Activity Template

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Subject Area(s) Physical Science, Science and Technology

Associated Unit Evolutionary Engineering: Simple machines from Pyramids to Skyscrapers

Yellow highlight = required component

Associated Lesson Powerful Pulleys

Activity Title The Mechanical Advantage

Header

Figure 1

ADA Description: A construction crane is shown on a city street, highlighting the cables that extend from the base of the crane to the top, on which a pulley system resides.

Caption: Figure 1: A construction crane on a city street is a common example of the use of pulleys.

Image file: figure_1.tif

Grade Level 04 (03-05)

Activity Dependency

Time Required 40 minutes

Group Size

Expendable Cost per Group US$___

Summary

Students learn about the mechanical advantage that is offered by pulleys in an interactive and game-like manner. By virtue of the activity's mechatronic presentation, the students learn to study a mechanical system not as a static image, but rather as a dynamic system that is under their control. The system that is shown is that of a mechanized elevator system, which is built using the LEGO Mindstorms robotics

platform and common hardware items. The ability to control different parameters, such as motor power, testing load, and pulley arrangement offers the educator, as well as the students, to emphasize and reinforce particular aspects/effects of mechanical advantage.

Engineering Connection

The mechanical advantage offered by pulleys is probably the most self-evident example of simple machines, used in all forms of industry and everyday life. Pulleys, in their various configurations, will often be seen in cranes, elevators, boats, and on construction hoists. Although knowledge of simple machines is often conveyed in the form of diagrams on blackboards or on paper, pulleys are in fact not as static as they are presented; witnessing the mechanical advantage offered by pulleys benefits from movement, as this activity shows.

Engineering Category = #2

Keywords

force, gravity, mechanical advantage, movable, pulley, simple machine, robot

Educational Standards

Choose from http://www.jesandco.org/asn/viewer/default.aspx.
ITEEA (provide standard number, grade band, benchmark letter and text):
State/national science/math/technology (provide source, year, number[s] and text):
NY Science Standard 1.2 Scientific Inquiry
NY Science Standard 6.2 Models

Pre-Requisite Knowledge

Teacher should be familiar with LEGO NXT Mindstorms as a building and programming platform. Knowledge of pairing NXT Intelligent Bricks via Bluetooth is necessary.

Learning Objectives

After this activity, students should be able to:

- Clearly and confidently explain that pulleys are **simple machines** that offer **mechanical advantage**, defining mechanical advantage in the form of examples
- Draw a diagram of a pulley setup that is capable of applying mechanical advantage
- Predict observations that would occur if pulleys are added to a system:
  - Ability to lift objects, which the motors were previously unable to lift
  - Loosening of tension amongst load line segments

Materials List

2 LEGO NXT Intelligent Bricks (2x$144.99) are need for each setup, plus additional LEGO Technic parts for the construction of the pulley systems (estimated $100).
Each group needs:

- A constructed and preprogrammed pulley setup, as per the construction and setup instructions.

Introduction / Motivation

Many students in 4 and 5th grade science classes have already learned about pulleys. However, we have found that, surprisingly, many students do not know how to assemble pulleys to offer mechanical advantage to a system, nor do they fully understand the benefits and trade-offs of utilizing pulleys. Therefore, we recommend that teachers first engage students by asking them what they know about pulleys, for which participation will be high. A teacher may start by posing the question: what are **simple machines**? Students will often define this term by listing devices that are traditionally presented as simple machines (i.e. pulleys, lever, and ramps). In addition, polling the students as a class for examples of pulleys used in everyday life examples also reinforces the self-evidence and prevalence of pulleys. Displaying images of these typical examples (e.g. cranes, elevators, and construction hoists) allows the

students to feel as if their answers are contributing to the flow of the lesson. Then, segue into the concept of **mechanical advantage**, perhaps by asking the students what property relates all simple machines. If students are not confident in responding, then the alternative question – what is mechanical advantage? – may be posed. Either way, the teacher should announce to the class that they will observe **mechanical advantage** in the activity, not just "pulleys." The overall goal for this activity is to provide the first steps in communicating to students that **simple machines** are not defined solely by the devices that are classified as such.

Vocabulary / Definitions

Word	Definition
Simple machine	A device that applies force, changes the direction of a force, or changes the strength of a force, in order to perform a task, generally involving work done on a load.
Mechanical advantage	The ratio of output force (acting on a load) produced by a machine to the applied effort (the input force).
Pulley	A machine consisting of a wheel over which a pulled rope or chain runs to change the direction of the pull used for lifting a load.
Load	The resistance or weight sustained by a machine.

Procedure

Background

In this lesson, students will use a combination of fixed and movable pulleys to provide mechanical advantage to a mechatronic setup. Figure 1 shows the fixed-position mechanics of the setup. The setup in Figure 1 (left) is mounted in an upside-down position as shown in Figure 1 (right). The mounting surface may be ¼" modeling wood, which is prepared and setup by the teacher beforehand. The spacings for the motor, reel and extension pulley mounts are indicated in the attached template. Fishing line or strong thread may be used to the setup, as long as the reel can sufficiently take up slack and maintain the load. The one (or two) motors that are configured with each setup should be attached to ports on a designated pulley station Brick.

Image Insert Figure 2 here, [note position: left justified]

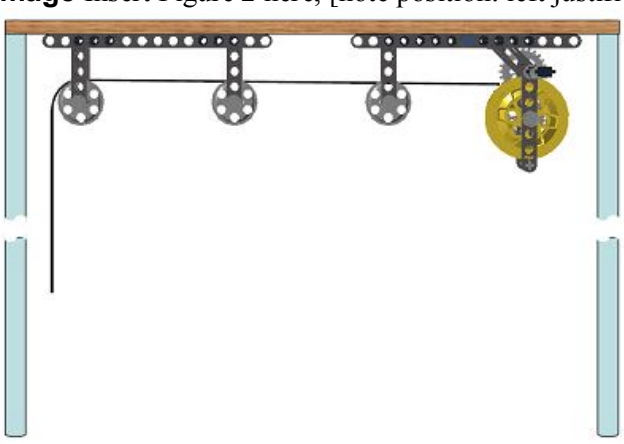


Figure 2

ADA Description: Two diagrams. One showing a profile view of the pulley setup, in which three fixed pulleys are tethered to immobilized Technic beams. All three pulleys are vertically level with each. A line of string is depicted to run through the pulleys and fed into a motorized reel device. The diagram on the right shows the same setup from an isometric viewpoint.

Caption: Figure 2: Profile view of mounted pulley setup (right). Isometric view of the setup, attached to a motor (left).

Image file: figure_2.tif

Before the Activity

The mechanical system was designed to take on only two configurations: 1) a system for which no mechanical advantage is offer (shown in Figure 2, left) and only fixed pulleys are maintaining tangential contact with the load line, with the exception of the pulley at the very left end; 2) a system for which mechanical advantage is offered by four pulleys – 2 moving and 2 fixed.

Image Insert Figure 3 here, [note position: centered]

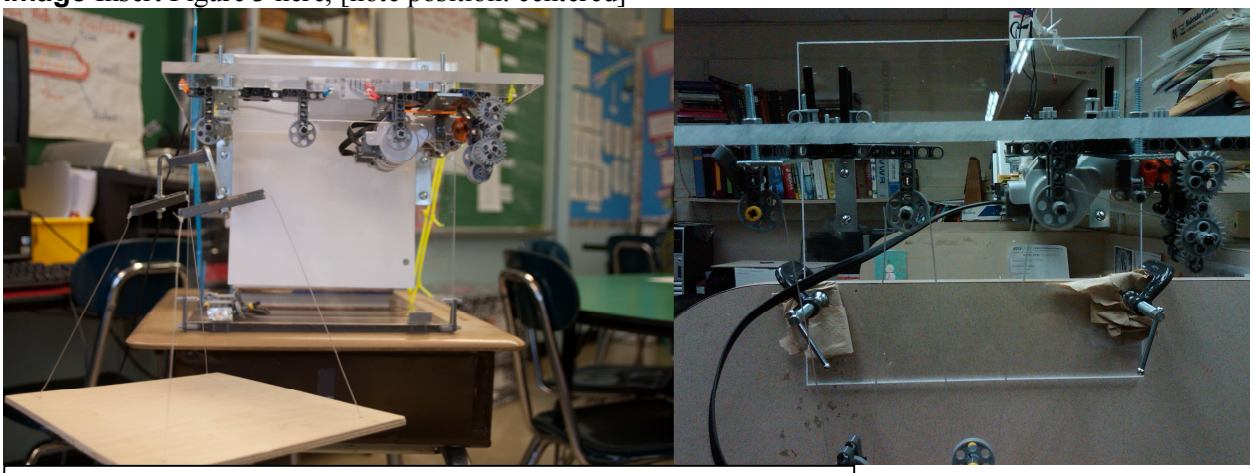


Figure 3

ADA Description: Photos of the 2 configurations of the pulley setup. Both setups show two NXT motors connected to a reel system, littered with interconnecting gears. Fishing line runs from the reel system through a series of three fixed pulleys in the image on the left. The line is then extended down and tethered to a wooden platform. The image on the right depicts the same setup with the addition of two movable pulleys, which are the only pulleys attached to the wooden platform.

Caption: Figure 3: Pulley setup in a configuration with no movable pulleys (left), and with two movable pulleys (right).

Image file: figure_3.tif

Before the Activity

All NXT Brick battery packs should be fully charged prior to the class. In addition, pulley station NXT Bricks should be plugged into an AC outlet during operation, to ensure the battery does not rapidly drain due to the constant load of the motors. Each of the setups should be preconfigured to configuration 1 (no movable pulleys in the system, Figure , right) adjusted such that the slack is taken all the way up. This will allow the students to become accustomed to the controls by letting them lower the platform all the way to the ground. Prior to the students arriving, all NXT Intelligent Bricks that are designated as "controller bricks" should be paired, via Bluetooth, with their respective pulley station Bricks. Figure 2 shows an example of how the general controller setup is mounted on a Plexi Glass frame to exude the appearance of a console game controller, an optional effort.

Image Insert Figure 4 here, [note position: left justified]

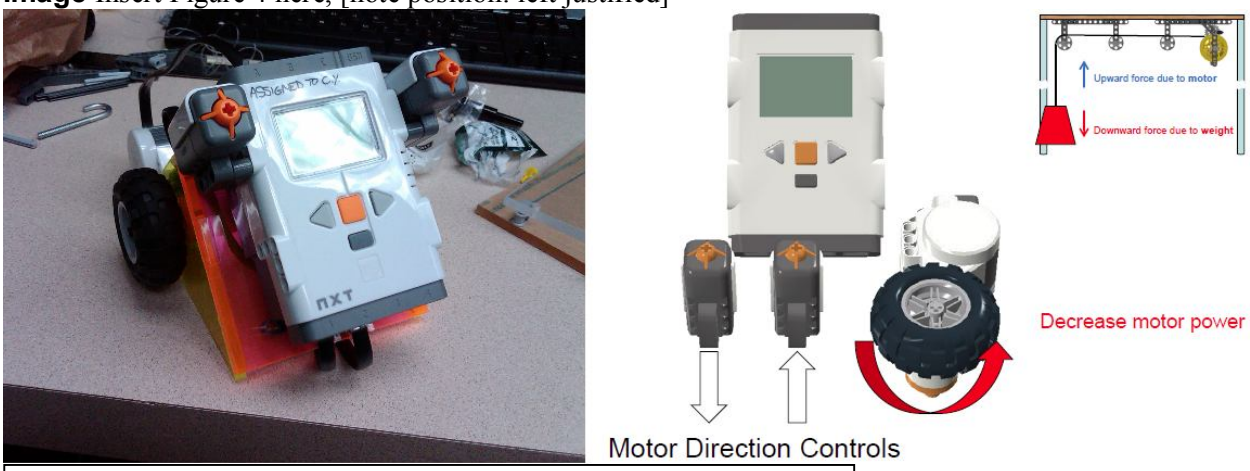


Figure 4

ADA Description: An NXT Intelligent Brick, mounted onto an orange plastic ramp, positioning the Brick at an angle to the user. Two LEGO touch sensors are mounted onto the side of the NXT Brick. A motor is attached to the side of the plastic ramp, presenting the user with a wheel with which to adjust program parameters. On the right, an image depicting the nature the controls is shown. One touch sensor controls the motors to move in one direction; the other touch sensor controls the motors to move in the opposite direction. A motor with a wheel attached is depicted to adjust the motor power.

Caption: Figure 4: An example of one way to present the user interface to students, using a meager amount of 1/8" thick plastic sheets (left). The controls are meant to be used as depicted in the diagram (right).

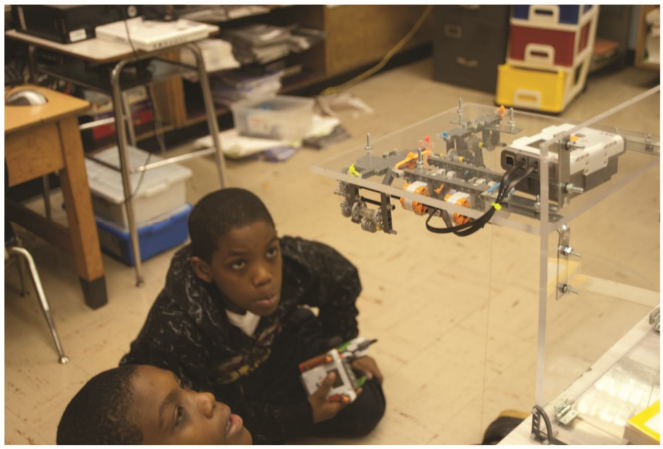
Image file: figure_4.tif

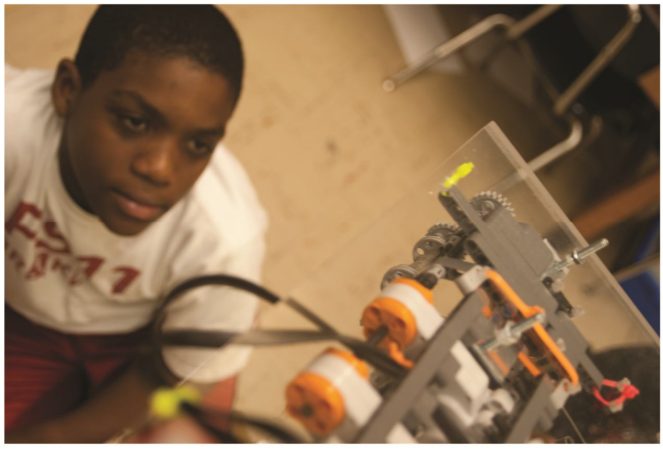
With the Students

1. Administer the pre-assessment evaluation prior to exposure to the activity setup, perhaps in a lecture/homeroom setting.
2. Do not let students approach their group station setups upon entering the room; gather them in a common area such as a rug or an area in which no pulley setups reside. Covering the pulley setups with a shroud, to avoid having to compete with the students' curiosity, has also been successful is past executions of this activity.
3. Prior to breaking the students up into groups, instruct the students that they will be attempting to observe mechanical advantage by way of pulleys, proving to themselves what has already been taught to them.

4. Instruct them with your own demo, using the images in Image 2 as guides, how to easily switch between configurations 1 and 2
5. Then describe the NXT controller interface operation, which upon execution of the program, first prompts for a power setting, adjustable by turns of the motor-attached wheel. After pressing the centered orange button, the program then allows application of torque of the motors by way of pressing one button (for one direction) and the other button (for the other direction), allowing upward or downward movement of the platform. Encourage the picking of power values just enough to move the platform up and down and a reasonable speed, which will allow the observation of mechanical advantage to be more straightforward. You may outline these steps of program operation on the board as well for easy reference for the students.
6. Instruct the students to lower the platform to the floor, but not any farther. Tell the students to document the power to which they set the motors. Then distribute thin textbooks or workbooks to the students, and instruct them to load the platform with a successive amount of books. After adding each successive book, tell the students to lower the platform all the way to the ground again and attempt to bring the platform up. Instruct the students to stop after they can no longer add books to the load which the motors are no longer capable of lifting.
7. Instruct the students to document the number of books they stacked. Weighing the books would also be an option for more quantitative evaluation of mechanical advantage. Additionally observations are also valuable, such as feeling the tension along the string/thread supporting the load. Then instruct the students to lower the platform all the way to the ground.

Image Insert Figure 5 here, [note position: centered]





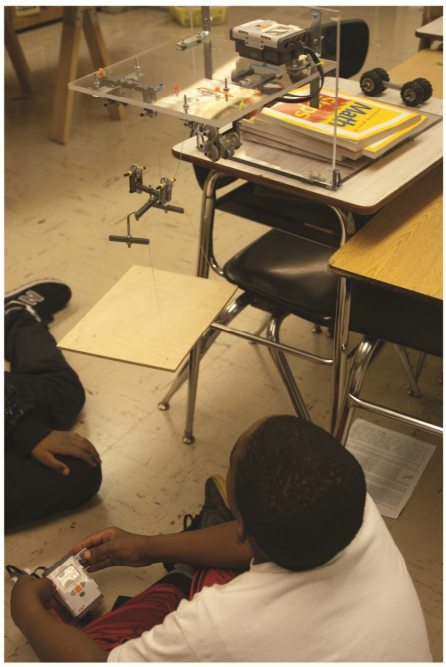


Figure 5

ADA Description: Two male students are shown carrying out the activity in a classroom. The setup is mounted onto a cantilevered Plexi-Glass mount. Each student is shown to control the pulley setup via the controller Brick in each of the setups two configurations. Each student's eyes are focused onto the mechanized motion of the gears and pulley-assisted platform.

Caption: Figure 5: An example of the typical level of engagement the pulley setup obtains in a classroom.

Image file: figure_5.tif

8. Instruct the students to modify the system such that is in configuration 2. Students committing errors in this step is welcomed. This building process is part of the activity as a learning and exploration experience, remembering that some students have never even touched a pulley system before, despite learning about them.
9. Upon successful completion of the configuration switch, instruct the groups to lower the platform to the ground again. (Slack would have been taken up by the addition of the two movable pulleys to the system.) Instruct the students to add the number of books, with which the motors struggled lifting previously, and attempt to lift the platform using the controller Brick.
10. Instruct them to document their observations (including the tension along the load line) and potential hypotheses as two how mechanical advantage – if the name seems appropriate to them – is actually working. The tension along the load line should be reduced by approximately a factor of 4 (Figure 3).
11. Ask the students as a group how they all **changed** their setups and what the observed **effects** were. These may be listed in a chart-like format on the board to collaborate findings amongst the groups.

Image Insert Figure 6 here, [note position: centered]

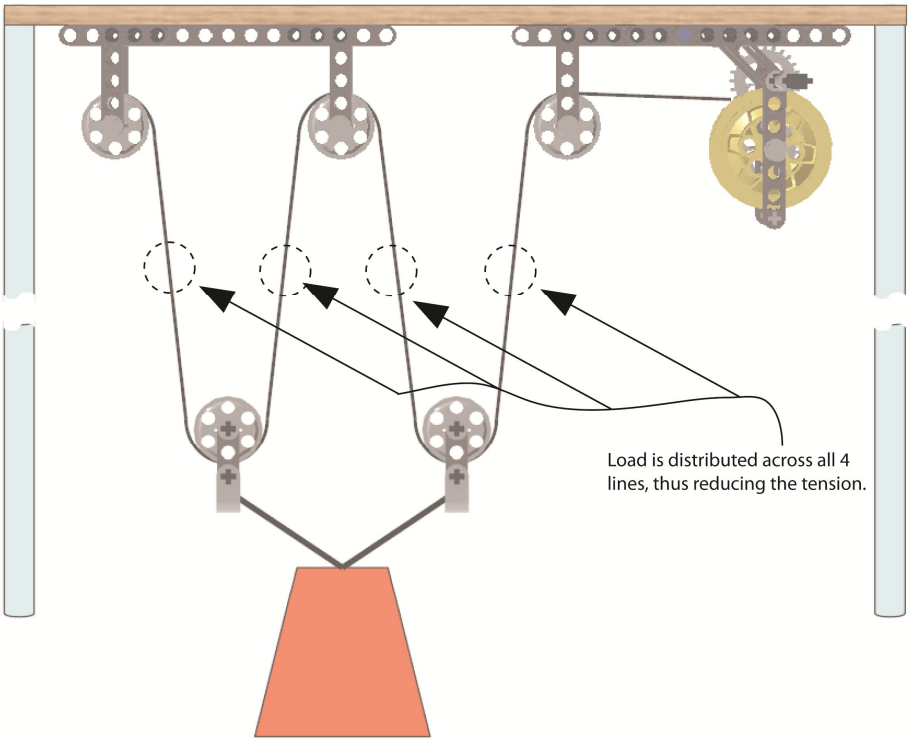


Figure 6

ADA Description: A profile view of the pulley setup, including the incorporation of two movable pulleys, both tethered to a weight. The resultant four strings that extend from the three fixed pulleys to the movable pulleys are highlighted, with the indication that load is distributed across all four lines, thus reducing the tension.

Caption: Figure 6: Distribution of load amongst four lines occurs when using two movable pulleys in such a manner.

Image file: figure_5.tif

Attachments

1. NXT program: pulley_station.rbt
2. NXT program: pulley_remote.rbt
3. Mounting overlay template: mounting_template.pdf
4. Building instructions for setups: building_instructions.zip
5. Pre-assessment worksheet: pre-assessment.doc
6. Post-assessment worksheet: post-assessment.doc
7. Sample of properly completed assessment: assessment.pdf

Safety Issues

- Though rare, it is possible that bushings may slide off their respective axles under excessive loads onto the pulley system. Such cases has, in rare cases, resulted in the projection of the bushing at questionable velocities out from the setup, posing an eye safety threat. It is recommended that teachers keep a close eye on the setups and the maintenance. Bushings and axles should be checked on each setup after each use for bending and potential structural failures. With those precautions in place, eye protection is up to the discretion of the instructor.

Troubleshooting Tips

Investigating Questions

Assessment

Pre-Activity Assessment

Pre-assessment Quiz: Distribute the attached pre-assessment worksheet, consisting of 3 questions designed to probe the students' current understanding of the application of pulleys. Question 1 is aimed at assessing the students' current working definition of pulleys. Question 2 is aimed at assessing the students' ability to visualize the piecing together of elements of a pulley system as well as their ability to derive the optimal use of pulleys given the spatial arrangement of elements as a leading clue. Question 3 is aimed at determining the extent of their knowledge of pulleys, assessing whether they have a strong enough foundation in simple machines to sub-categorize them (i.e. into fixed and movable pulleys).

Post-Activity Assessment

Discussion: After the students have completed their observations on both configurations, hold a class discussion, during which the instructor drafts a table similar to Figure , on the board. This will serve as a compilation chart of all the relevant parameters and observations for the experiments.

Image Insert Table 1 here, [note position: centered]

Group	Power	Cutoff Weight	Abilities to Lift	Speed of Lifting	Tension in Strings
Group 1	43	3 books	Motors able to lift books ☺	Slow	Loose
Group 2	55	4 books	Motors able to lift books ☺	Slow	Loose
Group 3	50	3 books	Motors able to lift books ☺	Slow	Loose
Group 4	60	4 books	Motors able to lift books ☺	Faster than not moving	Loose
Group 5	45	3 books	Motors able to lift books ☺	Slow	Loose
Group 6	49	3 books	Motors unable to lift books ✖	Not moving	Loose

Table 1

ADA Description: Table showing an example of data collections from various class groups. Each group, represented by individual rows, reports the power that was used during their experiments, the cutoff weight in terms of number of books set on the platform, the ability to lift the weight in the presence of the movable pulleys, the speed at which the books were lifted, and the tension felt along the string, or strings, supporting the load.

Caption: Table 1: Example of a table to tabulate and present during a post-activity discussion

Image file: table_1.tif

Post-assessment Quiz: Distribute the post-assessment quiz to the class. The first three questions are the same as for the pre-assessment. Question 4 expands on the term "simple machine" and is aimed to assess whether students describe a simple machine by the property of offering mechanical advantage, or rather as a collection of arbitrary devices by the names of: ramp, pulley, and lever. Question 5 offers contextual assessment, allowing the students to recall the observation they made during their inquiry and report it.

Activity Extensions

None

Activity Scaling

None

Additional Multimedia Support

None

References

"mechanical advantage." *The American Heritage® Science Dictionary*. Houghton Mifflin Company. 21 Dec. 2010. <Dictionary.com http://dictionary.reference.com/browse/mechanical advantage>.

"simple machine." *The American Heritage® Science Dictionary*. Houghton Mifflin Company. 21 Dec. 2010. <Dictionary.com http://dictionary.reference.com/browse/simple machine>.

"pulley." *The American Heritage® Science Dictionary*. Houghton Mifflin Company. 21 Dec. 2010. <Dictionary.com http://dictionary.reference.com/browse/pulley>.

"load." *The American Heritage® Science Dictionary*. Houghton Mifflin Company. 21 Dec. 2010. <Dictionary.com http://dictionary.reference.com/browse/load>.

Other

None

Redirect URL

None

Contributors

Primary Developer: Carlo Yuvienco

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None

Supporting Program

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Polytechnic Institute of NYU

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