Level A Investigations

A-1 Ropes and Pulleys

How can you use the ropes and pulleys to lift large weights with small forces?

In this Investigation, students learn to define force and identify input and output force in a simple machine. They gain quantitative experience working with force through the use of spring scales. Next, students build a block and tackle machine and discover how this simple machine can be used to multiply force. The students develop a mathematical relationship between the number of supporting strands of rope and the force needed to lift the block.

A-2 What is Work?

How can a simple machine multiply forces?

In the first Investigation, students discovered that a simple machine can multiply forces. In this Investigation, students learn that this multiplication of forces has a “cost”: they must pull a longer length of rope to lift the block a certain height. The relationship between force and distance in a simple machine is explained using the concept of work. As students explore the nature of work in this Investigation, they come to an interesting conclusion that is true for all machines—that output work can never exceed input work.

Level B Investigations

B-1 Forces in Machines

How do simple machines work?

Students build a simple machine using ropes and pulleys. They measure the input force required to lift a weight as the number of pulleys over which the string passes is increased. Students develop a mathematical rule based on their observations. Finally, students learn to calculate the mechanical advantage of their simple machine for each arrangement of the string.

B-2 Work and Energy

What happens when you multiply forces in a machine?

This Investigation extends the concepts of force and distance in a simple machine to the definition of work. Through measurements of input and output forces on a ropes and pulleys machine, students begin to understand the concept of conservation of work and energy. As students explore the nature of work and energy in the Investigation, they come to the conclusion that work output can never exceed work input.

B-3 Efficiency

How can you measure the efficiency of a simple machine?

Students learn to distinguish ideal mechanical advantage, which does not take into account the effect of friction in the system, and actual mechanical advantage, which does. They calculate the efficiency of an inclined plane using the ratio of work output to work input. Next, students measure the efficiency of an inclined plane. Finally, they have an opportunity to design and test their own method of improving the efficiency of an inclined plane.

Level C Investigations

C-1 Simple and Complex Pulley Systems

How can pulley systems be used to move objects?

In this Investigation, students review the three types of levers and compare them with three types of pulley systems. They build each type of pulley system and calculate its ideal and actual mechanical advantage. They learn to use a pulley system in an unconventional manner to increase output distance without increasing input distance. Finally, they are given a series of hypothetical tasks and asked to apply what they have learned to determine the type of pulley system that works best for each task.

C-2 Compound Pulley Systems

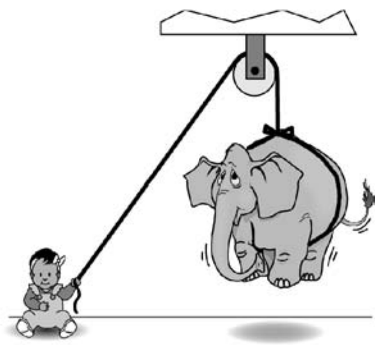
How can pulleys be used to alter the speed of moving objects?

Students use a combination of CPO equipment to discover how pulleys can be used to change the speed of moving objects. They set up a pulley system that moves a car along a horizontal surface. Using the photogates, students measure the speed of the moveable pulley block and compare it with the speed of the car. They also calculate work done on the moveable block and the car. Students then learn of an application of this type of pulley system—the compound bow.

Question: How can you use the ropes and pulleys to lift large weights with small forces?

In this Investigation, you will:

1. Learn to build machines that allow you to lift large weights with small forces.
2. Discover the relationship between the input force needed to lift a load and the number of pulleys in your machine.



Would you believe that a small child can lift an elephant with just muscle power? It's true! You could make it possible by building a simple machine with some rope and pulleys.

1 What is force?

In this Investigation, you measure the amount of **force** you need to lift a block. To understand what's happening, you need to know about forces.

In science, force is defined as a push, pull, or any action that has the ability to change motion. It takes force to start a soccer ball rolling, and it takes force to change its direction or to stop its motion.

This definition doesn't mean that forces *always* change motion. If you were to push down on a table, for example, it probably wouldn't move. However, if the legs were to break, the table *could* move.

Name some examples of forces you observed today. Include one of each:

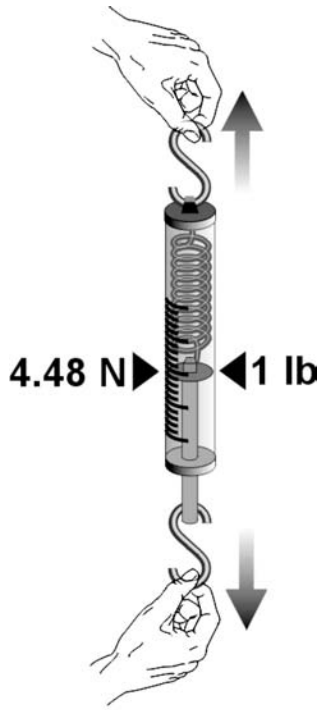
a. A force that increased motion.

b. A force that decreased motion.

c. A force that changed the direction of motion.

2 How is force measured?

A-1



1 lb = 4.48 N

Force is usually measured in **pounds (lbs)** or **newtons (N)**. You are probably familiar with using pounds to measure weight but not force. However, when you measure weight, you are actually measuring force.

Weight describes the force of gravity acting on an object. This is easy to see when you use a spring scale to measure weight. If you hang a one-pound weight on the end of a spring scale, the force of gravity between the object and Earth *pulls* the spring scale. The spring scale measures one pound (or 4.48 newtons) of pull. If you remove the weight and pull down on the spring scale with your hand, your muscles, rather than gravity, provide the force. You can measure the force of your pull in pounds or newtons, just like you measured the pull of gravity.

Scientists commonly use newtons to measure force. A newton is smaller than a pound. There are 4.48 newtons in a pound. A person weighing 100 pounds weighs 448 newtons.

a. Name two units used to measure force.

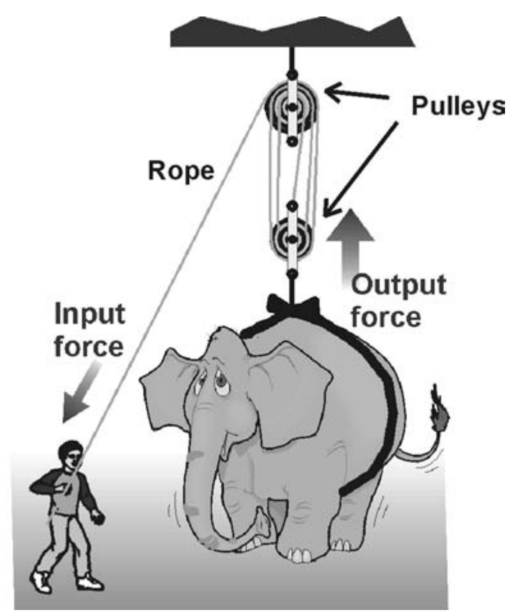
b. A dog weighs 50 pounds. How much does the dog weigh in newtons?

3 Ropes and pulleys

A rope with some pulleys can be used to change the size and direction of forces, allowing someone to lift a heavy load with a smaller amount of force. One person could easily lift an elephant with a properly designed set of ropes and pulleys!

You can think of a set of rope and pulleys as having an **input force** and an **output force**. The input force is the force you apply to the rope. The output force is the force applied to the load you are trying to lift.

In this Investigation, you will measure the amount of input force needed to lift a certain amount of weight (the output force). You will change the number of pulleys the rope passes through for each trial.



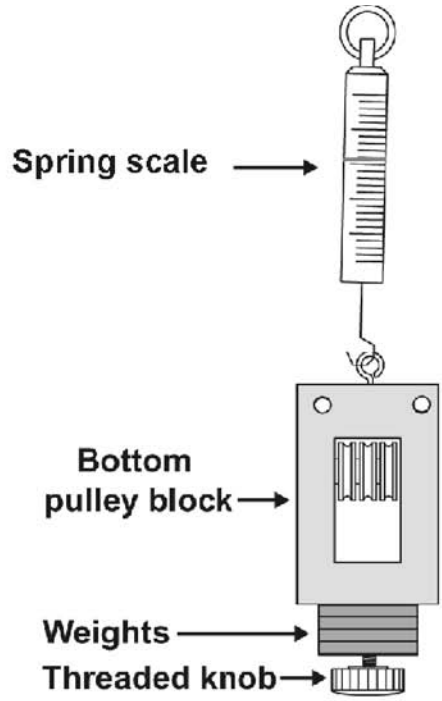
a. How do you think adding more pulleys affects the amount of input force needed to lift a certain amount of weight?

Setting up the experiment

1. Attach four weights to the bottom block. Use a spring scale to weigh the bottom block after you attach the weights.

   The weight of the bottom block is equal to the **output force** used to lift the block.

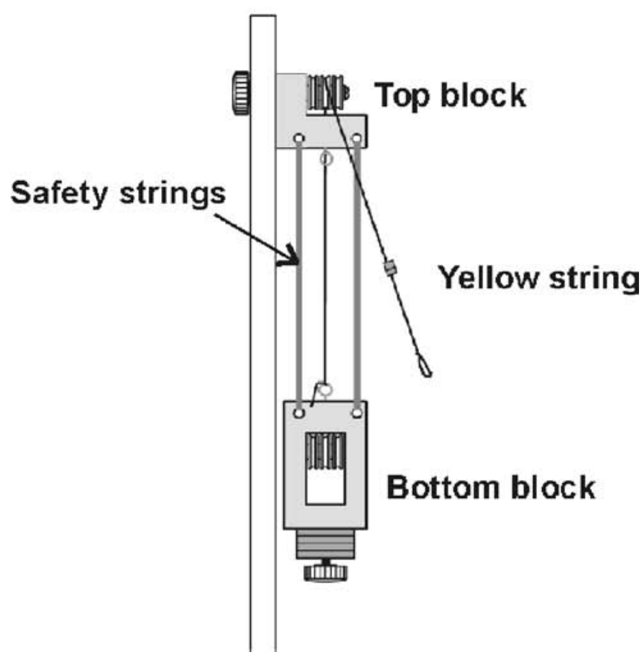
   Record the weight of the bottom block in newtons.



2. Attach the top block near the top of the physics stand. Clip the yellow string to the bottom block.

3. The yellow string (pull string) will be used to move the bottom block with the weights up and down. You will pull on the end of the yellow string.

   The yellow string can be clipped to either the top or bottom block. It will pass around one or more pulleys.



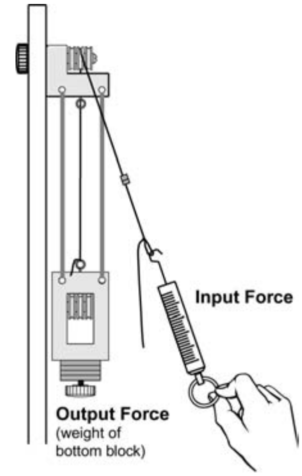
4. The pink string is the *safety string*. It holds up the bottom block while you rearrange the yellow string.

5. Attach the spring scale to the yellow string as shown. You will use the spring scale to measure the **input force**.

SAFETY TIP: Pull the rope downward. Don't pull the rope horizontally, or you could tip the stand over.

5 Doing the experiment

1. Record the output force (the weight of the bottom block) in the last column of the table below. This will be the same for each trial of the experiment.
2. Clip the end of the yellow string to the bottom block and pass the string over the middle pulley of the top block. In this arrangement, the yellow string passes over one pulley.
3. Use the spring scale to measure the force it takes to slowly lift the bottom block. This is the input force.
4. Record the input force in the table. Use the row corresponding to one pulley.



5. Take the yellow string off, and clip the end to the top block. Pass the string around the middle pulley on the bottom block and back over the middle pulley on the top block.
6. Measure the force it takes to slowly lift the bottom block (input force).
7. Record the input force in the row for two pulleys.
8. Rearrange the yellow string so that it passes over three pulleys. Then try arrangements that pass over four, five, and six pulleys.
9. Measure and record the input force it takes to lift the bottom block for each new setup.

In this arrangement, yellow string passes over one pulley.

In this arrangement, yellow string passes over two pulleys.

Number of pulleys	Input force (newtons)	Output force (newtons)
1		
2		
3		
4		
5		
6		

6 Thinking about the data

a. As the yellow string passes over more pulleys, what happens to the force used to lift the bottom block? Does this agree or disagree with your original idea about adding pulleys?

b. Write a rule that describes how the input force changes as more pulleys are used to lift the block.

Name: ______________________

A-1 Ropes and Pulleys

Question: How can you use the ropes and pulleys to lift large weights with small forces?

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b. A force that decreased motion.

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a. Name two units used to measure force.

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b. A dog weighs 50 pounds. How much does the dog weigh in newtons?

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3 Ropes and pulleys

a. How do you think adding more pulleys affects the amount of input force needed to lift a certain amount of weight?

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____

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4 Setting up the experiment

1. Weight of bottom block:______________________

5 Doing the experiment

Number of pulleys	Input force (newtons)	Output force (newtons)
1		
2		
3		
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6 Thinking about the data

a. As the yellow string passes over more pulleys, what happens to the force used to lift the bottom block?

b. Write a rule that describes how the input force changes as more pulleys are used to lift the block.

Questions

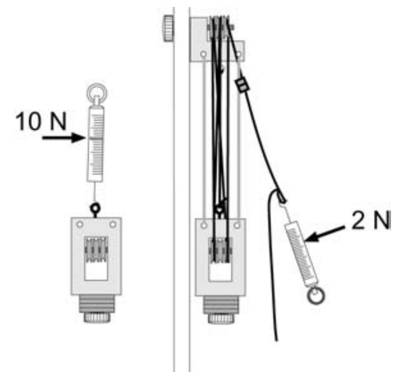
A-1

1. Two children are playing on a seesaw. The younger child weighs 35 pounds. The older child weighs 50 pounds. The children find that if the older one sits close to the middle of the seesaw, the younger child can lift him up by sitting on the opposite end of the seesaw.

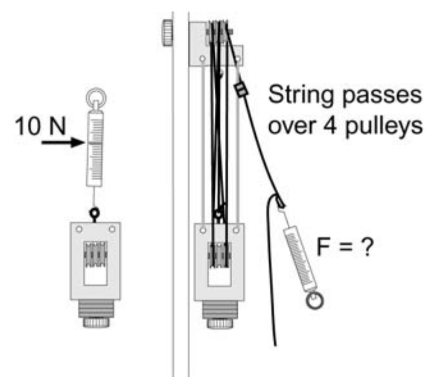
a. The seesaw is a simple machine, like the ropes and pulleys. In the situation described above, what is the input force?

b. What is the output force?

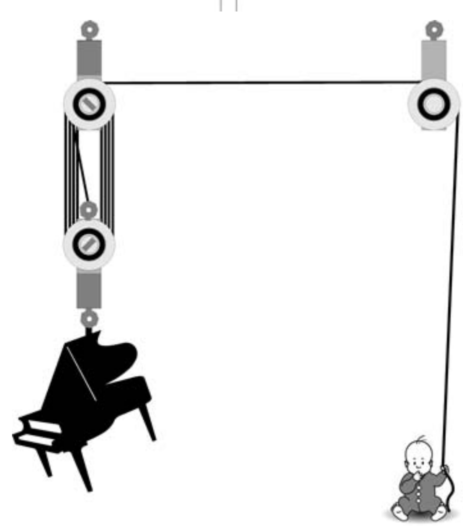
2. The weight of the bottom block in the picture is 10 newtons. The spring scale measures 2.0 newtons when attached to the ropes and pulleys with the same weight on the lower block. How many pulleys are used in this arrangement of the yellow string?



3. The spring scale again measures a force of 10 newtons to hold the bottom block. The yellow string passes over four pulleys. How much force is needed to lift the lower block?



4. CHALLENGE! Cleverly using a rope and pulleys to decrease the input force needed, the small baby in the figure lifts the piano. The piano weighs 800 pounds. The baby weighs 20 pounds. How many pulleys must the rope pass over so the piano doesn't lift up the baby instead?



Curriculum Resource Guide: Ropes and Pulleys

Credits

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