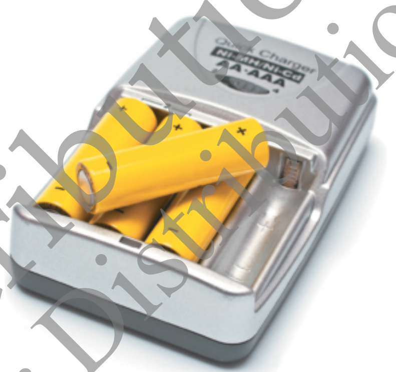
Pearson

18.1: Nature's Heat Tax: You Can't Win and You Can't Break Even

Energy transactions are like gambling—you walk into the casino with your pockets full of cash and (if you keep gambling long enough) you walk out empty-handed. In the long run, you lose money gambling because the casino takes a cut on each transaction. So it is with energy. Nature takes a cut—sometimes referred to as "nature's heat tax"—on every energy transaction so that, in the end, energy is dissipated (dispersed or scattered).

Recall from Section 9.3 that, according to the first law of thermodynamics, energy is conserved in chemical processes. When we burn gasoline to run a car, for example, the amount of energy produced by the chemical reaction does not vanish, nor does any new energy appear that was not present as potential energy (within the gasoline) before the combustion. Some of the energy from the combustion reaction goes toward driving the car forward (about 20%), and the rest is dissipated into the surroundings as heat (feel the hood of a car after a drive if you doubt this). The total energy given off by the combustion reaction exactly equals the sum of the amount of energy that goes to propel the car plus the amount dissipated as heat—energy is conserved. In other words, when it comes to energy, we can't win; we cannot create energy that was not there to begin with.



A rechargeable battery requires more energy to charge than the energy available for work during discharging because some energy is always lost to the surroundings during the charging/discharging cycle.

The picture becomes more interesting, however, when we consider the second law of thermodynamics. The second law—which we examine in more detail throughout this chapter—implies that not only can we not win in an energy transaction, *we cannot even break even*. For example, consider a rechargeable battery. Suppose that when we use the fully charged battery for some application, the energy from the battery does 100 kJ of work. Recharging the battery to its original state will *necessarily* (according to the second law of thermodynamics) require *more than* 100 kJ of energy. Energy is not destroyed during the cycle of discharging and recharging the battery, but some energy must be lost to the surroundings in order for the process to occur at all. Nature imposes a heat tax, an unavoidable cut of every energy transaction.

The implications of the second law for energy use are significant. First of all, according to the second law, we cannot create a perpetual motion machine (a machine that perpetually moves *without any energy input*). If the machine is to be in motion, it must pay the heat tax with each cycle of its motion—over time, it therefore runs down and stops moving.

Second, in most energy transactions, not only is the heat tax lost to the surroundings, but additional energy is also lost as heat because real-world processes do not achieve the theoretically possible maximum efficiency. Consequently, the most efficient use of energy generally occurs with the fewest transactions. For example, heating your home with natural gas is generally cheaper and more efficient than heating it with electricity. When you heat your home with natural gas, there is only one energy transaction—you burn the gas and the heat from the reaction warms the house. When you heat your home with electricity, several transactions occur. Most electricity is generated from the combustion of fossil fuels; the heat from the burning fuel boils water to create steam. The steam then turns a turbine on a generator to create electricity. The electricity travels from the power plant to your home, and some of the energy is lost as heat during the trip. Finally, the electricity runs the heater that generates heat. With each transaction, energy is lost to the surroundings, resulting in a less efficient use of energy than if you burn natural gas directly.