Three Thought Experiments to challenge the 2nd Law of Thermodynamics

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Due to recent inventions and developments, I believe that perpetual motion machines of the second kind, i.e. those which violate the second law of thermodynamics, are possible to construct.

Understandably, there is a lot of skepticism regarding alleged perpetual motion machines. Historically, there have been numerous failed attempts at developing perpetual motion machines of all kinds. This has led physicists to extrapolate from the past failures and dismiss all future ideas for perpetual motion machines. This generalization is institutionalized in the form of the second law of thermodynamics. As epitomized by the fallacy of induction, extrapolating from an incomplete and limited data set to make inferences about all future data can produce incorrect results, even if that data has been seemingly consistent for more than 160 years.

In order to defend the second law of thermodynamics, one must at a minimum resolve the following three simple thought experiments which challenge it.

First Thought Experiment

In the first thought experiment, consider a magnetocaloric material. In a thermodynamic cycle, the material is (1) compressed adiabatically by a piston in the absence of a magnetic field. See Figure 1 below. The magnetocaloric material is then (2) subjected to a magnetic field at constant volume, which reduces its specific heat capacity and increases its temperature and pressure via the magnetocaloric effect. In the magnetocaloric effect, the number of active rotational DOF of the molecules is reduced, resulting in a transfer of energy from rotational kinetic DOF into translational kinetic DOF. This increased energy in the translational DOF results in the observed increase in temperature and pressure. Note that this increase in temperature occurs adiabatically, i.e. without an external heat source. The material thus experiences an adiabatic reduction in its entropy (due to the reduction in the number of available states, or DOF).

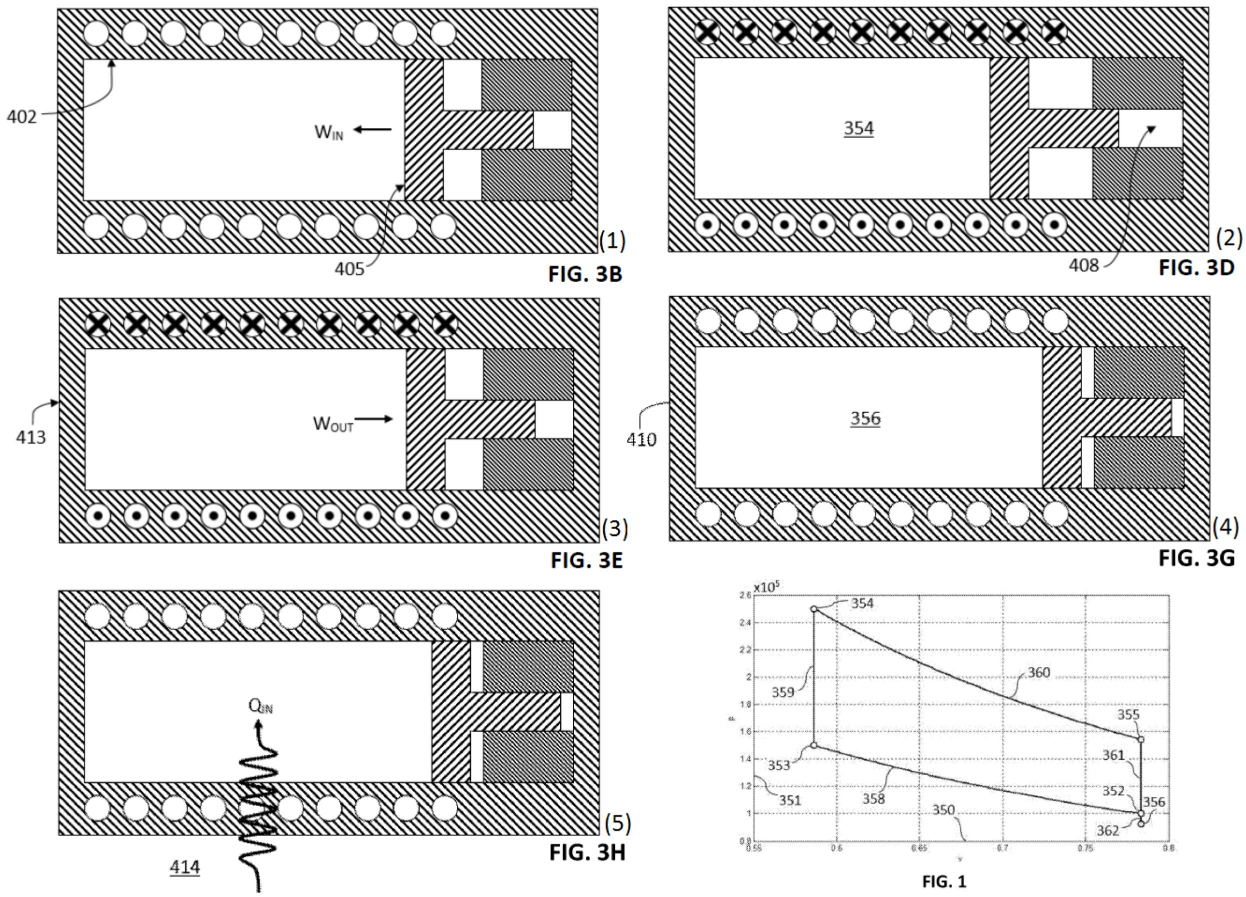

Figure 1 – Thermodynamic Cycle for first thought experiment: (1) Adiabatic compression of magnetocaloric material. (2) Magnetization of material. (3) Adiabatic expansion of magnetized material. (4) Demagnetization of material (5) Heat addition from environment. Patent application 16/509,491 from 2018-07-11.

In the next phase of the cycle, (3) the material then does work adiabatically against the piston while the magnetic field remains unchanged, and the specific heat capacity remains small. Note that, for a gas, the ratio of specific heats has been increased by the magnetization due to the magnetocaloric effect. This increases the slope of the adiabatic expansion curve on the p-v diagram. Note that the pressure of the material is larger due to the magnetization and the associated transfer of energy into the translational kinetic DOF, i.e. the DOF which are responsible for the pressure of the material. Therefore, more work can be recovered from the material during phase (3) than is done on the material during phase (1). The expansion continues until the initial volume has been reached. Typically, the pressure is still higher than the initial pressure at this point.

Subsequently (4) the magnetic field is turned off at constant volume, and the specific heat capacity increases to its original value, and the temperature and pressure reduces. Energy is transferred from the translational kinetic DOF into the newly available rotational kinetic DOF. This demagnetization amounts to an adiabatic increase in entropy of the material. Note that the electric work done on the material during the magnetization can be recovered during the demagnetization, with the exception of any losses to electrical resistance, which is lost in the form of Joule heating to the environment.

Because more work was done by the material on the piston during phase (3) than was done by the piston on the material during phase (1), the material is now cooler and at a lower pressure than it was initially, i.e. the total specific entropy has been reduced. This is due to the first law of thermodynamics: no heat was exchanged with the environment, but a net amount of work was done by the material. In order to return to its initial position and complete the cycle, the material therefore needs to (5) absorb heat from the environment or a single heat reservoir at constant volume. This cycle can be modeled with a hypothetical magnetocaloric ideal gas, for example. Thus a large portion of the heat absorbed from a single heat reservoir can be converted into work. The remaining portion of the heat absorbed is converted into heat by frictional losses and returned to the environment or to the single heat reservoir. This violates the Kelvin-Planck statement of the second law of thermodynamics.

When heat is removed from the material between the phases (2) and (3) of the cycle and delivered to a hot second thermal reservoir, then the cycle can also be used to transfer heat from a cold reservoir to a hot reservoir without consuming a net amount of work. This violates the Clausius statement of the second law of thermodynamics.

Second Thought Experiment

In a second thought experiment, consider an ideal gas subject to a body force, such as gravity. The gas will develop a temperature and pressure gradient, just like the temperature and pressure gradient in the atmosphere of earth. The formula for the temperature variation is given by the Navier-Stokes equations, or the equation for enthalpy: $dh=cp\ dT=-g\ dz$. The temperature variation is thus linear with altitude, and the gradient is $-g/cp$. Note that the temperature variation within a gas depends on the specific heat capacity of the gas. This variation comes out to -10/1004 for air, or -0.01 Kelvin per meter, which we also see in the atmosphere (https://en.wikipedia.org/wiki/Barometric_formula). This is why mountain tops are colder than mountain bottoms. At a rate of -0.01 Celsius per meter, the temperature can be 30 degrees Celsius at sea level, and 0 degrees Celsius at a mountain peak 3 km above sea level, for example.

Now consider two different gases in two fully enclosed and thermally insulated 1-meter long containers. The gases are subject to an approximately uniform body force 10,000 times stronger than gravity (e.g. via centrifugal 'acceleration') along the length of the containers. See Figure 2 below. One gas can be Hydrogen, with a specific heat capacity of 14,300 J/kgK, and the other gas can be Argon, with a specific heat capacity of 520 J/kgK. Over the 1 meter length of the container, the insulated Hydrogen gas will develop a temperature difference of (-100,000/14,300) *1=-7 degrees Kelvin between the bottom and top, with the bottom being warmer than the top. The Argon will develop a temperature difference of (-100,000/520) *1=-192 degrees Kelvin between the bottom and the top of the container.

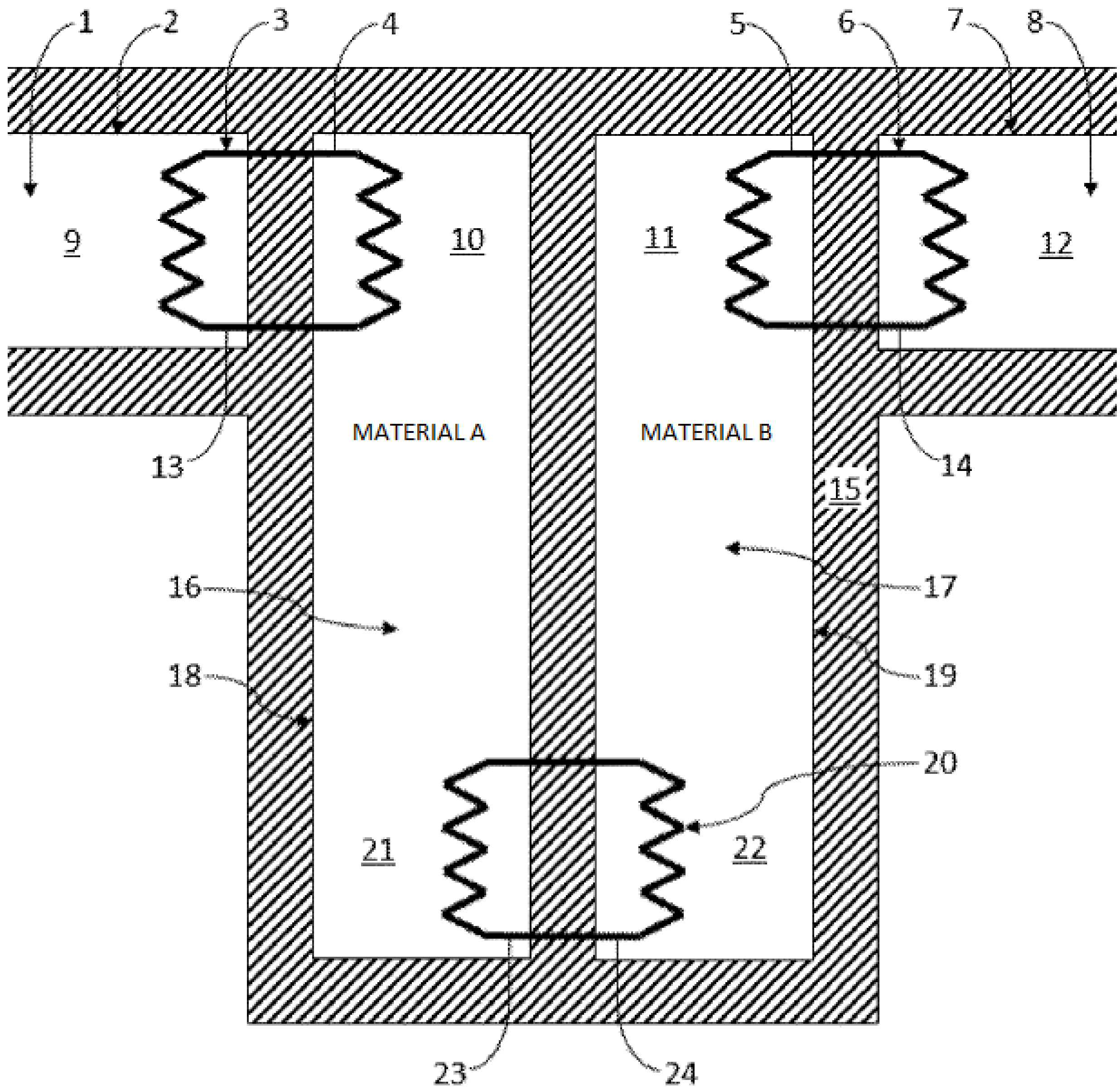

Figure 2 – Second Thought Experiment. Material A = Argon. Material B = Hydrogen. Both materials are subject to a body force (e.g. gravity or centrifugal loads), resulting in an artificial linear temperature gradient with slope –g/cp. Because the specific heat capacity at constant pressure of Argon is much smaller than of Hydrogen, temperature difference in Argon between stations 10 and 21 is much larger than temperature difference in Hydrogen between stations 11 and 22. This difference in the difference in temperature results in larger temperature at station 12 compared to station 9. This allows temperature amplification. Patent application 16/185,772 from 2017-11-10.

The absolute temperatures at the bottom and the top of the containers will depend on the boundary conditions. Now connect the top of the container containing Argon via a thermal contact (i.e. a heat exchanger), to an infinitely large heat reservoir, such as the atmosphere of earth, called “reservoir A”. Let this reservoir be at 300 degrees Kelvin. In this case, the temperature of the Argon at the top will be 300 K, and the temperature at the bottom it will be 492 K. The temperature varies linearly with altitude, i.e. position along the length of the container relative to the bottom of the container. The pressure and density are determined by the amount of gas in the container, vary adiabatically with temperature, and are not important in this thought experiment.

Now consider the bottom of the container containing Hydrogen being thermally connected to the bottom of the container containing Argon. In this case, the temperature of the Hydrogen at the bottom will be 492 K, just like the Argon at the bottom, due to the boundary condition provided by the infinitely large reservoir A. The temperature at the top of the container containing Hydrogen will be 7 K less, i.e. 485 K. Note that the top of the container containing Hydrogen is at the same altitude, i.e. the same potential energy level, as the top of the container containing Argon.

Now consider a finite thermal reservoir, such as a gas or steam container, called “reservoir B”, being thermally connected to the top of the container containing the Hydrogen. Because reservoir A is infinite in size, the boundary condition provided by reservoir A, i.e. the atmosphere of earth, dictates the temperature in the finite Argon container, the finite Hydrogen container, and the finite reservoir B. In equilibrium, therefore, reservoir B will be at 485 K, just like the Hydrogen at the top, when reservoir A is at 300 K. To summarize, the thermal connection between reservoir B and reservoir A is formed by the two containers containing Argon and Hydrogen, where the Argon and Hydrogen are subject to the same uniform body force.

Now consider a second finite reservoir, called “reservoir C”, which can be brought into thermal contact with finite reservoir B at will. When reservoir C is at a temperature which is less than 485 K at the point in time at which reservoir C is brought into thermal contact with reservoir B, then heat will flow from reservoir A at 300 K through the Argon gas, the Hydrogen gas, reservoir B and into reservoir C. This heat will flow until the temperature in reservoir C has been brought to 485 K and equilibrium is restored.

In conclusion, heat can be made to flow from a cold reservoir at 300 K to a hot reservoir at a temperature less than 485 K, such as 400 K. The thermal connection between reservoir B and reservoir A can therefore be described as a “temperature amplifier”. The temperature amplifier can be used to allow heat to flow from a cold reservoir to a hot reservoir, which violates the Clausius statement of the second law of thermodynamics.

The temperature difference between reservoir B and reservoir A can also be used to power a conventional heat engine, such as a Carnot engine, or a steam engine. Thus the temperature amplifier can be used to convert heat from a single reservoir into work, which violates the Kelvin-Planck statement of the second law of thermodynamics.

Third Thought Experiment

In a third thought experiment, consider a thin circular plate. The plate is irradiated by uniformly distributed parallel rays of photons perpendicular to the plane of the plate. For simplicity, the intensity of the irradiation is equal in magnitude for both sides of the plate and uniform in space and time. The photons incident on the top side of the plate, denoted “side A”, can be considered to be the thermal radiation which originates from a first thermal reservoir, denoted “reservoir A”. The photons incident on the bottom side of the plate, denoted “side B”, can be considered to be the thermal radiation which originates from a second thermal reservoir, denoted “reservoir B”. The reservoirs A and reservoirs B can be identical, small, spherical black bodies located at the focal points of a parabolic mirror. See Figure 4 below. The mirrors can be configured to parallelize the photons emitted by the thermal reservoirs, such that the thermal radiation from the thermal reservoirs incident on the side A and side B of the plate is indeed parallel and uniformly distributed in space and time.

On side A the plate contains a closely-spaced array of large convergent convex lenses configured to focus the parallel photons incident on side A onto an array of an equal number of small divergent concave lenses. See Figure 3 below. The lenses are configured to be perfectly transparent to the photons in this simplified example. The small divergent lenses sit at the opening of channels in the plate, which allow photons from side A to pass through to side B, and vice versa. Parallel photons which are incident on side A and pass through a converging lens are redirected from a converging path back onto a parallel path by the subsequent encounter with the diverging lens, where a parallel path is a path perpendicular to the plane of the plate and parallel to each other. Similarly, parallel photons which are incident on side B and pass through a channel and through a diverging lens are also redirected from a diverging path back onto a parallel path by the subsequent encounter with the converging lens.

The surfaces on side A or side B of the plate which are not covered in converging lenses or channels are perfectly flat and perfectly reflective to the photons in this example. The surface on side B which is not covered by channels is larger than the surface on side A which is not covered by converging lenses. All parallel photons which are incident on these reflective surfaces are reflected back along the parallel path from which they came, and back into the thermal reservoir from which they originated.

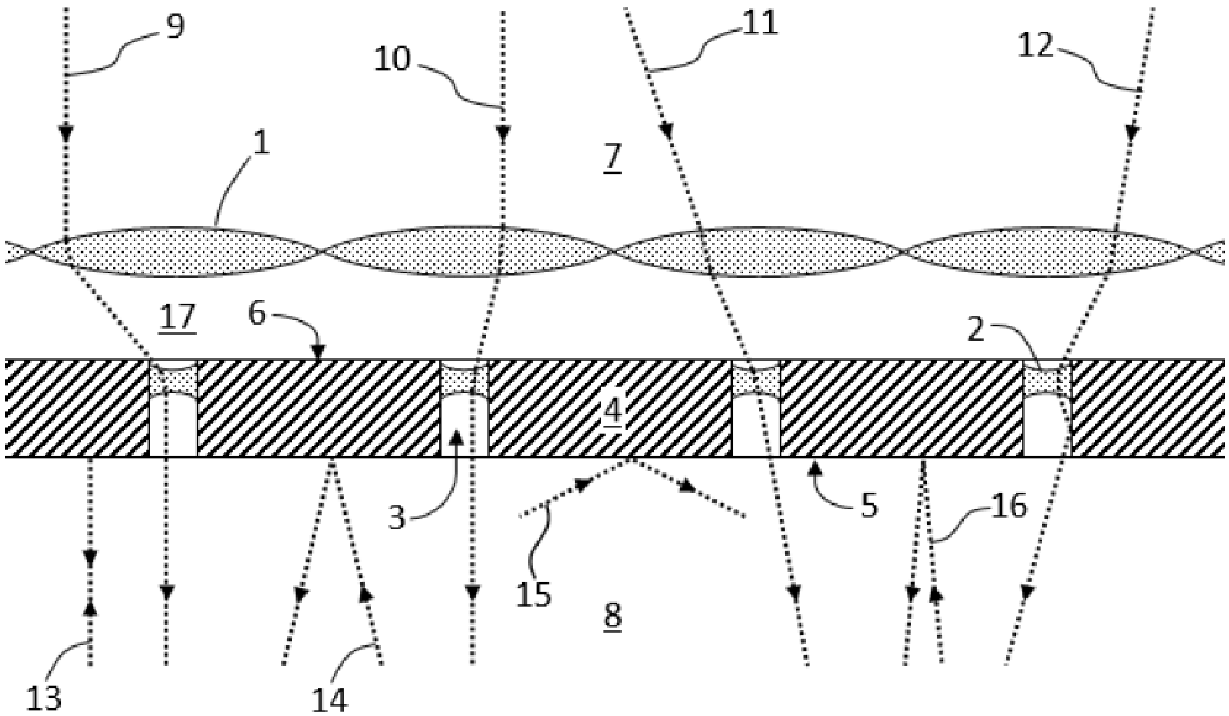

Figure 3 – Third Thought Experiment. Plate in Cross-sectional view. Converging lenses (1) focus photons (11) towards diverging lenses (2) sitting at the openings of channels (3). Plate otherwise has reflective surfaces (5). Photons coming from side A (7) have a higher likelihood of passing to side B (8) through a converging lens, a diverging lens, and a channel, compared to photons coming from side B (8) and passing to side A (7) through a channel, a diverging lens and a converging lens. The difference in transmissivity allows temperature amplification. Patent application 16/273,139 from 2018-02-09.

All the parallel photons from reservoir A which are incident on the surface on side A which is covered in converging lenses are transmitted through to side B, where they are subsequently incident on and absorbed by reservoir B. Similarly, all the parallel photons from reservoir B which are incident on the surface on side B which is covered in channels are transmitted through to side B, where they are subsequently incident on and absorbed by reservoir B. Due to the focusing effect of the converging lenses on side A, the surface on side A which is covered in converging lenses is larger than the surface on side B which is covered in channels. As a result, the percentage of photons which are incident on side A and pass through to side B is larger than the percentage of photons which are incident on side B and pass through to side A. The transmissivity of the plate to photons incident on side A is larger than the transmissivity of the plate to photons incident on side B. The plate can be considered to be a “geometric diode”.

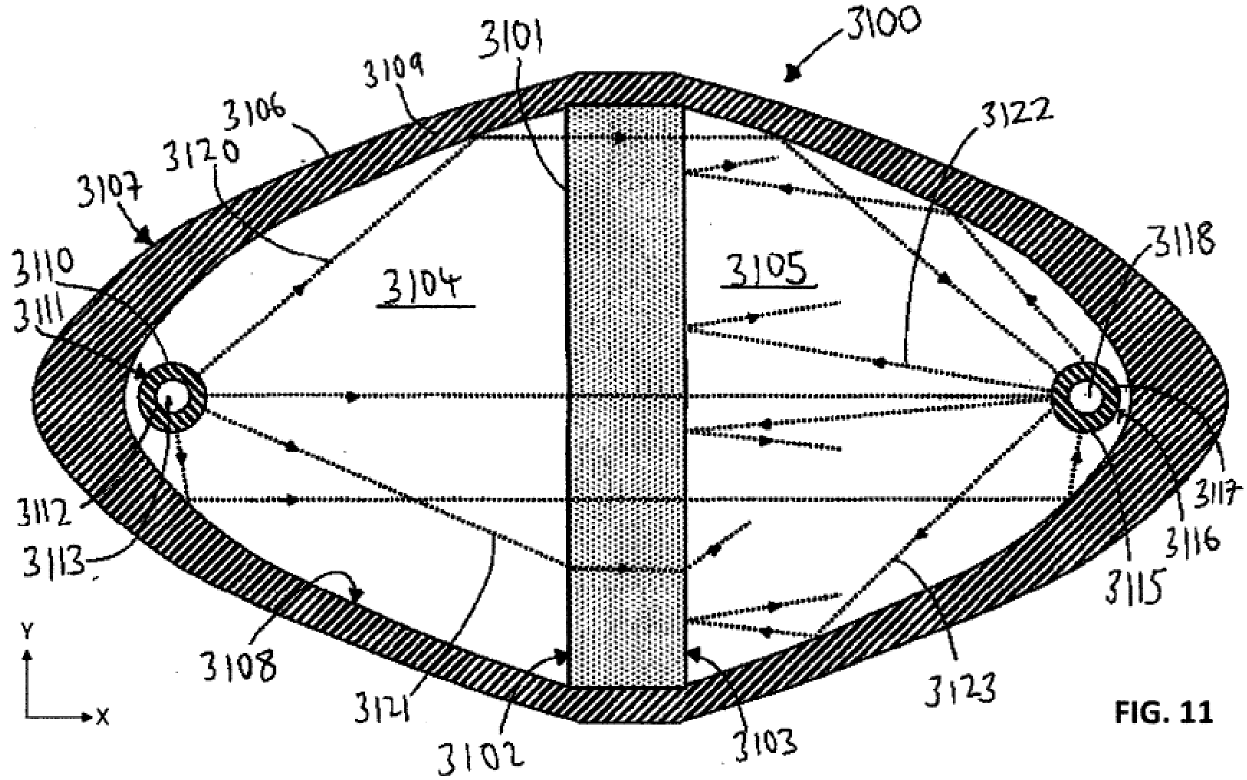

Figure 4 – Third Thought Experiment. Parabolic Mirrors (such as 3108), re-direct and parallelize the thermal radiation from thermal reservoir A (3110) and thermal reservoir B (3115) onto plate (3101). Plate preferably allows the passage of thermal radiation from side A (3102) to side B (3103) compared to passage of radiation from side B to side A. Patent application 16/278,705, from 2018-02-18.

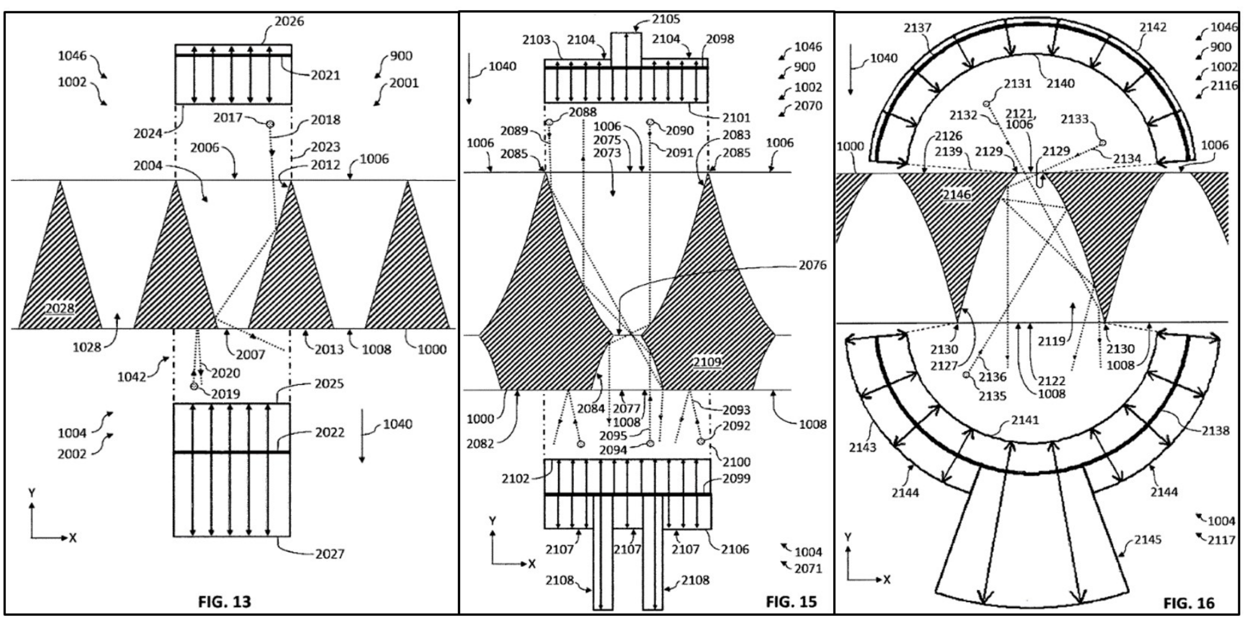

Figure 5 - Third Thought Experiment. Three other examples for geometric diodes. Figure shows plates with an array of conical holes in a cross-sectional view. Left and Middle: Particularly useful for particle or photon trajectories which are normal to the plane of the plate and parallel to each other, as shown in Figure 4. Right: Particularly useful for particle or photon trajectories which are anisotropic, i.e. arranged in arbitrary in directions, as is the case for trajectories of molecules in a gas. Patent application 16/273,139 from 2018-02-09.

Due to the difference in transmissivity, a larger percentage of photons emitted by reservoir A is transmitted to reservoir B compared to the percentage of photons emitted by reservoir B and transmitted to reservoir A. This results in a net heat flux from reservoir A to reservoir B in the case in which both reservoirs are emitting the same intensity of photons, i.e. when both reservoirs are at the same temperature. The net heat flux from reservoir A to reservoir B will persist until the temperature of reservoir B is sufficiently larger than the temperature of reservoir A, such that the heat flux from reservoir A to B is equal to the heat flux from reservoir B to A. In equilibrium, therefore, the temperature of reservoir B is larger than the temperature of reservoir A. In the process of reaching equilibrium, heat can be made to flow from a colder reservoir A to a hotter reservoir B.

The plate between reservoir B and reservoir A can therefore be considered to be a "temperature amplifier". This also appears to disprove the Clausius and Kelvin-Plank statements of the 2nd law of thermodynamics.