ACTIVITY 5

Wheels Overcome Friction

OBJECTIVES

Students discover how wheels reduce friction.

The students

- measure the amount of force it takes to drag a load
- measure the amount of force it takes to roll a load on dowels
- conclude that even the most primitive wheels reduce friction between an object and the surface over which it moves

SCHEDULE

About 40 minutes

VOCABULARY

roller
wheel

MATERIALS

For each student

1	Activity Sheet 5

For each team of four

1	brick, half
6	dowels
1	plastic ring
1	push-pull meter
1 roll	string
1	transparency, Egyptian Pyramid

For the class

	pictures of pyramids (optional)*
1	projector, overhead*
1 pair	scissors*
	world map or globe (optional)*

*provided by the teacher

PREPARATION

1. Make a copy of Activity Sheet 5 for each student.
2. Cut one 1-m (3-ft) length of string for each team of four.
3. Arrange to have an overhead projector in the classroom for showing the Egyptian Pyramid transparency. As an option, you might also look in books and magazines for pictures of the Egyptian pyramids for students to examine at the start of the activity.
4. Each team of four will need a push-pull meter, a length of string, a plastic ring, a half brick, and six wooden dowels. (Replace any push-pull meter rubber bands that have become stretched.)

BACKGROUND INFORMATION

When we think of wheels, we usually think of the disk-shaped objects attached to bicycles and cars. But a ***wheel*** is any circular object that turns around a center point. A wheel may be spherical, like a ball, or cylindrical, like a pipe. It may be solid or hollow. Some wheels turn so fast you can hardly see them spin. Others turn so slowly they seem to be barely moving.

The wheel has been around for nearly 6,000 years and is considered one of the greatest inventions of humankind. The ancient Egyptians must have thought so. When building their

pyramids, they knew that it was much easier to roll a heavy block of stone over tree trunks than it was to drag it over the ground.

The ancient Egyptians used the tree trunks as ***rollers***—cylindrical-shaped wheels—to reduce the friction between the stone block and the ground. You can feel the difference between rolling and dragging every time the wheel on your shopping cart jams.

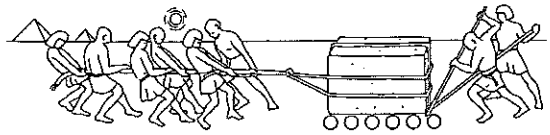
A wheel by itself is not a simple machine. No force is transferred or modified by a rotating wheel. Instead, a rotating wheel can make work easier by reducing the friction between an object and the surface over which it moves.

A wheel reduces friction by allowing the contacting surfaces to roll rather than to drag or slide over each other. By reducing friction, a wheel can enable you to use less force to move an object. The less force you use to move an object, the easier your work becomes.

In this activity, students experiment with a primitive type of wheel called the roller. They use their push-pull meters to compare the amount of force it takes to drag a load and to move it on rollers.

▼ **Activity Sheet 5**

Wheels Overcome Friction



1. This building stone is very heavy and hard to move! How could these workers make it easier to move the stone?
   Possible answer: using animals instead of people to pull the stone, using more people to push and pull the stone, and so on
2. Why doesn't your brick slide easily? Friction between the brick and the desktop/floor keeps the brick from sliding easily.
3. How much force did it take to drag the brick?
   about 6 $^{1}/_{2}$ units of force
4. How much force did it take to roll the brick on dowels?
   about 1 $^{1}/_{2}$ units of force
5. A roller is a kind of wheel. How do wheels make it easier to move things?
   by reducing the friction between the object and the surface over which it moves
6. Now you know how the workers moved the building stone with less force. Finish the picture above by drawing the missing parts. rollers beneath the stone

Guiding the Activity

1 Look at Project the Egyptian Pyramid ~~transparency~~ Picture ~~on a light-colored wall~~. Tell students that these structures were built by Egyptians over 5,000 years ago. Each one is made of millions of blocks of stone, some weighing more than 20 tons.

Add that the workers who built these great monuments did not have heavy machinery like trucks or forklifts or cranes to transport the stones from the quarries (where they were removed from the ground) to the building sites. Ask, **How do you think they moved the stones?**

Additional Information

You may want to show students where Egypt is on a map or globe.

Students may suggest that they used a lot of people or animals to drag them, or that they floated them on barges. Accept all answers.

Guiding the Activity

Additional Information

Distribute a copy of **Activity Sheet 5** to each student. Bring students' attention to the drawing at the top of the sheet. Explain that the ancient Egyptians did indeed pull the building stones by ropes. Ask, **How could these workers make it easier to move this stone?** Have students write their thoughts on question 1 of the activity sheet.

Students may suggest using horses or oxen, or perhaps adding more workers to push and pull on the stone.

Ask, **How could these workers make it easier to move the stone without adding any more people or animals?**

Accept all answers. Remembering the previous activity, some may suggest using a lubricant like grease or oil to help the stones slide.

Tell students that in this activity they will learn how the ancient Egyptians made the hard work of building pyramids a little easier.

2

Divide the class into teams of four. Distribute a half-brick and a length of string to each team. Ask students to imagine that the brick is a 20-ton building stone and the string is a thick rope.

Note: *If your classroom is carpeted, you may need to find a different location for this activity. If you are concerned that the bricks may scratch desktops, you can perform the activity on large sheets of paper or another surface of your choice.*

Tell students to tie one end of the string around the brick and to pull the brick across their desks or the floor. Ask, **What keeps the brick from sliding easily?** Ask students to write their answer to question 2 on their activity sheets.

Friction between the brick and the surface over which it moves.

Next, distribute a push-pull meter and a plastic ring to each team. Tell students to clip the ring onto the rubber band of the push-pull meter. Have students tie the free end of the string to the plastic ring.

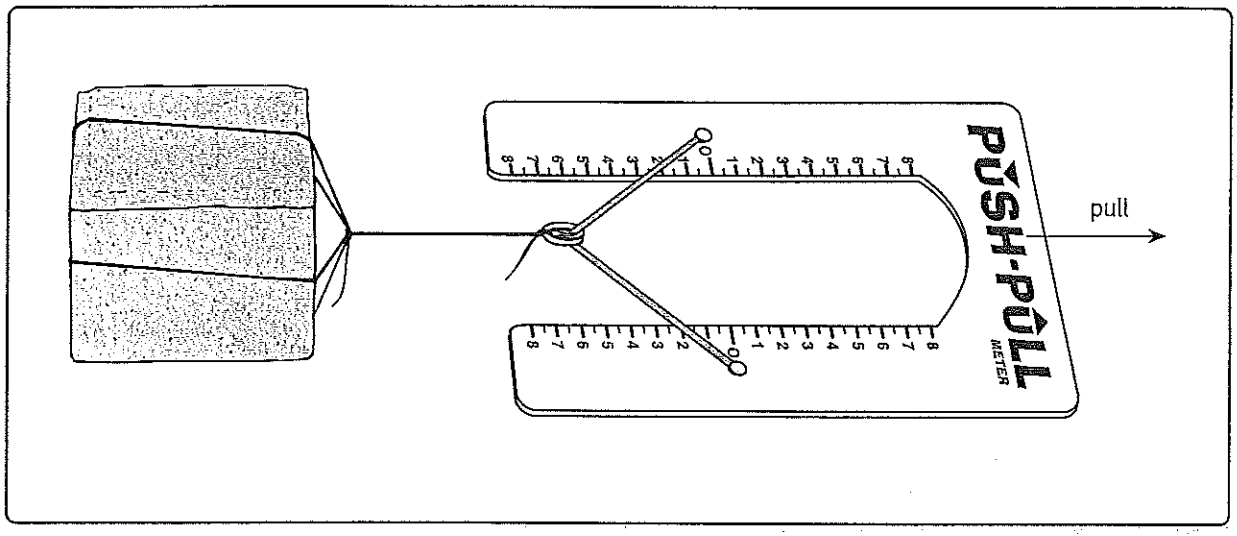
done

Tell students to use their push-pull meters to measure the amount of force it takes to drag the brick across their desks or the floor (see Figure 5-1). Tell them to record their measurement on question 3 of the activity sheet.

Remind students to pull the brick with a smooth, steady motion.

Guiding the Activity

Additional Information



▲ *Figure 5-1. Measuring the amount of force it takes to drag the brick.*

3 When students have finished, ask, **How much force did it take to move the brick?**

It probably took between 4 and 8 units of force, although answers may vary.

Ask, **How can we reduce the amount of force it takes to move this brick?**

by reducing the friction between the brick and the table

~~Remind students of the motion lotion they used in the previous activity to reduce friction~~. Ask, **Do you suppose the Egyptians used lubrication between each stone and the ground?**

No. That wouldn't be practical.

4 Distribute six wooden dowels to each team. Tell students to line up the dowels side by side, about an inch apart. Tell students to place the brick on the dowels and give it a little push. Then ask, **Do you think it takes more force or less force to move the brick with the dowels?**

It takes less force.

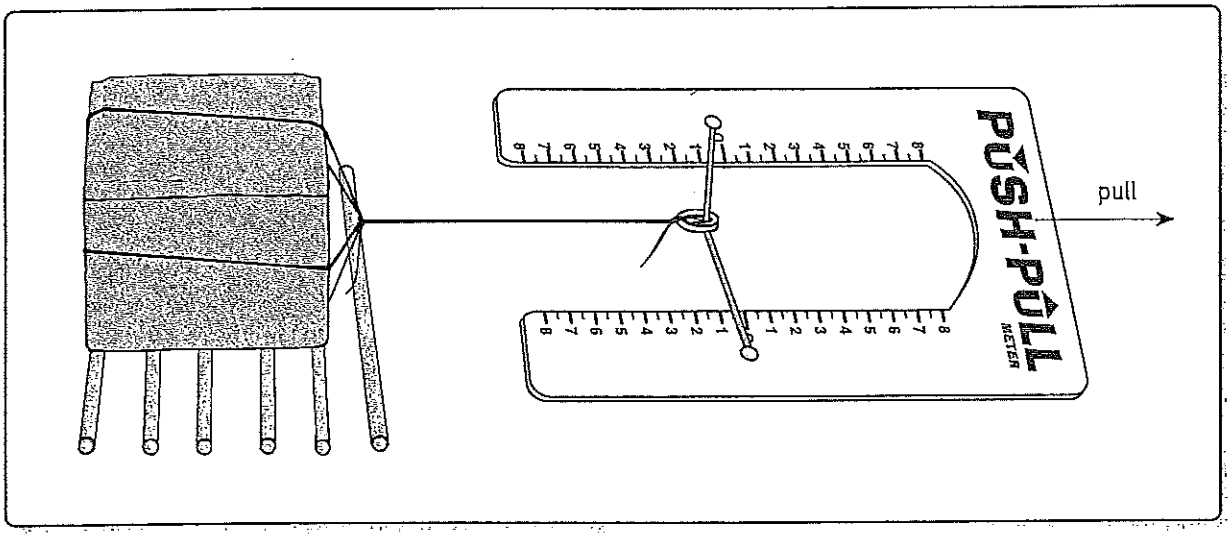
Tell students to use their push-pull meters to measure the amount of force it takes to move the brick over dowels (see Figure 5-2). Have them write their measurement on question 4 of the activity sheet.

Guiding the Activity

Additional Information

5 When students have finished, ask, **Which took less force: dragging the brick or rolling it on dowels?**

Students should have discovered that it takes much less force to roll the brick on dowels than it does to drag it. Rolling probably requires about 1 unit of force.



▲ *Figure 5-2. Measuring the amount of force it takes to roll the brick.*

~~Write the word *roller* on the board~~. Tell students that the dowels were used as rollers to move the brick. A **roller** is a tube-shaped wheel. Write the word *wheel* on the board. Ask, **What is a wheel?**

Students will probably say it is a round object that spins or rolls.

Tell students that a **wheel** is any circular object that spins around a center point, or axis.

Explain that the ancient Egyptians made rollers from tree trunks stripped of their bark and branches. They used the rollers like wheels to move the heavy building blocks. Ask, **How do wheels make it easier to move heavy things?** Tell students to write their answer to question 5 on the activity sheet.

The wheels reduce the friction between the object and the surface over which it moves, thereby reducing the amount of force needed to move the object.

Guiding the Activity

Additional Information

6 Have students unhook the push-pull meter and set it aside. Tell them to line up the dowels side by side on the floor and place the brick on top of the dowels, like before. Then instruct students to work as a team to slowly pull their brick a distance ~~of about~~ across the table ~~1 m (3 ft) across the floor.~~ (Show them the approximate distance using your hands.)

7 When students have finished, ask, **What is one drawback of using rollers to move an object?**

As the object passes over the rollers, the rollers in back must be moved to the front again.

Have students complete the activity sheet. Tell them that in the next activity, they will learn about a second type of simple machine, called the wheel and axle.

ACTIVITY 9

Inclined Planes

OBJECTIVES

Students are introduced to a fourth type of simple machine: the inclined plane.

The students

- measure the amount of force it takes to lift a load
- measure the amount of force it takes to drag the same load up an inclined plane
- discuss the tradeoff of force for distance when using an inclined plane

SCHEDULE

About 30 minutes

VOCABULARY

inclined plane

MATERIALS

For each student

1	Activity Sheet 9, Parts A and B

For each team of four

1	board, long
1	board, short
	books, about a 4-in. stack*
1	brick, half
1	push-pull meter
1	ruler, dual-scale*
1	S-hook

For the class

1	projector, overhead*
16	rubber bands, small
1	ruler, dual-scale*
1 pair	scissors*
1 roll	string
1	transparency, Egyptian Pyramid

*provided by the teacher

PREPARATION

1. Make a copy of Activity Sheet 9, Parts A and B, for each student.
2. For each team of four, cut one length of string 1 m (3 ft) long.
3. To make the push-pull meters strong enough to lift the bricks, add two more rubber bands to each meter before beginning the activity (three rubber bands per meter).
4. Each team of four will need a brick half, a length of string, an S-hook, a push-pull meter, a ruler, a stack of books about 4 inches high, a short board, and a long board. Arrange to have an overhead projector in the classroom for showing the Egyptian Pyramid transparency.

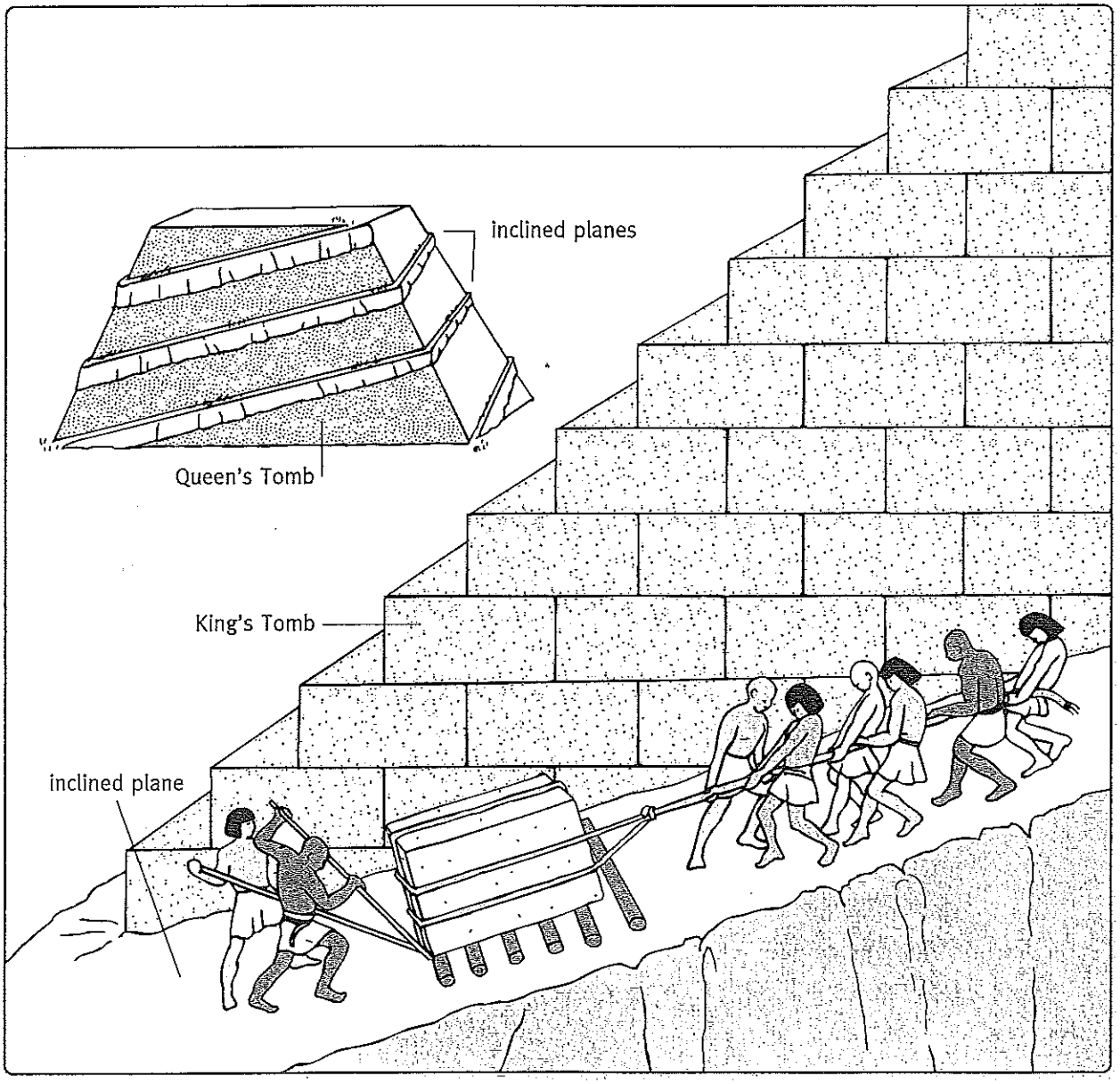
BACKGROUND INFORMATION

A fourth type of simple machine is the ***inclined plane,*** commonly called the ramp. An inclined plane is a flat surface that slants, or slopes. The inclined plane is the only simple machine that does not move. Instead, objects are moved over it in an effort to raise them.

Inclined planes are used to help us lift heavy things using less effort. That is because it takes less force to drag an object up an inclined plane than it does to lift it straight up. However, the object must be moved a greater distance. In other words, an inclined plane can help make work easier by reducing the amount of force it takes to raise an object, but the force must be applied over a greater distance.

The inclined plane is one of the simplest of simple machines, and probably the oldest. The ancient Egyptians used inclined planes to help them raise heavy building stones into place. They built ramps made of mud around the perimeter of the structure, then hauled the stones on sleds or rollers up the ramp to where they were needed. Figure 9-1 shows how ramps were used in the construction of an Egyptian king's tomb (the larger pyramid) and a queen's tomb (the smaller pyramid).

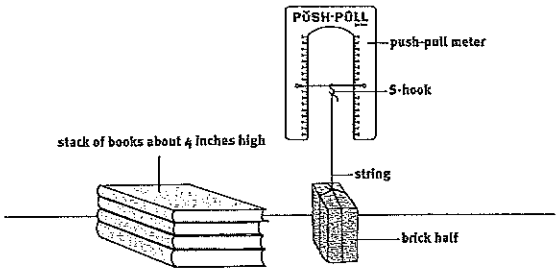
In this activity, students will see for themselves how an inclined plane can make lifting a building block a little easier.



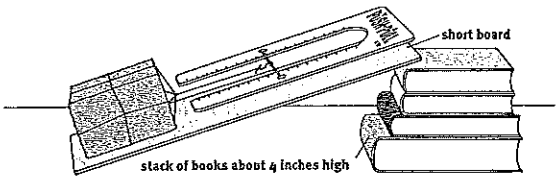
▲ *Figure 9-1. Inclined planes were used in the construction of the pyramids.*

▼ **Activity Sheet 9, Part A**

Inclined Planes



1. Lift the brick to the top of the books.
   Amount of force needed to lift brick: $7\frac{1}{2}$ units
   Distance brick was lifted: 4 inches



2. Drag the brick up the inclined plane to the top of the books.
   Amount of force needed to drag brick: 4 units
   Distance brick was dragged: 14 inches

▼ **Activity Sheet 9, Part B**

Inclined Planes

3. How can you make it even easier to drag the brick to the top of the books?
   Use a longer inclined plane.

   Amount of force needed to drag brick: $3\frac{1}{2}$ units
   Distance brick was dragged: 24 inches

4. How do inclined planes make work easier?
   by reducing the amount of force needed to raise an object

5. What is the *tradeoff* when using an inclined plane?
   You can use less force to raise an object, but the object must move a greater distance.

Guiding the Activity

Additional Information

1 Divide the class into teams of four. ~~Project~~ the Egyptian Pyramid ~~transparency~~ picture for students to examine again.

Remind students that the building blocks that make up these massive structures weigh up to 20 tons each, and that the ancient Egyptians had no heavy machinery to help them move the stones. Ask students, **How did the ancient Egyptians transport the stones to the building site?**

Students should recall from Activity 5 that they used rollers. Ancient Egyptians rolled the blocks of stone on tree trunks.

Bring students' attention to the pointed shape of the pyramid. Tell students that the largest pyramid ever built is approximately 482 ft high—about the height of a modern thirty-story building. Ask, **How do you think the workers lifted the heavy stones to the top of the structure?**

Accept all reasonable answers.

Tell students that this activity will show them how.

Guiding the Activity

Additional Information

2 Distribute a copy of **Activity Sheet 9, Parts A and B,** ~~to each student, and a ruler, a push-pull meter, a length of string, an S-hook, and a half-brick to each team.~~ will be ready

blocks of wood

Tell each team to stack ~~some books~~ on their desk to a height of about 4 inches. (Show them an example of a 4-in. stack.) ~~Then have them tie the string around the brick and connect the brick to the push-pull meter with the S-hook.~~

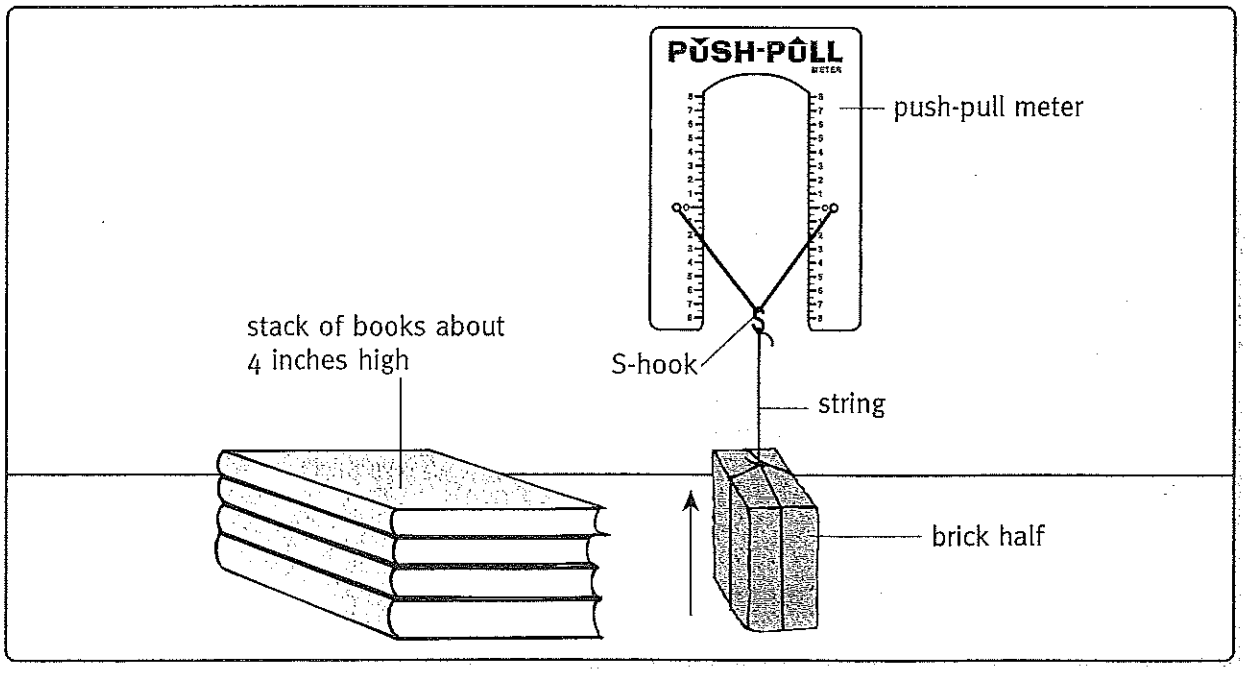
Note: The reinforced push-pull meters should all have three rubber bands, not one.

Tell students to use the push-pull meter to measure the amount of force it takes to lift the brick straight up to the top of the ~~books.~~ blocks Ask them to record the amount of force in question 1 on their activity sheet (see Figure 9-2).

When students have finished, ask, **How much force did it take to lift the brick?**

It should have taken about 7½ units of force to lift the brick.

Next, have students measure the distance that the brick was moved. This is the distance from the desktop to the top of the stack of wood ~~books~~ about 4 inches. Tell students to record this distance in question 1 of their activity sheet.



▲ *Figure 9-2. Measuring the amount of force it takes to lift the brick.*

Guiding the Activity

Additional Information

Now ask students to imagine that this brick is an ancient building stone, and the stack of books is a pyramid in progress. Ask, **How could you make it easier to lift the stone to the top of the pyramid?**

Students may mention using simple machines that they have already learned about, such as a wheel and axle, a lever, or a pulley. Accept all reasonable answers.

3

Distribute a short board to each team. Tell the teams to place the board against the stack of books to make a ramp. Tell students that this ramp is really a simple machine called an inclined plane. Write the words *inclined plane* on the board.

Explain that in this sense of the term, the word *plane* means "flat surface." Ask, **Does anyone know what the word *inclined* means?**

It means "sloped" or "slanted."

Tell students that an **inclined plane** is a flat surface that slopes or slants. Ask, **Where have you seen inclined planes used before?**

Students should mention ramps they have seen in everyday life: on the back of trucks, at the entrance to buildings, at curbsides, in parking garages, on playgrounds (slides), and so on.

4

Tell students to place the brick at the end of the board that rests on the desk. Have one student hold the board to keep it from slipping while another student drags the brick up the board with the push-pull meter (see Figure 9-3).

Tell students to measure the amount of force it takes to drag the brick up the inclined plane to the top of the ~~books~~ wood blocks. Tell them to record the amount in question 2 of their activity sheets.

When all teams have finished, ask, **How much force did it take to move the brick to the top of the ~~books~~ wood blocks using an inclined plane?**

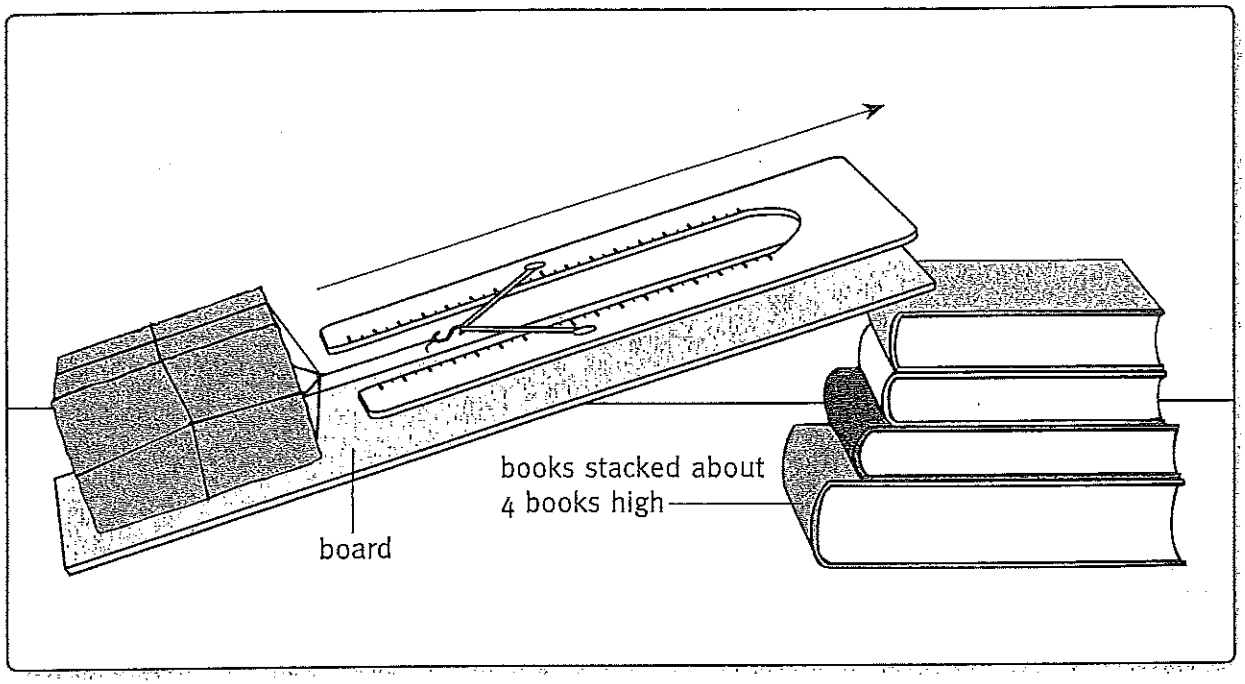
It should have taken about 4 units of force.

Have students measure the distance that the brick was dragged—which is the length of the inclined plane. Tell them to record this distance in question 2 of the activity sheet.

The brick was moved a distance of 14 inches.

Guiding the Activity

Additional Information



▲ *Figure 9-3. Measuring the amount of force it takes to drag the brick up an inclined plane.*

5 Have students examine the results of their experiments on the activity sheet. Ask, **Was it easier to lift the brick or drag it up an inclined plane?**

Students should recognize that it took less force to drag the brick up the inclined plane than it did to lift it.

Ask, **How far did the brick move each time?**

The brick moved farther when it was dragged up the inclined plane than when it was lifted.

Tell students that the ancient Egyptians built mud ramps against the sides of the pyramids. They placed the building stones on rollers or wooden sleds and dragged the sleds up the ramps to where the stones were needed on the pyramid.

6 Ask students, **How can we make it even easier to move the brick to the top of the books?**

Some students may suggest using a longer inclined plane. Accept all reasonable answers.

Distribute a long board to each team, and tell them to repeat step 4. Instruct them to record their results in question 3 of the activity sheet. Then, when students have finished, review their results as a class.

Students should note that it takes even less force (about 3½ units) to move the brick up a 2-ft board, but that the brick must be moved an even greater distance.

Finally, ask, **How do inclined planes make your work easier? What is the tradeoff?**

Inclined planes make work easier by reducing the amount of force needed to raise an object. The tradeoff is that the force must be applied over a greater distance—that is, over a longer inclined plane.