

## 13.1: Introduction

The last two lectures this semester are about thermodynamics, an extremely important branch of physics that developed throughout the 19th century, motivated in part by the development of the steam engines that brought about the Industrial Revolution. Physics majors will study thermodynamics at much greater length in University Physics III and subsequent courses, whereas Engineering and Chemistry majors will encounter it also in specialized courses in their own disciplines.

There is really no escaping thermodynamics, but you may wonder why bring it up here (in this course, at this time) at all? The answer is twofold:

- From the point of view of the study of energy and its transformations, which has been one of the major themes of this course, thermodynamics provides us with the last missing pieces: it is here that we find out what thermal energy really is, and how it is different from other forms of energy (so much so, that we say that energy has been “dissipated” or “lost” when it becomes thermal energy). It is also here that we deal with the **other** way that energy can be transferred from a system to another (other, that is, than by doing work): this is the “direct transfer of thermal energy,” or what is normally called an *exchange of heat*.
- From the point of view of the study of motion, which has been also another running theme, thermodynamics also represents the next logical step beyond what we have learned so far. Recall that we started looking at the motion of extended objects as if they were simple point particles, moving as a whole along with their center of mass, and slowly introduced tools to deal with more complex kinds of motion: first rigid body rotations, then elastic deformations (waves) in which the constituent parts of an object move relative to each other in a way that looks “organized,” or synchronized, from a macroscopic perspective. What is needed next is to account for the random motion, on a microscopic scale, of the smallest parts (atoms or molecules) that make up an extended object. This motion is constantly happening, and it is a key ingredient of the concepts of thermal energy and temperature.

Conceptually, thermodynamics involves the introduction of two new physical quantities, *temperature* and *entropy*. Temperature will be introduced in this lecture, and entropy in the next one. It is interesting to note from the start, however, that these are very different from all the quantities we have introduced so far this semester, in a fundamental way. In classical physics, at least, there is no difficulty in extending all those other quantities to the study of the smallest parts making up an object: we can perfectly well talk about the position, velocity or energy of a molecule. But temperature and entropy are *statistical* quantities, which are only properly defined, from a fundamental point of view, for a large collection of (small) subsystems: it makes no sense to speak about the temperature or the entropy of a single molecule. This shows that there was really a profound change in perspective and methodology in classical physics when *statistical mechanics* (the part of physics that provides a microscopic foundation for thermodynamics) was developed.

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