Name _____

I SHOT AN ARROW INTO THE AIR

Work-energy lab for a variable force

The Arrow and the Song

I shot an arrow into the air,
It fell to earth, I knew not where;
For, so swiftly it flew, the sight
Could not follow it in its flight.

I breathed a song into the air,
It fell to earth, I knew not where;
For who has sight so keen and strong,
That it can follow the flight of song?

Long, long afterward, in an oak
I found the arrow, still unbroke;
And the song, from beginning to end,
I found again in the heart of a friend.

Henry Wadsworth Longfellow

Purpose

Investigate the work done by a variable force.

Discussion

1. The kinetic energy of an arrow is obtained from the potential energy stored in a drawn bow. The potential energy 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. When an applied force is not constant, the work done on the system can be found by finding the area under a force as a function of distance plot.

2. In this lab, you will measure the force required to draw a bow and plot the required force as a function of the distance drawn. The force is relatively small for small deflections and becomes progressively larger as the bow is bent. The area under the force versus distance curve 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 stored in the fully drawn bow.

Lab Procedures

3. Fasten the bow at its handle with a clamp. Pull horizontally on the bowstring with a spring scale.

4. Stretch the bowstring by 1.0 cm, and record the distance and force reading. Continue to stretch the bowstring in 1.0-cm increments, and record your data in a table. Be sure to record the distances in meters and the equivalent force values in Newtons.

5. Plot force as a function of distance and determine the area under the graph. The units for the area are Newton-meters. Since 1 N•m = 1 Joule (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.

6. Find the mass of the arrow.

Mass = _____

Analysis

7. Using the concept of energy conservation, determine how fast the arrow will be moving as it leaves the bow. Assume a 15% loss due to friction and vibration.

8. Determine the height it should achieve if shot straight up. Assume a 10% loss due to air resistance.

9. How fast and high would an arrow of twice the mass fly?

10. List three other everyday devices that store potential energy for our later use.

    a.

    b.

    c.

What to turn in

11. Each student needs to turn in the following:

    a. Graph of force as a function of distance

    b. Data table (can be on same page as the graph)

    c. Formal solutions to the questions raised in the Analysis section (paragraphs 7, 8, and 9)