© 1995-2023 by Isidoro Martínez

BAR BETWEEN THERMAL BLOCKS

Statement

Consider the steady heat transfer in a laterally isolated rod joining to thermal blocks at T_1 y T_2 with $T_2<T_1$. One wants to:

a) Deduce from $\Delta S_{univ}>0$ that heat must flow from T_1 to T_2.

b) Entropy change in every system.

c) Entropy generation in every system.

Considérese la transmisión de calor en régimen estacionario en una varilla de paredes aisladas y cuyos extremos están en contacto con sendas fuentes térmicas a T_1 y T_2 con $T_2<T_1$. Se pide:

a) Demostrar a partir de que $\Delta S_{univ}>0$ que el calor ha de fluir de T_1 a T_2.

b) Variación de entropía de la varilla y de las fuentes.

c) Generación de entropía en la varilla y en las fuentes.

Solution

The sketch may be:

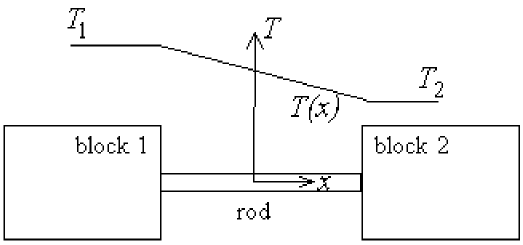

Fig. 1. Sketch.

The universe (i.e. all participating systems) is here comprised of the three bodies sketched. The entropy variation of the blocks in an infinitesimal heat-transfer process, assuming a small and slow energy exchange, will be $dS_1=dQ_1/T_1$ and $dS_2=dQ_2/T_2$, according to Eq. (2.11), whereas the entropy variation of the rod is zero because of the steady state. It should be stressed that the indication of 'steady state' in the statement can only refer to the rod, and not properly to the blocks.

a) Deduce from $\Delta S_{univ}>0$ that heat must flow from T_1 to T_2.
The global energy balance (First Thermodynamic Principle) forces $dQ_1+dQ_2=0$, and the global entropy increase (Second Thermodynamic Principle) forces $dS_{univ}=dS_1+dS_2>0$, and their combination, $dS_{univ}=dQ_1(1/T_1-1/T_2)=dQ_1(T_2-T_1)/(T_1T_2)>0$, shows that the sign of dQ_1 must be opposite to the sign of the difference T_1-T_2, i.e. energy must be lost by the hotter and gained by the colder, i.e. heat can only flow from hot to cold bodies.

b) Entropy change in every system.
$dS_1=dQ_1/T_1$, $dS_2=dQ_2/T_2$ and $dS_{rod}=0$. For the universe (the combined system) $dS_{univ}=dQ_1(1/T_1-1/T_2)$, always positive.

c) Entropy generation in every system.

Assuming ideal thermal blocks (uniform temperature), there is no generation of entropy there, so $dS_{gen1}=0$, $dS_{gen2}=0$ and $dS_{gen,rod}=dQ/T_{frontier}=dQ_1/T_1+dQ_2/T_2=dQ_1(1/T_1-1/T_2)=dS_{univ}$, always positive.

Note that when the connecting rod is assumed infinitesimally short, there is still a finite entropy generation there, i.e. in the limit of discontinuous temperature fields, physical properties must be ascribed to the geometrical entities.

Back