

Ozobot Evo Classroom Application: Projectile Shot from the Edge of a Cliff

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Introduction

The study of projectile motion is central to any introductory course in physics. Fortunately, Ozobot Evo can be programmed to behave like a projectile when used with an appropriate map. For ready reference while discussing this classroom application, a small copy of the map used is shown in Figure 1. A full-page version that can be printed for actual use with Ozobot Evo appears on the last page of this document.

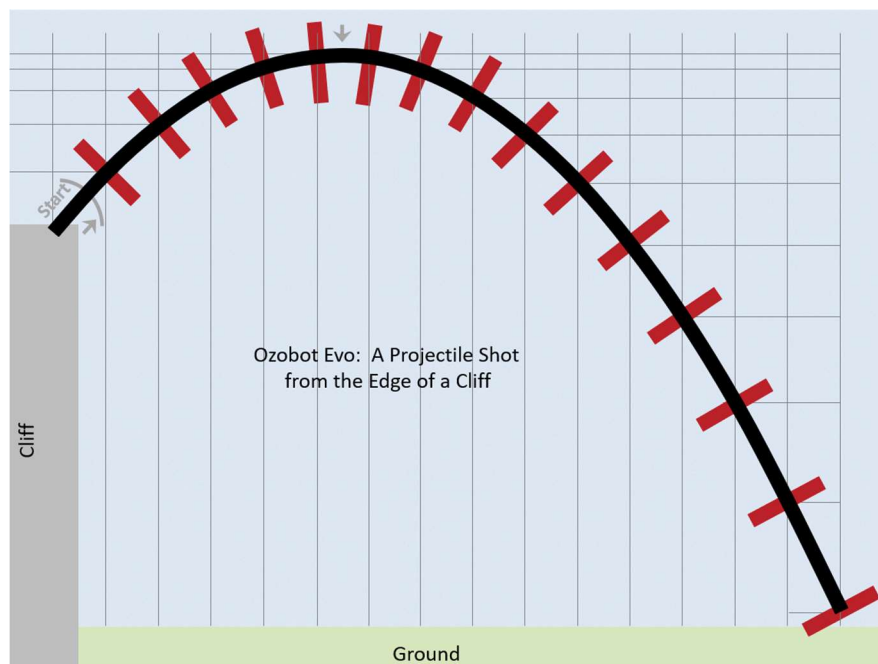


Figure 1

As can be seen in the map of Figure 1, Ozobot Evo will behave as a projectile that has been shot from the edge of a cliff. The heavy black line is the parabola that he follows as he moves through the “air”. Actually, we assume that there is very little air resistance so that it is negligible. This is a common assumption in the initial studies of projectile motion in the physics classroom. The red hash marks on the parabola *are equally space in time*. Gray vertical and horizontal lines meet at the intersection of the parabola with each of the hash marks.

General Considerations

1. Make sure that Ozobot Evo is calibrated before running the program.
2. Make copies of the map at the end of this document for each lab group.
3. Ozobot Evo should be loaded with the program *EvoProjectile.ozocode* (share code kmmtzn).

- Ozobot Evo should always be placed at the Start location on the map facing the direction shown by the gray arrow, and with his leading edge at the gray curved line.
- Start Ozobot Evo by pressing the start button, and then double-press the button to start the program.
- Ozobot Evo will show a RED LED, follow the parabolic path, and stop when he reaches the red hash mark at the bottom right corner of the map.

Student Exercise #1: The first thing you need to do is convince yourself that the red hash marks are equally spaced in time (not in distance). Start Ozobot Evo at the start location. When he reaches the second red hash mark, you should start counting aloud at 1. Continue counting from 2 through 14 as he reaches successive hash marks before coming to a stop on the last hash mark. You will notice that you are counting quite **evenly in time**, even though the hash marks are not evenly spaced in **distance**. What does this observation tell you about the time between each of the vertical gray lines on the map? What does this observation tell you about the time between each of the horizontal gray lines on the map?

Student Exercise #2: As you can see from the map, Ozobot Evo is fired from the cliff at an angle of approximately 45° above the horizontal. In vector terms, Ozobot's velocity vector at any time can be thought of as the sum of a horizontal (x) component and a vertical (y) component of velocity as shown in Figure 2. (A vector is any quantity that has both magnitude and direction.)

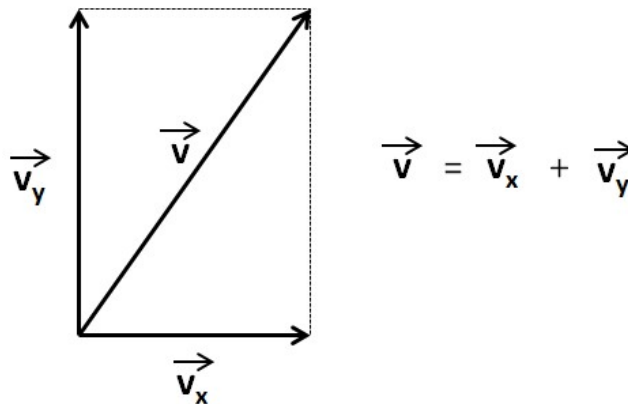


Figure 2

- In light of your answer to exercise #1, what can you say about the horizontal component of velocity throughout Ozobot Evo's flight?
- Ozobot's vertical component of velocity is zero at the top of its parabolic path (marked on the map with a light gray arrow). What is happening to the vertical component of velocity as Ozobot rises from the cliff to the top of its flight? What happens to its vertical component of velocity as it travels from the top of its path to the ground?

Student Exercise #3: Now you should be able to determine the value of the horizontal component v_x of Ozobot's velocity. Use a stop watch to measure the time of flight, i.e., the time from when Ozobot's leading edge reaches the first red hash mark until it reaches the last red hash mark. Use a metric ruler to measure the horizontal distance (in cm) covered during this time period. Since you know that the horizontal component of velocity is constant, you can use the equation $d_x = v_x t$ to determine v_x . [Typical answers will be ≈ 3.5 cm/sec, but may vary somewhat from one Ozobot Evo to another.]

Student Exercise #4: Now you should be able to determine the value of Ozobot Evo's **acceleration** due to "gravity", g , as he travels through the "air" to the ground. Probably the easiest way to do this is to measure:

1. The time t required to fall from the top of the parabola, where his y -component of velocity is zero, until he reaches the ground.
2. The distance d_y from the top of the flight to the ground.

The equation that applies here is $d_y = v_{iy}t + \frac{1}{2}gt^2$. Since the initial y -component of velocity, v_{iy} , is 0 at the top of the parabola, then $v_{iy}t$ is zero. We then simply have $d_y = \frac{1}{2}gt^2$. You can solve this equation for g . [Typical answers will be $\approx 1.6 \text{ cm/sec}^2$, but may vary somewhat from one Ozobot Evo to another.]

Student Exercise #5: When a projectile is fired, one of the items of interest is to determine its **initial velocity**, and by this we are referring to the length of the velocity vector $\mathbf{v}$ shown in Figure 2. The average velocity of Ozobot between the first and second red hash marks should be a pretty good indication of the initial velocity. Back in exercise #3, you determined the total flight time. The 15 red hash marks provide 14 equal time intervals. So if you divide the total flight time by 14, you should know the time between red hash marks. Measuring the distance in cm between the centers of the first and second red hash marks should give you a close measure of the distance traveled during the first interval. From the formula $d = vt$, you should be able to determine the average velocity in cm/sec. [Typical answers will be $\approx 4.8 \text{ m/sec}$, but may vary some from one Ozobot to another.]

Student Exercise #6: Also of interest is the velocity of a projectile just before it hits the ground. In a manner similar to that of exercise #5, determine this velocity. [Typical answers will be $\approx 8.2 \text{ cm/sec}$, but, as usual, can vary some from one Ozobot to another.]

Conclusions

This Ozobot Evo Classroom Application has given your students the opportunity to study projectile motion in a manner unlike any existing methods **because it has simulated a gravitational acceleration that is much smaller than earth's acceleration due to gravity** of 9.8 m/s^2 or 980 cm/s^2 . Instead of the need to use expensive electronic equipment and photogates to measure time intervals, the time intervals involved are large enough for students to use simple stop watches. This classroom application also encourages the use of both STEM and NGSS standards

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Cliff

Ground

Start

