "Wasted Heat into Power." For the elaboration section this lesson (or in addition to the elaboration section of this lesson), have students redesign their turbines from the previous lesson to be both efficient *and* to maximize the effect of inertia. ***Evaluate*** student understanding of concepts as they apply what they have learned and consider what they still do not know.
Evaluation	Teacher and students should evaluate student learning throughout the lesson.

TEACHER RESOURCES

BSCS 5E Instructional Model[1]
The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications[2]

[1] https://bscs.org/bscs-5e-instructional-model
[2] http://static.nsta.org/files/sc1408_10.pdf

STANDARDS ALIGNMENT

Colorado State Science Standards

SC09-GR.8-S.1-GLE.2	There are different forms of energy, and those forms of energy can be changed from one form to another – but total energy is conserved.
SC09-GR.6-S.3-GLE.3	Earth's natural resources provide the foundation for human society's physical needs. Many natural resources are nonrenewable on human timescales, while others can be renewed or recycled.

Next Generation Science Standards

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

MS-PS3.A: Definitions of Energy

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

MS-PS3.B: Conservation of Energy and Energy Transfer

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

National Standards – Benchmarks for Science Literacy

4E/M1 (Grades 6-8) Whenever energy appears in one place, it must have disappeared from another. Whenever energy is lost from somewhere, it must have gone somewhere else. Sometimes when energy appears to be lost, it actually has been transferred to a system that is so large that the effect of the transferred energy is imperceptible.

4E/M4 (Grades 6-8): Energy appears in different forms and can be transformed within a system. Motion energy is associated with the speed of an object. Thermal energy is associated with the temperature of an object. Gravitational energy is associated with the height of an object above a reference point. Elastic energy is associated with the stretching or compressing of an elastic object. Chemical energy is associated with the composition of a substance. Electrical energy is associated with an electric current in a circuit. Light energy is associated with the frequency of electromagnetic waves.

4F/M3a (Grades 6-8): An unbalanced force acting on an object changes its speed or direction of motion, or both.