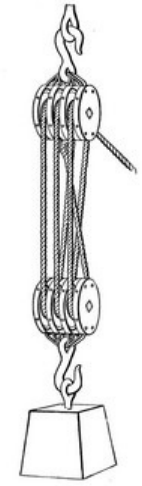
Name: _____ Date: _____

Student Exploration: Pulley Lab

Vocabulary: block and tackle, conservation of energy, efficiency, friction, input force, load, mechanical advantage, output force, pulley, pulley system, simple machine, work



Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
A **pulley** is a wheel with a groove for a rope or cable. The image at left shows an example of a **pulley system**, also called a **block and tackle**.

1. Why do you think people use pulley systems to lift heavy loads? _____

   _____

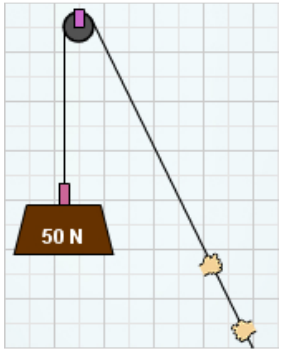
   _____

2. In what places have you seen pulleys at work? _____

   _____

Gizmo Warm-up
The *Pulley Lab* Gizmo™ demonstrates why pulleys are useful for lifting loads. To begin, check that the Gizmo has the following settings:

- The **Pulley configuration** is **1 fixed**.
- **Ideal pulleys (0.0 N)** is selected.
- The **Weight** is 50 N (50 newtons), and the **Efficiency** is 100%.



To apply an **input force**, drag the **Input force** spring balance to the right. Slowly increase the force until the 50-N **load** begins to rise.

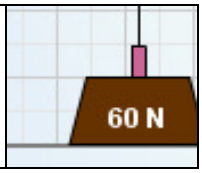
1. What is the minimum force required to lift a 50-N load with one fixed pulley? _____

2. Change the **Pulley configuration** to **1 fixed, 1 moveable**. As you did before, slowly drag the **Input force** balance to the right until the load begins to lift.

   A. What force is required to lift a 50-N load with this pulley system? _____

   B. What is one advantage of using a pulley system? _____

      _____

Activity A: **Mechanical advantage**	Get the Gizmo ready: • Select the **1 fixed** pulley configuration. • Set the **Weight** to 60 N and **Efficiency** to 100%. • You will need a calculator for this activity.	

Introduction: A pulley is an example of a **simple machine**. Many simple machines are useful because they allow the user to lift a heavy weight using less force than it would take to lift the weight directly. The **mechanical advantage** of the machine is a measure of this benefit.

Question: What is the mechanical advantage of each pulley system?

1. Predict: How will adding more pulleys affect the input force needed to lift the load?

   _____

2. Gather data: With the **Weight** set to 60 N and the **Efficiency** set to 100%, find the minimum input force needed to lift the load with each system. Fill in the table below. Include units.

Pulley system	Weight (N)	Minimum input force (N)
1 fixed	60 N	
1 fixed, 1 moveable	60 N	
2 fixed, 2 moveable	60 N	
3 fixed, 3 moveable	60 N	

3. Summarize: How does the minimum input change as you add more pulleys to the system?

   _____

4. Analyze: Compare the input force to the number of pulleys in each system. Do you see a pattern? If so, describe it: _____

   _____

   _____

5. Apply: How much force do you think would be needed to lift a 100-N load with a pulley system composed of two fixed and two moveable pulleys? _____

   Check your answer with the Gizmo. How much force was actually needed? _____

(Activity A continued on next page)

Activity A (continued from previous page)

6. Calculate: The mechanical advantage of a pulley system is equal to the **output force** (F_{out}) divided by the input force (F_{in}):

$$MA = \frac{F_{out}}{F_{in}}$$

The input force and output force for each pulley system is shown in the bottom-right corner of the Gizmo. Use the Gizmo to find the input force and output force for each pulley system. In each case, use the same input force that you used to lift the 60-N load.

Pulley system	Input force (N)	Output force (N)	Mechanical advantage
1 fixed			
1 fixed, 1 moveable			
2 fixed, 2 moveable			
3 fixed, 3 moveable			

7. Make a rule: How is the mechanical advantage related to the total number of pulleys in the pulley system? _____

8. Apply: Imagine a pulley system with four fixed and four moveable pulleys.

   A. What would be the mechanical advantage of this system? _____

   B. Using this system, how much input force would be needed to lift a 500-N load?

   _____

9. Think and discuss: So far, you've been working with an "ideal" pulley system. How do you think real pulley systems are different, and how would that affect the mechanical advantage of real pulley systems?

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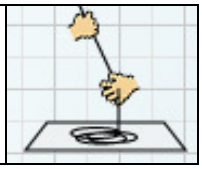
Activity B: **Work and energy**	Get the Gizmo ready: • Select the **1 fixed** pulley. • Set the **Weight** to 80 N and **Efficiency** to 100%. • You will need a calculator for this activity.	

Introduction: The law of **conservation of energy** states that in a closed system the total energy is constant. In other words, energy is neither created nor destroyed.

Question: How does a pulley system demonstrate conservation of energy?

1. Observe: Lift the 80-N load with different pulley systems. Notice the length of the rope pile. How does adding pulleys affect the distance you have to pull the rope to lift the object?

   _____

2. Gather data: Lift the 80-N load to the top with each pulley system. In each case, record the input force, input distance, output force, and height. Include units.

Pulley system	Input force (N)	Input distance (m)	Output force (N)	Height (m)
1 fixed				
1 fixed, 1 moveable				
2 fixed, 2 moveable				
3 fixed, 3 moveable				

3. Calculate: When a force is exerted over a distance, **work** is done on an object. Work is measured in joules (J) and is equal to the product of force and distance: $W = F \cdot d$. For each pulley system, calculate the input work (input force • input distance) and the output work (output force • height). Units of work are newton-meters, or joules (J).

Pulley system	Input work (J)	Output work (J)
1 fixed		
1 fixed, 1 moveable		
2 fixed, 2 moveable		
3 fixed, 3 moveable		

4. Analyze: Work is a measure of energy. Look at each pair of input-output values. How do pulley systems illustrate conservation of energy? _____

   _____

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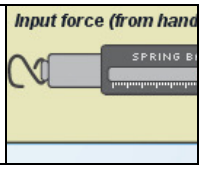
Extension: **Friction and efficiency**	Get the Gizmo ready: • Select **1 fixed** pulley, and set the **Weight** to 40 N. • Select the **Standard pulleys (5 N)**. • You will need a calculator for this activity.	

Introduction: So far you have studied "ideal" pulley systems. In the real world, **friction** reduces the advantage of any pulley system. **Efficiency** is a measure of how much friction is present.

Question: How does friction affect the mechanical advantage of a pulley system?

1. Observe: Use the fixed pulley to lift the 40-N load. Vary the efficiency of the pulley. How does the efficiency of the pulley affect how much force is needed to lift the 40-N load?

   _____

2. Gather data: Use the **1 fixed** pulley to lift the 40-N load at the following efficiencies. In each case, record the input force and output force shown at bottom right.

Efficiency	Load (N)	Input force (N)	Output force (N)	Ratio (Output ÷ Input)
100%	40.0 N			
75%	40.0 N			
67%	40.0 N			
50%	40.0 N			

3. Calculate: Divide each output force by the input force to find the ratio. Fill in the last column. How does the ratio of output force to input force compare to the efficiency of the pulley?

   _____

4. Make a rule: Given the input force and output force of a fixed pulley, how do you calculate efficiency? _____

5. Challenge yourself: An ideal system with one fixed and one moveable pulley has a mechanical advantage of two. Suppose a real system with one fixed and one moveable pulley had an efficiency of 80%. (Recall that a standard pulley has a weight of 5 newtons.)

   A. Using this system, how much force will be needed to lift a 45-N load? _____

   B. Check your answer using the Gizmo. How much force was needed? _____

   C. Modify your efficiency equation from #4 above to factor in mechanical advantage.

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