

Ball Sports: Bouncing

Turn off all electronic devices

Observations about Bouncing Balls

- Some balls bounce better than others
- Dropped balls don't rebound to their full height
- Balls bounce differently from different surfaces
- Balls bounce differently from moving objects

4 Questions about Bouncing Balls

1. Why doesn't a ball rebound to its original height?
2. Why does the floor's surface affect the bounce?
3. How does a moving bat drive a ball forward?
4. What happens to the bat when a ball hits it?

Question 1

Q: Why doesn't a ball rebound to its original height?
 A: It wastes some of its energy during the bounce

While slowing as it hits a rigid floor, a ball's

- ◊ kinetic energy decreases by the collision energy
- ◊ elastic potential energy increases as it dents

While rebounding from the floor, the ball's

- ◊ elastic potential energy decreases as it undents
- ◊ kinetic energy increases by the rebound energy

Not all of the collision energy becomes rebound energy

- ◊ The "missing energy" has become thermal energy

Measuring a Ball's Liveliness

Two common measures of a ball's liveliness:

$$\text{coefficient of restitution} = \frac{\text{rebound speed}}{\text{collision speed}}$$

$$\text{energy ratio} = \frac{\text{rebound energy}}{\text{collision energy}}$$

Since kinetic energy is proportional to speed²,

$$\text{energy ratio} = \text{coefficient of restitution}^2$$

Question 2

Q: Why does the floor's surface affect the bounce?
 A: If the floor dents, it also receives collision energy

The denting floor stores and returns energy

- ◊ Floor also has an energy ratio that affects the bounce

The impact forces on the ball and floor are equal but opposite,

- ◊ so the work done on each is proportional to its dent
- ◊ The fraction of collision energy each receives is proportional to its dent

A soft, lively floor can help the ball bounce!

Question 3

Q: How does a moving bat drive a ball forward?

A: Ball bounces off bat, in bat's frame of reference

When bat and ball are moving toward one another

- ◊ The collision speed becomes their speed of approach
- ◊ The rebound speed becomes their speed of separation

The bat has an inertial frame of reference

- ◊ The perspective in which bat's center of mass is motionless
- ◊ and in which the moving ball simply bounces off the motionless bat

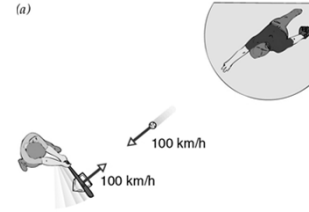
Ball and Bat (Part 1)

Ball heads toward home plate at 100 km/h

Bat heads toward pitcher at 100 km/h

Collision speed is 200 km/h

(a)



Ball and Bat (Part 2)

Collision speed is 200 km/h

Baseball's coefficient of restitution: 0.55

Rebound speed is 110 km/h

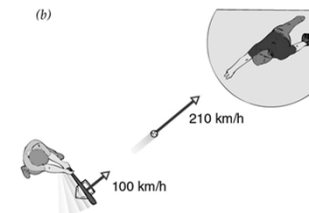
Ball and Bat (Part 3)

Rebound speed is 110 km/h

Bat heads toward pitcher at 100 km/h

Ball heads toward pitcher at 210 km/h

(b)



Question 4

Q: What happens to the bat when a ball hits it?

A: It accelerates, angular accelerates, and vibrates

The ball's impact force on the bat

- ◊ transfers both momentum and angular momentum to the bat
- ◊ can deform the bat, doing work on it and causing it to vibrate
- ◊ increases with the stiffnesses of the bat and the ball
- ◊ lasts longer when the bat and ball are livelier

Summary about Bouncing Balls

Each ball has a coefficient of restitution

Energy lost in a bounce becomes thermal

The bouncing surface can affect a ball's bounce

Surfaces bounce, too