

The Power of Pulleys

Objective

Explore the advantages that pulleys offer

Materials

Per youth or team of 2

- 2 cereal (or similar) boxes
- 2 (or more) pencils or straws
- 6 (or more) washers
- String
- Paper clips
- Scissors
- Tool to create hole in boxes that pencil or straw can fit in
- Optional: small ruler

Time

45 - 60 minutes

Audience

Grades 5 and up



Contact Information

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Background

A pulley is a simple machine that can be used to give us a mechanical advantage in moving objects. Pulleys work by allowing us to move objects over a distance or in a direction that would be difficult without the use of a pulley or pulley system.

A pulley system in the diagram below labeled with a 1, uses one fixed pulley to lift a weight. In this system, the amount of force that must be applied to lift the object is equal to the weight of the object.

The pulley systems labeled 2 and 3 below are compound pulley systems that use a combination of fixed and moveable pulleys.

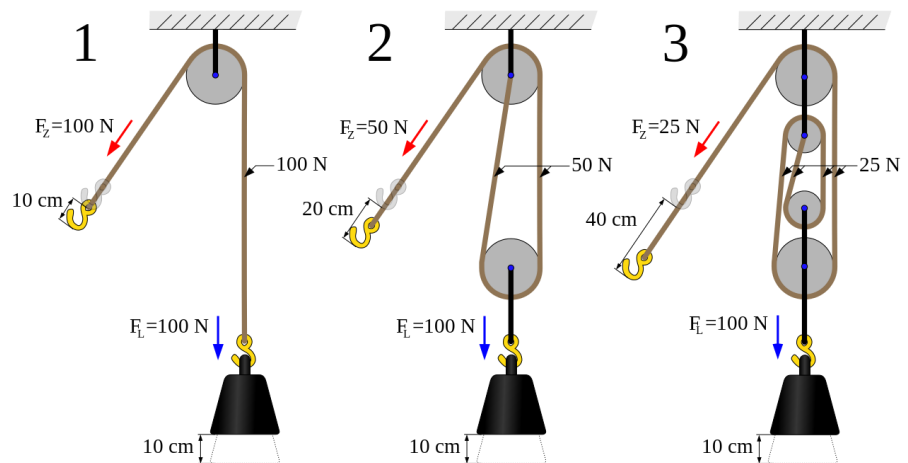


Image from <https://www.cleanpng.com/png-block-and-tackle-pulley-mechanical-advantage-wheel-1490074/>

The force that needs to be applied to a fixed pulley to move the object is equal to the force being applied to the rope/string on the other side of the pulley.

The mechanical advantage of a pulley system comes into play when the rope / string is anchored to a fixed point and uses a moveable pulley. The tradeoff is that the distance the rope must be pulled is increased (for a good explanation of this, see the article on pulleys by explainthatstuff cited in the resources section at the end of this document).

Pictures of how to set up this activity are included in the appendix.

Vocabulary

Simple machine - a device with few or no moving parts that is used to modify motion (movement) and force (strength or energy) in order to make work easier

Mechanical advantage - assistance or help we get when we can use a simple machine to help us do work; there is often a tradeoff in the effort—for example, in using more than one pulley, we don't have to apply as much force, but we have to apply that force over a longer distance

Force - push or pull on an object; strength or energy created from the physical action or movement of an object

Fixed pulley - pulley is attached to a fixed point and stays in one place (example: pulley on a flag pole)

Moveable pulley - pulley that is not anchored to a fixed point and is free to move

Compound pulley system - a combination of fixed and moveable pulleys

What to Do

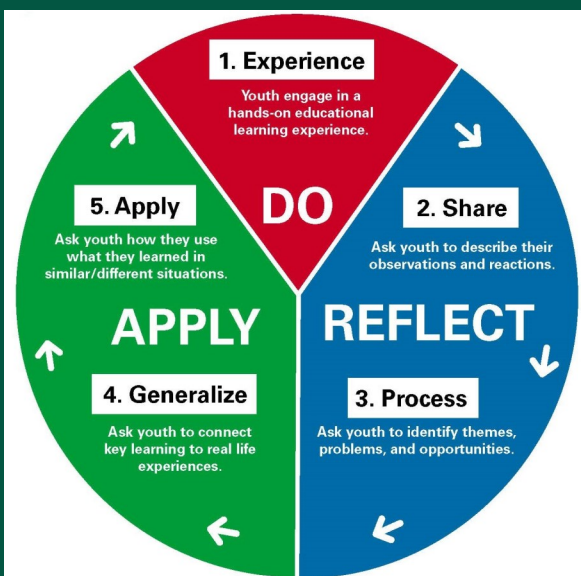
OPTIONAL PREPARATION

Depending on the age of the youth you are working with, you may want to prepare the boxes ahead of the activity by poking / drilling 4 parallel holes in each box that the pencils or straws can fit in. Boxes should have the holes at the same height (see pictures at the end of this document). Ideally each youth will have their own materials but if necessary, youth can work in teams of two.

DO

1. Connect youth to what they already know: Ask youth what if they know what the six simple machines are (lever, inclined plane, wedge, screw, wheel and axle, pulley).
2. Ask youth what they know about pulleys: What is a pulley? What are examples of pulleys? (flag poles, window blinds, cranes)
3. Tell youth that today we are going to explore the advantages of using pulleys.
4. If you have not prepared the boxes ahead of time, instruct youth to stand the two cereal boxes up parallel to each other. If you have prepared the boxes, skip to step 7.
5. Poke two holes across from each other towards the top of the boxes so you can push a straw or pencil through the holes and it will be supported by the boxes.
6. Create another set of holes about 3 centimeters from the first two holes. Then create one more set of holes.

4-H Experiential Learning Model



4-H uses the experiential learning model. Through this model of learning, youth engage in a hands-on activity, connect what they learned through that activity to what they already know and then apply their knowledge to new situations or problems. Suggestions on how to facilitate this model are included in the instructions.

7. Tell youth to cut a piece of string that is slightly longer than one cereal box is tall. Provide these instructions to youth:
 - Insert a pencil or straw into one set of holes.
 - Tie a paper clip to each end of the string.
 - Hang the string over the pencil / straw so that each end of the string has a paper clip hanging off of it.
 - Explain to youth that the pencil / straw will act as their **fixed pulley**.
 - Hang two washers from one of the paper clips (tell youth they can slightly bend one end of the paper clip so they can use it as a hook for the washers).
 - Explain to youth that these two washers are the weight to be lifted. Let the washers rest on the table.
 - Tell youth to start hanging washers carefully, one at a time on the other paper clip. These washers represent the force necessary to lift the weight. Tell youth to notice how many washers do they have to hang on the paper clip until the weight starts to lift up off the table.
8. Have youth share their results as a group. Explain that in a perfect world the force required to lift the weight will be equal to each other, so ideally we would only have to add two of the same type of washers to the empty paper clip to lift the other two washers. Ask youth if they know why that isn't the case in our example (in our system, there is a lot of friction because the string is rubbing directly against the pencil / straw).
9. Tell youth that now we are going to build a **compound pulley** and use a moveable pulley and a fixed pulley. Provide these instructions:
 - Add another pencil / straw to the next set of holes so that it is parallel to the first one.
 - Cut a new piece of string, roughly twice as long as one box is tall.
 - Tie one end of the string to the second pencil, and drape the other end over the first pencil.
 - Hang a paper clip from the part of the string between the two pencils or straws, so it dangles down between them. Hang two washers from this paper clip, and lower them fall down to the table. This will be the weight they will be lifting. The paper clip will act as a **moveable pulley**.
 - Tie the free end of the string to another paper clip. This paper clip should be up off the table, close to the pencils. Youth can shorten their string if they need to.
 - The second pencil / straw will act as a **fixed pulley**.
 - Start hanging washers carefully, one at a time, to the second paper clip. Ask youth to keep track of how many washers they have to hang on the paper clip until the weight starts to lift up off the table.
10. As a group compare the results for the two different types of pulleys. Did it take more or fewer washers to lift the same load using a compound pulley compared to a single fixed pulley? Ask youth if they know what that is. (facilitators can refer to the diagram in the background section)
11. Now tell youth we're going to add a representation of second moveable pulley by wrapping the string twice through the paper clip. Provide these instructions:
 - Add another pencil / straw to the next set of holes so that it is parallel to the first two.
 - Cut a new piece of string, roughly three times as long as one box is tall.
 - Similar to the compound pulley we just built, tie one end of the string to the first pencil, and drape the other end over the first pencil.
 - Hang a paper clip from the part of the string between the two pencils or straws, so it dangles down between them. Hang two washers from this paper clip, and lower them fall down to the table. This is the weight they will be lifting. The paper clip will act as a moveable pulley.
 - Loop the string back over the pencil or straw it is dangling from and then loop the string through the paper clip again. The paperclip should have two loops of string through it and will act as a double moveable pulley
 - Bring the free end of the string over the third pencil or straw.

- Tie the free end of the string to the second paper clip. This paper clip should be up off the table, close to the pencils. Youth can shorten their string if they need to.
12. The third pencil / straw will act as a fixed pulley.
 13. Start hanging washers carefully, one at a time, to the second paper clip. Ask youth to keep track of how many washers they have to hang on the paper clip until the weight starts to lift up off the table.
 14. As a group compare the results for this pulley system. Did it take more or fewer washers?
 15. If time allows, have youth investigate adding more fixed and moveable pulleys in different configurations.

REFLECT

Review the results again as a group.

Ask youth if they noticed any relationship between the number of pulleys and the number of washers needed to move the weight.

For older youth, ask what they think the relationship might be if this were a perfect system.

Ask youth if they noticed any difference in the distance the washers they were adding (the force being applied to lift the weight) had to travel to move the two washers (the weight)?

If time allows, have youth go back and measure the distance the string must be pulled by force to get the weight to move 10 centimeters for each pulley system.

APPLY

Ask youth if they know how elevators use pulleys. If no one mentions weights, ask how an elevator pulley system might use weights (counterweights to offset some of the force required to lift the elevator).

Ask youth, now that they know how pulley systems work, where else do they think pulleys are being used.

Ask youth how they might be able to use pulleys in their lives now that they know how pulley systems work.

Resources consulted:

Finio, B. (2024). "Lighten the Load with a Pulley." Science Buddies, www.sciencebuddies.org/stem-activities/lighten-the-load-with-a-pulley, accessed 5/23/24.

Integrated Teaching and Learning Program., College of Engineering (2024). "Powerful Pulleys." Regents of the University of Colorado Boulder, https://www.teachengineering.org/lessons/view/cub_simple_lesson05, accessed 5/23/24.

Woodford, C. (2023). "Pulleys." explainthatstuff, www.explainthatstuff.com/pulleys.html, accessed 5/23/24.

CK-12. (2024). "Pulleys." CK-12 Physical Science for Middle School, flexbooks.ck12.org/cbook/ck-12-middle-school-physical-science-flexbook-2.0/section/13.12/primary/lesson/pulley-ms-ps/, accessed 5/24/24.

Brain, M. (1970). "How a Block and Tackle Works." HowStuffWorks.com. science.howstuffworks.com/transport/engines-equipment/pulley.htm, accessed 5/24/24

Woodford, C. (2022). "Elevators." explainthatstuff, <https://www.explainthatstuff.com/how-elevators-work.html>, accessed 5/24/24

"Iowa State University Extension and Outreach. (n.d.). "4-H Experiential Learning Model. <https://store.extension.iastate.edu/product/4-H-Experiential-Learning-Model>, accessed 5/24/24.

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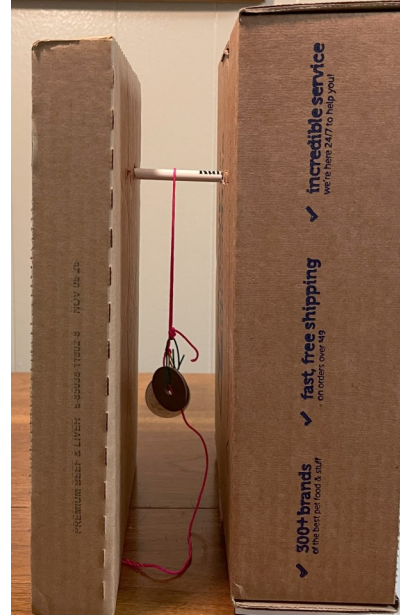
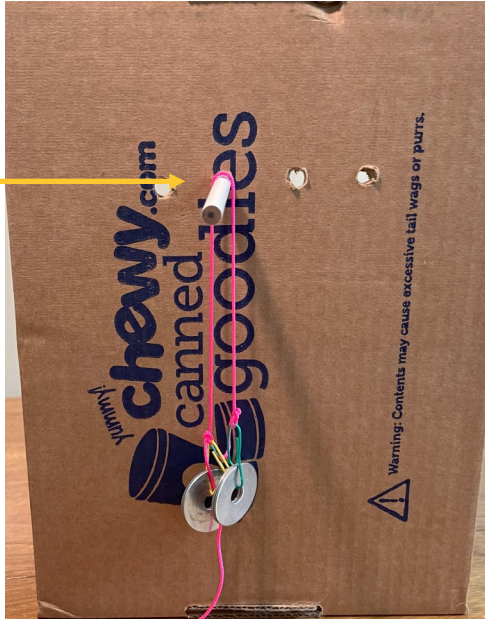
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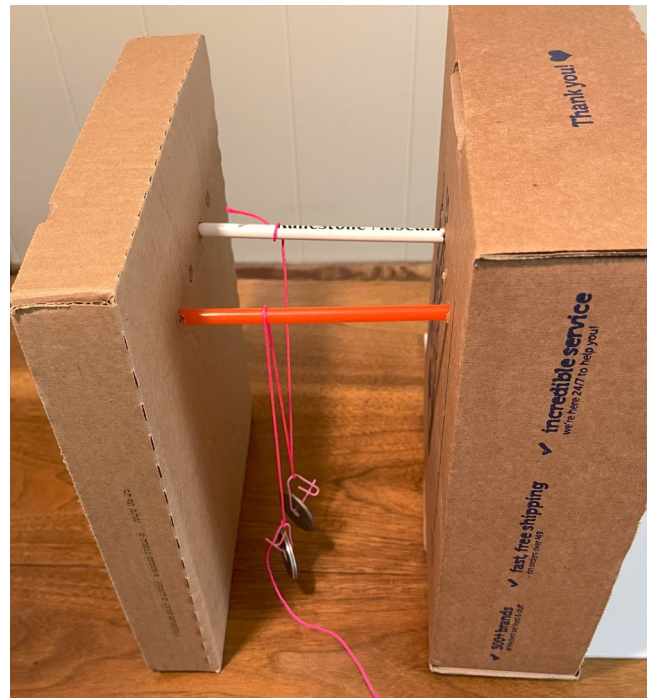
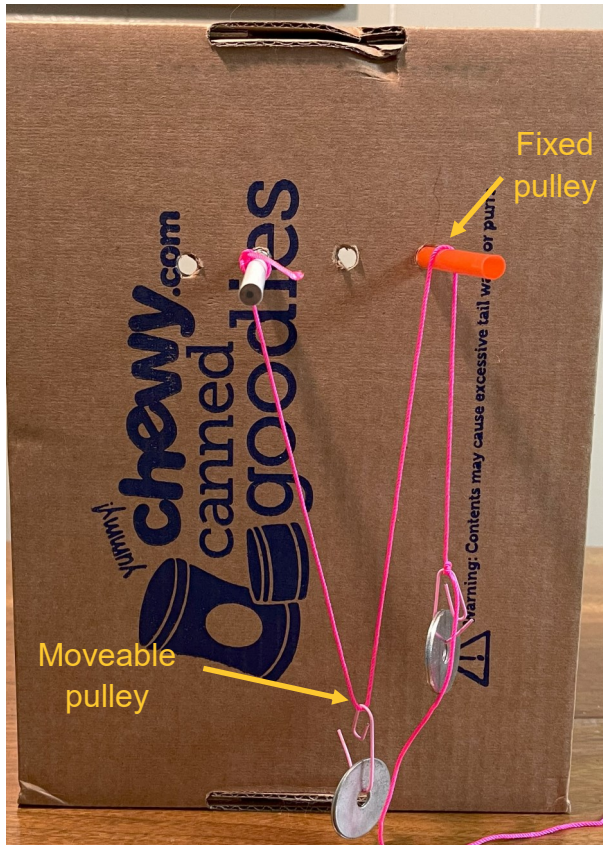
APPENDIX

Fixed pulley

Fixed pulley



Moveable pulley



APPENDIX

Fixed and moveable (2) pulleys



Fixed pulley

String is wrapped twice through paper clip, acting as 2 moveable pulleys

