Ballistics with air resistance

FizziQ activity · High school · 30 min

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In the browser-based FizziQ Web ballistics simulation, students superimpose shots with and without drag to compare range, trajectory asymmetry and the role of mass.

Learning objectives

- Compare projectile trajectories with and without air resistance
- Observe the asymmetry of the trajectory in the presence of drag
- Understand why mass matters with air resistance but not without
- Find the optimal launch angle with air resistance and compare it to 45°
- Model the drag force as proportional to the square of velocity

Instruments and sensors

FizziQ Web Ballistics simulation

Materials

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

Protocol

1. Open the Ballistics simulation in FizziQ Web. Set the initial speed to 25 m/s and the angle to 45°.
2. Disable air resistance. Launch a shot (REC). Observe the trajectory and note the range in the experiment notebook.
3. Without changing the parameters, enable air resistance. Launch a new shot. The second trajectory is superimposed on the first for comparison.
4. Compare the two trajectories: what is the range difference? Is the trajectory with air symmetric like the one without?
5. With air resistance enabled, perform a series of shots at different angles (30°, 35°, 40°, 45°, 50°). For which angle is the range maximum?
6. Return to 45° angle. Perform a shot with a low mass, then another with a high mass (if the parameter is available). Compare the ranges.
7. Disable air resistance and repeat the mass comparison. Does the range change this time?
8. Record your results in a table: for each condition (with/without air, low/high mass), note the angle, range, and maximum height.
9. Sketch the trajectories with and without air for the same angle and describe the differences: shape, range, maximum height, symmetry.
10. Write a conclusion about the effect of air resistance: why is it sometimes a good approximation to neglect it, and when is it not?

Expected results

Without air, the trajectory is a symmetric parabola and the range at 45° is $R = v_0^2/g \approx 63.8$ m for $v_0 = 25$ m/s. With air resistance, the range decreases significantly (30 to 50 m depending on parameters). The trajectory is no longer symmetric: the descending phase is steeper than the ascending phase. The optimal angle drops below 45° (typically 35-40°). Mass matters with air: a heavier projectile travels farther because the drag-toweight ratio is smaller. Without air, mass has no effect on the trajectory.

Questions

- Why does mass not affect the trajectory without air but does affect it with air?
- How can you explain that the descending phase is steeper than the ascending phase in the presence of air?
- Why does the optimal angle decrease below 45° with air resistance?
- Is the drag force stronger during ascent or during descent? Why?
- In which real-life situations is it justified to neglect air resistance?
- How would the trajectory change if the drag force were proportional to v instead of v^2?

Going further

- Fix the angle and mass, then vary the initial speed to observe that air effects become more significant at high speed
- Compare the ranges with and without air for the same angle and plot the ratio as a function of angle
- Investigate the effect of the drag coefficient by changing it while keeping other parameters fixed
- Compare the trajectories of a tennis ball and a cannonball launched with the same speed and angle
- Find the angle that maximizes range with air resistance for several different speeds