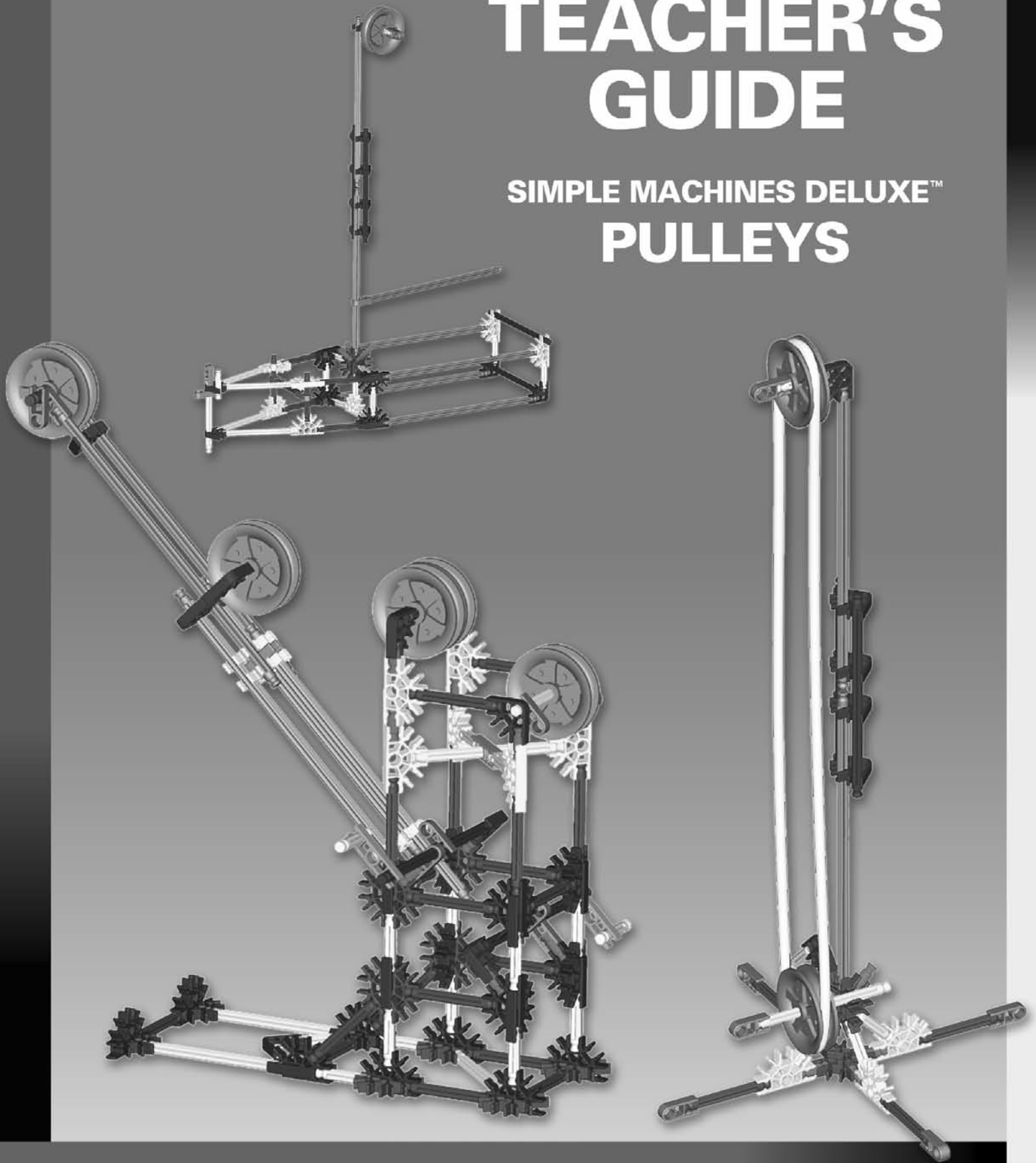


TEACHER'S GUIDE

SIMPLE MACHINES DELUXE[™]
PULLEYS



TEACHER'S GUIDE

SIMPLE MACHINES DELUXE™ PULLEYS

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WARNING:

CHOKING HAZARD - Small parts.
Not for children under 3 years.



AVERTISSEMENT :

DANGER D'ÉTOUFFEMENT - Pièces de petite taille.
Ne convient pas aux enfants de moins de 3 ans.



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Introduction:

OVERVIEW

This Teacher's Guide has been developed to support you as your students investigate the K'NEX Education Simple Machines Deluxe Set. In conjunction with the K'NEX materials and individual student journals, the information and resources here can be used to build your students' understanding of scientific concepts and channel their inquiries into active and meaningful learning experiences.

SIMPLE MACHINES DELUXE

This K'NEX Education set is designed to introduce students to the scientific concepts associated with simple machines. Students are provided with the opportunity to acquire skills using a hands-on, inquiry based approach to information and concepts. Working cooperatively, students are encouraged to interact with each other as they build, investigate, discuss and evaluate scientific principles in action.

TEACHER'S GUIDE

Designed as a resource for the teacher, this guide provides a glossary of key terms and definitions, includes an overview of the concepts associated with the different simple machines, identifies student objectives for each investigation, and offers plans and scripts to successfully present selected models and their associated activities. We have also provided Student Activity and Reference Sheets. These comprise illustrations and definitions of some of the concepts featured in the model building activities. Most lessons can be completed in 30 to 45 minutes. We recommend that teachers review their curriculum and science education standards to identify those activities that best support their academic needs.

STUDENT JOURNALS

It is expected that students will have journals available for recording information. They should be encouraged to enter initial thought at the start of an inquiry – what they “think” will happen. These initial thoughts may be amended, based upon their ongoing inquiry and analysis, until the students feel comfortable about drawing conclusions. Their journal entries will help make a connection between the models they have built, the experiments they have conducted, and how this information is applied to the real-world machines they use on a regular basis. The journals will also provide students with a place to practice making drawings and diagrams of systems. Finally, the journals will serve as a method of assessment for the Simple Machines units. Journal Checklists are also included in the Teacher's Guide for each model and its associated activities.

Alignment with National Standards Grades K-4

The National Science Education Standards

Unifying Concepts and Processes	<ul style="list-style-type: none"> • Systems, order, and organization • Evidence, models, and explanation • Change, constancy, and measurement • Form and function
Physical Science	<ul style="list-style-type: none"> • Properties of objects and materials • Position and motion of objects
Science and Technology	<ul style="list-style-type: none"> • Abilities of technological design • Understandings about science and technology

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Alignment with National Standards Grades 5 - 8

The National Science Education Standards

Unifying Concepts and Processes	<ul style="list-style-type: none"> • Systems, order, and organization • Evidence, models, and explanation • Change, constancy, and measurement • Form and function
Physical Science	<ul style="list-style-type: none"> • Motions and Forces • Transfer of Energy
Science as Inquiry	<ul style="list-style-type: none"> • Abilities necessary to do scientific inquiry • Understanding about scientific inquiry
Science and Technology	<ul style="list-style-type: none"> • Abilities of technological design • Understandings about science and technology

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Alignment with Standards for Technological Literacy Grades 3-5

Standards for Technological Literacy	
<p>The Nature of Technology</p>	<p>Core Concepts of Technology</p> <ul style="list-style-type: none"> • Systems • Processes • Requirements <p>Relationships among technologies</p> <ul style="list-style-type: none"> • Technologies integrated
<p>Design</p>	<p>The Attributes of design</p> <ul style="list-style-type: none"> • Requirements of design <p>Engineering Design</p> <ul style="list-style-type: none"> • Engineering design process • Creativity and considering all ideas • Models <p>The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving</p> <ul style="list-style-type: none"> • Troubleshooting • Invention and innovation • Experimentation
<p>Abilities of a Technological World</p>	<p>Apply design process</p> <ul style="list-style-type: none"> • Collecting information • Visualize a solution • Test and evaluate solutions • Improve a design

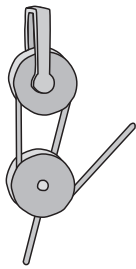
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Alignment with Standards for Technological Literacy Grades 6 - 8

Standards for Technological Literacy

<p>The Nature of Technology</p>	<p>Core Concepts of Technology</p> <ul style="list-style-type: none"> • Systems • Processes • Requirements <p>Relationships among technologies</p> <ul style="list-style-type: none"> • Interaction of systems • Knowledge from other fields of study and technology
<p>Design</p>	<p>The Attributes of design</p> <ul style="list-style-type: none"> • Design leads to useful products and systems • There is no perfect design <p>Engineering Design</p> <ul style="list-style-type: none"> • Brainstorming • Modeling, testing, evaluating, and modifying <p>The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving</p> <ul style="list-style-type: none"> • Troubleshooting • Invention and innovation • Experimentation
<p>Abilities of a Technological World</p>	<p>Apply design process</p> <ul style="list-style-type: none"> • Identify criteria and constraints • Test and evaluate • Make a product or system

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All About PULLEYS

What is a Pulley?

- A pulley is a wheel with a groove on its outside edge. A cord or belt runs in this groove.
- At one end of the cord is the load that needs to be lifted.
- To use a pulley, you (or a motor) provide the effort, by pulling the cord, to lift the load.
- Pulleys can change the amount of force needed to do work and the direction of the applied forces.



Key Words and Definitions

Effort - the force that is applied to do work; the push, pull, squeeze or lift provided to use a pulley to move an object

Resistance - the force provided by the object on which one is trying to do work; the object works against (pushes back) the effort

Mechanical Advantage (MA) - a mathematical calculation that reveals how many times easier a job is to do when a pulley is used; can also be determined by counting the cords that support movable pulleys

$$\mathbf{MA = \frac{\text{force needed to lift load without pulleys}}{\text{force needed to lift load with pulleys}}}$$

Work - the job being done while using the pulley

Load - the object (weight) lifted or moved; provides resistance to the pulley

Force - any kind of push or pull applied to an object

Fixed pulley - a pulley attached to a solid surface; does not move when cord is pulled other than turning in place

Movable pulley - a pulley attached directly to the load being lifted; moves when the cord is pulled

Combination pulley - a series of fixed and movable pulleys used together to get the advantages of both in the work

Block and tackle - a specific combination pulley grouping used to lift very heavy objects; the block is the frame holding the pulleys; the tackle is the rope or cable

Key Concepts

How does a fixed pulley help you?

- Fixed pulleys change the direction that the force is applied.
- The force is applied in the direction that is easiest—pulling down—with the help of gravity.
- Only one cord supports a fixed pulley so the Mechanical Advantage is 1.
- Lifting with a fixed pulley takes the same amount of force as lifting without the pulley.

How does a movable pulley help you?

- Movable pulleys reduce the force needed to lift the load while increasing the distance you use the force.
- The movable pulley supports part of the load weight.
- The force is applied over a longer distance (by pulling a longer cord).
- More movable pulleys make the job easier because more cords support the load.

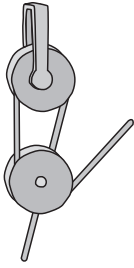
How does a combination pulley help you?

- Combination pulleys allow you to reap the benefits of both kinds of pulley arrangements.
- The fixed pulleys control the direction you pull while the movable pulleys reduce the force it takes to lift the load.

REMEMBER

Using movable pulleys in a system make it easier to lift a load but the work is done over a longer distance.





Getting Started With Pulleys

What is a pulley?

- A pulley is a wheel with a groove on its outside edge.
- A cord runs in the wheel's groove.
- At the end of the cord is the **load**—a weight you want to lift.
- You (or a motor) provide the **effort**, by pulling on the cord, to lift the load.
- Some pulleys help by making work easier.
- Other pulleys help by letting you pull in one direction while the load moves in a different direction.

How does a pulley help you?

Like all simple machines, pulleys help make work easier.

Some pulleys help by letting you use your force in the direction that's easiest for you. Other pulleys help by letting you use less force to do a job. (See Fixed and Movable Pulley Reference Sheets.)

Here's an example of how pulleys can help.

Imagine that you want to carry a piano to the 10th floor of a building. The piano does not fit in the building's elevator, but could fit through a window on the 10th floor. How could you possibly get the piano up to the window? Pulleys can help!



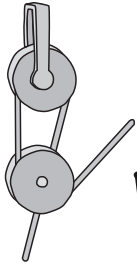
Picture this.

From the 10th floor window, run a rope over a pulley and down the side of the building. Attach one end of the rope to the piano. Then, grab the other end from inside the window and pull. The pulley actually allows you to lift the **HEAVY** piano off the ground using much less effort than you could ever imagine.



A Bright Idea!

Pulleys are a common simple machine but one which is not always visible on the outside of something. Often a pulley or a series of pulleys are hidden inside the machine. There they make the work of the particular object easier. Investigate the internal workings of different objects which you think might use pulleys.



What's the Mechanical Advantage?

How much do movable pulleys help you?

If you can count, you can find out!

- Count the cords that hang down to hold up each movable pulley. Don't include the cord that runs from a top fixed pulley to your hand—it doesn't have a movable pulley hanging from it.

The number of cords equals the **Mechanical Advantage (MA)**. This number tells you how many times easier your job is when you use one or more movable pulleys. Another explanation is that this is the number of times the machine multiplies your force so that you can lift heavy objects.

- Now try calculating the MA. Use a K'NEX Rubber Band Scale to lift a weight without pulleys, and then with pulleys. Then, divide the first number by the second.

$$\text{MA} = \frac{\text{Force needed to lift load without pulleys}}{\text{Force needed to lift load with pulleys}}$$

Are your answers for Step 1 and Step 2 the same? (If there is a difference in the numbers it is probably due to the friction of the pulley.)

- You can use your value for MA to find out how much force you need to lift a load with movable pulleys. Just do this division problem:

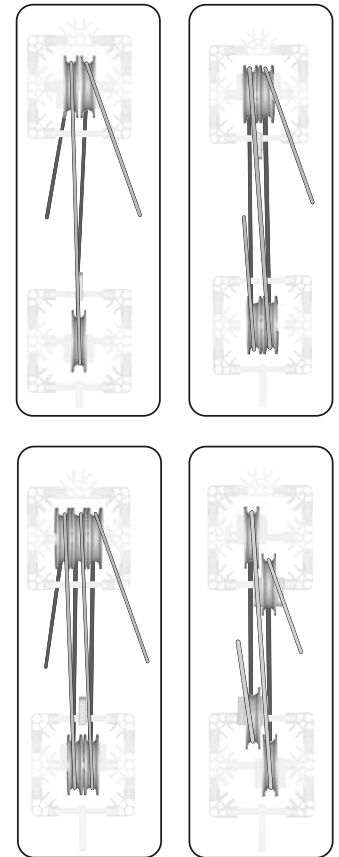
$$\frac{\text{Force needed to lift load without pulleys}}{\text{MA}} = \text{Force needed to lift load with pulleys}$$

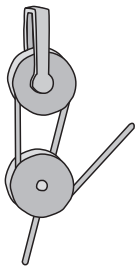


Imagine you're using three movable pulleys which are supported by six cords. The Mechanical Advantage is 6. You measure the force to lift the weight without pulleys. Your K'NEX Rubber Band Scale reads 12. Divide the force by the Mechanical Advantage.

$$\text{Force} \div \text{MA} = 12 \div 6 \quad \text{Force needed to lift with pulleys} = 2$$

Use your K'NEX Rubber Band Scale to lift the weight. Is your force measurement the same as your calculation? Explain.





What is a Fixed Pulley?

A fixed pulley is a pulley that doesn't move when you pull the cord. Fixed pulleys are usually attached to a wall or ceiling, a pole or another solid surface.

Here's an example.

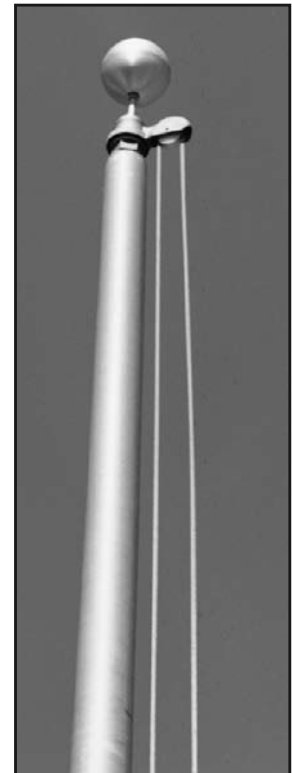
On the top of a flagpole, a fixed pulley is attached to the pole. When you pull the cord, the flag goes up.

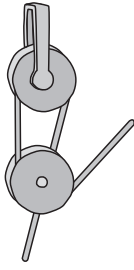
How does a fixed pulley help you?

Fixed pulleys help by letting you move a load in one direction when you pull in a different direction. To make the flag move up, you pull the cord down.

To raise the flag, pulling down is easier than pulling up would be. To pull the flag up without a pulley, you'd have to be at the top of the flagpole! But with a pulley, you can do the job as you stand on the ground. Also, you can use the weight of your body to put pressure on the cord. Gravity pulling down on your body helps you pull down on the cord.

A fixed pulley lets you pull in the direction that is easiest for you.





What is a Movable Pulley?

A movable pulley is a pulley that moves when you pull the cord. It's attached directly to the load you're lifting.

Here's an example.

Imagine you're building a skyscraper and you have to lift a huge bucket of concrete all the way to the top. A movable pulley, attached to the bucket, makes lifting such a heavy load easier.

How does a movable pulley help you?

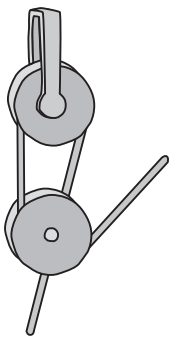
A movable pulley lets you lift a load with less force than you would need without the pulley.

You have to lift for a longer time by pulling on a longer cord, but you don't have to pull as hard. The reason you need less force is because you only have to support part of the load's weight.

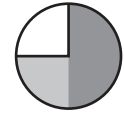
Imagine you're using a movable pulley like the one in the picture. You hold up half the load's weight by holding up one side of the cord. The other part of the cord supports the other half of the weight. If you used two movable pulleys, with a total of four cords, you would only have to support one quarter ($\frac{1}{4}$) of the weight. The more movable pulleys—the easier your job gets!

A movable pulley reduces the force you need, while increasing the distance you use the force. You do less work but for a longer distance.



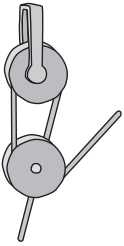


Fixed Pulley Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify a fixed pulley
- Demonstrate how a fixed pulley functions
- Experiment to find the Mechanical Advantage of the Fixed Pulley
- Measure forces with a Rubber Band Scale
- Deduce that a fixed pulley changes the direction of the applied force
- Lay the groundwork to distinguish between fixed and movable pulleys

Materials

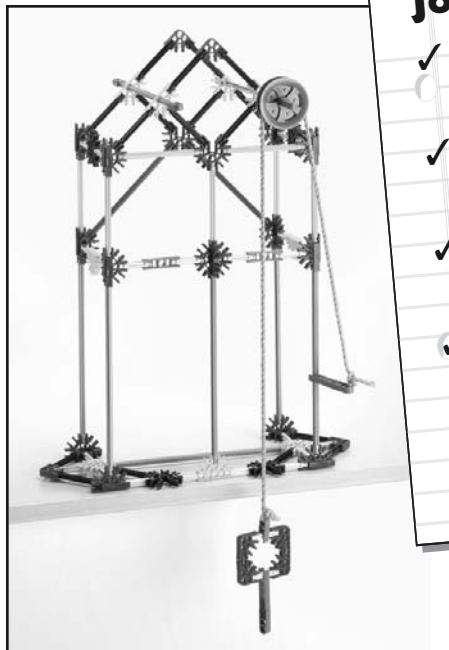
- K'NEX Pulley Stand
- weights, such as a large K'NEX Tire
- ruler
- K'NEX Rubber Band Scale

Every pulley has a job to do

Students should make a list of pulleys commonly found at home, school or elsewhere. Fixed pulleys are found in curtain rods, mini-blinds, sash windows, grandfather clocks, tow trucks, cranes and more. This list will grow with the continued study of pulleys.

What kind of pulley is it?

Fixed pulleys are stationary; a cord runs over them but they do not move. They change the direction of the applied force to one that is easiest for you. With a fixed pulley, you can pull down on something to lift it, with the help of gravity, rather than pulling it up. Fixed pulleys do not make it easier to lift a weight.



Journal Check

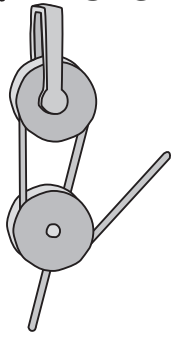
- ✓ Record of weight lifted, ease and direction of lifting
- ✓ Distance measurements for cord and weight
- ✓ Force measurements from Rubber Band Scale
- ✓ Mechanical Advantage for Fixed Pulley
- ✓ Measurements for modified Fixed Pulley model

QUESTIONS

- On one end of a cord, attach a weight, such as a large K'NEX Pulley. Lift the weight by pulling on the cord. Feel how much force it takes to lift the weight.
 - Build the K'NEX Pulley Stand model. Set up your Fixed Pulley on the stand. Run the cord over the Pulley and pull on the cord to lift the weight. Which way must you pull the cord - up or down? Does the Pulley make lifting harder, easier or is it about the same as without the Pulley?
- Hang a weight from the Pulley's cord, and let the weight rest on the ground with the cord pulled tight. Grip the cord just below the Pulley and pull down to lift the weight. Use a ruler to measure, from your fingertips to the Pulley, how far you pulled the cord. Then, measure how far up the weight moved from the ground to the bottom of the weight. Are the two measurements the same? Why or why not?
- With a K'NEX Rubber Band Scale, measure how much force it takes to lift a weight with your Fixed Pulley. Record your results. You will be comparing them with measurements for a Movable Pulley. What is the Mechanical Advantage (MA) of this pulley? (*Refer to the "What's the Mechanical Advantage" Reference Sheet.*)
- There are lots of spots to mount Pulleys on your Pulley Stand. Try mounting several Fixed Pulleys on Rods that stick out from the stand. Rig up a cord between the Pulleys and lift a weight. Take the same measurements as you do in Step 3 and record your results.

ANSWERS

- To lift the weight up, force must be applied to the cord by pulling it down. However, the amount of effort remains the same with or without the Fixed Pulley. [Actually, the force needed to lift the weight with the Fixed Pulley is slightly greater, due to friction between the pulley wheel and its axle. The benefit of the Fixed Pulley is not in reducing the force required to lift the load but in changing the direction of the applied force so it is more convenient.
- The measurements of how far the cord and the weight moved should be the same for the Fixed Pulley. For every centimeter you pull the cord, the weight moves a centimeter. Fixed pulleys do not make work easier therefore the two measurements are the same, with a 1:1 ratio.
- Measurements will be the same (1:1 ratio). Again, a fixed pulley offers no Mechanical Advantage.
- Students answers will vary. There should be no "wrong" answers when conducting open-ended, hands-on exploration. After building and running the cord, refer students to the "What is a Fixed Pulley?" Reference Sheet to confirm and clarify what they have learned about fixed pulleys.



The Fixed Pulley

Every pulley has a job to do

A fixed pulley stays in one place, while the rope that runs through the pulley moves. People use fixed pulleys to raise flags and sails and to lift loads. These pulleys help by changing the direction of the work you do. With a fixed pulley, you can pull a rope down and make your flag or load go up.

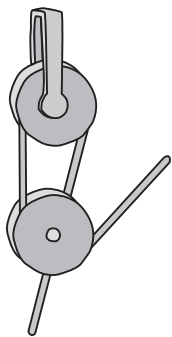
What kind of pulley is it?

- List three traits of a fixed pulley.

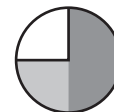


Student Challenge

- On one end of a cord, attach a weight, such as a large K'NEX Pulley. Lift the weight by pulling on the cord. Feel how much force it takes to lift the weight.
 - Build the K'NEX Pulley Stand model. Set up your Fixed Pulley on the stand. Run the cord over the Pulley and pull on the cord to lift the weight. Which way must you pull the cord - up or down? Does the Pulley make lifting harder, easier or is it about the same as without the Pulley?
- Hang a weight from the Pulley's cord, and let the weight rest on the ground with the cord pulled tight. Grip the cord just below the Pulley and pull down to lift the weight. Use a ruler to measure, from your fingertips to the Pulley, how far you pulled the cord. Then, measure how far up the weight moved from the ground to the bottom of the weight. Are the two measurements the same? Why or why not?
- With a K'NEX Rubber Band Scale, measure how much force it takes to lift a weight with your Fixed Pulley. Record your results. You will be comparing them with measurements for a Movable Pulley. What is the Mechanical Advantage (MA) of this pulley? (Refer to the "What's the Mechanical Advantage" Reference Sheet.)
- There are lots of spots to mount Pulleys on your Pulley Stand. Try mounting several Fixed Pulleys on Rods that stick out from the stand. Rig up a cord between the Pulleys and lift a weight. Take the same measurements as you do in Step 3 and record your results.

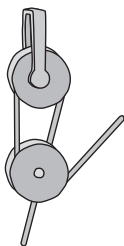


Movable Pulley Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify a movable pulley
- Demonstrate how a movable pulley functions
- Experiment to find the Mechanical Advantage of the Movable Pulley
- Measure forces with a Rubber Band Scale
- Deduce that a movable pulley reduces force over an increased distance
- Compare and contrast the function and purpose of fixed and movable pulleys

Materials

- K'NEX Pulley Stand
- weights, such as a large K'NEX Tire
- ruler
- K'NEX Rubber Band Scale

Every pulley has a job to do

There's an endless variety of heavy things that can easily be lifted using movable pulleys. Some examples are pianos, cars, loads of bricks or lumber. Students should develop a list of these items and others that are determined throughout this course of study.

What kind of pulley is it?

Movable pulleys move up or down along the cord as a weight is lifted. The pulley doesn't stay in one place as a fixed pulley does. Movable pulleys let you trade force for distance, so while the same amount of work is done, less force is applied over a longer distance. The movable pulley actually supports part of the weight of the load. This makes it significantly easier to lift a weight.



Journal Check

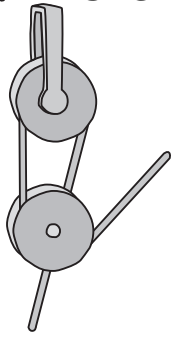
- ✓ Record of weight lifted, ease and direction of lifting
- ✓ Comparison of Movable and Fixed Pulley function
- ✓ Distance measurements for cord and weight
- ✓ Comparison and assessment of measurements
- ✓ Force measurements from Rubber Band Scale
- ✓ Comparison and assessment of MA for Movable vs Fixed Pulleys from prior activity
- ✓ Definition of the relationship between distance measurements for the weight and cord

QUESTIONS

- 1 Using the K'NEX Pulley Stand, attach a weight to the orange Connector hanging beneath the Movable Pulley. Tie one end of the cord to a Rod on the Pulley Stand and hang the Movable Pulley and its weight along the cord. Pull on the cord to lift the weight. In what direction do you pull? Do you pull in the same direction when you use a fixed pulley?
- 2 Lower the Pulley so the weight touches the ground and its cord is tight. Pull on the cord to raise the weight. Use a ruler to measure, from your fingertips to the Pulley, how far up you pulled the cord. Then, use a measuring tape to determine how far up the weight moved. Record your results. Are the two measurements the same? Which one moves more, the weight or the cord?
- 3 Attach the K'NEX Rubber Band Scale to the cord on your Movable Pulley. Measure how much force it takes to lift a weight with your Movable Pulley. Does this Pulley require more or less force than the Fixed Pulley?
- 4 Figure out the Mechanical Advantage (MA) of the Movable Pulley. (Use the "What's the Mechanical Advantage" Reference Sheet for help.) How does the MA of the Movable Pulley compare to the Fixed Pulley?
- 5 Lower the Movable Pulley again so the weight touches the ground, with the cord pulled tight. Pull on the cord to raise the weight 5cm off the ground. How far did you pull the cord? Record your results. Raise the weight 7cm and 10cm and measure how far you pulled the cord for each. Compare the relationship between the distance the weight moved and distance the cord moved. Describe this relationship and what you noticed.

ANSWERS

- 1 To lift a weight using one Movable Pulley, the effort must be applied to the cord by pulling up. This contrasts with the Fixed Pulley, which changes the direction of the force and lets you lift by pulling down.
- 2 The Movable Pulley's cord moves more than the weight. (They will determine later that it moves twice as far as the weight.)
- 3 The Movable Pulley requires less force to lift the weight than the Fixed Pulley; about half the force is needed to lift the same weight.
- 4 The MA of this Movable Pulley is two. This is determined by counting the two cords attached to the pulley or dividing the distance the cord moved by the distance the weight moved. (The cord moves twice as far as the weight.) The Fixed Pulley did not offer a MA. Use the "What is a Movable Pulley?" and (Use the "What's the Mechanical Advantage" Reference Sheet for help.) to reinforce how and by how much this type of pulley makes work easier.
- 5 The pulley cord will be pulled over a distance that is twice as long as the distance moved by the weight. This activity reinforces that a movable pulley makes lifting heavy things easier but the work must be done over a longer distance. It also reflects that a single movable pulley has a MA of 2.



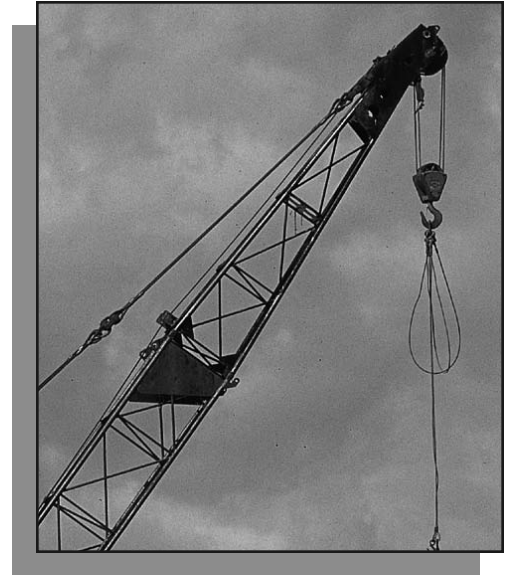
The Movable Pulley

Every pulley has a job to do

When you pull up on the cord of a movable pulley, the pulley moves up too. This type of pulley is used for lifting heavy loads such as a piano or a bale of hay. The load hangs right on the pulley. A movable pulley makes work easier because you don't need as much force to lift a weight as you do without the pulley.

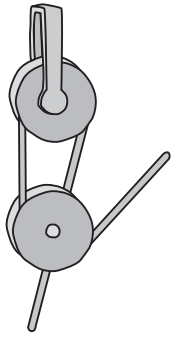
What kind of pulley is it?

- Identify three traits of a movable pulley.

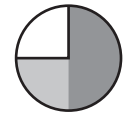


Student Challenge

- 1 Using the K'NEX Pulley Stand, attach a weight to the orange Connector hanging beneath the Movable Pulley. Tie one end of the cord to a Rod on the Pulley Stand and hang the Movable Pulley and its weight along the cord. Pull on the cord to lift the weight. In what direction do you pull? Do you pull in the same direction when you use a fixed pulley?
- 2 Lower the Pulley so the weight touches the ground and its cord is tight. Pull on the cord to raise the weight. Use a ruler to measure, from your fingertips to the Pulley, how far up you pulled the cord. Then, use a measuring tape to determine how far up the weight moved. Record your results. Are the two measurements the same? Which one moves more, the weight or the cord?
- 3 Attach the K'NEX Rubber Band Scale to the cord on your Movable Pulley. Measure how much force it takes to lift a weight with your Movable Pulley. Does this Pulley require more or less force than the Fixed Pulley?
- 4 Figure out the Mechanical Advantage (MA) of the Movable Pulley. (Use the "What's the Mechanical Advantage" Reference Sheet for help.) How does the MA of the Movable Pulley compare to the Fixed Pulley?
- 5 Lower the Movable Pulley again so the weight touches the ground, with the cord pulled tight. Pull on the cord to raise the weight 5cm off the ground. How far did you pull the cord? Record your results. Raise the weight 7cm and 10cm and measure how far you pulled the cord for each. Compare the relationship between the distance the weight moved and distance the cord moved. Describe this relationship and what you noticed.

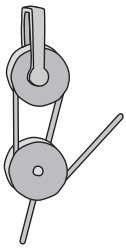


Combination Pulleys Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify a combination pulley system
- Demonstrate how a combination pulley functions
- Distinguish between fixed and movable pulleys
- Understand the benefits of a combination pulley system
- Experiment to find the Mechanical Advantage of the Combination Pulleys
- Measure forces with a Rubber Band Scale
- Experiment with rigging pulley cords and their relationship to force, direction and Mechanical Advantage

Materials

- K'NEX Pulley Stand
- weights, such as a large K'NEX Tire
- ruler
- K'NEX Rubber Band Scale

Every pulley has a job to do

Pulleys are often used in combination to obtain the advantages of both fixed and movable pulleys. This allows you to lift a very heavy weight while applying a small amount of force in the direction it is easiest to pull. The movable pulley makes the work easier and then the fixed pulley lets you change the direction when you pull the cord.

What kind of pulley is it?

The Combination Pulley uses both a fixed and movable pulley.



Journal Check

- ✓ Direction of work done by Combination Pulleys and comparison with Fixed and Movable Pulleys
- ✓ Distance measurements for cord and weight
- ✓ Rubber Band Scale force measurements
- ✓ Mechanical Advantage for Combination Pulleys
- ✓ Comparison, assessment and explanation of all measurements
- ✓ Assessment of combination pulley benefits
- ✓ Description and assessment of rigging pulley cords

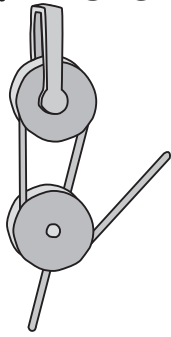
Student Challenge

QUESTIONS

- 1 Set up your Combination Pulleys on the Pulley Stand. Use the Pulleys to lift a weight. Which way do you pull the cord to raise the weight? Do you pull in the same direction when you use a single Fixed Pulley? a single Movable Pulley?
- 2 Measure the distance you pull the cord and the distance you lift the weight, as you did with the Fixed and Movable Pulleys. Compare your results. Are the measurements the same? Why or why not?
- 3 Use the K'NEX Rubber Band Scale to measure the force used to lift the weight with the set of Combination Pulleys. Compare your answer to the measurements you made when you lifted the same weight with only a Fixed Pulley or Movable Pulley. What do you find? How do the Combination Pulleys help move the weight?
- 4 What is the Mechanical Advantage (MA) of the Combination Pulley? (Use the "What's the Mechanical Advantage" Reference Sheet for help.) What does this tell you about the usefulness of combination pulleys?
- 5 Experiment with other pulley combinations and cord riggings. Do all of your combinations work properly? Why might certain combinations not work? Discuss your findings in writing.

ANSWERS

- 1 To lift the weight with the Combination Pulleys, the cord is pulled down. The Fixed Pulley in the combination changes the direction and allows you to pull down instead of pull up.
- 2 When using the Combination Pulleys, the cord moves twice the distance that the weight moves. The Movable Pulley makes the lifting easier, but the distance you have to pull is longer.
- 3 Measurements with the Rubber Band Scale should be similar to those taken when the single Movable Pulley lifted the weight. This is because the Fixed Pulley does not have an effect on the applied force and only one Movable Pulley is being used. Therefore the ratio and Mechanical Advantage would be 1 : 1.
- 4 The MA for the Combination Pulleys will also be the same as for the single Movable Pulley for the same reasons. Combination pulleys are helpful because they reduce the force needed to do work and change the direction of the applied force.
- 5 Some pulley arrangements may slip when the cord is pulled and therefore the configuration won't do any lifting. Note that combination pulleys need to be arranged in a logical order so that each type of pulley is used in its proper fashion.



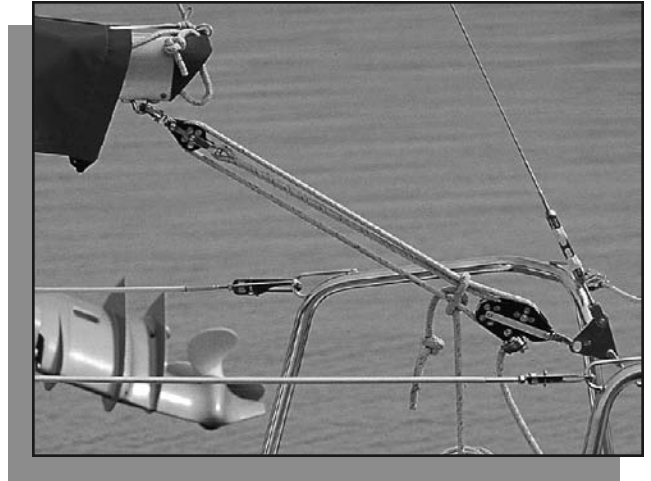
The Combination Pulleys

Every pulley has a job to do

Often people use several pulleys together to lift something heavy. Each pulley is useful in its own way. The fixed pulley controls the direction you pull. For example, you can pull down to make a load move up. The movable pulley reduces the force it takes to lift the load so you don't have to work so hard. Together, combinations of fixed and movable pulleys help do jobs and make the work easier.

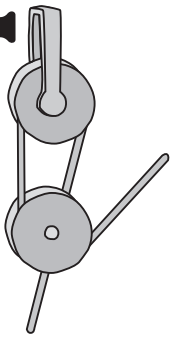
What kind of pulley is it?

- Identify the fixed and movable pulleys in the Combination Pulley.
- Use stickers or tape to label each pulley:
F Fixed **M** Movable

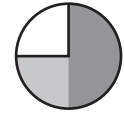


Student Challenge

- 1 Set up your Combination Pulleys on the Pulley Stand. Use the Pulleys to lift a weight. Which way do you pull the cord to raise the weight? Do you pull in the same direction when you use a single Fixed Pulley? a single Movable Pulley?
- 2 Measure the distance you pull the cord and the distance you lift the weight, as you did with the Fixed and Movable Pulleys. Compare your results. Are the measurements the same? Why or why not?
- 3 Use the K'NEX Rubber Band Scale to measure the force used to lift the weight with the set of Combination Pulleys. Compare your answer to the measurements you made when you lifted the same weight with only a Fixed Pulley or Movable Pulley. What do you find? How do the Combination Pulleys help move the weight?
- 4 What is the Mechanical Advantage (MA) of the Combination Pulley? (Use the "What is the Mechanical Advantage" Reference Sheet for help.) What does this tell you about the usefulness of combination pulleys?
- 5 Experiment with other pulley combinations and cord riggings. Do all of your combinations work properly? Why might certain combinations not work? Discuss your findings in writing.

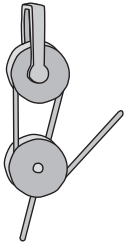


Flagpole Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify the type(s) of pulley used on a flagpole
- Demonstrate how a fixed pulley functions on a flagpole
- Describe how pulleys do work on a flagpole
- Investigate flags from different countries and what they symbolize
- Practice creative problem-solving
- Investigate and draw conclusions about conditions in space as they relate to flying a flag
- Enhance deductive reasoning skills when decoding flag messages

Materials

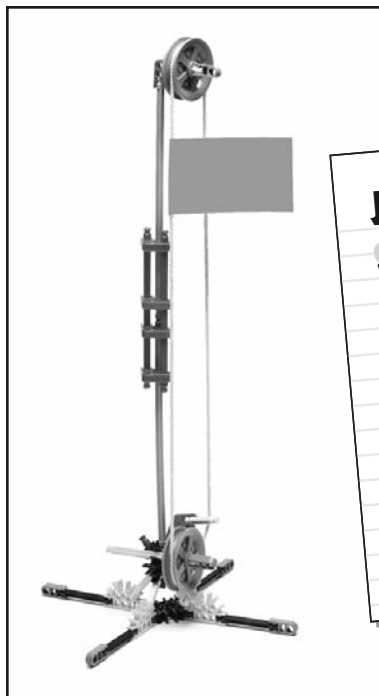
- blank dot stickers or pieces of masking tape
- marker
- colored paper or cloth
- colored markers, crayons, pencils or paints
- scissors
- needles and thread (optional)
- paperclips, glue or tape

Every pulley has a job to do

Try raising and lowering the flag on your school's flagpole. If the flagpole has more than one fixed pulley (one each at the top and bottom), notice how the top one helps raise the flag and the bottom one helps return the cord. Keep in mind that the pulleys may be hidden inside the core of large flagpoles.

What kind of pulley is it?

This Flagpole uses fixed pulleys to raise and lower the flag.



Journal Check

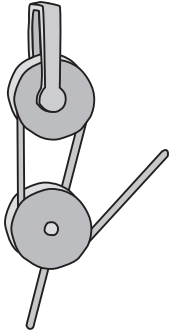
- ✓ Flag design and description of what it represents
- ✓ Explanation of message codes
- ✓ Decoded messages of classmates
- ✓ Description of the atmosphere in space and explanation of how a flag would fly there

QUESTIONS

- 1 Create your own flag to represent a newly developed country, using cloth or paper. Then, fold one side of the flag around the Flagpole's cord. Place one or two paperclips over the fold to hold the flag in place. Experiment with raising and lowering the flag. Watch the pulley at work.
- 2 Try making your Flagpole taller by adding more Rods to the pole. Experiment to find out the best way to add supports to the Flagpole to keep it stable. Have a contest with your classmates to raise the highest flag.
- 3 Send signals to classmates using your flag and Flagpole. Make flags with different colors, pictures or symbols to stand for something else. Work together to decode the messages.
- 4 When the flag is raised, how is it held in place? Why are flags sometimes raised to only half mast? What does this mean? Design a way to hold your flag on the Flagpole at half mast.
- 5 Design a flagpole and flag for your country's portion of the International Space Station. What are some things you want your flag to represent?
How would you raise and lower your flag in space? Would the pulleys on your flagpole work the same way in space as they do on Earth? Do some investigation about space atmosphere to answer this question.

ANSWERS

- 1 Tie in the study of geography when making flags for flagpoles. Use real flags as a foundation to create others with symbolic meaning. Then, have students creatively design flags to represent your class, grade or school. Use them at assemblies or other events. They might stitch flags from cloth or decorate cloth with fabric markers or paints. Paper flags could be made using cut-outs from papers of different colors or textures. Attach the flag to the cord with paperclips to change flags easily or use tape or glue for a more permanent solution.
- 2 To build a taller K'NEX Flagpole, students might make a wider base, add upright Rods to brace the pole or make the pole out of a cluster of Rods. Have a contest to raise the highest flag.
- 3 Use flags for hand-raising in class or to send other simple messages (e.g. gone to library; gone to special class, etc.). Explore how flags are used to send other signals, (e.g. between ships at sea.)
- 4 When a flag on a real flagpole is raised, there is a fixture near the bottom of the pole around which the rope is wrapped. This fixture is called a cleat. The flag is raised to the desired height and the extra rope is wrapped around the cleat to fasten it so the flag does not move.
A flag raised to only half mast typically symbolizes mourning a death or remembering people who died.
- 5 Students answers may vary. They should include reference to the atmosphere in space, lack of gravity and how pulleys function.



The Flagpole

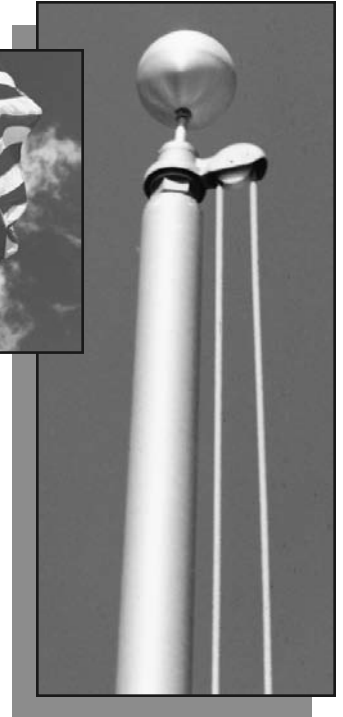
Every pulley has a job to do

A pulley can make the job of raising and lowering a flag much easier. The flag is attached to a rope which runs through a pulley at the top of the pole. Pull on the rope and up goes the flag. Without the pulley and its rope, you'd have to climb the pole to hitch the flag on top!

What kind of pulley is it?

Does the Flagpole use a fixed pulley, a movable pulley or both?

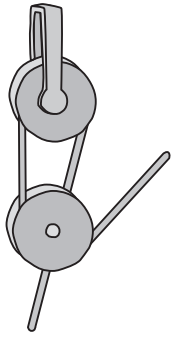
- Test each pulley to see if it moves when you lift a weight.
(Turning in place doesn't count since all pulleys turn in place!)
- Use stickers or tape to label each pulley:
 Fixed Movable



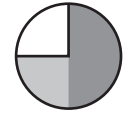
Student Challenge

- 1 Create your own flag to represent a newly developed country, using cloth or paper. Then, fold one side of the flag around the Flagpole's cord. Place one or two paperclips over the fold to hold the flag in place. Experiment with raising and lowering the flag. Watch the pulley at work.
- 2 Try making your Flagpole taller by adding more Rods to the pole. Experiment to find out the best way to add supports to the Flagpole to keep it stable. Have a contest with your classmates to raise the highest flag.
- 3 Send signals to classmates using your flag and Flagpole. Make flags with different colors, pictures or symbols to stand for something else. Work together to decode the messages.
- 4 When the flag is raised, how is it held in place? Why are flags sometimes raised to only half mast? What does this mean? Design a way to hold your flag on the Flagpole at half mast.
- 5 Design a flagpole and flag for your country's portion of the International Space Station. What are some things you want your flag to represent?

How would you raise and lower your flag in space? Would the pulleys on your flagpole work the same way in space as they do on Earth? Do some investigation about space atmosphere to answer this question.

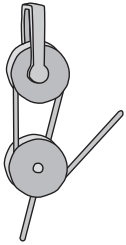


Sailboat Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify the type(s) of pulley used on a sailboat
 - Demonstrate how a fixed pulley functions on a sailboat
 - Describe how pulleys do work on a sailboat
 - Understand how sailboats utilize their sails
 - Practice creative problem-solving to alter the Sailboat design
 - Gain hands-on experience using windpower with a sailboat model
- Investigate the effects of different weather conditions on sailing and sail function as it relates to pulleys

Materials

- blank dot stickers or pieces of masking tape
- pictures of sailboats and ships
- pieces of lightweight cloth
- scissors
- colored markers or paints
- paperclips, glue or tape
- extra K'NEX pieces
- electric fan or blow dryer

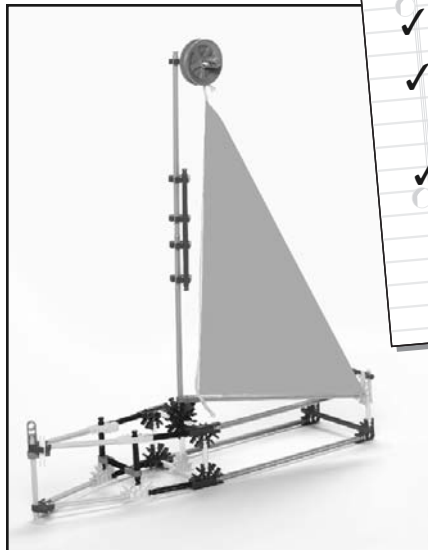
Warning: *Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.*

Every pulley has a job to do

Sailboat pulleys are essential when the wind changes and a sailor has to raise or lower a sail in a hurry. If the sail is not in the right position to handle weather conditions, the results can be very dangerous and life-threatening to the crew.

What kind of pulley is it?

This Sailboat uses a fixed pulley to raise and lower the sail. However, there are often many fixed, movable and combination pulleys used on larger sailboats.



Journal Check

- ✓ Design for sails
- ✓ Research information about sailing and sails
- ✓ Description & assessment, in paragraph form, of sail position in different wind and weather conditions

QUESTIONS

- 1 Design a sail for your Sailboat using paper or cloth. Use reference materials to learn about sailing and to get ideas for designs and shapes for the sail.

Then, attach the sail to the cord using paperclips, tape or glue. The sail captures the wind to help the boat move through the water.

Research sailing to learn about tacking. Then, move your sail as if you were tacking your sailboat across the lake.

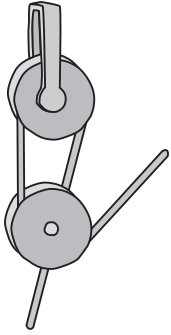
- 2 Attach wheels and axles to your boat so it can roll along the ground. Then, use a fan to blow air against the sail and make the boat move. Try having a sailboat race with a friend.
- 3 Build a bigger sailboat with several sails. Use a Pulley to raise each sail.
- 4 When might you want to keep your sail lowered? There are times when it is important to drop the sail quickly, especially in stormy conditions. What do you think could happen if the sail wasn't dropped quickly enough? Describe this situation in a short paragraph. Experiment with raising and lowering your sail.

ANSWERS

- 1 Sailboats use triangular sails which are easily raised by a single fixed pulley. Other sails could be shaped like a square or trapezoid but may require a pulley at each corner to hoist them. Clipper ships use sails of different shapes and may serve as a reference for creative design.

Tacking is a sailing procedure where the boat takes a zig zag course in order to sail against the wind. This procedure allows sailors to maximize the power of the wind on the sail so they can travel faster.

- 2 When wheels are added to the Sailboat, experiments will require a large, clear area with a smooth surface. Experiments should be creative with alterations in the size or angle of the sail or the position of the wheels, in order to make the Sailboat run better or faster. However, when conducting tests, only one variable should be changed at a time so it is possible to see how each factor affects how the Sailboat moves. Reference materials will come in handy to determine whether these kinds of sail "boats" actually exist. (These boats are often used on the California and Utah flat deserts.)
- 3 When building multi-sail boats, students might work together in groups to make a single large boat. Have each student in the group add a sail and rig its pulley. Provide pictures of sailing ships so students can get ideas for their models. Set up courses to time how long each boat takes to travel specified distances (2 meters). Discuss the effect that the sails have on the travel time.
- 4 Students answers will vary. Results could be very hazardous to the boat's crew. In some cases, the sails could capture the wind in such a way as to make it flip over and capsize which could be life-threatening to the crew.



The Sailboat

Every pulley has a job to do

The wind is picking up, so it's time to raise the sail and cast off! The pulley at the top of the mast makes raising the sail an easy job. When you pull down on the rope, the sail goes up and off you go!

What kind of pulley is it?

Does the Sailboat use a fixed pulley, a movable pulley or both?

- Test each pulley to see if it moves when you lift a weight. (Turning in place doesn't count since all pulleys do that!)
- Use stickers or tape to label each pulley:
 - F** Fixed
 - M** Movable



Student Challenge

- 1** Design a sail for your Sailboat using paper or cloth. Use reference materials to learn about sailing and to get ideas for designs and shapes for the sail.

Then, attach the sail to the cord using paperclips, tape or glue. The sail captures the wind to help the boat move through the water.

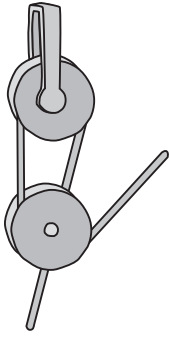
Research sailing to learn about tacking. Then, move your sail as if you were tacking your sailboat across the lake.

- 2** Attach wheels and axles to your boat so it can roll along the ground. Then, use a fan

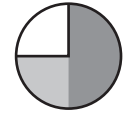
to blow air against the sail and make the boat move. Try having a sailboat race with a friend.

- 3** Build a bigger sailboat with several sails. Use a Pulley to raise each sail.

- 4** When might you want to keep your sail lowered? There are times when it is important to drop the sail quickly, especially in stormy conditions. What do you think could happen if the sail wasn't dropped quickly enough? Describe this situation in a short paragraph. Experiment with raising and lowering your sail.

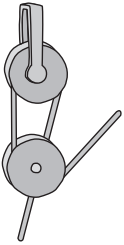


Clothesline Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify the type(s) of pulley used in a clothesline
- Demonstrate how fixed pulleys function on a clothesline
- Determine how pulleys do work on a clothesline
- Practice creative problem-solving for Clothesline functions
- Modify the Clothesline to function as a type of ski lift machine
- Design and create models using fixed pulleys
- Investigate the technological evolution of the pulley relating to the Clothesline

Materials

- blank dot stickers or pieces of masking tape
- marker
- a roll of heavy string
- clothespins or paperclips
- extra K'NEX pieces

Every pulley has a job to do

Technology is constantly changing, and this has been the case with a machine as simple as the clothesline. The clothes dryer is probably the most common means of drying clothing today. But before this invention, people used clotheslines which made use of a simple machine - the pulley.

People strung up clotheslines in backyards, as well as between the upper stories of apartment buildings. By leaning out a window, a person could attach a shirt to the line, reel it out and then hang out another shirt. The pulleys helped move the clothes where people couldn't reach. Today, some people continue to use clotheslines rather than drying machines to save electrical energy and because they prefer their clothes dried by fresh air.

What kind of pulley is it?

The Clothesline uses a fixed pulley at each end of the line.



Journal Check

- ✓ Description of how a clothesline works
- ✓ Application of how the clothesline pulley concept can be applied to do other work
- ✓ Explanation of jobs being done using pulleys and how an assembly line process works

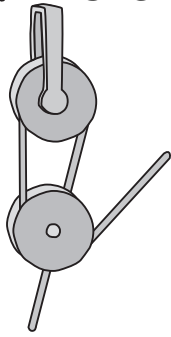
Student Challenge

QUESTIONS

- 1** a. You can hang more than just clothes on a clothesline! Set up a long Clothesline that stretches across your classroom. Write a message on a piece of paper and use the Clothesline to send your message to a friend across the room.
b. Make a Clothesline that can turn corners. What do you need to do to make this work? Use paperclips to hang your notes from the cord. Hook paperclips through the cord so that they can roll past each Pulley as the cord goes around a corner.
- 2** Redesign your Clothesline to function as a tow rope, T-bar or J-bar ski lift.
- 3** Use a series of fixed pulleys to set up an assembly line which performs at least four different tasks. Explain how your assembly line works.
- 4** Another place you'll be sure to find a series of pulleys is on window blinds or curtains at home and school. Experiment with these pulleys and then search for other examples of a pulley series in your home or school.

ANSWERS

- 1** a. The K'NEX Clothesline can be locked around a table/desk leg or top, a door knob or hinge, a window ledge or any other stable object. It is important that the pulleys are securely fastened. Clothespins are a helpful tool (a lever) which make it easy to affix notes or artwork to the Clothesline. Paperclips will also do the job.
b. A pair of pulleys at each corner will accommodate the pair of cords running opposite ways which are needed to set up a route for the Clothesline to travel around a corner. The route might include running a line up a wall and then turning a corner to go across the room; or the Clothesline route could run from a classroom, around a doorway, across the hall to another classroom.
- 3** Students answers will vary. They should be able to provide the reasoning for how they designed their assembly line and the order in which tasks are performed.



The Clothesline



Every pulley has a job to do

A clothesline has a pulley at each end with a cord making a loop around them. On some clotheslines, people hang out shirts to dry. The same kind of line can be used in a restaurant to send orders to the kitchen. Tow rope and T-bar ski lifts work like a giant clothesline to move people from the bottom to the top of a mountain. Either way, the pulleys make it easy to move objects from one place to another.

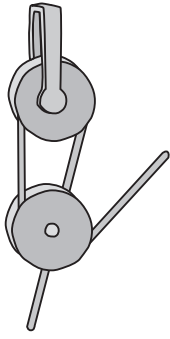
What kind of pulley is it?

Does the Clothesline use a fixed pulley, a movable pulley or both?

- Test each pulley to see if it moves when you lift a weight.
(Turning in place doesn't count since all pulleys turn in place!)
- Use stickers or tape to label each pulley:
 - F** Fixed
 - M** Movable

Student Challenge

- 1 a. You can hang more than just clothes on a clothesline! Set up a long Clothesline that stretches across your classroom. Write a message on a piece of paper and use the Clothesline to send your message to a friend across the room.
 - b. Make a Clothesline that can turn corners. What do you need to do to make this work? Use paperclips to hang your notes from the cord. Hook paperclips through the cord so that they can roll past each Pulley as the cord goes around a corner.
- 2 Redesign your Clothesline to function as a tow rope, T-bar or J-bar ski lift.
- 3 Use a series of fixed pulleys to set up an assembly line which performs at least four different tasks. Explain how your assembly line works.
- 4 Another place you'll be sure to find a series of pulleys is on window blinds or curtains at home and school. Experiment with these pulleys and then search for other examples of a pulley series in your home or school.

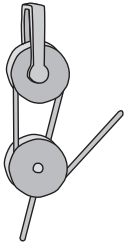


Elevator Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify the type(s) of pulley used in an elevator
- Demonstrate how fixed and movable pulleys function on an elevator
- Describe how both fixed and movable pulleys do work in an elevator
- Differentiate between fixed and movable pulleys
- Distinguish between different types of elevators and the loads they lift
- Practice creative problem-solving to design a counterbalance for the Elevator
- Compare and contrast the benefits of each pulley in the Elevator
- Measure the distance of Elevator movement for each type of pulley
- Evaluate usefulness of different types of pulleys

Materials

- blank dot stickers or pieces of masking tape
- marker
- small weights to make a counterweight
- extra K'NEX pieces

Every pulley has a job to do

Elevators don't just lift people. Certain types of elevators lift cars or loads of grain. An aircraft carrier has special elevators to lift fighter jets from one deck of the carrier to another. There are even bridges, called lift bridges, which have a special elevator to raise and lower the center portion of the bridge to allow boat traffic to pass underneath. Consider other objects lifted more easily by an elevator.

What kind of pulley is it?

The Elevator shaft with one pulley uses a fixed pulley. The other Elevator shaft uses both a fixed pulley and a movable pulley.



Journal Check

- ✓ Distance measurements to lift the movable and fixed pulley elevators
- ✓ Comparison, assessment and evaluation of the distances moved and work done by fixed and movable pulleys

QUESTIONS

- 1 A real elevator has a cab full of people at one end of a set of cables and a counterweight at the other end. The counterweight is a heavy block that weighs about as much as the cab. It balances the weight of the cab, so the motor doesn't have to pull as hard to raise the cab.

Make a counterweight for your Elevator that uses a single fixed pulley. Test it to see if it balances the cab's weight.

- 2 a. Raise the Elevator cab with the movable pulley. How does the movable pulley change the way the Elevator works? Which Elevator is easier to lift? Why?

b. Pull the cord to lift the fixed pulley Elevator to the top of the shaft. Measure the length of the cord from your fingertips to the fixed pulley. Record this measurement.

Now, pull the cord to lift the movable pulley Elevator to the top of the shaft. Again, measure the distance you pulled the cord. Record your measurement. Compare your measurements. What do you find? For which Elevator did you have to use more cord?

c. Pick the words to make this statement about pulleys true. (Use your measurements to help you decide.) Movable pulleys make work (harder/easier) than fixed pulleys and the work is done for a (shorter/longer) distance.

- 3 Test your counterweight from Step 1 on the movable pulley Elevator. Does it work as well as it did on the fixed pulley Elevator? If not, how can you change the counterweight to make it work?

ANSWERS

- 1 The Elevator cab can use any type of counterbalance including K'NEX. The weight of the Elevator cab and the counterweight will be the same if the counterweight is a K'NEX duplicate of the Elevator cab.

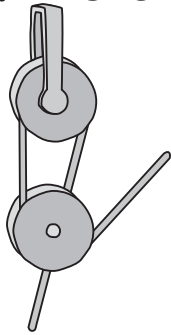
If the Elevator can sit still anywhere along the shaft, due to being weighted down by the counterweight, then the counterweight is properly balanced. It will appear that the Elevator is stopping at different floors.

- 2 a. Adding a movable pulley to the Elevator makes the lifting twice as easy, but it also requires a cable that is twice as long.

b. The measurement for the distance the fixed pulley cord is pulled should be half the distance for the movable pulley. More cord is used to lift the movable pulley Elevator.

c. Movable pulleys make work **easier** than fixed pulleys but the work is done for a **longer** distance.

- 3 The counterweight for the fixed pulley Elevator is too heavy for the movable pulley Elevator. Since the movable pulley lets you lift the Elevator with half the force, the counterweight need only be half as heavy. Removing half the K'NEX pieces from the counterweight should bring the Elevator into balance.



The Elevator

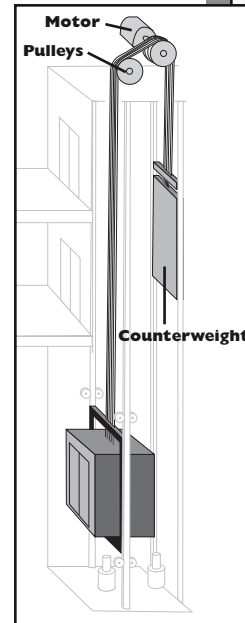
Every pulley has a job to do

Imagine climbing more than 2,000 steps (110 stories) to the top of the Willis Tower (formerly known as the Sears Tower) in Chicago, one of the tallest buildings in the world. You'd save a lot of time and energy if you rode an elevator instead! Elevators use pulleys and strong cables to travel up and down.

What kind of pulley is it?

Does the Elevator use a fixed pulley, a movable pulley or both?

- Test each pulley to see if it moves when you lift a weight. (Turning in place doesn't count since all pulleys turn in place!)
- Use stickers or tape to label each pulley:
 - F** Fixed **M** Movable



Student Challenge

1 A real elevator has a cab full of people at one end of a set of cables and a counterweight at the other end. The counterweight is a heavy block that weighs about as much as the cab. It balances the weight of the cab, so the motor doesn't have to pull as hard to raise the cab.

Make a counterweight for your Elevator that uses a single fixed pulley. Test it to see if it balances the cab's weight.

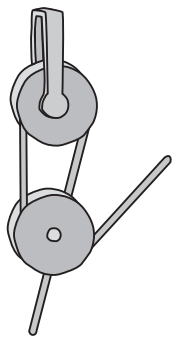
2 a. Raise the Elevator cab with the movable pulley. How does the movable pulley change the way the Elevator works? Which Elevator is easier to lift? Why?

b. Pull the cord to lift the fixed pulley Elevator to the top of the shaft. Measure the length of the cord from your fingertips to the fixed pulley. Record this measurement.

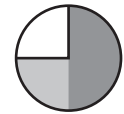
Now, pull the cord to lift the movable pulley Elevator to the top of the shaft. Again, measure the distance you pulled the cord. Record your measurement. Compare your measurements. What do you find? For which Elevator did you have to use more cord?

c. Pick the words to make this statement about pulleys true. (Use your measurements to help you decide.) Movable pulleys make work (harder/easier) than fixed pulleys and the work is done for a (shorter/longer) distance.

3 Test your counterweight from Step 1 on the movable pulley Elevator. Does it work as well as it did on the fixed pulley Elevator? If not, how can you change the counterweight to make it work?

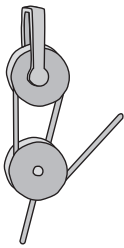


Block and Tackle Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify the type(s) of pulley used in a block and tackle
- Demonstrate how fixed and movable pulleys function in a block and tackle
- Describe how both fixed and movable pulleys work in combination in a block and tackle
- Measure forces with a Rubber Band Scale
- Understand and demonstrate the advantage of the Block and Tackle pulley arrangement

Materials

- blank dot stickers or pieces of masking tape
- marker
- K'NEX Pulley Stand
- weights, such as a cup of pennies or laboratory weights
- K'NEX Rubber Band Scale
- extra K'NEX pieces

Every pulley has a job to do

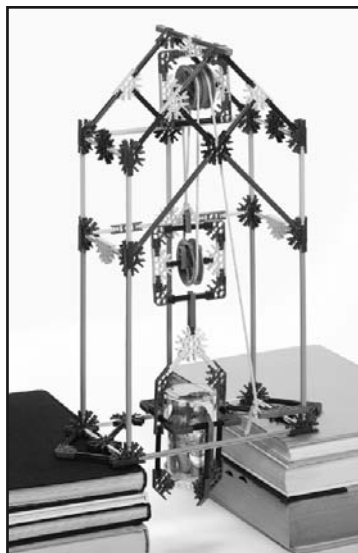
Pulleys can make lifting heavy weights easier. The block and tackle is a specific configuration of fixed and movable pulleys that work together to increase Mechanical Advantage.

Each movable pulley added to the block and tackle combination makes the work easier.

So, if five pulleys are added then the work would be five times easier or five times as much weight could be lifted than without the block and tackle.

What kind of pulley is it?

The Block and Tackle includes both fixed and movable pulleys.



Journal Check

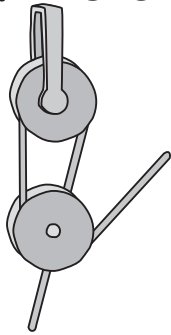
- ✓ Force measurements for lifting weight with and without Block and Tackle pulleys
- ✓ Comparison of force measurements with different pulley arrangements
- ✓ Explanation of experiments with different combinations and numbers of pulleys
- ✓ Mechanical Advantage for different Block and Tackle arrangements
- ✓ Explanation of how Block and Tackle arrangement affects MA

QUESTIONS

- 1 a. Place your Pulley Stand across two desks so that the weight can hang through the space between the desks. Attach a weight to the orange Connector below the block on the Block and Tackle.
b. Lift a heavy weight using the Block and Tackle. How does it feel?
c. Use the K'NEX Rubber Band Scale to measure how much force it takes to lift the weight using the Block and Tackle. Then, measure how much force it takes to lift the weight by itself, without using any pulleys. How do the two measurements compare?
- 2 Build and test a Block and Tackle with more or fewer Pulleys. Is lifting easier with more Pulleys or with fewer Pulleys? Discuss your findings.
- 3 Find the Mechanical Advantage (MA) for different Block and Tackle arrangements. (Use the "What's the Mechanical Advantage" Reference Sheet for help.) How does the arrangement affect the MA?

ANSWERS

- 1 Scale measurements, when lifting with a four cord Block and Tackle, will indicate that it takes about one-quarter the force to lift the weight than is needed when lifting without it.
- 2 Students should find that the more pulleys they add, the more cords will be supporting the weight. As a result, lifting will be easier. Reinforcing the work pulleys do can be dramatic. Compare lifting a gallon water bottle with a fixed pulley alone, and then with a series of movable pulleys. Take measurements with each experiment as each movable pulley is added.
The Block and Tackle instruction card provides several different ways to add pulleys to the Block and Tackle. Students can use these examples to determine the effect of adding more pulleys. They should also test the Block and Tackle with their own pulley arrangements. The purpose of this is to determine if the arrangement of the pulleys within the Block and Tackle affects the force needed and MA or if it is just the number of pulleys used.
- 3 Review the "What's the Mechanical Advantage?" Reference Card to determine how much the Block and Tackle reduces the force needed to lift a weight. (With four cords supporting the weight, the Mechanical Advantage is 4.)
Students should find that when comparing Block and Tackle combinations with the same number of pulleys, the MA will be the same despite the arrangement of the pulleys.



The Block and Tackle

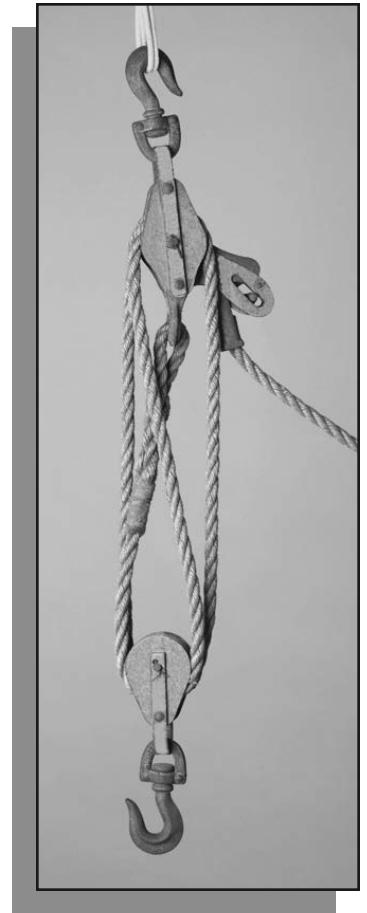
Every pulley has a job to do

In a block and tackle, several fixed and movable pulleys work together to make lifting easy. The block is a frame that holds the pulleys. The tackle is the rope or cord. People use these combination pulleys to lift very heavy things, such as lumber, car engines, pianos and even railroad cars!

What kind of pulley is it?

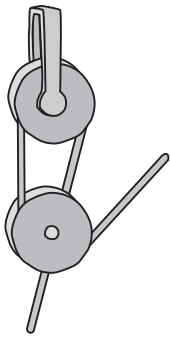
Does the Block and Tackle use a fixed pulley, a movable pulley or both?

- Test each pulley to see if it moves when you lift a weight.
(Turning in place doesn't count since all pulleys turn in place!)
- Use stickers or tape to label each pulley:
 - F** Fixed
 - M** Movable

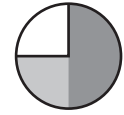


Student Challenge

- 1 a. Place your Pulley Stand across two desks so that the weight can hang through the space between the desks. Attach a weight to the orange Connector below the block on the Block and Tackle.
 - b. Lift a heavy weight using the Block and Tackle. How does it feel?
 - c. Use the K'NEX Rubber Band Scale to measure how much force it takes to lift the weight using the Block and Tackle. Then, measure how much force it takes to lift the weight by itself, without using any pulleys. How do the two measurements compare?
- 2 Build and test a Block and Tackle with more or fewer Pulleys. Is lifting easier with more Pulleys or with fewer Pulleys? Discuss your findings.
- 3 Find the Mechanical Advantage (MA) for different Block and Tackle arrangements. (Use the "What's the Mechanical Advantage" Reference Sheet for help.) How does the arrangement affect the MA?

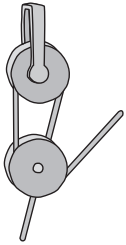


Crane Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify the type(s) of pulleys used in a crane
- Differentiate between fixed and movable pulleys
- Demonstrate how fixed and movable pulleys function on a crane
- Describe how both fixed and movable pulleys work in combination in a crane
- Determine different uses for cranes and the loads they lift
- Compare and contrast the benefits of each pulley and the loads they can lift
- Modify the Crane design to perform different types of work

Materials

- blank dot stickers or pieces of masking tape
- marker
- small weight or K'NEX Tires
- magnet
- string
- metal and non-metal scraps and small objects, such as: pencils, paper clips, safety pins, erasers, staples, thumbtacks, bits of paper, chalk
- extra K'NEX pieces

Every pulley has a job to do

A crane has many different components which perform various tasks including the crane's cab and arm, with a pulley at the top of the arm, and a cable running over the pulley. Often they include a movable pulley that lifts the arm. Real cranes have a motor at the base which winds the cable(s) as the load moves up.

What kind of pulley is it?

The Crane uses both fixed and movable pulleys.



Journal Check

- ✓ Description and comparison of how the Crane works including all its mechanisms, particularly the pulleys
- ✓ Assessment of how much weight can be lifted when outriggers are added to the Crane

Student Challenge

QUESTIONS

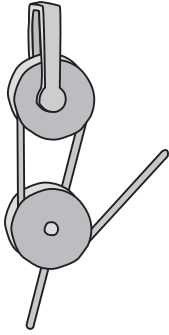
- 1 Attach a weight to your Crane and try lifting it. Try this by rolling up the string or by working the Crane's mechanisms to lift its arm. Wind the upper crank first to pull up the string. Then, wind the lower crank to lift the arm. Which one turns easier? Why?
- 2 Tie a magnet to the cord on your Crane or design and attach a claw that can grab objects. Then, set up a "recycling center," with a pile of metal and non-metal scraps and objects. Your job is to collect the recyclable iron and steel from the scrap pile. Use your Crane to do the job.
- 3 At one end of a crane's long arm or boom, a heavy load pulls down. The crane must have a counterbalance or some weight at the other end of the arm to keep from tipping over. Often the cab (where the driver sits) is heavy enough to balance the crane. Also, some cranes have special legs called outriggers that stick out from the cab to keep them balanced. Add weights and outriggers to your K'NEX Crane. Then, see how much weight you can lift.
- 4 Modify your Crane so it can remain stationary (stay in one place) instead of having the whole Crane travel while it moves objects from one location to another.

ANSWERS

Use the Crane as a culminating activity. Review what students have learned about pulleys and assess their understanding by seeing if they can identify the various pulleys within this model.

Provide the students with ample room and materials so they can be creative as they come up with ways to use their Cranes. Some students might choose to accomplish useful tasks, while others might work best with an imaginary scenario.

- 1 The lower crank (for the combination pulleys that raise the arm) is easier to wind than the upper crank (for the fixed pulley at the end of the arm). The reason for this difference is that the lower crank supplies the effort for a movable pulley, which makes the work of lifting easier. The upper crank operates a fixed pulley, which changes the direction of pull but doesn't reduce the effort needed for lifting.
- 2 Construction sites and recycling centers are common places for a crane to do work. Cranes often sort scraps and objects which might be tedious to sort otherwise.
- 3 A crane requires a counterbalance, as does an elevator. Weights must be added to keep the Crane balanced. Weights could be added in the form of a wider base with K'NEX Tires or other weights stacked on the base. Outriggers, another type of balance, can be added by attaching K'NEX Rods at the base, extending out to each side.



The Crane

Every pulley has a job to do

A crane has a long arm that reaches out to lift a heavy load. The crane has pulleys that move the arm up and down, and others that pull the load up on a cable. Cranes lift beams and walls for buildings, and they load cargo onto ships. A wrecking crane swings a heavy ball to knock down old buildings. Other cranes use powerful magnets to pick up crushed cars in junkyards. There's even a special crane that loads the Space Shuttle onto the back of a NASA jet!

What kind of pulley is it?

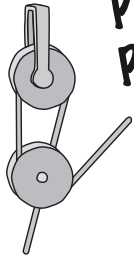
Does the Crane use a fixed pulley, a movable pulley or both?

- Test each pulley to see if it moves when you lift a weight. (Turning in place doesn't count since all pulleys do that!)
- Use stickers or tape to label each pulley:
 - F** Fixed
 - M** Movable











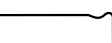









Student Challenge

- 1** Attach a weight to your Crane and try lifting it. Try this by rolling up the string or by working the Crane's mechanisms to lift its arm. Wind the upper crank first to pull up the string. Then, wind the lower crank to lift the arm. Which one turns easier? Why?
- 2** Tie a magnet to the cord on your Crane or design and attach a claw that can grab objects. Then, set up a "recycling center," with a pile of metal and non-metal scraps and objects. Your job is to collect the recyclable iron and steel from the scrap pile. Use your Crane to do the job.
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- 4** Modify your Crane so it can remain stationary (stay in one place) instead of having the whole Crane travel while it moves objects from one location to another.



PULLEYS Part & Model List

		FIXED, MOVABLE & COMBINATION PULLEYS	FLAGPOLE	SAILBOAT	CLOTHESLINE	ELEVATOR	BLOCK & TACKLE	CRANE	TOTAL PARTS IN PULLEYS SET
	Tan Connector	0	0	0	0	0	0	0	14
	Gray Connector	8	6	6	0	14	14	15	19
	Orange Connector	4	0	0	4	4	6	3	11
	Red Connector	8	6	9	0	12	16	12	16
	Green Connector	0	0	0	0	0	6	0	6
	Yellow Connector	7	4	7	4	12	12	9	12
	Blue Connector	7	3	2	0	8	8	8	8
	White Connector	2	0	0	0	2	3	0	4
	Purple Connector	25	0	8	0	32	24	24	32
	Green Rod	4	7	4	0	14	19	12	21
	White Rod	24	6	11	0	24	24	18	26
	Blue Rod	18	4	7	2	18	31	21	32
	Yellow Rod	7	1	5	4	4	7	5	7
	Red Rod	2	2	4	0	0	3	2	4
	Gray Rod	8	2	7	0	2	6	5	11
	Lge. Pulley	2	2	1	2	3	5	5	5
	Rubber Band #18	0	0	0	0	0	0	0	3
	Cord	1	1	1	1	2	1	2	2
TOTALS FOR MODELS		127	44	72	17	151	185	141	233