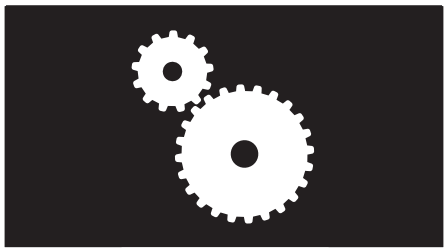
Hands-On Science



Simple Machines

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TEACHER RESOURCE PAGE

Instructional Objectives

Students will be able to:

- calculate the mechanical advantage of a flight of stairs
- calculate the effort force of one's legs when using a flight of stairs

National Science Education Standards Correlations

Grades 5–8

Content standard	Bullet number	Content description	Bullet number(s)
A	1	Abilities necessary to do scientific inquiry	1–5, 7–8
A	2	Understandings about scientific inquiry	1–5
B	3	Transfer of energy	1

Grades 9–12

Content standard	Bullet number	Content description	Bullet number(s)
A	1	Abilities necessary to do scientific inquiry	1–5
A	2	Understandings about scientific inquiry	3, 5
B	4	Motions and forces	1
B	5	Conservation of energy and increase in disorder	1–2

Vocabulary

- **inclined plane:** a simple machine; a slanted surface generally used to lift objects
- **machine:** a device that changes the magnitude and/or direction of an applied force
- **mechanical advantage:** the ratio of resistance force to effort force

Materials

- flight of stairs (well-lit, with a handrail)
- metric ruler or meterstick (per student)
- bathroom scale

= Safety icon

11. What Mechanical Advantage Do Stairs Provide?

TEACHER RESOURCE PAGE

HELPFUL HINTS AND DISCUSSION

Time frame: 40 minutes, or one class period

Structure: individuals

Location: at home and other locations

In this activity, students will investigate why it is easier to use stairs than a ladder to travel vertically. Using a vertical ladder requires one's legs to generate a force equal to one's full body weight, while using stairs requires a much lower force. Students will take simple measurements of a flight of stairs and then calculate the mechanical advantage of the stairs. That will enable them to calculate the actual force that their legs exert in climbing the stairs.

Make certain you define a machine. Be sure that students also understand a flight of stairs as an example of an inclined plane. Some students might be reluctant to have their weight known. If you suspect this might be a problem, discourage sharing of data in this activity, or allow students to use a fictitious weight.

Note that while in most activities we specify MKS (meter-kilogram-second) units, it is all right to use pounds for students' weights since we only want them to understand that the stairs lower the needed force.

MEETING THE NEEDS OF DIVERSE LEARNERS

Ask students who need extra challenges an additional question: Why do the muscles of your legs have to exert more force than will be calculated? (Answer: to overcome inertia) These students should be encouraged to do the Extension Option and the Follow-Up Activity.

Review the relevant concepts of force and mechanical advantage with students who need extra help. Have them take the measurements using the ruler to give them more experience with scientific tools. Review with them how to do the calculations.

SCORING RUBRIC

Students meet the standard for this activity by:

- correctly calculating the mechanical advantage of a flight of stairs
- correctly calculating the force exerted by their legs
- correctly using the appropriate scientific terms
- safely following the procedure

11. What Mechanical Advantage Do Stairs Provide?

TEACHER RESOURCE PAGE

Recommended Internet Sites

- **School for Champions—Physical Science: Simple Machines**
  www.school-for-champions.com/science/machines.htm
- **Utah State University Junior Engineering—Graduate Credit Workshop: Simple Machines**
  www.juniorengineering.usu.edu/workshops/machines/machines.php

Answer Key

1. Stairs have a greater mechanical advantage than ladders.
2. Answers will vary.
3. Mechanical advantage should be greater than 1. The higher the number, the smaller the input force needed. A mechanical advantage of 1 means that to lift 2000 N, a person would have to be able to exert 2000 N (about 450 pounds) of force. With a mechanical advantage of 10, a person would only have to exert about 200 N of force.

Name _____ Date _____

11. What Mechanical Advantage Do Stairs Provide?

STUDENT ACTIVITY PAGE

OBJECTIVE

To correctly calculate the mechanical advantage of a flight of stairs

BEFORE YOU BEGIN

You probably already know that it is easier to climb a flight of stairs to a given height than it is to climb a ladder to the same height. This is because a flight of stairs is actually a **machine**. You can think of a flight of stairs as an **inclined plane** (or ramp) with steps cut into it. As you might remember, a machine changes either the direction or the amount of a force you apply. In the case of stairs, the ramp multiplies the force of your legs, so you don't have to use as much force. This is called **mechanical advantage**. This mechanical advantage is not free, however. In payment you must travel a greater distance walking diagonally up the steps than if you had gone straight up on a vertical ladder. In this activity, you will calculate the mechanical advantage of the stairs. You will also calculate the actual force your legs have to exert in climbing a flight of stairs.

MATERIALS

- flight of stairs (well-lit, with a handrail)
- metric ruler or meterstick (per student)
- bathroom scale

= Safety icon

PROCEDURE

1. Find your weight in pounds and record it in the Data Collection and Analysis section.
2. Locate a flight of stairs.
3. Using a metric ruler, measure the height *H* of one step to the nearest 0.1 cm. Record this information in the Data Collection and Analysis section.
4. Measure the diagonal distance *D* between the front edge of one step and the front edge of the next higher or lower step, also to the nearest 0.1 cm. Record this distance in the Data Collection and Analysis section.
5. Use these measurements to perform the calculations in the Data Collection and Analysis section.

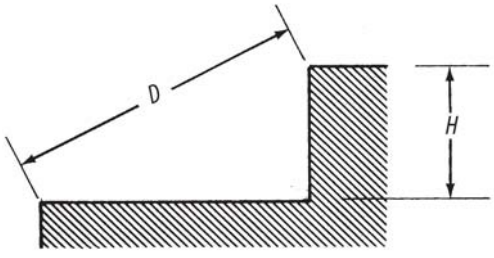

Figure 1

Name _____ Date _____

11. What Mechanical Advantage Do Stairs Provide?

STUDENT ACTIVITY PAGE

EXTENSION OPTION

The mechanical advantage you find for different stairways will vary. While doing the survey in the Follow-Up Activity, record the age (old or new) and type (residence or workplace) of the building along with the mechanical advantage of the stairway. Consider a building built or renovated after 1960 to be "new." Is the mechanical advantage different for residences compared with workplaces? Is the mechanical advantage different for new buildings compared with old buildings? You might have to visit a large number of stairways to see clear trends. Can you think of reasons for your findings?

DATA COLLECTION AND ANALYSIS

Body weight: _____ pounds

Height of one step: _____ cm

Diagonal distance between steps: _____ cm

Calculating Mechanical Advantage

Machines increase (or decrease) the force you exert by multiplying it by some number. That number is called the mechanical advantage of a machine. In the case of an inclined plane, you find the mechanical advantage by dividing the length of the ramp by the height the ramp raises you to. Similarly, for a flight of stairs, you find the mechanical advantage by dividing the distance you travel diagonally up the step by the height of the step:

$$\text{mechanical advantage} = \frac{\text{diagonal distance}}{\text{height}} = \frac{\qquad}{\qquad}$$

Calculating Force of Legs

Without the help of a machine, the force your legs must produce to lift you is equal to your body weight. With the stairs, the force needed is lower than your body weight.

$$\text{force of legs} = \frac{\text{body weight}}{\text{mechanical advangage}} = \frac{\qquad}{\qquad} \text{ pounds}$$

CONCLUDING QUESTIONS

1. Why do we build stairs rather than vertical ladders between floors of a building?

_____

_____

_____

_____

Name _____ Date _____

11. What Mechanical Advantage Do Stairs Provide?

STUDENT ACTIVITY PAGE

2. Are you surprised by the value of the mechanical advantage provided by the flight of stairs? Why or why not?

_____

_____

_____

_____

3. For a machine to make a task easier, should it have a mechanical advantage less than or greater than 1? Explain your answer.

_____

_____

_____

_____

FOLLOW-UP ACTIVITY

Visit stairways in a variety of buildings (old buildings, new buildings, homes, government offices, and so forth). Take the same measurements of each set of stairs. Calculate and record the mechanical advantage provided by each stairway. Compute also the average mechanical advantage of all the stairways in your survey.