AIR CONDITIONERS

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Reference: Daniel V. Schroeder, *An Introduction to Thermal Physics*, (Addison-Wesley, 2000) - Problem 4.13.

An air conditioner is an example of a refrigerator in which the cold reservoir is the room to be cooled and the hot reservoir is the outside atmosphere. On a hot day, the rate at which heat leaks into an air conditioned room from the outside is roughly proportional to the temperature difference $T_h - T_c$ between the outside and inside. In that case, the work done to remove an amount Q_c of heat in time Δt is

$$W = Q_h - Q_c = Q_h - K(T_h - T_c) \tag{1}$$

where Q_h is the heat expelled to the outside and K is a constant.

In an ideal refrigerator (e.g. one working on a reversed Carnot cycle) the entropy gained in absorbing Q_c is equal to the entropy lost in expelling Q_h, so

$$\begin{aligned} \frac{Q_c}{T_c} &= \frac{Q_h}{T_h} &(2)\\ Q_h &= \frac{T_h}{T_c}Q_c &(3)\\ &= K\frac{T_h}{T_c}(T_h - T_c) &(4) \end{aligned}$$

The work required to maintain a temperature of T_c is therefore

$$\begin{aligned} W &= K\frac{T_h}{T_c}(T_h - T_c) - K(T_h - T_c) &(5)\\ &= \frac{K}{T_c}(T_h - T_c)^2 &(6) \end{aligned}$$

Thus lowering the inside temperature by a small amount can have a large effect on the work required to maintain this temperature, and thus on the cost of running the air conditioner. For example, suppose the outside temperature is 30° C = 303 K and the inside temperature is 22° C = 295 K. If we wish to lower the inside temperature by only one degree, the extra work required is

$$\frac{W_{294}}{W_{295}}=\frac{295}{294}\frac{9^2}{8^2}=1.27 \tag{7}$$

We need to use 27% more power to achieve a single degree more cooling. This is one reason why it is much more economical to bear with a slightly higher indoor temperature on a hot day.

PINGBACKS

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