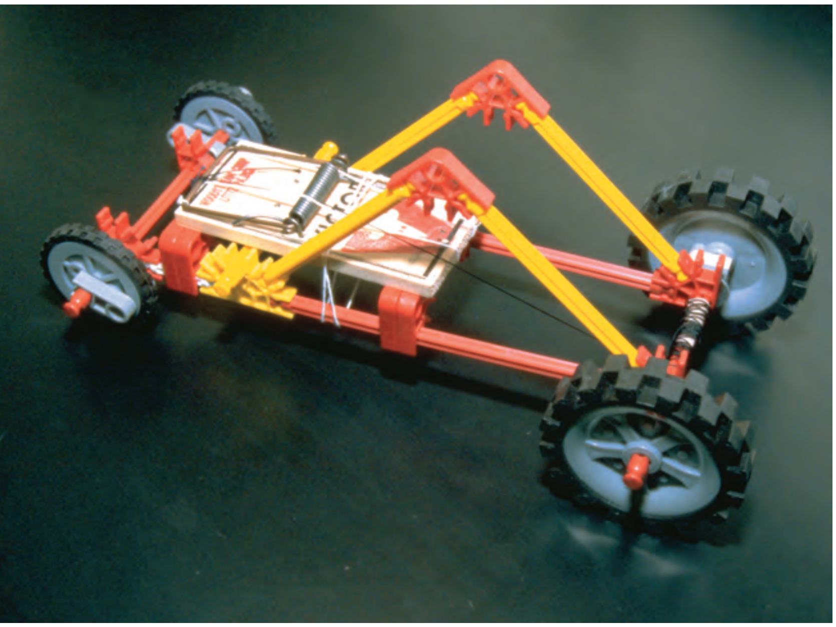
LESSON **19**

Motion of a Mousetrap Car



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The assembled mousetrap car

INTRODUCTION

In Lesson 18, you built a fan car and measured its speed. In this lesson, you will build a "mousetrap car" and investigate its motion. You will design an experiment that will enable you to measure the speed of the car as it moves after the trap is released. You will also identify the forces acting on the car and describe how these forces affect the car's motion. You will then compare the motions of the fan car with those of the mousetrap car.

OBJECTIVES FOR THIS LESSON

Identify and describe the forces acting on the mousetrap car.

Observe and measure the speed of the mousetrap car as it moves.

Describe how forces affect the motion of the mousetrap car.

Describe the energy changes in the mousetrap car as it moves across the floor.

Compare the motion of the fan car with the motion of the mousetrap car.

Getting Started

1. Assemble the mousetrap car as shown in Figure 19.1; the exploded diagram shows all the parts needed to assemble the car and how they connect. Figure 19.2 shows the car with the pieces properly connected. (The photo at the beginning of this lesson also shows the assembled mousetrap car.) It is important that you use a long piece of nylon line so that the axle will keep rotating after the trap has been released. If the nylon line is too short, it will unwind and then begin winding the opposite way.

MATERIALS FOR LESSON 19

For your group

- 1 student timer
- 1 meterstick
- 1 0- to 10-N spring scale
- 1 piece of adding machine tape
- K'NEX® parts for the mousetrap car (see Appendix A: Directory of K'NEX® Parts):
  - 6 gray connectors (C1)
  - 2 tan connectors (C2)
  - 14 red connectors (C4)
  - 2 yellow connectors (C10)
  - 6 white rods, (R2)
  - 5 yellow rods (R4)
  - 4 red rods (R6)
  - 2 small tires (T1)
  - 2 large tires (T2)
  - 2 small wheels (W1)
  - 2 large wheels (W2)
- 1 mousetrap
- 4 small washers
- 1 piece of string
- 1 piece of nylon line
- 1 piece of masking tape

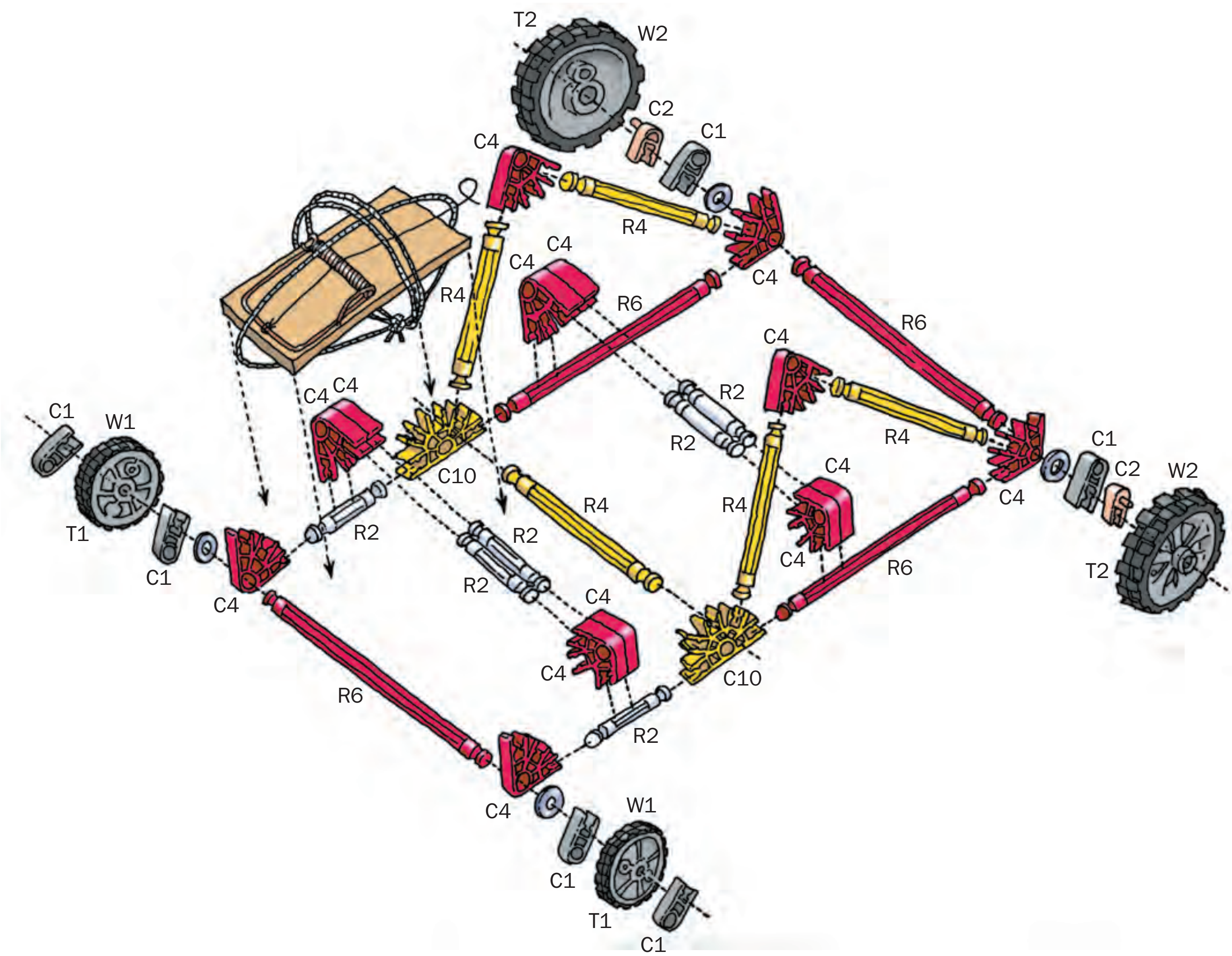


Figure 19.1 *Exploded view of the mousetrap car*

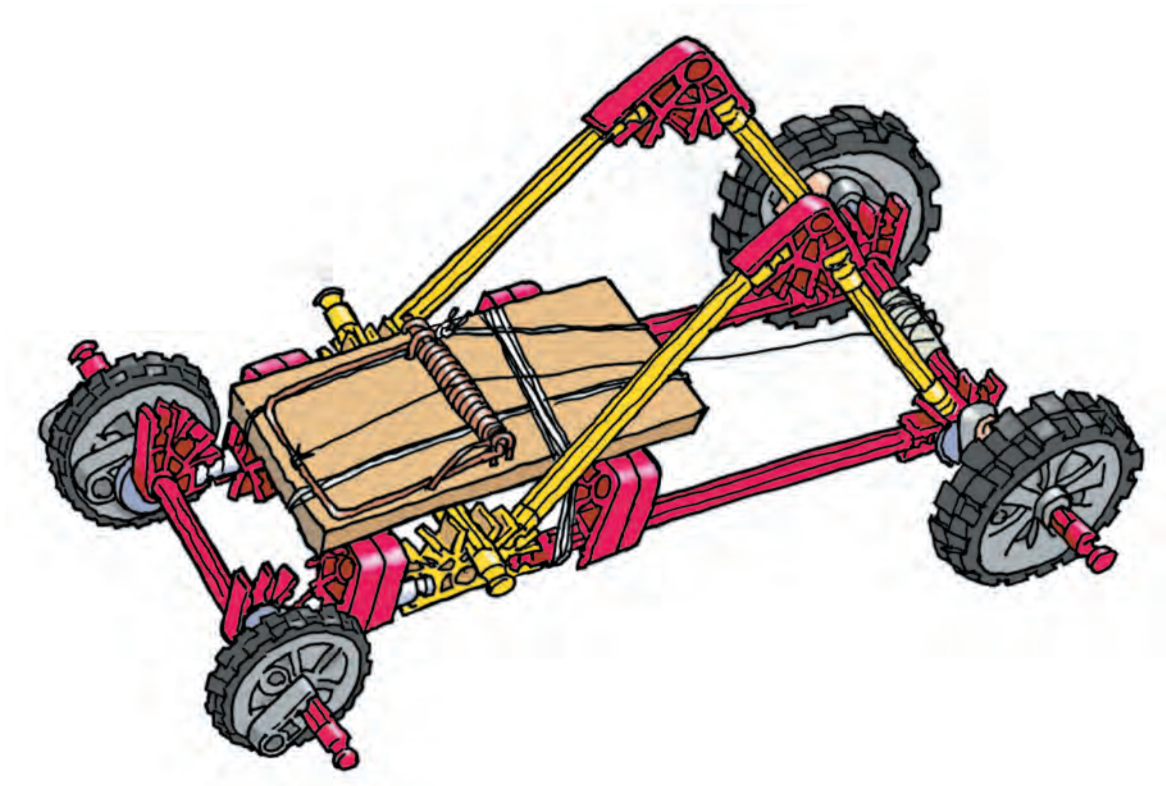


Figure 19.2 *Assembled mousetrap car. The mousetrap in this illustration has been sprung. The nylon line is attached to the jaws of the trap and to the rear axle. By turning the wheels, you can wind the nylon line around the axle and pull the jaws of the trap open.*

2. Double-check your vehicle to be sure that the trap is securely attached to the car and that the jaws of the mousetrap will open and close properly.

3. How can you put energy into the mousetrap car? Discuss this question with the class.

SAFETY TIP

Do not put your fingers in the clamping device of the mousetrap.

Inquiry 19.1
Observing the Motion of the Mousetrap Car

PROCEDURE

1. Complete the activities that follow. Record your observations and answers to the questions in your science notebook. Be prepared to share your observations with the class.

2. Set the car on the table or floor and attach a spring scale to the mousetrap bar. Holding the car firmly, slowly pull the bar back with the spring scale. Observe the force on the spring scale as you pull the bar. Record what happens to the force as you keep pulling the bar. Slowly release the bar so that it returns to its resting position; then remove the spring scale hook from the bar (see Figure 19.3).

3. Hold the car so that it does not touch the floor. Set the mousetrap spring by turning the wheels of the car so that the nylon line winds around the axle and pulls the mousetrap bar all the way back. Let go of the wheels while still holding the car off the floor. Do this several times. Describe what happens.

4. What do you think the motion of the car would be if you set the mousetrap and released it with the car on the floor? Write your prediction in your science notebook.

5. Reset the mousetrap. Place the car on the floor and release it. Describe what happens.

6. Write a paragraph describing the motions of the mousetrap car after the trap was set and the car was released. Discuss with your lab partner what forces you think are producing the motions.

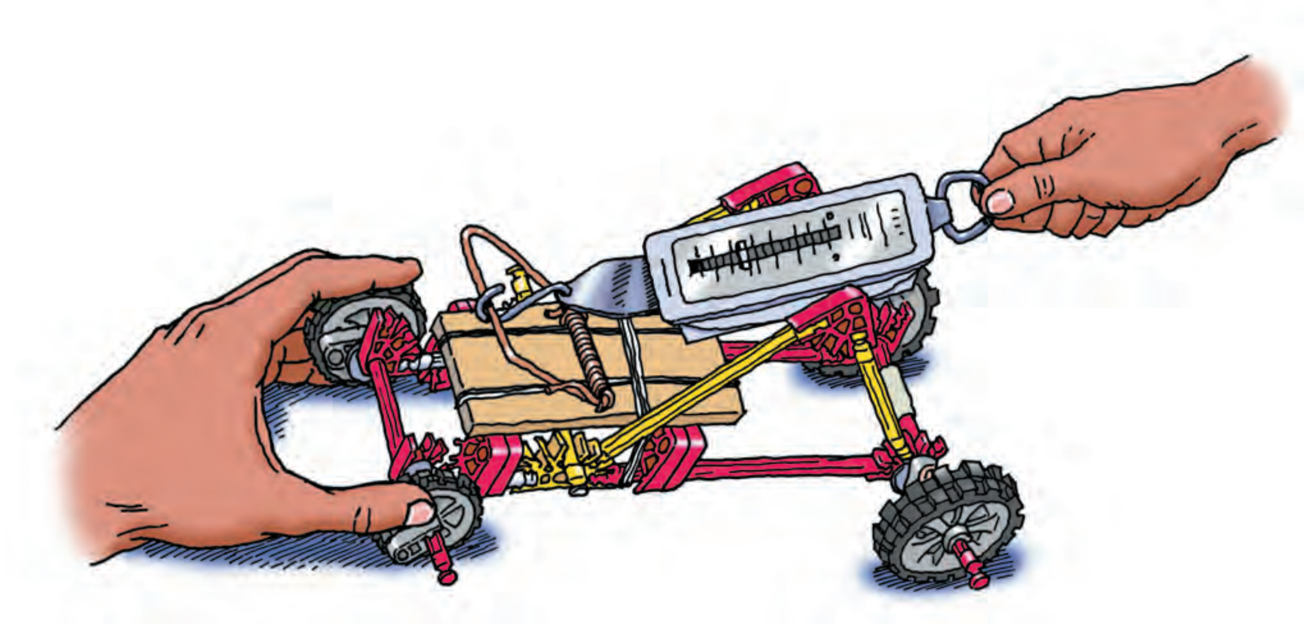


Figure 19.3 *Attach and pull the spring scale as shown here to measure the force of the mousetrap spring.*

Inquiry 19.2
Measuring the Speed of the Mousetrap Car

PROCEDURE

1. Share with the class what you wrote about the motion of your mousetrap car.

2. With the class, discuss the following questions:

   A. Is the speed of the car constant as it moves across the floor?

   B. How could you calculate the average speed of your car?

   C. How could you design an experiment to measure the speed of the mousetrap car as it travels along the floor?

3. With your group, develop a plan to measure the motion. Design an experiment to determine the mousetrap car's speed at different positions along its path. Write your plan in your science notebook. Design a data table on which to record your measurements and any calculations.

4. Carry out your plan.

5. When you are done, summarize the conclusions you can draw from your data.

6. Follow your teacher's instructions to disassemble your car and return the parts to storage.

REFLECTING ON WHAT YOU'VE DONE

Answer the following questions in your science notebook. Be prepared to share your answers with the class.

A. Summarize what you found out about the motion of the car. Give evidence from your data for your conclusions.

B. Explain the changes in the mousetrap car's speed in terms of the forces acting on the car.

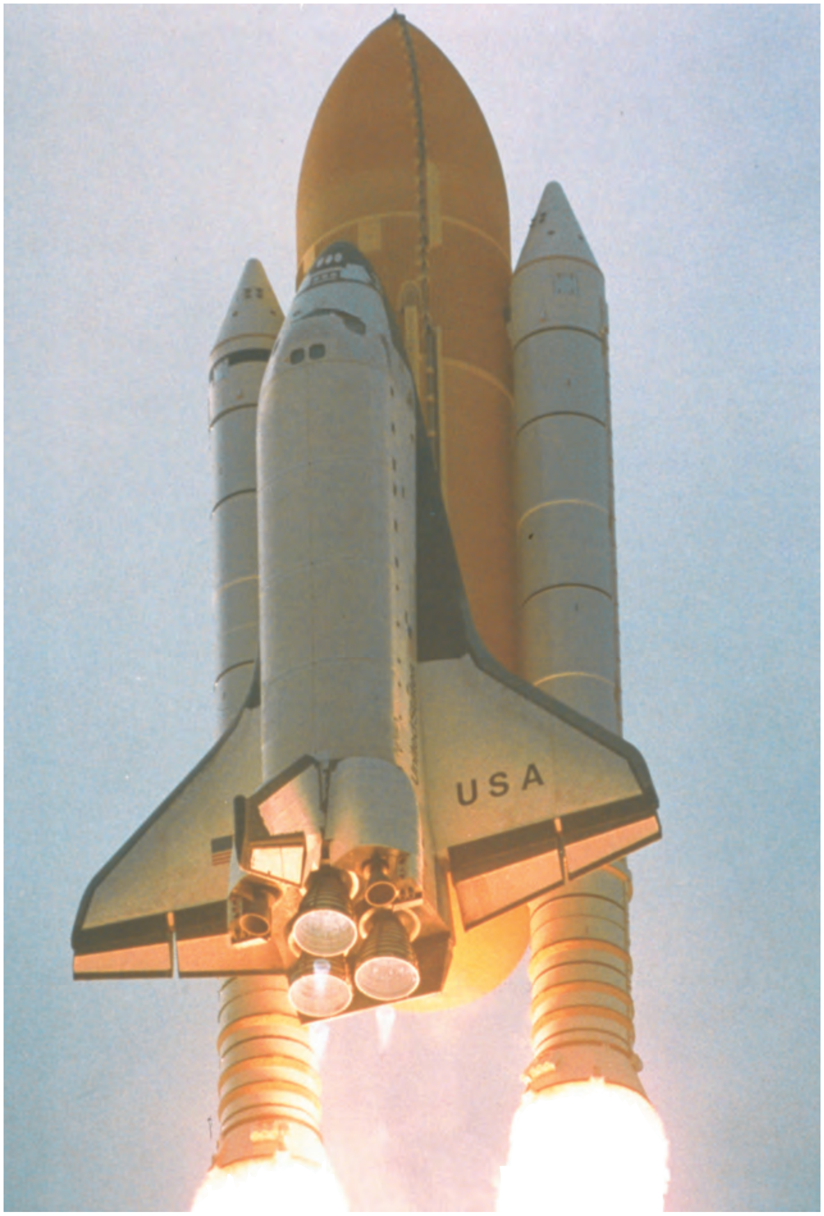
C. When you set the mousetrap, do you do work on it? If so, why?

D. Write a paragraph describing the energy changes that took place when you set the trap and released the car.

E. How does the motion of the mousetrap car compare with the motion of the fan car? Identify similarities and differences. What forces acted each time?

Rocket Science 101

NASA



Powerful rockets are needed to launch the Space Shuttle into orbit.

You don't need to be a rocket scientist to understand how a rocket works. All you need to know is Newton's Third Law of Motion, which states that for every action, there is an equal and opposite reaction.

Newton's Third Law of Motion works for all forces, including the ones you have been exploring in the lab. For example, when your fan car was running, the fan pushed on the air and the air pushed back on the fan. It was the air pushing on the fan that pushed the car. The air went one way and the car went the other.

Something similar happens with rockets. Rockets go forward by expelling hot gas backward. Rocket engines generate the force to push the gas out at very high speed by burning a lot of fuel quickly. Rapidly burning fuel creates the huge force that sends the hot gases out of the rocket. According to Newton's Third Law of Motion, as the rocket pushes the gas out the back, the gas pushes the rocket forward. Newton, in fact, knew that if something was launched with enough force, it could gain enough speed to orbit the earth or even to escape the earth, but he did not have rockets powerful enough to do it.

To launch a rocket, a rocket engine must expel its gases with enough force (thrust) to exceed the force of gravity. People had been using this principle for centuries. For example, the Chinese were using rockets for military purposes in the 13th century. The Chinese also invented fireworks, which are another example of rockets. These early rockets were powered by solid fuel, which was similar in composition to gunpowder.

In the early 1800s, a British officer, William Congreve, improved existing rockets for military use. Their glow inspired the words "rockets' red glare" in "The Star-Spangled Banner," the national anthem of the United States. But none of these rockets was powerful enough to launch anything into space. Like the Chinese rockets, the rockets launched with this gunpowder-type fuel all fell back to the ground.

Launching satellites into orbit and sending them to other planets requires very powerful rockets. The force of the rockets must push on the satellites and give them enough speed so they will go around the earth continuously and not fall back to the ground. To send a spacecraft to the moon or to other planets in our solar system, the force of the rocket has to be strong enough, and last long enough, to give the spacecraft the speed to escape the earth and not be bound by its gravity. The speed needed to leave the earth and not be bound by its gravity is called escape velocity. Clearly, if space travel were to become a reality, scientists would need to find a way to make more powerful rockets.

It wasn't until 1926 that American physicist Robert Hutchings Goddard developed and launched the world's first liquid-fueled rocket. This breakthrough eventually led to the development of rockets powerful enough to launch satellites and other spacecraft into orbit around the earth. In 1957, Russia successfully launched Sputnik, the first artificial satellite. In 1958, the United States successfully launched a satellite into space. It was named *Explorer I*. These satellites orbited the earth and were a wonder of science and technology. They marked the beginning of the Space Age.

AP/WIDE WORLD PHOTOS

Fireworks are rockets, too.

In the 1960s, scientists and

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Left: *An early space rocket designed by Robert Goddard is prepared for launching.*

engineers in the United States developed and built Saturn V, the biggest and most powerful rocket ever built. It stood almost 20 meters higher than the Statue of Liberty; on the launch pad, it weighed 13 times more than the statue. The engines on the rocket had the horsepower of 4300 automobiles. Saturn V was used to send a three-man crew to the moon in 1969. It needed so much fuel that it was built in stages, or sections. Each stage was released when the fuel in it was used up. This process made the rocket lighter after each release so that it was easier to speed up the rocket and send its payload of astronauts on their way.

Rockets like the Saturn V are no longer being built. They are too expensive, and future manned missions would require rockets even more powerful than the Saturn V. But scientists and engineers continue to improve rocket technology. They are exploring new designs that will eventually enable humans to travel back to the moon and beyond. Someday, you will even be able to take a space vacation. (Book early. Reservations required.) ☐

QUESTIONS

1. What is the energy source for a rocket?
2. What energy changes take place in a rocket when it is launched?
3. How are the forces in a rocket similar to the forces in a mousetrap car? How are they different?

From 1968 to 1972, the Apollo mission sent crews of astronauts to explore the moon. Astronauts took this picture, which shows how the earth looks as seen from the moon.

NASA

Medieval Warfare in Modern Times

A young man in leather armor and carrying a wooden shield runs from the fire of a catapult that is throwing missiles at him. Temporarily out of the catapult's range, he pauses to rest, checks his digital watch, and looks around at the Arizona landscape. Digital watch? Arizona? This man isn't a medieval warrior but a member of a war reenactment group in the 21st century. The catapult is built, as much as possible, like a medieval catapult. However, rather than throwing heavy stones, reenactment catapults throw groups of tennis balls that are taped together. (The word "catapult" comes from two Greek words: *kata* means "down" and *pallein* means "to hurl.")

Catapults were war machines during medieval times. They were used to attack castles and fortresses. The catapults hurled large stones and other things at the castle walls or even over the walls of fortresses. Persistent battering could eventually win the battle. Medieval warriors used at least three different kinds of catapults, and the people who participate in medieval battle reenactments today build and use all three of them.

One kind of catapult is the *mangonel.* The Romans designed it in the third century. It was the most popular kind of catapult of the medieval period. It is also the most popular catapult built for reenactments today. How does a mangonel work?

Setting a mangonel is very much like setting a giant mousetrap. A mangonel has a single arm with a cuplike extension at the end. Two ropes attached to this arm can be wound around a pole using a lever. As the ropes are wound around the pole, the throwing arm is pulled down so that it can be loaded. The more tightly the rope is wound, the greater the force pulling on the throwing arm—the same as when you pull back the bar on a mousetrap. When the throwing arm is released, it snaps forward into a crossbar, which suddenly stops the throwing arm and sends a rock flying out of the cup and through the air. Unfortunately, this is an inefficient kind of catapult, since much of the available energy is lost into the framework of the catapult when the throwing arm hits the crossbar. Only a small portion of the energy put into the catapult when the ropes are stretched is converted to energy in moving the stone.

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Medieval soldiers setting a mangonel for action

A second type of catapult from medieval times is called a *traction trebuchet.* With a long pole mounted on a tall frame, this catapult uses the principles of a lever. The pole is positioned so that the fulcrum is close to one end. A sling that holds a rock is attached to the end of the pole farthest from the fulcrum. Ropes are attached to the other end of the pole, which is at the end closest to the fulcrum. When a crew of warriors pulls down on these ropes at the end closest to the fulcrum, the long end of the pole rises quickly into the air and sends the rock hurtling toward the target.

In recent years, a crew of five people using a reconstructed traction trebuchet was able to throw a 900-gram lead ball 170 meters. Medieval traction trebuchets were known to have crews of 30 men or more.

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The trebuchet was a kind of catapult. This one used counterweights to fire its loads.

A much more powerful catapult used in medieval times was the *counterweight trebuchet.* Like the traction trebuchet, the counterweight trebuchet uses the principles of a lever. However, gravity, rather than a crew of warriors, provides the downward force that sends the rock into the air. A heavy weight is attached to the short end of the pole. The longer end has to be pulled down by the crew and loaded before it can be used. When the long end of the pole is released, gravity pulls the heavy weight on the short end down. The long end is raised into the air, and the stone is sent flying. This design worked well; 44 such catapults spread havoc around Europe during medieval times. A modern counterweight trebuchet with a 5400-kilogram weight has been used to throw a 635-kilogram car 79 meters and 45 kilograms of iron 215 meters.

While catapults like these and others from medieval times are no longer used in war, they are still of great interest to a number of people. War-reenactment groups, historians, and others build them. Over the years, all sorts of items have been launched with catapults—from stones and spears to people, pianos, and pumpkins. □

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Today people reenact medieval catapult launches in mock battles.