Work and Power

Strand Work, Force, and Motion

Topic Investigating work and power

Primary SOL PS.10 The student will investigate and understand the scientific principles of work, force, and motion. Key concepts include

c) work, force, mechanical advantage, efficiency, and power; and
d) technological applications of work, force, and motion.

Related SOL PS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

b) length, mass, volume, density, temperature, weight, and force are accurately measured;
d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, probeware, and spring scales are used to gather data;
f) independent and dependent variables, constants, controls, and repeated trials are identified;
g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted;
i) frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted;
j) valid conclusions are made after analyzing data;
k) research methods are used to investigate practical problems and questions;
l) experimental results are presented in appropriate written form;
n) current applications of physical science concepts are used.

Background Information

Scientifically speaking, *work* is performed when a force is applied to an object, causing that object to move in the direction of the applied force. For example, when you push a grocery cart and it moves forward, work was done. On the other hand, when you push against a brick wall but the wall remains still, work was not done because the wall did not move. Also, if you are carrying a heavy bag of groceries while walking, work is not being done. In this case, your applied force in holding the groceries is upward yet you are moving them forward as you walk. Since the force and motion are in different directions, work is not performed. *Power* is the rate at which work is done, which is stated as a ratio per unit of time.

In physics and engineering, *mechanical advantage* (MA) is the factor by which a machine multiplies the force put into it. As a machine's mechanical advantage increases, the amount of force required to complete the work decreases. The *efficiency* of a machine measures the degree to which friction and other forces reduce the work output of that machine's potential. Since all objects on Earth are exposed to friction as a result of gravitational forces, machines are not able to

achieve 100% efficiency. Engineers are continually striving to use technology to increase the efficiency of machines. Examples include increasing the performance of automobiles, machine productivity, and the output of various energy sources. Technological applications of work, force, and motion continue to change the world.

Materials

- Meter stick or measuring tape
- Flight of stairs (e.g., bleachers in the gym/stadium)
- Timer
- Scale for weighing students (or estimate weight in pounds)
- Computers with Internet access

Vocabulary

efficiency, mechanical advantage, Newtons, power, work

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Students will investigate and calculate the values for force, work, and power involved in walking up a flight of stairs with out their backpack and with their backpack. Teachers should monitor safety and assist with calculations as needed.

In this investigation, the force involved is weight that will be moved vertically. Therefore, the distance the force is applied is only in the vertical direction. The power of the students can be calculated by measuring the time it takes for students to travel from the bottom to the top stair. Students collect their data then use the following formulas to complete the data chart and analysis:

- Work (J) = force x distance (W = Fd)
- Power (W) = work /time (P = W/t)
- Weight in Newtons = (pounds x 2.2)/9.8

Rules for student travel on stairs:

- Students must touch each stair with at least one foot. No skipping stairs to go faster for safety reasons.
- Students may not use the hand rail (it adds confounding factors of force).
- Students may walk up the stairs.

Timing of students can be done by the teacher or by student volunteers. Usually it is best if timers sit at the top of the flight of stairs and give the "Ready, Set, Go" signal. Usually timing is not accurate; therefore, three times should be collected and the mean time calculated.

Part 1

1. Ask students what variables are involved in the concept of power (e.g., force, distance, time). Then discuss the forces involved in walking up the stairs.
2. Have students identify the most influential and measurable force as gravity, the force of their mass being attracted to the Earth. Once students measure (or estimate) their weight in pounds, give them the conversion formula: Weight in Newtons = (pounds × 2.2)/9.8

3. Help students devise a data table (see example) to record the relevant information (i.e., weight, distance traveled, work, time trials, mean time traveled, power).
4. Conduct a discussion to determine the direction of motion and the total distance traveled in this direction. When a conclusion is reached, have students measure the vertical height of one step and multiply this distance by the number of steps. An alternative would be to drop a line or tape measure to follow the vertical distance, and measure the line.
5. Have the students record force and distance measurements in the table, then calculate for work.
6. One at a time, students should travel up the stairs while the timers measure the number of seconds it takes to go from the bottom to the top of the stairs. Record the time and calculate the power. Students should share their data and check each other's results.

Part 2

In this activity, students will compare and contrast various monocycles, bicycles, and tricycles noting how technological applications have enhanced their performance.

1. Review the vocabulary terms with students, then lead a discussion on how technology has impacted the motion of objects. New applications allow objects to have more power, perform work with less force, and be more efficient. Discuss how maglev (magnetic levitation) trains use electromagnets to propel them down the tracks at unprecedented ground speeds. Because these magnets force the train to levitate above the track, friction is virtually eliminated and the train's motion becomes more efficient. Provide a picture or video clip, if possible, to show this example. Ask students to share other examples of how technology has changed the motion of objects.
2. Divide students into eight groups. Have each group select a cycle from the list at right. Allow the groups approximately 20 minutes to conduct Internet research and prepare a brief presentation about their selected cycle. During that time, they should complete the following:
   - Print an 8 x 10 inch drawing or photo of the cycle.
   - List three to five facts about the cycle that make it interesting and unique. Write these facts neatly on note cards and attach them to the picture or photo.
   - Give three reasons why someone would want the cycle.
   - Prepare a 2-minute commercial to "sell" the cycle to the class.

   Electric-Assisted Bicycle (E-bike)
   Arm-Powered Bicycle
   Folding Bicycle
   Water Filtration Tricycle
   Bamboo Bicycle
   Single Wheel Bike (Monocycle)
   Surfbike
   Transformation Trike
3. After all groups have completed their presentations, have each group present their commercial to the class. After each presentation, hang the picture on a bulletin board for the class to review at the end of all presentations.

Assessment

- **Questions**
  - Since the distance was constant for all students, what role did force play on how large or small the value of work was?
  - How would the amount of work change if you traveled up the stairs twice as fast? Half as slow as the original speed? Explain your answer.

  - Sami, the Olympic track athlete, has ¾ as much mass as you and is able to run up the stairs in ½ your time. What is her work and power? How do her results compare to yours? Discuss how work and power are affected by mass and time.
  - Student A has higher work than Student B, but Student B has higher power than Student A. Is this scenario possible? If so, how?
  - Which cycles would require the least amount of work to move them 10 meters? Which would require the greatest?
  - Which of these cycles do you feel has the greatest mechanical advantage? Explain.
  - Choose one cycle. What are three ways to improve its efficiency?
  - How has technology enhanced each cycle?
- **Other**
  - On a double-line graph, graph the work and power for each member of your lab group. Label each axis of the graph with the appropriate variables, increments, and units. Color-code the data so you can tell the data apart. Does anything surprise you about the data? Write a conclusion summarizing the results of your group's data, including how mass and time affected work and power.
  - Conduct a private survey to determine which cycle each student would purchase. Construct a graph or pictorial representation to share the results with the class.

Extensions and Connections (for all students)

- Hold an "Olympic Games of Power." Create events where force, distance, and time could be measured to determine student-generated power. Have students create a table to collect their trial data and record calculations. Students would complete the various events and compete for the most powerful in each event.
- Have students go to the local amusement park and compare the newest and oldest roller coasters in the park. Ask them to answer the following:
  - How is force applied to propel the coaster down the track?
  - What materials were used to build each coaster?
  - What is the highest speed each one is able to reach?
  - What braking system is used to stop the roller coaster?
  - How has technology impacted the motion of roller coasters today?

Strategies for Differentiation

- Have students create a foldable and program it with the terms and their definitions.
- Students unable to climb the stairs could be in charge of recording data or timing.
- Allow calculations to be completed in small groups as necessary.
- Guide students in the selection of the facts they collect during their research in Part 2.