





PART 2 Machines

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The Inclined Plane



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Inclined planes make getting around easier.

INTRODUCTION

Have you ever used a machine to do a job? What kind of machine was it? What did it do for you? What exactly do machines do?

In the next three lessons, you will explore these questions by investigating how three simple machines—inclined planes, pulleys, and levers—operate. Understanding simple machines will help you understand more complex machines, such as bulldozers, cranes, and bicycles. Later in this module, you will have the opportunity to use a machine and a motor together.

You will begin your investigation of machines by focusing on the inclined plane. Inclined planes are ramps. You see them everywhere. Many places have ramps to help physically disabled people enter and exit buildings. Sometimes people use ramps to move heavy loads. If you had to raise a heavy load to some height, would you rather lift it straight up or push it along an incline? Think about that as you do this inquiry.

OBJECTIVES FOR THIS LESSON

Learn how an inclined plane works.

Investigate how the force to pull a load up an incline depends on the slope of the incline.

Compare the work done in pulling a load up an incline with the work done in lifting the load straight up.

Getting Started

1. Review what you wrote in your science notebook about frictional force in Lesson 6. Then discuss this with your lab partner and the class.

2. Discuss the following questions with the class:

A. Have you ever seen a ramp used to move an object or a person onto a platform or to a higher position? If so, where?

B. Did the ramp have a gentle slope or a steep slope?

C. Why do you think a ramp was used?

3. Have your science notebook ready so you can record your data and answers to questions in Inquiries 11.1 and 11.2.

MATERIALS FOR LESSON 11

For you

- 1 copy of Student Sheet 11.1: Forces on a Cart on the Inclined Plane
- 1 copy of Student Sheet 11.2: What Is the Work Done Using an Inclined Plane?

For your group

- 1 inclined plane (wooden board)
- 1 pegboard double loop hook
- 1 K'NEX® sled (from Lesson 8)
- 1 pegboard assembly
- 1 large paper clip
- 1 0- to 2.5-N spring scale
- 1 0- to 10-N spring scale
- 1 meterstick
- 2 pieces of masking tape
- Additional K'NEX® parts for wheel assembly (see Appendix A: Directory of K'NEX® Parts):
 - 4 gray connectors (C1)
 - 2 red rods (R6)
 - 4 small wheels (W1)

Inquiry 11.1

Measuring Forces on a Cart on an Inclined Plane

PROCEDURE

1. For this inquiry, you will use the sled you built in Lesson 8. Attach a spring scale to the sled's orange connector and measure the force required to pull the sled at a steady speed across a table. Record this force in your science notebook.
2. Why does it take this force to move the sled?
3. Now add wheels to your sled to turn it into a "cart," as shown in Figure 11.1.
4. Use the spring scale to measure the force needed to pull the cart at a slow, steady speed across the tabletop. Record the force in your science notebook.
5. The force you exert to pull the sled or cart is called the effort force. How does the effort force needed to pull the cart compare with the effort force needed to pull the sled? Why was there a difference between the two forces?
6. Using the double loop hook, attach the inclined plane to the pegboard, as shown in Figure 11.2. Now place the cart on the inclined plane. Measure and record the force required to hold the cart on the plane. What creates the force on the cart on the inclined plane?

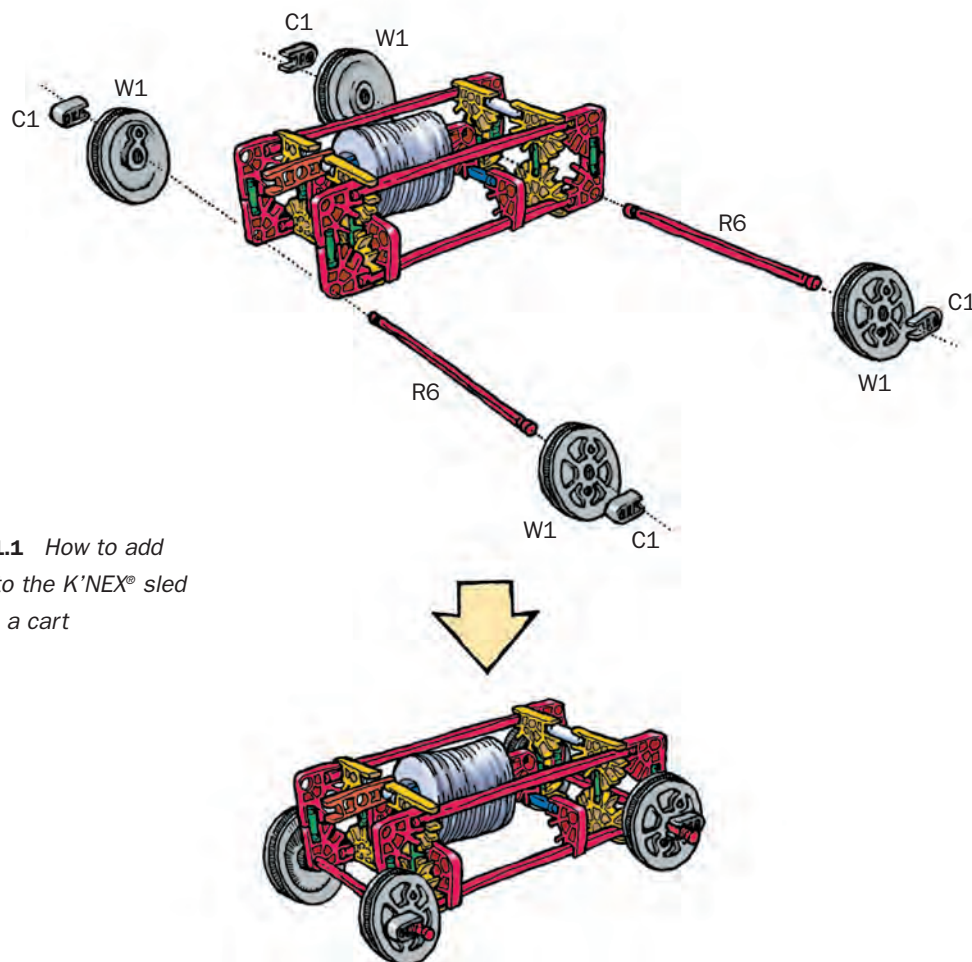


Figure 11.1 How to add wheels to the K'NEX® sled to make a cart

7. Suppose you pulled the cart up an inclined plane like the one shown in Figure 11.2. How do you think the effort force needed to pull the cart up the incline at a slow, steady speed would compare with the effort force needed to move the sled across the table? Explain your reasoning.
8. Test your prediction and record the results.
9. What do you predict will happen to the effort force required to move the cart up the inclined plane if the slope of the incline is increased? Develop your prediction with your lab partners and record your prediction on Student Sheet 11.1: Forces on a Cart on the Inclined Plane.
10. Design a procedure to test your prediction. Use equipment in the materials list for this inquiry. Describe your procedure in the space provided on your student sheet. Make sure your procedure describes the way you will measure the slope of the incline.
11. Draw a data table on the student sheet to record your measurements.

12. Carry out your procedure and test your prediction.

13. Examine your results and decide with your partner how you will analyze your data. Explain or show your analysis of your data on your student sheet.

14. On your student sheet, write a conclusion supported by your data about effort force to move the cart along the incline and the slope of the incline.

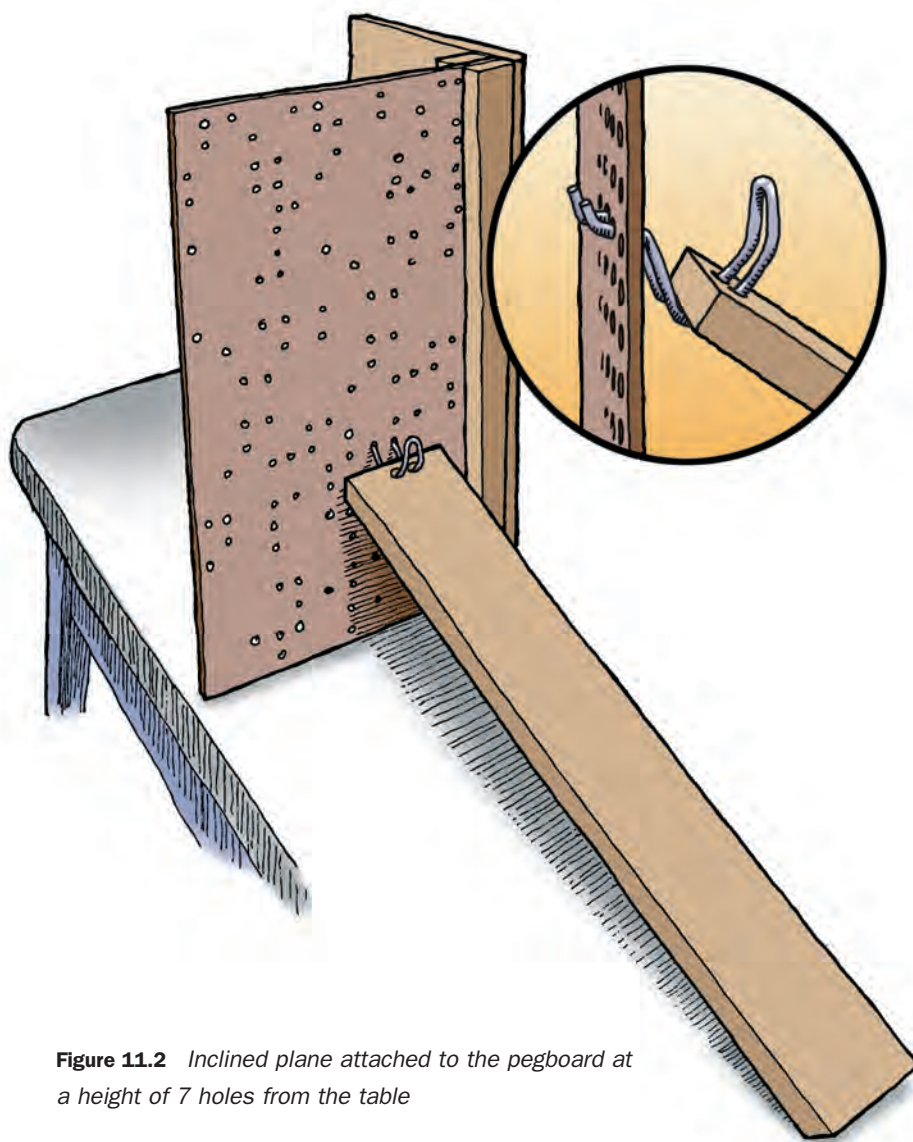


Figure 11.2 Inclined plane attached to the pegboard at a height of 7 holes from the table

Inquiry 11.2

Measuring Work on a Cart on an Inclined Plane

PROCEDURE

1. Record your data, calculations, and answers for this inquiry on Student Sheet 11.2: What Is the Work Done Using an Inclined Plane?
2. In this inquiry, you are asked to lift a cart, or load, a vertical distance of 0.10 meter (m) each time. This vertical distance to which you lift the cart is called the *load distance*. The force you need to exert to lift the cart straight up is called the *load force*. Figure 11.3 shows how to measure load force and load distance.

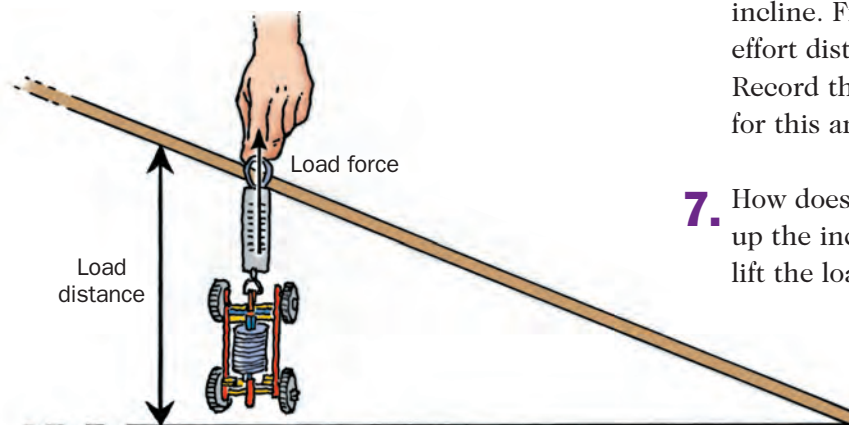


Figure 11.3 How to measure load force and load distance

3. Use the spring scale to measure the force to lift the cart straight up through a distance of 0.10 m. Use the load force and load distance to calculate the amount of work to lift the cart.
4. Instead of moving the cart straight up, suppose you pulled the cart up the incline so it moved 0.10 m vertically. Would the work you did pulling it up the incline be more, less, or the same as the work needed to lift

the cart 0.10 m straight up? Record your prediction and explain your reasoning.

5. Set up the pegboard and inclined plane so the inclined plane is attached at hole 7, counting from the bottom of the pegboard. Place the cart on the inclined plane and hold it so it does not roll down the incline. Discuss with your group how you can tell when the cart has moved the load distance (0.10 m straight up) when you pull the cart up the incline. Share your ideas with the class.
6. Now pull the cart up the incline so that it moves a load distance of 0.10 m. Measure the distance the cart moves along the incline. This distance is the *effort distance*. The spring scale measures the *effort force* needed to pull the cart up the incline. Figure 11.4 shows effort force and effort distance on an inclined plane. Record the effort force and effort distance for this angle of the incline.
7. How does the work done to pull the cart up the incline compare with the work to lift the load straight up?
8. Repeat these measurements of effort force and effort distance with different slopes of the incline. Set the inclined plane at four different slopes, and each time record the effort force and effort distance to raise the cart 0.10 m along the incline. Figure 11.5 shows different inclines positioned so the load distance is constant at 0.10 m while the angle of incline changes. For each slope, measure the effort distance and the effort force while raising the cart the load distance (0.10 m) each time.

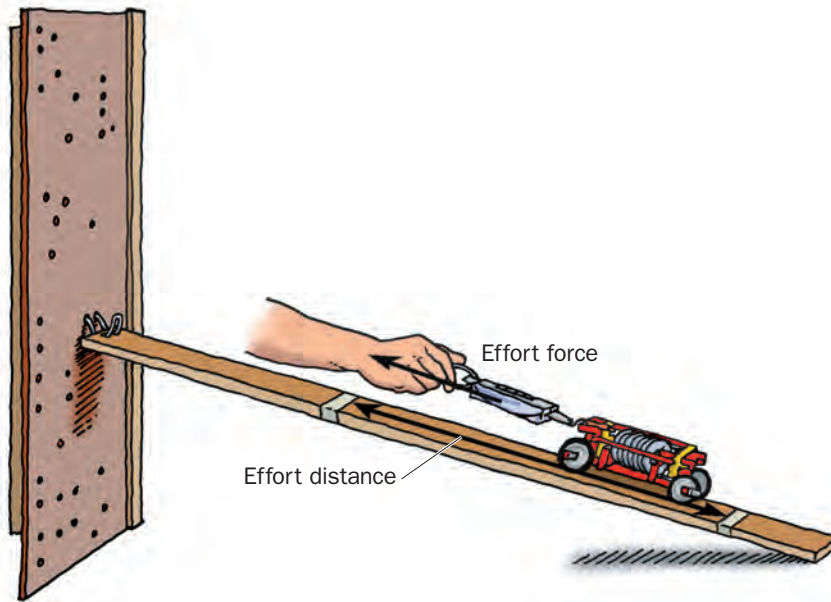


Figure 11.4 Effort force and effort distance on an inclined plane

9. Complete Table 1 on Student Sheet 11.2 by calculating the work you did each time you applied the effort force along the plane. Remember: Use newtons (N) to measure force and meters (m) to measure distance. Calculate work in newton-meters (N-m) or joules (J). If a force of 1 N moves an object 1 m, then 1 N-m or 1 J of work is done. Be sure to use the correct units in your data table.

10. How does the work needed to pull the cart up the inclined plane compare with the work needed to lift the cart straight up? With the rest of the class, develop an explanation of your results. Record your answers in your science notebook.

REFLECTING ON WHAT YOU'VE DONE

Answer the following questions in your science notebook.

- A. On the basis of the results of these inquiries, how would you define a machine?
- B. In your view, is an inclined plane a machine?
- C. Why are ramps for people with physical disabilities long and gently sloping, rather than short and steep?
- D. Suppose you repeated Inquiry 11.2 with a sled instead of a cart. Would you get different results? If so, how would they be different?

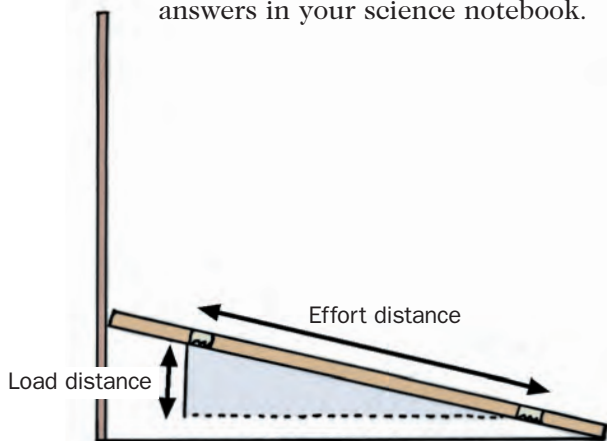
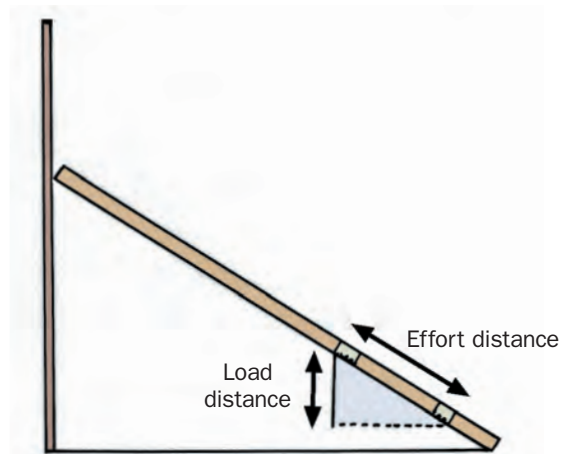


Figure 11.5 For the same load distance, the effort distance changes when the slope of the incline changes. What happens to the effort force when the slope of the inclined plane changes?



Escape Route in Johnstown

A century or so ago, the little city of Johnstown, Pennsylvania, was a disaster waiting to happen. Like many other American cities, Johnstown had been established in a river valley. The Little Conemaugh River, which ran through the city, had always been prone to flooding. As the city grew, the banks of the river were narrowed to make room for more buildings. The possibility of flooding increased. The South Fork Dam, which held back the river and formed a lake about 22 kilometers upstream, was poorly maintained.

May 1889 was a rainy month in Johnstown. At 4:00 P.M. on May 31, the dam broke and released 20 million tons of water into the narrow valley.

The resulting flood and fires killed more than 2200 people.

Finding a Solution

The people of Johnstown knew that a disaster like the flood of 1889 could happen again. They needed a plan. They decided that the solution would be to have a way to get people out of the city quickly in the case of another flood. An inclined plane would do the trick, they reasoned.

They hired the Cambria Iron Company to build the inclined plane. Two years later, the work was completed. The inclined plane, measuring nearly 300 meters in length, was designed



Flood damage in Johnstown, Pennsylvania, in 1889

JOHNSTOWN AREA HERITAGE ASSOCIATION ARCHIVES, JOHNSTOWN, PENNSYLVANIA

as a modified railroad. To match the steepness of the valley, the inclined plane was built at a grade of 71 percent. This earned it a spot in *The Guinness Book of World Records* as the steepest vehicular inclined plane in the world.

Riding in a railroad car that goes up at a sharp angle would be uncomfortable. To make the ride easier, the cars for the inclined plane were specially designed to stay level as they descend into and climb out of the valley. Each car can hold up to 15 tons of cargo, including people, bikes, cars, and—originally—horses and wagons.

Today the Johnstown inclined plane is mainly a tourist attraction. But during floods in 1936 and 1997, it was used successfully to evacuate valley residents and to carry rescue personnel, equipment, and supplies into the valley. □

QUESTIONS

1. In what parts of the world besides Johnstown, Pennsylvania, do you think you might find vehicular inclines?
2. Visit the Internet and see if you can find an example of another vehicular incline. Where is it? How steep is it? How long?



The Johnstown Vehicular Incline

JOHNSTOWN INCLINED PLANE, INC.