4 Heat and the First Law of Thermodynamics

The total energy of the entire universe is conserved: it's value does not change with time. But the universe is too big. We are small, and interested in small things. Often there is one small thing we care about in particular, like an electric motor, or a bucket of water. We draw an imaginary box around this small thing, and call everything inside the box *the system*. The rest of the universe, outside of the box, is called *the environment*.

Within the system there is energy, E_{int}. It does not have to stay there – it can leave through the walls of the box as heat or work and enter into the environment. Or it can enter into the system by the same fashion. But that is it. **The only way the internal energy of a system can change is if energy is transferred between the system and the environment.** Often we say this energy transfer "passes through the walls" separating the system from its environment (the rest of the universe).

First Law of Thermodynamics:

$$\Delta E_{int} = Q - W \tag{4.1}$$

- Q is the energy transferred (as heat) from the environment to the system because of a temperature difference between them. A heat transfer that occurs entirely within the system boundary is not included in Q.
- W is the work done by the system by forces that act through the system boundary. Work done by forces that act entirely within the system boundary is not included in W.
- ΔE_{int} is the change in the internal energy of the system that occurs when energy is transferred into or out of the system as heat or work.

(Note we've chosen the sign convention that $Q > 0$ means energy entering *the system, while $W > 0$ means energy* leaving *the system.)*

4.a Heat capacity

"We can change the state of a body by transferring energy to or from it in the form of heat, or by doing work on the body. One property of a body that may change in such a process is its temperature T. The change in temperature ΔT that corresponds to the transfer of a particular quantity of heat energy Q *will depend on the circumstances under which the heat was transferred*."

In particular, we often have to decide which quantities are kept constant during the process. Then we define the heat capacity for that process as

$$C_X = \lim_{Q\to 0} \frac{Q}{\Delta T}\bigg|_{X \text{ constant}} = \frac{\mathrm{d}Q}{\mathrm{d}T}\bigg|_{X \text{ constant}} \tag{4.2}$$