PHYSICS IN DAILY LIFE: HEATING PROBLEMS

* L.J.F. (Jo) Hermans * Leiden University, The Netherlands * Hermans@Physics.LeidenUniv.nl * DOI: 10.1051/epn/2009804

It's winter; our house is warm and cozy, but we need fresh air. In an earlier daily-life column (*Fresh air*, EPN 36/2) we noticed that if we instantly refresh our room with cold outside air while keeping the heating off, the temperature will return almost to its original value once thermal equilibrium has been re-established. The reason is that the heat capacity of the air is small compared to that of all the solid-state stuff in our room, certainly if we include part of the walls. In turn, this is because the number density of atoms in solids is roughly 1000 times the density in air at ambient temperature and pressure, while the contribution to the heat capacity of every single atom, whether in a solid, a liquid or a gas, is roughly the same: a few times the Boltzmann constant k.
Incidentally: just how instantaneous must the venting be in order for the argument to be valid? Obviously, the venting time has to be small compared to the thermal relaxation time of the room. But this is not simple to assess. For one thing: temperature equilibration of a room is not a single-relaxation time process, given the wide variety in thermal relaxation times RC of all the objects in the room (R is the thermal resistance and C the heat capacity). The relaxation time of an empty wine glass, for example, may be just half a minute; the value for a full bottle of wine is about three hours, and that for the walls and other large objects may be even longer. In any case, the values are large enough so that 'instantaneously' refreshing the air is easily achieved. Subsequently, convection in combination with the small heat capacity of the air will rapidly raise the air temperature almost to its original level. Old-fashioned as this procedure may be, from an energy-saving perspective it has an advantage over having a continuous draught of cold air through our room, since this would make the temperature gradient near our skin steeper and make us feel cold.

The process of warming up the air in our room offers an interesting physics problem. If we compare the two situations, cold air and warm air in our room, in which of the two cases will the total kinetic energy of the air molecules in our room be largest, if we ignore convection currents? The answer seems obvious: since the mean kinetic energy of a gas molecule is directly proportional to temperature (*viz., 3/2 kT*), the total kinetic energy should go up.
But there is a catch. While the temperature goes up, some of the air will escape, since the atmospheric pressure will not change, being dictated by the outside pressure. And lo and behold: if we may consider air as an ideal gas (which is a very good approximation at ambient conditions) the density is inversely proportional to the temperature at constant pressure. And since the volume of our room remains constant, the number of molecules in it also decreases inversely proportional to the temperature.
So, the answer may be somewhat surprising: if we heat our room, the total kinetic energy of the air in it remains exactly constant. ■

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