Coefficient of restitution

FizziQ activity · High school · 25 min

Scan to open in FizziQ

By recording bounce sounds with the smartphone microphone in FizziQ, students time the intervals between impacts and calculate a ball's coefficient of restitution.

Learning objectives

- Measure the time intervals between ball bounces using the microphone
- Calculate the rebound height from the time intervals using free-fall equations
- Determine the coefficient of restitution from the ratio of successive heights
- Verify that the coefficient of restitution remains approximately constant
- Compare different ball materials and their energy dissipation properties

Instruments and sensors

Sound level meter · Microphone

Materials

- Smartphone or tablet with FizziQ
- Small dense ball (steel ball, squash ball, bouncing ball)
- Hard flat surface (tile, concrete, table)
- Note: the protocol remains adaptable to any comparable sound acquisition tool.

Protocol

1. Open FizziQ and select the Sound Level (amplitude) instrument. Place the smartphone flat on a hard surface.
2. Prepare a small dense ball (steel ball, squash ball, bouncing ball). Balls that produce a sharp impact sound work best.
3. Start the sound recording in FizziQ.
4. Drop the ball from a known height (for example 50 cm) right next to the smartphone microphone, without throwing it — just let it fall.
5. Let the ball bounce freely until it stops (typically 5 to 8 audible bounces).
6. Stop the recording and observe the sound level graph as a function of time.
7. Identify the peaks corresponding to each impact. Note the times t_1, t_2, t_3... of each bounce.
8. Calculate the intervals $\Delta t_\square = t_{\square+1} - t_\square$ between two successive bounces. The maximum height between two bounces is: $h_\square = g \times (\Delta t_\square/2)^2 / 2$.
9. Calculate the energy ratio conserved after each bounce: $E_{\square+1}/E_\square = h_{\square+1}/h_\square = (\Delta t_{\square+1}/\Delta t_\square)^2$. This ratio is the square of the coefficient of restitution e.
10. Verify that the coefficient of restitution remains approximately constant from one bounce to the next. Compare it for different ball types.

Expected results

The sound graph shows intensity peaks that become increasingly close together, corresponding to successive bounces. The intervals between bounces form a geometric sequence with ratio e (the coefficient of restitution). Typical values: steel ball e ≈ 0.90-0.95, rubber ball e ≈ 0.80-0.85, tennis ball e ≈ 0.70-0.75. The coefficient remains approximately constant across bounces (within ±5%).

Questions

- Why do the intervals between bounces form a geometric sequence?
- What happens if you drop the ball from a greater height: does the coefficient of restitution change?
- Why does a squash ball bounce less than a tennis ball?
- What fraction of kinetic energy is lost at each bounce for a ball with $e = 0.85$?
- Why does the ball eventually stop even though each bounce conserves a fixed fraction of energy?
- How could you determine the drop height from only the sound recording?

Going further

- Compare the coefficient of restitution of different balls (steel, rubber, tennis, squash, golf, ping-pong)
- Study the influence of the surface (tile, wood, carpet, rubber mat) on the coefficient of restitution
- Drop the ball from different heights and check whether the coefficient changes
- Record in slow motion to distinguish the double bounce that sometimes occurs
- Calculate the total distance traveled by the ball across all bounces