DATE ______ NAME ______

EXPERIMENT

15 Pulleys

Purpose

Find the mechanical advantage and the efficiency of several different pulley systems.

Concept and Skill Check

Pulleys are simple machines that can be used to change the direction of a force, to reduce the force needed to move a load through a distance, or to increase the speed at which the load is moving, but that do not change the amount of work done. However, if the required effort force is reduced, the distance the load moves is decreased in proportion to the distance the force moves. Pulley systems may contain a single pulley or a combination of fixed and movable pulleys.

In an ideal machine, one lacking friction, all the energy is transferred, and the work input of the system equals the work output. The work input equals the force times the distance that the force moves, $F_e d_e$. The work output equals the output force (load) times the distance it is moved, $F_r d_r$. The ideal mechanical advantage, *IMA*, of the pulley system can be found by dividing the distance the force moves by the distance the load moves. Thus $IMA = d_e/d_r$. The ideal machine has a 100% efficiency. In the real world, however, the measured efficiencies are less than 100%. Efficiency is found by the following:

$$\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}} \times 100\%.$$

Materials

2 single pulleys
2 double pulleys
set of hooked metric masses
spring scale
pulley support
string (2 m)
meter stick

Procedure

1. Set up the single fixed pulley system, as shown in Figure 1a.

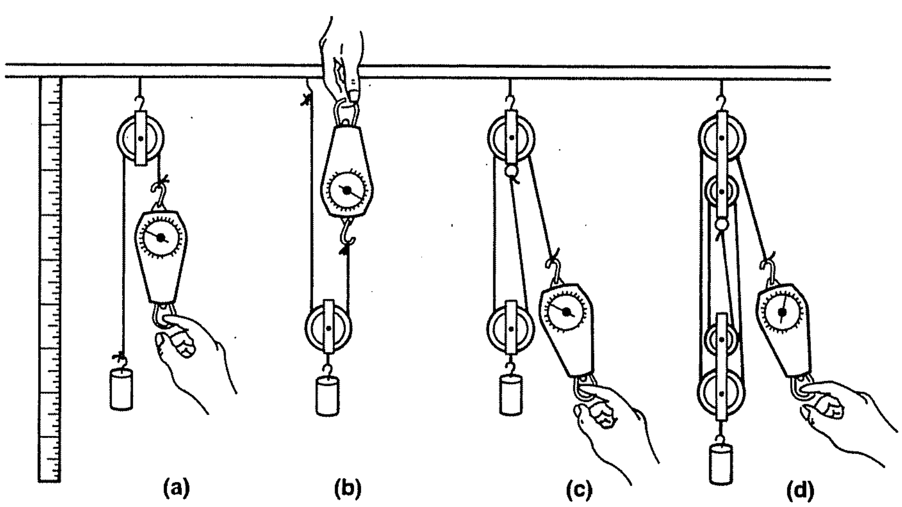

Figure 1. In (a), (c), and (d), the spring scale's weight acts as part of the force raising the load. Therefore, the scale must be used upside down so that it will register its own weight.

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2. Select a mass that can be measured on your spring scale. Record the value of its mass in Table 1. Determine the weight, in newtons, of the mass to be raised by multiplying its mass in kilograms by the acceleration due to gravity. Recall that $W = mg$.
3. Carefully raise the mass by pulling on the spring scale. Measure the height, in meters, that the mass is lifted. Record this value in Table 1. Calculate the work output of the mass by multiplying its weight by the height it was raised. Record this value in Table 2.
4. Using the spring scale, raise the mass to the same height it was raised in Step 3. Ask your lab partner to read, directly from the spring scale, the force, in newtons, required to lift the mass. (If your spring scale is calibrated in grams, rather than newtons, calculate the force by multiplying the reading expressed in kilograms by the acceleration due to gravity.) Record this value in Table 1 as the force of spring scale. As you are lifting the load with the spring scale, pull upward at a slow, steady rate, using the minimum amount of force necessary to move the load. Any excess force will accelerate the mass and cause an error in your calculations.
5. Measure the distance, in meters, through which the force acted to lift the load to the height it was raised. Record this value in Table 1 as the distance, d, through which the force acts. Determine the work input in raising the mass by multiplying the force reading from the spring scale by the distance through which the force acted. Record the value for the work input in Table 2.
6. Repeat Steps 2 through 5 for a different load.
7. Repeat Steps 2 through 6 for each of the different pulley arrangements in Figures 1b, 1c, and 1d. Be sure to include the mass of the lower pulley(s) as part of the mass raised.
8. Count the number of lifting strands of string used to support the weight or load for each arrangement, (a) through (d). Record these values in Table 2.

Observations and Data

Table 1

Pulley arrangement	Mass raised (kg)	Weight (W) of mass (N)	Height (h) mass is raised (m)	Force (F) of spring scale (N)	Distance (d) through which force acts (m)
(a)					
(b)					
(c)					
(d)					

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Table 2

Pulley arrangement	Work output (Wh) (J)	Work input (Fd) (J)	IMA (d_e/d_r)	MA Number of lifting strands	Efficiency %
(a)					
(b)					
(c)					
(d)					

Analysis

1. Find the efficiency of each system. Enter the results in Table 2. What are some possible reasons that the efficiency is never 100%.

2. Calculate the ideal mechanical advantage, IMA, for each arrangement by dividing d_e by d_r. Enter the results in Table 2. What happens to the force, F, as the mechanical advantage gets larger?

3. How does increasing the load affect the ideal mechanical advantage and efficiency of a pulley system?

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4. How does increasing the number of pulleys affect the ideal mechanical advantage and efficiency of a pulley system?

5. The mechanical advantage may also be determined from the number of strands of string supporting the weight or load. Compare the calculated *IMA* from Question 2 with the number of strands of string you counted. Do the two results agree?

6. Explain why the following statement is false: A machine reduces the amount of work you have to do. Tell what a machine actually does.

Application

In the space provided below, sketch a pulley system that can be used to lift a boat from its trailer to the rafters of a garage, such that the effort force would move a distance of 60 m while the load will move 10 m.