Chapter 9 Answers

9.1 Section Review

1. Sample answer: Examples of simple machines include a lever and gears. These are unpowered mechanical devices that accomplish a task with only one movement. Simple machines are arranged to make complex machines such as bicycles or cars. Complex machines may be powered and work by doing multiple movements to accomplish a task.
2. Sample answer: A simple machine is useful because it multiplies force and can improve the power and efficiency of doing a task.
3. In order to get work output, you need to apply work input to a machine.
4. Table answers:

Comparing input and output for a bicycle		
Work	Input	Similar
	Output	Similar
Force	Input	Larger
	Output	Smaller
Distance	Input	Smaller
	Output	Larger

5. Part A: input force; Part B: fulcrum; Part C: output force
6. The output work is 60 joules (20 N × 3 m). Therefore, you need to pull the rope a distance of 6 meters (10 N × 6 m = 60 joules) for the input work to achieve 60 joules of output work.

Solve It!

a. The efficiency is 100% [(5 joules ÷ 5 joules) × 100]. For a ropes and pulleys machine it is possible for the friction to be minimal so that work input and output appear to be equal and the efficiency appears to be 100%. However, all machines have friction which makes work output always less than work input and efficiency always less than 100%.

b. Power = 5 joules ÷ 2 s = 2.5 watts

Journal

Sample answer: From my experiences on a daily basis, I think it is impossible to get through the day without using simple machines. This morning I used a fork like a lever to pick up food and eat it. I needed to turn doorknobs (wheel and axle) to get from one room to the next at school. Also, because I walk and use my arms all day, I am using levers!

Extension: Student answers will vary. Make sure that students highlight the key values of using simple machines—namely that they multiply force and improve power and efficiency of doing work.

9.2 Section Review

1. Yes, you can calculate the mechanical advantage of the lever. The formula is

$$\text{Mechanical advantage} = \frac{\text{Length of input arm}}{\text{Length of output arm}}$$

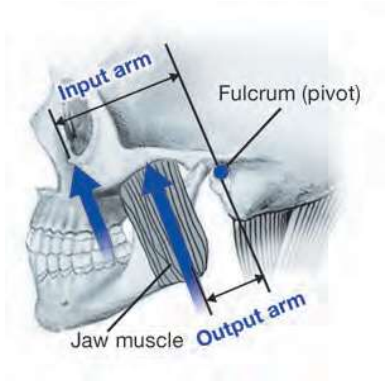
1. The mechanical advantage of a machine is defined as the ratio of output force to input force. However, arriving at the mechanical advantage of a machine can be done using a variety of methods depending on the machine (such as using the ratio of the output lever arm length to the input lever arm length).
2. A wheelbarrow is a second class lever. Therefore, it's mechanical advantage is always greater than 1.
3. A broom is a third class lever because the fulcrum is at one end of the lever (where you hold one hand) and because the input force is applied between the fulcrum and the output force making the output arm always longer.
4. Answers:
   a. If the 12-tooth output gear turns two times, the 24-tooth input gear turns one time. The gear ratio is 2 so the mechanical advantage is 1/2 or 0.5.
   b. Speed is multiplied in this gear combination.
5. Answer:
   Input force = ? N × 10 m = 4,000 joules
   Output force = 2,000 N × 2 m = 4,000 joules
   The input force is 400 N. The mechanical advantage is 5.
6. The answer is d.
7. The mechanical advantage is 5.
8. The design of a screw is a ramp wrapped around a center rod. Therefore, a screw works like a ramp by making it easier to lift or pull two separate objects together.
9. Force is multiplied by applying the force to the wheel to rotate the axle.
10. A ramp is always stationary. The mechanical advantage of using a ramp depends on objects moving along the ramp. A wedge can move (or be stationary). The mechanical advantage of a wedge depends on the angle (or degree of sharpness) of the leading edge.

Challenge

Student answers will vary. For this activity, encourage students to describe the simple machines they use instead of just listing names. Having this information will make it easier for them to figure out if the machine is multiplying force or speed. Also, they may want to see if they can figure out or predict the mechanical advantage of each machine they use.

9.3 Section Review

1. The human body is a complex machine because its structure is based on more than one lever or simple machine. For example, the jaw, neck, and arms, and legs all function as levers.
2. The answer is (b) Your lower leg. The lower leg acts like a lever when it kicks a ball. The knee is the fulcrum, the calf muscle is the input force, and the foot provides the output force to move the ball.
3. Answers:
   a. The lower jaw as a third class lever.
   b. The arm (both the biceps and forearm) are third class levers.
   c. The legs (both the thigh and the lower leg) are third class levers.
   d. When chewing occurs, the lower jaw is a second class lever.
   e. The neck is a first class lever.
4. Answers:
   a. The lower jaw multiplies speed.
   b. The output force would be 350 newtons (0.7 × 500 newtons).
   c. When a lever is third class, it does not multiply force, but it can multiply speed and it has a wide range of motion. The lower jaw needs to be able to open wide to take bites of large things like an apple or a big sandwich.
5. Answers:
   a. The output force is 140 newtons (1.4 × 100 newtons).
   b. The input lever arm is longer than the output lever arm. Diagram:



Connection

1. Technologies mentioned in the article include hydraulics, carbon fiber, mechanical linkages, motors, and computer microprocessors.
2. Computers can monitor velocities of upper and lower leg, angle of knee bend, and other data in order to make adjustments in the prosthetic device that increase its stability and efficiency.
3. New foot designs have heel and front foot components that act like springs, storing and releasing energy in the appropriate parts of the stride.
4. Biomechanics is the study of the mechanical nature of biological processes, such as the movement of limbs, the pumping action of the heart, and the body's response to external and internal forces. There are countless biomechanics applications for further study. Here are a few samples: Aerodynamics of insect flight; sport shoe technology; athletic training and injury rehabilitation; blood pressure and heart disease.

Chapter 6 Assessment

Vocabulary

Section 9.1 and Section 9.2

1. lever
2. mechanical advantage
3. gear
4. simple machine
5. machine
6. input; output
7. gear ratio

There are no vocabulary words in section 9.3.

Concepts

Section 9.1

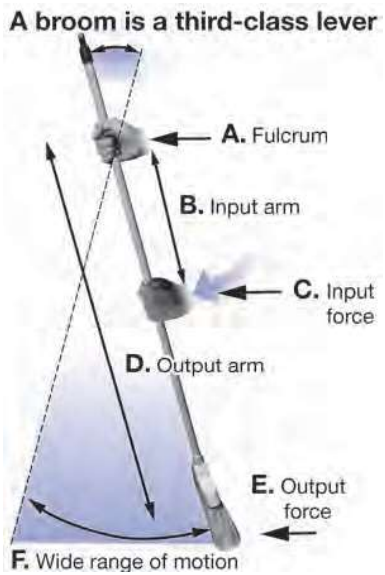
1. Sample answer: The design of a bicycle includes wheel and axle systems and gears.
2. The input work is applied to the machine. The output work is done by the machine.
3. A gas-powered lawn mower is a complex machine because for it to function it does more than one motion. For example, it has a wheel and axle system so it can move when powered. It has an engine and needs fuel. And it has a system of simple machines and other parts that are put together to accomplish the task of cutting grass.
4. No, this machine is not possible nor can it work. This is because the output work (100 N × 1 m = 100 joules) is greater than the input work (50 newtons × 0.5 m = 25 joules). The output work can only be equal to or less than the input work.
5. Sample answers:
   Simple machines and examples
   Gears: Gears are used in a egg beater
   Ramp: A wheelchair ramp
   Wheel and axle: A ferris wheel
   Wedge: An ice scrapper
   Ropes and pulleys: An elevator
   Lever: A scale for measuring mass

Section 9.2

6. Answers:
   a. Correct. The formula for mechanical advantage using lever arm lengths is: input arm ÷ output arm.
   b. Correct. You can use the lever arm lengths to calculate the mechanical advantage. Then, using mechanical advantage and the value for input force, you can determine the output force.
7. Answers:
   a. Gears: The inverse of the following formulas — (1) Number of output turns ÷ Number of input turns, or (2) Number of input teeth ÷ Number of output teeth.
   b. Lever: (1) Output force ÷ Input force, and
   (2) Input arm length ÷ output arm length
8. The mechanical advantage for a second class lever is always greater than 1 because the input arm length is always longer than the output arm length. The mechanical advantage for a third class lever is always less than 1 because the input arm length is always shorter than the output arm length.
9. Answers: nutcracker (2nd class); baseball bat (2nd class); golf club (3rd class); hammer (3rd class); scissors (1st class)
10. Both people are pulling with a force of 150 newtons.
11. The simple machines include the ramp and the wheel and axle system on the cart. The ramp is used because there is more mechanical advantage in using the ramp than in lifting the luggage straight upward. The cart has a wheel and axle system because this system also has more mechanical advantage and improved efficiency than you would have if you carried the luggage piece by piece or tried to push it up the ramp (you would have to overcome a lot of friction to move the luggage this way).

Section 9.3

12. The answer is (c) All three classes.
13. Answers:
    a. See diagram at right.
    b. A broom is a third-class lever.
    c. The advantages to using a broom are that you are able to multiply the speed of accomplishing the task and you have a wide range of motion.
    d. No, I would not use a broom to move large rocks. However, I could use the handle of the broom as a first-class lever. I would place one end of the handle under a rock and rest the middle on a fulcrum. Then I would push up on the other end of the handle to pry each rock out of the ground and possibly roll it out of the way.



14. Sample answer: My favorite animals are fish. The fins of fish act as third-class levers. The point that the fin is connected to a fish's body is the fulcrum. The bones in the fin and muscles

provide the input force. And the far end of the fin provides the output force that is required to push water so a fish can move.

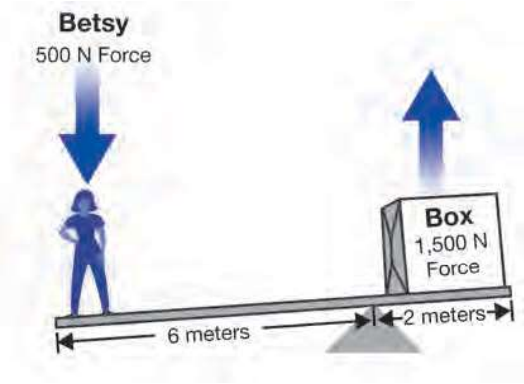
Problems

Section 9.1

1. The mechanical advantage is 10 and you need to pull 10 meters of rope to achieve the output work. The power is 40 joules (200 N ÷ 5 s).

Section 9.2

2. Answers:
   a. Lever arms: (A) input = output; (B) input > output; (C) input < output
   b. Force: (A) input = output; (B) input < output; (C) input > output
   c. Mechanical advantage: (A) MA = 1; (B) MA > 1; (C) MA < 1
3. In this case, the mechanical advantage is 0.7 (2 m ÷ 3 m). This lever does not multiply force as determined by the mechanical advantage of less than 1. This lever would, however, be able to multiply speed with which the work was being done.
4. Betsy needs a lever with a mechanical advantage of 3 (1,500 N ÷ 500 N). For this system, the lever input arm could be 6 meters and the output arm could be 2 meters. Diagram:



5. With a wheelbarrow with a mechanical advantage of 3.5, you could carry about 228 newtons (65 N × 3.5) of soil with an input force of 65 newtons.
6. The mechanical advantage is 1/4 (the inverse of the gear ratio = 48 teeth ÷ 12 teeth). Speed is multiplied in this example because mechanical advantage is less than 1.
7. The output gear will turn two times and the input gear has half as many teeth as the output gear.
8. Answers:
   a. 100 N
   b. 50 N
   c. 20 N
   d. 10 N
9. The sailor's input force needs to be 100 newtons.
10. Table answers:

Input force (N)	Output force (N)	Mechanical advantage
10	100	10
30	30	1
500	1,350	2.7
625	200	0.32

11. The lever with the lowest mechanical advantage requires 625 newtons of input force to lift 200 newtons. The mechanical advantage is only 0.32. Therefore, I wouldn't not want to use this particular machine. I would probably use one of the other machines listed that have mechanical advantages of 1 or greater.

Section 9.3

12. Answers:
   a. MA of the jaw = 7 cm ÷ 10 cm = 0.7; MA of the arm = 5 cm ÷ 35 cm = 0.14; The jaw has a larger mechanical advantage.
   b. Output force of the jaw = 0.7 × 800 N = 560 N; Output force of the arm = 0.14 × 800 N = 112 N; The output force of the jaw is larger.
   c. To produce an output force of 500 N in the jaw, you need 714 N of input force. To produce an output for of 500 N in the arm, you need 3,571 N of input force.

Applying Your Knowledge

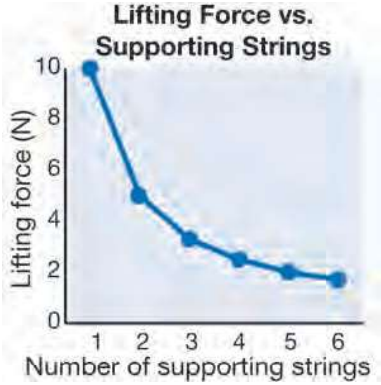
Section 9.1

1. Student answers will vary. Possible ideas: a machine that makes drying dishes easier, a machine that makes sandwiches, a machine that fills bird feeders, a machine that feeds your fish regularly. For the Extension, each student could

present his/her machine in an oral presentation that includes visuals (like sketches or even a model). The class can decide is the design of the machine makes sense in terms of what the task requires (multiplied speed or force) and whether or not the design can accomplish the task. All comments should be constructive.

Section 9.2

2. No, mechanical advantage is a value that does not have units. This is because the units cancel when doing the calculation (force units, for example, cancel when you divide output force by input force).
3. Sample answers:
   a. The length of a ramp is 20 meters and its height is 2 meters. What is the ramp's mechanical advantage? Answer: 10 (20 m ÷ 2 m)
   b. The lead of a screw is 1.4 mm and its circumference is 20 mm. What is the mechanical advantage? Answer: 14 (20 mm ÷ 1.4 mm)
   c. A knife is a kind of wedge. In time, it gets duller and duller. Does this mean its mechanical advantage increases or decreases? Answer: Its mechanical advantage decreases because sharpness of a wedge is directly related to its mechanical advantage.
   d. The radius of a wheel in a machine is 10 centimeters and the radius of its axle is 1 centimeter. What is it's mechanical advantage? How is speed increased for a wheel and axle? Answer: The mechanical advantage is 10 (10 cm ÷ 1 cm). In this situation, speed is increased by applying a force to the axle.
4. Answers:
   a. As the number of supporting strings increases, the lifting force decreases.
   b. Graph:



   c. The mechanical advantage is the same as the number of supporting strings. (Number of strings, MA) = (2, 2), (4, 4), (6, 6), (1, 1), (3, 3), (5, 5).

Section 9.3

5. Student answers will vary. Sample answer: The field of biomechanics is a growing field in that more and more biologists are applying the concepts to more and more systems. For example, these scientists study trees, seaweed, tiny marine animals, insects, and other biological systems. They do their work both indoors and outdoors. For example, they might set up wind tunnels in an indoor laboratory facility to learn how an organism flies in different types and speeds of wind currents. Outdoors, these scientists might measure how strongly the organism is attached to a surface (like a rock in the intertidal zone). Resources: Students may want to use "biomechanics" as a search term on the Internet. One way to get specific information about possible careers is to look up "biomechanics degree programs." The field of biomechanics is part of many disciplines includes biology, ecology, engineering cars and other machines for people, designing safe practices, sports science, medicine, and in space science (designing space modules that work with the human body)