LESSON 12

The Pulley

CORBIS/JAMES P. BLAIR

Pulleys come in handy when hoisting a sail.

INTRODUCTION

In Lesson 11, you measured forces and distances and you calculated work on an inclined plane. You used the inclined plane to make it easier to raise a load to a certain height. But inclined planes do not work in all situations. For example, suppose you needed to lift a load to a great height but you didn't have space for a long ramp. You would need another kind of machine to do the job. In this lesson, you will use a different machine to lift the sled. That machine is a pulley system.

OBJECTIVES FOR THIS LESSON

Understand how pulleys work.

Construct different pulley systems and use them to lift a load.

Investigate the relationship between effort force and effort distance in pulley systems.

Communicate your observations about pulley systems to your classmates.

Getting Started

1. Describe a situation in which you would need to raise a load to a particular height but for which an inclined plane would not be practical. Discuss your answer with your partners and then share your example with the class.

2. Study the photos in "Uses of Pulleys," on pages 110–111. Then answer the following questions in your science notebook:

A. What is a pulley?

B. How do pulleys help lift loads?

C. What determines how heavy a load a pulley can lift?

MATERIALS FOR LESSON 12

For you

- 1 copy of Student Sheet 12.1: How Is a Pulley System Used To Do Work?

For your group

- 1 K'NEX® sled (from Lesson 11)
- 1 pegboard assembly
- 4 pegboard hooks
- 2 large paper clips
- 1 0- to 2.5-N spring scale
- 1 0- to 10-N spring scale
- 1 piece of string
- 2 metersticks
- K'NEX® parts for movable pulley and fixed pulley assemblies (see Appendix A: Directory of K'NEX® Parts):
  - 6 gray connectors (C1)
  - 4 red connectors (C4)
  - 6 purple connectors (C6)
  - 6 blue connectors (C7)
  - 2 yellow connectors (C10)
  - 4 white rods (R2)
  - 6 blue rods (R3)
  - 4 red rods (R6)
  - 2 gray rods (R7)
  - 4 large wheels (W2)

USES OF PULLEYS

CORBIS/JOSEPH SOHM; CHROMOSOHM INC.

Pulleys are often used to lift things up very high.

CORBIS/JAMES L. AMOS

A pulley is a chain or rope wrapped around a wheel. A pulley can change both the amount of effort force needed to do a job and the direction in which the effort force is applied.

CORBIS/THE MARINERS' MUSEUM

The number and strength of supporting ropes in a pulley system determine how large a load the system can lift.

CORBIS/DEAN CONGER

Pulleys like the one on this crane make it possible to build skyscrapers.

CORBIS/JOEL W. ROGERS

Shipyards use cranes and pulleys to load and unload cargo.

Inquiry 12.1
Using Pulleys To Do Work

PROCEDURE

1. In this lesson, you will make a variety of pulley assemblies using K'NEX® parts. First, you need to construct the two pulley assemblies shown in Figures 12.1 and 12.2. Your teacher has a model of each assembly for you to study.

FIXED PULLEY, FRONT VIEW

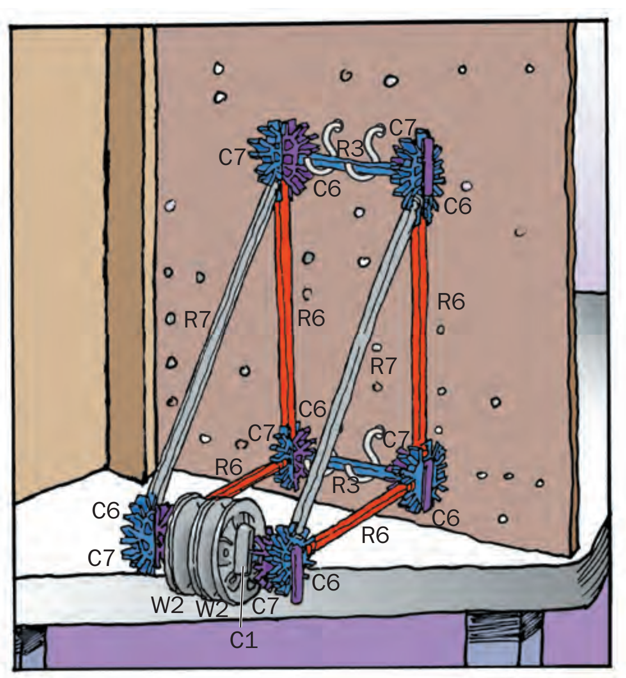


Figure 12.1 *Fixed pulley assembly*

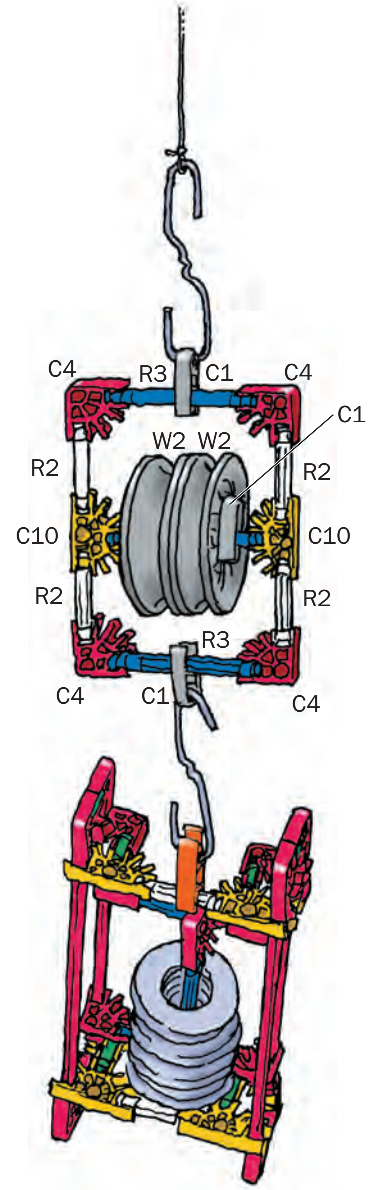


Figure 12.2 *Movable pulley assembly with the sled attached*

2. Attach the sled to the movable pulley assembly. Weigh the movable-pulley-and-sled combination (see Figure 12.3). To lift the pulley assembly, what load force must you exert? Record the load force in Table 1 on Student Sheet 12.1: How Is a Pulley System Used To Do Work?

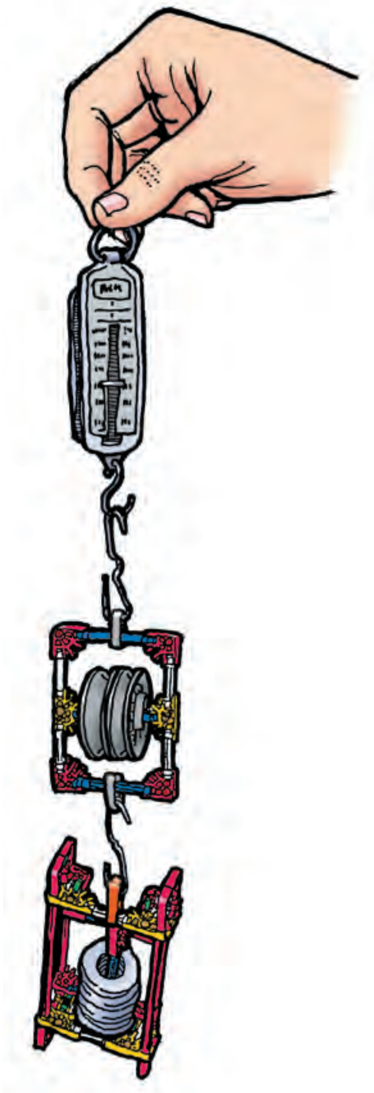


Figure 12.3 *Weighing the movable pulley assembly and sled*

3. Discuss with your partner why it is necessary to include the weight of the movable pulley in your measurement of load force.

4. Set up a single fixed pulley with the fixed pulley assembly attached to the pegboard, as shown in Figure 12.4. Use enough string so the movable-pulley-and-sled combination rests on the floor when the string is over the pulley.

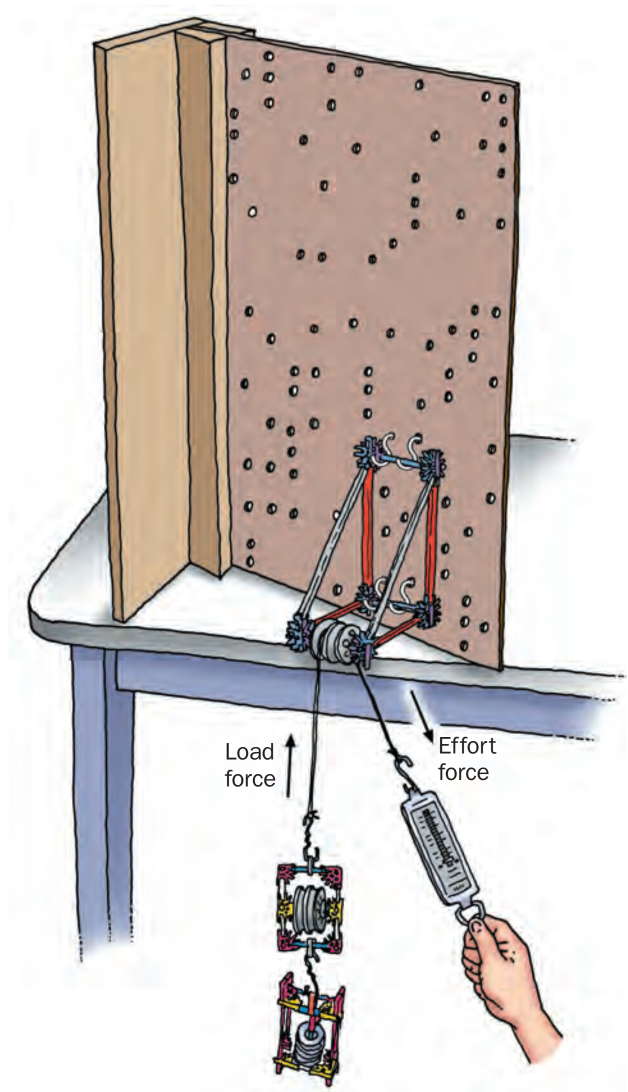


Figure 12.4 *Raising the movable-pulley-and-sled combination using a single fixed pulley*

5. Raise the movable-pulley-and-sled combination at a steady speed to a height of 0.10 m (10 cm) above the floor (see Figure 12.4). Work as a team to measure and record the following on your student sheet:

- how high the load rises (Record this as "Load Distance.")
- how much force the spring scale registers as a team member lifts the load (This is "Effort Force.")
- how far a team member's hand moves as the load rises 0.10 m (This is "Effort Distance.")

6. Answer the following questions in your science notebook:

A. How did the force you exerted compare with the weight of the movable-pulley-and-sled combination?

B. In what direction did the team member pull the string to raise the sled?

7. Set up the remaining three pulley systems one at a time as shown in Figures 12.5, 12.6, and 12.7. For each setup, measure the effort force and the effort distance needed to raise the movable-pulley-and-sled combination 0.10 m. Add these data to Table 1 on Student Sheet 12.1.

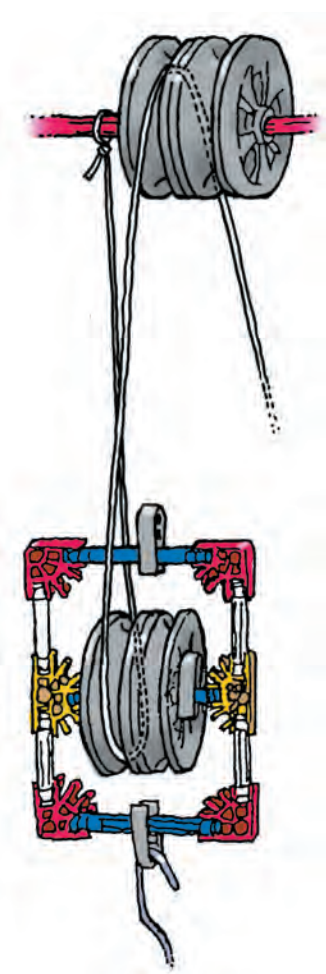


Figure 12.5 *Single fixed, single movable pulley setup*

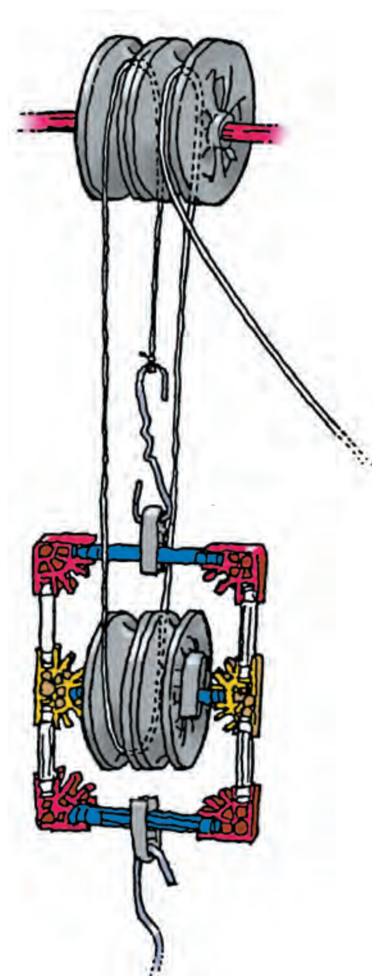


Figure 12.6 *Double fixed, single movable pulley setup*

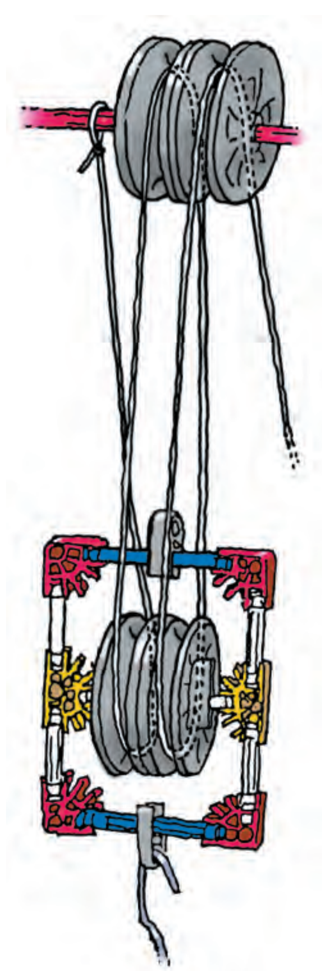


Figure 12.7 *Double fixed, double movable pulley setup*

8. Calculate the input work for each pulley arrangement in Table 1 on the student sheet. Input work is the work you did to lift the load. To compute this, multiply effort force by effort distance. Show your work in the "Calculations" column.

REFLECTING ON WHAT YOU'VE DONE

1. Discuss the following questions with your lab partners and record your group's responses in your science notebook:

   A. What did you observe about the effort force with the different pulley combinations?

   B. What happened to effort distance as you changed the pulley systems?

   C. What do your data tell you about the relationship between effort force and effort distance?

   D. Look at the input work done for each trial. Is it the same or different? Discuss this question with the class.

   E. Did the load force change each time? Did the work done to lift the load change each time?

2. On the basis of what you learned in this inquiry, write a definition of "machine" in your science notebook.

GOING UP!

It was May 1854. The World's Fair was being held in New York City. On display were the newest inventions from many countries. The crowds were amazed by the promise of technology.

A crowd gathered around a tall, dignified man in a top hat. He mounted a platform. As people looked on, the platform was slowly raised by a rope that was wrapped around a motor-driven drum.

When the platform had ascended well above the crowd, another figure standing on a landing above the platform suddenly reached out and slashed the heavy rope by which the platform was suspended. The crowd gasped.

The platform dropped—but only by a few centimeters. Then it came to a stop. "All safe, ladies and gentlemen, all safe!" the man on the platform proclaimed.

Elisha Otis demonstrates his "safety elevator" to an astonished crowd.

CORBIS/BETTMANN

This drawing shows how early elevators were used to lift people from one floor to the next in a building.

The man on the platform was Elisha Otis, and he'd just proudly demonstrated his invention—the safety elevator. His device would become the first public passenger elevator. Just three years after this dramatic demonstration, the first public passenger elevator was put into service at a New York City department store. By 1873, more than 2000 Otis elevators were being used in office buildings, hotels, and department stores.

An Elevator Fit for a King

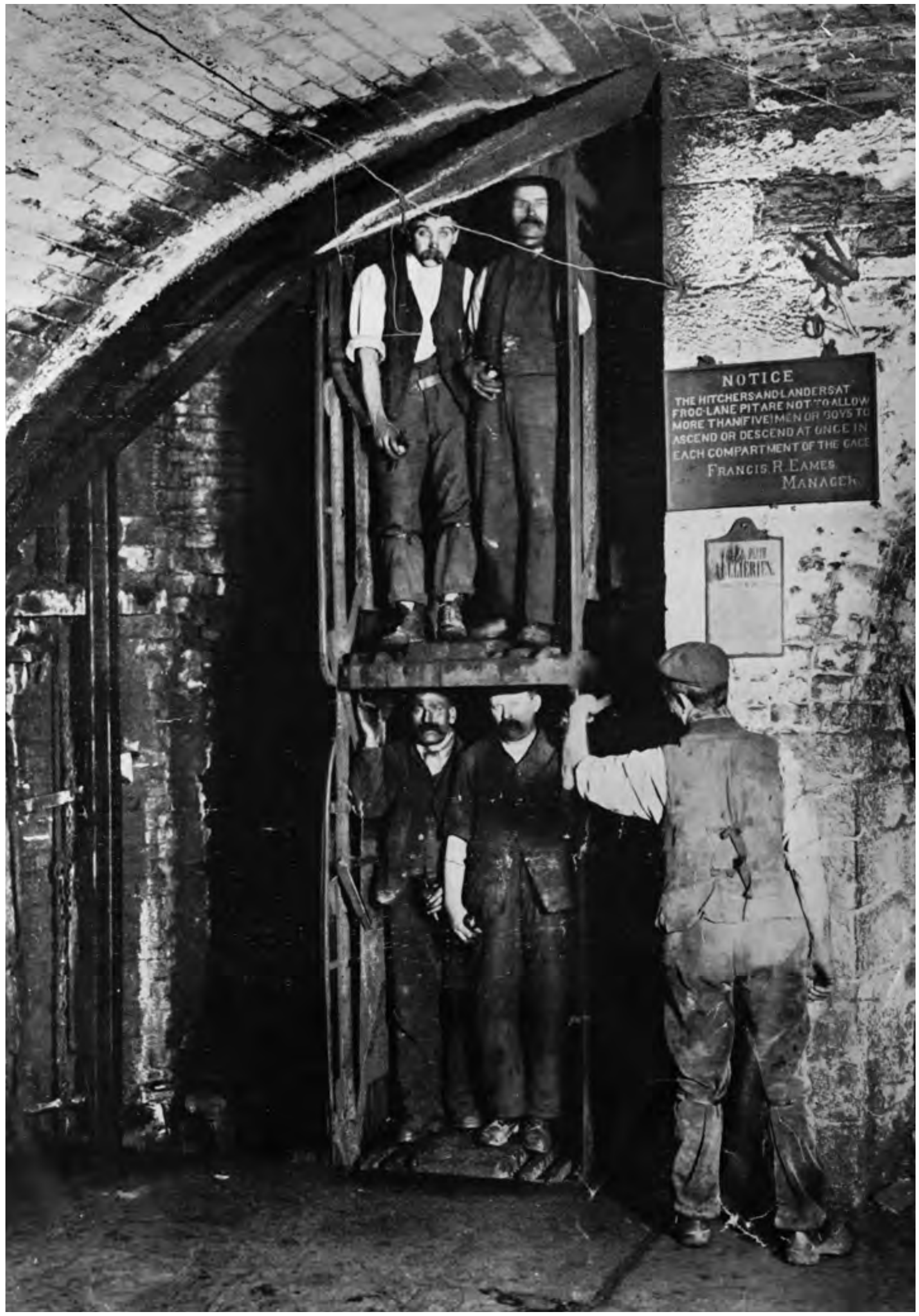
The earliest elevators were little more than lifting platforms. More than 2000 years ago, the Romans described lifting platforms that featured pulleys and rotating drums. The power for these devices was supplied by humans or animals. In 1743, France's King Louis XV had a private elevator built in his palace at Versailles. It was operated using human power. Servants pulled on ropes to lift and lower the king. Counterweights helped balance the weight of the king as he moved from floor to floor.

These early elevators had a simple design. The car was suspended by a rope or cable that ran over a pulley at the top of the elevator shaft. At the other end of the cable was a counterweight that balanced with the weight of the car plus the average weight of the load the elevator carried. The car and the counterweight were guided between rails to keep from swinging freely.

Putting on the Brakes

Beginning in 1830 or so, freight elevators were in common use. But all these elevators, including the one used by King Louis XV, had a big drawback: If the rope from which they were suspended snapped, the elevator went crashing to the ground. There was nothing to cushion or stop its descent.

That's why Otis's invention was so important. His safety elevator had something that none of the earlier models did—a brake. If the rope broke, a large spring forced two large latches to lock into ratchets on the guide rails. These latches kept the elevator from falling.



CORBIS/HULTON-DEUTSCH COLLECTION

This elevator was used in about 1900 to carry miners to the pits far below ground.

New Forms of Power

The earliest passenger elevators were powered by steam engines. As years passed, other power sources were used. Water pressure was tried. The invention of electric-powered elevators, like Otis's safety device, was an important advance in elevator technology.

The invention of the electric-powered elevator for passengers had a strong effect on city living. Before it came into use, most buildings were no more than four stories high. People just couldn't huff and puff their way up any more flights of stairs! The lack of appropriate building materials was another drawback to the growth of tall buildings.

Changing the Landscape—And People's Lives

By the beginning of the 20th century, the word "skyscraper" had entered the English language. Buildings were built taller and taller—and, thanks to elevators, people could make their way easily to the top. Additional refinements included self-opening doors, an automatic leveling feature, and faster speeds. Modern elevators travel up to 600 meters a minute.

Today, you can zoom to the top of the Washington Monument or the Empire State Building and back in minutes, thanks to electric-powered elevators. And, thanks to Elisha Otis, you can be assured of a safe trip in both directions. □

CORBIS/THE PURCELL TEAM

Safe elevators made living and working in tall buildings practical.

QUESTIONS

1. How are pulleys used in elevators?
2. What is the purpose of the counterweight in an elevator?
3. What has been the impact of elevators on building design?