AAAS Conference: "2nd Law Challenges" University of San Diego 2016

Maxwell Demons by Phase Transitions Severing the link between Physics and Information Theory

Remi Cornwall
University of London Alumni Society, Malet Street, London WC1E 7HU
http://webspace.qmul.ac.uk/rocornwall http://www.researchgate.net/profile/Remi_Cornwall

Abstract

The search for new power sources has increasingly challenged the second law of thermodynamics; one such cycle is presented herein with both experimental and rigorous theoretical underpinnings. These analyses, both kinetic and thermodynamic inevitably lead to the Maxwell Demon problem. It is clear that, against the Szilard-Brillouin-Landauer argument, that phase transition processes in conjunction with the cycle and apparatus requires no molecular information to be kept, negating the argument and need that the demon's entropy change by 1/2kTln 2 per molecule processed. The Demon was thought to bring Information into the fold of Physics. We ask the question, if all computing can be made reversible by heat recovery and furthermore, if the speed of information appears not to be limited by Relativity, due to the author's protocol to send classical data over an entangled Bell Channel, if the Landauer maxim, "Information is Physical", is entirely true?

1. Introduction

Thermodynamics is eclectic covering "prosaic concerns" of steam engines and power generation for a burgeoning 21st century civilisation, Life, Cosmology and even Information Theory. It is inevitable, just as its inception, that practical concerns have the deepest impact in theoretical physics. Given the spate of publications challenging the second law[1-4], we present a new thermodynamic cycle which bears similarity to conventional magneto-calorific effect devices but extends the theory beyond these realms, whilst keeping a footing firmly in experimental actuality by utilising thermodynamics, kinetic theory and the magneto-dynamics of ferrofluids.

The next section finds the underlying reason of why such processes are permitted and links trajectories on a T-S diagram (or P-V diagram), in conventional thermodynamic reasoning regarding cyclical processes, to the working substance undergoing phase change, to a molecular sorting process viewed from the kinetic theory perspective. This clearly invokes Maxwell's Demon. The flaws in the anti-demon arguments are then recounted to note that natural kinetic processes require no computing equipment, memory storage or erasure of memory step; the sorting is inherent.

Finally the author briefly summarises their work in another field that asks the question, "What is the ultimate speed of information"? The Demon problem was meant to bring Information into the sphere of physical understanding by the link with thermodynamics, if de-facto reversible computing is possible by heat recovery by the cycles discussed herein and elsewhere *and furthermore*, the speed of information transit is not governed by Relativity, how can Landauer's claim that "Information is physical" be entirely true? Information appears to take on *at least* a mathematical, if not *metaphysical* aspect.

2. The Limitation of Magneto-calorific Effect Carnot cycles

We shall focus on magnetic heat engines to arrive at our second law challenging mechanism. First, the state of the art in conventional magneto-calorific effect engines is discussed, to reassure the reader about the commonplace phenomena and analysis and where the train of thought can lead one, if not least to show that conventional thought is creaking at the seams. The impetus for magnetic heat engine research is the potential of having machines with few moving parts, high efficiency and low environmental impact.

Magnetic heat engines need a variation of magnetisation with temperature and two effects are noted: the force experienced by magnetic materials in an external field[5-7] ($\mathcal{M}$ is the volume magnetisation) and the magneto-caloric effect[8-11].

$$F = -\nabla\left(\mathcal{M}\cdot\mathbf{B}\right) \qquad \text{eqn. 1}$$

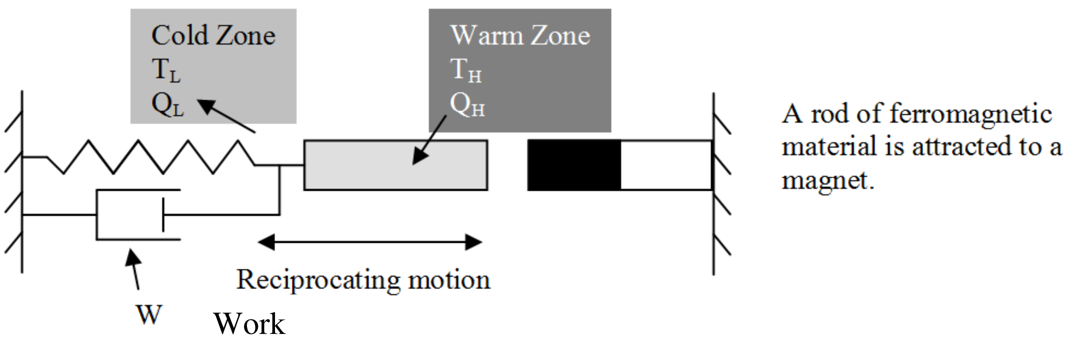


Figure 1 – A Simple Reciprocating Magnetic Motor

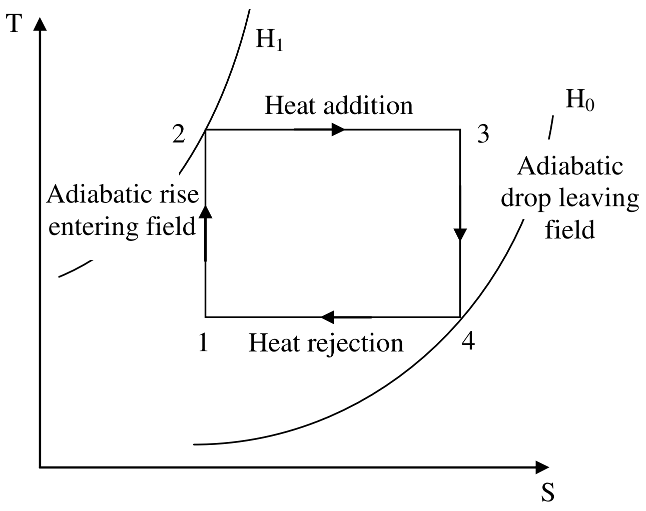


Figure 2 – T-S diagram, Magnetic Heat Engine

Figure 1 shows a means to convert heat energy to work by a simple reciprocating motor. A rod of ferromagnetic material is attracted to a magnet and does work against a spring. However at the same time near the magnet it is heated, absorbing heat Q_H, above its Curie temperature (the temperature above which the material becomes paramagnetic) with the result that its moment, $\mathcal{M}$, becomes smaller. Consequently the force on rod diminishes and it is retracted into the cold zone rejecting heat Q_L into the lower reservoir. Useful work is shown as being merely dissipated in the dashpot.

Thermodynamic analysis can be quickly performed by analysing this heat engine as two adiabatic processes alternated with isothermal processes (fig. 2). The Thermodynamic Identity equates the change in heat to the work around a cycle and thus the area on the T-S diagram is equivalent to multiplying the adiabatic temperature change on magnetisation by the isothermal change in entropy ([12] appendix 1),

$$\left(\Delta T\right)_S = -\frac{\mu_0 T}{C_H}\left(\frac{\partial \mathcal{M}}{\partial T}\right)_H \Delta H \qquad \text{eqn. 2}$$

$$\Delta S = -\mu_0 \left(\frac{\partial \mathcal{M}}{\partial T}\right)_H \Delta H \qquad \text{eqn. 3}$$

Thus,

$$W = \int_{H_0}^{H_1} \frac{\mu_0 T}{C_H}\left(\frac{\partial \mathcal{M}}{\partial T}\right)_H dH \cdot \int_{H_0}^{H_1} \mu_0 \left(\frac{\partial \mathcal{M}}{\partial T}\right)_H dH \qquad \text{eqn. 4}$$

Or approximately,

$$W \approx \frac{\mu_0^2 T}{C_H}\left(\frac{\partial \mathcal{M}}{\partial T}\right)_H^2 \left(\Delta H\right)^2 \qquad \text{eqn. 5}$$

The magneto-caloric effect (MCE) can also be used to refrigerate/pump heat and the MCE Carnot cycle's TS diagram is just the reverse of figure 2.

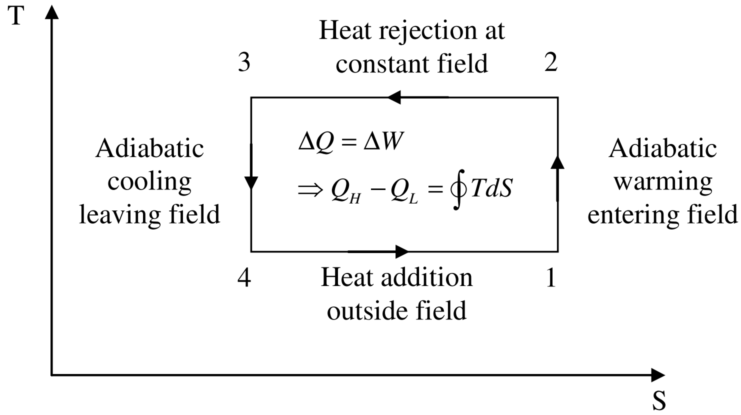


Figure 3 – T-S diagram MCE Carnot Refrigerator

2.1 The Limitation of MCE Carnot cycles

The heat engines discussed previously are more practically realised by heat transfer at constant magnetic intensity in the magnetic analogy of Brayton and Ericsson cycles[13] (figures 4 and 5). The former cycle performs heat transfer when the magnetic intensity is higher and thus achieves a higher temperature range and heat transfer between the magneto-caloric material and the heat transfer fluid. Figure 4 shows this as two adiabatic processes and two constant intensity processes. Process 2a-3 is an additional cooling caused by a regenerator that exchanges heat with process 4a-1. The Ericsson cycle heat pump features isothermal magnetisation and demagnetisation processes with regeneration at processes 2-3 and 4-1. Since the heat exchange process of regeneration in both cases requires a finite temperature difference, this is an irreversible process and so is a decrease in the efficiency of both cycles compared to the Carnot cycle.

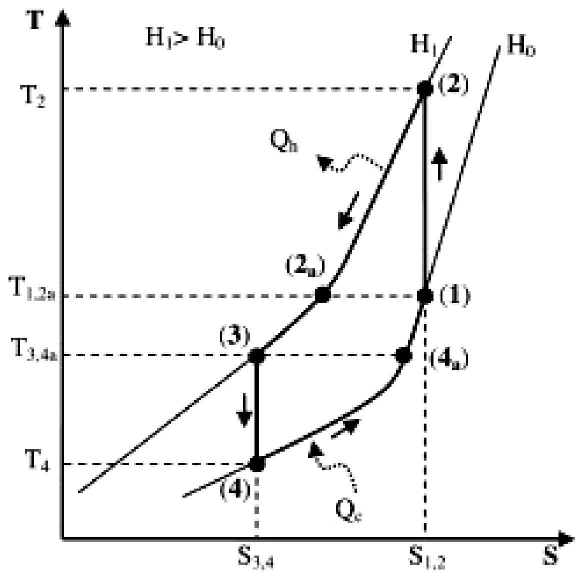


Figure 4 – Magnetic Brayton cycle

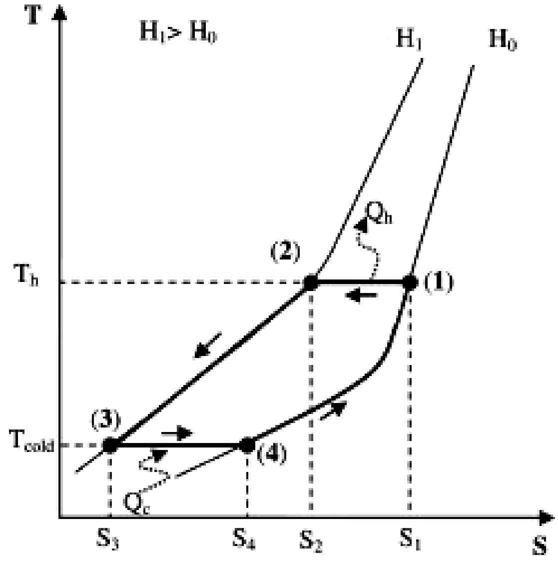


Figure 5 – Magnetic Ericsson cycle

Cornwall[12] and Gschneidner et-al[13] go into more detail about cascade Ericcson and the Active Magnetic Regeneration cycle but what is important to the research community is improving the magneto-caloric effect at the core of these cycles. A number of desirable material features are listed[13, 14]:

- Low Debye temperature[15].
- Curie temperature near working temperature.
- Large temperature difference in the vicinity of the phase transition.
- No thermal or magnetic hysteresis to enable high operating frequency and consequently a large cooling effect.
- Low specific heat and high thermal conductivity.
- High electrical resistance to avoid Eddy currents.

Gadolinium alloys and Lanthanum-Iron-Colbalt-Silicon alloys, $La(Fe_{1-x}Co_x)_{11..9}Si_{1.1}$ with their "giant magneto-caloric effect" are the focus for materials research due to their inherent high MCE although traditional ferromagnetic materials enter the scene again in the form of colloidal suspensions called ferrofluids.

3. Detail on the new Temporary Remanence Cycle

We present now a new type of cycle based upon a feature of so-called super-paramagnetic materials called Temporary Remanence, unused in current heat engines, that has a wide temperature range of operation by being able to boost (eqn. 15) the MCE effect by a phenomenon called "dipole-work" (eqn. 6, Cornwall[12], fig. 9 and sec. 3.3). It is possibly easier to present the cycle first from the kinetic theory viewpoint *then* the thermodynamics viewpoint, whereupon the last presentation will link with the previous discussion about the thermodynamics of conventional MCE engines; we shall see that the arguments flow on logically from convention (eqn. 15). Finally we shall discuss the electrodynamics of the process, which is mainly a crucial engineering concern.

$$W_{dw} = \int_{M,V} \mu_0 M dM \cdot dV = \frac{1}{2}\mu_0 M^2 V \qquad \text{eqn. 6}$$

This dipole-work leads to an extra term on the thermodynamic identity and is related to the Faraday Law collapse of the temporary magnetic flux generating power into a resistive load. This can be made greater than the magnetisation energy input,

$$E_{mag} = \int_{M,V} \mu_0 H dM \cdot dV = \mu_0 HMV \qquad \text{eqn. 7}$$

The difference come from the heat energy converted (secs. 3.1 and 3.2) into work. Thus the heat engine generates electrical power directly and also cools.

In our research we use a stable nanoscopic suspension of magnetic particles in a carrier fluid called ferrofluid[11]. The particles are so small that they are jostled continuously by the Brownian motion. As a consequence they on magnetisation display "super-paramagnetism"[9, 11, 16] which on the spectrum from diamagnetism to anti-ferro/ferrimagnetism to paramagnetism to ferri/ferromagnetism, displays properties similar to both paramagnetism and ferri/ferromagnetism: they display no permanent remanence but are somewhat easy to saturate compared to paramagnets due to their large spin moment. Temporary remanence is manifest by two mechanisms:

$$\text{Néel:} \quad \tau_N = \frac{1}{f_0} e^{\frac{KV}{kT}} \qquad \text{eqn. 8}$$

And

$$\text{Brownian:} \quad \tau_B = \frac{3V\eta_0}{kT} \qquad \text{eqn. 9}$$

The first relaxation rate can be understood as internal to the ferrofluid particle and involves lattice vibration and hence it contains the energy term KV related to the crystalline anisotropy constant and the volume of the particle. The latter is related to the jostling of the particle by the suspending fluid and contains an energy term related to the viscosity of the suspending fluid and the volume. Nature uses the principle of least time to determine which dominates the relaxation rate. Obviously these quantities are amenable to engineering.

Another feature they display on rapid magnetic cycling is hysteresis loss[17, 18]. This is most pronounced if the rate of magnetisation is comparable to the relaxation rate. The phenomenon is directly related to the Fluctuation-Dissipation Theorem.[19].

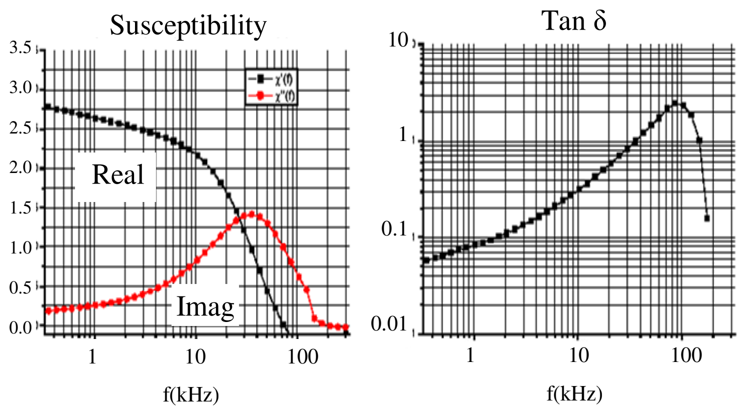


Figure 6 – Hysteresis loss in typical ferrofluid (Courtesy Sustech Gmbh)
LHS Bodé plot in and out-phase components, RHS: Power loss angle

The cycle (called a micro-cycle) is implemented as a magnetising step followed by a de-magnetising step:

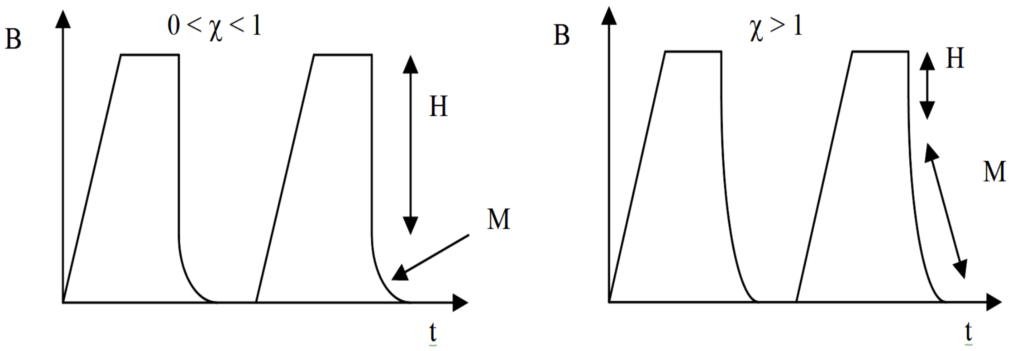


Figure 7 – *Micro-cycle* magnetising pulses
for 0 < χ< 1 and then χ> 1

The figure above shows a train of magnetising pulses for two cases, small and large susceptibility[9]. Observe how the switch-on phase is slow, so that significant hysteresis loss isn't incurred and the switch-off is abrupt to leave a temporary remnant flux (the "Independent Flux Criterion" sec. 3.3.1). Micro-cycles are completed many times a second and result in an adiabatic cooling of the ferrofluid working substance.

To complete the heat engine, the working substance needs to be placed in contact with an external (albeit only one) reservoir. The plant diagram or macro-cycle is depicted in the next figure. In this figure, the micro-cycles happen many times as the working substance transits the "power extraction area" A-B.

For the purposes of argument, let us dispel concerns about the pressure-volume work that must be expended circulating the fluid against its tendency to be drawn into the magnetised power extraction area by saying there is a portion of the operation when the magnetising fields are switched off and fluid is simply pumped further around to the heat exchange area C-D.

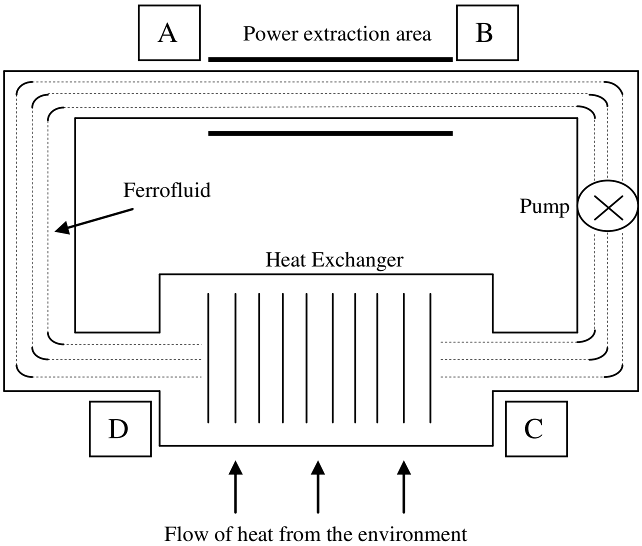


Figure 8 – Plant Diagram (*Macro-cycle*)

We shall develop the theory of the temporary remanence (TR) cycle heat engine by three intersecting analyses: Kinetic Theory, Thermodynamic and Electrodynamic Theories.

3.1 Kinetic Theory

In the thesis[12] a lattice of magnetic dipoles is set up to model the ferrofluid (fig. **9**).

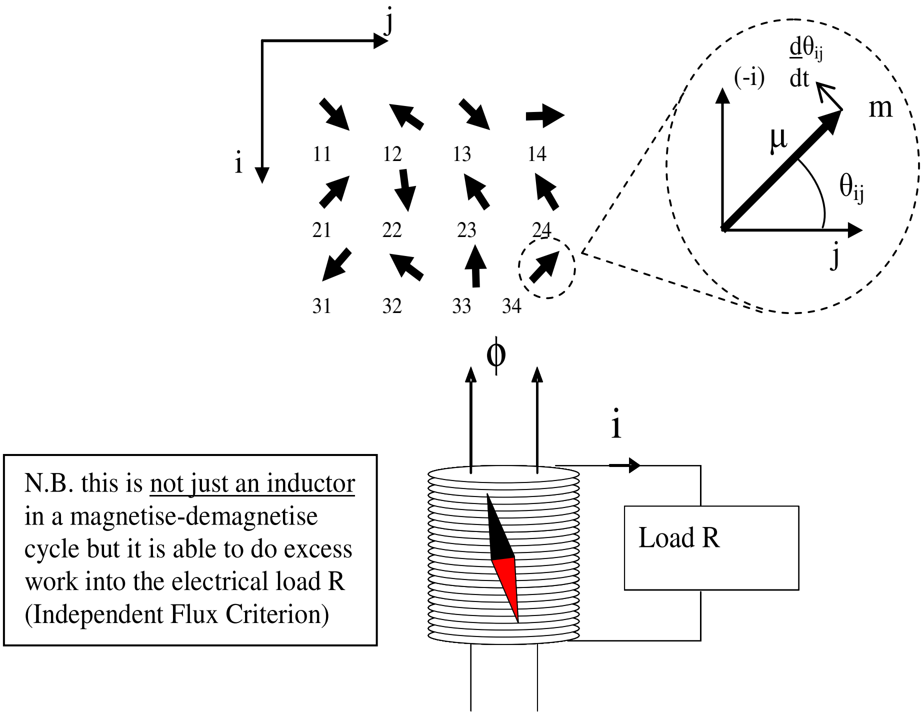


Figure 9 – The Kinetic Theory Model

The model of dipole-dipole interactions leads to the angular acceleration of each dipole:

$$\ddot{\theta}_{ij} = \frac{1}{I}\left(-k_{dip} \sum_{\substack{ii=i-1,\\ jj=j-1\\ ii\neq i \wedge jj\neq j}}^{\substack{ii=i+1\\ jj=j+1}} \tau\left(\theta_{i,j},\theta_{ii,jj},\mathbf{m},\mathbf{r}\right) - \mathbf{m}_{ij}\times\mathbf{B}_{ext} \right) \qquad \text{eqn. 10}$$

The torque experienced by each dipole is from the external field of the solenoid (B_{ext}) and the dipole-dipole interactions resulting from the local fields of its neighbours:

$$\tau\left(\theta_{ij},\theta_{ii,jj},\mathbf{m},\mathbf{r}\right) = -\mathbf{m}_{ij}\times\overline{\mathbf{B}_{local.neighbour}} \qquad \text{eqn. 11}$$

Taken as a bulk effect, this is of the form const x MdM or the dipole-work[12] () where $B = \mu_0 M$

The model can be run as a molecular dynamics simulation and the author attempted this to good success, apart from the lack of convergence or *Energy Drift* in these type of simulations from use of non-sympletic algorithms[20]. It wasn't thought worthwhile to pursue this further when, as we shall see, analytical solution exists. Nethertheless the entropies of position and velocity and the temperature are calculated:

$$\begin{aligned} S_{pos} &= const \times \ln\left(\text{standard deviation } \theta_{ij}\right) \\ S_{vel} &= const \times \ln\left(\text{standard deviation } \dot{\theta}_{ij}\right) \\ T &= const \times \text{average}\left(\dot{\theta}_{ij}^2\right) \end{aligned} \qquad \text{eqn. 12}$$

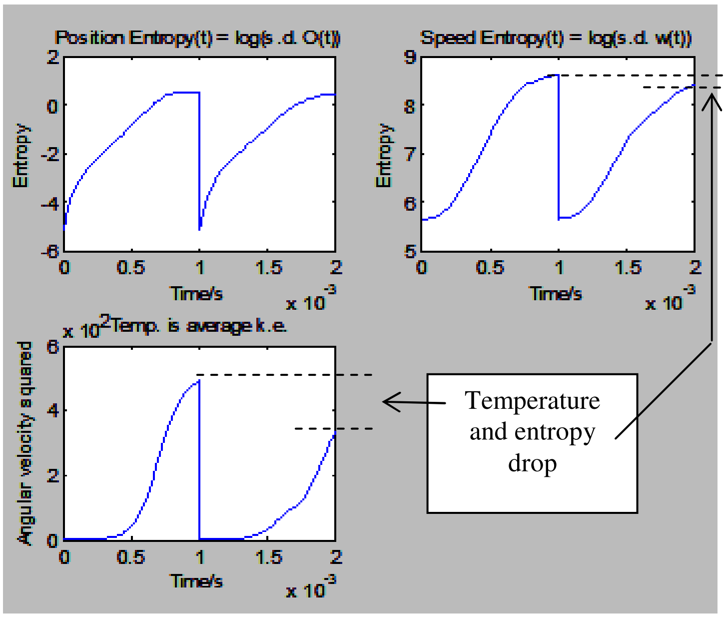


Figure 10 – Relaxing to equilibrium and then the same but with dipole-work

Two simulations were performed, one after the other: In the first simulation the dipoles were all aligned at the start with zero kinetic energy. The simulation shows this "relaxing" to a random orientation (the position entropy increases). The potential energy at the start is converted into random kinetic energy (hence the temperature rises as does the velocity entropy).

The second simulation following right after for comparison models relaxation with dipole-work, that is, the assembly generates electrical work which leaves the system and gets dumped into the resistive load.

An analytical solution[12] can be obtained by the statistical averaging of the ensemble eqn. 10:

$$\overline{I\ddot{\theta}_{ij} = -k_v m_{ij} \sum_{ii,jj} \frac{\partial}{\partial t}\left(m_{ii,jj}\cos\theta_{ii,jj}\right)\sin\theta_{ij}} \rightarrow I\ddot{\theta}_{ij} = -k_v\left(m_{ij}\sin\theta_{ij}\right)^2\dot{\theta}_{ij} \quad \text{eqn. 13}$$

Thus each dipole experiences a drag force (hence proportional to the angular velocity $\dot{\theta}_{ij}$) and slows (hence both temperature and entropy decrease) and this is directly related to the dipole-work (eqn. 11). This shows the mechanism for the transduction of heat energy from the working substance to the electrical load.

Kinetic Theory/Statistical Mechanics is the source of the Boltzmann expressions in equations 8 and 9. Anisotropy can be added to the model (eqn. 10) such that rotation cannot occur unless an energy barrier is exceeded. This has the obvious effect of slowing down the relaxation rate. It is shown ([12] section 2.1.3) that compared to the intrinsic anisotropy energy barrier for the ferrofluid, the additional energy barrier from the dipole-work is entirely negligible, thus kinetically the process of the magnetise-demagnetise TR cycle occurs.

3.2 Thermodynamics

The relation between Kinetic Theory, Statistical Mechanics and Thermodynamics is close. The first is a low-level description of single microscopic entities acting in concert; the next is a statistical description of a multitude of these low-level equations; finally thermodynamics relates bulk properties to average properties predicted by Statistical Mechanics.

To be a heat engine, the working substance must first have a property that is a strong function of temperature. This is immediately apparent in equations 8 and 9 with ferrofluid. However with conventional magneto-caloric effect (MCE) engines, focus dwells upon the paramagnetic-ferromagnetic transition and the Curie Point[9, 12]. In the author's thesis a link is made between the TR cycle (figures **7** and **8**) and conventional MCE engines by the thermodynamic identity:

$$dU = TdS + \mu_0 H d\mathcal{M} + \mu_0 M d\mathcal{M} \qquad \text{eqn. 14}$$

The last term is the dipole-work such that an amended delta-T equation is derivable by considering 2nd cross-derivatives ([12] section 2.2 and appendix 1) related to the change in magnetising field *and* remnant magnetisation:

$$\Delta T = -\mu_0 \frac{T}{C_H}\left(\frac{\partial \mathcal{M}}{\partial T}\right)_H \left[\Delta H + \Delta M_{rem}\right] \qquad \text{eqn. 15}$$

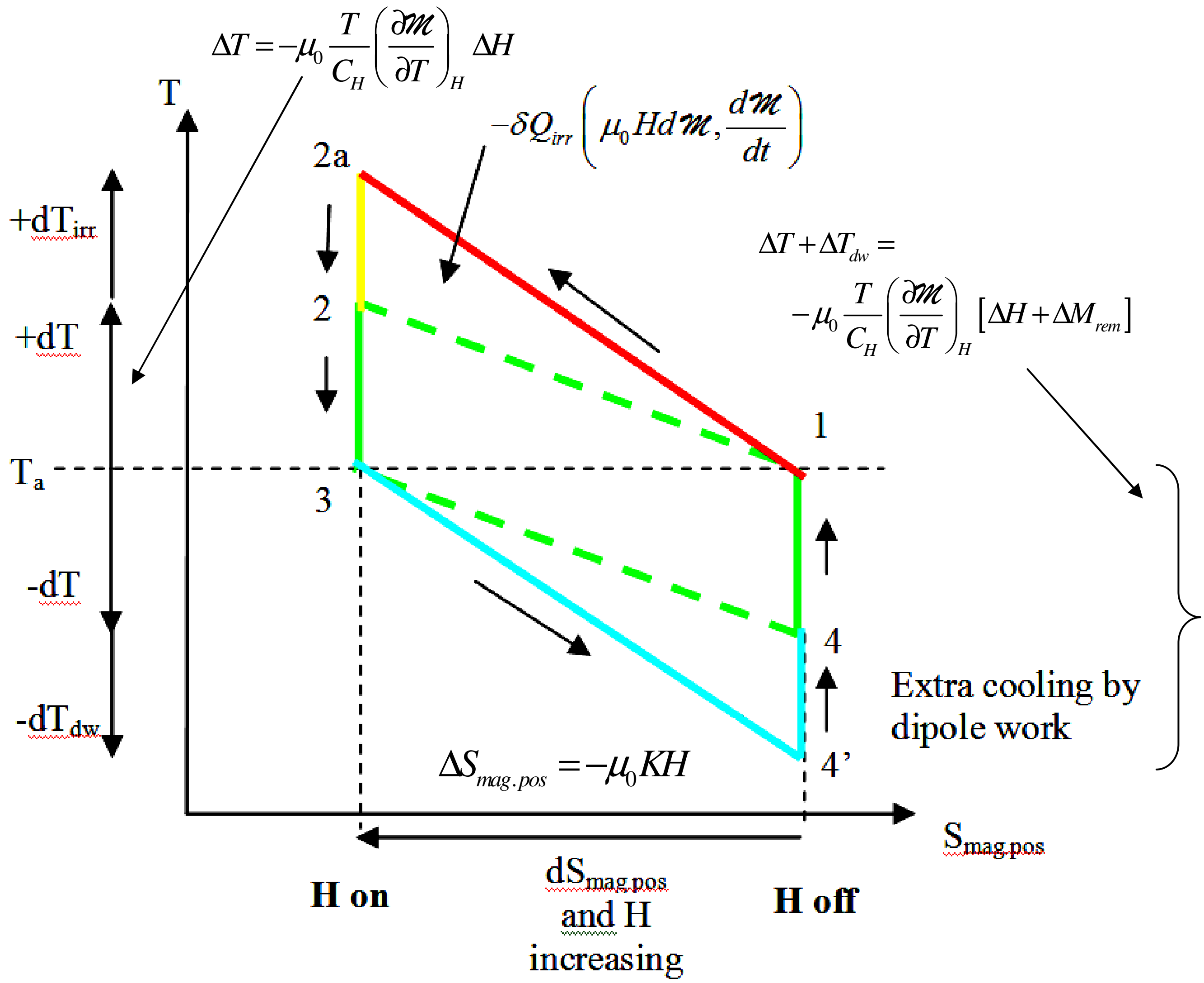


Figure 11 – Temperature- Positional Entropy Diagram for the micro-cycle

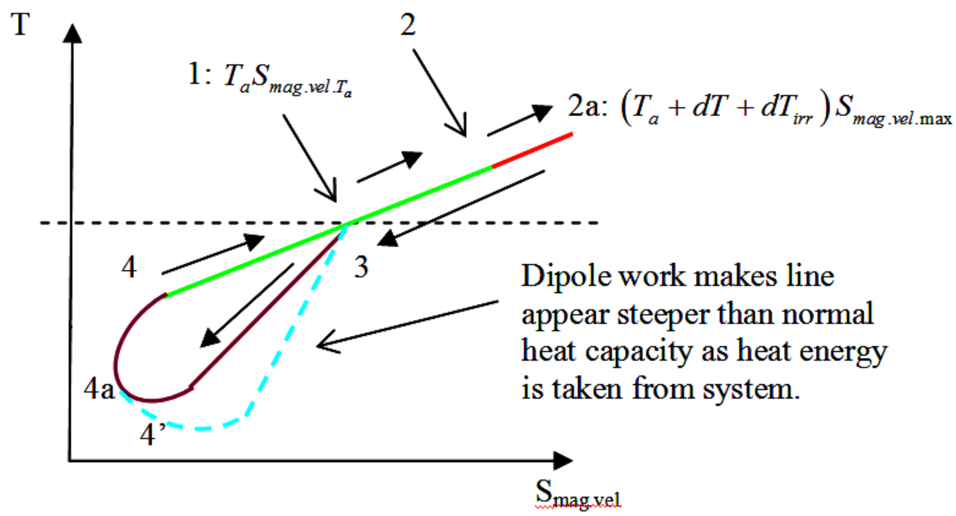


Figure 12 – Temperature- Velocity Entropy Diagram for the micro-cycle

This shows that, unlike conventional MCE cycles, the TR cycle can operate below the Curie point (so that ΔT on magnetisation from ΔH is negligible) because the magneto-caloric effect occurs from the new dipole-work term in equation 14. Also we point out that, although ΔT is small, the immense surface area of nanoscopic magnetic particles in contact with the ferrofluid carrier liquid ensures massive heat flow ([12] section 2.2.3).

It is possible to construct ([12] section 2.2.1 to 2.2.4) a temperature-entropy diagram for the micro and macro-cycles (figs. 11 and 12). The figures depict temperature entropy diagrams for an infinitesimal TR cycle. They are somewhat of an abstraction in that the cycle places the magnetic component of the ferrofluid in contact with the carrier fluid at set points in the cycle (2-3) and (4, 4'-1) and considers them thermally isolated for the rest, whereas in reality the magnetic and fluid systems are always in intimate thermal contact. Thermodynamics requires one to construct a series of states with discernable, stable thermodynamic parameters and this is difficult when the system passes through a series of meta-states.

Figure 11 depicts positional entropy which directly related to magnetic ordering hence the magnetic field of the working substance. The internal cycle represented by numbers 1-4 is the simple MCE in contact with a reservoir. The field switches on between 1 and 2 with the temperature of the working substance raising as the heat capacity is lowered by the magnetising field (the magnetic heat capacity falls and heat is repartitioned to mechanical/kinetic part of the system). Between 2-3 the magnetic system is placed in contact with the ferrofluid carrier liquid which acts as a virtual reservoir and heat is rejected to it. Then between 3-4 the magnetic part, isolated once again, has the magnetising field switched off whereupon the heat capacity rises and heat flows from the mechanical part of the heat capacity to the magnetic part once again such that the magnetic system drops below $T_{a,}$ the temperature of the carrier fluid. On step 1-4, the magnetic system is placed in contact with the fluid reservoir and heat flows from it to the magnetic system.

The TR cycle is an adjunct to the reversible MCE cycle in contact with an external reservoir at points 1-2a-2, which represents hysteresis heating of the magnetic component and 3-4'-4, which represents the extra cooling by dipole-work.

The step numbers correspond similarly the T-S diagram for the mechanical part of the heat capacity of the magnetic system (fig. 12). We see that it is once again based on the reversible MCE cycle in contact with an external reservoir at steps 1-2-3-4. The difference occurs at point 2-2a with the hysteresis heating (and hence heat transfer between 1-2 on figure 11) and dipole-work cooling 3-4'-4 and heat transfer on figure 11 between 4'-4-1.

One further point is the conversion of the magnetisation energy () into internal energy as the magnetising field is switched off at point 3-4. This is shown as an extra heat input 3-4a-1 in the diagram below and in figure 12 as steps 3-4'-4a-4-1.

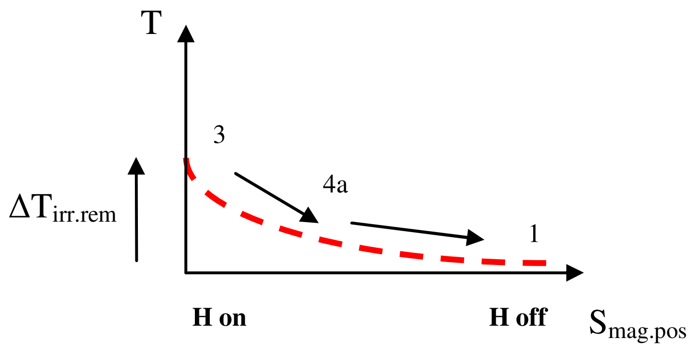


Figure 13 – The magnetising energy becomes internal energy

The consideration of these diagrams([12] appendices 6 and 7) allows the development of the energy balance equation:

$$-C_H \frac{d}{dt}(T_{mechanical}) = \frac{d}{dt}(Q_{external}) - \frac{d}{dt}(W) + \frac{d}{dt}(W_{irreversible}) \quad = \; 0 \qquad \text{eqn. 16}$$

This states the obvious really, that the internal energy is dependent on the heat dumped into the ferrofluid minus the dipole-work. Overall the combined T-S diagram for the positional and mechanical entropies of the working substance is shown in figure 14. Once again, at its core is the reversible MCE cycle 1-2-3-4.

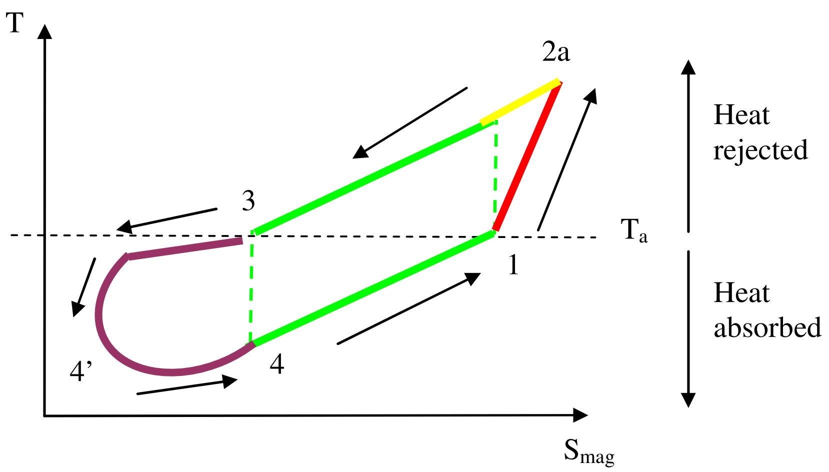


Figure 14 – Temperature-Entropy diagram for the Microcycle
Composed of the positional
and velocity T-S diagrams sub-cycles

As mentioned in the discussion about the plant diagram (fig. 8), the macro-cycle is made from many concatenated micro-cycles in the power extraction area. The micro-cycles cause the adiabatic cooling (if we neglect hysteresis heat inputs) of the ferrofluid working substance and we arrive at figure 15 (see [12] section 2.2.4 for original figure).

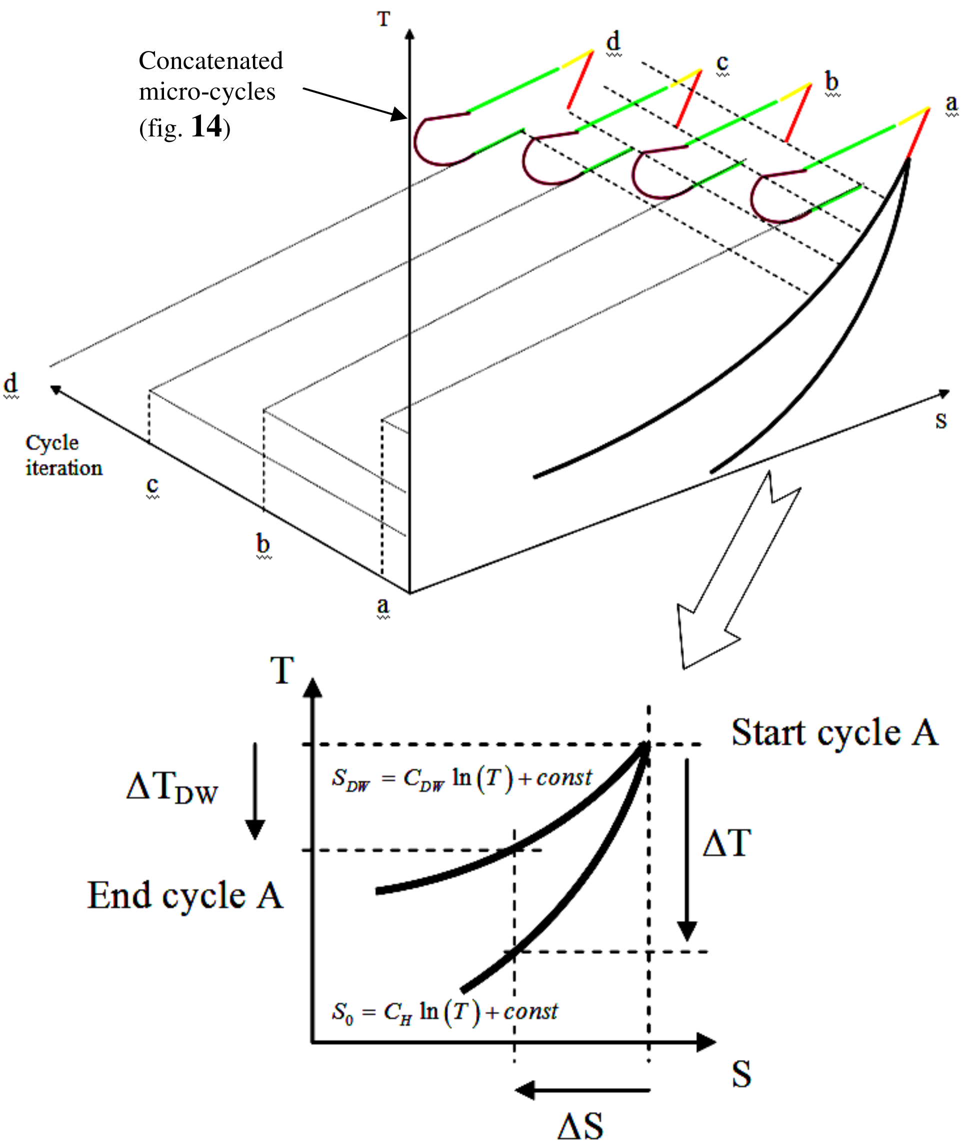


Figure 15 – How Micro-cycles relate to the Macro-cycle on a T-S diagram

The 2nd order phase change and the dipole-work in the thermodynamic identity make the working substance (eqn. 14) seem like another substance (more of this later in the discussion) with a higher heat capacity. In the lower sub-figure of figure 15 the dipole-work causes a temperature drop ΔT_{DW} for entropy change ΔS as heat energy leaves the system. If we reverse our direction and go up the up trace and imagine we are warming the virtual substance, heat energy not only goes to the working substance but to the external system because of the dipole-work. In comparison the “native” heat capacity of the working substance without the dipole work in lower trace of the sub-figure is:

$$S_0 = C_H \ln(T) + const \qquad \text{eqn. 17}$$

The upper trace has an higher virtual heat capacity:

$$S_{DW} = C_{DW} \ln(T) + const \qquad \text{eqn. 18}$$

Zooming out from the upper sub-figure of figure 15 we arrive at the macro-cycle T-S diagram and then relate that to the plant diagram of figure 8 by the labels A-B-C-D:

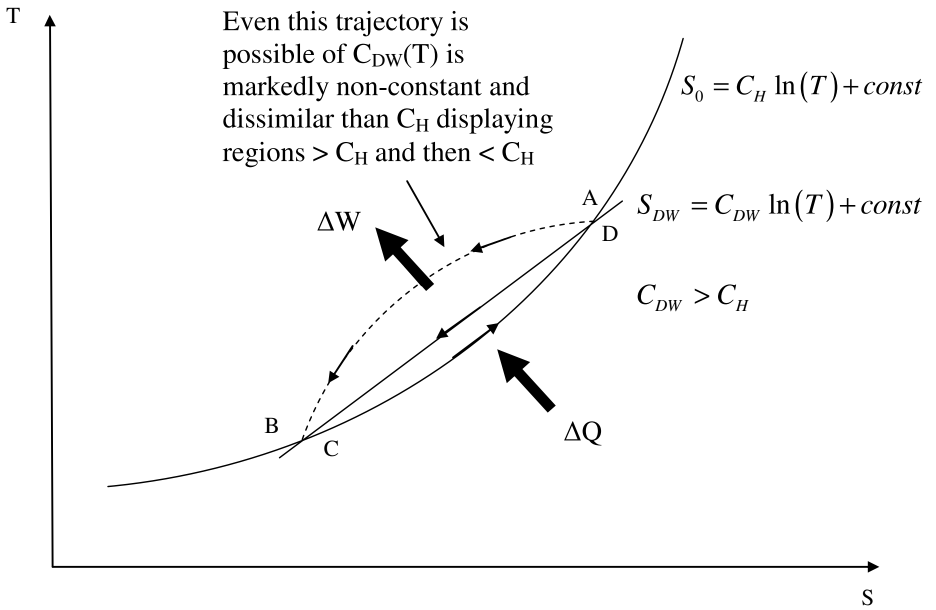


Figure 16 – Macro-cycle T-S diagram related to points on plant diagram

The area between the two trajectories of heat capacity C_H (eqn. 17) and C_{DW} (eqn. 18) is the heat absorbed at the heat exchanger and converted into electrical energy in the power extraction zone.

3.3 Electrodynamics

The Kinetic Theory and Thermodynamic analysis of the previous section have laid the groundwork for the TR cycle. It would seem a simple matter of Faraday/Lenz law collapse of the remnant flux in to a coil attached to an electrical load to deliver the goods of heat energy conversion, as depicted in figure 9. However there is some subtlety in the explanation of the demagnetisation step and a final electrical method to deliver excess power.

3.3.1. Not "just an inductor"

The lower sub-figure in figure 9 and the magnetise-de-magnetise cycle creates the impression that the setup is just a simple electrical circuit and if anything, should act as a dissipative sink of energy due to hysteresis losses. We show that this is not so and that excess electrical energy can enter the circuit from an external source of mechanical "shaft-work", effectively rotating the source of the magnetic flux inside the coil.

Firstly we consider the net electrical work around a magnetisation, de-magnetisation cycle.

$$\oint vi \, dt = -\oint \frac{d\lambda}{dt} i \, dt \qquad \text{eqn. 19}$$

Where λ is the flux linkage. Integrating the RHS by parts:

$$\oint i(t)\frac{d\lambda(t)}{dt}dt = \left[i(t)\lambda(t) - \int \lambda(t)\frac{di(t)}{dt}dt \right]_{0^+}^{0^-}$$
$$= i(0^-)\lambda(0^-) - i(0^+)\lambda(0^+) - F\left(\lambda(0^-), i(0^-)\right) + F\left(\lambda(0^+), i(0^+)\right) \qquad \text{eqn. 20}$$

Where F(..) is the integrand of the parts term. Now, since $i(0^+) = i(0^-)$ and $\lambda(0^+) = \lambda(0^-)$ the first two terms cancel. Let a <u>dependent flux</u> be represented by,

$$i(t) \; = \; g\left(\lambda(t)\right) \qquad \text{eqn. 21}$$

Where g is an arbitrary function. The second integral of eqn. 20 can be integrated by parts a second time by applying the chain rule:

$$\int \lambda(t)\frac{di(t)}{dt}dt = \int \lambda(t)\frac{dg\left(\lambda(t)\right)}{d\lambda(t)}\frac{d\lambda(t)}{dt}dt \qquad \text{eqn. 22}$$

Thus,

$$\oint \lambda(t)\frac{dg\left(\lambda(t)\right)}{d\lambda(t)}d\lambda(t) = \left[\lambda(t)g\left(\lambda(t)\right) - \int g\left(\lambda(t)\right)\cdot 1 \cdot d\lambda(t)\right]_{0^+}^{0^-} \qquad \text{eqn. 23}$$
$$\Rightarrow G\left(\lambda(0^+)\right) - G\left(\lambda(0^-)\right) = 0$$

The first term on the RHS cancels due to the flux being the same at the start and end of the cycle. The integrand on the RHS cancels for the same reason. The above result shows that a dependent flux (eqn. 21) cannot lead to net power. The proof sheds more light on the necessary condition for an independent flu*x: the flux is constant for any current including zero current* – it bares no relation to the modulations of the current. The proof also dispels any form of dependent relation, non-linear or even a delayed effect. If equation 21 was $i(t) = g\left(\varphi(t-n)\right)$ this could be expanded as a Taylor series about $g(\phi(t))$ but there would still be a relation, the flux would still be dependent.

Thus it is a statement of the obvious (the First Law of Thermodynamics) that excess power production in an electrical circuit cannot happen by electrical means alone; flux changes must happen by some <u>outside agency</u> such as electro-mechanical shaft-work to cause energy transduction.

In regard to the Kinetic Theory section and figure 9, we are drawing an analogy with the microscopic dipoles rotating via the randomisation process and the "micro-shaftwork" of heat energy. In fact, considering the energy of a dipole in a field[5-7]:

$$E = +\mathcal{M}\cdot\mathbf{B} + const \qquad \text{eqn. 24}$$

It matters not whether the magnetic moment is rotated wholesale or randomised between the maximum and minimum energy configuration, it is the same result:

$$\Delta E\Big|_{\max}^{\min} = \mathcal{M}B\cos\theta\Big|_0^{\pi/2} \;\text{ or }\; \mathcal{M}\Big|_{\mu_{\max}}^{0} B\cos\theta \qquad \text{eqn. 25}$$

3.3.2. Simple resistive load returns less than the input magnetisation energy

We can model the electrodynamics of the de-magnetisation step into a resistive load by a set of state equations[12]:

$$\frac{dM}{dt} = -\frac{1}{\tau}\left(M - \chi\mu_r H\right) \qquad \text{eqn. 26}$$

$$-\frac{d\lambda}{dt} - iR = 0 \qquad \text{eqn. 27}$$

Where,

$$H = \frac{N}{D} i \qquad \text{eqn. 28}$$

And

$$\lambda = NAB \Rightarrow NA\mu_0\mu_r\left(H + M\right) \qquad \text{eqn. 29}$$

Equation 26 represents very accurately[9, 11, 17, 18] the dynamics of the ferrofluid to a magnetising field, H[†]. The "effective susceptibility" $\chi\mu_r$ is just the product of the susceptibility and the relative permeability of a co-material placed intimately in contact with it. This is just an engineering feature for easier design.

The author then solves the set of equations in the s-domain[12] for the current as R→0:

$$i\left(t\right) = \frac{DM_0}{N} e^{-t/\tau'_{ferro}} = \frac{DM_0}{N} e^{-tR/L\left(1+\mu_r\chi\right)} \qquad \text{eqn. 30}$$

And calculates the ultimate electrical work delivered to the load:

$$\int_0^\infty i^2\left(t\right) R dt \Rightarrow W_{dw.L/R\to\infty} = \frac{1}{2}\frac{\mu_0}{\left(1+\chi\mu_r\right)} M^2 V \qquad \text{eqn. 31}$$

The work done magnetising is given by: $\int HdB \cdot dV$ of which the "H" field energy is discarded, as this can be returned with total efficiency if done by a mechanical magnetisation process or very nearly so with an electronic process ([12] sec. 3.2), leaving:

$$\int_{M,V} \mu_0\mu_r HdM \cdot dV = \mu_0 HM'V$$

The integrand has been resolved with the relative permeability of the material in close proximity to the working substance (the "co-material") subsumed into M'. We can further write the integrand by $M' = \mu_r\chi H$ as (dropping the primes):

---

† Feynman in his lecture notes is quite scathing about the term "H-field" which is used by electrical engineers and those working in the magnetics of materials,

"… there is only ever B-field, the magnetic field density … it is a mathematical arrangement to make the equations of magneto-statics come out like electro-statics when we know isolated magnetic poles don't exist by Maxwell's Equations, div B = 0."

$$E_{mag} = \frac{\mu_0}{\chi \mu_r} M^2 V \qquad \text{eqn. 32}$$

The dynamical equations can be simulated (or indeed plotted by experiment[12]) and the electrical work plotted against 1/R:

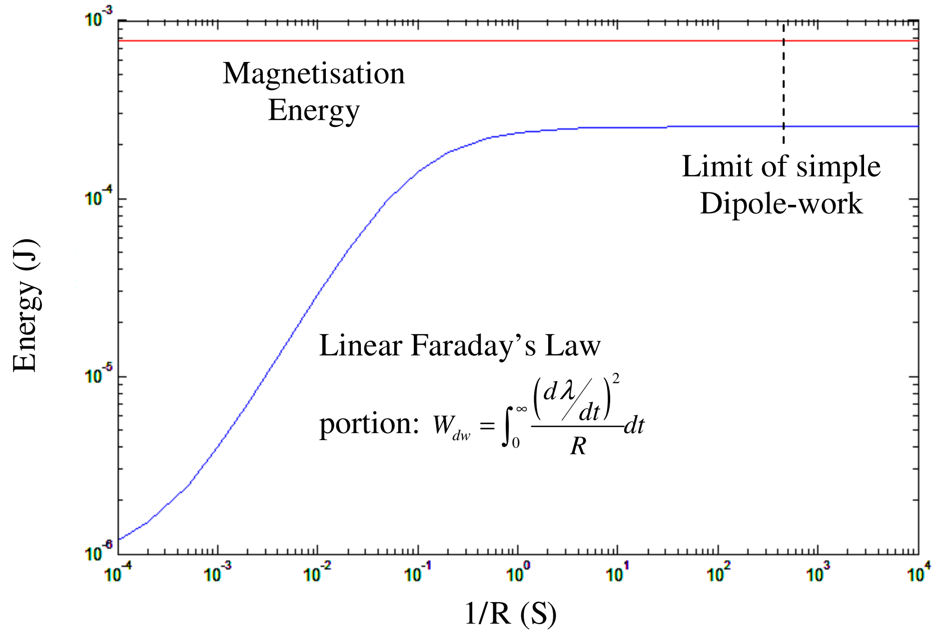


Figure 17 – Magnetisation Energy always exceeds simple dipole-work into resistive load

For the simple arrangement of coil with decaying ferrofluid flux into a resistive load depicted in the lower sub-figure of figure 9, the magnetisation energy input will always exceed the electrical work output. How to circumvent this is discussed in the next section.

3.3.3. The "H-field" cancellation method

The source of the problem for the returned electrical work being less than the magnetisation energy is from the slowing of the current waveforms as the electrical load tends to zero:

In the s-domain, the current is:

$$I(s) = \frac{\dfrac{DM_0}{N}}{s^2 \tau_{ferro} + s\left(\dfrac{R}{L}\tau_{ferro} + (1+\mu_r \chi)\right) + \dfrac{R}{L}} \qquad \text{eqn. 33}$$

The dominant pole of this function shows that the time constant tends to a function purely of the circuit inductance and resistance:

$$s \cong \frac{c}{b} \Rightarrow -\frac{1}{\tau'_{ferro}} = -\frac{1}{\tau_{ferro} + \dfrac{L(1+\mu_r \chi)}{R}} \qquad \text{eqn. 34}$$

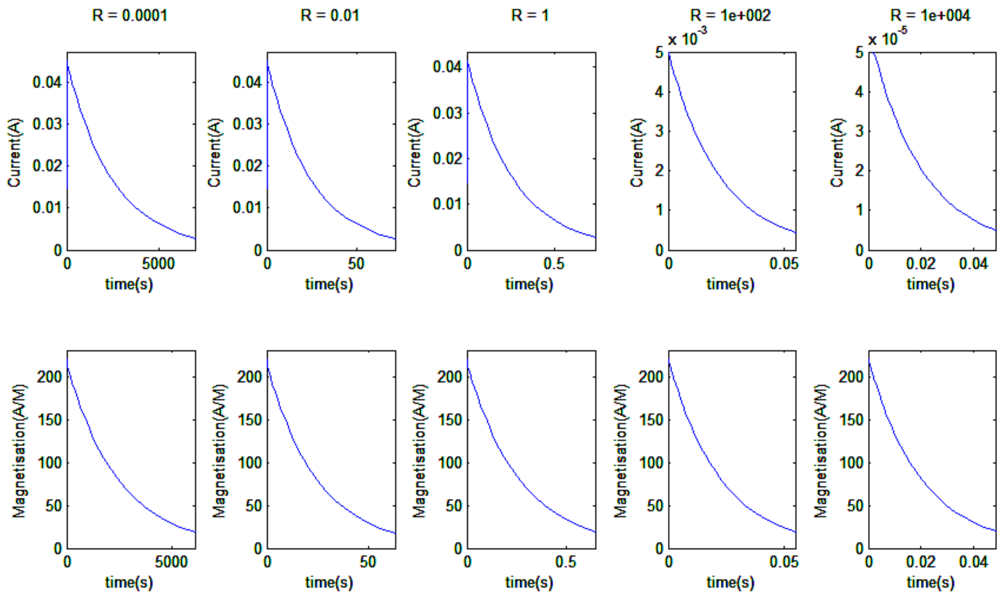


Figure 18 – The slowing current and magnetisation waveforms with lower resistance electrical load

The way around this is to strike out the re-magnetising H-field[7, 8] in equation 26:

$$\frac{dM}{dt} = -\frac{1}{\tau}\left(M - \underline{\chi\mu_r H}\right)$$

Whereupon new current dynamics result:

$$I(s) = \frac{\dfrac{DM_0}{N}}{s^2\tau_{ferro} + s\dfrac{R}{L}\tau_{ferro} + \dfrac{R}{L}} \qquad \text{eqn. 35}$$

The current in the time domain in the limit R→0 is,

$$i(t) = \frac{DM_0}{N}e^{-t/\tau_{ferro}} = \frac{DM_0}{N}e^{-tR/L} \qquad \text{eqn. 36}$$

And then the dipole-work limit by the cancellation method is obtained by $\int_0^\infty i^2(t)Rdt$ once again:

$$W_{dw.cancel.L/R\to\infty} = \frac{1}{2}\mu_0 M^2 V \qquad \text{eqn. 37}$$

This is seen to be the magnetic field energy of the ferrofluid flux and is greater than the input magnetising energy, equation 32. Simulating the dynamic equations with the approach[12] one can plot and obtain the graph below for one set of parameters $\chi\mu_r \sim 30$:

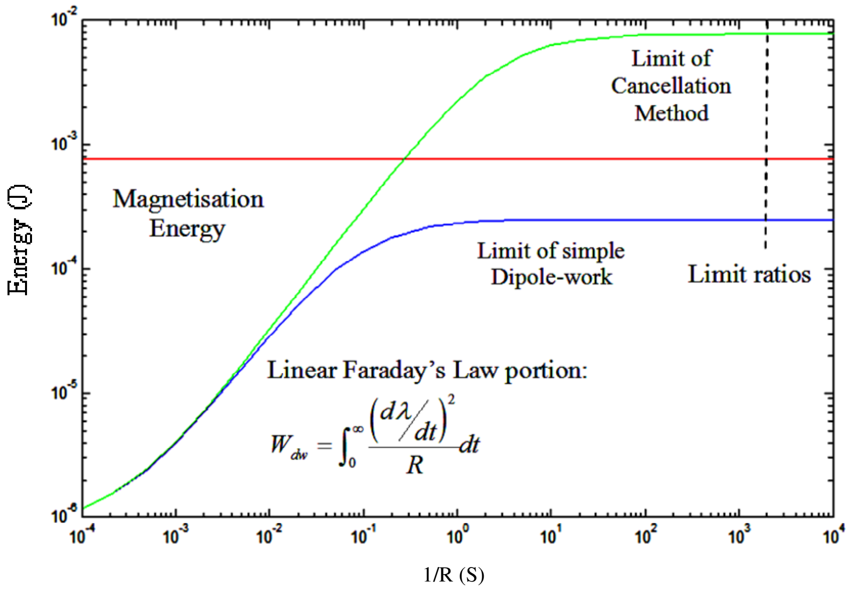


Figure 19 – Dipole-work exceeding magnetisation energy by the H-field cancellation method

We can plot the variation in the limit ratios of the simple dipole-work, the magnetisation energy and the dipole-work with the cancellation method versus parameter $\chi\mu_r$ by taking the ratio of equations 31, 32 and 37:

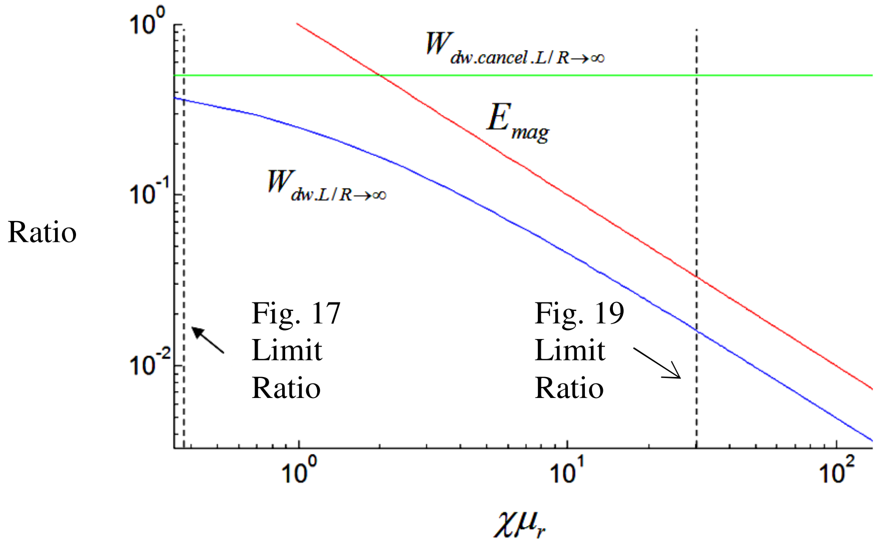


Figure 20 – Variation of parameter $\chi\mu_r$

For all variation of parameters, the magnetisation energy is always greater than the dipole-work without the cancellation method. However if $\chi\mu_r > 2$ the dipole-work, <u>with the cancellation method</u>, will exceed the magnetisation energy input. The power produced by the device is then:

$$P = \left(W_{dw.cancel} - E_{mag} - W_{losses}\right) F_{cycle}$$

Confirming what was said in the thermodynamic section and equation 16.
The circuit to perform the cancellation method is shown below and detailed description of its mechanism of action can be found in the thesis ([12], sec. 4.3).

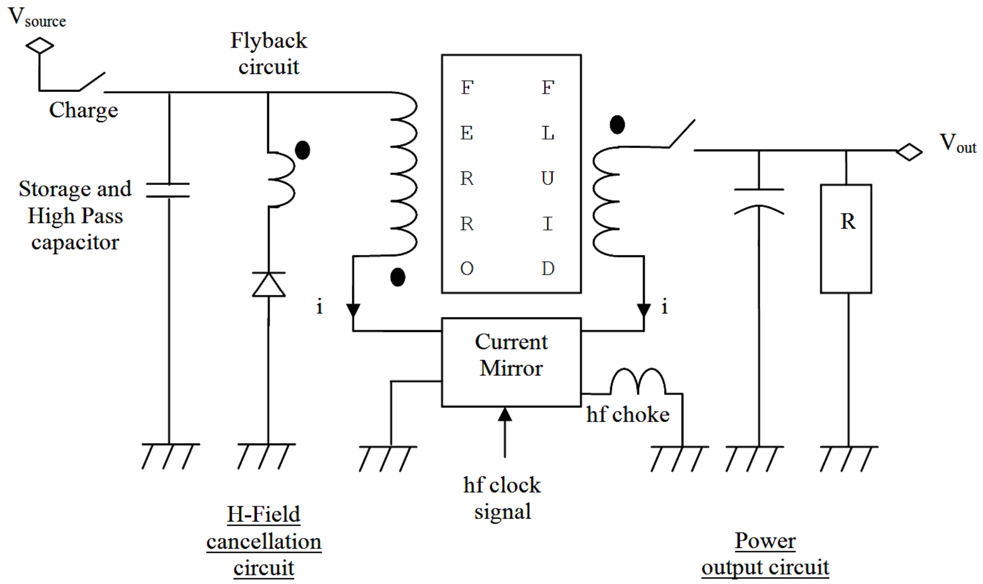


Figure 21 – The H-Field Cancellation Scheme (LHS circuit)

The circuit works by sampling the current in the power circuit (RHS) and makes a “chopped” proportional copy of it.

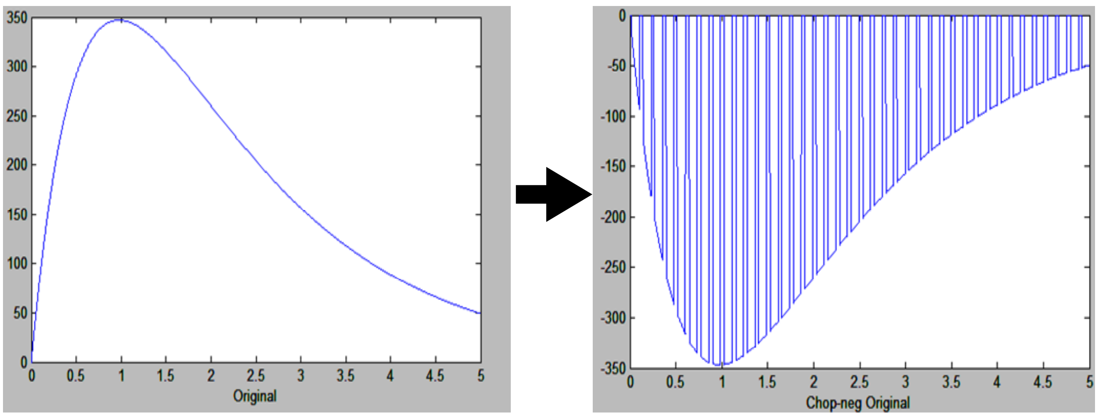


Figure 22 – Sampling, inverting and “chopping” the current/H-field

The LHS then generates its own H-field which sums with the RHS. The ferrofluid naturally low-pass filters this resultant H-field because of its high harmonics and even more so at very high frequency where the ferrofluid will not exhibit a response nor dissipation (fig. 6). One can observe how the resulting H-field is reduced in the rightmost figure.

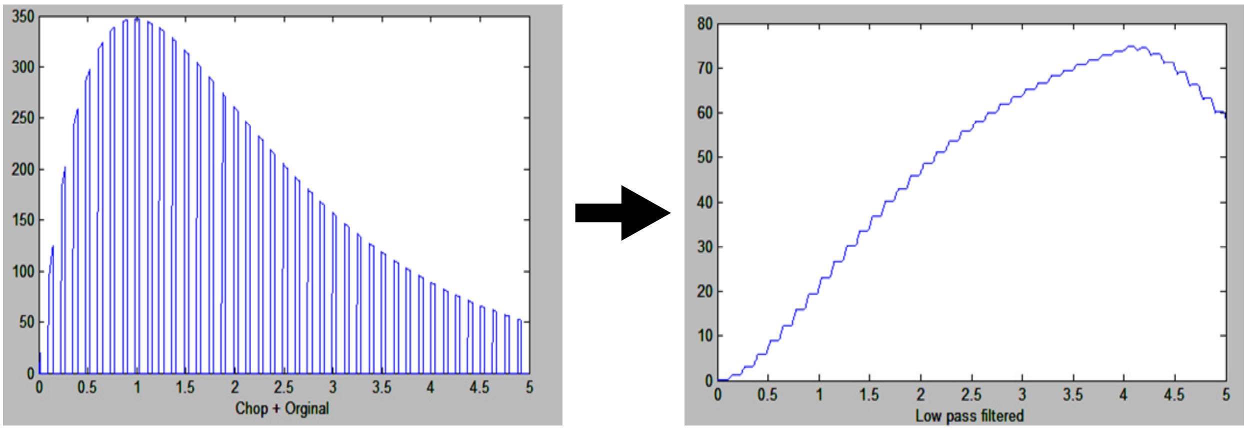


Figure 23 – The resultant high frequency H-field gets low-pass filtered

Even better cancellation comes from asymmetric summation of the inverted, chopped field to the magnetising field. Below is shown the result of summing -1.5 x the original field:

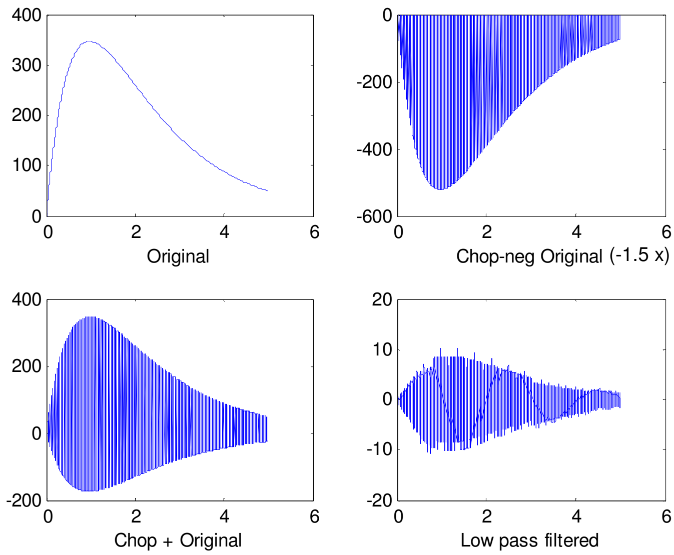


Figure 24 – Asymmetric sampling and summation

The author analyses the electrical work required to operate the H-field cancellation scheme ([12], sec. 4.3.1) and notes that by the inclusion of filtering elements and the “flyback” circuitry, that the LHS circuit only does work establishing the cancellation field and this can be done with high efficiency in a regenerative manner.

3.4 Summary of the Temporary Remanence cycle

This section on the analysis of the Temporary Remnant cycle is built on the foundations of Kinetic Theory, Thermodynamics, Electrodynamics and experiment.

Kinetic Theory shows that the relaxing magnetic field acts as a velocity damping term to each magnetic particle undergoing Brownian motion. The electromagnetic field couples to the thermal system, the electromagnetic system then couples to the external electrical system to which power is transferred.

Thermodynamics shows:

- A "delta T", a change in temperature of the working substance from the magnetic work related to the magnetic properties of the material.

- On considering the magnetic enthalpy[12], a new term "MdM" called the dipole-work is added onto the thermodynamic identity and is only relevant when heat transfer occurs. This happens on the second half of the Temporary Remanence cycle. This ties in with the Kinetic Theory where MdM is the velocity damping term.

- T-S diagrams show how the entropies of the magnetic system form a heat engine. Tying in with Kinetic Theory, once again, the variation in entropy associated with the velocity distribution of the magnetic particles is the source of the heat transference.

- An energy balance equation that shows how the internal energy of the working substance falls with electrical work it performs.

Electrodynamics shows:

- The dynamics of the electrical generation process.

- The work delivered to an electrical load by Faraday/Lenz/Maxwell induction law and that this is of the form MdM, once again.

- The work delivered to an electrical load with the field cancellation technique and that this exceeds the input magnetisation energy substantially. The difference comes from the conversion of heat energy to electrical energy.

Cornwall[12] (2.2.3) shows that power densities at least around 1MW per $1m^3/s$ flow-rate are possible with the technique and this is comparable to existing heat engines and heat pumps, though high efficiency and few moving parts.

4. Analytical proof that phase change engines can be Maxwell Demons

Should we be so scared by the concept of type 2 perpetual motion? We already know that heat energy *is* microscopic perpetual motion with the continual exchange of kinetic to potential energy; two-body simple harmonic oscillation does this and we might extend the notion and call it "n-body complicated oscillation". Clearly our Maxwell Demon is part of the n-body complicated oscillatory dynamics of the system and we should find the law, mechanism or rationale providing the underlying reason why this is possible.

If one deals with microscopic fluxes at equilibrium, one can say that an exceedingly large amount of *microscopic work* can occur at *constant temperature,* as this clearly is how individual particles rise in potential at equilibrium. There is no conflict with the Carnot result if one takes this viewpoint, that as $T_H - T_C \rightarrow 0$, the efficiency η tends to zero,

$$\frac{\Delta W}{\Delta Q_H} = \eta = \left(\frac{T_H - T_C}{T_H}\right)$$

We argue that the microscopic work-flows at constant temperature become essentially limitless based on the microscopic heat-flows, which are essentially limitless too. All we are saying is that if the micro-flow of heat, δQ is exceedingly large near (or approaching near) constant temperature, then even if η is not quite zero, the work-flows will be large like the microscopic heat-flows too. This is guaranteed by the statistical fluctuation of temperature at equilibrium[15, 19], figure 25.

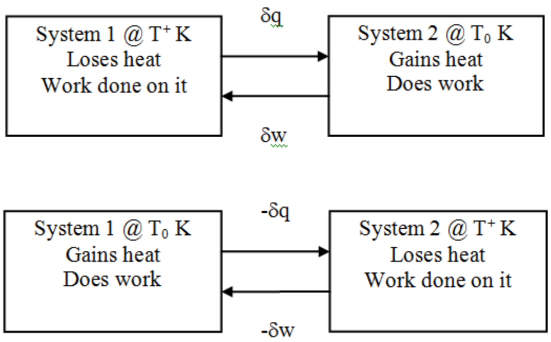


Figure 25 – Statistical fluctuation in temperature with micro-heat and micro-work flows

We are now in a position to see why phase change is key to making a Maxwell Demon. At equilibrium between two phases, microscopic fluctuations in temperature effectively form microscopic heat engines that are able to do work against the phase boundary.

<u>Lemma: Constant Temperature</u>

At constant temperature microscopic heat and work are available and can partition energy across a phase boundary.

So if a *microscopic* demon is possible how is a *macroscopic* demon made?

<u>Lemma: Phase Transition Sorting</u>

Macroscopic work is obtainable from microscopic work processes at constant temperature by the working substance undergoing a phase transition.

By definition, a phase is a macroscopic representation of underlying microscopic properties. In a sense, the phase change has “magnified” the microscopic demon.

This can be understood from the thermodynamic identity:

$$dU = TdS - PdV + \mu(P, T, \varphi)$$

Where ϕ is a potential function of position.

Since dU is an exact integral, any means of cycling the working substance by any of the variables of the system will not produce excess energy from the lowering of the internal energy of the working substance. Let us understand this more by reviewing a conventional Carnot engine.

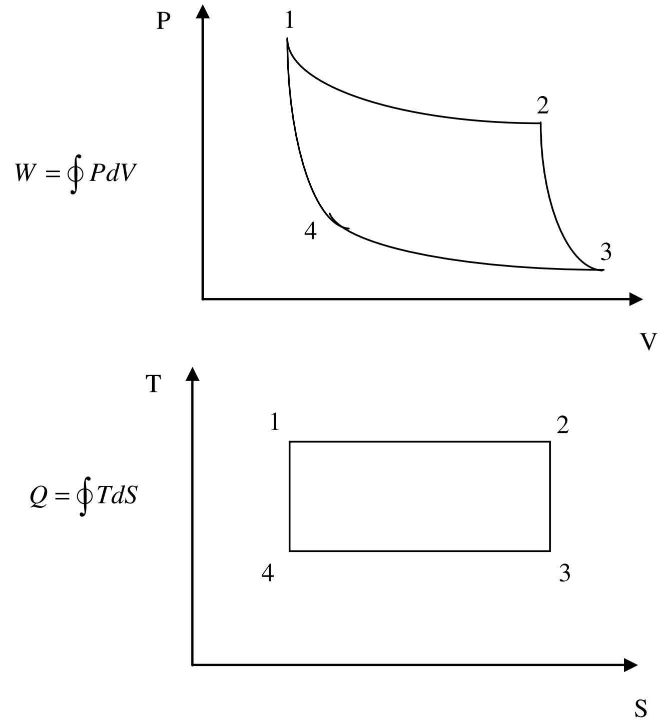


Figure 26 – PV and TS diagrams for Carnot Engine

The working substance being only one material is constrained to traverse fixed trajectories in PV or TS space. The familiar alternating of isothermals with adiabatics is required to map out an area, as moving reversibly along 1-2: isothermal-adiabatic or 1-2-3: isothermal-adiabatic-isothermal, will not return to the starting co-ordinates. The last step maps out an area so that:

$$\Delta U = \Delta Q - \Delta W = 0$$

$$\Rightarrow \Delta W = \Delta Q$$

This cannot be done with just one reservoir and the last step 3-4 must come into contact with the lower reservoir. Consider now the meaning of the chemical potential, it is the thermodynamic potential per particle:

$$du = Tds - pdV + \mu \qquad \text{eqn. 38}$$

Lower case indicates that this is per particle. The chemical potential has two parts, the internal and external[10]. If at some point in a thermodynamic cycle an external potential μ_{ext} is added or changed then the thermodynamic identity can be made inexact,

$$\delta u = Tds - pdV + \mu_{\text{int}} + \mu_{ext} \qquad \text{eqn. 39}$$

A change of μ by external potential can only correspond to a phase change as this will introduce potential energy terms, such as that pertaining to latent heat or new magnetisation energy terms, for instance i.e. dipole-work (eqn. 14). It is as though we have a different working substance not constrained to the trajectories of one substance in PV or TS space and we can achieve net work from only one reservoir. For instance, in the hypothetical PV diagram shown below, the working substance might expand adiabatically from 1-2, undergo a phase change and do work 2-3 and then be placed back in contact with the one reservoir 3-1.

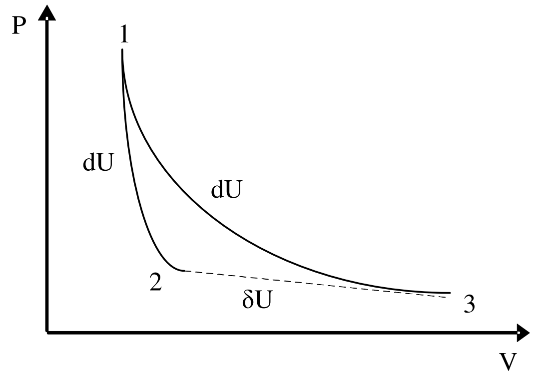


Figure 27 – Illustrative PV diagram

These considerations are not unlike the TS diagrams in figures 14 and 16.

5. What is an heat engine?

An engine or machine is understood to be a device that transforms one form of energy into another, usually mechanical energy. An heat engine is then one which a substantial change in its entropy that is intrinsic to its operation. Thus a charged capacitor discharging into an electric motor is an engine but not an heat engine; although there is a change in chemical potential of the electrons constituting the current, it operates at high efficiency and a little of the electrical energy is converted to heat, the device can operate, in the limit (using superconductors, etc.) of turning all the electrical energy into mechanical energy. Let us see how this is so:

$$dU = TdS - PdV + Fdx + \sum_{i=1}^{n} \mu_i dN_i$$

Where we have included a generalised force term and generalised displacement Fdx. Then we note that entropy is a property of the system and an exact differential:

$$\Delta S = \int_{T_0}^{T} \left(\frac{\partial S}{\partial T}\right)_{V,x,N_i} dT + \int_{V_0}^{V} \left(\frac{\partial S}{\partial V}\right)_{T,x,N_i} dV + \int_{x_0}^{x} \left(\frac{\partial S}{\partial x}\right)_{T,V,N_i} dx + \sum_{i=0}^{n} \int_{N_{0,i}}^{N_i} \left(\frac{\partial S}{\partial N_i}\right)_{T,V,x} dN_i$$

eqn. 40

It is possible for some types of engine to proceed from a starting to an end state with little variation in T, V and also $\left(\frac{\partial S}{\partial x}\right)_{T,V,N_i}$ or $\left(\frac{\partial S}{\partial N_i}\right)_{T,V,x}$ such that the generalised work term responds to the changes in the chemical potential. In other words, the energy conversion is very efficient. This is the case with our capacitor-motor analogy or indeed, an hydro-electric dam. The chemical potential of water in a dam or electrons in a charged capacitor will have a potential term from gravity Mgh or the electric field QV, respectively but this doesn't affect the entropy before or after the process.

However for the type of cycle or process where it is part-and-parcel of the operation that working substance undergoes a change in temperature, pressure, volume, particle number, chemical association or disassociation, then that cycle or process has an entropy change intrinsic to its operation – heat is unavoidably generated. This of course includes Carnot cycle limited engines but it must include batteries, fuel cells and biochemical processes too. These latter categories are not thought of as heat engines but they must be: one has only to look at the change in standard entropies of the reactants and products and note that this change is part-and-parcel to their operation!

We make the assertion that amongst heat engines, that there is a continuum from pure heat conduction, to Carnot limit engines, to fuel cells and biological systems to Maxwell Demon processes (fig. 28).

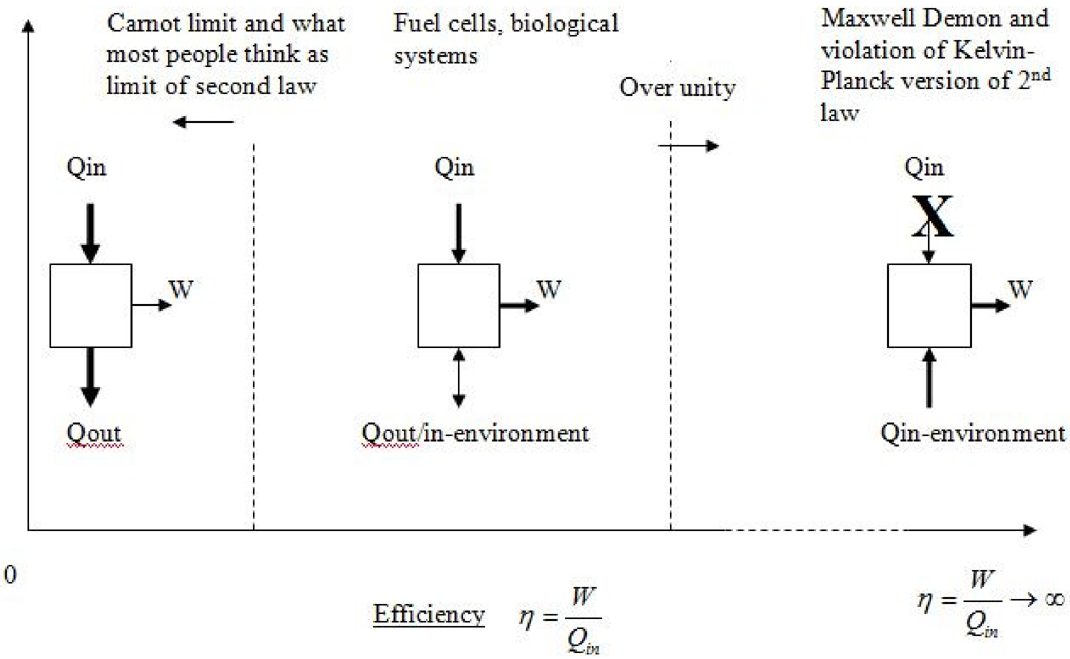


Figure 28 – The continuum of heat engines

The chart shows from the point of view of efficiency how particular types of engine fit into the continuum scheme. Logically to the left at zero efficiency, where any heat we might develop is wasted in heat conduction. Next comes the Carnot cycle limited engines we can deliver some useful work up to their efficiency limit.

Next, we insist (for the argument given previously) must be the position of batteries, fuel cells and biological systems as heat engines. It is known that they exceed Carnot efficiency and indeed, E. T. Jaynes[21] in a contentious unpublished work took the Carnot reasoning applied to a muscle to an illogical conclusion, that living muscles must be operating at some 6000K to achieve their work output! Correctly Jaynes points out that the degrees of freedom for the release of chemical energy are very curtailed, unlike the random motion of linear motion being cohered from a piston in a Carnot cycle, muscles fibres extend and contract in one very specific direction under the control of ATP. Try as one might to deny that fuel cells and biological systems aren't heat engines, one cannot deny the change in entropy of the reactants.

We think our diagram (fig. 28) makes it clear that one can utilise heat energy much more subtly than a Carnot cycle. The continuum from the middle ground and especially biological systems to Maxwell Demon type processes becomes apparent. Moving to the limit of the middle sector of figure 28, Mae-Wang-Ho[22] has argued that some biochemical processes (especially enzyme catalysis) utilise random thermal motion to achieve more than can be explained by conventional thermodynamics – an input of heat energy from the environment in addition to that from chemical sources is needed to explain the work, such as surmounting the activation energy requirement. Thus in the right sector of figure 28, we include the possibility where there is no energy input and the work is achieved wholly by the conversion of environmental heat energy input – a Maxwell Demon.

6. Severing the link between Information Theory and Physics?

Boltzmann's identification of entropy as related to the microstates of a system, the Maxwell Demon thought experiment and then the analyses of Szilard and then Brillouin was meant to bring information into the fold of physics, even though information concepts of Turing and Shannon[23] seemed abstract. Information was seen as a branch of thermodynamics, leading to the celebrated maxim of Rolf Landauer, "Information is physical". However the concepts and experiments discussed in this conference raise the prospect of de-facto reversible computing by heat recovery; it doesn't matter if we try to make each logic step reversible rather than use a conventional computer and recover the heat energy expended by it, it amounts to the same thing. How then can the claim that information is branch of thermodynamics be upheld?

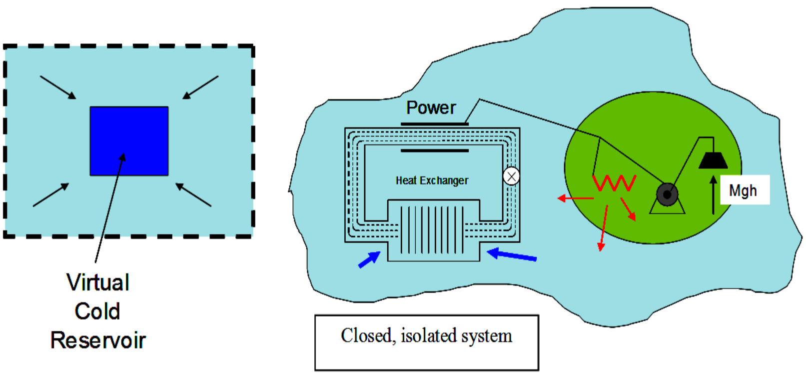


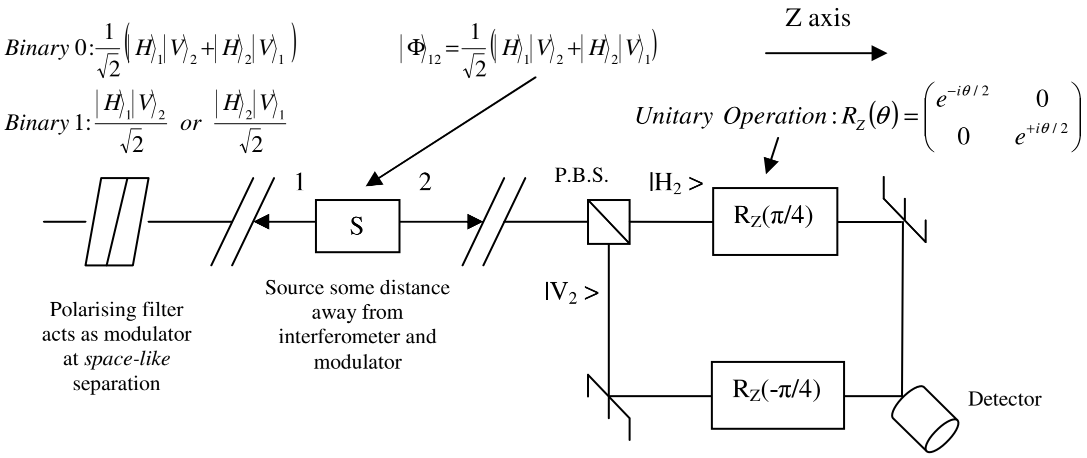
Figure 29 – A Thermodynamic Paradox – macroscopic work at constant entropy

A further development is work by the author on the ultimate speed of information transit in abeyance of Relativity. Utilising a classical protocol over a quantum channel[24, 25], the author claims a disproof of the "No-communication" theorem[26]. The essence of this is to send an entangled state between two parties ("Alice" and "Bob") so that the latter can discern a pure (corresponding to the entangled and unmeasured state by the former) and the mixed state (corresponding to the un-entangled and measured state by the former), thus implementing a digital protocol (fig 30, this can also be achieved by single particle path entanglement[25] too, fig. 31). The speed of wavefunction collapse appears extremely fast[27], if not *instantaneous* for reason of the conservation of probability current. If the transfer of this "influence" cannot obey a wave equation in some manner,

$$\frac{\partial^2 \psi}{\partial t^2} = \frac{1}{c^2}\frac{\partial^2 \psi}{\partial x^2}$$

how can the process claim to be *physical*? Physics is understood as the interplay of energy, matter, space and time.

Figure 30 – Transmitting classical data down a entangled two-particle quantum channel



Measurement/Modulation at distant system and state of two photon system	State of distant system	State of local system	Local measurement by interferometer after modulation of distant system
No modulation: 'Binary 0' $\frac{1}{\sqrt{2}}\left(\lvert H\rangle_1\lvert V\rangle_2+\lvert H\rangle_2\lvert V\rangle_1\right)$	Entangled => Pure state $\frac{1}{\sqrt{2}}\left(\lvert H\rangle_1+\lvert V\rangle_1\right)$ (Or at least some superposition)	Entangled => Pure state $\frac{1}{\sqrt{2}}\left(\lvert V\rangle_2+\lvert H\rangle_2\right)$	Pure state results in interference (Or at least some interference since source is not ideally pure)
Modulation: 'Binary 1' $\frac{\lvert H\rangle_1\lvert V\rangle_2}{\sqrt{2}}$ or $\frac{\lvert H\rangle_2\lvert V\rangle_1}{\sqrt{2}}$	Not entangled <=> Mixed state $\frac{\lvert H\rangle_1}{\sqrt{2}}$ or $\frac{\lvert V\rangle_1}{\sqrt{2}}$	Not entangled <=> Mixed state $\frac{\lvert H\rangle_2}{\sqrt{2}}$ or $\frac{\lvert V\rangle_2}{\sqrt{2}}$	Mixed state gives no interference

Table 1 – The protocol for transmitting classical data down a quantum channel

Clearly to manifest, information takes on physical form as matter or photons but to use a computing engineering analogy, a Java virtual machine[28] (or any virtual machine) can run on any platform: processor or operating system, then information must take on a mathematical, meta-physical aspect too; it can somehow just exist abstractly. This deeply philosophical matter is related to the idea of whether mathematics is created or discovered (as one might perform an experiment and find a law of nature).

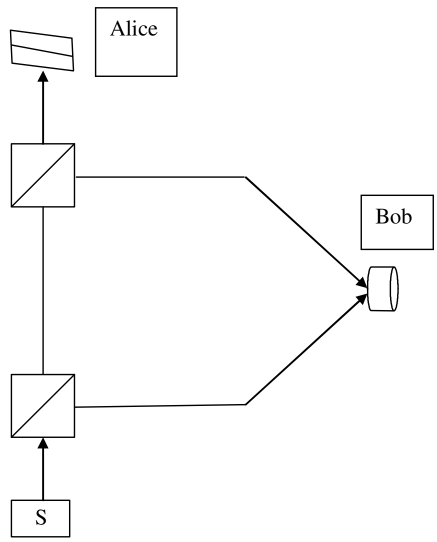


Figure 31 – Single photon path entanglement to send classical data over a quantum channel

The path lengths and cancellations are implied. The source, S, is a single photon transmitter incident upon two beam splitters.

"Alice" lets pass or absorbs the *wavefunction* such that "Bob's" interference pattern either in the mixed state or cancels/reinforces respectively.

Some theoretical physicists would probably like to believe that all Creation is mathematics. A computer scientist can create a virtual universe on a computer by a combination of software (algorithms and equations) running on hardware governed by physical principles. In mathematical physics there is no dichotomy between software and hardware… nature's laws need no computer to run, they seem to bootstrap and have a life of their own. Indeed, as already mentioned, real Maxwell Demons do just that in abeyance of our computing model that has the requirement that state information be kept. The self-computing ability of mathematical-physics laws is most puzzling.

7. Conclusion

This paper has lain out the theory and engineering required to generate sizeable quantities of heat from a single reservoir by a magneto-calorific-kinetic process. The status of the research is on-hold for further funding to pursue ferrofluid development. However it is clear by standard theory (thermodynamics, kinetic and electrodynamic), provisional experiments and computer simulations, that there would need to be a "ghost in the machine", "a cosmic censor" or some "anti-demon" to suspend kinetic theory and prevent the process from occurring. Given the successes of Sheehan[1] and others, this seems unlikely.

The author clearly identified the type of mechanism and reason for the operation for this type of phase transition demon: at the kinetic level a molecular sorting was identified for 1st order[29] and 2nd order transitions; furthermore on T-S or work diagrams, an addition to the thermodynamic identity was noted which rendered it inexact around a cycle. This allowed a break from the traditional isothermal-adiabatic-isothermal-adiabatic of the Carnot cycle and the necessary rejection of heat to a lower reservoir; thus heat energy could be obtained from one reservoir in abeyance of the Kelvin-Planck/Clausius statements of the 2nd law. Purely theoretically, this simple proof is enough to call into question Carnot's theorem.

The author then challenged the general ignorance that only Carnot cycle limit engines are heat engines. Logically, if the start and end states of a process or cycle experience an intrinsic change in entropy (not just something that can be engineered out or minimised, such as flow resistance), then it too is an heat engine. This definition brings batteries, fuel cells and even life into the fold. The suggestion that catalysis or even enzyme catalysis benefits from thermal motion, leads one to the belief that these are over-unity heat engines, delivering more "bang for the buck" than the simple input of chemical energy would have us believe – bear witness to the activation energy. Another consideration in biological systems, due to E. T. Jaynes[21], is that biological systems may be severely limiting the degrees of freedom in liberating chemical energy and achieving efficiencies way beyond the random energy input to a Carnot cycle limited process. In fact, upon comparing muscle to a Carnot cycle, Jaynes calculates that a muscle's temperature would need to be in excess of 6000K! It is a natural step in this continuum of heat engines: from Carnot to thermal agitation enhanced catalysis to the over-unity Maxwell Demon, where the thermal bath energy input exceeds any energy input (indeed, those auxiliaries are powered by the power generated).

Discussion

To conclude, the author then wondered if the link between thermodynamics and information theory was warranted. De-facto reversible computing will be possible by the methods presented in this conference. Where is then this "cost" of information? If the link to thermodynamics was severed, the author highlighted another area of their work related to the ultimate speed of transit of information. Entanglement correlation over space-like intervals is well known. The author has a disproof of the "No communication theorem" and two schemes for avoiding the randomness of quantum measurement, indeed to utilise it to an advantage, such that classical data can be sent over space-like separations. What then is the link of information to Relativity or physics in general?

This reasoning suggests something profound, mathematical and even metaphysical about information. Rolf Landauer's maxim "Information is physical" cannot be entirely true. An aspect of information seems implementation independent, much as virtual machines (ie. Java) are to hardware and operating systems. The author believes that mathematical physics has some independent "life" – it needs no hardware to run; to quote a private correspondence between the author and D. Sheehan, his words were "it just goes". This is very pertinent to the Demon problem – the Szilard/Brillouin/Landauer/Bennet view is that the decision making machinery of the demon must reject information and this step involves the rejection of heat. We are saying that the hardware-software dichotomy doesn't exist for the Demon, the equations describing the particle interactions of the sorting process "just go".

The final status of the 2nd law is of course generally true, if there are energy dissipation processes. Maxwell Demon processes form an exception to this, with the possibility of regions of zero change or decreasing entropy. However there is a problem with saying that the Arrow of Time is synonymous with the increase in entropy. A large region of space could form an isolated environment with these heat-reuse engines. Life would go on, live, die, evolve and there is much change, yet the global entropy change for this region would be zero. We must search elsewhere for the Arrow of Time; given now our knowledge of chaotic dynamics or even the quantum measurement process, the Arrow of Time is obviously Loss of Information.

References

1. D.P. Sheehan, D.J.Mallin.e.a., *Experimental Test of a Thermodynamic Paradox.* Found Phys, 2014. **44**.

2. D'Abramo, G., *Thermo-charged capacitors and the Second Law of Thermodynamics.* Phys. Lett. A, 2010. **374**: p. 1801-1805.

3. Sheehan, D.P., *The Second Law of Thermodynamics: Foundations and Status.* Found Phys, 2007. **37**: p. 1653-1658.

4. V. Čápek, D.P.Sheehan., *Challenges to the Second Law of Thermodynamics*. 2005: Springer.

5. Jackson, J.D., *Classical Electrodynamics*. 2nd ed. 1975: Wiley.

6. Landau, L., *A Course in Theoretical Physics: Classical Theory of Fields*. Vol. Vol. 2 1982: Butterworth-Heinemann.

7. Feynman, L., Sands, *The Feynman Lectures on Physics*. Addison-Wesley, Reading, Massachusetts. Vol. Vol.1, Vol. 2 1989. 14.7, 15.1-6, 35.4

8. Bozorth, R.M., *Ferromagnetism*. IEEE Press 1978.

9. Aharoni, A., *Introduction to the Theory of Ferromagnetism*. Oxford Science Publications 1996.

10. Kittel C., K.H., *Thermal Physics*. W. H. Freeman and Company, San Francisco. Vol. 2nd ed. 1980.

11. Rosensweig, R.E., *Ferrohydrodynamics*. Cambridge University Press. 1998.

12. Cornwall R. O., *Novel Thermodynamic Cycles involving Ferrofluids displaying Temporary Magnetic Remanence.* 2013(http://vixra.org/abs/1311.0078).

13. Gschneidner, K.A., Jr.; Pecharsky, V. K., *Recent developments in magnetocaloric materials.* IOP Reports on Progress in Physics, 2005. **68**(6): p. 1479–1539.

14. J. Romero Gómez, R.F.G., A. De Miguel Catoira, M. Romero Gómez, *Magnetocalorific effect: A review of the thermodynamic cycles in magnetic refrigeration.* Renewable and Sustainable Energy Reviews, 2013. **17**: p. 74-82.

15. Landau, L., *A Course in Theoretical Physics: Statistical Physics*. Vol. Vol. 5. 1996: Butterworth Heinemann.

16. Vallejo-Fernandez, O.G., Patel, *Mechanisms of hyperthermia in magnetic nanoparticles.* J. Phys. D: Appl. Phys., 2013. **46**.

17. Fannin, P.C., *A Study of the Complex Susceptibility of Ferrofluids and Rotational Brownian Motion.* Journal of Magnetism and Magnetic Materials, 1987. **65**: p. 279-281

18. Fannin, P.C., *On the Analysis of Complex Susceptibility Data of Ferrofluids.* Journal of Physics D: Applied Physics, 1988. **21**: p. 1035-1036

19. Landau, L., *A Course in Theoretical Physics: Kinetics*. Vol. Vol. 10. 1981: Butterworth-Heinemann.

20. Haile J. M., *Molecular Dynamics Simulation*. 1997: John Wiley and Sons.

21. Jaynes, E.T., *The muscle as an engine.* 1983(http://bayes.wustl.edu/etj/articles/muscle.pdf).

22. Ho, M.-W., *The Rainbow and the Worm: The Physics of Organisms*. 2nd ed: World Scientific.

23. Harvey L. S., A.F.R., *Maxwell's Demon: Entropy, Information and Computing*. Adam Hilger, Bristol 1991.

24. Cornwall, R.O., *Secure Quantum Communication and Superluminal Signalling on the Bell Channel.* Infinite Energy, 2006. **69**(http://vixra.org/abs/1311.0074).

25. Cornwall, R.O., *Superluminal Signalling by Path Entanglement.* 2015(http://vixra.org/abs/1410.0113).

26. Cornwall, R.O., *Disproof of the No-communication Theorem by Decoherence Theory.* 2015(http://viXra.org/abs/1506.0068).

27. Zbinden, H.G., N., et al, *Testing the speed of 'spooky action at a distance'.* Nature, 2008. **454**.

28. Sun-Microsystems/Oracle, *The Java™ Tutorials.* http://docs.oracle.com/javase/tutorial/).

29. Cornwall, R.O., *How to build a Maxwell Demon from a 2nd order Phase Change System.* 2013(http://vixra.org/abs/1311.0077).

30. Landau, L., *A Course in Theoretical Physics: Mechanics*. Vol. Vol. 1. 1982: Butterworth Heinemann.

31. *The Ergodic Theorem*, in *Encyclopaedia Britannica Inc.*

32. Jordan D. W., S.P., *Nonlinear Ordinary Differential Equations*. Clarendon Press Oxford. Vol. 2nd ed. . 1991.

33. Kapitaniak, T., *Chaos for Engineers*. Springer 1998.