Elastic collision: billiards

FizziQ activity · High school · 40 min

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A video study of a billiard ball collision: with FizziQ's Kinematics module on a smartphone, high school students measure velocities and test energy conservation.

Learning objectives

- Analyze a billiard ball collision using video-based kinematic tracking in FizziQ
- Measure the velocities of both balls before and after the collision
- Calculate the total kinetic energy before and after impact
- Determine the coefficient of restitution and characterize the elasticity of the collision
- Identify and quantify the factors responsible for energy dissipation

Instruments and sensors

Video (kinematics) analysis module · Camera

Materials

- Smartphone with the FizziQ application (Kinematics/video analysis module)
- Billiard ball collision video (from the FizziQ video library, or a personal recording)
- FizziQ experiment notebook for graphs and calculations
- Note: the protocol remains adaptable to any comparable video analysis tool.

Protocol

1. Open FizziQ and navigate to the Kinematics module. Load the billiard ball collision video from the FizziQ library, or import your own video.
2. Establish a scale using a known dimension in the video (e.g., the diameter of a billiard ball: 5.25 cm, or the width of a table pocket).
3. Set the coordinate origin and orient the x-axis along the initial direction of motion of the moving ball.
4. Begin tracking Ball 1 (the striking ball) by clicking on its center in each frame. Track at least 5 frames before and 5 frames after the collision.
5. Repeat the tracking process for Ball 2 (the target ball), using the same frames.
6. After completing the tracking, examine the position vs. time graphs for both balls in the FizziQ notebook.
7. Determine the velocity of Ball 1 before the collision (v_1) from the slope of the position-time graph before impact.
8. Determine the velocity of Ball 1 after the collision (v_1') from the slope after impact. It may be zero or reversed.
9. Determine the velocity of Ball 2 after the collision (v_2') from the slope of its position-time graph after impact. Note that Ball 2 was initially stationary ($v_2 = 0$).
10. Calculate the kinetic energies: $Ec = ½mv^2$ for each ball before and after the collision. Since billiard balls have equal masses, you can work with v^2 directly.
11. Compare the total kinetic energy before ($½mv_1^2$) and after ($½mv_1'^2 + ½mv_2'^2$) the collision. Calculate the percentage of energy lost.
12. Calculate the coefficient of restitution: $e = (v_2' - v_1') / (v_1 - v_2)$. For a perfectly elastic collision, $e = 1$.

Expected results

For a well-executed head-on collision between billiard balls, the striking ball should nearly stop ($v_1' \approx 0$) while the target ball moves away at approximately the initial speed of the striker ($v_2' \approx v_1$). The coefficient of restitution should be between 0.92 and 0.98. The total kinetic energy after the collision should be 85-96% of the initial kinetic energy, with losses due to sound generation (the characteristic click of a billiard collision), slight ball deformation, friction with the felt, and rotational energy transfer. For oblique (non-head-on) collisions, the analysis is more complex as both balls will have velocity components in two dimensions, but the total kinetic energy should still be approximately conserved. Pointing errors will introduce uncertainty of approximately ±5-10% in the velocity measurements.

Questions

- What physical factors explain the small percentage of energy lost during the collision?
- How would the result differ if the collision were perfectly head-on versus slightly off-center?
- Is momentum conserved in this collision? How could you verify this from your data?
- What role does the spin of the balls play in the collision outcome?
- How would the results change if you used balls of different masses (e.g., a snooker ball and a pool ball)?
- Why are billiard ball collisions considered nearly elastic while a car crash is highly inelastic?

Going further

- Compare head-on and oblique collisions to observe how the scattering angles relate to energy conservation
- Analyze a collision involving three balls (a double impact) and assess energy conservation for the system
- Record your own collision video at different speeds and investigate whether the coefficient of restitution depends on impact velocity
- Track both x and y components of velocity for oblique collisions and verify 2D momentum conservation
- Compare the collision of billiard balls with that of softer objects (e.g., tennis balls or marbles) to illustrate the concept of coefficient of restitution