Chapter 1

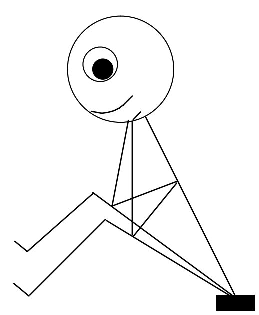
THE FIRST LAW

If you were asked to prove that two and two made four, you might find some difficulty, and yet you are quite sure of the fact.

Sherlock Holmes

– Sir Arthur Conan Doyle (*A Study in Scarlet*)

Thermodynamics is a subject that gives us the foundation needed to deal with energy. One of the fundamental laws in thermodynamics is the first law of thermodynamics, which states energy is conserved. Introducing the first law to absolute beginners is the objective of this chapter.



Conservation of Energy

Conservation of energy means energy cannot be created or destroyed, but energy can change from one form of energy to another. The first law of thermodynamics is simply the principle of conservation of energy. An object falling from a tall building gains speed as it comes down, which could be explained by the principle of conservation of energy as follows. A falling object losses its potential energy, and the loss in potential energy gets converted into a gain in kinetic energy. The gain in kinetic energy accounts for the increase in the speed of the object falling through a height.

Similarly, water falling through a height as in a waterfall attains high speed. The high speed water, when directed to the blades of a turbine (as shown in the simplified diagram of Figure 1.1), sets the turbine blades in motion, which in turn set the turbine shaft supporting the blades in rotary motion. The rotating shaft can be used to do useful work. The potential energy lost by water as it falls through a height is therefore converted into useful work. We, of course, know that not all the potential energy lost gets converted into useful work. A part of the potential energy lost, for example, gets converted into work needed to overcome friction.

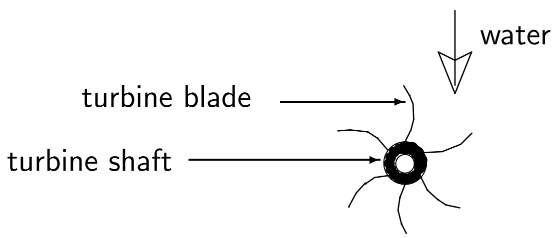


Figure 1.1 A simplified diagram showing how a turbine shaft is set in motion.

Electricity can be generated in an electric generator in which a coil is spun between the north and south poles of a magnet or an electromagnet. To spin the coil, we require the rotation of a shaft, which can be provided by water falling through a height as discussed above. This is the basic principle behind hydroelectric power generation. Part of the potential energy lost by water as it falls through a height is thus converted into electrical energy in hydroelectric power generation.

Conversion of heat energy into electrical energy can be achieved using a steam turbine, the basic working principle of which is shown in Figure 1.2. Water from a water source, such as a river, is pumped into a boiler operating at a high pressure. The water in the boiler is heated by burning a fuel, such as furnace oil, in the furnace of the boiler. Steam at high pressure, generated in the boiler-furnace arrangement, is further heated in a superheater and directed to strike the turbine blades so as to set them is motion. The turbine blades are attached to a turbine shaft such that the moving blades set the shaft in rotary motion. The rotating shaft spins a coil between the poles of an electromagnet and thereby electricity is produced. Part of the heat energy released by the fuel burning in the furnace is thus converted into electrical energy, which is yet another example of conversion of energy from one form to another.

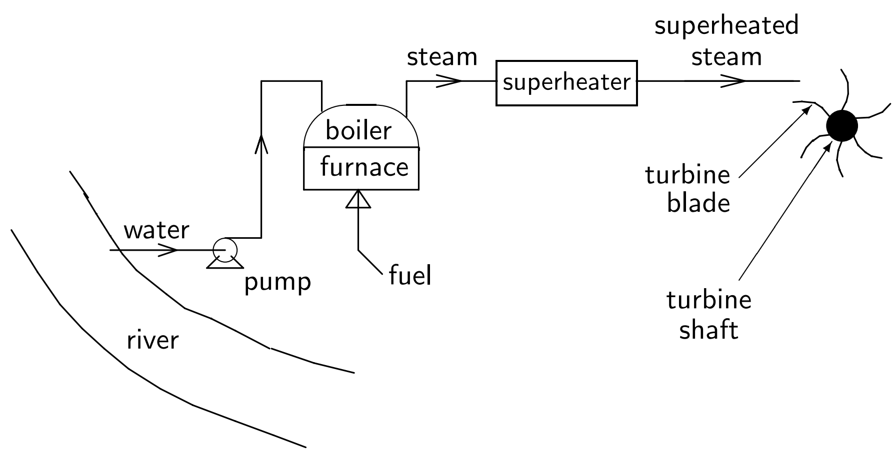


Figure 1.2 Basic working principle of a steam turbine.

What is Energy?

We spoke of potential energy, kinetic energy and electrical energy, and we are very familiar with all these forms of energy. However, if we are asked to define energy in a clear and simple way, we find it difficult to do so. For example, we can write an equation to calculate potential energy, but we cannot describe in simple words what potential energy is. We can write an equation to calculate kinetic energy, but we cannot describe what kinetic energy is. It is the same with all other forms of energy as well. Even though, it is difficult to define energy in a simple way, one could look at energy as some entity which possesses the capacity to do work.

Why is Energy Conserved?

Nobody really knows the answer to the question why energy is conserved. Yet, we believe in conservation of energy because our experience has shown us that energy is always conserved. That is, energy can be neither created nor destroyed, but energy changes from one form to another. Conservation of energy is therefore taken as a fundamental law, and is named as the First Law of Thermodynamics.

What is a Fundamental Law?

A law that is in use because nobody has disproved it, is known as a fundamental law. The first law of thermodynamics has never been proved. Even though the first law has never been proved, we use it because nobody has disproved it either. The first law of thermodynamics is therefore a fundamental law. We will believe in the first law of thermodynamics and continue to use it until someday, someone finds out that the first law of thermodynamics fails to describe some particular event.

`Student:` Teacher, you said that we can't prove the first law of thermodynamics, and that we shall have to believe in it. Do you really mean that I should simply believe that the first law of thermodynamics is true?

`Teacher:` Yes, if you want to continue with learning thermodynamics, you should take the first law of thermodynamics to be a true statement about how the nature works, until the day someone disproves it.

`Student:` Please, permit me to ask another question. I am familiar with the principle of conservation of mass, which states that mass cannot be created or destroyed. Can the principle of conservation of mass be proved?

`Teacher:` No, the principle of conservation of mass cannot be proved. There is also the principle of conservation of momentum which cannot be proved either. They are all fundamental laws.

`Student:` I have one more question, Teacher. We talk of mass, momentum and energy as though they are distinctly different things like mangoes, bananas and grapes. I have read something about the Einstein's theory of relativity which says, I believe, that mass can be converted into energy. If Einstein had it right then how could we treat mass and energy as two separate things?

`Teacher:` It is perfectly alright for a beginner in thermodynamics to treat mass and energy as two distinctly different things, and to use the principle of conservation of mass and the principle of conservation of energy as two separate principles. When we get interested in learning more about the sun, the stars or the formidable nuclear reactors, in all of which mass is being converted into energy, then it would be the right time for us to find out how to apply the conservation principles to such systems. We may find the books listed below to be of great help to us in our quest then.

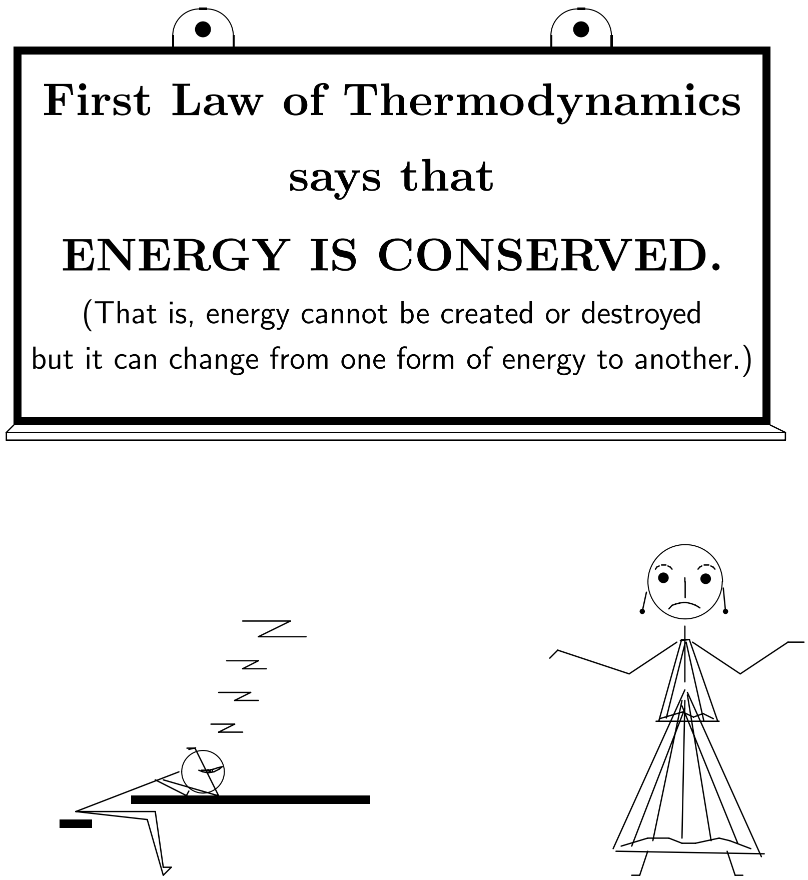
Born, Max 1951 *The Restless Universe*. Dover Publications, Inc., New York.

Feynman, R.P., Leighton, R.B. & Sands, M. 1997 *The Feynman Lectures on Physics*, Volumes 1, 2 & 3. Narosa Publishing House, New Delhi.

Venkataraman, G. 1994 *At the Speed of Light*. Universities Press (India) Limited.

Application of the First Law

This book will show you how to apply the first law, that is, the principle of conservation of energy, to thermodynamic systems as they go from one state to another executing a process, during which the properties of the system change. I am sure that you are familiar with the words such as system, state, process and properties, and you know what these words mean in everyday life. In thermodynamics, however, these words have very specific meanings as described in the next chapter. Getting familiar with thermodynamic terminology in the next chapter is essential to learn thermodynamics with ease.



"Nooooo..., I am not talking about this kind of energy conservation . . . ."