8.4.2: Forms of Energy

Learning Objectives

- Describe some of the many forms of energy.
- Categorize forms of energy as kinetic or potential.

Earlier in this chapter we introduced the concept of kinetic and potential energy as ways of understanding particular types of mechanical energy. We also introduced the law of conservation of energy and stated that it applied to more than just the mechanical energy that we had considered so far. We will now explore some of these other types of energy and how they fit within the context of kinetic and potential energy.

Some of the Many Forms of Energy

Here are some of the many forms of energy. You probably have heard of some of these before; many of these will be covered in later chapters, but let us detail a few here. **Electrical energy** is a common form that is converted to many other forms and does work in a wide range of practical situations. Fuels, such as gasoline and food, carry **chemical energy** that can be transferred to a system through oxidation and other methods that can result in the kinetic energy of a moving car or the potential energy of climbing a mountain. Chemical fuel can also produce electrical energy, such as in batteries. Batteries can in turn produce light, which is a very pure form of energy. Most energy sources on Earth are in fact stored energy from the energy we receive from the Sun. We sometimes refer to this as **radiant energy**, or electromagnetic radiation, which includes visible light, infrared, and ultraviolet radiation. **Nuclear energy** comes from processes that convert measurable amounts of mass into energy. Nuclear energy is transformed into the energy of sunlight, into electrical energy in power plants, and into the energy of the heat transfer and blast in nuclear bombs. Atoms and molecules inside all objects are in random motion. This internal mechanical energy from the random motions is called **thermal energy**, because it is related to the temperature of the object. These and all other forms of energy can be converted into one another and can do work.

Transformation of Energy

As you have probably gathered from reading about these different forms of energy, the transformation of energy from one form into others is happening all the time. The chemical energy in food is converted into thermal energy through metabolism; light energy (a form of radiant energy) is converted into chemical energy through photosynthesis. In a larger example, the chemical energy contained in coal is converted into thermal energy as it burns to turn water into steam in a boiler. This thermal energy in the steam in turn is converted to mechanical energy as it spins a turbine, which is connected to a generator to produce electrical energy. That electrical energy moves through wires to homes and businesses where it is used to perform a variety of tasks which all require energy. (In all of these examples, not all of the initial energy is converted into the forms mentioned. This important point is discussed later in this text.)

Another example of energy conversion occurs in a solar cell. Sunlight impinging on a solar cell (see Figure $8.4.2.2$) produces electricity, which in turn can be used to run an electric motor. Energy is converted from the primary source of solar energy into electrical energy and then into mechanical energy.

Figure $8.4.2.2$: Solar energy is converted into electrical energy by solar cells, which is used to run a motor in this solar-power aircraft. (credit: NASA)

Categorizing Energy

As you read through the different forms of energy, were there aspects of it that seemed similar to the ways we have previously discussed energy in this text? There were some forms of energy that seemed to fit the pattern of storage, while others seemed to fit the pattern of movement. These are also the patterns we saw when analyzing mechanical energy in more detail earlier in the chapter. We referred to energy as either being kinetic if it was moving or potential if it was stored. We can do the same for these other forms of energy we are now introducing. We will not be able to get into many of the details on these other forms of energy just yet, but we can hopefully see these trends.

Potential Energy: the energy of position and storage

In our introduction to potential energy we looked at springs and gravity as places where energy was stored. We can very clearly see the ways in which the energy stored in these situations might be converted into mechanical energy. Now we will examine some of the other forms of energy mentioned and how some of them might fit into the category of stored energy.

One way of understanding potential energy is to think of it as the position of an object somewhere within a field of force. We had earlier established that the force of gravity varies based on the distance between objects. As an object moves to different positions within a force field the energy stored will change. Likewise, we can think of the force fields associated with **electromagnetism.** As objects move to different locations within these fields they will consequently store different amounts of energy. It turns out that this property of electromagnetism is very important to our ability in the modern world to have energy available to us on demand by the literal flip of a switch. This is a concept we will explore in greater detail later in this text.

If you read through the portions of this section on the forms of energy and transformation of energy, you will see **chemical energy** described as "being transferred," "producing," or "converted into." This language suggests that this chemical energy is stored in a way similar to the ways the potential energy in springs is stored. We will discuss chemical bonding in greater detail later in this text, but for now we can understand chemical bonds as a location between atoms where energy is stored. When chemical bonds are broken the energy stored in those bonds is released in some form. New bonds might form that store energy in a different way and by a different amount than the ways in which that energy was stored previously. We might imagine an elaborate contraption of springs that is rearranged from an initial situation where some of those springs are storing energy to a final situation where different springs are storing energy. This is actually very similar to how some chemists understand the changes that occur during a chemical reaction. The difference is that we can't see those changes going on at the molecular level the way we can see changes in springs at the macrosopic level.

You may have also noticed a mention of converting mass itself into energy. How is that possible if both mass and energy are conserved? It turns out that mass itself is a form of potential energy. This is far from intuitive and was described by Einstein in one of the most famous equations in science: $E=mc^2$. We will exploring this equation in more detail when we consider the atomic nucleus later in this text.

Kinetic Energy: the energy of movement

Just as we read through our forms of energy looking for examples of position or storage as clues for types of potential energy, we can also read through our forms of energy for examples of movement for types of kinetic energy. Although we did not include an example of it in the list above, we have previously looked at waves in this text. Waves, of course, involve movement. So any energy transferred through a wave would be a form of kinetic energy and might be referred to as **wave energy**.

When we discussed energy coming to Earth from the Sun in the form of **radiant energy**, we can clearly see that movement is involved. Radiant energy does not have to come from the Sun, in fact radiant energy comes from everything. But it is always a form of energy that is only possible when there is movement. We will learn more about radiant energy in this text when we explore the concept of heat, and even more when we discuss electromagnetic radiation. We will also learn that **nuclear energy** is a very specific type of radiant energy.

We described **thermal energy** as a form of random motion. As such, it could be classified as a form of kinetic energy. Thermal energy is the random movement of the atoms that make up a substance. As we will see later in this text, there is a connection between thermal energy and what we measure as temperature. Thermal energy is also where much of the energy ends up that is "lost" to friction when we try to do work. It is often the missing piece when conservative forces are added together and it might appear that energy into and out of a process do not add up. But the energy is still there. In fact, that energy is still capable of doing some amount of work. We shall explore this idea in more detail later in this text.

When we discussed "electrical energy moving through wires" you might have recognized that it is also a form of kinetic energy. However, we had earlier discussed electromagnetic energy as being a form of potential energy. Is there a conflict here? Just as we can have mechanical energy exist as kinetic energy or potential energy, we can also have both kinetic and potential energy related to elecotromagnetism. The movement of an electrical charge through a wire demonstrates how **electrical energy** is a form of kinetic energy.

Section Summary

- Commonly encountered forms of energy include electric energy, chemical energy, radiant energy, nuclear energy, and thermal energy.
- Potential energy involves storage of energy, sometimes due to position.
- Kinetic energy involves movement, sometimes of matter.

Glossary

Kinetic energy
: energy due to movement

potential energy
: energy due to position, shape, or configuration

electrical energy
: the energy carried by a flow of charge

chemical energy
: the energy in a substance stored in the bonds between atoms and molecules that can be released in a chemical reaction

radiant energy
: the energy carried by electromagnetic waves

nuclear energy
: energy released by changes within atomic nuclei, such as the fusion of two light nuclei or the fission of a heavy nucleus

thermal energy
: the energy within an object due to the random motion of its atoms and molecules that accounts for the object's temperature

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