

Pulleys

A *pulley* is a simple machine having a rope that passes over a grooved wheel. A fixed pulley (see Figure 1) is attached to a solid support and changes the direction of force. The resistance force is the weight of the object being lifted. This force is applied to one end of the rope that goes over a fixed pulley. The effort force is exerted on the other end of the rope, in opposition to the resistance force.

A movable pulley (see Figure 2) moves along the rope with the resistance force, and the direction of the force is not changed. A pulley system may have a single pulley or a combination of pulleys (see Figure 3). Pulleys are used to make work easier.

Mechanical advantage is a value that tells the number of times a machine increases the applied force. In this experiment, you will use a Force Sensor to measure the effort force (in N) for three different pulley systems and then determine the mechanical advantage of each system.

OBJECTIVES

In this experiment, you will

- Use a Force Sensor to measure force.
- Calculate actual mechanical advantage and ideal mechanical advantage.
- Determine efficiency.
- Make conclusions about pulley systems.

MATERIALS

LabPro or CBL 2 interface
TI graphing calculator
DataMate program
Vernier Force Sensor
500 g mass

string
single pulley
double pulley
ring stand
10 cm ring

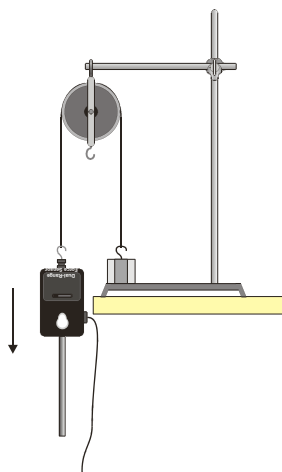


Figure 1

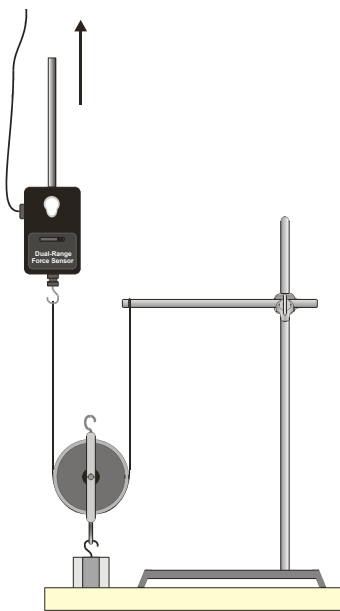


Figure 2

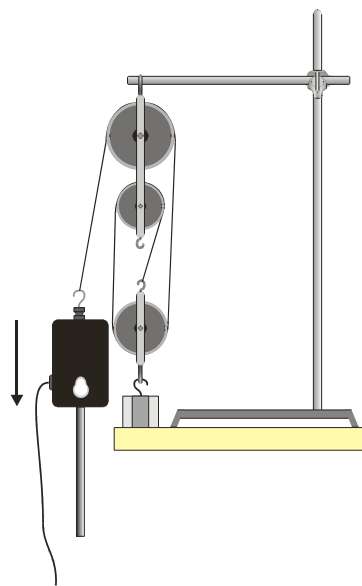


Figure 3

PROCEDURE

Pulley System 1

1. Plug the Force Sensor into Channel 1 of the LabPro or CBL 2 interface. Use the link cable to connect the TI graphing calculator to the interface. Firmly press in the cable ends. If you are using a Dual-Range Force Sensor, set the range switch to 10 N.
2. Turn on the calculator and start the DATAMATE program. Press **CLEAR** to reset the program.
3. Set up the calculator and interface for the Force Sensor.
 - a. Select **SETUP** from the main screen.
 - b. If the calculator displays the correct Force Sensor in CH 1, proceed directly to Step 4. If it does not, continue with this step to set up your sensor manually.
 - c. Press **ENTER** to select CH 1.
 - d. Select **FORCE** from the **SELECT SENSOR** menu.
 - e. Select the correct Force Sensor and setting from the **FORCE** menu.
4. Zero the Force Sensor with its hook pointing down.
 - a. Hold the Force Sensor in a vertical position with its hook pointing down. Make sure the hook is not touching anything.
 - b. Select **ZERO** from the **SETUP** menu.
 - c. Select **CH1-FORCE (N)** from the **SELECT CHANNEL** menu.
 - d. Press **ENTER** to zero the Force Sensor.
5. Hang the mass to be used as the resistance from the Force Sensor. After the readings have stabilized, read the force (in N). This is the resistance force (F_r) for all three pulley systems to be studied. Record this value in all three resistance-force blanks in the data table.

6. Zero the Force Sensor with its hook pointing up.
 - a. Hold the Force Sensor in a vertical position with its hook pointing up. Rest the tip of its handle on the tabletop.
 - b. Select SETUP from the main screen.
 - c. Select ZERO.
 - d. Select CH1-FORCE (N) from the SELECT CHANNEL menu.
 - e. Press **ENTER** to zero the Force Sensor.
7. Set up Pulley System 1. Attach a single pulley to a ring on a ring stand as shown in Figure 1.
8. Attach the Force Sensor to one end of the string and the resistance to the other end. Rest the resistance on the tabletop.
9. Raise the resistance 5 cm from the tabletop by pulling with the Force Sensor in the direction indicated in the figure (straight down for Pulley System 1). Read and record the effort force.

Pulley System 2

10. Zero the Force Sensor with its hook pointing down.
 - a. Hold the Force Sensor in a vertical position with its hook pointing down. Make sure the hook is not touching anything.
 - b. Select SETUP from the main screen.
 - c. Select ZERO.
 - d. Select CH1-FORCE (N) from the SELECT CHANNEL menu.
 - e. Press **ENTER** to zero the Force Sensor.
11. Set up Pulley System 2 as shown in Figure 2. Repeat Step 9.

Pulley System 3

12. Zero the Force Sensor with its hook pointing up.
 - a. Hold the Force Sensor in a vertical position with its hook pointing up. Rest the tip of its handle on the tabletop.
 - b. Select SETUP from the main screen.
 - c. Select ZERO.
 - d. Select CH1-FORCE (N) from the SELECT CHANNEL menu.
 - e. Press **ENTER** to zero the Force Sensor.
13. Set up Pulley System 3 as shown in Figure 3. Repeat Step 9.
14. Look at Figures 1–3 and count the supporting ropes for each pulley system. All ropes are considered to be supporting except a rope that you pull downward (with the Force Sensor). A rope that you pull upward counts as a supporting rope. Record these numbers.

DATA

Pulley system	Resistance force (N)	Effort force (N)	Supporting ropes
1			
2			
3			

PROCESSING THE DATA

1. Calculate the actual mechanical advantage for each pulley system using the formula

$$AMA = F_r / F_e$$

where AMA = actual mechanical advantage, F_r = resistance force, and F_e = effort force. Show your work below. Record results in the table that follows Question 3.

2. The ideal mechanical advantage of a pulley is equal to the number of supporting ropes. See the supporting rope numbers in your Data table and record the IMA values in the table following Question 3.
3. The efficiency of each pulley system can be calculated using the formula

$$\text{efficiency} = \frac{AMA}{IMA} \times 100\%$$

Calculate the efficiency of each pulley system. Record the results in the table below.

Pulley system	AMA	IMA	Efficiency
1			
2			
3			

4. How did the mechanical advantage of the single-movable pulley (Pulley System 2) compare to the mechanical advantage of the single-fixed pulley (Pulley System 1)?

Name _____ Date _____

5. How did increasing the number of pulleys affect the effort needed to raise the resistance?

6. Diagram a pulley system (different from the ones used in this experiment) that has a mechanical advantage of 2.

7. Discuss two factors that might have caused the efficiency values in this experiment not to be 100 percent.

EXTENSIONS

1. Test the pulley system you designed in Question 6. Calculate its AMA, IMA, and efficiency.
2. Design and test pulley systems with higher mechanical advantages.