Pulleys: Work and Energy

Main Topic	Forces
Subtopic	Simple Machines
Learning Level	Middle
Technology Level	Low
Activity Type	Student

Description: Investigate a complex block-and-tackle system and evaluate its efficiency.

Required Equipment	Workshop Stand, Pulleys, Bolts, Pulley String, Pinch Markers, 500g Hooked Mass, 500g Spring Scale, 250g Spring Scale, Meterstick.
Optional Equipment	

Educational Objectives

- Evaluate the efficiency of a block-and-tackle system of pulleys.

Concept Overview

In the first lab, students will assemble and work with a block-and-tackle with a total of six pulleys. They will determine the Ideal Mechanical Advantage (IMA) of the system by counting the strings, and then they will measure input and output forces and distances. The 6-pulley system will allow them to use a fraction of the force to lift an object.

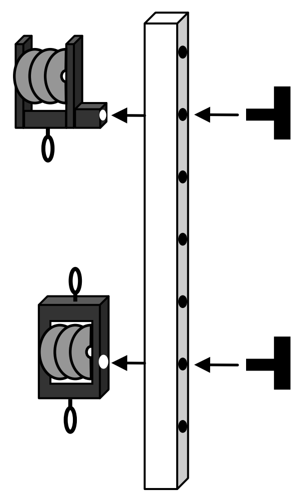
The second activity does not require lab work, but draws from the data obtained in the first lab. They will find that the Actual Mechanical Advantage of the system is not equal to the IMA, but somewhat less. They will identify sources of energy loss, such as stretching in the string and friction in the pulley wheels.

Lab Tips

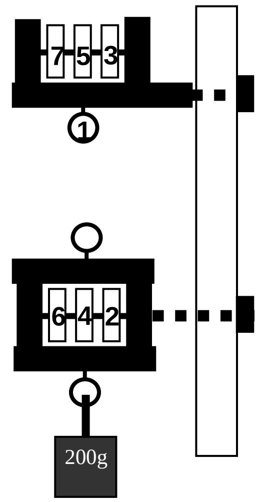
Students will assemble their own pulley systems in these labs. Below are instructions for the most complex assembly possible with these systems.

Assembly:

1. Push the attachment bolt through the Workshop Stand at approximately eye level.
2. Screw the bolt into the side of each pulley, as shown in the diagram.
3. Make sure that the bolts are tight, so that the pulley frames do not rotate. (*Note: The lower pulley is attached to the stand only for convenience during stringing. It will be detached after being strung in a pulley system.)*



4. Students will use each pulley singly, as fixed and floating pulleys, then together in a pulley system (block-and-tackle). To string the pulley system:
    a. Hang a hooked mass from the lower pulley, to prevent its frame from rotating once detached from the stand.
    b. Use a length of string 7-8 times the distance between the two attached pulleys (or longer).
    c. Tie or clip one end of the string to the lower hook (1) on the upper pulley.
    d. It is important to keep the string taut through the stringing process, or it will slip off the wheels and be difficult to manipulate.
    e. Pass the string through the lower pulley, under the right-side wheel (2).
    f. Pass the string over the right-side wheel on the upper pulley (3).
    g. Repeat: lower (4), upper (5), lower (6), upper (7). See the numbered diagram for reference.
    h. The last string will come down over the upper pulley. This will be the string on which you pull. Until you are ready to begin the experiment, wrap this string around one of the bolts in the Workshop Stand.
    i. Hold the lower pulley in one hand while you detach the bolt. The lower pulley will now be supported by the strings alone.
    j. <u>Tip</u>: During the experiment, keep the free end wrapped on the stand base so the pulleys will not easily unstring.



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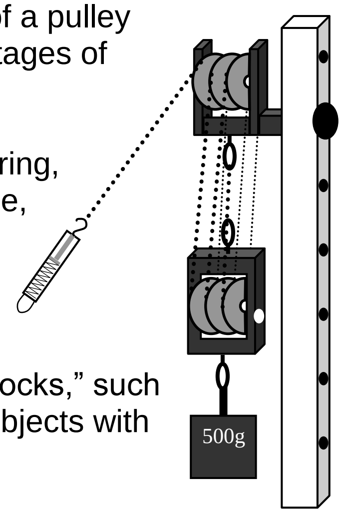
Pulleys: Block and Tackle

Objective: To maximize the mechanical advantage of a pulley system and investigate the advantages and disadvantages of such a system.



Materials: Workshop Stand, Pulleys, Bolts, Pulley String, Pinch Markers, 500g Hooked Mass, 500g Spring Scale, 250g Spring Scale, Meterstick.

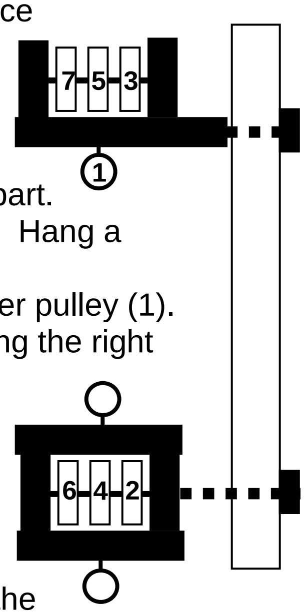
Background:

A <u>block and tackle</u> is a system of pulleys (or pulley "blocks," such as the ones in this lab) that is used to lift very heavy objects with much smaller forces.

Procedure:

Assembly

1. Measure and record the mass of the closed (lower) pulley. ___________
2. Use a length of string approximately 7-8 times the distance between the pulleys.
3. Assemble a block and tackle system as shown in the diagram. Use the numbers as a guide for stringing. <u>Keep the string taut during the stringing process</u>.



   a. Bolt both pulleys to the stand, at least 30cm apart. (You will detach the lower, movable one later.) Hang a 500g mass from the lower pulley.
   b. Tie or clip the string to the hook under the upper pulley (1).
   c. Thread the string through the lower pulley, using the right side wheel (2).
   d. Pass the string over the upper pulley, using the right side wheel (3).
   e. Repeat: lower center (4), upper center (5), lower left (6), upper left (7). Keep the string taut, and don't hurry through the process!
   f. Wrap the free end of the string around one of the bolts in the Workshop Stand. This will keep your pulleys from unstringing.
   g. Hold the lower pulley steady while you detach the bolt. It will then be supported only by the strings.
4. Slide two pinch markers up next to the upper pulley, on the free end of the string. Hook the 250g spring scale through the outer pinch marker.

Force, Direction, and Mechanical Advantage

5. Pull on the string and lift the mass.

6. What direction does the mass move? _____________ This is the direction of the Output Force.
7. What direction do you pull? _____________________ This is the direction of the Input Force.
8. What is the size of the Output Force? (Be sure to include everything that moves when you pull.) _____________
9. What is the size of the Input Force? ______________
10. Does this pulley system change the direction of a force? ___________
11. Does this pulley system change the size of a force? ___________
12. The Ideal Mechanical Advantage is equal to the number of strings supporting the weight. (Do <u>not</u> count any strings you pull <u>down</u> on.) What is the IMA of this system? ___________
13. How does the Mechanical Advantage describe the relationship between the Input and Output Forces in this system?
    ____
    ____

Distance and Mechanical Advantage

14. Release the string so that the two pinch markers are near the top pulley. Remove the spring scale.
15. Use a meterstick to record the initial height of the bottom of the 500g mass.
    ____
16. Pull the string until the mass has risen <u>20cm</u>. This is the Output Distance.
17. Hold the string in this position, and slide the upper pinch marker up next to the upper pulley. Measure the length of string between the two markers.
    ___________ This is the distance you pulled, or the Input Distance.
18. Compare the Input and Output Distances.
    ____
    ____
19. How does the Mechanical Advantage describe the relationship between the Input and Output Distances in this system?
    ____
    ____

Questions

1. List some occupations and industries that might use block and tackle systems.

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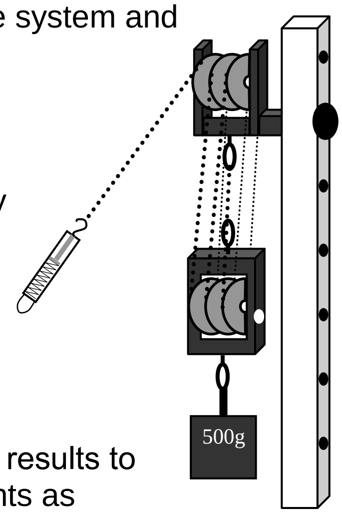
Pulleys: Work, Energy, and Efficiency

Objective: To find the efficiency of a block and tackle system and identify sources of energy loss.



Background

The Law of Conservation of Energy states that energy cannot be created or destroyed, but can change form. Mechanical systems always experience some degree of energy "loss."

Procedure:

Complete "Pulleys A3: Block and Tackle" and use the results to answer the questions below. Make your measurements as precise as possible.

Questions and Analysis

1. Transfer the following quantities from the activity. (Convert any mass units into units of force.)
   Output Force: ___________
   Output Distance: ____________
   Input Force: ___________
   Input Distance: ____________

2. Calculate the Output Work done by the machine.

3. Calculate the Input Work done by you.

4. Efficiency can be found using the following equation. Calculate the efficiency of the block and tackle.

$$efficiency = \frac{work \cdot output}{work \cdot input} \bullet 100\%$$

5. If a machine were a perfect energy converter (lost no energy to heat or other forms), what would its efficiency be?

6. If you calculated an efficiency greater than 100% for your pulley system, identify possible sources of error. If your efficiency was less than 100%, go to #7.

7. The Actual Mechanical Advantage can be found by multiplying the Ideal Mechanical Advantage by the efficiency (expressed as a decimal less than one). What is the Actual Mechanical Advantage of the block and tackle?

8. Identify sources of energy "loss" in the pulley system. Consider sources that might affect the distances, as well as those that might affect the forces. (Be specific. Don't just say "friction." Where is the friction?)

9. Are any of those forms of energy easily retrievable? Explain.

10. Identify design components of this pulley system that help to reduce energy losses.

11. Consider your own strength. How massive an object could you lift with a mechanical advantage of 6? Give an example of a real object that is about that mass.