An exception to the Carnot theorem: The temperatures of two black bodies at equilibrium differ due to the influence of a pair of rapidly rotating polarizers

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Abstract

This paper tackles a physics problem persisting for over 150 years—the unsolved issue tied to 'Maxwell's demon' since 1871. It offers a potential solution to the longstanding problem of the second law of thermodynamics. The second law of thermodynamics states that the conversion rate of thermal energy into other forms of directional energy, such as kinetic, potential, or electrical energy, is constrained by the temperature difference divided by the absolute temperature. Essentially, without a temperature difference, thermal energy cannot be converted into other forms of directional energy. In this paper, we identify and theoretically demonstrate a scenario that surpasses this limitation. Specifically, we show that under certain conditions, thermal energy can be continuously converted into electrical energy. The proposed method involves placing a pair of uniformly rotating polarizers between two black bodies. When radiation from the black bodies perpendicularly strikes the polarizers, the conservation of angular momentum ensures that, in the absence of friction, the rotation speed of the polarizers does not decrease. With an appropriate configuration, this setup can cause asymmetric radiation exchange between the black bodies, thereby generating a temperature difference automatically. This temperature difference can then be harnessed to convert thermal energy into electrical energy. Thus, it is possible to naturally generate a temperature difference from an initial state of thermal equilibrium and convert it into electrical energy without any loss of angular momentum or energy, thereby transcending the limitations of the second law of thermodynamics. This breakthrough suggests the potential for a sustainable and environmentally friendly energy source.

Keywords: Carnot's theorem, thermodynamics, reversibility of light, rotating polarizers, black bodies, radiation

Symbols:

c	The speed of light.
I_A	The radiant energy flux from blackbody A incident on polarizer C.
I_{AC}	The radiant energy flux from blackbody A transmitted through polarizer C and incident on polarizer D.
I_{ACD}	The radiant energy flux from blackbody A transmitted through polarizers C and D and incident on blackbody B.
I_B	The radiant energy flux from blackbody B incident on polarizer D.
I_{BD}	The radiant energy flux from blackbody B transmitted through polarizer D and incident on polarizer C.
I_{BDC}	The radiant energy flux from blackbody B transmitted through polarizers D and C and incident on blackbody A.
I_C	The radiant energy flux emitted by polarizer C due to its own temperature and incident on blackbody A and polarizer D.
I_{CD}	The radiant energy flux emitted by polarizer C and transmitted through polarizer D and incident on blackbody B.
I_D	The radiant energy flux emitted by polarizer D due to its own temperature and incident on blackbody B and polarizer C.
I_{DC}	The radiant energy flux emitted by polarizer D and transmitted through polarizer C and incident on blackbody A.
L	The distance between polarizer C and polarizer D.
T_A	Equilibrium temperature of black body A.
T_B	Equilibrium temperature of black body B.

1 Introduction

Ever since Maxwell introduced "Maxwell's demon" in 1871, a physics problem related to the second law of thermodynamics has remained unsolved for more than 150 years [1]. This paper proposes a potential solution to this long-standing issue. Polarizers can polarize light, causing the electric field components of the light to concentrate in a specific direction perpendicular to the direction of propagation, while the magnetic field concentrates in another direction perpendicular to both the direction of propagation and the electric field. When polarized light passes through a polarizer, only the component aligned with the polarization direction of the polarizer remains, while the component perpendicular to the polarization direction cannot pass through. Since light travels at the speed of light, if during the time it takes for light to pass through two polarizers, the polarization direction of the rear polarizer is rotated to align perfectly with the polarization direction of the light that has passed through the front polarizer. And then the light can smoothly pass through both polarizers. However, if the polarization direction of the rear polarizer is rotated to align perpendicularly to the polarization direction of the light that passed through the front polarizer, the light may be blocked by the rear polarizer and unable to pass through smoothly. Using this principle, we can design a set of polarizers with a slight angular deviation between the front and rear polarizers, rotating both at the same angular velocity. When light propagates in one direction, it encounters a consistent polarization alignment between the front and rear polarizers, whereas, in the opposite direction, the polarizations are misaligned. This design allows a higher proportion of light to pass through in one direction and a lower proportion in the opposite direction. By placing a blackbody on each side, we can exploit this asymmetry in light transmission rates, resulting in an unequal exchange of radiation between the blackbodies and creating a temperature difference at equilibrium. This temperature difference can then be harnessed to generate electricity. This satisfies the conditions of Maxwell's demon, enabling the transcendence of Carnot’s theorem [2] and the restrictions of the second law of thermodynamics.

If this principle can be harnessed for power generation, it could create an endless, sustainable energy source, extracting energy from environmental heat, thereby becoming one of the most environmentally friendly energy sources available.

2 Theoretical derivation

Consider a system with two blackbodies and two polarizers. Blackbody A has an aperture facing polarizer C, while blackbody B has an aperture facing polarizer D. The configuration is illustrated in Fig.1. Polarizers C and D are separated by a distance L, and the structure connecting blackbody A to blackbody B, which houses polarizers C and D, is a smooth, white tube that does not absorb any radiation.

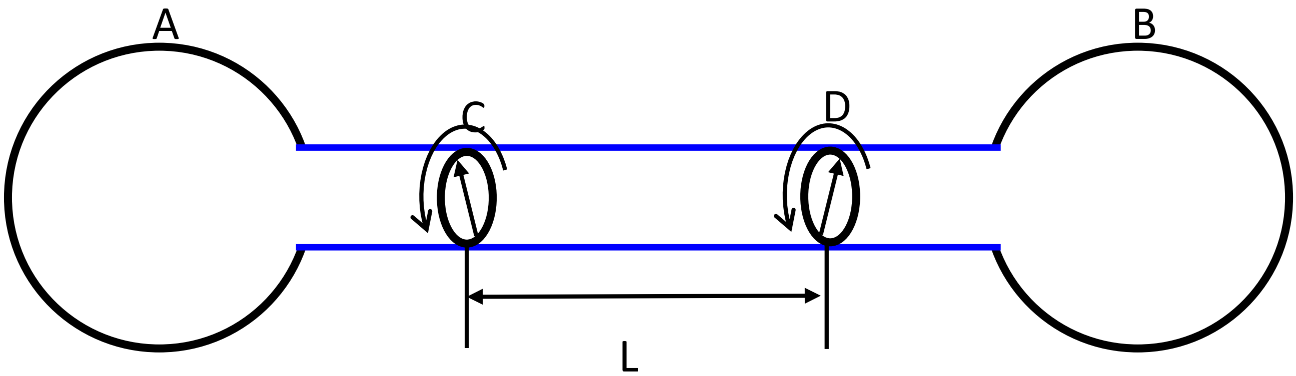

Fig.1. Blackbody A has an aperture facing polarizer C, while blackbody B has an aperture facing polarizer D. Polarizers C and D are separated by a distance L, and the structure connecting blackbody A to blackbody B, which houses polarizers C and D, is a smooth, white tube that does not absorb any radiation.

Both polarizers C and D rotate in the same direction with a period of $8L/c$, where c is the speed of light. Polarizer D is positioned at an angle lagging $\pi/4$ radians behind polarizer C. This setup ensures that the radiation from blackbody A, polarized along the direction of polarizer C, reaches polarizer D after a time interval of L/c. At this moment, polarizer D has rotated $\pi/4$ radians, compensating for its initial angular lag, allowing the light from blackbody A, polarized by polarizer C, to align perfectly with the direction of polarizer D. Consequently, the light passes through polarizer D and reaches blackbody B. Conversely, when radiation from blackbody B, polarized along the direction of polarizer D, travels the distance L in a time L/c

to reach polarizer C, polarizer C will have rotated an additional $\pi/4$ radians on top of its initial $\pi/4$ lead. This results in a total angular difference of $\pi/2$ between the polarization direction of the light from blackbody B and polarizer C. Consequently, the radiation from blackbody B is unable to pass through polarizer C and thus cannot reach blackbody A.

We define the radiant energy flux from blackbody A incident on polarizer C as I_A, the radiant energy flux from blackbody A transmitted through polarizer C and incident on polarizer D as I_{AC}, and the radiant energy flux from blackbody A transmitted through polarizers C and D and incident on blackbody B as I_{ACD}. Similarly, we define the radiant energy flux from blackbody B incident on polarizer D as I_B, the radiant energy flux from blackbody B transmitted through polarizer D and incident on polarizer C as I_{BD}, and the radiant energy flux from blackbody B transmitted through polarizers D and C and incident on blackbody A as I_{BDC}. The radiant energy flux emitted by polarizer C due to its own temperature and incident on blackbody A and polarizer D is denoted as I_C, while the radiant energy flux emitted by polarizer C and transmitted through polarizer D and incident on blackbody B is denoted as I_{CD}. Similarly, the radiant energy flux emitted by polarizer D due to its own temperature and incident on blackbody B and polarizer C is denoted as I_D, and the radiant energy flux emitted by polarizer D and transmitted through polarizer C and incident on blackbody A is denoted as I_{DC}.

Furthermore, assuming that unpolarized radiation passing through a polarizer results in half of the radiation being absorbed and the remaining half being polarized and transmitted, we derive equations describing the relationship between the radiant energy fluxes.

Based on the previous assumptions, the relationship between the radiant energy flux emitted by blackbody B and the flux transmitted through polarizer D is described by Equation (1).

$$I_{BD} = \frac{1}{2} I_B \qquad \dots\dots\dots (1)$$

Since the flux I_{BD} passing through polarizer D travels a distance L in a time L/c to reach polarizer C, it encounters a polarization angle difference of$\pi/2$ relative to polarizer C and is thus absorbed by polarizer C. This relationship is captured by Equation (2).

$$I_{BDC} = 0 \qquad \dots\dots\dots (2)$$

The relationship between the radiant energy flux emitted by blackbody A and the flux transmitted through polarizer C is defined by considering that the light passing through polarizer C travels a distance L in a time L/c to reach polarizer D. As there is no polarization angle difference upon reaching polarizer D, the light passes through polarizer D, as described by Equation (3).

$$I_{ACD} = I_{AC} = \frac{1}{2} I_A \qquad \dots\dots\dots (3)$$

The radiant energy flux emitted by polarizer C and the flux transmitted through polarizer D is described by Equation (4), while the flux emitted by polarizer D and the flux transmitted through polarizer C is described by Equation (5).

$$I_{CD} = \frac{1}{2} I_C \qquad \ldots\ldots\ldots (4)$$
$$I_{DC} = \frac{1}{2} I_D \qquad \ldots\ldots\ldots (5)$$

At equilibrium, the radiant energy flux emitted by blackbody A I_A is equal to the incident flux on blackbody A, which is the sum of the fluxes $I_C + I_{DC} + I_{BDC}$. By referring to Equations (2) and (5), Equation (6) is derived.

$$I_A = I_C + I_{DC} + I_{BDC} = I_C + \frac{1}{2} I_D \qquad \ldots\ldots\ldots (6)$$

Similarly, at equilibrium, the radiant energy flux emitted by blackbody B I_B equals the incident flux on blackbody B, which is the sum of the fluxes $I_D + I_{CD} + I_{ACD}$. By referring to Equations (3), (4), and (6), Equation (7) is derived.

$$I_B = I_D + I_{CD} + I_{ACD} = I_D + \frac{1}{2} I_C + \frac{1}{2} I_A = I_C + \frac{5}{4} I_D = I_A + \frac{3}{4} I_D > I_A \qquad \ldots\ldots\ldots (7)$$

Equation (7) reveals that at equilibrium, the radiant energy flux emitted by blackbody B is greater than that emitted by blackbody A. This is shown in Equation (8), indicating that the temperature of blackbody B is higher than that of blackbody A.

$$T_B > T_A \qquad \ldots\ldots\ldots (8)$$

Thus, a temperature difference exists between A and B at equilibrium. This temperature difference can be harnessed for power generation, thereby surpassing the limitations of the second law of thermodynamics. This means that the system's entropy could potentially decrease.

3 Discussion

From the previous derivation, it is evident that there exists a device capable of surpassing the limitations imposed by the second law of thermodynamics. However, another critical issue needs to be addressed: whether the absorption of light by the polarizers generates resistance to their rotation, potentially causing a gradual decrease in their rotational speed. This scenario is indeed plausible. Nonetheless, if we focus the light emitted from the blackbody, reducing the average radius of the light spot passing through the polarizer to half of its original size, the resistance encountered would be reduced to one-quarter of its initial value. This reduction occurs because the same amount of light passes through a smaller area, thereby maintaining the same temperature differential while decreasing resistance. When the light spot is sufficiently small, this resistance becomes negligible.

Another method to mitigate this resistance is to increase the distance between the two polarizers. If the distance is doubled, the angular velocity of the polarizers can be halved, resulting in the energy required to counteract the rotation dropping to one-quarter of its original value. Thus, by creating the same temperature differential effect while extending the distance between the polarizers, the resistance can be rendered negligible. Consequently, the impact of this resistance on the system can be minimized to the point where it does not significantly affect the theoretical implications of surpassing the second law of thermodynamics. This means that the system's entropy could potentially decrease, indicating that this principle could be harnessed to realize an extremely environmentally friendly energy source.

4 Conclusion

The theoretical derivations presented in this paper demonstrate the potential existence of a device capable of breaking the reversibility of light, as exemplified by the pair of rapidly rotating polarizers discussed herein. Such a device can naturally establish a temperature gradient at equilibrium, thereby reducing the system's entropy. This reduction in entropy suggests the possibility of converting thermal energy into directional energy, such as electrical energy, without the need for a temperature differential. Therefore, it can be argued that this work provides a solution to the 150-year-old problem known as "Maxwell's demon." Consequently, this leads to the conclusion that a perpetual motion machine of the second kind could be feasible.

Declarations

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Availability of data and material:

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Authors' contributions:

Kuo Tso Chen designed the study, performed the experiments, analyzed the data, and wrote the manuscript.

Ethics approval

I confirm that the manuscript has been approved by the author for publication. I would like to declare that the work described herein is original research and that it has not been published previously.

Code availability:

Not applicable

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