CHAPTER OVERVIEW

14: C14) Collisions

14.1: Types of Collisions

14.2: Examples

14.E: Collisions (Exercises)

In this chapter we are going to drill down a bit more carefully on the topic of collisions. We've already studied collisions in some detail when we first introduced momentum transfer (Chapter 2) as well as "full" conservation of momentum (Chapter 5), but now we are going to make the process of collisions more realistic by looking at conditions under which both momentum and energy are conserved.

The very first thing we want to do is to clarify what we mean when we say things like "energy is not being conserved in this interaction". If we consider our entire Universe as the system, **energy and momentum are both conserved in every single interaction in that system**. So when we state that a particular interaction is "not conserving energy", we are basically admitting that we didn't pick the system "correctly". Sometimes we don't have the knowledge to do so, or sometimes it's actually simpler to consider a system that doesn't conserve energy, but we should be aware it's a problem with the choice of system, not about the interaction or phenomena itself. An immediate example of this is friction - we often say "energy is not conserved in systems that contain friction", but that's incorrect - the energy in friction is being converted from motion to heat, and we don't always keep track of that because it's often too difficult, particularly when our focus is on mechanics.

With that clarification, we can start to classify collisions depending on if they conserve energy or momentum - one, both, or neither. The first thing to say outright is that *momentum is conserved in all the collisions we are going to consider*. The reason is actually pretty simple - we've only studied two possible sources of momentum, either motion ($\vec{p} = m\vec{v}$) or impulse ($\Delta\vec{p} = \vec{F}\Delta t$). We can remove impulse by saying "we are only going to consider collisions in which there is no external forces acting on the system". So since we've gotten rid of impulse, there can only be momentum in the form of motion - we can't "hide" momentum anywhere except in all the mvs running around the system. Since momentum is only in the form of mvs, we can always track it, and thus insure that it is conserved.

The situation is different for energy (which is why we talked about it in the friction example). Energy comes in many different forms - kinetic (linear and rotational), potential (gravity, springs, and a myriad of other interactions we haven't talked about), and work ($W = \vec{F} \cdot \Delta\vec{r}$). If we are throwing out external forces (like we did above), we can throw out work, but energy can be stored in many other places. Thermal (heat) energy is typically the best example of something we can't track in mechanics, but the world of physics is full of other interactions that store energy without needing motion[1], and any of those interactions could be a source of the missing energy.

It turns out that the situation in the preceding paragraph is the most common situation - it's typically hard / impossible to track all the sources of energy in our systems, so all we have to go on is conservation of momentum; these kinds of collisions are called **inelastic**. However, there are some very special kinds of collisions in which we actually can track all the energy (in the form of motion, $K = \frac{1}{2}mv^2$), and so energy actually is conserved, and these are called **elastic** collisions. Examples of elastic collisions are bouncing superballs, collisions of billard balls, or collisions involving springs.

On one hand, you are going to have to memorize the names of these two collisions. On the other hand, we can get a good physical picture for each of them - for example, a car crash is a good example of an inelastic collision. There's "no bouncing", and energy is clearly being "lost" in the form of sound and mechanical deformation. On the other hand, if a cart runs into a spring and shoots backwards, it's "very bouncy", and not at all clear where lost energy could be stored - the kinetic energy went into the spring, and then back into the cart! So you need to keep these two kinds of collisions separate in your head, but it's also important to remember that **most collisions are inelastic, only very special collisions are elastic**.

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[1]In physics 2, you will study electromagnetism, and learn about energy storage in electric and magnetic fields. That covers a lot of interactions in the world, but there are still nuclear interactions (the strong and weak force) that can store energy and evade our considerations.