Inconsistency of Carnot Principle and Second Law of Thermodynamics

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Abstract

We know that internal energy of an ideal gas is a state function and it solely depends on the temperature of the gas. The temperature of the gas can be changed by many ways. We can change it by compressing the gas or by supplying the heat from outside or by injecting more molecules into a given volume of the gas. We know that Carnot principle is based on the temperature difference of thermal reservoirs and their thermal capacities. Due to different ways of production of heat the temperature difference between two thermal reservoirs can be created in different ways. There are many ways for creating such temperature gradients. One way is to pump the heat from one reservoir to another reservoir by the means of an ideal heat pump. Second way is to heat up one reservoir by burning some sort of fuel. Third way is to heat up one reservoir by stirring its fluid or by passing electric current through it whatever the medium may be. In the fourth way we can compress one reservoir made up of gas and can expand the second reservoir of the gas simultaneously as happens in sound waves. From all of these four methods of creating temperature differences, first and fourth methods are striking and this lead to a very interesting result. This result is that Carnot principle and second law of thermodynamics are not consistent.

1. Introduction

According to Carnot principle, there is not any engine, working between a temperature gradient and two thermal reservoirs which is more efficient than Carnot engine working between same temperature gradient and thermal reservoirs. It implies that if a Carnot engine draws some heat from some hot place, performs some work and rejects some heat to the cold reservoir then there is no possibility that some other engine (if run in reverse order) absorbs more heat from same cold reservoir and injects it to the same hot place by consuming the same work produced by the Carnot engine. If it were not true then Kelvin and Clausius statements would be invalid.

We know that the internal energy of a monatomic ideal gas solely depends on its temperature. Hence, it is a state function. The change in its internal energy can be calculated by considering its initial and final temperatures. The internal energy of the ideal gas can be represented as 3/2nRT. Therefore change in internal energy will be

$$\Delta U = 3/2nRT_1 - 3/2nRT_0$$

where T_1 and T_0 are final and initial temperatures. This change in temperatures can be brought by either compressing the gas adiabatically or by heating up the gas. We know that Carnot engine works between a temperature difference and its efficiency depends on the temperature difference. Suppose we have two reservoirs of gas. If we heat up one reservoir by compressing it adiabatically and cool down the other by allowing it to expand adiabatically then we can obtain the work done by us by fitting a Carnot engine between these two reservoirs.

2. Inconsistency of Carnot Principle and Second Law of Thermodynamics

Suppose there is a cylinder, and a monatomic ideal gas is trapped inside it. There is a partition in the middle of the cylinder as shown in diagram 1. Thus the cylinder is divided into two sections of equal volume which means there is equal amount of gas in both the sections.

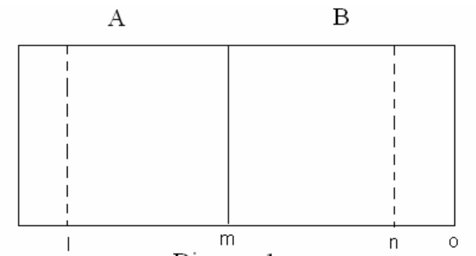

Diagram 1

The cylinder is isolated from the surrounding and both the sections are also isolated from each other by the partition. Hence no heat can enter or escape the cylinder and no heat can cross the partition as well. Suppose the temperature of the gas inside the cylinder and its surrounding is T1.

Let us push the partition towards right up to point n as shown in diagram 2. Due to this action the

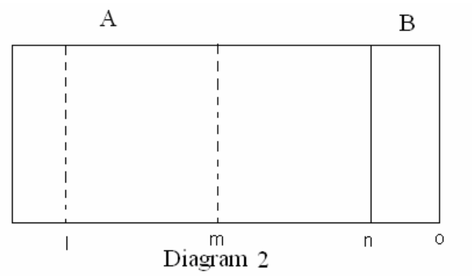

Diagram 2

section B is compressed adiabatically and its temperature increases from T1 to T2 whereas section A expands adiabatically and its temperature falls to T0 because it performs the work along with the external force applied by us on the partition.

It means

$$T0 < T1 < T2$$

Thus a thermal disequilibrium is established between both the sections.

If we leave the partition free it will keep oscillating between extreme positions n and l. Thus this system can be considered as a simple harmonic oscillator. It means displacements lm and mn are equal.

Let us lock the partition at position n. According to law of conservation of energy

$$\Delta U_{\text{section B}} = W_{\text{external force}} + W_{\text{section A}} \qquad (1)$$

Where

$\Delta U_{\text{section B}}$ is the change in internal energy of section B

$W_{\text{external force}}$ is the work done by external force and

$W_{\text{section A}}$ is the work done by section A.

From equation 1, it is clear that the partition is acting like a compressor of a heat pump. If some external force is applied on the partition it transfers some amount of heat energy from section A to section B. From equation it is also clear that the mode of transportation of heat energy is mechanical work.

Now let us fit a Carnot engine between the two sections as shown in diagram 3. The partition is locked in its position. The heat can flow from section B to section A through Carnot engine only but it is not allowed to flow across the boundaries and partition. There is temperature difference between two sections. The temperature of section B is T2 whereas that of section A is T0.

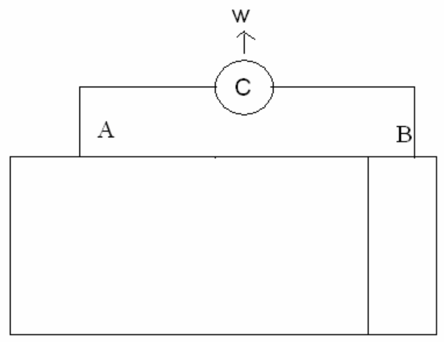

Diagram 3

Let us allow the heat to flow. Since T2 is greater than T0 therefore heat starts flowing from section B to section A through the Carnot engine. With this flow engine produces some work w and when both the sections attain the thermal equilibrium it stops running. We can store that work in any form.

Now here it is very important to ask a question.

"Is the work produced by Carnot engine is equal to the work performed by us in pushing the partition towards right?"

The answer to the above question can be provided by Carnot principle. Since our partition is acting like a heat pump that transferred some heat from section A to section B whereas Carnot engine is working like a heat engine that makes the use of temperature difference of two sections created by the partition in order to produce some work w. Carnot principle says that two engines working between a temperature difference and same reservoirs are equally efficient no matter if one of them is run in reverse order like a heat pump. In other words no engine or heat pump can be more efficient than Carnot engine working between same temperature difference and reservoirs.

In our demonstration Carnot engine and partition are working between same sections therefore both of them should be equally efficient according to the Carnot principle. If it is not so then we are disobeying the Carnot's theory.

Thus we can say that Carnot engine and partition in the above demonstration are equally efficient which means Carnot engine produces as much work as was done by the external force applied by us on the partition in order to push it towards right.

Now reconsider the equation 1 which is as follows:

$$\Delta U_{\text{section B}} = W_{\text{external force}} + W_{\text{section A}}$$

The $W_{\text{external force}}$ (work done by external force) has been recovered through Carnot engine and $W_{\text{section A}}$ (work done by section A) has been recovered by the section A when Carnot engine dumps the heat into it. Thus the sections attain the initial thermal equilibrium at temperature T1. Now let us remove the Carnot engine and put the cylinder in thermal communication with the surrounding. The partition remains locked in its position as shown in diagram 4.

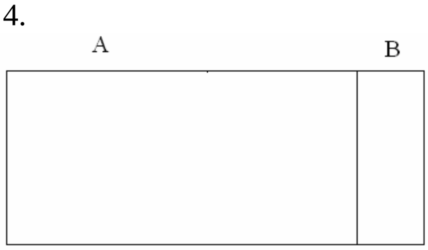

Diagram 4

The temperature of the cylinder and surrounding is T1 therefore no heat flows into or out of the cylinder. Hence at this position we can say that we succeeded in compressing the section B without spending any energy because Carnot engine gave us back the energy spent by us.

Now let us unlock the partition. Since the pressure of section B is greater than section A partition will move from right to left as shown in diagram 5.

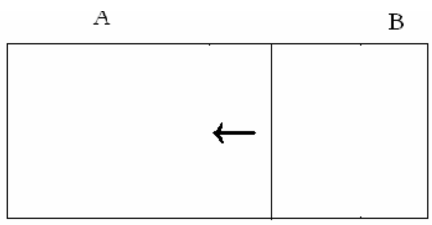

Diagram 5

The cylinder is in thermal communication with the surrounding therefore section B expands isothermally whereas section A is compressed isothermally. Section B receives more heat from the surrounding than the heat rejected by section A because expansion in volume of the former is greater than the compression in the volume of the latter. Thus a net amount of heat enters the cylinder. We can obtain useful work from this movement of the partition. This work is obtained by consuming the heat of the surrounding which means that internal energy of the surrounding decreases. This surrounding is the part of the universe and universe is the ultimate closed system. At this point we are led to make the following generalization:

"The entropy of the universe can be decreased."

To deny this statement means to overthrow the Carnot principle which has been the important part of our demonstration. Thus we can say that Carnot principle and second law of thermodynamics are inconsistent.

3. The Closed cycle of Carnot Engine between the Sections A and B

Now we will see how the above mentioned thermodynamic processes can be drawn on a p-v diagram. In our demonstration there is a Carnot engine that works between two sections of different temperatures. Therefore we have to consider a Carnot cycle. We know that in a Carnot cycle there are two isothermal and two adiabatic processes but here sections A and B are of finite thermal capacities therefore there will be two adiabatic and two diabatic processes. Let us see diagram 6.

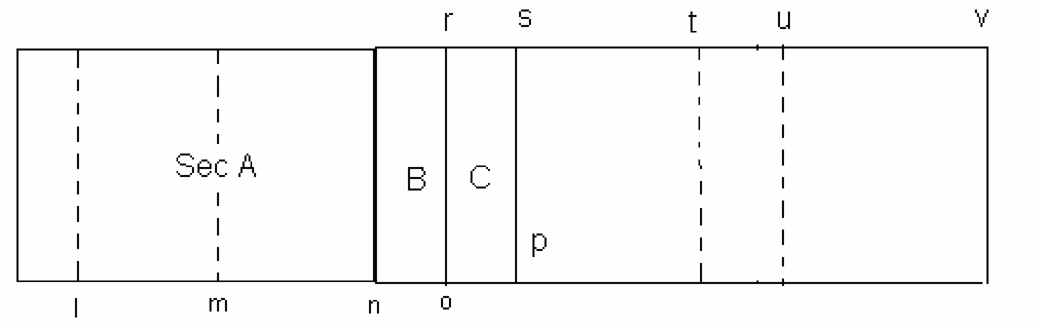

Diagram 6

In diagram 6, the compressed section B is in contact with a Carnot engine C. The temperature of both is T2 and they are also at equal pressure and volume which means both are having equal amount of gas. Carnot engine is in thermal communication with the section B. Displacements st and uv are equal to displacement mn.

(1) Let us allow the piston p of Carnot engine to move up to point u. This expansion is diabatic which means engine is receiving the heat from compressed section B. Here we assume that piston p is doing the work against some resistance like flywheel. Let us suppose that at point u temperature of section B and the engine falls to T1 which is equal to the temperature when both the sections were in thermal and pressure equilibrium at point m.

We have supposed that initially the volume and temperature of Carnot engine is equal to section B therefore if we allow the Carnot engine to expand without any input of heat from section B then the temperature of the engine should fall to T1 at point t because displacement st is equal to displacement mn. But we have supplied the heat to the engine from section B that is why the piston p of the engine jumps the point t and attains the temperature T1 at point u. At point u section B has given up all the heat to the engine which it has gained when it was compressed. Thus from equation 1 heat supplied to the engine by the section B is:

$$Q \quad = \quad \Delta U_{section\ B} \quad = W_{external\ force} \quad + \quad W_{section\ A} \qquad (2)$$

Where Q = heat supplied to the engine from section B

$\Delta U_{section\ B}$ is the change in internal energy of section B when it was compressed

$W_{external\ force}$ is the work done by external force used in compressing the section B

$W_{section\ A}$ is the work done by section A along with the external force

Thus extra displacement tu of the piston p at temperature T1 is because of heat Q.

(2) Let us now remove section B and allow the piston p to move up to point v. This expansion is adiabatic. At this position the temperature of the gas of Carnot engine falls to T0. The displacement uv should be equal to displacement st if we ignore the displacement tu caused because of input heat Q because in this step we are not injecting any heat.

(3) We know that temperature T0 is the temperature of section A in diagram 2. Let us fit the section A with the Carnot engine as shown in diagram 7:

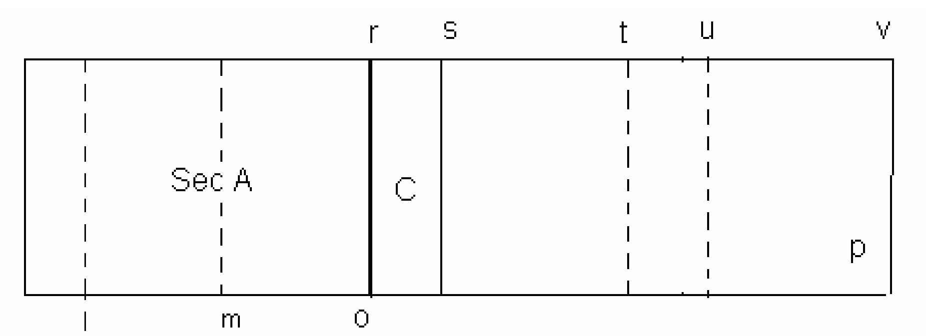

Diagram 7

In diagram 7, piston p is at position v. Now the surrounding performs the work on the piston and compresses the gas diabatically which means some heat is given to the section A. The piston keeps compressing the gas until its temperature and that of section A reaches T1. The temperature of section A will be T1 if it receives the heat equal to the work done by it when section B was compressed in diagram 2. The work done by the external force is extracted in the form of motive power as the piston p compresses the gas. Displacement tu represents the sum of work done by section A and work done by external force (equation 2).This means piston will cover the displacement uv plus tu and will be at point t when the temperature of the section A and temperature of gas of Carnot engine is T1. Displacement uv is equal to displacement st. This implies that displacement tv (tu + uv) is equal to displacement su (st + tu).

(4) Now remove the section A. The piston p keeps moving and compresses the gas adiabatically up to point s. At this position temperature of the gas of the engine reaches initial value T2. Thus engine is again at its initial temperature, volume and pressure.

These four steps can be shown on a p-v diagram shown as follows:

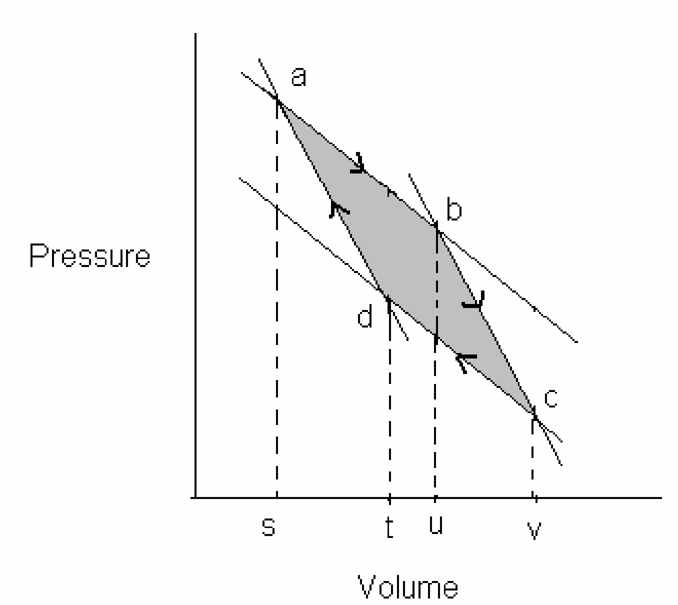

Diagram 8

In diagram 8, volume displaced by piston p is shown on perpendicular axis and pressure at different positions of piston is shown on vertical axis.

1. The curve ab shows the diabatic expansion. Carnot engine takes the heat from section B due to which piston displaces the volume su.
2. The curve bc shows the adiabatic expansion due to which piston displaces the volume uv.
3. The curve cd is diabatic compression thus heat is rejected to section A. The piston displaces volume vt.
4. da is adiabatic compression. The piston displaces volume ts and reaches the initial position.

The area of parallelogram abcd is the motive power produced by the engine. This motive power is equal to the work done by external force on the partition in diagram 2. In this way a Carnot engine works between the temperature gradient of two sections. After the complete cycle section A and section B have the temperature T1 but section B has greater pressure than the section A. Thus we succeeded in compressing the section B without spending any energy because the work done by us been recovered through Carnot engine.

5. The modified Cycle based on the above demonstration

The Carnot cycle explained in section 3 can be modified if we remove the Carnot engine and use the compressed section B in place of it. In that case the diabatic and adiabatic processes do not occur alternatively. First we get two adiabatic expansions one after another and then two diabatic compressions.

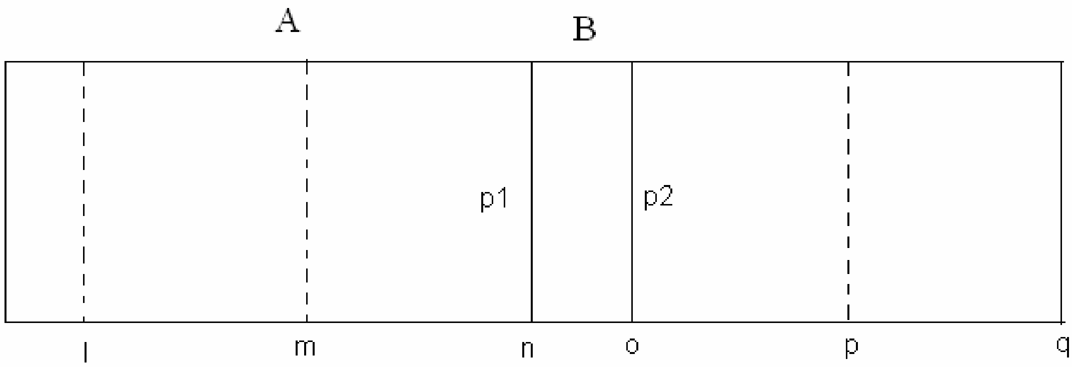

Diagram 9

Consider diagram 9 where section B is compressed and section A is expanded. The temperature of the former is T2 whereas temperature of the latter is T0. Both sections were at temperature T1 when partition p1 was in the middle point m. Thus

$$T0 < T1 < T2$$

Similarly we can say about that the pressure i.e.

$$P0 < P1 < P2$$

Displacement mn is equal to displacement op and op is equal to pq. This implies displacement np is equal to displacement mo. Partitions p1 and p2 are locked and the compressed gas of section B is trapped between them.

(1) Let us unlock the partition p2 whereas partition p1 remains locked in its position. Here we assume that partition p2 is moving in vacuum but is connected to some external resistance like fly wheel. Due to the pressure of the gas partition moves towards right up to point p. Due to this the temperature of the section B falls to T1 and pressure falls to P1. This change is same if we would have allowed the partition p1 to move towards left to position m against the pressure of the gas of section A. Thus we can say that at point p the temperature of the section B will be T1. This expansion is adiabatic.

(2) Let us allow the partition p2 to keep moving till point q. This expansion is adiabatic again. The temperature of the section B falls to T0 because at point q the volume of section B is equal to the volume of section A. Pressure falls to P2 So now both the sections are in thermal and pressure equilibrium at temperature T0.

(3) In this step the partition p2 returns from point q to point p after the half revolution of the fly wheel. This compression of the section B is diabatic which means there is transfer of heat with the section A. At this point the temperature of both the sections is in between T0 and T1. Let it be t . Similarly pressure of the section B will be in between P0 and P1. Let it be P_B whereas pressure of section A will be less than P_B.

(4) In the fourth step partition p2 keeps compressing the section B diabatically up to point o. At this point temperature of both the sections settle at T1 and pressure of the section B increases to P3. According to our theory the surplus power obtained from the flywheel will be equal to the work done by external force in order to compress the section B in diagram 2. These four steps can be shown on p-v diagram as follows:

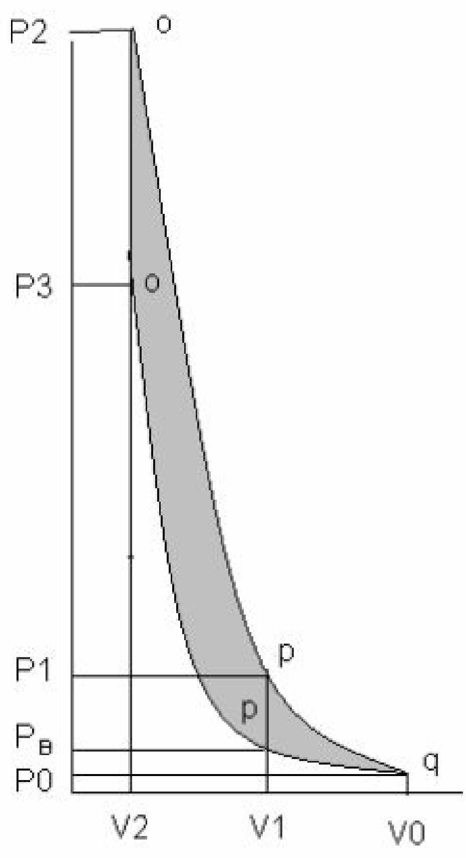

Diagram 10

Diagram 10 shows the thermodynamics processes under which section B goes. In the beginning of the first step section B is at some pressure 2. Then it starts expanding adiabatically. Curve op shows this adiabatic expansion. With this expansion pressure falls to P1 and volume increases from V2 to V1.

After that it keeps expanding adiabatically. This next adiabatic expansion follows the same curve up to point q. At this point pressure falls to P0 and volume increases fromV1 to V0. At this point volume of both the sections is equal therefore their pressure and temperature is also equal.

In the third step section B is compressed diabatically which means there is transfer of heat between both the sections. This compression follows the lower curve qp. The volume decreases from V0 to V1. The pressure of section B rises from P0 to $P_{B.}$ The temperature of both the sections also rises.

In the fourth step, the section B is compressed from volume V1 to V2. This compression follows the same curve lower curve up to point o. The temperature of both the sections becomes T1 whereas pressure of section B becomes P3. The area 'opqpo' is the recovered work which was done in compressing the section B in diagram 2.

Thus after the complete cycle both the sections attain the initial thermal equilibrium T1 but with a pressure disequilibrium. After the cycle we get the state shown in diagram 11. It is same state as shown in diagram 4.

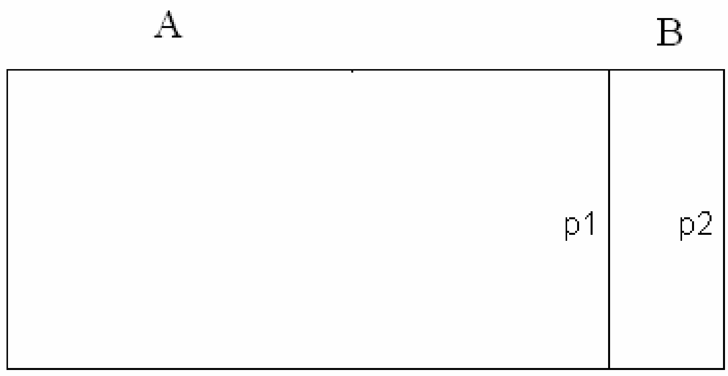

Diagram 11

We can unlock the partition p1 and lock the partition p2 and can use the pressure disequilibrium for producing extra motive power. This process can be carried out isothermally by putting the cylinder in thermal communication with the surrounding.

At this point we can say that Carnot principle and second law of thermodynamics are not consistent.

Reference:

A Treatise on Perpetual Motion of Second Kind (2012): Charanjeet Singh Bansrao, Unistar Books Pvt. Ltd. India. ISBN 978-93-81832-05-9