5.1: Steady-State Energy-Density Model

Most traditional physics textbooks discuss the flow of fluids and the flow of electric charge in electric circuits as completely separate topics. Our goal in this chapter is to understand both kinds of transport phenomena using the *Steady-State Energy Density Model*. Historically, different words and symbols have been used for the description of each of these phenomena, making their similarity even more difficult to see. We will generally use conventional notation and vocabulary, because this is the notation you will see and use in your other science courses and in research. While becoming comfortable with the specific notation and vocabulary of each of these different types of steady-state transport phenomena, you need to simultaneously become conscious of the more universal nature of the underlying model and approach. In this way, you can use your understanding in one area to help develop understanding in other less familiar areas.

The principle of conservation of energy applied to fluid phenomena is expressed in a relation historically known as *Bernoulli equation*. When dissipation effects and sources of energy input are included, the term *extended Bernoulli equation* is sometimes used. We will generally use the terms “energy-density equation” and “complete energy-density equation” for both fluid flow and electric circuit phenomena. Changes in the total energy-density of a small element of fluid include changes in its kinetic energy-density, its gravitational potential energy-density, and its pressure. The first two terms are familiar, except the energy is not divided by volume to yield energy density. The pressure term, however, is more challenging. The energy density represented by the pressure is related to whatever it is that confines the liquid and gives rise to the pressure. For the common occurrence of static incompressible fluids in open containers, the pressure is ultimately due to gravitational forces acting on the fluid.

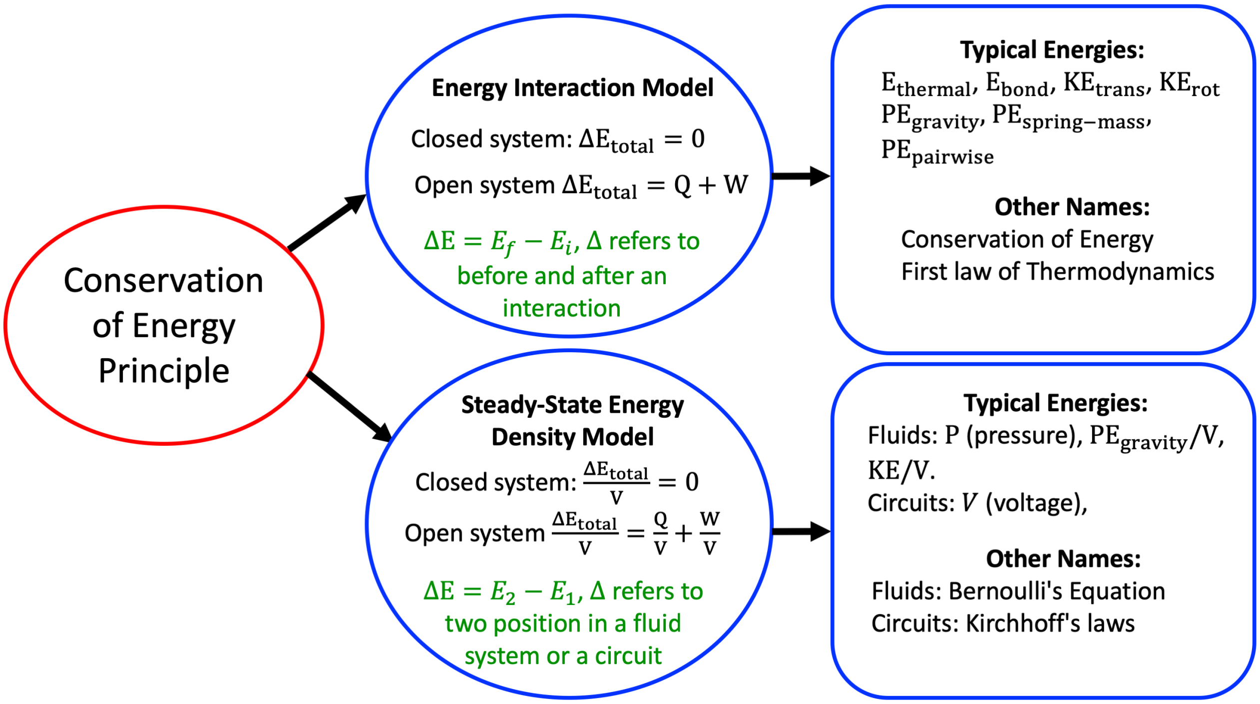
Relationships of exactly the same form and meaning as used to make sense of fluid phenomena are used to express energy conservation in electric circuits. Instead of pressure, the energy density is the voltage. This is the same voltage you are familiar with when installing 1.5 or 9 Volt batteries in your electronic gadgets. We will develop and use the *Steady-State Energy Density Model* in terms of both real fluid flow and electric circuits. Our goal is to make sense of both kinds of phenomena using a common model, and thus take advantage of the understanding we have in one domain to help us make sense of the other. Both static-fluid and flowing-fluid phenomena are very common, of course, in living organisms.

Differences in the Two Basic Energy Models

The most general and universal approach to getting answers to questions about phenomena in the physical world is to use conservation principles. The most universal of these principles is conservation of energy. However, to actually use this very general principle of conservation of energy, we need to cast it in a form that is useful for analyzing particular types of phenomena.

Here is a comparison of the energy-interaction model from Chapters 1 and 2 of 7A and the steady-state energy density model for fluids and electricity that we are developing in this chapter of 7B. Figure 5.1.1 shows both the similarities and differences in our two energy conservation models.

Figure 5.1.1: Two Energy Model Comparison



To use either of these models, we follow these basic steps in carrying out the approach:

1. Determine useful initial and final states (two useful positions) of the physical system based on the questions we are asking.
2. Identify the observable parameters (indicators) that significantly changes in time (or as we move from one position to another) for the two states (position) selected, and calculate the corresponding change in energy (or energy-density).
3. Write down an equation expressing conservation of energy (or energy density). One way to write this equation is as a sum of the changes in energy (or energy-density). If no energy is added or removed from outside systems, i.e., a closed system, the sum is set equal to zero. If there are outside sources of energy, i.e., an open system, then the sum is set equal to those energy sources.