

# Elastic and Inelastic Collisions

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We now know that **momentum** is conserved in collisions.

- This will hold true as long as the objects are an **isolated system**.

**Isolated:** No matter or energy is allowed to enter or leave the system.

**Closed:** No matter is allowed to enter or leave the system. Energy can enter or leave.

**Open:** Energy and matter can enter or leave.

If we are dealing with a collision involving really small objects (like atoms or molecules, things that are **microscopic**) you'll often find that **kinetic energy** is also conserved.

- The total kinetic energy of all particles before the collision equals the total kinetic energy of all particles after the collision.
- This is a special case of conservation of energy. Notice that rather than just saying “energy is conserved” (which would imply that we need to take into account all kinds of energy), we have to focus on only **kinetic energy**.
- These types of collisions are **elastic collisions**; they are quite rare, and as already pointed out usually only happen at an atomic level.

In “regular” collisions involving “regular” sized objects (like people, watermelons, and asteroids, things that are **macroscopic**), kinetic energy is **not** conserved.

- In these cases you'd probably measure that the kinetic energy after the collision is less than the kinetic energy before. These are **inelastic collisions**.
- The energy might have been “lost” in one of several ways...
  1. Friction between the objects could cause some of it to be converted to **heat** (thermal energy).
  2. If the **object was permanently changed** (broken, bent, snapped, twisted, etc.) from its original shape.
  3. Some energy might have been converted into the energy of a **sound** or **light** that was released.

Energy would have to be used to do any of these.

- If the change is very small (like two pool balls bouncing off of each other) than the “lost” energy is very small.
- If the change is big (a rock shatters when hit by a bullet) the energy “lost” is great.

Make sure that you keep these two types of collisions straight, based on whether or not kinetic energy is conserved.

**Elastic collisions** – [Rare, usually microscopic] Total kinetic energy before the collision equals total kinetic energy after. You can use conservation of momentum with conservation of kinetic energy.

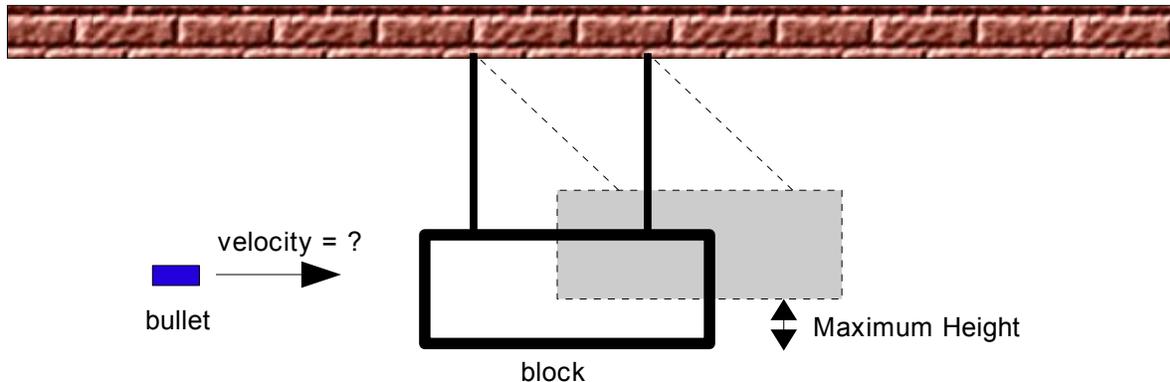
**Inelastic collisions** - [More common, usually macroscopic] The kinetic energy changes. If the objects stick together after the collision, we say that the collision is completely inelastic. Conservation of momentum still works in these collisions

If we know that a collision is elastic, we can use momentum and energy together to solve it, as the following example shows. This example is intended just to show you how you could do it, and why we

need to use conservation of energy in one part, and conservation of momentum in another.

**Example 1:** One way to test the speed of a bullet shot from a gun is to use a device called a ballistic pendulum. Because it is based on well understood physics, it can give very accurate results even though the equipment is quite simple. A block of material such as wood is hung from supporting wires as shown below. When the bullet is shot at the pendulum, it hits and becomes embedded in the pendulum. Together, the pendulum and the bullet swing upwards. By measuring the maximum height that the pendulum and bullet swing to, the speed of the bullet just before impact can be calculated.

Figure 1: A ballistic pendulum



For this problem, a 0.0200 kg bullet collides with a 5.7500 kg pendulum. After the collision, the pair swings up to a maximum height of 0.386 m . **Determine** the velocity of the bullet just before impact.

First, we need to decide if this is an elastic or inelastic collision. Figuring that out from the start will give us an idea of how we need to go after it.

Since a bullet hitting something is a macroscopic event, it must be inelastic. That means that we will **not** be able to say that kinetic energy is conserved during the collision itself. We can still use regular conservation of energy though for the whole thing swinging like a pendulum. We will be able to use conservation of momentum for the collision of the pendulum and the bullet, since momentum always works.

### Part 1: Conservation of Energy

We can use the information about the whole pendulum-bullet swinging upwards like a pendulum to figure out some stuff that is happening *after* the collision. We know that the kinetic energy of pendulum-bullet just after the collision is turned into gravitational potential energy as it swings upwards, so...

$$\begin{aligned} E_k &= E_p \\ \frac{1}{2} mv^2 &= mgh \\ \frac{1}{2} v^2 &= gh \\ v &= \sqrt{2gh} \\ v &= \sqrt{2(9.81)(0.386)} \\ v &= 2.75 \text{ m/s} \end{aligned}$$

This is the velocity of the pendulum-bullet just *after* the collision has happened.

## Part 2: Conservation of Momentum

Now we have enough information to calculate the conservation of momentum before and after the collision, which will allow us to calculate the velocity of the bullet just before it hit the pendulum.

$$\begin{aligned}p_{\text{total}} &= p_{\text{total}}' \\m_p v_p + m_b v_b &= m_p v_p' + m_b v_b' \\0 + m_b v_b &= v'(m_p + m_b) \\0.0200 v_b &= 2.75 (5.7500 + 0.0200) \\0.0200 v_b &= 2.75 (5.7700) \\0.0200 v_b &= 15.9 \\v_b &= 794 \text{ m/s}\end{aligned}$$

The bullet was traveling at 794 m/s just before it hit the pendulum.