Realization of Maxwell's Hypothesis

An Experiment Against the Second Law of Thermodynamics

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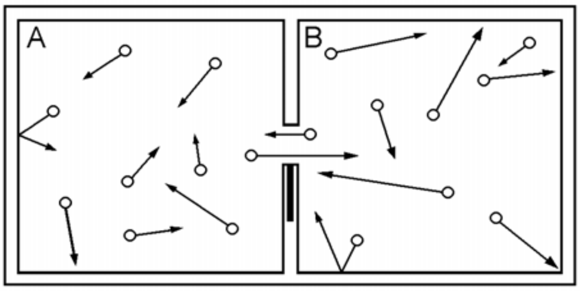
Abstract. This is an experiment report on a special energy conversion. Two similar and parallel Ag-O-Cs cathodes in a vacuum tube eject electrons at room temperature continuously. A static magnetic field applied to the tube plays the role of the famous "Maxwell's demon". The thermal electrons are so controlled by the magnetic field that they can fly only from one cathode to the other, resulting in a charge collection and an electric potential. A load, a resistance for example, is connected to the cathodes, getting an electric power from the tube continuously. Here, the air within the laboratory is a single heat reservoir and all of the heat extracted by the electronic tube from the reservoir is converted into electric energy, without producing any other effects. The authors believe that the experiment is in contradiction to Kelvin's statement of the second law of thermodynamics.

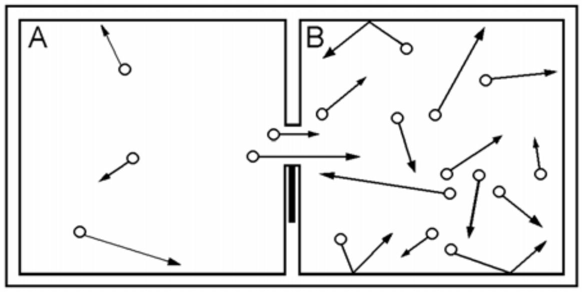
1. Introduction

In 1850 and 1851, Clausius and Kelvin established the famous second law of thermodynamics. According to this law, all actual energy conversion and transmission processes happened in the universe have a general direction-----from useful energy to useless one. Every such process is accompanied with increase in entropy, and is intrinsically "irreversible". Hence, for any piece of energy that the Nature grants us, we can poorly use it once only. Energy can only go forward in the direction that leads to its "degeneration", and finally, to its death (Clausius', "heat death").

Aiming at this law, the prominent British physicist James Clerk Maxwell put forward a hypothesis in 1871 [(1)], the so-called Maxwell's demon. The hypothesis starts with an initially equilibrium gas contained in a vessel, which is divided into two equal parts, portion A and portion B, as shown in Fig.1. The function of Maxwell's demon is to observe the motions of the individual molecules of the gas and open and close a small door in the division between A and B at proper times so as to interfere with the random thermal motion of the molecules. The demon can work in either of two different modes. In the first mode, as shown in Fig. 1(a), it lets only swifter molecules pass the door from A to B, and slower ones pass from B to A, causing a difference in temperature between A and B. In the second mode, as shown in Fig. 1(b), the



(a) By the first method, demon makes An inequality in temperature



(b) By the second method, demon makes an inequality in pressure

Fig. 1 Maxwell's demon

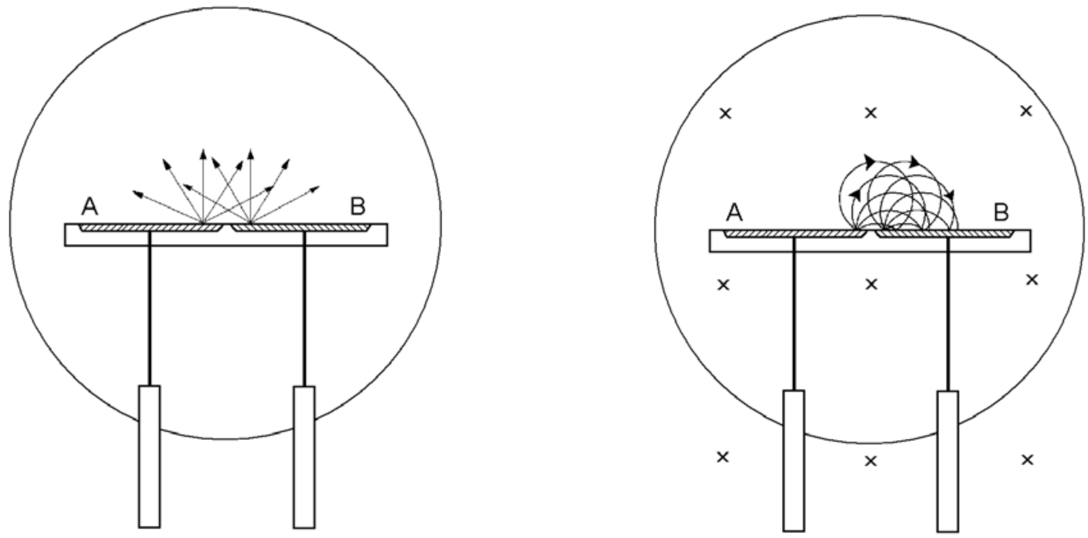
demon lets the molecules, both swifter ones and slower ones, pass the door only from A to B, never from B to A, causing a difference in pressure. Getting a difference in temperature or a difference in pressure means a renewing of energy----from waste one to useful one [(2)].

The authors hold that Maxwell's hypothesis will be much easier to realize if we, instead of relying on the neutral molecules, turn for help to the thermal electrons ejected by cathodes in a vacuum electronic tube [(3)]. To illustrate this, let us imagine an electronic tube whose essential part is an insulated plate (a quartz plate for example) coated with two similar and parallel cathodes on its upper surface, as shown in Fig. 2(a). We, after Maxwell, refer to them as cathode A and cathode B. There is a narrow interval between A and B, keeping A and B well insulated each other. The whole electronic tube should be immersed in a single heat reservoir whose temperature is high enough that the cathodes can eject thermal electrons continuously.

In order to satisfy "to extract heat from a single reservoir and convert it completely into work without producing any other effects," it is a convenient choice to choose cathodes like Ag-O-Cs photoelectric cathodes, which can eject thermal electrons at room temperature, and let the air within the laboratory be the single heat reservoir, and the whole circuit be at a same temperature.

Fig. 2 (a) illustrates the electrons ejected from two points on A and B near the interval when there is no exterior magnetic field applied to the electronic tube. It is apparent that a part of electrons ejected by A can fly onto B, while an equal part of electrons ejected by B can also fly onto A. The two tendencies cancel each other, resulting in no collection of net charge.

Now, if we apply a uniform magnetic field to the electronic tube in the direction parallel to the interval between A and B, the tracks of the ejected electrons will change into circles with different radii-swifter electrons move along bigger circles and slower ones move along smaller



(a) Electrons ejected without a magnetic field **(b)** Electrons ejected in a magnetic field

Fig. 2 A modern demon works with thermal electrons

circles. Now, a part of the electrons ejected by A can fly easily onto B, but all the electrons ejected by B can no longer fly onto A, as shown in Fig. 3(c). Such a net transition of electrons from A to B will quickly result in a charge distribution, with A positively charged and B negatively charged. A potential difference is formed simultaneously between A and B. (The situation is similar to the second mode of Maxwell's demon by which the gaseous molecules move only from portion A to portion B, causing a difference in pressure, as shown in Fig.1 (b)). Connecting cathodes A and B with two metal wires to an outer load, a resistor for example, the load will obtain a current and a voltage, both small but macroscopic.

Such a current, together with the voltage, means a small but macroscopic electric power. The electronic tube is now supplying electric energy for the load continuously. One may ask, where does this electric energy come from?

It comes from the heat extracted by the electronic tube from the surrounding air. Once cathode A gets positively charged and cathode B gets negatively charged, these charges will produce immediately a static electric field over the interval between A and B. Such a field tends to prevent thermal electrons ejected by cathode A from flying onto cathode B. The electrons, nevertheless, have thermal kinetic energy. At room temperature, T = 300 K for example, the mean value of the kinetic energy of electrons is $\bar{\varepsilon} = 3kT/2 = 6.21 \times 10^{-21}$ J = 0.0388 eV, and the corresponding speed (r.m.s. speed) is $v_{rms} = \sqrt{3kT/m} = 117$ km sec^{-1}. Relying on this kinetic energy, the electrons can break through the obstruction of the static electric field and fly from A to B. On arriving at B, each electron has got a small amount of electric potential energy at the cost of losing an equal amount of its kinetic energy. The electrons are thus cooled down (slightly), and consequently the temperature of the electronic tube also drops down (very slightly), which can be compensated by extracting heat from the surrounding air.

In the above process, the electronic tube extracts heat from the air and all of the heat is converted into electric energy, without producing any other effects. We hold that the process is in contradiction to Kelvin's statement of the second law of thermodynamics

The following is a detailed description of an actual experiment based on the above idea with two practical electronic tubes made by the authors, FX1-1 and FX1-6.

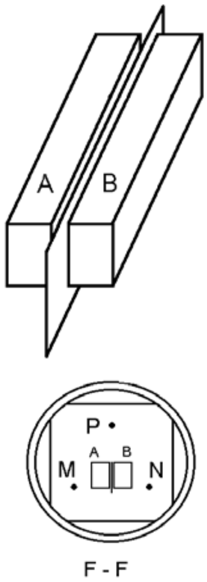
2. Electronic tube FX1

(1) The cathodes (electron ejectors) The two cathodes A and B in FX1 are common Ag-O-Cs photoelectric cathodes. As is well known, due to their particularly low work function of 0.7 to 0.9 eV, Ag-O-Cs cathodes are sensitive to near infrared rays and they can eject the greatest amount of thermal electrons at room temperature among all existing cathodes [(4)]. Generally speaking, at room temperature, the dark thermal current density ejected from the surface of an Ag-O-Cs cathode may range from 10^{-9} to 10^{-14} A cm^{-2}.

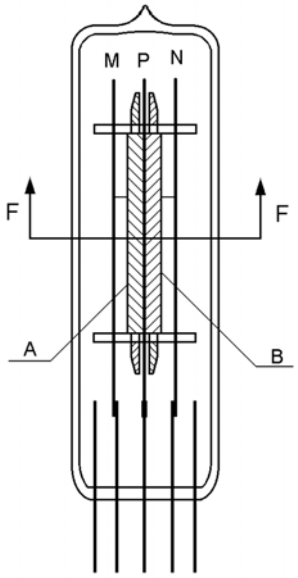
(2) Structure of FX1 The structure of FX1 is shown in Fig.3. The upper surface of A and B are two similar and parallel Ag-O-Cs cathodes, each with an area of 4 x 40 mm^2. Between A and B, there is a mica sheet 0.07 ~ 0.09 mm in thickness, which keeps A and B very close (about 0.10 mm) but well insulated from each other. M, N and P are three molybdenum supporting rods. M and N are also used as lead out wires for A and B respectively. P is actually also a temporary anode, which hangs 6 mm over A and B and is parallel to the interval. P, as an anode, is used in the process of making the Ag-O-Cs cathodes ----- oxidizing the silver films on the upper surfaces of A and B by oxygen-discharge.

For a common photoelectric tube or a photoelectric multiplier tube, the less the dark thermal electron current, the better the quality of the tube. In our experiment, however, we prefer a rather strong dark thermal-electron emission from the cathodes. The typical dark thermal-electron current for each cathode of an FX1 tube ranges from 0.1 ~ 2. 5 nA.

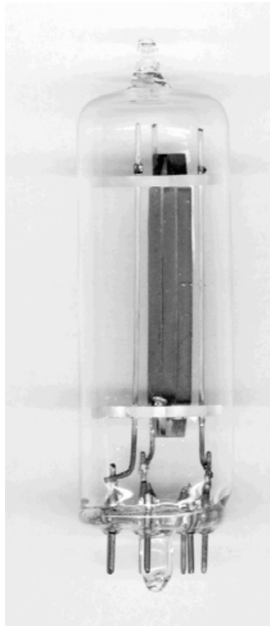
The leakage resistance between the two cathodes A and B should be higher than 100MΩ. Otherwise, according to our experience, the tube is unqualified for the experiment. The leakage resistance depends mainly on the final exhausting process of the extra cesium.



(a) Cathodes A and B, mica sheet, supports, and so on



(b) The general structure of an electronic tube FX1



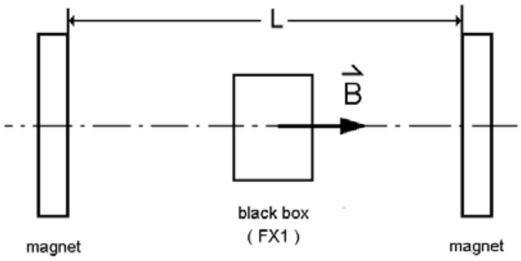
(c) A photo of an electronic tube FX1

Fig. 3 Electronic tube FX1

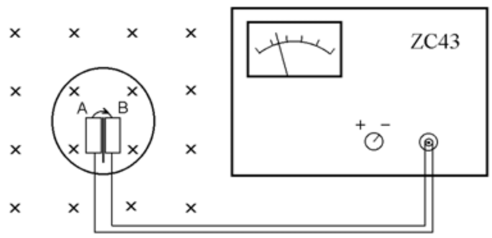
3. Ways of measurements used

(1) Magnetic field

The magnetic field applied to deflect the track of the thermal electrons is produced by a pair of magnets of the size 150 x 100 x 25 mm^3 (Ceramic 8, MMPA Standard), as shown in Fig. 4(a). Let L stands for the distance between the two magnets, and B stands for the magnetic induction at the center of the central axis of the two magnets. The $L \sim B$ relation is measured in advance with a gauss meter.



(a) Magnetic field produced by a pair of magnets. B depends on L, and the relation is measured in advance.



(b) Current-measuring circuit. ZC43 is an electrometer, whose two scales with minimum values of 10^{-13} A and 10^{-14} A are used.

Fig. 4

(2) **Output current and voltage**

In this experiment, tube FX1 is an electric power. We will take the input resistance of an electrometer Model ZC43 as a load to this electric power. The electrometer ZC43 can be used at the same time to measure the output current and voltage of the power. The measuring circuit is shown in Fig. 4(b).

The current measuring range of ZC43 (produced by Shanghai Sixth Electric Meter Factory) is from 1 x 10^{-5}A to 1 x 10^{-14}A. Two measurement scales with minimum scale values of 1 x 10^{-13}A and 1 x 10^{-14}A respectively are used in our experiment. Both of the voltages corresponding to the minimum scale values for the two scales are the same, namely, 0.01volts.

The whole circuit, including the electric power and the load, is kept at the same room temperature.

4. The experiment and results

Put an electronic tube FX1 in a copper-screening box and connect the circuit. The four walls of the copper-screening box, as well as its cover and bottom, are all 6 mm in thickness, so visible light and other electromagnetic waves are all well kept out of the box. The expected output current of the tube FX1 is transferred from the box to the electrometer ZC43 through an accessory concentric cable.

At first, we do not apply a magnetic field to the electronic tube, and there should be no current in the circuit. Regulate carefully the indicating pointer of ZC43 to zero. (In the next steps of the experiment, pay attention closely to the possible drift of the pointer). Now, if we apply a positive magnetic field with a rather weak magnetic induction B_+ to the tube ($B_+ = 3.6$ gausses for example, corresponding to L = 100cm) in the direction parallel to the interval between A and B, a weak positive output current I_+ appears immediately. Then, step by step, strengthen the magnetic induction B_+ by reducing L, giving a sufficiently long pause for every step (to eliminate Farady's motional electric motive force), we get every time a stable current I_+ corresponding to a stable magnetic induction B_+. At the beginning, I_+ increases as B_+ increases. There is then a peak of I_+ , after which I_+ decreases as B_+ increases further. Such a peak is easy to explain-----as B_+ getting stronger, the radii of the electron orbits getting smaller; after the peak, as more and more electrons (the slower ones first) can no longer cross the 0.10mm interval between A and B, the current drops down.

Reverse the direction of the magnetic field, and we have B_- now. The electrometer shows that the direction of the output current, as expected, reverses, too-----we now call the current I_-.

As the distance L reduces step by step, B_- gets stronger and stronger, and I_- increases first, then decreases after a similar peak in a similar way.

We refer to the currents I_+ and I_- briefly as Maxwell's current. Generally speaking, for a giving tube FX1, Maxwell's current I is decided by two factors: the magnetic induction B and the temperature t. We may write

$$\boldsymbol{I = I\,(\,B\,,\,T\,).}$$

The detailed results of the experiment are shown in tables and by curves as follows.

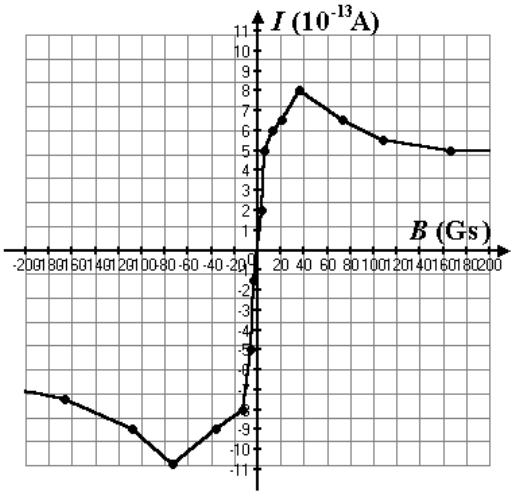
Table 1 and Table 2 illustrate the data of two tests about the $I \sim B$ relation of the electronic tube FX1-6, and Fig. 5 (a) and (b) are the corresponding $I \sim B$ curves. In each of the two tests, the temperature is regarded as a constant parameter.

Table 1 $I \sim B$ relation of FX1-6 ($t = 23.0^{o}$C)

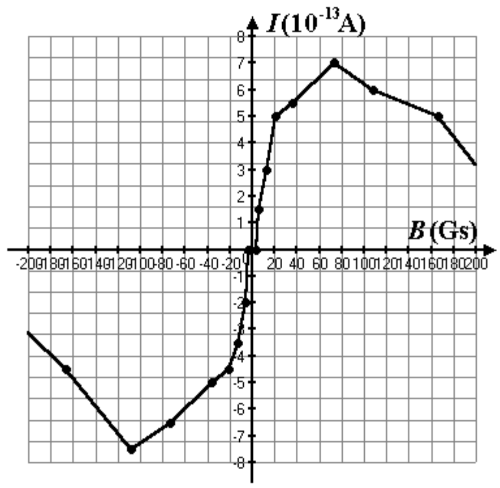
L (cm)	∞	100	80	60	50	40	30	25	20	18
B (gauss)	0	3.6	6.2	13	21	36	73	108	166	203
$I_+(10^{-13}$A)	0	+2	5	6	6.5	8	6.5	5.5	5	5
$I_-(10^{-13}$A)	0	-1.5	-5	-8		-9	-10.7	-9	-7.5	-7

Table 2 $I \sim B$ relation of FX1-6 ($t = 22.0 \sim 22.8^{o}$C)

B (gauss)	0	3.6	6.2	13	21	36	73	108	166	203	∞
I+(10-13A)	0	0	1.5	3	5	5.5	7	6	5	3	0
I-(10-13A)	0	0	-2	-3.5	-4.5	-5	-6.5	-7.5	-4.5	-3	0



(a) $I \sim B$ relation of FX1-6 (1)



(b) $I \sim B$ relation of FX1-6 (2)

Fig. 5

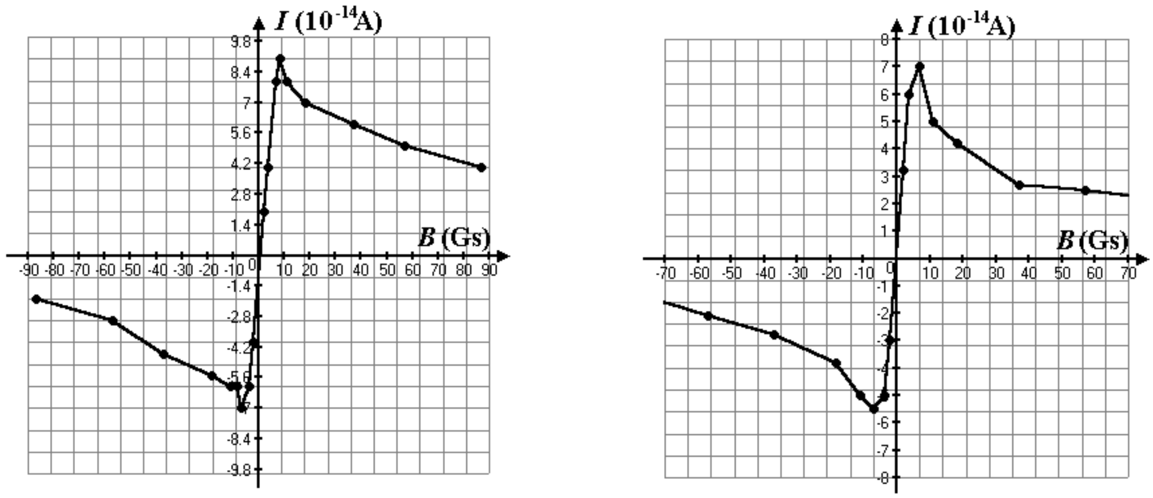
Table 3 and 4 illustrate the data of two tests about the $I \sim B$ relation of tube FX1-1, and Fig. 6 (a) and (b) are the corresponding $I \sim B$ curves. In each of the two tests, the temperature is also regarded as a constant parameter.

Table 3 $I \sim B$ relation of FX1-1 ($t = 23.8^{o}$C)

B **(gauss)**	0	2	3.5	7	8.5	11	18.5	37	57	87	0
$I_+(10^{-14}A)$	0	2	4	8	9	8	7	6	5	4	0
$I_-(10^{-14}A)$	0	-4	-6	-7	-6	-6	-5.5	-4.5	-3	-2	-2

Table 4 $I \sim B$ relation of FX1-1 ($t = 22.2^{o}$C)

B **(gauss)**	0	2	3.5	7	8.5	11	18.5	37	57	87	0
$I_+(10^{-14}A)$	0	3.2	6.0	7.0		5.0	4.2	2.7	2.5	2.0	1.0
$I_-(10^{-14}A)$	0	0	-5	-5.5		-5.0	-3.8	-2.8	-2.1	-1.0	-0.5



(a) $I \sim B$ relation of FX1-1 (1) **(b)** $I \sim B$ relation of FX1-1 (2)

Fig. 6

The experiment can be finely repeated.

The output currents of the experiment are very small, but they are already macroscopic currents. In the case of I =8.0 x 10^{-13} A, the peak value in Fig. 5(a), the number of electrons passed from A to B in each second is N = 8.0 x 10^{-13} A / 1.6 x 10^{-19} Col = 5.0 x 10^{6} sec^{-1}. With five million electrons move in the same direction each second, we should say, this is a macroscopic current. The corresponding voltage is 8.0 x 0.01 V = 0.08 V. Such a DC voltage is obviously a macroscopic one. A large number of such direct currents can be added up by connecting them in parallel, and the voltages can be added up by connecting them in series, to form a considerable electric power.

Such macroscopic direct currents and voltages, though still very small, are distinctly different from the fluctuating currents and voltages in the famous Johnson effect (caused by the fluctuations of the random thermal motion of the free electrons in a metal). Johnson fluctuating currents and voltages are microscopic ones. They are random. They alternate ceaselessly, having no stable period or frequency. They cannot be added up to form a considerable electric power.

The experiment points at a completely new way of direct generation of electricity, too.

5. Conclusion

In the above experiment, the heat extracted by the electronic tubes from the air converts completely into electric energy without producing any other effects. The experiment shows clearly that the second law of thermodynamics is not universally valid and there are ways by witch energy can convert from waste one to useful one again!

Thus, after so long a delay, Maxwell's cherished wish has eventually been realized. The human beings have recognized a major and deeply hidden truth of the nature: **Energy is immortal, its vitality (conversion ability) lasts forever!**

Acknowledgement

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REFERENCE

1. James Clerk Maxwell *Theory of Heat*, P.328, (1871)

2. W. Ehrenberg Maxwell's Demon, *Scientific American*, pp.103-110 (1967)

3. Fu Xinyong An Approach to Realize Maxwell's Hypothesis, *Energy Conversion and Management* Vol.22 pp1-3 (1982).

4. A. H. Sommer *PHOTOEMISSIVE MATERIALS Preparation, Properties, and Uses* John Wiley & Sons (1968) Section 10.7.1, Chapter 10.

APPENDIX Maxwell's original idea about the being (the demon)

One of the best established facts in thermodynamics is that it is impossible in a system enclosed in an envelope which permit neither change of volume nor passage of heat, and in which both the temperature and the pressure are everywhere the same, to produce any inequality of temperature or of pressure without the expenditure of work. This is the second law of thermodynamics, and it is undoubtedly true as long as we can deal with bodies only in mass, and have no power of perceiving or handling the separate molecules of which they are made up. If we conceive a being whose faculties are so sharpened that he can follow every molecule in its course, such a being, whose attributes are still as essentially finite as our own, would be able to do what is at present impossible to us. For we have seen that the molecules in a vessel full of air at uniform temperature are moving with velocities by no means uniform, though the mean velocity of any great number of them arbitrarily selected, is almost exactly uniform. Now let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being, who can see the individual molecules, opens and closes this hole, so as to allow only the swifter ones to pass from A to B, and only the slower ones to pass from B to A. He will thus without expenditure of work, raise the temperature of B and lower that of A, in contradiction to the second law of thermodynamics."

From James Clerk Maxwell *Theory of Heat*, 1871