30 Wrap Your Energy in a Bow

Purpose

To determine the energy transferred into an archer's bow

Required Equipment/Supplies

toy bow and arrow (with rubber suction cup tips)
large-capacity spring scale
meterstick
clamp
graph paper

Discussion

The kinetic energy of an arrow is obtained from the potential energy of the drawn bow, which in turn is obtained from the work done in drawing the bow. This work is equal to the average force acting on the bowstring multiplied by the distance it is drawn.

In this experiment, you will measure the amounts of force required to hold the center of a bowstring at various distances from its position of rest, and plot these data on a force-vs.-distance graph. The force is relatively small for small deflections, but it becomes progressively larger as the bow is bent further. The area under the force-vs.-distance curve out to some final deflection is equal to the average force multiplied by the total distance. This equals the work done in drawing the bow to that distance. Therefore, your graph will show not only the relationship of the force to the distance stretched, but also the potential energy possessed by the fully drawn bow.

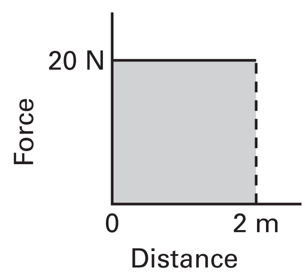

Fig. A

The effect of a constant force of 10 N acting over a distance of 2 m is represented in the graph of Figure A. The work done equals the area of the rectangle.

$$\text{work} = F \times d = (20\text{ N}) \times (2\text{ m}) = 40\text{ N}\bullet\text{m} = 40\text{ J}$$

When the force is not constant, as in Figure B, the work done on the system still equals the area under the graph (between the graph and the horizontal axis). In this case, the total area under the graph equals the area of the triangle plus the area of the rectangle.

$$\begin{aligned}\text{work} &= \text{total area} = \text{area of triangle} + \text{area of rectangle}\\ &= [(1/2)\ (\text{base}) \times (\text{height})] + [(\text{base}) \times (\text{height})]\\ &= [(1/2)\ (2\text{ m}) \times (20\text{ N})] + [(3\text{ m}) \times (20\text{ N})]\\ &= (20\text{ N}\bullet\text{m}) + (60\text{ N}\bullet\text{m})\\ &= 80\text{ N}\bullet\text{m}\\ &= 80\text{ J}\end{aligned}$$

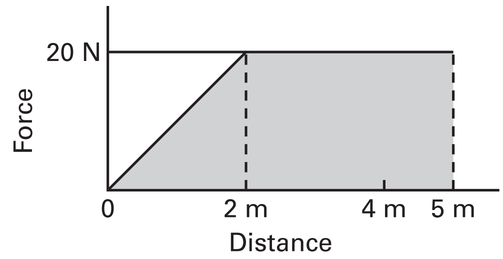

Fig. B

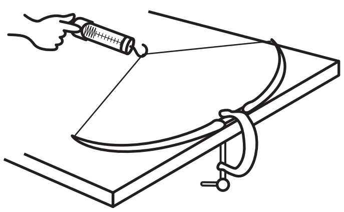

Fig. C

Procedure

Draw data table.

Step 1: Fasten the bow at its handle with a clamp in a vertical position, as shown in Figure C. You will pull horizontally on the bowstring with a spring scale. You will measure the distance the bowstring is stretched from its original position and the force required to hold the bowstring that far out. In the space below, prepare a table in which to record your data. Show the stretch distances in centimeters in the first column, and their equivalent values in meters in the second column. Show the force readings in the third column. If they are not in newtons, show the equivalent force values in newtons in a fourth column. Leave 10 rows for data in your table.

Stretch bowstring and measure forces.

Step 2: Stretch the bowstring by 1.0 cm, and record the stretch distance and force reading. Continue to stretch the bowstring in 1.0-cm increments, and record your data in the table. Compute the stretch distances in meters and the equivalent force values in newtons.

Make a graph.

Step 3: Plot a graph of the force (vertical axis) vs. distance (horizontal axis). Use the units newtons and meters.

Compute area.

Step 4: Estimate the area under the graph in units of newtons times meters, N•m. Since 1 N•m = 1 J, this area is the total energy transferred to the bow. When the bow is drawn, this energy is in the form of elastic potential energy.

area = ________________

Name Period Date

Analysis

1. If a 50-g arrow were shot straight up with the bow stretched to the maximum displacement of your data, how high would it go? (To find the answer in meters, express 50 g as 0.05 kg.)

2. How high would a 75-g arrow go?

3. At what speed would the 50-g arrow leave the bow?

4. List three other devices that transform potential energy into work on an object.