

## The Bat-Ball Collision

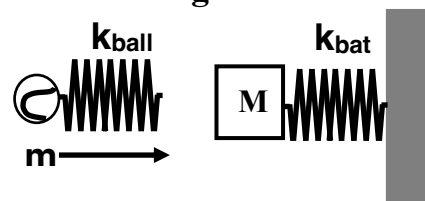
Throw a baseball against a wall and it bounces back with less energy. The post-bounce energy is about 25% of the pre-bounce energy. The collision is said to be **partially elastic**. The ball's kinetic energy (KE) is transformed into other forms of energy. For any collision, the **coefficient of restitution** (COR) is the ratio of the post-collision to pre-collision speed of the ball. **Figure 1** shows the formula relating KE to the speed ( $v$ ) and the mass ( $m$ ) of an object. The COR is about 0.5 for a collision in which approximately 25% of the KE is maintained by the colliding object. A higher COR would be consistent with a larger post-collision speed.

**Figure 1**  
 $KE = \frac{1}{2} \cdot m \cdot v^2$

A bat-baseball collision is slightly more elastic than a ball-wall collision. The greater elasticity is due to the flexibility of the bat - an effect known as the *trampoline effect*. A simplistic model of the collision represents the ball and bat as compressible springs that are colliding with each other as shown in **Figure 2**.

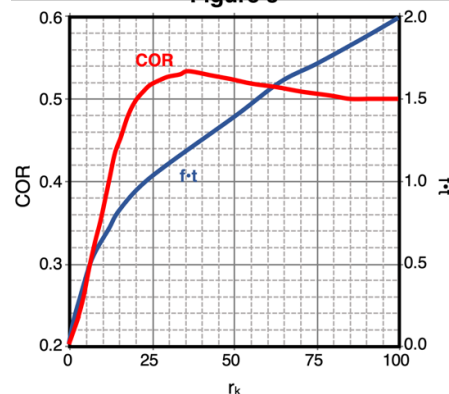
Compressible objects are described by a **spring constant** ( $k$ ). Easily compressed springs have low  $k$  values and act like *springy* trampolines. A rigid, difficult-to-compress spring has a larger  $k$  values. When modeling a bat-ball collision,  $k_{bat}$  and  $k_{ball}$  are used as the spring constants of the bat and the ball.

**Figure 2**



Computer modeling of a bat-ball collision indicates that the ratio of the spring constants ( $r_k = k_{bat}/k_{ball}$ ) has a major effect on the COR of the collision. **Figure 3** shows the COR as a function of the spring constant ratio. Another variable of importance to an effective ball-bat collision is the product  $f \cdot t$ . This product varies with the ratio of spring constants as shown in **Figure 3**. The  $f$  is the frequency with which the bat naturally vibrates and  $t$  is the collision time for the collision. A larger  $f \cdot t$  value indicates that more of the bat's vibration is transferred back to the ball to enhance the *trampoline effect*.

**Figure 3**



The ball-bat collision lasts for less than a millisecond (ms). During this time, a portion of the original KE of the ball is transformed into other forms of energy; see **Figure 4**. Some energy is transformed back into KE once the collision is over. But the majority of the energy exists as internal energy in the ball (PE-ball) and in the bat (PE-bat). This energy is the energy associated with the vibrations of the molecules of the bat and the ball. Like springs, these molecules continue to vibrate long after the contact between the bat and ball have ceased.

**Figure 4**

