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SIMPLE MACHINES
BLOCK & TACKLE

CAT NO. WDMS21

Experiment Guide

GENERAL BACKGROUND :

Machines are used to make work easier. Here work is defined as a force applied over a given distance. The force applied and the distance traveled 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:

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

Using just one pulley will change the direction the force is needed to be applied. Using more than one pulley can increase the mechanical advantage provided that every other pulley is moveable so that the distance the string is pulled can be different and proportional to the distance the load travels. It is recommended that students study the "Simple Machines: Wooden Pulley WDMS12" before studying the block and tackle apparatus. However, activity 1 is included for students who have not studied just one pulley before.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Wooden Block and Tackle Apparatus	1

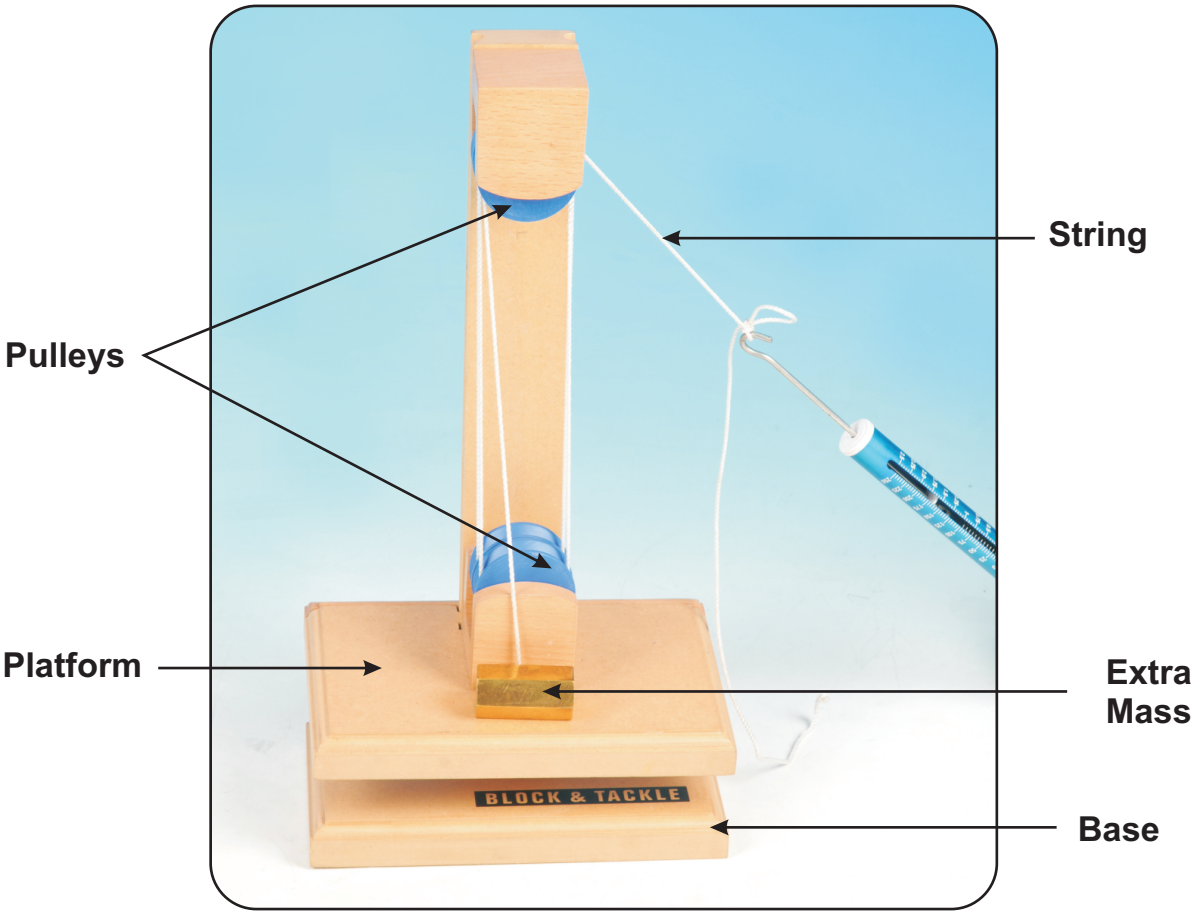
REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Hammer	1
Meter stick/ruler	1
Masses (slotted or hanging masses, something that will not slide easily off the block and tackle platform)	4
Spring scale 5.0N and 10.N	1 each

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.

DIAGRAM LABELING ALL PARTS:



ACTIVITY 1: THE ADVANTAGE OF A PULLEY
(TEACHER ANSWERS)

PROCEDURE:

1. Using your spring scale, record the weight in Newtons of your mass in the space provided below.
2. Attach a 5.0 N spring scale to one end of the rope and attach your mass to the other end of the rope.

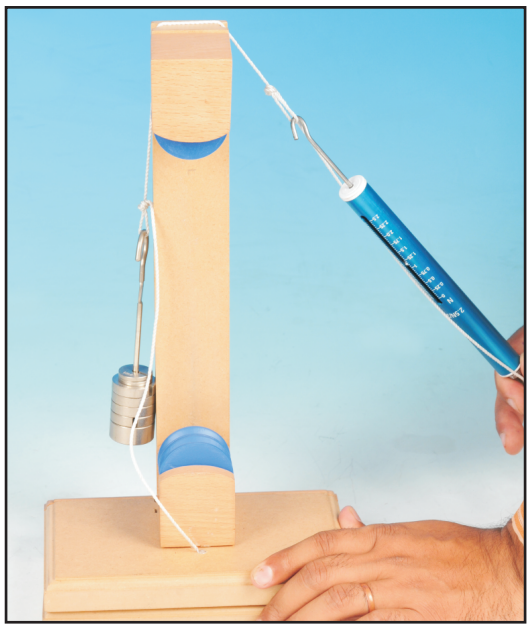


Diagram 1

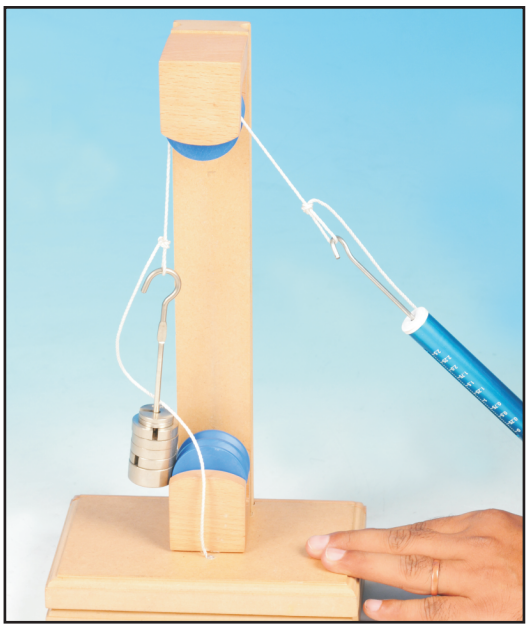


Diagram 2

3. Drape the rope over the back of the block and tackle apparatus and pull the mass with the spring scale. Be sure to have one person in your group securely hold the base of the pulley so it doesn't tip over while you are pulling as shown in diagram 1. Record the force used to pull your 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 as shown in diagram 2. Record the force used to pull the mass at a constant velocity in the chart below.

DATA:

Original Weight of the mass __0.9__ N

Force required to pull the mass over the bar __2.3__ N

Force required to pull the mass over the pulley __1.0__ N

DATA ANALYSIS:

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

$$\text{Efficiency} = \frac{\text{Energy delivered}}{\text{Energy needed}} = \frac{\text{Force*}\cancel{\text{distance}}}{\text{Force * }\cancel{\text{distance}}} = \frac{0.9\text{ N}}{2.3\text{ N}} = 0.39$$

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

$$\text{Efficiency} = \frac{\text{Energy delivered}}{\text{Energy needed}} = \frac{\text{Force*}\cancel{\text{distance}}}{\text{Force * }\cancel{\text{distance}}} = \frac{0.9\text{ N}}{1.0\text{ N}} = 0.90$$

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

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}} = \frac{0.9\text{ N}}{2.3\text{ N}} = 0.39$$

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}} = \frac{0.9\text{ N}}{1.0\text{ N}} = 0.90$$

For younger students it might be appropriate to ask, which took more work, to pull using the pulley or to pull over the edge of the block and tackle apparatus. Students should be able to tell even without the spring scale that it was easier to pull up the mass using the pulley than pulling using the back of the block and tackle apparatus.

1. Compare the amount of force needed to pull the mass over the back of the block and tackle demonstration apparatus versus pulling over the pulley.
   (It took less force to pull the mass when using the pulley versus pulling over the back of the apparatus.)

2. Was any less work done on mass using the pulley? If not, then what is the advantage of using a pulley?
   A pulley is used to change the direction that work is done. Instead of pulling up to lift the mass, using the pulley we can pull down to lift something up and use the force of gravity on our bodies to help us pull with more force.

NAME:_____ DATE:_____

ACTIVITY 1: THE ADVANTAGE OF A PULLEY

PROCEDURE:

1. Using your spring scale, record the weight in Newtons of your mass in the space provided below.

2. Attach a 5.0 N spring scale to one end of the rope and attach your mass to the other end of the rope.

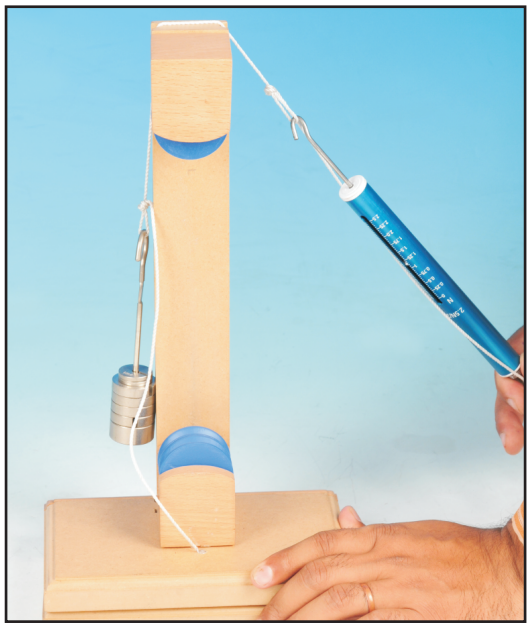


Diagram 1

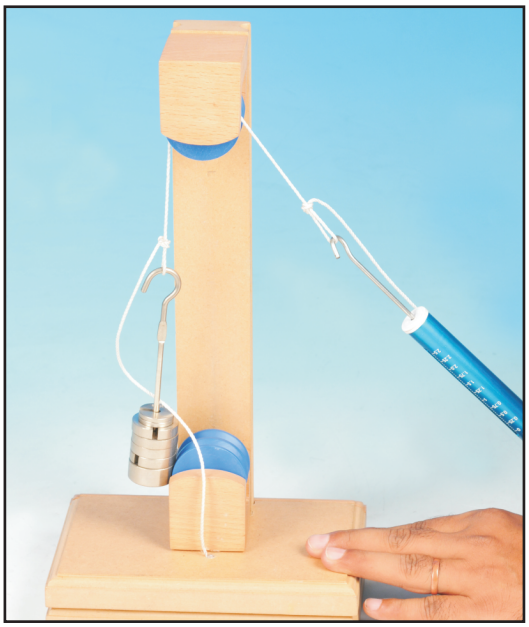


Diagram 2

3. Drape the rope over the back of the block and tackle apparatus and pull the mass with the spring scale. Be sure to have one person in your group securely hold the base of the pulley so it doesn't tip over while you are pulling as shown in diagram 1. Record the force used to pull your 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 as shown in diagram 2. Record the force used to pull the mass at a constant velocity in the chart below.

DATA:

Original Weight of the mass _____ N

Force required to pull the mass over the bar _____ N

Force required to pull the mass over the pulley _____ N

DATA ANALYSIS:

1. Calculate the efficiency of the pulley in diagram 1. Show all work including formulas and substitutions with units.

2. Calculate the efficiency of the pulley in diagram 2. Show all work including formulas and substitutions with units.

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

ANALYSIS:

1. Compare the amount of force needed to pull the mass over the back of the pulley demonstration apparatus versus pulling over the pulley.

   _____

   _____

   _____

2. Was any less work done on mass using the pulley? If not, then what is the advantage of using a pulley?

   _____

   _____

   _____

ACTIVITY 2: MECHANICAL ADVANTAGE
(TEACHER ANSWERS)

PROCEDURE:

Be sure that one person holds the base every time someone pulls on the rope.

1. Add some given mass that will not slip off the platform of the base and use your spring scale to find the gravitational force on the base and masses by gently pulling up on the base with the spring scale until it moves at a constant speed as shown in diagram 3.
2. Record the force applied by the load in your data table.

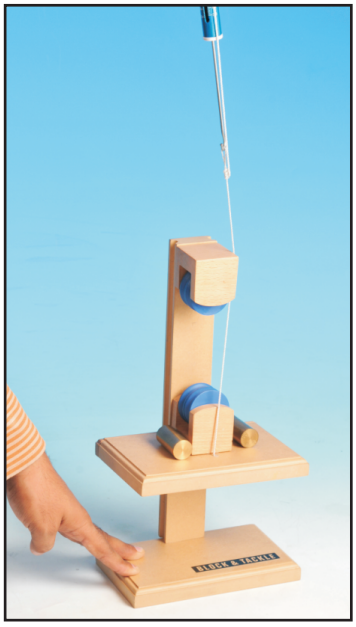


Diagram 3

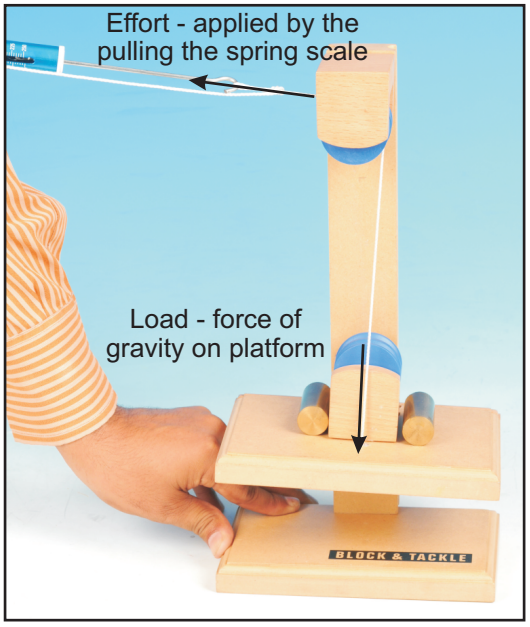


Diagram 4

3. Wrap the string around the top pulley of the apparatus as shown in diagram 4 and label the load and the effort. The force of the load is equal to the force of gravity on the platform and the reading on the spring scale is the force of effort.
4. Then slowly add effort by pulling on your spring scale until the load just starts to move upward at a constant speed.
5. Record these values in your data table.
6. Let the tension off the spring scale so that the platform rests on the base. Then pull on the spring scale while measuring the distance between the base and the platform. When the platform is 5.0cm away from the base stop pulling on the spring scale.
7. With a ruler or meter stick measure the distance the effort (spring scale) moves while the load moves 5.0 cm upwards.
8. Record these values on your data table.
9. Have two pulleys do work on the system by threading the string around two pulleys as shown in diagram 5.

10. Again slowly add effort by pulling on the spring scale until the load just starts to move upward at a constant speed.

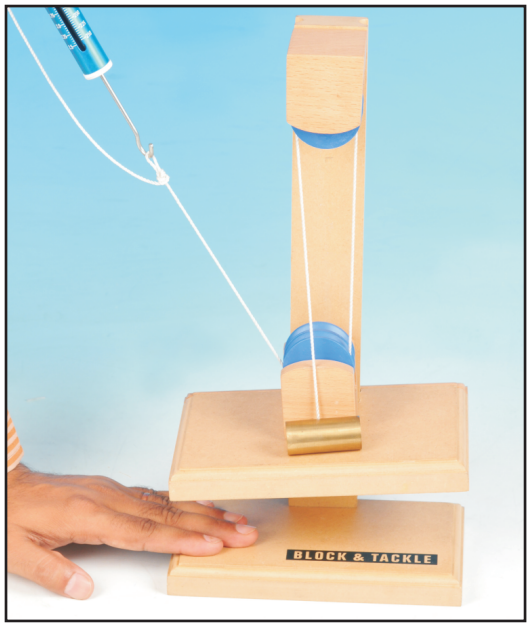


Diagram 5

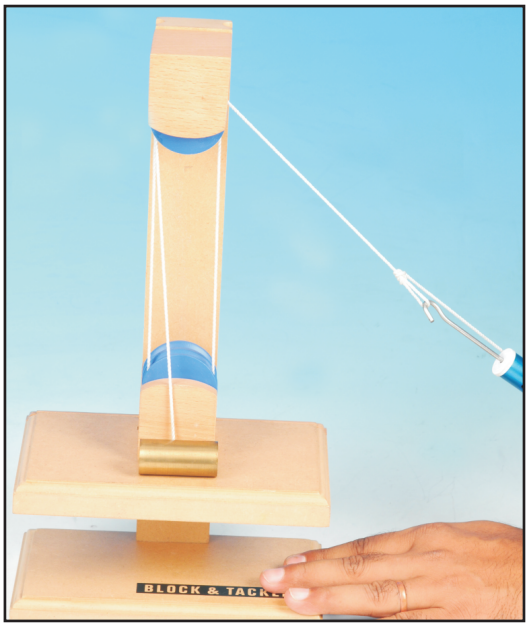


Diagram 6

11. Record your effort force in your data table.

12. Let the tension off the spring scale so that the platform rests on the base. Then pull on the spring scale while measuring the distance between the base and the platform. When the platform is 5.0cm away from the base stop pulling on the spring scale.

13. With a ruler or meter stick measure the distance the effort (spring scale) moves while the load moves 5.0 cm upwards.

14. Record these values on your data table.

15. Have three pulleys do work on the system by threading the string around three pulleys as shown in diagram 6.

16. Repeat steps 10-14 with the string around 3 pulleys.

17. Have four pulleys do work on the system by threading the string around four pulleys as shown in diagram 7.

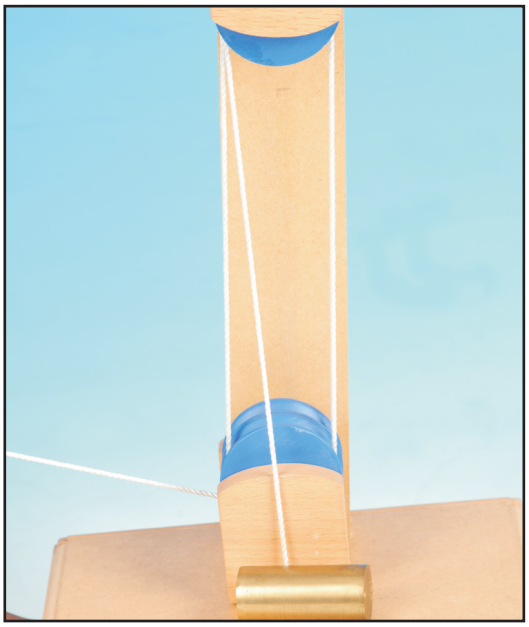


Diagram 7

DATA TABLE:

Number of	Load	Effort	Distance load	Distance effort

3. What would the mechanical advantage of a 5 pulley system be?

An ideal pulley system of five pulleys would have a mechanical advantage of five.

4. What is the relationship between the number of pulleys used and the mechanical advantage?

Each additional pulley increases the mechanical advantage by 1.

NAME:_____ DATE:_____

ACTIVITY 2: MECHANICAL ADVANTAGE

PROCEDURE:

Be sure that one person holds the base every time someone pulls on the rope.

1. Add some given mass that will not slip off the platform of the base and use your spring scale to find the gravitational force on the base and masses by gently pulling up on the base with the spring scale until it moves at a constant speed as shown in diagram 3.
2. Record the force applied by the load in your data table.

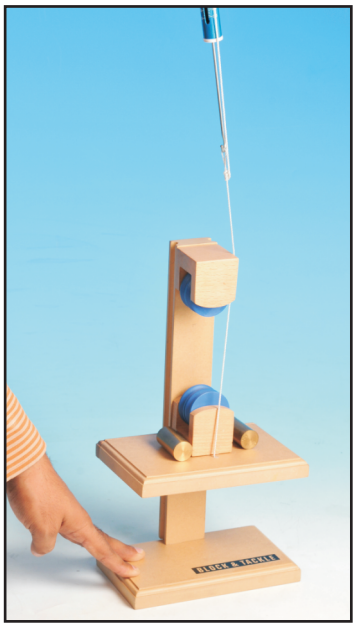


Diagram 3

Diagram 4

3. Wrap the string around the top pulley of the apparatus as shown in diagram 4 and label the load and the effort. The force of the load is equal to the force of gravity on the platform and the reading on the spring scale is the force of effort.
4. Then slowly add effort by pulling on your spring scale until the load just starts to move upward at a constant speed.
5. Record these values in your data table.
6. Let the tension off the spring scale so that the platform rests on the base. Then pull on the spring scale while measuring the distance between the base and the platform. When the platform is 5.0cm away from the base stop pulling on the spring scale.
7. With a ruler or meter stick measure the distance the effort (spring scale) moves while the load moves 5.0 cm upwards.
8. Record these values on your data table.

9. Have two pulleys do work on the system by threading the string around two pulleys as shown in diagram 5.

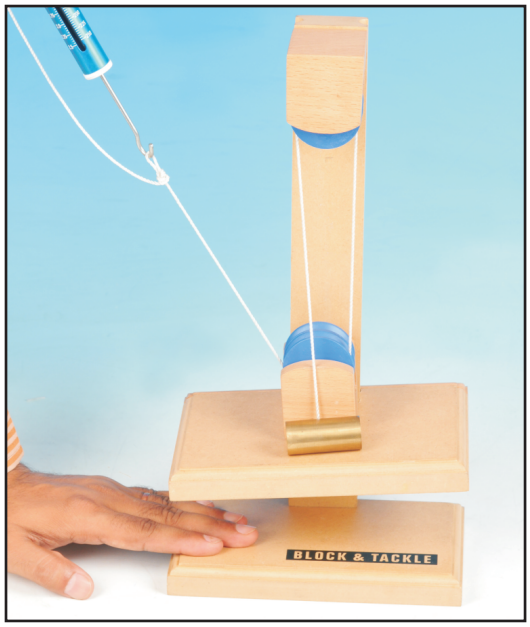


Diagram 5

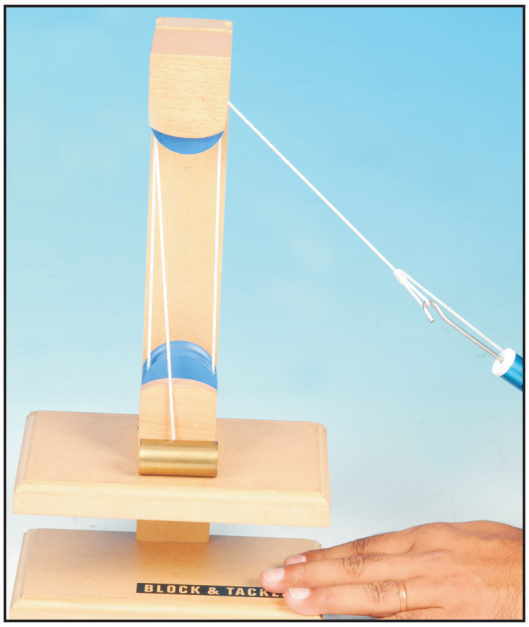


Diagram 6

10. Again slowly add effort by pulling on the spring scale until the load just starts to move upward at a constant speed.

11. Record your effort force in your data table.

12. Let the tension off the spring scale so that the platform rests on the base. Then pull on the spring scale while measuring the distance between the base and the platform. When the platform is 5.0cm away from the base stop pulling on the spring scale.

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14. Record these values on your data table.

15. Have three pulleys do work on the system by threading the string around three pulleys as shown in diagram 6.

16. Repeat steps 10-14 with the string around 3 pulleys.

17. Have four pulleys do work on the system by threading the string around four pulleys as shown in diagram 7.

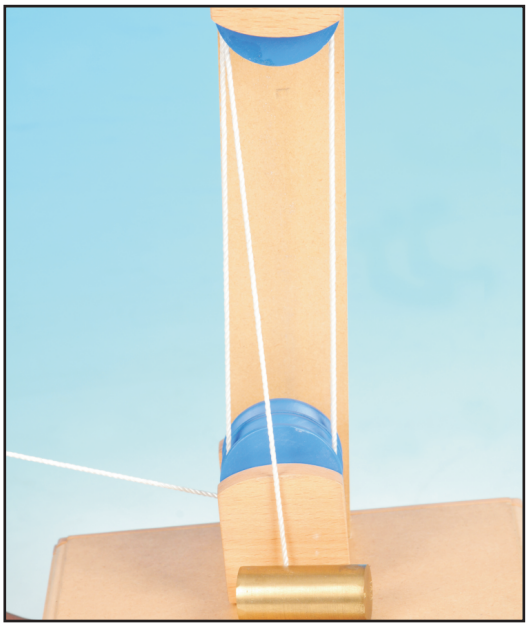

Diagram 7

DATA TABLE:

Number of Pulleys Used	Load (Newtons)	Effort (Newtons)	Distance load traveled (cm)	Distance effort traveled (cm)
1				
2				
3				
4				

DATA ANALYSIS:

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

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

3. 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.

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						
2						
3						
4						

CONCLUSION QUESTIONS:

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

_____

_____

_____

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

_____

_____

_____

3. What would the mechanical advantage of a 5 pulley system be?

_____

_____

_____

4. What is the relationship between the number of pulleys used and the mechanical advantage?

_____

_____

_____

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