CHAPTER OVERVIEW

2: C2) Particles and Interactions

In this chapter we will study particles and interactions. We will make our first step into the abstraction of the real world by **replacing any objects we want to describe with points**. As we talked about in the last chapter, this is to make things not only 1) simpler, but more importantly 2) mathematical well-defined. The way this works with points is dead simple - take a real object, made up of many (essentially an infinite number of) points, and pick one of it's point to represent the entire thing. This is now well-defined because we can now talk about the position $\vec{r}$ of the object as being exactly the position of the point we chose. And it's far simpler, since we are only dealing with a single point instead of innumerably many.

So after we have a bunch of points, what then? Well, we want to understand the **interactions between the points** (remember, that was one of the ways we described what physics is - the study of these interactions). While we might be tempted to call these interactions "forces", in many cases the forces acting on a particular object are relatively complicated. So first, we are actually going to choose the simplist possible interaction between two objects we can consider - a collision. This is simply when one object comes into contact with another, changing the motion of both.

So what can happen in such a collision? Well, the position $\vec{r}$ and the velocity $\vec{v}$ of either object can change - and that's kind of it, since our objects are just points! The points might have masses, for sure, but for now we are going to assume these masses don't change. (Consider a two-car collision - for sure, some mass is moved back and forth if the collision is bad enough, but generally the two cars keep all their points within each other and don't exchange them.) But how does (for example) the velocity change when the objects interact? It turns out that the velocity is actually not the thing that tells us what happens when two objects collide, it's actually the product of the mass and the velocity, the momentum $\vec{p} = m\vec{v}$. It's pretty intuitive that both the mass and the velocity have to play a role here, since a heavy object hitting a light object is going to be different from two light objects hitting each other. This brings us to our first real principle of physics we are going to study:

Principle of Momentum

Objects interact by transferring momentum

Although this statement seems quite trivial, it actually allows us to perform our first calculations. Consider a collision between two points, each of mass 1 kg, and let's say one of the objects is at rest, while the other is moving towards the first at a speed of 10 m/s. That means the first object has a momentum of 10 kg m/s, while the second has zero (since it's not moving). After they collide, let's say the second object moved away at a speed of 2 m/s. That means it gained 2 kg m/s of momentum...and based on our principle of momentum transfer, the first object must have lost that same 2 kg m/s, leaving it with 8 kg m/s. But that also means we know how fast the object is moving after the collision - since it's mass is 1 kg, it's moving at 8 m/s! This simple example gives us all the essential concepts we are going to be studying not just for this chapter, but for the entire first half of the text.

A brief final note - we didn't really consider anything about the directions that the two objects moved in that example, because it was pretty clear they were moving in a straight line. However, some quantities in physics carry direction, like velocity $\vec{v}$ and position $\vec{r}$ - what about momentum? Well, we defined momentum with a particular formula, $m\vec{v}$. Velocity carries direction, but mass does not, so the momentum will be in the same direction as the velocity. This makes perfect sense with our momentum transfer principle above as well - an object with a particular momentum $\vec{p}$ in a particular direction will transfer that same momentum to the other object, in the same direction.

This chapter is dedicated to a conceptual understanding of this principle - not that there are no calculations, but we are going to be a little careless with things like vectors and directions. We first want to be sure we get some of the conceptual ideas surrounding momentum transfer, and in later chapters we will add in the mathematical formalism required to handle the directions - and all kinds of other interesting collisions!