PULLEY DEMONSTRATION SET STUDENT'S

CAT NO. PH 0305



Experiment Guide

PULLEY DEMONSTRATION SET - STUDENT'S

GENERAL BACK GROUND:

Machines are used to make work easier. Here work is defined as a force applied over a given distance. The work and the distance must be in the same direction.

Pulleys are one of six simple machines that include levers, pulleys, inclined planes, wedges, wheel and axels, and screws. Compound machines have two or more simple machines that when used together make work easier. A pulley is a variation of a wheel and axel in which a rope or cord is stretched over a wheel to make it rotate as the rope is pulled.

Mechanical advantage is a way of measuring how much easier it is to do work or how much less force is required. Written as a formula:

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}}$$

The load is the amount of force or weight that is being lifted
The effort is the amount of force or weight being applied to the rope in order to move the load.

Another parameter used to describe machines is efficiency. All machines have an efficiency of less than one because all machines lose some energy due to friction and other factors. Written as a formula:

$$\text{Efficiency} = \frac{\text{Energy delivered}}{\text{Energy needed}}$$

STANDARDS : (Taken from the May 2012 draft of the Next Generation Science Standards)

- When machines or animals "use" energy (e.g., to move around), most often the energy is transferred to heat the surrounding environment. (e)

- Design and evaluate solutions that minimize and/or maximize friction and energy transfer in everyday machines. [Clarification Statement: Solutions can include use of oil as a lubricant on a skateboard, bicycle, or in a lawnmower engine, and wax on skis. Energy transfer can include the transfer of energy from motion to thermal energy due to friction. Everyday machines can include skateboards, bicycles, lawnmowers, skis, and toy cars.]

- PS3.D: Energy in Chemical Processes and Everyday Life „X Machines can be made more efficient, that is, require less fuel input to perform a given task, by reducing friction between their moving parts and through aerodynamic design. Friction increases energy transfer to the surrounding environment by heating the affected materials. (f),(g).

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- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (b),(h)

REQUIRED COMPONENTS (INCLUDED)

S.No.	Name of Part	Quantity
1	Single Pulleys	8
2	Double Sheave Pulleys	2
3	Base (15 x 20 cm)	1
4	Vertical threaded rod (61 cm x 12.5 mm)	1
5	Horizontal rod (20cm x 9.5 mm) with clamp	1
6	Collars with hooks	6
7	Right angled clamp	1
8	Wheel and Axel	1
9	Cord (string)	2 rolls
10	Tommy Bar to tighten vertical rods	1
11	Brass Hooked Mass Set with hooks	9 nos. (10g, 20g, 20g, 50g, 100g, 200g, 200g, 500g, 1000g)

REQUIRED COMPONENTS (NOT INCLUDED)

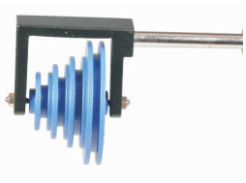
Name of Part	Quantity
Spring Scale 2.5 N, 5.0 N, 10 N	1 each
OR Force Probe	1

SAFE HANDLING OF APPARATUS:

Warning: Masses are heavy and injury can be caused to masses and to others when masses are dropped from a height. Be careful when transporting masses that they are properly supported and do not fall off of mass hanger.

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DIAGRAM LABELING ALL PARTS:

1 Single Pulleys 	2 Double Sheave Pulleys 	3 Base (15 x 20 cm) 
4 Vertical threaded rod 		5 Horizontal rod with clamp 
6 Collars with hooks 	7 Right angled clamp 	8 Wheel and Axle 
9 Cord (string) 	10 Tommy Bar to tighten vertical rods 	11 Brass Hooked Mass Set with hooks 

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ACTIVITY 1: A HORSE AND HIS SADDLE

(TEACHER ANSWERS)

PROCEDURE:

1. Measure the weight in Newtons of a 200 gram hook mass and record your answer below:
2. Attach a 5.0 N spring scale to one end of the rope and attach a 200. gram mass to the other end of the rope.
3. Drape the rope over the bar and pull the mass with the spring scale. Record the force used to pull a 200. gram mass at a constant velocity in the chart below.
4. Now drape the rope over the pulley and again pull the mass with the spring scale. Record the force used to pull a 200. gram mass at a constant velocity in the chart below.

DATA:

Original Weight of the 200 g mass ____2.0_____ N

Force required to pull the 200 g mass over the bar ____4.25_____ N

Force required to pull the 200 g mass over the pulley _____2.1_____ N

DATA ANALYSIS:

1. Calculate the efficiency of the pulley in diagram 1:

$$\text{Efficiency} = \frac{\text{Energy delivered}}{\text{Energy needed}} = \frac{\text{Force*}\cancel{\text{distance}}}{\text{Force * }\cancel{\text{distance}}} = \frac{2.0\ \text{N}}{4.25\ \text{N}} = 0.47$$

2. Calculate the efficiency of the pulley in diagram 2:

$$\text{Efficiency} = \frac{\text{Energy delivered}}{\text{Energy needed}} = \frac{\text{Force*}\cancel{\text{distance}}}{\text{Force * }\cancel{\text{distance}}} = \frac{2.0\ \text{N}}{2.1\ \text{N}} = 0.95$$

3. Calculate the mechanical advantage of the pulley in diagram 1 & 2. Show all work including formula and substitution with units.

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}} = \frac{2.0\ \text{N}}{4.25\ \text{N}} = 0.47$$

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}} = \frac{2.0\ \text{N}}{2.1\ \text{N}} = 0.95$$

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CONCLUSION:

1. Using one pulley (or one tree branch) does not give the thief any mechanical advantage. Why would the thief put the rope over the tree branch in the first place?

   Using one pulley can be helpful because it can change the direction you need to apply a force. The horse could now pull up on the safe instead of trying to drag it and scrap against the sides of the hole.

2. Why was the second experiment with the pulley more efficient then the first set up?

   The pulley reduced the amount of friction to almost nothing. In the first experiment we lost almost half our energy due to friction.

3. Why was the horse able to pull the safe out using the saddle?

   The surface of the saddle was smooth and the tree branch was rough. We can assume there was less friction between the rope and the saddle and therefore the horse was able to pull the safe up and out of the hole.

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Name:_____ Date:_____

Lab Section:_____

BACKGROUND:

Efficiency is one way of measuring how much energy is lost by a machine as it does work. The formula for efficiency is:

$$\text{Efficiency} = \frac{\text{Energy delivered}}{\text{Energy needed}}$$

Mechanical advantage is a way of measuring how much easier it is to do work or how much less force is required. Written as a formula:

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}}$$

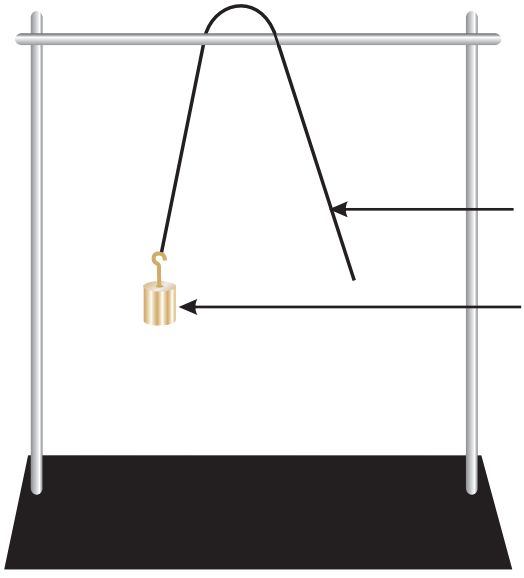
The load is the amount of force or weight that is being lifted

The effort is the amount of force or weight being applied to the rope in order to move the load.

You are sitting at home watching an old western with your Grandmother, who is really into Westerns, and see pulleys used in two different ways. In the first scene a criminal tries to pull a heavy safe out of a hole in the ground by tying a rope to the safe and then wrapping the rope over a branch of the tree. At first he can't get his horse to pull the safe up. Then he gets an idea and puts the horse's saddle over the tree limb and then puts the rope on top of the saddle and is able to pull the safe out of the ground.

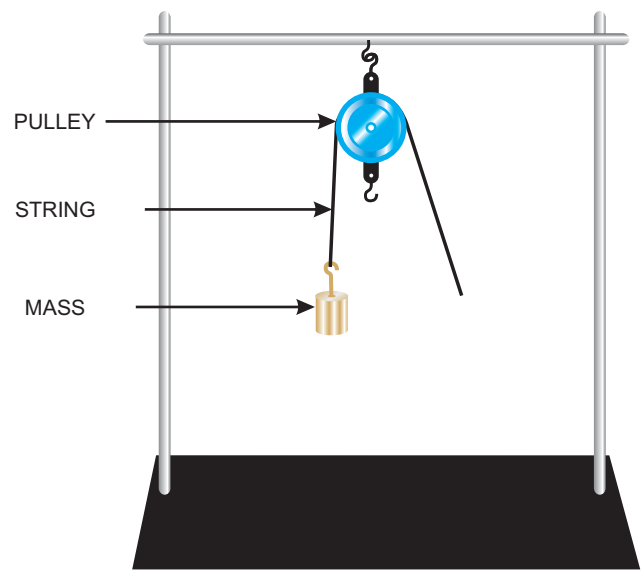
Conduct the following experiment and use your results to help explain why the horse succeeds the second time.

Diagram 1:



Horse using only the tree limb

Diagram 2:



Horse using the saddle

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PROCEDURE:

1. Measure the weight in Newtons of a 200 gram hook mass and record your answer below:
2. Attach a 5.0 N spring scale to one end of the rope and attach a 200. gram mass to the other end of the rope.
3. Drape the rope over the bar and pull the mass with the spring scale. Record the force used to pull a 200. gram mass at a constant velocity in the chart below.
4. Now drape the rope over the pulley and again pull the mass with the spring scale. Record the force used to pull a 200. gram mass at a constant velocity in the chart below.

DATA:

Original Weight of the 200 g mass _____ N

Force required to pull the 200 g mass over the bar _____ N

Force required to pull the 200 g mass over the pulley _____ N

DATA ANALYSIS:

1. Calculate the efficiency of the pulley in diagram 1:

2. Calculate the efficiency of the pulley in diagram 2:

3. Calculate the mechanical advantage of the pulley in diagram 1 & 2. Show all work including formula and substitution with units.

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CONCLUSION:

1. Using one pulley (or one tree branch) does not give the thief any mechanical advantage. Why would the thief put the rope over the tree branch in the first place?

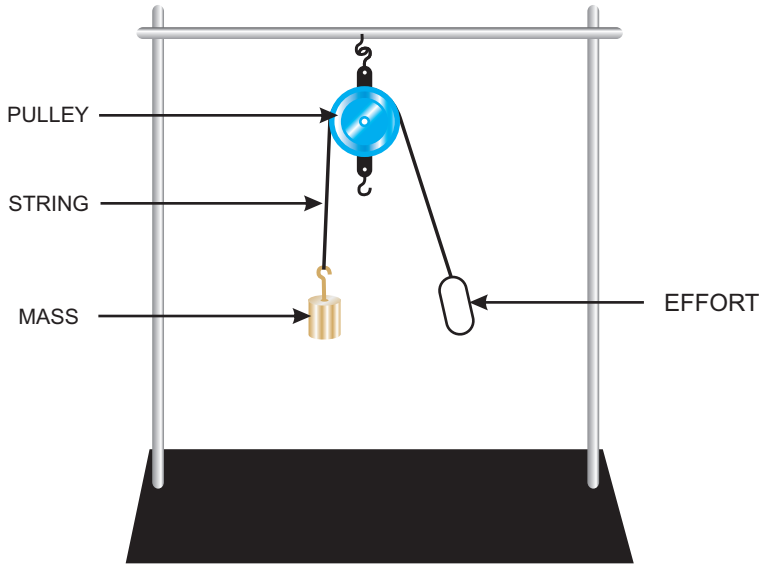
2. Why was the second experiment with the pulley more efficient then the first set up?

3. Why was the horse able to pull the safe out using the saddle?

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ACTIVITY 2: MECHANICAL ADVANTAGE

ASSEMBLY OF APPARATUS:

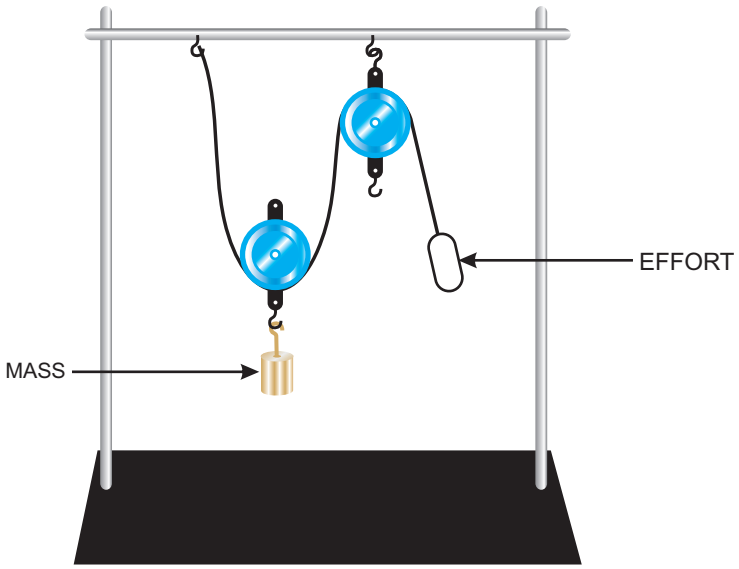


EXPERIMENT 1:

Adding a Pulley, efficiency and mechanical advantage

1. Have students suspend a pulley from the apparatus as shown above and label the load and the effort. Use a 500 gram mass for the load and then slowly add effort until the load just starts to move upward. Record these values in your data table.

2. Move the load a distance of 10 cm from its original position and record how far the effort moves from its original position in your data table.



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3. Have students add one pulley into the system by setting up the system as shown above. Use a 500 gram mass for the load and then slowly add effort until the load starts to move upward.



4. Set up three pulleys as shown in the diagram above. Start by attaching one end of the string to the top hook of a single pulley and then attach the load to the bottom hook of this pulley. Take the loose end of the string and feed it through one of the top two pulleys and suspend the double pulley from the horizontal bar. Loop the string around the bottom single pulley and then thread it back through empty pulley on the double pulley on the top. Then attach the effort to a loop at the end of the string. Keep slowly adding mass to the effort until the load just starts to move. Record your data in the data table below.



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5. Set up a system of four pulleys as shown in the diagram above. To start tie one end of the string to the top of the horizontal bar. Add the load to one of the double pulleys and thread the string around one of the two pulleys with the load attached. Hang the second double pulley set from the horizontal bar and thread string around one of these two pulleys. Send the string back down and around the second empty pulley with the load attached and then send the string up through the second empty pulley attached to the horizontal bar. Then attach the effort to the end of the string. Keep adding mass until the load just barely starts to move. Record your results in the data table.



6. Make a system of five pulleys by doing the following. Attach one end of your string to the top hook of the double pulley with a knot. Attach your load to the other hook on the bottom of the double pulley. Attach the other double pulley to the horizontal bar. Take the string and thread it through the one of the two top pulleys and then bring the string down to go through the bottom double pulley attached to the load. Then bring the string up again and go through the second pulley on the top. Bring the string down and go through the second pulley on the bottom. Attach one more single pulley to the top horizontal bar and then thread the string through this pulley. Attach the effort to the end of the string. Add mass to the effort until the load just begins to rise. Record your data on the data table below.

(Note to Teacher: Depending on the level your students are at and time constraints, you may be able to set up the one through five pulley systems around the room and have the students find the necessary effort to get the load to start moving and then rotate to the next station. However there is valuable experience in really figuring out how pulleys work by trying to figure out how to set the system up on their own.)

DATA TABLE:

Number of Pulleys Used	Load (grams)	Effort (grams)	Distance load traveled (cm)	Distance effort traveled (cm)
1	500	510	10	10
2	500	260	10	20
3	500	180	10	30
4	500	130	10	40
5	500	110	10	50

DATA ANALYSIS:

1. Calculate the force of the load and the force of the effort in Newtons. Show a sample calculation Include formula and substitution with units.

$$\text{Force} = \text{Weight} = \frac{\text{mass(in grams)*acceleration due to gravity}}{\text{1000 (to convert grams to kg)}} = \frac{500g*9.8\ m/s^2}{1000} = 4.9\ N$$

2. Calculate the amount of work done to lift the 500g load with 4 pulleys. Show all work including formula and substitution with units.

   Work = Force * Distance = $0.130kg*9.8m/s^2*0.40m = 0.51\ J$

3. Calculate the amount of energy gained by the 500g load with 4 pulleys. Show all work including formula and substitution with units.

   Gravitational Potential Energy = mass*acceleration due to gravity*change in height
   $= 0.500kg*9.8\ m/s^2*0.10m$
   $= 0.49\ J$

4. Calculate the efficiency and mechanical advantage for each system of pulleys. Show a sample calculation for both the efficiency and mechanical advantage. Include formula and substitution with units.

$$\text{Efficiency} = \frac{\text{Energy delivered}}{\text{Energy needed}} = \frac{\text{Force*distance}}{\text{Force * distance}} = \frac{0.49\ J}{0.51\ J} = 0.96$$

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}} = \frac{4.9\ N}{1.3\ N} = 3.8$$

Fill out the following chart with your calculations:

Number of Pulleys	Force of load (N)	Force of Effort (N)	Work done by effort (J)	Energy gained by Load (J)	Efficiency	Mechanical Advantage
1	4.9	5.00	0.50	0.49	0.98	1.0
2	4.9	2.55	0.51	0.49	0.96	1.9
3	4.9	1.76	0.53	0.49	0.93	2.8
4	4.9	1.27	0.51	0.49	0.96	3.8
5	4.9	1.08	0.54	0.49	0.91	4.5

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CONCLUSION QUESTIONS:

1. Describe the relationship between the number of pulleys used and the amount of force needed by the effort.

   As the amount of pulleys increased, the amount of force needed by the effort decreased.

2. Describe the relationship between the number of pulleys used and the amount of work done by the effort.

   As the amount of pulleys increased the amount of work done by the effort remained the same.

3. What happens to the efficiency of your machine (the pulleys) as more pulleys are added to the system?

   As more pulleys are added the efficiency seems to get smaller. This is because adding more pulleys adds more friction, also adding more pulleys adds more weight to the load, even though the pulleys are assumed to have no mass, they still do.

4. What would the efficiency of the machine be if we used an "ideal pulley"? Here an "ideal pulley" means that the pulley is frictionless and massless.

   An ideal pulley would make the machine 100% efficient or have an efficiency of 1.

5. In a world with "ideal pulleys" what would the mechanical advantage of the 5 pulley system be? How close was your result? Why was your system of pulleys less than ideal?

   An ideal pulley system of five pulleys would have a mechanical advantage of five. My result was 4.5, which is close but slightly lower than an ideal system. I think my system was less than ideal because my pulleys had friction and mass.

6. In a world with "ideal pulleys" what would be the relationship between the number of pulleys used and the mechanical advantage?

   Each additional pulley increases the mechanical advantage by 1.

7. To a person who has not studied simple machines it may seem that the pulleys are able to create energy. Pulleys allow for less force to be used to pull up a heavier object. The more pulleys the less force is needed. Explain why energy is indeed conserved and not created by pulleys.

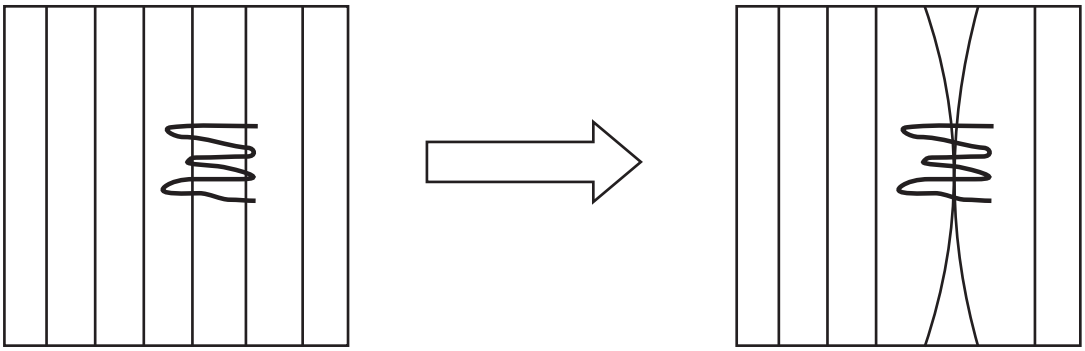
   Pulleys do in fact allow you to move heavy objects with less force; however, you apply this force over a greater distance. Since work (a form of energy) is the amount of force applied over a distance, then the amount of work you need to do is still the same, however if the force is cut in half, the distance you need to apply the force is doubled. This is how machines work.

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ACTIVITY 3:

HOLLYWOOD MOVIE PART 2 : BREAKING OUT OF JAIL

You are still watching that western movie with your Grandmother and wouldn't you know it? Our thief from the first scene got himself caught trying to steal the safe and is thrown in jail. First he tries to bend the iron bars with his hands with no luck. But our thief is very clever. Using his knowledge of pulleys again he plans his escape. While the sheriff is snozzing in the front room the thief takes a belt from around his waist and wraps it several times around the iron bars. He attaches one end with a knot to the bar and pulls with all his strength on the other end of the rope to bend the bars and slip through the new wider opening.



Conduct the following experiment to see why the thief is able to bend the iron bars.

Set up your pulley system like so:



1. Tie your string to the horizontal bar and then thread the string through the pulley on the bottom. Attach a 500 gram mass to the bottom double pulley. Pull the string to make the bottom pulley move upward. Then thread your string through one of the top double pulleys connected to the horizontal bar. Again pull the string to move the 500 gram mass upward.

    a. Qualitatively decide which was easier (which required less effort). Was it easier to move the 500 g mass when the string was wrapped around just the bottom pulley or when it was wrapped around the bottom and the top pulley?

    It was easier to move the pulley when it was wrapped around the bottom and the top pulley.

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2. Now wrap your string around the second pulley on the bottom and pull the string to move the mass.

   a. How many pulleys are now rotating when you pull the string?

      Three

   b. Is it easier to move the 500 gram mass (the load) when the string is wrapped around three pulleys or two?

      It is easier to move the load when the string is wrapped around three pulleys

3. Try one to make one more pulley move. This time thread the string through the second top pulley and pull the string.

   a. Is it easier to move the string with four pulleys moving or three pulleys moving?

      It is easier to move the string with four pulleys moving.

   b. Finish this statement. As the number of pulleys moving is increased, the amount of effort it takes to move the load _____*decreases*_____.

   c. If you were the clever thief, how many times would you wrap the rope around the bars?

      If I were the clever thief I would wrap the rope around the bars as many times as it would fit.

   d. Name two ways the clever thief could make it easier to bend the bars?

      Increase the amount of times the rope is wrapped around the bars and decrease the amount of friction between the rope and the bars.

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Name:_____ Date:_____

Lab Section:_____

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a. Qualitatively decide which was easier (which required less effort). Was it easier to move the 500 g mass when the string was wrapped around just the bottom pulley or when it was wrapped around the bottom and the top pulley?

2. Now wrap your string around the second pulley on the bottom and pull the string to move the mass.

   a. How many pulleys are now rotating when you pull the string?

   b. Is it easier to move the 500 gram mass (the load) when the string is wrapped around three pulleys or two?

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   a. Is it easier to move the string with four pulleys moving or three pulleys moving?

   b. Finish this statement. As the number of pulleys moving is increased, the amount of effort it takes to move the load _____

   c. If you were the clever thief, how many times would you wrap the rope around the bars?

   d. Name two ways the clever thief could make it easier to bend the bars?

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EISCO
Electronic Instrumentation
12, Mahesh Nagar, Ambala Cantt. 133 001
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Eisco Scientific
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