Optimal launch angle: 45°

FizziQ activity · High school · 30 min

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Fire projectiles from 10° to 80° in the FizziQ Web ballistics simulation on computer: plot range against angle, find the 45° maximum and check $R = v_0^2 \sin(2\alpha)/g$.

Learning objectives

- Identify the launch angle that maximizes projectile range
- Observe the symmetry of trajectories for complementary angles
- Record data in the FizziQ experiment notebook and plot range versus angle
- Verify the formula $R = v_0^2 \sin(2\alpha)/g$
- Understand the interplay between horizontal and vertical velocity components

Instruments and sensors

FizziQ Web Ballistics simulation

Materials

- Computer, tablet, or smartphone with FizziQ Web
- Note: the protocol remains adaptable to any comparable simulation-based measurement tool.

Protocol

1. Open FizziQ Web. In the sidebar, click Experiment, then Simulations, and select Ballistics Simulation.
2. Set the initial speed to 20 m/s. Disable air resistance to start. These parameters will remain fixed throughout.
3. Set the launch angle to 10°. Press REC to fire and record the data. The trajectory appears on screen. Note the range in the experiment notebook.
4. Repeat for angles 20°, 30°, 40°, 45°, 50°, 60°, 70°, and 80°. Each trajectory appears in a different color on the same screen.
5. Observe the superimposed trajectories. Which angles seem to give the same range? Note your observations.
6. For each shot, read the range (horizontal distance at impact) from the experiment notebook.
7. Create a table with two columns: Angle (°) and Range (m). Enter your measurements.
8. Plot the graph of range versus angle. For which angle is the range maximum?
9. Compare the ranges for 30° and 60°, for 20° and 70°, for 10° and 80°. What do you notice?
10. State a conclusion: what is the optimal angle and why do complementary angles give the same range?

Expected results

The range-angle graph has a bell-shaped curve, symmetric about 45°. Maximum range is achieved at 45°. Complementary angles (e.g., 30° and 60°) give exactly the same range. For $v_0 = 20$ m/s: $R\_max = v_0^2/g \approx 40.8$ m at 45°. The formula $R = v_0^2 \sin(2\alpha)/g$ explains the symmetry since $\sin(2\times30°) = \sin(2\times60°) = \sin(60°) = \sin(120°)$.

Questions

- Why does the 45° angle give the maximum range?
- If two complementary angles give the same range, are the trajectories identical? What differs?

- How does the initial speed affect the maximum range?
- What would the optimal angle be if the launch point is higher than the landing point?
- How does air resistance change the optimal angle?
- Why is sin(2α) the key function in the range formula?

Going further

- Enable air resistance and redo the series: does the optimal angle drop below 45°?
- Fix the angle at 45° and vary the initial speed: verify that the range varies as v_0^2
- Compare trajectories at 30° and 60°: same range but different heights and flight times
- Investigate the optimal angle when the launch height is above ground level
- Plot sin(2α) versus α and compare with your range data