An Inexpensive Mechanical Model for Projectile Motion

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As experienced physicists, we see the beauty and simplicity of projectile motion. It is merely the superposition of uniform linear motion along the direction of the initial velocity vector and the downward motion due to the constant acceleration of gravity. We see the kinematic equations as just the mathematical machinery to perform the calculations. What do our students see? Likely, most see no deeper than the operational understanding needed to use the kinematic equations. Described below is a device (shown in Fig. 1) that illustrates the physicist's view of projectile motion. It can be used as a classroom demonstration or as a project for your students, and it costs less than three dollars to make.

Ayers[1] was the first to describe this type of demonstration. A lecture demo-sized version can be viewed at the North Carolina State University Physics Demonstrations website.[2] The advantage to the version presented here is that it can be made cheaply as a student project from readily available items, and it allows for easy variation of the magnitude of the initial velocity. The parts list includes a 7/16-x-36-in wooden dowel, a small eye screw, some beads, thread, and a ¼-in braided elastic band.

Cut a 2–3-cm piece off the end of the dowel. Insert the eye screw in one end of the dowel. The elastic band is attached to the dowel near the other end, run down the length of the dowel and through the eye screw. Pull the elastic so that it is somewhat taut and tie it off on the short piece cut from the dowel.

Now calculate (or better yet, have your students calculate) the distance an object falls after 0.04 s, 0.08 s, 0.12 s, etc. Hang beads at these lengths from the elastic band at intervals around 3 cm. Now, hold the stick horizontally allowing the beads to hang vertically. The trajectory of a horizontally thrown object is manifest. Pulling on the elastic causes the trajectory to change as if the initial velocity was increased. The demonstration shows that while the ball goes further before it lands, it still lands at the same time.

As explained by others[3] the device can also be used to understand the motion of a projectile with an initial velocity above or below the horizontal. The effect of changing the magnitude of the velocity can again be illustrated by pulling on the elastic. The device also can be used to address the underlying physics of the maximum range occurring at 45° and the subtleties of the monkey/hunter problem.

As physicists we understand that projectile motion is completely determined by the initial velocity vector and gravitational free fall. Now perhaps your students can develop that insight more easily.

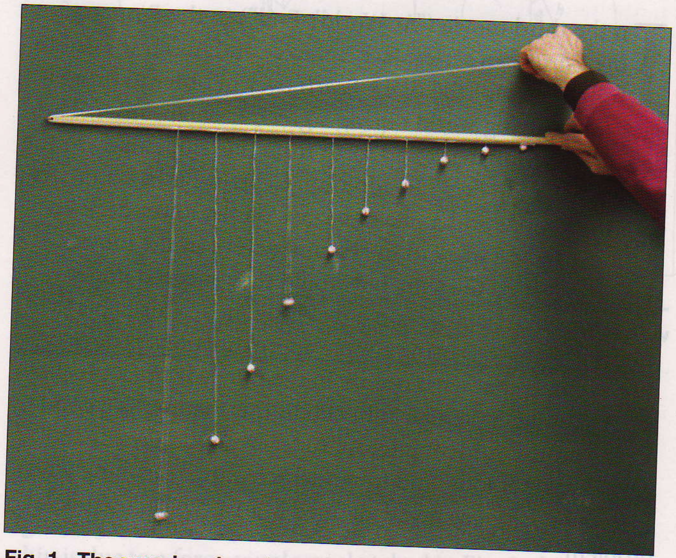

Fig. 1. The wooden dowel represents the direction of the magnitude of the initial velocity vector. The hanging beads trace out the resulting trajectory. Pulling on the elastic shows the trajectory for a higher initial speed.

References

1. R. Dean Ayers, "Simple device for representing trajectories," *Am. J. Phys.* 47, 1097–1098 (Dec. 1979).
2. demoroom.physics.ncsu.edu/html/demos/422.html.
3. P. G. Hewitt, *Conceptual Physics*, 10th ed. (Pearson/Addison-Wesley, New York, 2006), pp. 186-189.

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