Milkweed Seed Dispersal: A Means for Integrating Biology & Physics

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Success for plants and most other organisms means living long enough to produce viable offspring. For many of the plants with which we are familiar, this means being able to produce and disperse seeds. Dispersal of the seeds is important so that a plant is not competing for the same resources—light, water, nutrients—as its offspring or other close relatives. Seed dispersal is also extremely important as a means for colonizing suitable habitats. While seed dispersal occurs throughout the year, in many areas it peaks during the late summer and autumn—just in time for the beginning of the school year!

If you have access to vegetation you can find good examples of seed dispersal. Burs and acorns are animal dispersed, wood sorrel and lupine propel their seeds through the air, coconut and mangrove trees make use of water dispersal, and maple trees and dandelions disperse seeds on the wind. A discussion of the types of seed dispersal and the advantages of each can lead to a more in-depth study of the dispersal methods. An activity we use successfully at Arrowhead High School integrates biology and physics concepts by experimenting with the seed dispersal of common milkweed (*Asclepias syriaca*) or any other similar wind-dispersed seed.

The class experiment begins in mid-Fall after the seed pods have begun to burst open. Because milkweed is a perennial plant, it should be present at the same location year after year. Students venture out to a berm located on the school grounds. Each team of two or three students works with one or two plants. Because of the rigor of later mathematical calculations, it is beneficial for each team to include a student with a strong mathematical background. Each team makes a sketch of the plant and determines its height, the number of seed pods on the plant, and the distance from the ground to the center of each pod. Later, we will determine average values for each of these measurements. We collect several hundred seeds and take them back to the classroom.

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In the classroom, we review the basic principles of trajectory motion. This involves the mathematics of free-fall versus parabolic path (see Figure 1). One important thing to remember is that the time it takes the seed to drop free-fall is equivalent to the time it takes the seed to follow a parabolic path. Because the vertical distance is the same for both paths and gravity acts only on the vertical motion, the length of time to fall the vertical distance, d, would be the same for both. This is counterintuitive to most people so it may be necessary to demonstrate this to the students before going further. There are some excellent pieces of equipment available for demonstrating this phenomenon (Pasco, Vertical Acceleration Demonstration and/or Ballistic Cart Accessory; Science Kit, Falling Body Acceleration apparatus)—just check with the physics teacher at your school.

We begin with the assumption that the only way the seed gains its horizontal speed is by the force provided by the wind; this is the horizontal velocity of the seed. If the time for free-fall (descent time) is measured, a simple calculation of

$$\text{horizontal distance} = \text{wind velocity} \times \text{descent time}$$

can be used to find the horizontal distance, or range, which the seed falls from the parent plant at various wind speeds.

Next, the students drop a seed from a height of two meters and, using a stopwatch, determine the length of time required for the seed to reach the floor. Using a height of two meters helps to minimize errors in the measurements. Student groups are organized as shown in Figure 2. Each team works with at least 10 seeds and all data are pooled on a spreadsheet for a larger sample size. The rate of descent will remain relatively constant because the seed reaches terminal velocity almost immediately upon release. Using the average time for the seeds to fall a vertical distance two meters, we determine the average rate of descent by using the formula:

$$\text{average velocity} = 2\ \text{meters/average time.}$$

Once we have calculated the average velocity of a milkweed seed, we determine the amount of time that it would take for a seed to fall from the height of an average milkweed seed pod by using the equation,

$$\text{descent time from the height of an average pod} = \frac{\text{average pod height}}{\text{average velocity}}$$

Another option to using a stopwatch may be to use a dual photogate system. This would allow you to directly measure the velocity of the fall.

Once you have determined the amount of time the seed stays in the air, it is possible to calculate the range at various wind speeds using this equation:

$$\text{range} = \text{descent time from the height of average pod} \times \text{wind speed}$$

Figure 3 takes you through a sample calculation.

Manually or using a spreadsheet, students calculate and then graph the horizontal distances traveled for wind velocities from zero to 30 miles per

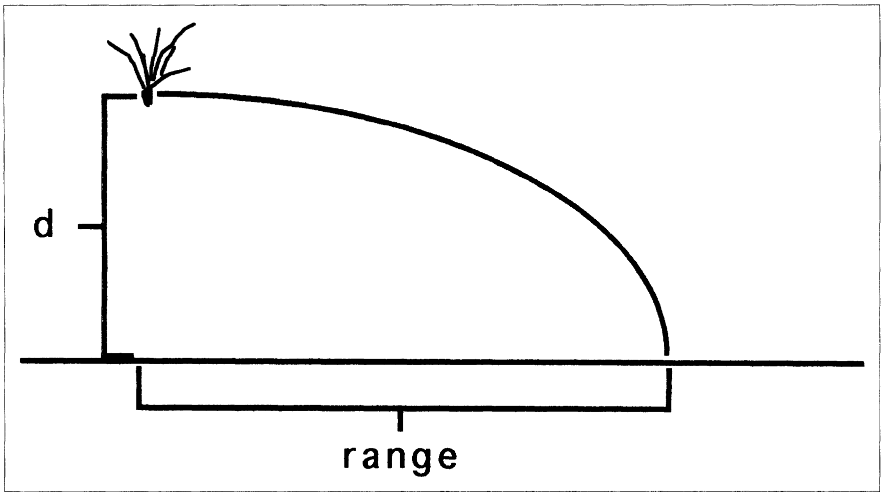

Figure 1. The distance for the seed to fall straight down is equal to the vertical distance for the parabolic path. Therefore, the time for the seed to hit the ground from height d is the same for both.

Student 1	handles and drops the seeds
Student 2	operates the stopwatch
Student 3	records data and ensures measurements are taken properly

Figure 2. Cooperative learning roles.

Let's say that your students went out to collect their seeds and their data and found the average height of the milkweed pods to be 0.95 meters.

Back in the classroom, it is determined that the average length of time for a seed to fall 2 meters is 9.50 seconds. Therefore . . .

$$\text{average velocity} = 2 \text{ meters/average time}$$
$$= 2 \text{ m}/9.50 \text{ s}$$
$$= 0.21 \text{ m/s}$$

So the time for a seed to fall 0.95 meters from the average height of a milkweed pod is:

$$\text{descent time} = \text{average pod height/average velocity}$$
$$= 0.95 \text{ m}/0.21 \text{ m/s}$$
$$= 4.52 \text{ s}$$

Now, to determine the range for a seed at a wind speed of 5 miles/hour:

$$\frac{5 \text{ mi}}{\text{hr}} \times \frac{1609 \text{ m}}{1 \text{ mi}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} = 2.2 \text{ m/s}$$

$$\text{range} = \text{descent time} \times \text{wind speed}$$
$$= 4.52 \text{ s} \times 2.2 \text{ m/s}$$
$$= 9.94 \text{ m}$$

Figure 3. A sample problem.

hour, calculating first in meters per second and then converting to the more familiar miles per hour. This procedure can be very difficult for many students and you may want to have the more advanced math student on each team perform this part of the activity. We have the students graph the data with wind speed on the x-axis (independent variable) and range on the y-axis (dependent variable) using Vernier Graphical Analysis software. The calculations result in data points along a single line that gives a perfect correlation coefficient which can then be compared to the experimental results of wind speed vs. range.

Once we have graphed the information, we take a collection of the seeds outside to obtain experimental data. We set up several 100-foot tape measures downwind from our release point on a large athletic field. Armed with our seeds and a wind speed meter, we release seeds from the average pod height one at a time. We record the wind speed at release with the distance each seed travels along the tape measures. Again, we pool data and graph the wind speed on the x-axis and range on the y-axis. It is best to use the same scale on both graphs, the mathematical model and the experimental data, or to graph both data sets on the same graph to simplify comparisons.

The assessment for this activity requires each team to write a scientific paper including: descriptive title, authors, abstract, introduction, methods, results, discussion, and literature cited. The discussion must include a comparison of the field data and the mathematical model. Our model does not predict the actual behavior of milkweed seeds due to the presence of other variables. Students attribute this discrepancy to wind turbulence, differences in humidity, and aerodynamic properties of the seeds. By the time they have completed the activity and the paper, students have learned not only about seed dispersal and milkweed plants but have examined the ideas of scientific/mathematical models, the scientific research process, and the importance of communicating research to others. This allows students to do science and to realize that research results in more questions.