# CHAPTER OVERVIEW

## 8: C8) Conservation of Energy- Kinetic and Gravitational



Starting in this chapter we are going to move away from our first basic principle of physics (conservation of momentum), and onto **conservation of energy**. As another conservation law, the essentials are the same - there is a quantity in the system that is not changing, and by keeping track of that quantity, we can learn things about unknown aspects of the system. The things we are looking for will be similar (final speeds, for example), but since the quantity we are keeping track of is different (energy instead of momentum), the details will be different.

One major difference is that unlike momentum, *energy takes many different forms*. Momentum was only ever mass times velocity; even if you have a collection of points that could be more easily described by angular momentum, $\vec{L} = I\vec{\omega}$, that was just a convenience of adding up all the individual point's $m\vec{v}$. But energy can take several different forms, and most notably can be stored without motion - something momentum cannot do[1]. Here we will quickly outline two different forms that energy can take.

The first is kinetic energy, or energy of motion. This is the energy stored in a moving object, and all moving objects have it. The nice thing about kinetic energy is that there is a simple formula to describe it (kind of like for momentum!):

$$K = \frac{1}{2}mv^2. \tag{8.1}$$

Here $m$ is the mass of the object, and $v$ is the speed. Although this shares some of the same intuition as momentum ("more mass and speed, more energy"), it's important to recognize one difference - unlike momentum, *kinetic energy is a scalar and does not have direction*. So it doesn't matter what direction $\vec{v}$ is pointed in, what matters is the square of the magnitude, $|\vec{v}|^2$. Also similar to momentum, there is a rotational version of this as well that we will use when we encounter extended objects.

The second form of energy we want to immediately introduce is potential energy, or *energy of interaction*. This new concept describes how objects interact, and allows us to study interactions at a more fundamental level than momentum. Objects interact by storing and moving energy around to different parts of the system. For example, when you stretch a spring, you are transferring energy from your arms into the spring, which stays there until you let the spring return to it's original length. Every interaction has a different way of storing energy, although sometimes we may not know how to easily describe it (friction is an example of this).

Our first example of potential energy will be gravitational potential energy near the surface of the Earth. You already know about this - when you drop something it falls! The interaction of gravity allowed whoever lifted the object to store energy in the system, and you can release it by dropping it. In this case, the energy turns into the kind we discussed before, kinetic energy. The formula for gravitational potential energy near the Earth is

$$U_g = mgh, \tag{8.2}$$

where $m$ is the mass of the object, $g = 9.81\ \mathrm{m/s^2}$ is the acceleration due to gravity, and $h$ is the height above the reference point (often taken to be the ground).

We are going to spend a lot of time understanding these two kinds of energy, but let's start by considering the simple example of dropping an object we just mentioned. Assuming the object is not moving before you drop it, the initial energy is completely made up of $U_g$. As the object falls, it converts the energy from $U_g$ into $K$, increasing the speed $v$ while the height $h$ decreases. That allows us to construct the formula,

$$mgh = \frac{1}{2}mv^2 \rightarrow v = \sqrt{2gh}, \tag{8.3}$$

which tells us the speed of the object when it falls from a height $h$. That's already a new result for us, but we should also point out that the only thing that changes how fast the object is moving is how high it's dropped from; the mass doesn't matter, and also we have no knowledge of the direction of motion (ok, yes we know in this case it's "downwards", but generally energy cannot tell us that!). This is typical for equations in energy problems - they are often pretty simple, but we have to be careful to know exactly what they can and can't tell us.

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[1]We have to be a little careful here - momentum can be stored in certain fields, like the electromagnetic and gravitational fields. However, understanding how that works takes a greater knowledge of the fundamental interactions then we can give here!

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