22 Tug-of-War

Experiment

Purpose

To investigate the tension in a string, the function of a simple pulley, and a simple "tug-of-war."

Required Equipment/Supplies

5 large paper clips
2 large identical rubber bands
2 m of strong string
2 500-g hook masses
2 low-friction pulleys
2 ring stands
spring scale
measuring rule

Discussion

Suppose you push on the back of a stalled car. You are certainly aware that you are exerting a force on the car. Are you equally aware that the car is exerting a force on you? And that the magnitudes of the car's force on you and your force on the car are the same? A force cannot exist alone. Forces are always the result of interactions between two things, and they come in balanced pairs.

Now suppose you get a friend to tie a rope to the front of the car and pull on it. The rope will be pulling back on your friend with exactly the same magnitude of force that she is exerting on the rope. The other end of the rope will be pulling on the car and the car will be pulling equally back on it. There are two interaction pairs, one where your friend grasps the rope and one where the rope is attached to the car.

A rope or string is a transmitter of force. If it is not moving or it is moving but has a negligible mass, the forces at its two ends will also be equal. In this activity, you will learn about balanced pairs of interaction forces and about the way a string transmits forces.

Fig. A

Procedure

Step 1: Suspend a 500-g load from a string that is held by a spring scale as shown in Figure A.

1. What does the scale reading tell you about the tension in the string?

Put tension on a string.

Hang weight over pulley.

Step 2: Drape the string over a pulley such that both ends of the string hang vertically, as shown in Figure B. Hold the scale steady so that it supports the hanging load.

2. What does the scale read, and how does this force compare with the weight of the load?

3. How does it compare with the tension in the string?

Move spring scale to different positions along vertical.

Step 3: Move the spring scale first to a higher, then to a lower position, keeping the strings on each side of the pulley vertical.

4. Does the reading at the higher position change?

5. Move the scale to a lower position. Does the reading at the lower position change? Briefly explain these results.

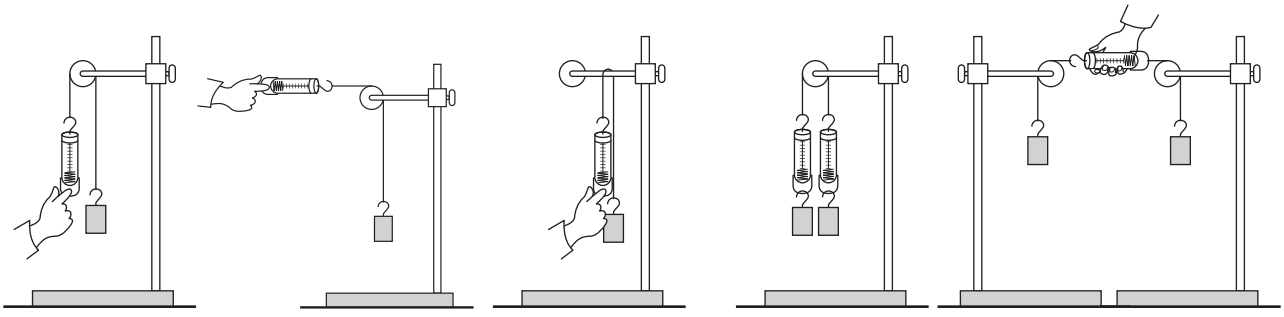

Fig. B **Fig. C** **Fig. D** **Fig. E** **Fig. F**

Step 4: Move the spring scale to various angles to the vertical, until the scale is horizontal, as shown in Figure C.

Move spring scale to different positions away from vertical.

6. Does the reading on the scale ever deviate from what you measured in the previous steps? Briefly explain your result.

Step 5: Remove the string from the pulley and drape it over a horizontal rod. Repeat Step 4, as shown in Figure D.

Hang weight over rod.

7. Do you find a difference between the results of Steps 4 and 5? Explain.

Step 6: Attach a spring scale to each end of the string. Drape the string over the pulley and attach equal masses to each end, as shown in Figure E.

Pull on both ends of string over pulley.

8. What do the scales read?

9. What role does friction play in the function of a pulley?

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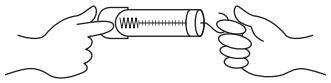
Have mini tug-of-war with two spring scales.



Step 7: Have your partner hold one end of a spring scale stationary while you pull horizontally on the other end. Pull until the scale reads the same force as it did when suspending the mass. Record the following observations.

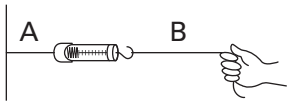
force you exert on the scale = _____

force the scale exerts on you = _____

force your partner exerts on the scale = _____

force the scale exerts on your partner = _____

Attach string to wall and tug.



Step 8: Attach strings on both ends of the spring scale. Fasten one end to the wall or a steady support. Call this String A. Pull horizontally on the other string, String B, until the scale reads the same as in the previous step. Record the following observations.

force you exert on String A = _____

force String A exerts on scale = _____

force the scale exerts on String B = _____

force String B exerts on the wall = _____

force the wall exerts on String B = _____

10. What is the essential difference between the situations in Step 7 and Step 8?

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Think and Explain

11. From a microscopic point of view, how does the spring or string transmit the force you are exerting on your partner or the wall?

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Step 9: Study Figure F and predict the reading on the scale when two 500-g loads are supported at each end of the strings. Then assemble the apparatus and check your prediction.

predicted scale reading = _____

actual scale reading = _____