Actual Time, Detached Time and Controlled Time: Physical Paradigms and Energy Constructions

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Outline

Introduction: actual life meets detached reason

Scientific methods treat time as a numerical quantity that can be perfectly represented by a mathematical variable and precisely measured by standardized clocks. Such a narrow rigid treatment clashes with the rich flowing texture of temporal forms, tempi and rhythms that personal experience continuously weaves from memories of the past; from movements, feelings and perceptions of the present; and from anticipations of the future. "Reversibility" of the mathematical variable clashes with actual life where "the moving finger writes; and, having writ, moves on." (*Rubaiyat* of Omar Khayyam.)

In this project, three kinds of time are related to three energy concepts. Part I discusses standard Conserved Energy (CE) paradigms; Part II discusses new Virtual Energy (VE) paradigms. Part III discusses psychological and philosophical implications of multiple time and energy concepts.

First: ***actual time*** tracks movements of and changes in material bodies. Bodies that move and change in actual time include those with a simple constitution – a falling iron weight or a molten metal alloy in a crucible – and also living animal bodies with complex cells and organs. Moving and changing animal bodies make up the domain of ***actual life*** that is foundational in this project.

My approach begins with materialistic presumptions that are similar to presumptions of science, chiefly that movements of and changes in bodies depend only on their material constitutions, their histories and the histories of their interactions. I presume that there is universal agreement among persons about the order of such events in time and about periods of time between events. Such presumptions provide a foundation of "objectivity" for discussion of such events. The presumptions are superseded in specific and limited ways in this project.

Principles of freedom distinguish my materialism from scientific materialism. Science seems to be committed to a materialism where "theories of mechanics" (e.g., Newton's, Einstein's, statistical, quantum) and "mechanisms" (e.g., chemical, computational) are presumed to describe and control all movements of and changes in material bodies. Such mechanical commitments exclude freedom. I hold to contrary principles, like those stated by Truesdell (p. 424), that such commitments "reflect a failure to come to grips with the real complications of nature. Beyond the easiest and long-mastered special cases, nature is too intricate for any inclusive theory."

I suggest that movements and changes of actual life – e.g., itching and scratching – confound all-inclusive theories of mechanics. While seated, I bend down and my right hand precisely scratches an itch on my left ankle, which lifts to meet the hand. I suggest that such itching and scratching is produced in my spine through an exercise of freedom and that all the vertebra in my spine participate in such productions. Preening of birds provides a more pointed example. I suggest that the feeling of an itch is needed to guide scratching. In contrast, no thought or "will" is needed, although thought and will may block movements when socially mandated. Similarly, a visual goal guides walking movements of the body. I suggest that, while producing whole-body movements in their spines in actual time, animal bodies of fish, birds, mammals and human beings exercise freedoms that are excluded from computational or mechanical theories of science.

Second: ***detached time*** operates in imagination, a domain that is occupied by ***images*** (feelings, perceptions, memories, plans, theories, etc.). Some images are based on ongoing actual events. Others are generated through memory or during fantasies or other mental activities that have no connection to ongoing actual events. Imaginary events in fantasies can be slowed down, sped up or skipped over in ways that are impossible for events in actual time. In imagination, a clock can be reset to a start time and different alternatives can be constructed. Different persons will have different memories and fantasies; temporal variations in imaginary events (slowing, speeding, skipping over) are impossible to compare from person to person.

Detached time operates during rational processes such as adding numbers mentally. "Detached" means that processes are independent of muscular movements and actual time. Some people add numbers quickly in their minds and other people are slower. A person might add quickly at work and slowly when contemplating the bill after a family meal at a restaurant.

Detached time operates in thermodynamics paradigms of Conserved Energy. As discussed below, such paradigms are constructed from continuous equipoise and equilibrium operations on stationary positions. Detached time also operates in computer algorithms. All such rational processes operate in detached time – in imagination, in equipoise/equilibrium physics paradigms and in computers. In such rational processes, movements can repeat incessantly without change. Such repetitions require ***time invariance***: an exact repetition of movements produces exactly the same results in the body and in the environment. If a variance is introduced in movements, any change in results is attributed to the variance. (Such an attribution maintains the ancient "principle of sufficient reason.") Time invariance requires a static environment and a fixed production system. Laboratories and consumer electronics devices aim to satisfy such requirements and to produce exact repetitions for prolonged periods. Animal bodies and movements of actual life have lesser capacities for such time invariance or for exact repetitions.

Movements that are repeated in detached time, e.g., arithmetic, can conform to principles of ***postponement*** and ***decomposition*** where details of movements are changed without changing results. In detached time, alternative imaginary courses of action can come to the same end. Postponement means that timings between movements can be stretched out. Decomposition means that a large movement can be broken into a sequence of smaller movements, perhaps in various different ways. Decomposed movements can then be composed to recover the original movement. Novel compositions of decomposed fragments are sometimes possible.

In some variations in detached time, changes in the ***ordering*** of movements – e.g., which of two movements is performed first and how movements are grouped in sequences – leave results unchanged; in mathematics, "commutative" and "associative" relationships are based thereon.

Other movements in detached time are ***reversals*** of original direct movements, also called "inverses" — subtracting where there was addition or backtracking in imagination to a prior position. A direct movement followed by a reversal movement adds up to a "zero" or ***null movement*** that is said to be the same as no movement at all.

Mathematical groups are made of composed and ordered movements, reversal movements and null movements that all take place in detached time.

Imaginary movements in detached time differ from those of animal bodies in actual time – e.g., romping on the floor with the kids – where trying to repeat movements, decompose movements, postpone movements or alter orderings of movements will almost always change results. Actual movements are never reversible; two actual movements cannot add up to a null, even if an appearance of restoration is achieved. "You can't go home again" while home is changing.

Third: in ***controlled time***, operations in rational domains co-exist with bodily movements and other changes in the domain of actual life. In other words, selections in rational domains trigger, inhibit or modify bodily movements in the actual domain; and perceptions and feelings that are rooted in the actual domain influence selections in rational domains. Practiced movements in a fixed environment (e.g., work bench, tennis court, kitchen) are especially suitable for rational controls that select and vary details of repetitive cycles. The universal design of a piano keyboard with distinct white and black keys in an invariant array defines a pianist's movements so that they can be controlled by means of notes printed on sheet music. Controlled actual movements can conform to rules of mathematical groups in limited ways under such conditions.

Many variants of controlled time occur in musical performances where movements of a musician are under the control of a conductor or ensemble or internal beat. Repetitive beats and cycling melodies provide gist for operational controls; but movements also require exercises of freedom in actual time on the part of each musician. Training programs of athletes provide long-range examples of controlled time, e.g., in records that track timings and laps in the swimming pool. Many electronics devices, e.g., computers, have internal clocks and operate in controlled time.

Particular controlled-time applications use rational methods to control actual movements but rational methods have ranges of application that are more limited than the ranges and repertoires of movement of bodies they control. An application is specific to particular kinds of actual movement; attempts to apply the same rational methods to different kinds of movements can be risky. Riding a bicycle in traffic has greater risks than driving an automobile. Risky situations impose speed limits on actual movements that are controllable by reason. Rational methods must operate quickly enough to "keep up with" actual movements and to interact with bodies that manifest the ongoing physical principle of momentum. Otherwise, the bicycle rider loses control of the bicycle and of the rider's own body.

When a pianist first picks out a tune from a new piece of sheet music, it is clear that rational methods are controlling the movements of fingers. It may take many repetitions before the pianist is able to produce the different parts of the composition, to put parts together and to integrate them into a musical whole. After the pianist has fully learned the piece and skilled fingers are quickly "moving on their own" and "expressing feelings," rational methods are no longer in control. Movements of a whole person are being produced.

In ***mimed time***, a special kind of controlled time, an imaginary clock tracks imaginary events that take place in an imaginary domain, such as events in a physics paradigm. Important Conserved Energy (CE) paradigms operate with mimed time. Mimed time is intended to resemble actual time but imagination can manipulate mimed time in fantastic ways, e.g., stretching, restarting.

Part I of this project constructs a course of progressive development of detached and mimed time paradigms that leads to a CE paradigm that is on the edge of freedom – the Ising Model. The Ising Model applies to a change or transformation in a magnetic body as temperature changes: at low temperatures, there is either a North polarity or a South polarity; but at high temperatures there is no polarity. When a hot un-polarized Ising Model cools below a "critical temperature," it goes through a whole-body change and acquires either a North polarity or a South polarity.

A whole-body change is called a ***phase change.*** An un-polarized body is in one form or phase and a polarized body is in another form or phase. Familiar phase changes occur when a body of liquid water changes into ice — or into water vapor. During a phase change in the Ising Model, the magnetic body "chooses" between a North polarity or a South polarity. During repetitive phase changes in a fixed environment, a "tiny change in influence" can change the result. The physical principles set forth in the Ising Model paradigm have actual commercial applications in magneto-optical computer memory devices. A magnetic element in the device stores a bit of information: a North element denotes a "1" and a South element denotes a "0."

Virtual Energy (VE) paradigms of part II follow a course of progressive development similar to that of part I but with new kinds of controlled time constructions. Critical point phase changes that are at the edge of CE constructions become central operating elements in VE constructions. Moreover, phase changes become ***activated***. VE paradigms operate with variable energy flows rather than with energy quantities that add up to a constant, as in CE. VE paradigms introduce flowing interactions and aim to operate in ways similar to those of animal bodies that speedily select from and combine rich repertoires of movements. In idealized paradigms, an organism – biological, engineered and/or psychologically controlled – operates cyclically; and a whole-body selection occurs during each cycle. VE paradigms aim to apply to biological activity such as the beating of a bird's wings to reach a certain perch; to personal psychological activity such as chopping vegetables according to a recipe; and to technological activity of a Quad Net device assembly that models activities of an animal spine.

In Virtual Energy paradigms, there is a ready pool of "abundant" energy available; and controls operate by opening, squeezing and interrupting flows of energy and by adjusting competing dissipations ("wasted energy" or "heat"). Such paradigms aim to apply to ordinary biological activities of muscle cells and nerve cells that drive muscles, where "more than enough" ATP energy packets are produced by mitochondria; energy consumption and muscular force productions involve friction, work loading and opposing muscles; and activations, energy consumption and resulting forces are controlled by combinations of signals originating from multiple locations and subject to multiple influences, e.g., pain from a pulled muscle.

Competing dissipations and phase changes in VE devices are included in ***kits of parts*** used in construction of models of muscular movements and related imagery (feelings, perceptions). Kits of parts in VE constructions are the alternative approach to general principles supplied by theories of science. In an activated design based on the Ising Model, ***Quad Net devices*** generate images through operations that involve Shimmering Sensitivity, a physical principle of freedom. As with persons, operations that generate images have independent repertoires and sensitivities and create continual innovations. Images that a person uses in actual life may have originated during prior events of actual life; they have since acquired an independent existence in memory and imagination and have become subject to operations in detached time.

Proposed device assemblies produce images and movements in ***sensory-motor modules***. In one kind of module, balance is first cyclically established and then lost during a phase change that involves Shimmering Sensitivity – and finally balance is again restored, ready for another round. During each phase change in such a module, a flicker of an image is generated and a movement is selected. In an anticipated model for preening of a bird, modules act like vertebrae and show how a locational image of an itch referred to a skin surface can select ongoing actual movements of the spine and a "beak" at the end that successfully touches the skin at the right location.

In a more complex model for "stop on red; go on green," each cycle of operations generates a perceived image that is based on a "traffic light" in the environment and that matches a red or green image reconstructed from memory; a change in matchings in detached time triggers processes that switch movements of the body in actual time. During repetitive activity in imagination, a delicate balance is shifted first one way and then the other way – with resulting consequences in movements of a person's body.

I. Actual Time, Detached Time and Mimed Time Paradigms of Conserved Energy

Summary of part I in context of the whole project. Certain standard physics paradigms are presented, analyzed and compared. Discussion aims at certain conclusions and bypasses mathematical details. Standard paradigms discussed in part I – based on Newtonian mechanics and Conserved Energy Thermodynamics (CET) – present features that are then reconstructed in new paradigms of Virtual Energy Thermodynamics (VET) discussed in part II, leading to Quad Nets (QN) paradigms, which embody Shimmering Sensitivity, a physical principle of freedom.

Features of ***equipoise*** and ***equilibrium*** paradigms that are discussed in part I reappear after reconstruction in ***balancing*** paradigms embodied in new devices. In QN paradigms, balance is cyclically lost and restored. A loss of balance can select one actual movement from multiple possible movements, influence other ongoing movements and generate imagery, which may be recorded in memory.

CET paradigms have a central focus where multiple forces or influences meet and come to rest. In some CET paradigms, rest persists for indefinitely long periods of time; in others, movement passes in imagination continuously through positions of rest; and, in still others, perturbations and relaxations revolve around moments of rest. CET presumes that paradigms based in rest comprehend all activities in the Universe. In contrast, VET paradigms begin with streams of pulses and produce various stationary, steady and jumpy movements, as well as exercises of freedom, by device operations that depend on, e.g., material properties of devices, histories of operation, influences from other devices, rest, dissipations and Shimmering Sensitivity.

Rest in CET paradigms starts with two equal weights in equipoise. Development then adds an elastic body governed by Hooke's Law, which defines a linear relationship between equipoise positions and weights. Development leads to varied equipoise positions in ideal gases; to equal flows of a perfect gas that are used to model equilibrium, perturbation and relaxation; to steady production based on equipoise and equilibrium in the Carnot cycle and applied to steam turbines; and to stable and unstable bodies near the critical point of the Ising Model. A "critical point" identifies two distinct ranges of activity; and it also identifies one singular form of activity that belongs to both ranges and that permits changing the range, a form of activity that serves, in other words, as a crossover point between two distinct ranges of activity. The "critical point" both marks a boundary and also has unique features that suggest new developments.

Each paradigm, CE or VE, is constructed in an imaginary domain and consists of ***operations*** that are imaginary movements of imaginary bodies. An imaginary ***domain clock*** operates in the paradigmatic domain. In one kind of operation, the domain clock mimics an actual clock and ***mimed time*** so measured by the domain clock exactly resembles actual time for a certain period but is under the researcher's control. An imaginary domain clock can also operate in detached time in ways that are contrary to actual time, e.g., slowing time, stepping time, resetting time to 0 and even reversing time. As a prime example of mimed time paradigms, the Simple Harmonic Oscillator, said to operate dynamically, is built on top of detached time operations.

A. Mechanical perspective: Atwood's machine and Hooke's Law

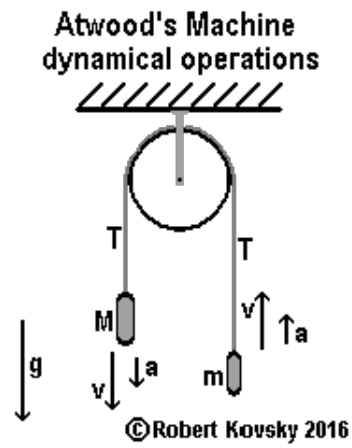
Overview. The chief focus in part I is on thermodynamics paradigms. A broader perspective is provided by starting with mechanics paradigms. Atwood's original machine operates in actual time. The simple harmonic oscillator (SHO), based on Hooke's Law, produces movements in mimed time. ***Equipoise operations*** in new versions of Atwood's machine and Hooke's Law occur in detached time and foreshadow the Carnot cycle and the Ising Model.

1. Atwood's machine

Important physics paradigms operate in actual time, e.g., Newton's and Einstein's gravitational theories that describes actual movements of celestial bodies and Maxwell's electromagnetic theory that is tethered to the actual speed of light. ***Atwood's machine*** exemplifies actual time applications of Newton's Laws; it is also adapted for equipoise operations in detached time.

a. original machine — dynamical operations in actual time.

Invented by George Atwood (1745-1807) to measure gravitational acceleration, the machine is a classic example of conserved-energy mechanics. (Marion, 261, n. 1; Goldstein, 18, 25-26.)



The adjacent figure shows an idealized and simplified design for Atwood's machine: a rope hangs over a pulley and connects two masses. Under the influence of gravity g, the heavier mass M falls, lifting up the lighter mass m. In this version of the paradigm, the rope has no mass.

One condition of operations is that the rope must be uniformly taut or tense; the tension is denoted by T. This ***taut rope condition*** binds movements of the rope and of the two masses into a single movement with a single velocity "v" and a single acceleration "a." In other words, both masses move with the same size v and a, but in opposite directions.

The taut-rope condition restricts movements and operations that can be permitted. Permissible movements must be ***smooth***, with changes in time that can be described by math functions that have continuous derivatives. ***Impulsive movements*** are prohibited. For example, a brief interruption of a movement by grabbing, holding and then releasing one mass would send a jerk through the rope, contrary to the taut-rope condition.

In this paradigm, operations are strictly limited. Movement is in one direction only. The only effective force is gravitational. Idealized movements require a "perfect vacuum" with no air resistance. No friction can be permitted that might slow the pulley or heat the rope.

The chief aim of the paradigm is to state the acceleration of movement (previously defined as a) in terms of the sizes of the masses M and m and the value of g, the acceleration due to gravity.

Answer: $a = [(M – m)/(M + m)] \times g$.

When m is close to M, a is much smaller than g; and a can be measured easily and precisely in a laboratory realization. At slow speeds, problems with friction and wear are reduced.

Suppose that a is greater than zero, that the machine is first held in a fixed position and that masses are released at time $t = t_0$. Velocity v increases uniformly with time; or $v = a \times (t - t_0)$. Assuming that nothing interrupts or modifies movements, velocity v increases without limit. The assumption applies for only a short period of time while there is rope left to run through the pulley; but it is good while it lasts.

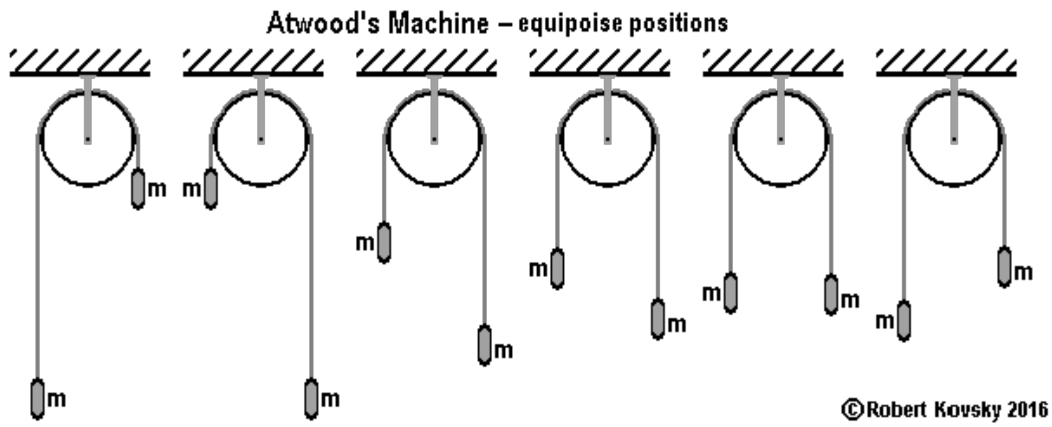
For purposes here, Atwood's machine provides a basis in mechanics for definitions and methods that are then developed to analyze thermodynamics paradigms, both CET and VET. A chief purpose of analysis is to distinguish actual dynamical operations in mechanics from detached equipoise and equilibrium operations in both mechanics and thermodynamics. During ***dynamical operations*** of the original Atwood's machine paradigm, movements of bodies occur in the paradigmatic domain at rates determined by values of g, M and m. The paradigmatic clock has no substantial variance from a clock synchronized with a national standard and can be bound to such a standard. When the principle of the machine is realized in a laboratory, movements are measured by such an actual clock and they occur in ***actual time***. I

Also of importance is the fact that in Atwood's original machine, movements are the sole form of activity; a stationary state is only part of preparation for a movement and requires the holding hand of a researcher or substitute. Realizations of the paradigm in a laboratory aim to produce movements and actual timings of movements are predicted from the paradigm. Movements in a laboratory domain are designed to conform to and coincide with movements in the paradigmatic domain – and any discrepancy is, at least at first, attributed to shortcomings in the laboratory realization. Movements in the two domains are indissolubly bound by a common time. In successful applications, operations of the rational paradigm predict or track or reproduce actual-time movements of working models, such as working models built by Atwood.

As discussed in more detail below, actual time operations of Atwood's original machine contrast with detached and mimed time operations of Hookes' Law and of the simple harmonic oscillator (SHO) that produces oscillatory movements and with similar detached time and mimed time operations in thermodynamics paradigms. Operations of the SHO are grounded in Hooke's Law that is first defined for stationary states and then carried over uncritically to movements. Quantities involved in Atwood's machine – m, M and g – are referenced to actual bodies and movements; in Hookes' Law and the SHO, in contrast, the chief property appears in the form of "k," a "spring constant" that exists only in imagination. An actual body may conform to a spring constant description but only for a limited range of movement and only in an approximate way. In practice, the value of k is adjusted to make actual measurements better fit the paradigm. The value of k so derived applies only to a specific piece of material over a specific range of movement. Specifying k requires a rational construction that forces a fit between limited phenomena and a mathematical form. In contrast, the specific value of g determined using Atwood's machine can be used anywhere on the surface of the Earth with a high level of precision.

b. adjustments and operations of an equipoise Atwood's machine occur in detached time.

A special version of Atwood's machine operates with ***equipoise positions*** if M = m and v = 0. As shown in the figure below, equal masses can be put into a large number of stationary or static or equipoise positions. An equipoise position never changes on its own; however, an equipoise position can be changed or adjusted by a researcher or other external cause. In other words, a researcher can adjust positions of masses to any stationary position within a range of positions. Operations in such an M=m, v=0 machine are defined as movements that adjust masses between stationary positions. More generally, ***equipoise operations*** are defined as movements between variable stationary positions that are established by equal and opposing forces.



Additional restrictions and limitations are imposed on operations of the equipoise Atwood's machine. First: if set in motion, masses will continue to move until stopped. In equipoise operations, only stationary positions are recognized. Second: an adjustment of stationary positions violates strict conservation rules since energy must be used to set masses into motion at the start of an adjustment and to stop movements at the end. However, it is presumed that additional energy needed to start and stop movements can be disregarded in equipoise operations.

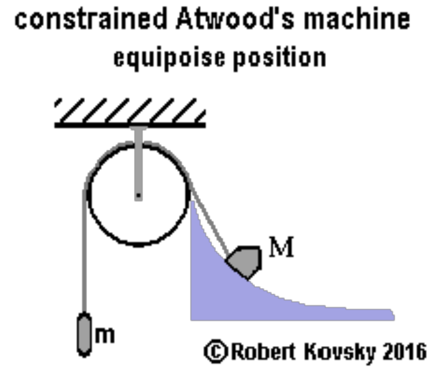
Operations of the equipoise machine occur in detached time as described in the Introduction. Sizes of adjustments to stationary positions are easily varied, at least within limitations. A big adjustment can be broken up or decomposed into several small adjustments. A big adjustment can be composed from small adjustments. Details of decompositions and compositions can be varied. An adjustment to a stationary position can be postponed without changing the operation.

For any designated adjustment in the equipoise paradigm, there is a reversal adjustment that restores masses to their positions prior to both adjustments. An adjustment followed by its reversal adjustment make up a composed adjustment that can be said to be a null adjustment. Adjustments, compositions, reversals and null adjustments make up a system of movements that can be modeled by a mathematical group.

Decomposition, postponement and reversal features of operations in detached time are absent from actual time operations of the original Atwood's machine. Actual dynamical movements are never reversible and reversed movements would resemble the "unreal" movements in a movie that is run backwards. In dynamical operations of Atwood's original machine, movements cannot be composed and attempts to postpone or decompose movements would cause interruptions and violate the taut-rope condition of operations.

c. equipoise operations in a constrained Atwood's machine.

A ***constrained version*** of Atwood's machine is shown in the adjacent image. The left side of the device is the same as in the original machine, with a "loose" mass m. On the right side, the "constrained" and larger mass M rests on a curved slope that bears a fraction of the weight. Perhaps the arrangement uses a slot track, like a cable car but without friction: the larger mass glides easily on the slope under force and rests in a stationary condition at the specific position on the slope that is determined by the ratio M/m. At that position, forces are in equipoise.



A ***continuity argument*** is used. The slope varies from nearly vertical close to the pulley to nearly horizontal far from the pulley. Where the slope is nearly vertical, an equipoise position occurs when the constrained mass M is just a little bit larger than the loose mass m. Where the slope is nearly horizontal, an equipoise position requires a constrained mass M that is much larger than the loose mass m. Assuming that the size of the loose mass m remains constant, the position on the slope where forces are in equipoise will vary with the size of the constrained mass M. A scale can be constructed on the curved slope where each position on the scale corresponds to a distinct ratio of the constrained mass M to the loose mass m.

An equipoise operation in the constrained Atwood's machine builds on that of the prior equipoise machine but adds another component. It combines an adjustment to an equipoise position with a corresponding adjustment in the size of the constrained mass M. The change in mass and change in position occur smoothly together, with a relationship that is defined by the condition of equipoise and by the shape of the curved slope.

Suppose that the larger mass M has an iron framework with a mass somewhat larger than m and also has ice as a filling material. As ice melts, the mass of M progressively diminishes and the equipoise position creeps up the slope. The rate of creep is controlled by controlling the rate at which ice melts. In such equipoise operations, each equipoise position is equivalent to a stationary position and could be frozen with a blast of cold air; but stationary positions appear to connect up into action, like an animated cartoon in a cinema.

Similar equipoise arrangements and creep operations are constructed below in paradigms of Hooke's Law, the ideal gas and the Carnot cycle. All such paradigms operate in detached time. Movements, adjustments and changes can be decomposed, composed, reversed and postponed.

The principle shown in the constrained Atwood's machine and generalized in later paradigms is that forces are in equipoise at each point along the curved slope. In imagination, on the curved slope, movements pass through a series of equipoise positions. There is ***continuous equipoise*** along the curved slope. As with the M=m equipoise machine, continuous equipoise operations on a curved slope occur in detached time.

d. oscillations of a constrained Atwood's machine would occur in actual time around equipoise positions set in detached time.

Suppose that the two masses in the constrained machine are in static equipoise. Then suppose that a researcher displaces positions of the masses while maintaining a taut rope: one mass is moved up and the other mass is moved down. If the masses are held at the displaced positions and then released, the masses move back towards the equipoise positions. The force driving the movement is based on the curvature of the slope. If the slope is a straight line between the displaced position and the equipoise position, the two weights will continue to be in equipoise at the displaced position. In other words, displacement will not result in a change in forces if the slope is a straight line; and weights that were in equipoise before displacement will still be in equipoise after displacement. A change in forces requires a change in slope and a continuous force requires a continuous change in slope.

Assuming a curved slope, weights acquire a common velocity of movement denoted by v; and they acquire kinetic energy denoted by [$\frac{1}{2}(M+m)v^2$]. They then pass through the static equipoise position at maximum speed, slowing afterwards until they reach an extreme position at the "far end" of the range-of-movement (ROM) on the other side, where they momentarily pause before beginning a reversed movement. Presuming an absence of friction or other loss of energy, the reversed movement proceeds until the masses return to the original displacement position that marks the "near end" of the ROM. There, movement pauses, before repeating the prior cycle.

Such movements, called ***oscillations***, would occur in actual time, like movements of the original Atwood's machine. Extending the definition of actual time used for the original machine, movements would occur at rates determined by values of g, M, m, the slope and the starting positions. If movements of the paradigm are calculated using Newton's Laws and the design is realized in a laboratory, actual timings of movements can be predicted from the calculations. Movements in the laboratory domain aim to conform to movements in the paradigm domain – and any discrepancy is attributed to shortcomings in realization in the laboratory. Movements in the two domains are indissolubly bound together.

e. adding dissipation to Atwood's machine paradigms.

Dissipation in an Atwood's machine paradigm can be introduced, e.g., by imagining friction in the pulley or rope or by imagining immersion of a machine in a dense gas or a liquid. It is possible to imagine starting with very little added dissipation and then to proceed by increasing dissipation in an incremental way.

First, suppose that equipoise versions of Atwood's machine are immersed in a viscous liquid such as water. Operations remain much the same after dissipation is introduced in both equipoise versions of the paradigm. Two masses at rest in equipoise positions will remain at rest in a dissipative machine, the same as in a machine without dissipation. Equipoise positions do not change as dissipation is increased. Adjustments may require more energy under dissipative conditions but such energy costs are ignored in equipoise operations. Adjustments are slower under dissipative conditions but adjustments are never "instantaneous" and can be postponed. The same as prior to dissipation, an adjustment operation for a dissipative equipoise machine can be decomposed into a series of adjustments; intermediate adjustments can be postponed; and adjustments can be reversed – all without changing essential features of operations.

In contrast to the indifference of equipoise operations to dissipation, dynamical operations of Atwood's original machine are substantially changed if dissipation is introduced. In a model of frictional dissipation, a new force opposes the force of gravity so that acceleration a is reduced: $a_d = a_o - cv$, where a_d denotes the acceleration in the dissipative machine; a_o denotes the acceleration in the original machine; v denotes the momentary velocity of movement; and constant c denotes a dissipative term that provides a linear relation between v and a_d. As v increases, frictional forces increase and a_d diminishes. If v were to reach the amount $v_t = a_o/c$, a_d would have diminished to 0 and there would be no more acceleration. For this reason, v_t is called the "terminal velocity."

The linear term cv provides a rationalized form of dissipation that is mathematically convenient. In this form, v starts at 0 and gets closer to terminal velocity as time passes. The mathematical expression for changing velocity is that $v = v_t \times [1 - \exp(-c \times (t - t_0))]$ where exp is the exponential function and t_0 is the instant when the weights are released. At the beginning of the movement, when t is close to t_0, the velocity is close to 0. As time passes, v approaches v_t but never reaches v_t.

Similar forms of dissipation are used below in standard paradigms based on the simple harmonic oscillator and the perfect gas. The Quad Nets functional, the mathematical basis of VE device operations, employs a similar form based on dissipation in a storage body.

2. Hooke's Law and the Simple Harmonic Oscillator (SHO) paradigm.

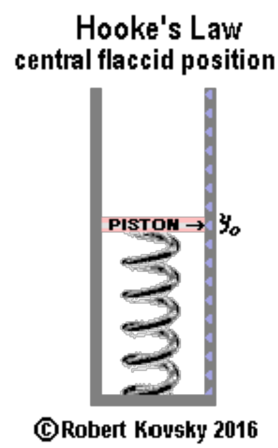
a. The SHO paradigm begins with static positions, detached time and Hooke's Law.

As introduced above, a physics paradigm begins with an empty imaginary domain and a domain clock. Hooke's Law adds to such a domain an imaginary "spring" that is pictured as a metal coil. Unlike an actual spring or metal coil, properties of a Hooke's Law spring are completely described by a single number called the "spring constant," along with a range of movement.

In the first construction, the only influence or force in the paradigm is embodied in the spring constant. Other potential influences are excluded from the imaginary domain. To start, there is no force of gravity in the imaginary domain. Movements in such a domain do not depend on the orientation of the spring in space. Movements do not slow because of friction in movements or heating of the spring.

In the Hooke's Law paradigm shown in the figure below, a cylindrical container, vertically oriented, is closed at the bottom. One end of a Hooke's Law spring is attached to the bottom of the cylinder and the other end of the spring is free to move up or down. A piston devoid of mass is attached to the free end of the spring; the piston slides easily inside the cylinder and steadies movements and positions.

At the center of the Hooke's Law paradigm is a ***static*** position (y_0) where the spring is resting in a "flaccid" condition of loose immobility. In this position, it is easy to jiggle the free end of the spring up or down a little bit; but, to go beyond the little bit, a substantial force must be imposed. It is presumed that, when jiggling or force ceases, the spring returns immediately to the central static position.

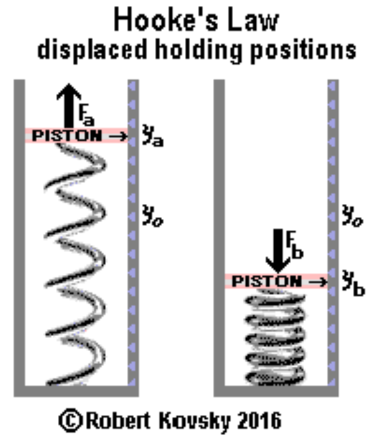


The central static position y_0 is called "y zero." In the absence of gravity, it does not change if mass is added to the piston. The y_0 position serves purposes like those of zero in arithmetic. It is a central position with symmetrized operations up and down, within a range of motion. Nothing happens when the device is left at y_0 and no force is needed to hold it there.

A period of time at the y_0 position can be prolonged indefinitely. While the device remains at the y_0 position, the domain clock can slow, stop or go backwards without changing any results.

The central y_0 position is the only position that fully manifests all of the foregoing indifferences. Indifferences are shed in subsequent developments and the position of y_0 in the cylinder is moved; but the foundational importance of y_0 is maintained.

Next, suppose that a researcher displaces the piston from the y_0 position, as in the adjacent figure. To track displacements, introduce a variable y. Suppose that the piston begins at position $y = y_0$ and that the piston is then moved to and held at a position $y = y_a$ that is different from $y = y_0$. In contrast to the loose immobile condition at $y = y_0$, it is necessary to impose a "holding force" F_a on the piston at $y = y_a$ or the piston will move back towards $y = y_a$. At a different position, e.g., $y = y_b$, a different holding force is needed, namely, F_b. F_b differs from F_a in both magnitude and direction. Displacement $(y_a - y_0)$ is greater than displacement $(y_b - y_0)$; the magnitude of F_a is greater than that of F_b.

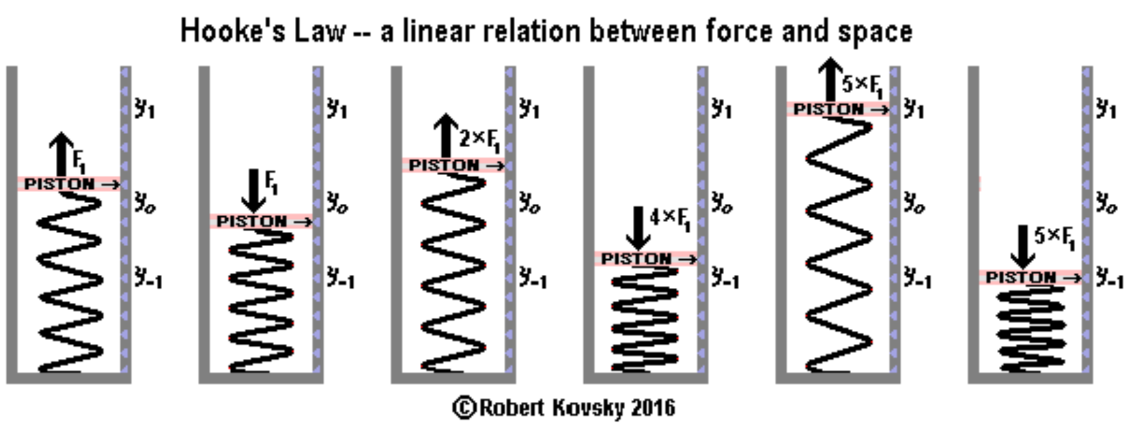


The holding force is defined in this paradigm as $F_h = k \times (y - y_0)$ where k, the spring constant, is a positive real number with appropriate dimensional units. The spring constant has the same value for all displacements $(y - y_0)$ where y is within a defined range of movement. The required holding force is in the same direction as that of the displacement from $(y = y_0)$.

A stationary paradigm such as Hooke's Law qualifies for application of Newton's Third Law of Motion. ("For every action there is an equal and opposite reaction.") Therefore, a holding force F_h is matched by an equal and opposing force F_s that is attributed to the spring. This spring force, $F_s = -k \times (y - y_0)$, is said to come out of the elastic properties of the spring. In other words, each stationary position is maintained by a pair of equal and opposing forces, a holding force and a spring force. This approach is supported by the experience of a person exerting a force against a spring where the person feels a force coming from the spring.

$F_s = -k \times (y - y_0)$ is called "Hooke's Law" after its discoverer, Robert Hooke (1635-1703). The figure below show operations of Hooke's Law that resemble those of the equipoise Atwood's machine. The range of movement (ROM) is the space between y_1 and y_{-1}. The piston is moved to multiple positions within the ROM and the force required to hold it is measured at each position. If the displacement is doubled, a doubled holding force is required. The same principles applies in finer detail: a change in displacement of a specific percentage is matched by a change in holding force that has the same specific percentage. This is a ***linear relationship***.

As in the flaccid version, the holding force defined by Hooke's Law does not depend on the mass of the piston or spring. Hence, it is sufficient to show massless elements in the figure.

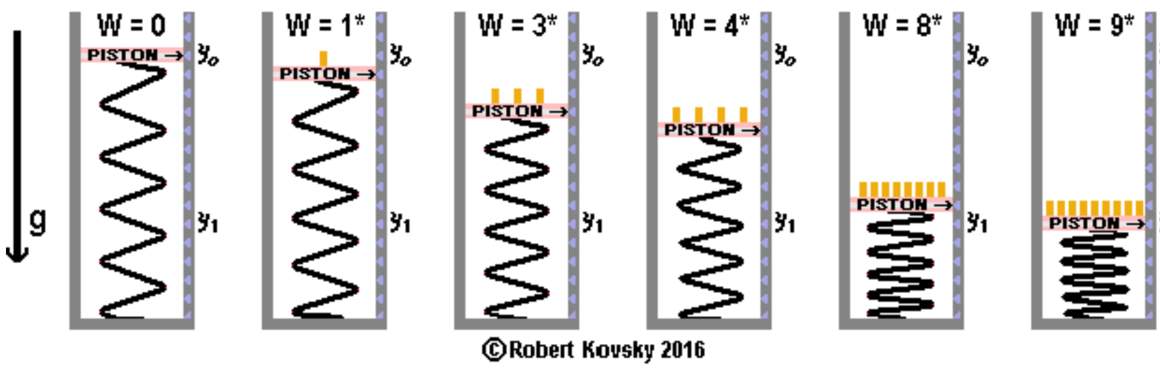


Static positioning and equipoise operations in the Hooke's Law paradigm occur in detached time. In other words, movements between equipoise positions and measurements of the holding force at various equipoise positions can be re-ordered and re-scheduled without changing results and for any movement between equipoise positions, there is a reversal movement that combines with the original movement to make a null movement.

b. The Hooke's Law paradigm with gravitational force operates between equipoise positions in detached time.

As introduced in prior Hooke's Law paradigms, it is necessary to impose a "holding force" in order to maintain a position of equipoise that is different from $y = y_0$. The equivalent of a holding force can be imposed by the influence of gravity on a mass or weight w, as shown in the figure below. An equipoise position is maintained by a spring force that is equal to the gravitational force. In this version, the Hooke's Law paradigm operates as a "scale," both in the sense of a physical device to weigh objects and also as a rational device to connect variations in total weight on a piston with marks on a line.

Hooke's Law -- spring force in equipoise with gravitational force



An operation starts in one equipoise position with a certain weight and then adds or subtracts weights while controlling the movement to a second equipoise position. Control means that movements are smooth, not jerky, and are slow enough to ensure smoothness. Such movements and positions resemble those of the equipoise Atwood's machine. The Hooke's Law with gravitation paradigm is an advancement from Atwood's machine paradigms in putting two different kinds of forces in equipoise instead of operating with the single force of gravity.

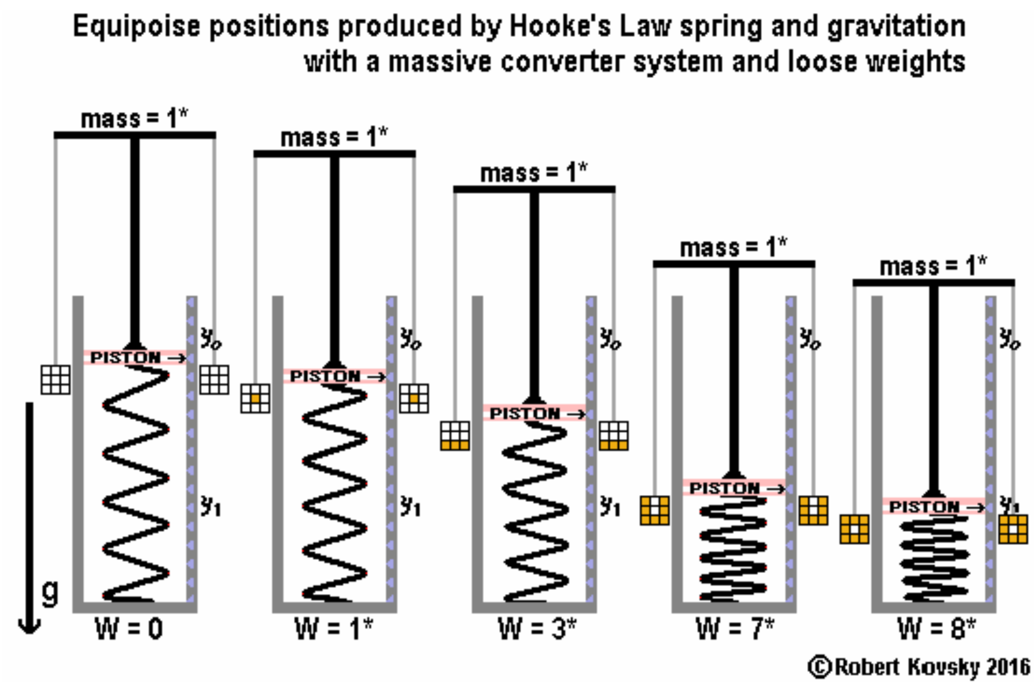
Additional restrictions are imposed on equipoise operations of this paradigm. Each mass size W will stand in equipoise at only a single position on the scale. Movements are confined within a ROM. Since mass must be positive, one end of the ROM is set at $y = y_0$. The other end of the ROM, denoted as $y = y_1$, is set by limits of the system. The massless piston is held at position $y = y_0$. The maximum mass W_M is held at $y = y_1$. A mass W can be any size between 0 and W_M. In the figure above, $W_M = 9*$. The unit of weight, 1*, is denoted by an orange marker.

In easy physics paradigms, forces are combined by additions and subtractions. The addition or subtraction of a constant force of gravity to a linear SHO force produces a linear sum. Therefore, the "Hooke's Law spring with gravitational force" operates with a linear scale, meaning that equal division marks in the ROM denote equal increments of weight. (In contrast, musical scales that relate pitch and frequency are not linear .)

Equipoise operations of the new paradigm manifest detached time features. First, sizes of adjustments between static positions are easily varied without changing results. One big adjustment can be broken up or decomposed into several small adjustments and details of such a decomposition can be highly variable. Second, timings can also vary: a movement between equipoise positions can be postponed without changing the operation.   Third, each adjustment has a reversal adjustment. Results are independent of decompositions and postponements; and operations can be attached to and detached from each other in various ways.

c. Equipoise operations of the Hooke's Law paradigm with added gravity can be controlled so as to model smoothly connected movements in detached time.

The figure below shows the Hooke's Law paradigm with added gravity in a revised version. Weights are relocated, with a pair of masses suspended by ropes. The supporting apparatus and ropes have a total weight of 1*. Equipoise operations previously discussed are not modified by these developments: beginning from an equipoise position, a change in weight is coordinated with a smooth movement to a changed equipoise position.   As before, everything operates without friction and ropes are always taut. As before, operations conform to the rules for mathematical groups. As before, operations occur in detached time.

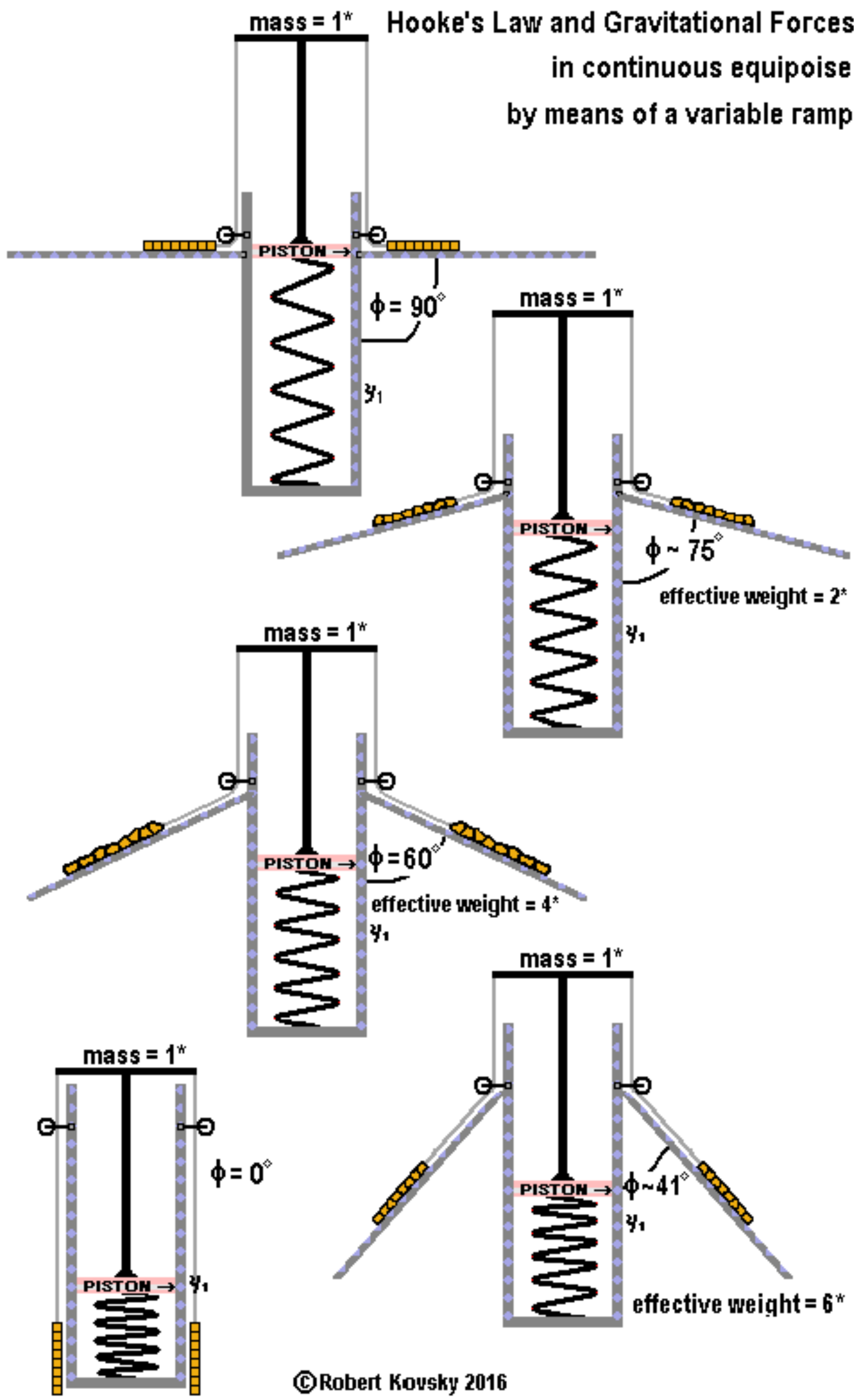


A ***ramped*** version of a Hooke's Law spring in equipoise with gravity, shown in the adjacent figure, introduces a new variable φ, which specifies the angle between the ramp and the vertical. Weights slide without friction on the ramp and the angle φ ranges between 0 and 90°.

When φ=90°, the whole weight is supported by the ramp and the spring force has only the mass of the apparatus, 1*, to oppose it; the equipoise position of the weight is $y = y_0 + 1$ for any weight. When φ=0, the position is the same as in the loose weight version.

At an intermediate point, the position of weights on the ramp varies according to φ.

It is possible to imagine that φ starts at 90° and then continuously shrinks to 0. As φ shrinks, the weight goes down on the ramp and the spring compresses. In the imaginary domain of the paradigm, such movements occur without friction and without any expenditure of energy. Spring force and gravitational force are in continuous equipoise or equipoise at each position.



In this paradigm, the position z of the weight on the scale depends on g, k, W and φ. In that g and k are constant, a function G is defined such that G(W, φ, z) = 0. Such a function anticipates the equation of state for the ideal gas F(p, V, T) = 0, namely, PV – nRT = 0.

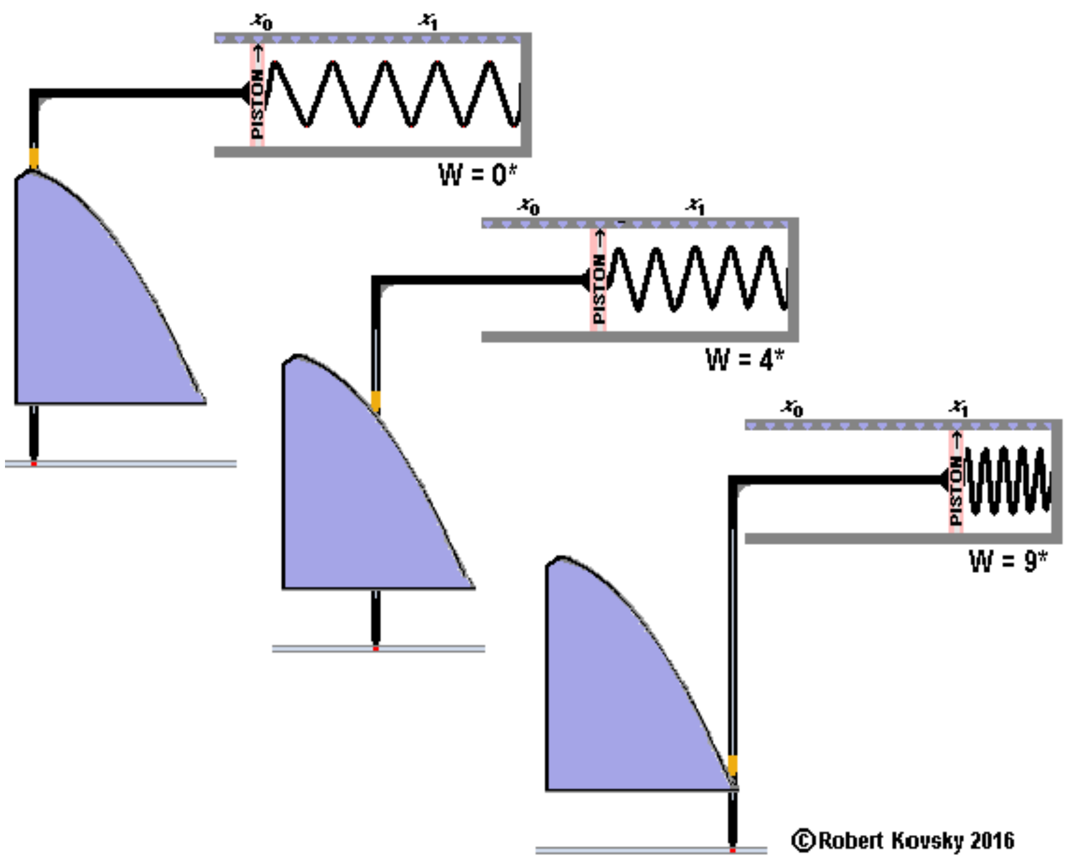
The weight slides without friction on the ramp and is supported by the ramp; the ramp pushes with a supporting force against the weight in a direction perpendicular (or "normal") to the weight. The magnitude of the supporting force F_n needed to maintain a static position is equal to W × cosφ. The figure below shows relationships between forces on the weight in the ramped gravitational version of the Hooke's Law paradigm. At each position, the forces on the weight are in equipoise, namely the force of gravity imposed on the weight, the force of the spring imposed on the weight through the taut rope and the force of the ramp supporting the weight. Three different force directions are involved and the forces add to a null. At any specific angle φ, both the force of gravity and the normal force of the ramp against the weight are constant; therefore, for any suspended weight within the range 0* to 8*, there is a position on the scale where forces add up to 0. The desired position exists and it is unique.

Equipoise forces in the ramped paradigm illustrate another important feature that is developed in ideal gas paradigms and Carnot cycle paradigms. Three different forces are involved in the paradigm: the spring force, the gravitational force and the supporting force of the ramp. Equipoise operations with three kinds of forces and with a ramp provide a mean to ***split forces in a variable way***. In this paradigm, the gravitational force F_g is matched or balanced by the sum of spring force F_s and supporting force F_n. That is, $F_g = -(F_n + F_s)$.

If φ=90°, F_n/F_g, = 1; if φ=0°, $F_n/F_g = 0$; the ratio F_n/F_g changes smoothly as φ changes from 0° to 90°.

Next, forces and movements are re-constructed in further developments. In the new version, the spring force operates in the horizontal x direction, the gravitational force operates in the vertical y direction and the supporting force operates in a variable intermediate position that carries out the requisite force split. Instead of $F_g = -(F_n + F_s)$, the split is $F_n = -(F_g + F_s)$. Again, results are produced under conditions of continuous equipoise. (The revised force split anticipates thermodynamics transformations discussed below that lead to enthalpy and latent heat.)

The piston and attached apparatus shown in the figure below weigh 1* and slide without friction both in the cylinder that holds the spring and also in the track at the bottom. The apparatus holds the "bolt" in a channel; the bolt (an orange weight greater than 8*) can move vertically in the channel without friction under the influence of the force of gravity and the two contact forces. As to one contact force, the channel presses on the bolt in the x direction with force F_s generated by the spring. The curved slope supports the bolt in a direction normal to the slope with a variable contact force that depends on the position. In imagination, the three forces are "added" within the bolt, which achieves equipoise when the forces sum to zero. The requirement of equipoise at each position determines the shape of the curve. When the piston is at x_0, the slope is horizontal. As in the original Hooke's Law paradigm, the piston can jiggle a little bit: the spring moves easily at that position and the weight glides easily on the flat surface. Moreover, the condition of "easy glide" continues at every position on the slope. Forces sum to zero all along the slope and adjustments with negligible energy costs move the bolt between positions. In other words, there is a condition of continuous equipoise all along the curved slope.



To calculate the shape of the slope, suppose that the weight is in equipoise at a position different from x_0, namely, at $(x - x_0)$ and $(y - y_0)$. The slope imposes a force F_n on the weight in a direction that is specified by φ. The channel imposes F_s on the weight which imposes $F_s \cos\varphi$ on the supporting slope. The weight imposes $F_g = w\ g \sin \varphi$ on the slope. Forces are in equipoise. Then suppose that there is a small additional displacement that moves the weight to a position at $(x + dx - x_0)$. The magnitude of the spring force at this position is $F_s = k \times (x + dx - x_0)$ and the magnitude of the gravitational force is $F_g = w \times g \times (y - y_0)$.

d. Dynamical oscillatory operations of the SHO occur in mimed time.

Equipoise operations of the Hooke's Law paradigm are of chief importance in this project. Most physics treatments focus on dynamical movements of the Hooke's Law paradigm, which then becomes the simple harmonic oscillator (SHO) paradigm.

During dynamical movements of the SHO, the paradigm domain clock operates in mimicry of actual time and events occur in mimed time. We prepare for such operations while in detached time by holding the piston with mass m at position y_1 that is different from y_0. Then, we simultaneously start the domain clock at t = 0 and release the piston. In developing the paradigm to describe dynamical operations, it is presumed that Hooke's Law continues to apply, namely $F_s = -k \times (y - y_0)$. A sizable force is produced by the spring and there is no gravitation force or holding force; hence, the mass accelerates according to Newton's First Law of Motion: a = F/m. Equating the two F's leads to the familiar solution:

$y = (y_1 - y_0) \times \cos(\omega t)$ where $\omega^2 = k/m$.

ω has a dimension "per sec" and is called the "angular frequency." Movements that follow a cos(ωt) are called ***oscillations***. In the paradigm, oscillations occur with a period $\tau = 2\pi/\omega$. The period τ does not depend on the magnitude of the displacement $(y_1 - y_0)$ or on anything other than k and m.

Examination of the movements of the dynamical SHO shows that y_0 retains its central position even though it is not a position of rest. Rather it is the position of maximum speed of the mass. Positions of momentary rest occur at positions y_1 and y_{-1}.

The oscillatory SHO paradigm applies to certain actual phenomena. Transmissions of sounds in bodies of air, water and metals are described by SHO principles operating at a molecular level. Quantum mechanical applications based on SHO principle include semiconductors like silicon. Math-like "harmonics" in music go back to Pythagoras in the 6th century B.C.E. Musical vibrations are described as oscillations; and vibrating musical instruments made of wood, metal and animal materials can be tuned exactly to frequencies that have a mathematical basis. For more examples of applications of the SHO, actual springs run clocks and watches with good precision and a similar paradigm applies to the pendulum clock, which can be even more precise.

Viewing SHO applications from a critical perspective, conformity of an actual material to the requirements of Hooke's law occurs, if at all, only approximately and only over limited ranges of motion. A wooden beam bears a substantial weight while bending proportionately; but it departs from Hooke's Law and breaks if the weight is too heavy. Overdriven musical instruments produce buzzing noises. Unlike imaginary springs in the SHO, nearly all actual solids do change with use; and deformations leave traces that, after many repetitions, have a cumulative effect. A piece of metal that is repeatedly flexed and released may develop "fatigue," including cracks that lead to fracture. Violins sound different after having been played for many years.

Especially troublesome is the all-too-easy inflation of Hooke's Law defined for a static holding force into a dynamic principle. In other words, a movement is said to be constructed from a succession of equipoise positions that are defined in detached time. As noted by Truesdell (79):

> First, in mechanics the concept of force originated in statics and was carried over bodily, if with much delay and discussion, to motions, If the restoring force exerted by a spring is proportional to the increase of its length in a static experiment, will it still be so when a ball is attached to the end and set into

> oscillations, especially if the experiment is performed in a spaceship in orbit around the moon? Indeed, does it make sense to talk about forces at all in a moving system? The forces, it seems, might be affected by the motions, yet we are supposed to know the forces first in order to determine what the motion will be. These questions, and far subtler ones of the same kind, were asked in the seventeenth century; today the freshman is trained specifically not to ask them.

Thus, a distinction between the Atwood's machine and SHO paradigms appears in the respective force relations. As to the former, Newton's Laws of Motion are generally stated for moving bodies and apply to static bodies only as a special case that fits within the general case. Hooke's Law is defined for the static case and is then generalized without limit to apply to moving bodies.

Mimed time operations of the SHO manifest features different from those of actual time operations of Atwood's machine. Quantities involved in Atwood's machine – m, M and g – are referenced to actual bodies and movements. In the SHO, material properties appear in the form of "k," the spring constant that exists only in imagination. An actual body conforms to a "spring constant" description only for a limited range of movement and only in an approximate way. When laboratory measurements are made, the value of k is adjusted to make measurements better fit the paradigm.

The SHO paradigm would be useless if all materials had the same k, like all earth-bound bodies have the same g. For example, tuning a string on a violin or piano involves an adjustment of tension. Although there is nothing in the SHO paradigm that connects k to tension of a spring or a string, we suppose that a suitable relationship can be constructed. However, a relationship that works for string instruments does not work for wind instruments, where tones are based on an air column in a pipe and the rate of vibrations can be adjusted by movements of the mouth of the performer (embouchure) or, in a larger way, by inserting an additional length of pipe, such as a brass horn "crook" that changes the key. In Atwood's machine, a single formula is precisely applied to a compact body of actual phenomena; in the SHO, a highly variable construction is manipulated for approximate conformity to various kinds and ranges of phenomena.

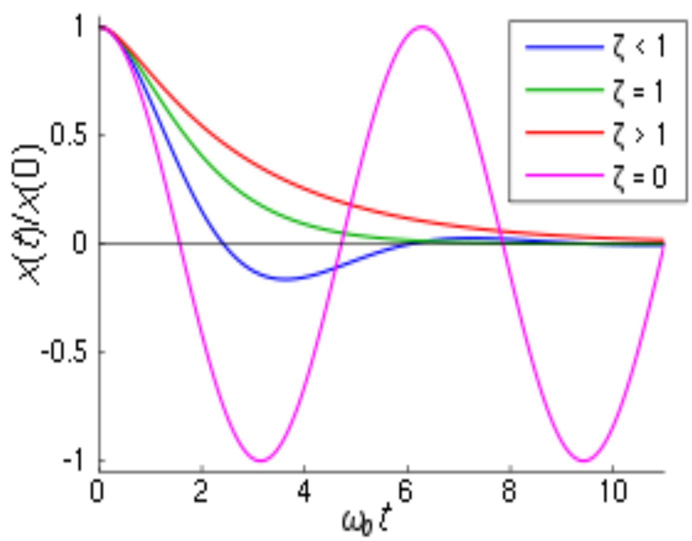
The distinction between actual time paradigms and controlled time paradigms is clearly shown by the ωt form of time that is used in the SHO. Actual time such as that used in dynamical operations of Atwood's machine cannot be stretched or compressed like an ωt form of time. Musical tempi also employ a stretchable ωt form of time, where ω appears in the form of metronome marks, e.g., ♩ = 80 or 80 beats per minute. Few performers maintain a metronomic beat but most, in contrast, vary the tempo to suit a mood or general approach, like an *accelerando* near the end of a lively movement.

e. Dissipative operations of the SHO are movements in mimed time based on positions and movements defined in detached time.

A major development of the SHO is the introduction of an additional influence that is called ***damping*** (in mechanical paradigms) or ***dissipation*** (in broader classes of paradigms), which model internal heating, heat discharges and friction in actual bodies. Dissipation provides an additional means of control for the SHO and suggests further controlled time operations.

The image and caption below are copied from https://en.wikipedia.org/wiki/Damping and show aspects of dissipative operations. Each trace follows a separate movement of a dissipative SHO as measured by a domain clock that mimics actual time. Each movement starts from a position y=1 and a speed v=0 that is defined in detached time. Times in the various traces can be directly compared as if an otherwise invariant system is run with variable amounts of dissipation.

The "damping ratio" ς tracks the amount of dissipation that affects such a movement. If $\varsigma = 0$, there is no dissipation; oscillatory movements continue indefinitely. If $\varsigma < 1$, there is small dissipation; oscillations die out — but, at least in the first return to the equipoise position, there is an "overshoot" or passing beyond the equipoise position, which occurs in the image below at about $\omega_0 t = 6$. If $\varsigma \geq 1$, the larger dissipation prevents an overshoot. The value $\varsigma = 1$ identifies the least dissipation that will avoid an overshoot. It is a "critical" value. Critical value operations of the SHO provide the fastest return to static equipoise that avoids an overshoot.



<u>Caption</u>

Time dependence of the system behavior on the value of the damping ratio ζ, for

undamped (cyan),

under-damped (blue),

critically damped (green), and

over-damped (red) cases,

for zero-velocity initial condition.

As mentioned in Wikipedia, a mechanical door-closer may have a "damped spring" to return a door to the closed position after being opened. Critical damping provides the fastest closing that avoids having the door bang into the door-frame. Some door-closing devices have an adjustment to make it easier to achieve this standard of performance.

Critical damping operations introduce important features that re-appear in critical point operations of the Ising model and in critical moment operations of Quad Net devices. In such critical paradigms, there is a boundary between two kinds of operations; and operations at the "critical point" not only mark the boundary but also have special features of their own.

B. Ideal Gas and Perfect Gas.

1. **Summary**.

In this project, ***ideal gas*** is the name of a class of thermodynamics paradigms that date from Boyle's Law in the 17th century. Operations in ideal gas paradigms consist of movements between equipoise positions in detached time. So-called laws of energy conservation and entropy increase that were stated by Rudolf Clausius and others in the middle part of the 19th century are based on ideal gas paradigms and on detached time paradigms of the Carnot cycle.

In contrast, perfect gas paradigms and larger "kinetic theories" are mechanics constructions of the latter part of the 19th century. Perfect gas paradigms start in a domain of overlapping detached time and actual time called "equilibrium" and are then developed in ways that mimic movements in actual time. Perfect gas paradigms thus operate in mimed time.

This project employs the foregoing definitions but other investigators use terms differently. See J. S. Rowlinson, "James Joule, William Thomson and the concept of a perfect gas," http://rsnr.royalsocietypublishing.org/content/64/1/43.article-info (Notes and Records: the Royal Society journal of the history of science).

According to Rowlinson, such paradigms were not immediately accepted by all the founders of thermodynamics. William Thomson (1824–1907), developer of modern thermometric scales and later achieving the status of Baron Kelvin, declared that: "a mere quicksand has been given as a foundation of thermometry, by building from the beginning on an ideal substance called a perfect gas, with none of its properties realized rigorously by any real substance, and with some of them unknown, and utterly unassignable, even by guess…"

Results showed that "kineticists were justified in saying that a perfect gas is acceptable as the working substance of a Carnot engine. What may have aroused Thomson's apparently exaggerated fulminations may have been the behaviour of this gas when not at equilibrium. The application of the original form of the kinetic theory to a perfect gas leads, for example, to the prediction that such a gas has an infinite viscosity and infinite thermal conductivity."

Ideal gas paradigms and perfect gas paradigms converge in simple applications where equipoise operations of an ideal gas are equated with equilibrium operations of a perfect gas. In other words, "quasi-static" equilibrium operations in actual time would be indistinguishable from equipoise operations in detached time. When developed into paradigms of irreversible and disequilibrium processes, however, ideal gas paradigms and perfect gas paradigms have distinctly different characters.

(A third class of "statistical mechanics" paradigms also converges, in the simplest applications, with classes of ideal gas paradigms and kinetic theory paradigms. As discussed below, statistical mechanics constructions are tightly bound to equilibrium conditions and operate exclusively in detached time.)

2. the ideal gas paradigm operates in detached time

a. equipoise positions of the ideal gas paradigm

The adjacent image shows an ideal gas paradigm. A body of gaseous material at uniform temperature T is confined inside a cylinder of volume V. The cylinder is tightly enclosed but has a movable, massless piston – like the piston used in Hooke's Law and the SHO – which is maintained in a static position by equality of upward force from pressure of the gas inside the cylinder (p) and downward gravitational force from a weight on the piston (W) combined with atmospheric pressure (*).

As shown in the image below, equipoise positions can be changed. For example, a researcher can add a weight on the piston. Hot or cold liquid can be introduced into the base of the cylinder to heat or cool the gas. A new volume may be required for equipoise to be re-established. The range of positions in the ideal gas paradigm resembles the scale of equipoise positions of the SHO plus gravity or in the constrained Atwood's machine. In ideal gas paradigms, mechanical forces and gas pressure forces add up to equipoise at each static position. Different static positions depend on different gas temperatures and different weights on the piston.

The ideal gas paradigm requires a perfect seal between the piston and the cylinder that provides frictionless sliding and that also prevents gas from leaving or entering the cylinder. Further requirements are that: the whole apparatus and all of its parts – including the piston, the cylinder and the base – are perfectly insulated and have no capacity to store heat – as a result, heat can neither enter nor leave the cylinder, except through the heat transfer element in the base of the cylinder. Heat is stored only in the body of the ideal gas. A "standard" operating environment is at sea level of the Earth, modeled by a fixed atmospheric pressure and a fixed gravitational force.

With a perfect seal and insulation and a fixed environment, "static" conditions can be maintained for an indefinite period of time. A static position is maintained by a balance or equality between the upward pressure of the gas within the cylinder and the sum of the downward forces on the piston. The downward force or "weight" provided by atmospheric pressure is denoted by "1*." Added forces are measured in units of 1*; various weights in the image are W=0, W=1*, W=2*, W=5*. A "standard" value of 1* is about 14.5 pounds per square inch (psi).

The temperature of the ideal gas is denoted by "T." Using standard parlance, T is measured by degrees Kelvin (°K), with the same spacing as degrees Celsius (°C) but with a different zero. Water freezes at the "standard temperature," 0 °C or about 273 °K. At T = 0 °K, "absolute zero," an ideal gas is inert. It is impossible to reach absolute zero: T must always be greater than 0 °K.

The changing volume of the cylinder occupied by the ideal gas is denoted by "V." Changes are also tracked by y, called ***the expansion***: $y \times A = V$ where A denotes the area of the cylinder.

To define gas pressure, apply Newton's Third Law of Motion. The upward forced exerted on the piston by the gas within the cylinder holds in equipoise the weight from atmospheric pressure * plus added weight W. Such force is expressed as pressure and denoted as $p = (1^* + W)/A$.

The definition of the character of an ideal gas – called its ***equation of state*** or ***constitutive relation*** – is based the foregoing rules and requirements for measuring values of variable quantities and is provided by the following formula:

p × V = n × R × T, generally written pV=nRT and based on variable quantities p, V and T discussed above.

Because T must always be greater than 0, both p and V must always be greater than 0.

Equivalently: F × y = nRT, relating force F = (1* + W), expansion y and temperature T in °K.

In the formulae, "R" denotes the "universal gas constant," a fixed number with a value that depends on the dimensional units used to define quantities in the laboratory where R is measured, e.g., depending on whether distance measurements are in inches or centimeters. R is the same fixed number for all gases that conform to the ideal gas paradigm.

The symbol "n" refers to the quantity of the gas; there is a "standard" where n = 1 denotes 1 mole of gas; a mole is standardized as a specific number of molecules or a specific volume. It is often convenient to ignore n and to assume a standard 1 mole.

The generality of the ideal gas law permits an arbitrary choice of dimensional units; and units can be chosen for pedagogical convenience. Suppose that we define a specific expansion ξ such that y = 1ξ occurs when the only weight on the piston is atmospheric pressure (F = 1*, W=0) and the temperature is 300 °K, just a bit above room temperature. Then: applying the ideal gas law, 1ξ × 1* = [nR] × 300 °K. (1* is many miles or kilometers in length and would amount to a substantial fraction of the height of the atmosphere above Earth.) The following table lists some of the equipoise positions that can be produced with such a system. Each position is defined by the ideal gas law and any two of: (a) temperature, (b) expansion, (c) force (weight) on the piston.

Temperature T =:				
1200 °K	F = 4* W = 3*	F = 2* W=1*	F = 1.33* W=0.33*	F = 1* W = 0
900 °K	F = 3* W = 2*	F = 1.5* W=0.5 *	F = 1* W = 0	
600 °K	F = 2* W = 1*	F = 1* W = 0		
300 °K	F = 1* W = 0			
expansion y =:	1ξ	2ξ	3ξ	4ξ

When corresponding properties of actual gases are investigated, experiments show that, within limited ranges of temperatures, the ideal gas law serves as a good approximation to a large class of actual gases but by no means all, The adjacent image is copied from Morse Figure 3-3 at page 26 and shows the ideal gas as a straight line at the center where the ratio pV/nRT is, by definition of the ideal gas, identically equal to "1.00" for all pressures. Morse states that: "Figure 3-3 shows curves displaying the departure from the ideal gas law of the equations of state of a few gases. We see that, except for gases near their temperature of condensation, such as CO_2 at 300° and H_2O at 600° the ideal gas law is correct to within a few per cent over a wide range of pressures and temperatures."

b. processes involving an ideal gas are operations that take place in detached time

The form pV=nRT is subject to mathematical methods that imply a thread of connections or "analytic continuity" between nearby values of variables. It is possible to imagine a sequence of equipoise positions of the ideal gas paradigm that resembles mathematical continuity and to imagine movements between equipoise positions that follow the mathematics. Such imaginary movements between equipoise positions that follow mathematical forms are called ***processes***. Processes are: "Basic, explicit, and mathematically precise assumptions." (Truesdell, 83.)

Imaginary processes of the ideal gas paradigm resemble equipoise operations of the SHO. Both occur in detached time. An imaginary movement between static positions can be decomposed or postponed without changing the forces or temperatures that produce particular static positions.

The image below shows a series of equipoise positions that are part of an ideal gas paradigm with a single body of gas. In the first position, the temperature of the ideal gas T = 300 °K, y stands at 2ξ and F = 1* + 5*. In the second position, T = 600 °K, y = 4ξ and F = 1* + 5*. In the third position, T = 900 °K, y = 6ξ and F = 1* + 5*). Out of many equipoise positions that could have been chosen, these all have the same weights (and pressure).

In imagination, equipoise positions in the image constitute a succession of momentary states that occur during a single process in which a body of ideal gas is progressively heated so that it expands and lifts the piston. Suppose that, initially, the expansion x = 2ξ and that the weight is maintained at F = 1* + 5*. Then imagine that the ideal gas is slowly heated from 300 °K and pushes the piston up. To start, a little bit of heat is put into the gas so it gets a little bit hotter. In symbols, T goes to (T + ΔT), where ΔT is small, perhaps 1 °K. Then, in the imaginary process, the added force from hotter gas will push the piston up an additional Δy where Δy = [nR/(1* + W)] × ΔT. Everything inside the brackets […] is fixed and there is a linear relationship between ΔT and Δy. Hence, little ΔT's can be added up to make a big ΔT.

The foregoing construction of a process becomes part of the ideal gas paradigm. It is called an "isobaric" process because the pressure remains the same. However, nothing is actually moving. The ideal gas paradigm does not include actual movements of the piston but only imaginary or constructive movements. In order to actually move, weights have to acquire momentum. Atmosphere weighing many pounds or kilograms would have to be pushed aside. Pushing aside such a weight requires energy in addition to the amount involved in a gravitational potential. Acquisitions of momenta and added energy requirements are ignored in the ideal gas paradigm.

Movements and operations in detached time are imaginary. In such operations, it is easy to imagine a series of "little bitty movements" and to combine them to construct a 'big" movement. Decomposition is equally simple. In such compositions and decompositions, energy costs of changes are disregarded. Jerky movements easily turn into smooth movements and smooth movements easily turn into jerky movements. Similarly, imaginary movements of ideal gas processes in detached time can be speeded up or slowed down without any costs.

3. perfect gas paradigms

   a. perfect gas paradigms that are restricted to equilibrium conditions can operate equivalently in actual time, detached time and controlled time.

Equipoise operations in detached time serve as steps that lead to ***equilibrium operations*** with a higher level of activation and multiple time forms. In equipoise operations, equal and opposing forces hold each other in stationary but variable positions. In equilibrium operations, equal and opposing flows produce a steady but variable condition.

Flows provide enlarged opportunities for control and innovation. Rational constructions using flows apply to many situations beyond the reach of static positions. Unlike static positions, flows can occur in actual time with rates that can be related to material properties.

In equilibrium paradigms, a body of material (gaseous, liquid or solid) can take on a variety of ***equilibrium conditions***. Seen from a large-scale perspective, a body in an equilibrium condition is devoid of movement or change. For example, distilled water sitting in a closed container at room temperature is in equilibrium – chemically, kinetically and thermally. The equilibrium condition, like conditions at equipoise positions, continues for an indefinite period of time. Changes can be decomposed into smaller changes and can be postponed. As with equipoise positions of the ideal gas, changes between equilibrium conditions are outside the equilibrium paradigm; but, unlike ideal gas paradigms, the perfect gas paradigm can be extended and varied so as to apply to some changes.

Equilibrium paradigms presume that a body in an equilibrium condition in a steady environment will remain in that condition unless moved or changed by an external influence. The simplest paradigms presume that any such movement or change is proportional to the external influence (a linear response). Further: it is presumed that if a body is isolated from all external influences, it will tend towards an equilibrium condition. A body left alone long enough in a steady environment will end up in equilibrium and stay there until moved by an external force.

Equilibrium requires conceptual isolation of the body. Perfect isolation is not possible in actual life. Any actual body radiates heat and receives heat radiated from other bodies. Some bodies conduct heat to other bodies. If a body remains in an equilibrium condition, and if no energy transfer occurs except by transfers of heat, the heat received must be equal to the heat radiated or conducted away. This requirement is troublesome to achieve in actual life but can be met by surrounding an inanimate body with walls at the same temperature as the body.

Equilibrium presumptions apply to some inanimate bodies that lack internal sources of energy; but the presumptions do not apply to living animal bodies. Live bodies never reach equilibrium. An animal will sleep for a while and then start moving on its own. Vegetable seeds also fail to fit the equilibrium model: they can remain inert for centuries and then spring into life.

Despite limitations, equilibrium has important uses. Branches of chemistry, e.g., biochemistry, are solidly rooted in equilibrium. Equilibrium operations in gases are explored in a branch of thermal physics called ***kinetic theory***. A kinetic theory is rational or axiomatic. The foundational construction of a perfect gas is stated in Morse at 14.

> Let us assume a very simplified model of a gas, one consisting of N similar atoms, each of mass m and of "negligible" dimensions with negligible interactions between them so that the sole energy of the *i*th atom is its kinetic energy of translation…

> The gas is confined in a container of internal volume V, the walls of which are perfect reflectors for incident gas atoms. By "negligible dimensions" we mean the atoms are very small compared to the mean distance of separation, so that collisions are very rare and most of the time each atom is in free motion. We shall call this simple model a *perfect gas of point atoms*.

It is also stated that "collisions are elastic." Of pivotal importance is the interplay between such elasticity, the restriction that "the sole energy … is … kinetic energy" and the restriction that "collisions are very rare." Suppose that two identical elastic atoms traveling at the same speed but in opposite directions collide directly head-on and then rebound in reversed directions. At the center-point of the collision, both atoms come momentarily to rest: applying Conserved Energy principles, the previous kinetic energies must be stored in elastic materials like that used in the SHO. But then, the sole energy is not kinetic. Because "collisions are very rare," energy stored in elastic materials might be ignored; but then changes occur very slowly. Similar problems beset the "perfect reflectors" in walls, which can be resolved by having the walls at the same temperature as the gas so that the walls and the gas are all at equilibrium together. Even this solution creates problems with changes because both walls and gas have heat capacities – but such problems are disregarded in kinetic theories.

A perfect gas, so defined, can be put into equilibrium conditions and also conditions where equilibrium is lacking. For an example of disequilibrium conditions, suppose that the container of the gas is divided into two equal regions by an insulated wall. On one side of the wall, a high density of atoms is maintained in equilibrium; on the other side of the wall a low density of gas atoms is also in equilibrium. At first, the two regions have no interaction. Next, suppose that tiny holes are opened in the insulated wall and that small flows of atoms pass through the wall. Flows will pass through in both directions but flows through the wall from the high density side will be heavier than flows from the low density side. As a result, the densities on both sides of the wall will change and conditions on both sides will depart from equilibrium. Eventually, the flows and changes will remove all difference in the densities and equilibrium will be restored.

To deal with such cases, James Clerk Maxwell (1831-1879) invented a concept that Truesdell (414-415) calls a "molecular density function *F*" and that Morse (162-63) calls it a "probability density *f*" or a "probability distribution." Morse states: "Probability distributions are the connecting link between atomic characteristics and thermodynamic processes." Truesdell concurs: "Thus the kinetic theory yields for equilibrium, duly defined, exactly the same gross differential equations as does … a corresponding ideal gas."

Truesdell provides an analytic definition. "MAXWELL regarded as being appropriate to equilibrium any molecular-density function *F* such as to be unaltered by collisions." Allowable flows under this definition would "include arbitrary expansions and rotations" and "represent something a little broader that what we think of in ordinary mechanics as equilibrium. WANG's definition of *local equilibrium* in the kinetic theory is $F(\mathbf{x}, \mathbf{v}, t) = F(\mathbf{x}, \mathbf{v}) = F(\mathbf{x}, -\mathbf{v})$. That is, *F* shall be steady and invariant under reversal of velocities."

In other words, there is a large class of *F* functions that apply to flows of atoms. If every flow of atoms were to be reversed, many *F* functions would change. For example, if flows in the disequilibrium situation described above were to be reversed, differences in densities would increase with time. Such events do not happen in actual life. Fortunately for perfect gas theories, equilibrium functions *F* as defined by WANG would be unchanged were such reversals to occur.

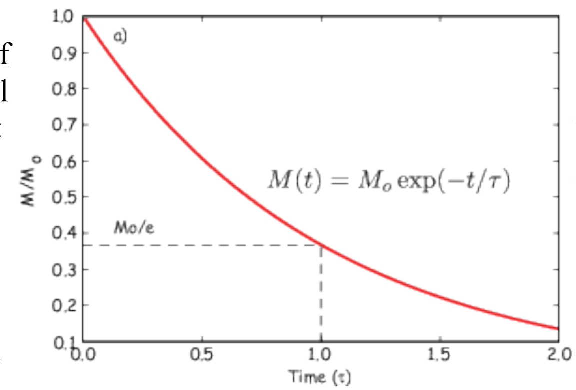
Alternatively, a definition of equilibrium is that *F* shall be steady and invariant under reversal of ***time***. If time reverses, velocities also reverse and the result would equivalent to that based on WANG's definition. As in the ideal gas paradigm, a body in equilibrium in the perfect gas paradigm would continue in equilibrium "the same" if time were to be reversed.

Another resemblance between classes of equipoise operations – e.g., in Atwood's machine, in the SHO and in the ideal gas – and the class of equilibrium conditions in a perfect gas – is that they are special classes that contain only a small fraction of possible operations. Special features that facilitate mathematical development also suggest that such development has only a limited reach.

b. disequilibrium and relaxation

In the SHO, oscillatory movements in mimed time are based on equipoise positions set in detached time. Hooke's Law is defined for fixed positions and carried over into movements. Similarly, perfect gas paradigms of Maxwell and Ludwig Boltzmann (1844-1906) begin with equilibrium conditions maintained under steady conditions in detached time and investigate departures from equilibrium. Under steady conditions, a small departure of a from equilibrium leads to a return to equilibrium. In some cases, operations can be related to certain specific classes of actual phenomena.

In the paradigm, after a small departure from equilibrium, a perfect gas ***relaxes*** with a rate of relaxation that is, at each moment, proportional to the departure from equilibrium; the constant of proportionality is determined by material properties, like the spring constant in Hooke's Lw. Such relaxation is expressed by the "exponential decay form" exp(-t/τ). Exponential decay forms also appear in the dissipative SHO when the damping ratio ς > 0.



The period τ is called the "relaxation time." After one τ period, a departure from equilibrium has diminished more than 63%. After two τ periods, the departure has diminished more than 86%.

The exponential decay form is smooth and continuous through multiple derivatives. In the dissipative form of Hooke's Law, a change in rate resulting from friction is similarly defined as proportional to the rate. Simple proportional relations also appear in ideal gas paradigms.

Such simple proportional definitions are called ***linear***. Linear forms are smooth and continuous. On the other hand, linear methods often fail to apply to jumpy or discontinuous movements. As to some situations and tasks, ***non-linear*** methods work better. Virtual Energy Thermodynamics is designed to work with jumpy and discontinuous movements.

Morse (206-207) assimilates the relaxation time τ to the average time between collisions of the gas atoms. This is because "the distribution can return to equilibrium in one collision time." "Detailed calculations for the few cases which can be carried out, plus indirect experimental checks … indicate that it is not a bad approximation…"

Truesdell provides a more critical view of "molecular interactions." "In kinetic theory, these interactions are called 'collisions' and are visualized as motions of pairs of molecules subject to their mutual attraction or repulsion alone. On the one hand, the gas is regarded as a vast multitude of speeding molecules; on the other, to describe the details of a collision the entire universe is supposed empty except for two molecules."

"Physicists no longer regard the molecules of even helium or hydrogen as mathematical points or spheres following the laws of the Newtonian mechanics of conservative systems. Moreover , the kinetic theory contradicts those laws, for they obey the reversibility theorem, while the kinetic theory …represents the gas as a dissipative material…[and] rests upon a peculiar stochastic hypothesis of quasi-equilibrium: The pairs are statistically independent not only before but also after each encounter. … The interest of the kinetic theory is purely rational, not physical."

3. The Carnot Cycle.

a. **Summary**.

The Carnot cycle is a thermodynamics paradigm that has many uses, e.g., in designing electrical power plants that run on steam. It was introduced by Sadi Carnot (1796-1832), a military engineer, in *Reflections on the Motive Power of Fire* (1824).

In his rational thermodynamics, Truesdell defines the Carnot cycle as an axiomatic sequence of processes operating in an imaginary "heat engine," e.g., as an idealized steam engine. Truesdell derives or deduces the First and Second Laws of Thermodynamics from Carnot cycle processes. In other words, Conserved Energy, the content of the First Law, and Entropy, the content of the Second Law, are rooted in axiomatic presumptions. "Carnot cycles are ordinary, sound elements of mathematics, and reasoning based upon them can be good, sound geometry." (Truesdell, 32.)

The Carnot cycle operates in detached time but has an irreversible and productive character. In the Carnot cycle, costly heat turns into productive work. On the other hand, processes requires that some productive work turns into waste heat. Fortunately, processes can be arranged so that there is a net gain in productive work.

The components of Carnot cycles are ***adiabatic processes*** and ***isothermal processes***. As discussed above, such processes are imaginary movements of imaginary bodies and take place in detached time.

As shown below, an adiabatic process consists of imaginary movements between equipoise positions in detached time, similar to equipoise operations of Atwood's machine, the SHO and the ideal gas. An isothermal process employs equilibrium operations that occur either in detached time or mimicked actual time, in a form called ***quasi-static*** that is highly restrictive. In brief, Carnot cycles are rational constructions based on imaginary movements in detached time so as to approximate certain actual movements in actual time. If actual movements are smooth and limited to well-defined ranges, imaginary approximations can be valid and useful.

Paradigms based on the Carnot cycle help to identify areas of useful application for Conserved Energy principles. Conversely, the limited reach of axiomatic presumptions helps to identify phenomena, chiefly "the critical point," where Conserved Energy has diminished utility.

Two representation of the Carnot cycle are shown below, Morse's Figure 5-1 (p.49) and Truesdell's Figure 1A.1 (p. 90). The definition according to Morse states:

> A Carnot cycle operates between two temperatures, a hotter, T_h, that of the heat source, and a colder, T_c, that of the heat sink. Any sort of material can be used…And any pair of mechanical variables can be involved, *P* and *V* or *J* [stress] and *L* [strain] or $\mathscr{H}$ [magnetic field] and $\mathscr{M}$ [magnetization] (we shall use *P* and *V* just to make the discussion specific). The cycle consists of four quasi-static operations: an isothermal expansion from 1 to 2 (see Figure 5-1) at temperature T_h, withdrawing heat [] from the source and doing work []; an adiabatic expansion from 2 to 3, doing further work [] but with no change in heat, and ending up at temperature T_c; an isothermal compression at T_c,. from 3 to 4 requiring work [] to be done on the system and contributing heat [] to the heat sink at temperature T_c, ending up at state 4, so placed that process 4 to 1 can be an adiabatic compression, requiring work [] to be done on the system to bring it back to state 1, ready for another cycle (Figure 5-1). This is a specialized sort of cycle but it is a natural one to study.

Morse further states (p. 50): "We note that, since all the operations are quasistatic, the cycle is *reversible*; it can be run backwards…"

Truesdell's representation shows two Carnot cycles; his construction "serves to define a Carnot cycle $\mathscr{C}$ within $\mathscr{C}_0$." The set of all possible $\mathscr{C}$'s makes up "the *Carnot web* that corresponds to $\mathscr{C}_0$." Important functions in his construction "depend … upon the cycle $\mathscr{C}_0$ that engenders the web." Features of each $\mathscr{C}$ resemble corresponding features of $\mathscr{C}_0$ so that $\mathscr{C}_0$ governs the web and all possible $\mathscr{C}$'s within it.

In a fashion similar to Truesdell's web, Morse presents an "Arrangement of two Carnot cycles so their combined effect is equivalent to one cycle between the temperature extremes." (Figure 5-3 at 54.) He uses two engines where the lower temperature of the first engine is the higher temperature of the second engine and heat discharged from the first engine during its stroke 3 to 4 is absorbed by the second engine during its stroke 1to 2. Figure 5-4 (p. 57) similarly shows a "Reversible cycle [] simulated by a combination of several Carnot cycles." "In principle we can build up a combination of Carnot cycles to simulate any kind of reversible cycle…" (P. 58.)

a. a reversible adiabatic process is produced by continuous equipoise operations that occur in detached time.

Constructions in this stage combine and develop features from the curved-slope SHO paradigm and the ideal gas paradigm. The cylindrical ideal gas arrangement and the cylindrical SHO arrangement maintain similar continuous equipoise operations on a curved slope. The two curved slopes have different mathematical forms. The form for the SHO is a parabola; the corresponding form for the curved slope used with the ideal gas is a ***reversible adiabatic process***.

b. "quasi-static" operations in an isothermal process combine detached time features with actual time features in constructions suitable for steady flows.

(Morse, p. 39.) "Of course the process must be that slow, stepwise kind called quasistatic, if we are to use our thermodynamic formulas to calculate its change." "remove enough heat from the gas, keeping its volume constant meanwhile, to lower is temperature… we could do this relatively quickly (but not quasistatically) by placing the gas in thermal contact with a constant-temperature heat source at temperature ξ. Such a source, sometimes called a *heat reservoir*, is supposed to have such a large heat capacity that the amount of heat contributed by the gas will not change its temperature. In this case the gas would not be in thermal equilibrium until it settled down once more into equilibrium at t=tξ. To carry out a quasisstatic process, for which we could use our formulas to compute the heat added, we should have to place the gas first into contact with a heat reservoir at temperature $T_1 - dT$, allowing it to come to equilibrium, then place it in contact with a reservoir at $T_1 - 2dT$, and so on.

Morse, p. 40) "Thus, thermodynamic computations, using an appropriate quasistatic process, can predict the change in [state variables] for any process, fast or slow, which begins and ends in an equilibrium state. But those calculations cannot predict the amount of inteake of heat or the production of work during the process unless the process differs only slightly from the quasistatic one used in the calculations."

Morse 42, "perfect gas ,,, perfect isothermal energy transformers, changing work into heat or vice versa without holding any of it along the way. The transformation cannot continue indefinitely, however, for physical limits of volume or elastic breakdown or magnetic saturation of the like will intervene."

Truesdell at 37, quotes and criticizes Bridgman. "It has always been a reproach to thermodynamics that its handling of irreversible phenomena was inadequate or even impotent. We are now finding out how to deal with large and important groups of irreversible phenomena by methods in the spirit of thermodynamics. … It is possible, I believe, to go even further in the treatment of irreversible phenomena in the spirit of thermocynamics. Classical thermodynamics defines the entropy only of those states of the body which can be reached from a standard state. Such a definition rules out on principle most of the matter of daily life, because most states can be subject to no reversible displacement whatever – any plastically deformed metal is an example, or any biological system." (Truesdell's developments beyond "classical thermodynamics" do not extend to "biological systems.")

c. the Carnot cycle is used for detached time models of steady production processes.

d. detached time investigations of phase changes use constructions (Clausius-Clapeyron relations) that resemble Carnot cycles and lead to the critical point.

4. The critical point.

II. Controlled Time Paradigms of Virtual Energy Thermodynamics

Summary of part II in a context of related projects. Paradigms of Virtual Energy Thermodynamics (VET) are set forth as device designs. Designs are intended to be congruent with recent developments in materials sciences, chemistry and electronics. No suggestions are made for realization of designs in a laboratory.

Designs for ***pulser devices*** and ***Quad Net devices*** were presented in the 2006 *Quad Nets* paper as endpoints of a range of pulsational activity, called "low-level" and "high-level" respectively. Low-level pulsing is simple and fixed; in Quad Nets (QN), high-level Shimmering Sensitivity generates the quickest and most complex repertoires. A full range of activities from pulsers to Quad Nets is organized by means of the ***Quad Nets VES functional***, a math-like form. ***Timing devices*** are implicit in the QN VES functional but have been developed in their own ways. Ensembles of ***bursting devices*** and ***force devices*** are recent developments. All of the foregoing devices are ***elemental***. In other words, they are rational constructions of well-defined elements and operations, based on an axiomatic "Virtual Energy Store" (VES) in each device.

In part II of this project, the first step is definition of the ***primal pulser*** that functions like a musical metronome with a fixed beat. Then, more general classes of pulser devices are defined. Rational principles guide development of variable pulsers, slower dissipative pulsers, multi-pulse pulsers and epicyclical pulsers that turn the beat on and off according to a slower cycle.

One line of development starts from the primal pulser and leads to ***timing devices*** and reconstructions of device designs previously presented (2009-2011). Another line leads towards the ***bursters*** and ***force devices*** project (2012) in which ensembles of muscle-like force devices are controlled by varieties of bursting devices that combine multiple kinds of inputs.

All the foregoing devices make up a ***kit of elemental parts*** for constructions of engineered organisms that exercise freedom, e.g., anticipated designs that will move like of an aquatic worm, octopus or eel. Rational designs of movements in time resemble geometrical constructions in space — idealized and strictly conforming to math-like principles.

In new developments, this project introduces models for the many kinds of variations seen in animal bodies, movements and changes.

In the biological domain, each animal body has unique features, capacities and limitations based on genes and experience. In any environmental situation, some organisms belonging to a species will perform more quickly and more efficiently and with greater success than other organisms in the species; and successful organisms will more often thrive and reproduce compared to organisms that lack such performance capacities. If the environment is changed, the class of thriving, successful organisms will also change. An organism that is barely subsisting or under the control of others in certain environments may become supremely successful and free in an environment that matches its capacities.

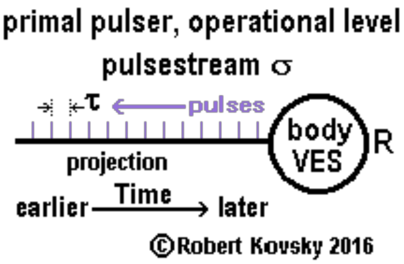
New designs introduce ***material embodiments, material environments*** and ***material interactions***. Additional classes of pulser devices manifest such principles. They incorporate features that resemble material properties of animal bodies. In other words, initial elemental designs are further developed by addition of embodiments and interactions that resemble interactions investigated in materials science and in the thermodynamics and statistical mechanics of irreversible processes, e.g., in the famous Onsager relations. In brief, a narrow elemental foundation is developed into broader variations through an over-layer of material variations.

A. Pulser devices

1. elemental pulser devices

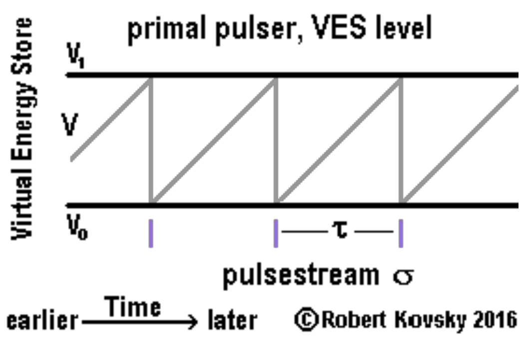
a. primal pulser — a metronomic beat based on a Virtual Energy Store

The ***primal pulser*** is the point of origin for development of VE devices. The figure below shows the primal pulser at the ***operational level***. Two kinds of time are unified in this design: paradigmatic time of the domain clock and pulsational time produced by the pulser. Paradigmatic time runs from "earlier" to "later." Pulsational time is a kind of controlled time.



The ***body*** of the device produces ***pulses***; pulses travel away from the body on a ***projection***. Pulsing occurs in a steady beat, like that of a musical metronome. VE flows into the body at a fixed continuous rate denoted by R; and the device converts the flow of VE into a pulsestream denoted by σ. Pulses are separated by a uniform ***pulse period*** τ. A purpule ***pulse chart*** resembles an oscilloscope trace of electrical impulses in a wire.

Each pulse carries 1 unit of VE called a ***bang*** and symbolized by "!." The operational definition of the device is R × τ = !. Each pulse lasts for an ***instant***, which is the shortest period of time used in designs; and a pulse travels instantaneously on the projection to reach a destination discussed below. A principle of design is that halving or doubling the duration of an instant does not change results. In math-like parlance, an instant is a like a point and lasts for an infinitesimal period of time. Thus, the pulse chart denotes the instants of pulse discharge in paradigmatic time.



On the ***VE level***, the body of the device contains a ***Virtual Energy Store*** or VES. VE flows into the VES at rate R and is stored in the VES until one bang of VE is accumulated; then a one-bang pulse is discharged via the projection. Such VE storage and discharge are depicted in the adjacent graph. The quantity of VE stored in the VES is tracked along the vertical of the graph, paradigmatic time is tracked along the horizontal and pulses are noted below.

A variable V is introduced to track the quantity of VE stored in the VES, shown in the gray trace in the figure. Except at instants of discharge, $V = R \times (t - t_a)$ where t_a denotes the last instant when a pulse was discharged. During discharge, the value of V drops from V_1 to V_0 in an instant.

The mathematical irregularity of an instantaneous drop can be smoothed over in simple cases by a method that first posits an extended and substantial instant during which there is a fast, steady drop of V; then it is shown that operational results are unchanged, or may become more regular, as the extended instant shrinks to an infinitesimal period of time.

Instantaneous operations of VE designs are convenient for rational constructions but present potential problems in attempted realizations. One approach to such problems uses strict definitions of ranges for motion (ROM) and avoids edgy operations. Another approach inserts devices with operational delays that model travel times of pulses. As a practical matter, electronics devices operate instantaneously compared to movement times of massive bodies.

The quantity $(V_1 - V_0)$ measures the total capacity of the device VES for VE storage, one bang in this case. The capacity is fully used in the primal pulser on a cyclical schedule. Even more important, VE is ***conserved*** at the operational and VE levels of this design: all the VE that enters into the device through R is converted into pulses and discharged in σ. Input VE = output VE. The primal pulser operates as a ***Conserved Energy*** paradigm on such levels. $(V_1 - V_0) = !$ in addition to $R \times \tau = !$. Conserved and quantified VE in the VES organizes and rationalizes operations of the primal pulser.

The VES rationalization in the primal pulser resembles that used by Rudolf Clausius (1822-1888) in his invention of Internal Energy in Conserved Energy Thermodynamics (CET). Like Internal Energy stored in a body of steam, a VES in a device body can be said to convert one form of energy into another form. Internal Energy in a steam engine rationalizes the conversion of heat into mechanical energy. The VES in the body of the primal pulser rationalizes the conversion of a continuous fixed VE flow R into a steady stream of pulses σ. R has no temporal variation but σ has a temporal variation measured by τ. The primal pulser changes a timeless flow into measurable time. Continuity is changed into discontinuity. As a result, a bang of VE is discharged every τ.

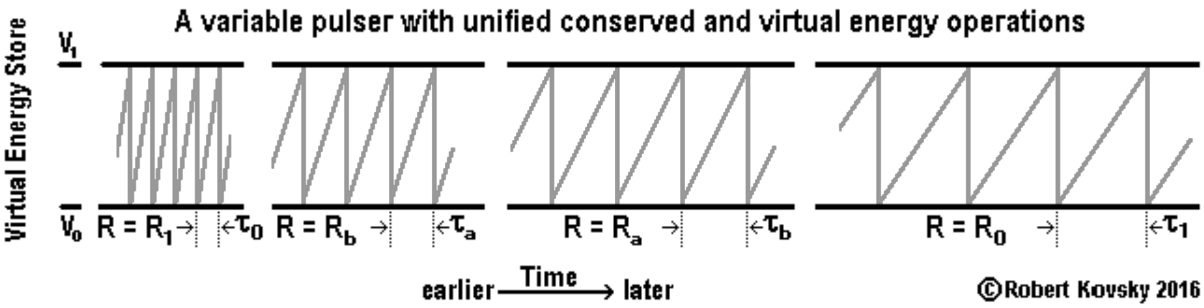
Operations of the primal pulser differ from those of CET paradigms in part I, which are built around moments of rest, equipoise and equilibrium. In the primal pulser, there is never rest or equipoise. Of central importance in operations of the primal pulser is the instant of pulse discharge and corresponding drop of the VES; and all other moments are preparatory for that central moment or instant. The primal pulser is a ***time generator***, like a metronome that sets the beat in a piece of music. It operates in a new variable kind of controlled time where the change in energy, R, is the controlling or independent variable. In contrast, fundamental CET paradigms operate in detached time and mimed time where energy is fixed.

Comparing essential operations, the primal pulser is an active device with a flow of VE that is being converted while the Ideal Gas and its offspring are made up of stationary positions that each have a fixed amount of CE. A static Ideal Gas paradigm operates in detached time while an ideal conservative primal pulser generates controlled time defined by $\tau = !/R$.

b. variable pulsers with ranges of operations

i. conservative variable pulsers

The operational definition of the primal pulser ($R \times \tau = !$) resembles the constitutive relation of an Ideal Gas ($p \times V = [nR]\,T$). Like the Ideal Gas where various values of P and V maintain a fixed T, a ***conservative variable pulser*** can be put into various combinations of R and τ, while maintaining the fixed size of a bang. The figure below shows variations in the VES that conserve energy, maintain the fixed one-bang size of a pulse and produce a range of values for τ.



It is possible to construct a ***reciprocal relationship*** that connects variations in τ with variations in R through coordinated movements in opposite directions, all while maintaining a fixed VE size of a pulse. As R decreases from its maximum, τ increases from its minimum; and vice-versa. Let τ be a real variable that can take any value in the closed interval $[\tau_0, \tau_1]$ and let R be a real variable that can take any value in the closed interval $[R_0, R_1]$. The reciprocal relationship is easily defined at its endpoints: $R_0 \times \tau_1 = R_1 \times \tau_0 = !$.

The reciprocal relationship stated below employs a proportional form that specifies τ for any value of R in the interval $[R_0, R_1]$: $(\tau_1 - \tau)/(\tau_1 - \tau_0) = [(R - R_0)/(R_1 - R_0)]$.

When $R = R_0$, the ratio of R's is equal to 0 and $\tau = \tau_1$. When $R = R_1$, that ratio is equal to 1; and τ is equal to τ_0. As R decreases from R_1, the increase in τ has a reciprocal relationship with that of R. Similarly, as R increases from R_0, reciprocity requires a decrease in τ from τ_1. In the figure, $R_1 > R_b > R_b > R_0$ and, correspondingly, $\tau_0 < \tau_a < \tau_b < \tau_1$.

When τ is uniform, it is possible to define a ***frequency,*** $\nu \equiv 1/\tau$. If R and τ are fixed or change slowly — e.g., less than 1% per cycle — activity can be tracked in terms of a slowly changing ν. Then $R = \nu \times !$. Like T tracks CE in an Ideal/Perfect Gas [$E=(3/2)nRT = (3/2)(p \times V)$], R tracks the flow of VE in a primal pulser. The pulsational frequency (ν) is like a pressure or force and the amount of VE in a pulse (!) is like a volume of work. It is possible to construct a relationship between ν and R using methods like those used to construct the reciprocal relationship between τ and R. The relationship that connects ν and R when changes in τ and ν are slow is a ***linear relationship***. $(\nu - \nu_0)/(\nu_1 - \nu_0) = [(R - R_0)/(R_1 - R_0)]$.

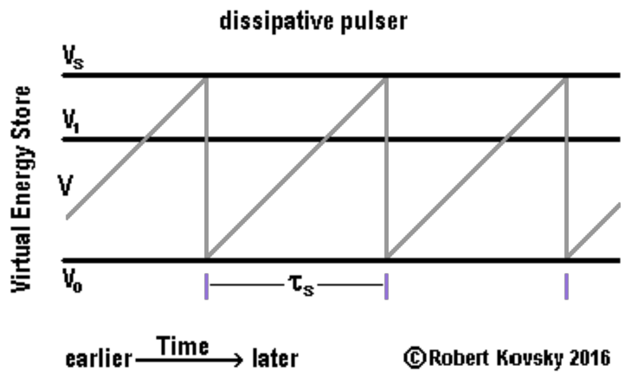
If $(R - R_0)$ slowly increases by a certain percentage, $(\nu - \nu_0)$ increases by the same percentage. In other words, ν and R stretch together in the same direction, rather than in opposite directions. Linear relationships stated with values of ν are more convenient for development than trying to work with reciprocal relationships stated with values of τ. However, in all VE designs, ν is a quantity that is derived from the more foundational quantity, τ, and only under certain restrictions. A period τ is directly measured from two successive pulses. A frequency ν requires numerous pulses sharing a nearly uniform period and/or a steady course of change.

ii. dissipative variable pulsers

A ***dissipative variable pulser*** can produce a pulsestream with τ larger than τ_1. Additional VE is required for production of each pulse. Such additional or ***dissipated*** VE is not converted into pulses – each pulse continues to carry one bang of VE – but is a cost required to produce longer pulse periods with a pulser that has a specific VES and a specific inflow of VE. As discussed below in connection with the material embodiment, such dissipated VE is carried away in a "dissipated VE stream" and can be otherwise disregarded.

The VES definition for a dissipative pulser shown in the figure below has more complex operations than those of the primal pulser design. A third V level is introduced, namely V_s.

V_s can be fixed or variable but is subject to the restriction that $V_s \geq V_1$ or, equivalently, $(V_s - V_0) \geq (V_1 - V_0)$. In the dissipative pulser paradigm, the pulser does not discharge a pulse when the amount of stored VE reaches V_1; instead, VE continues to increase until the quantity of VE in the VES reaches V_s and only then is a pulse discharged.



In the dissipative pulser, the operational definition is: $\tau = (V_s - V_0)/R$.

$(V_s - V_1)$ measures the dissipation in terms of bangs; where $(V_s - V_0)/(V_1 - V_0)$ states the number of bangs in $(V_s - V_0)$.

To construct the definition of the dissipative pulser: when the dissipation $(V_s - V_1) = 0$, operations are the same as for the conservative device. At the other end of the range of movement (ROM), define V_Z as the maximum value of V_s that can be reached in the particular device, that is, the highest level of dissipation reached in operations. Then $\tau_Z = (V_Z - V_0)/R_0$ is the longest obtainable pulse period. The range of operations is such that V_s takes on values in the range $[V_1, V_Z]$ and τ takes on values in the range $[\tau_0, \tau_Z]$. New reciprocal and linear relations can be defined.

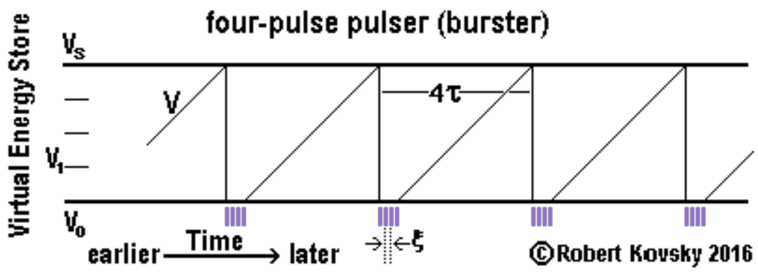
A pulser device with a variable dissipation has a set of pulse periods in contrast to the fixed period of the primal pulser, an enlargement of repertoire that is always a design goal. Development has also introduced the third variable V_s in addition to R and τ.

As shown in the operational definition $[\tau = (V_s - V_0)/R]$ the pulse period τ remains unchanged if $(V_s - V_0)$ and R change together in equal proportions. This resembles automotive experience where an old car that burns oil can run at the same low speed as a new car if you give the old car more gas. From this perspective, the introduction of dissipation into a conservative pulse does not restrict operations if a sufficiently larger R is also supplied and if operations do not depend on a speedy response. More generally, it appears that, in a course of construction, initial conservative paradigms may be easily extended, at least in some cases, into dissipative domains and may also thereby acquire larger repertoires of operations.

c. Pulsers that produce multiple bursts (bursters)

The V_s introduced in connection with dissipative variations is suggestive of further developments shown in an example of a ***multi-pulser*** in the figure below. In the example, $(V_s - V_0)$ contains 4 bangs of VE, there is no dissipation and as before, $(V_1 - V_0)$ is defined as 1 bang. The device produces 4 pulses at each discharge.

Suppose we start at the VES level $V = V_0$ at $t = t_a$; then V increases at the rate R for a period $T = 4\tau$; and then all the stored VE is discharged in 4 pulses with a period ξ between pulses. The period ξ between pulses is much smaller than the period τ between pulses resulting from operations of the one-pulse primal pulser. Perhaps $\tau = 0.01$ sec and $\xi = 0.001$ sec. After 4 pulses, V is reset to V_0 and another cycle commences. Each cycle lasts for a period of $(4\tau+3\xi)$. The cluster of four pulses is called a ***pulse burst***. The device is also called a ***burster***. In this device, a fraction of the VE flowing in is converted into pulses in conservative operations. The fraction is $[4\tau/(4\tau+3\xi)]$. While pulses are being discharged, inflow of R is dissipated and the fraction $[3\delta/(4\tau+3\xi)]$ ends up in the dissipated VE stream.

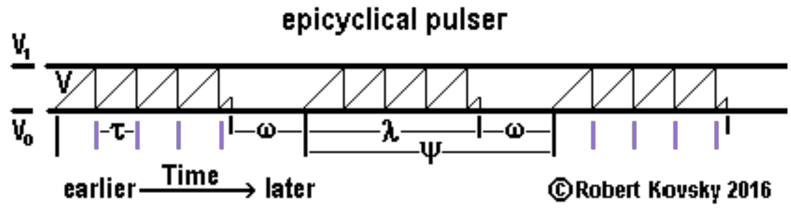


Suppose that initial operations of the burster are maintained with a value of $V_s = 4!$ and that the value of V_s is thereafter slowly increased, entering into dissipative operations. Suppose that in one cycle, $V_s = 4!$ and that, when discharge starts during the next cycle, $V_s = 4.01!$. The burster will again produce 4 pulses but the first pulse will occur a bit later ($\tau/100$) than when V_s was equal to 4! because of the additional time needed for the amount of VE in the VES to reach V_s. The additional .01! in the VES is dissipated and ends up in the dissipated VE stream. Hence, if V_s is slowly but steadily increased, pulse bursts will occur with steadily increasing periods between initial pulses and with a number of pulses that will rise in steps, four pulses for a while, then five pulses for a while, then six pulses for a while, and so forth.

d. epicyclical pulsers

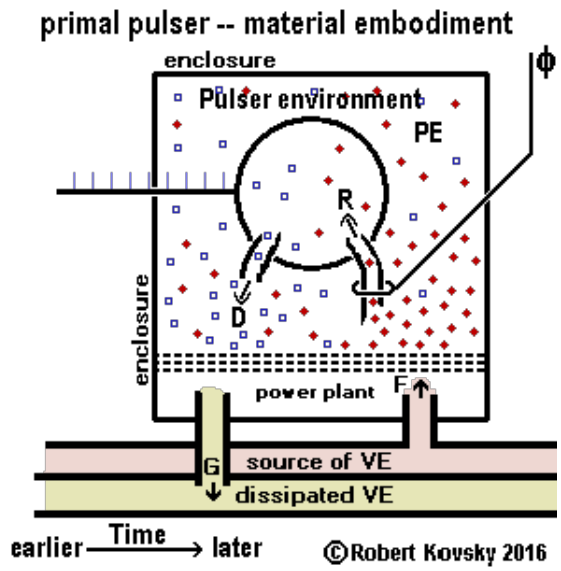
"Cycles within cycles" is a pervasive construction technique in VE device designs. A general technique uses a longer ψ cycle to organize shorter τ cycles.

The technique of cycles within cycles can be applied to pulsers, as shown in the figure below, in a design at the conservative VES level for an ***epicyclical pulser***. At the heart of the epicyclical pulser, a device similar to the primal pulser produces pulses with period τ. Activity is also controlled according to a longer period ψ. Each ψ period is composed of shorter periods λ, the ***active period***, and ω, the ***silent period***. Active periods and silent periods alternate with each other. During the active part of the ψ period (λ), the epicyclical pulser operates exactly like a primal pulser. During the silent part of the ψ period (ω), the epicyclical pulser is turned "off," the inflow of VE is closed or diverted to the dissipated VE stream and any VE in the VES drains away to the dissipated VE stream so that, when the next λ period starts, the VES stands at V_0.



2. a deeper definition of the primal pulser is based on a material embodiment

As a third level of definition, the primal pulser has a ***material embodiment*** that is shown in the figure below. Chiefly, an ***enclosure*** surrounds the primal pulser and the device is immersed in a ***pulser environment***, denoted by PE. The PE may have properties that depend on recent history of the device, chemical constitution of the PE and/or interactions with other devices. Two streams of pulses denoted as "τ" and "φ" travel out of and into the enclosure and connect to the pulser. Distinct from the pulser but within the enclosure and attached to the PE, is a ***power plant*** that is fueled by a ***source of active VE*** denoted "F" and that has an outlet for ***dissipated VE*** denoted "G." G connects to the ***dissipated VE stream*** that is like an automobile exhaust pipe without smog control or the radiation fins on the CPU of a personal computer.



VE is carried by particles moving in the enclosed environment. In the figure, active VE particles are shown as red stars (*). Particles flow into the pulser through inlet R, where VE is absorbed from active particles. Used particles, shown as blue boxes (□), are discharged through the drain D.

The inflow rate R is controlled by a pulsestream, φ, which operates a controller that is like a throttle in an automobile fuel system or like a sphincter muscle that controls a flow of material in an animal body. The control relationship between φ and R may depend on conditions in the PE. As discussed below, control relationships between φ and σ can be mediated by varieties of muscle-like controllers with linear forms or reciprocal forms.

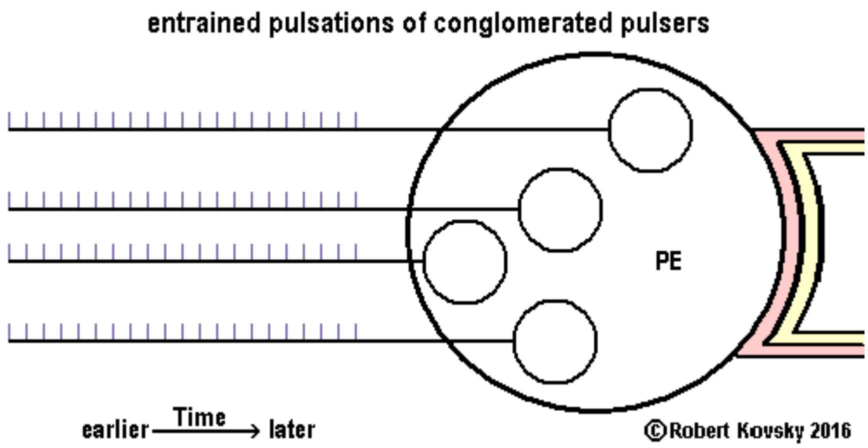
The power plant takes in used VE particles (□), re-charges them and returns them to the pulser environment (PE). (As models of biochemical activity, the power plant resembles mitochondria, *'s resemble ATP and □'s resemble ADP.) The power plant produces "more than enough" VE; VE is restricted by means of φ; and there is a ready supply in the source stream of active VE. Activity in the power plant produces dissipated VE that is carried away in the dissipation stream. The embodiment is consistent with both conservative and dissipative designs at the operational and VES levels of the device. A dissipative pulser requires more source VE and produces more dissipated VE, which ends up in the dissipated VE stream. There is no attempt to sum or balance source VE, dissipated VE, VE in particles, VE in pulses and VE in materials in the style of CET.

Electronics systems provide an analogy. Many electronics systems have a ***power supply*** that is independent of operational parts. The power supply connects to a standard AC signal of 110 volts/60 Hz and turns that standard AC signal into particular needed forms, such as 6 volts DC. Power supplies in electronics systems are dissipative and produce heat radiated into the air.

Some electronics designs include a power supply but others only indicate points at which power is to be supplied. In this project, rates of VE inflow such as R are steady or vary under control. VE is presumptively available in "abundant" quantities. Desired operations in a device are produced by features of the VES, not by a limit on VE. Designs at the operational and VES levels are sufficient for a structure of elemental designs and such elemental designs do not need definitions at the level of material embodiment.

Material embodiments provide means for new designs that extend beyond those available through elemental designs. In a ***conglomerate of pulsers***, shown in the figure below, several embodied pulsers share a pulser environment. Each pulser is supplied with sufficient VE and each produces a pulsestream with a common τ. Pulsers have identical definitions at the operational and VES levels and pulse productions at the level of material embodiment are indistinguishable, with a common τ, but with each pulser operating on its own.

A principle of ***entrainment*** states that discharges of such indistinguishable and conglomerated pulsers interacting through a material environment become ***synchronized*** and that all the pulsers in the conglomerate discharge together within a single instant. In the paradigm, as a result of the principle of entrainment, the entire conglomerate is pulsing and beating, including the pulsers, the pulser environment and the enclosure of the material embodiment.



B. Timing devices

1. Critique of pulser devices and introduction to the Quad Nets functional

The class of pulser devices has substantial capacities and also substantial shortcomings. On the positive side, pulsers generate pulse streams and pulse bursts, which are major classes of signals in VE constructions. They introduce rationalization of VE storage in a simplified form, similar to the simple constructions involving Atwood's machine in part I.

However, as to shortcomings, pulser constructions are limited to rudimentary designs. Pulses travel on projections to unknown destinations. The only point of possible application of a pulsestream in the foregoing constructions is as a φ that controls R through methods yet to be described.

Limitations of pulser devices are shown by review of related projects. While pulsers were used developmentally in the original *Quad Nets* paper as in this project, they have played no part in subsequent applications projects *Ear for Pythagorean Harmonics*, *Eye for Sharp Contrast*, *Dogtail for Wagging* in the free-will puzzles essay, the *Bursters* project or t he *Tube for Transport* herein. In such projects, pulse streams are generated by a coupled pair of timing devices; and pulse burst operations are externally controlled.

One limitation of pulsar devices

2. The primal timing device

C. Force devices and bursting devices

Constructions of force devices are set forth in detail in the *bursters* project discussed at www.quadnets.com/bursters.html The following materials are condensed from that project.

1. In a rigidly affixed and fully extended force fiber device, pulse bursts drive forceful twitches, operating with a linear variation.

A elemental movement in VE constructions is a ***twitch produced by a force fiber device***. As shown in Fig. 6, a force fiber device has two chief parts: (1) a signal ***detector*** which receives pulse burst signals; and (2) an ***effector***, which produces forceful contractile twitches and which can thus perform mechanical work, e.g., lifting a weight.

Arrival at the detector of the leading pulse of a burst starts the detector Ψ−form: the detector ***notices*** the burst for three ticks, denoted by “N” in its Ψ−form. During the next tick, joint ***processing*** in detector and effector, coded by “P,” includes ***triggering*** of a forceful ***contraction*** of the effector, coded by “q” and “Q.” The period of contraction starts at tick 2 (coded q) in the Ψ−form of the effector, with a force strength that starts at a minimum and that ramps up to the specified level as shown in the following Fig. 7. After a steady force for the next three ticks, marked Q, the strength level ramps down during effector tick 6, again marked q. On average, ramping q is half the force of steady Q. The tired effector ***recovers*** during its tick 7, activity coded by “R.” Then it waits for a new contraction while in a ***ready*** condition coded by “r.” When the effector is not contracting – during ticks P, R and r in the effector – the fiber has a minimal tautness. A tired detector recovers (R) after processing a burst but continues to be blocked (XXX) from receiving a new burst until expiration of the 8-tick detector Ψ−form.

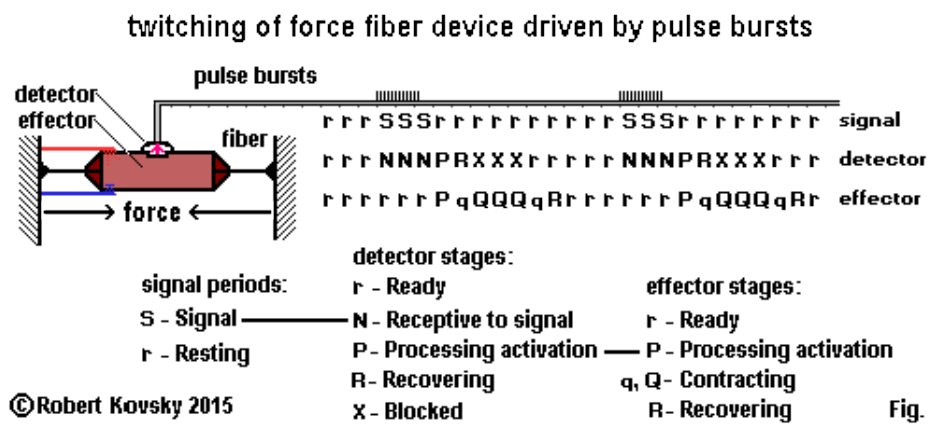


Fig. 6

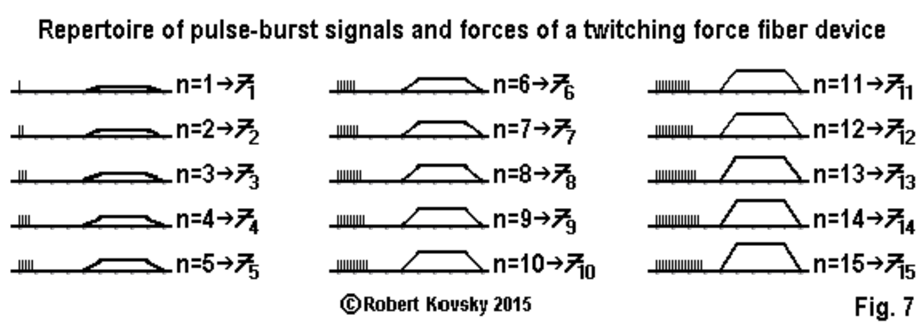


Fig. 7

2. A mobile force fiber device incorporates variations in the force of a twitch that depend on fiber length and movement.

Fig. 6 shows an ***affixed fiber*** attached to rigid supports at maximum length. An affixed effector contracts isometrically even though actual movement is impossible. Initial definitions apply to a rigidly affixed and fully extended force fiber device. Then rigid constraints are relaxed for development of actual movements. A shortened fiber device generates a smaller force. A rigidly-affixed fully-extended force fiber device can neither move nor perform work on an external object, no matter how much Virtual Energy it is consuming. Modifications develop the force fiber device for productive movement. Modifications are based on well-know facts about a typical muscle producing voluntary movements: when such a muscle shortens, it exerts less tension; and the tension further decreases as the speed of shortening increases.

Developing the definition of the elemental force fiber device, the expression for the twitch strength level $\mathcal{F}$ becomes the ***primal twitch strength expression***: $\mathcal{F} = n\mathcal{F}_1 - j(\ell_1 - \ell_x) - A|(d\ell_x/dt)|$. The fiber length ℓ_x varies between a minimum ℓ_0 and a maximum ℓ_1; ℓ_1 is the length of the fully extended device discussed above. For an affixed holding force at maximum length, as in the initial definition, $(d\ell_x/dt)=0$ and $\ell_x=\ell_1$; then, the new $\mathcal{F}$ reduces to the previous $\mathcal{F}= n\mathcal{F}_1$.

"Primal" means that the foregoing expression is the point of origin for development of force devices in this project. Other twitch strength expressions can be stated and used in different device designs; then, different kinds of devices might be combined for greater versatility.

The $j(\ell_1 - \ell_x)$ term in the strength expression states a reduction in the force of a twitch of a contracted device as a result of operational dissipation. The $A|(d\ell_x/dt)|$ term is a dissipative ***damper*** similar to the dashpot that is part of the harmonic oscillator paradigm of mechanics or to friction that slows movement of a rigid body in a viscous fluid: reduction of force strength resulting from movement is proportional to speed of movement, with the same results regardless of whether movement is shortening or lengthening the fiber.

3. Two force fiber devices operating as a duet are driven by reciprocating and repeating bursting devices to produce steady forces that hold a weight.

Fig. 9 shows two force fiber devices, a and b, coupled together in a ***duet***, the first in a series of ***ensembles***. The two force fiber devices share physical connections that carry forces; they produce alternating forces that combine to hold a mobile weight W steady inside a supporting and constraining cylinder. The only possible movements of the weight are up and down; the only forces are provided by gravity and by the duet. In initial constructions, forces are in balance.

Fig. 9 also shows two ***repeating bursting devices***, A and B, that are connected reciprocally and that generate pulse bursts in a stiff Σ-form on reciprocating and output projections, similar to steady pulse trains shown in Fig. 2. Each repeating bursting device or "burster," denoted by "R," has a detector and a body that resemble the detector and the effector of a force fiber device.

The duet design aims to produce a steady but variable force **F**. Duet fibers share a variable length, denoted by ℓ_x. The quantity $\ell_1 - \ell_x$ ranges between $\ell_1 - \ell_x = 0$ at full extension and $\ell_1 - \ell_x = L$ at full contraction ($\ell_x = \ell_0$). L defines the range of motion (ROM). The strength of **F** is equal to that of $\mathcal{F}$, the central twitch strength. A steady **F** is "patched" together from alternating twitches; a successor twitch ramps up just as a predecessor twitch ramps down. As to momentary force, q+q = Q = $\mathcal{F}$ = **F**. In Fig. 9, gray ramps appear below the blue line that is tracing a steady **F**.

Steady force produced by a duet:
two joined force fiber devices driven by two reciprocating bursting devices

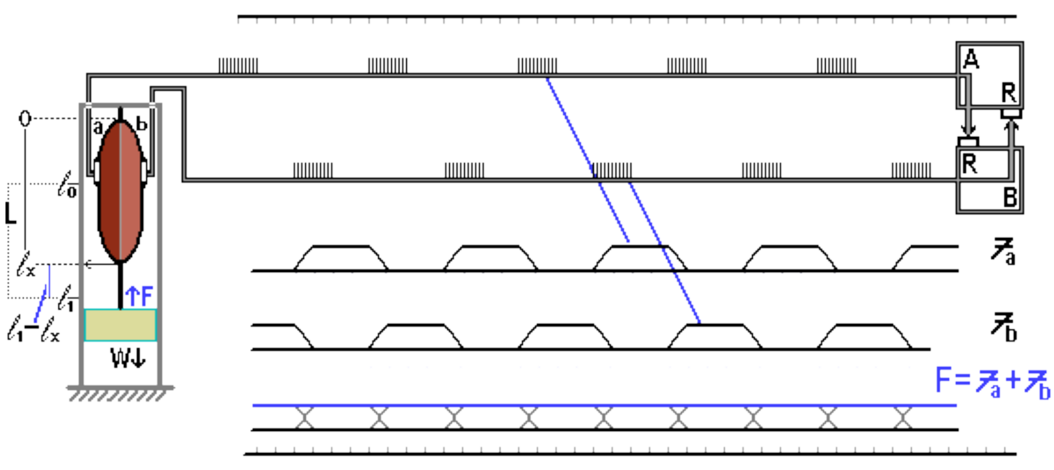


Fig. 9

4. Two opposing duets produce a spectrum of balancing positions.

Fig. 17 shows two equal and opposing duets, each affixed at one end and connected to the other duet at the other end. Outside the figure, a pair of reciprocating bursters sends signals to the left duet with pulse number m; similarly, an independent pair of reciprocating bursters sends signals with pulse number n to the right duet. The design in Fig. 17 establishes relations between pulse numbers and spatial locations in a spectrum of balancing positions. The design is the first in a series of constructions aiming to mimic movements of eyes of animals.

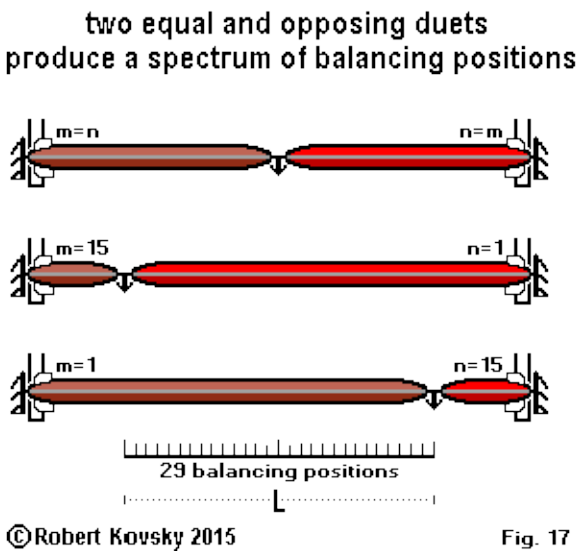


Fig. 17

The top image shows the duets in center-point balancing, where equal pulse bursts are sent to the two duets; that is, m=n. When signals are equal, the indicator arrow is centered and the location is called ***midline***. Equal forces and a centered indicator at midline can occur for pulse numbers of any size, from 1 to 15.

The range of motion in Fig. 17 is denoted by L, like L in Fig. 9. An end-of-range position occurs when one duet is driven by bursts with pulse number 1 and the other duet is driven by bursts with pulse number 15. At such limit positions, one duet is fully extended and the other duet is fully contracted.

In this design, fibers at full extension have a length that is 5 times the length of fibers at full contraction. That is, for each force fiber device, $\ell_1 = 5L/4$ and $\ell_0 = L/4$. $L+2\ell_0$ is the distance between points of affixation; and the distance from each such point to midline is 3L/4.

Let x be measured from midline, with positive values to the right. Balancing is expressed by: $F_m=F_n$, where $F_m=mF_1 - j(3L/4+x)$ and $F_n= nF_1 - j(3L/4-x)$. For duets to be in balance at extreme positions (e.g., $x=L/2$), $15F_1-5jL/4 = F_1-jL/4$; or $j=14F_1/L$.

In the $j=14F_1/L$ system, 29 equally spaced balancing positions are defined by $x/L=(n-m)/28$, where $-\frac{1}{2}L \leq x \leq \frac{1}{2}L$. When n>m, balancing points are to the right of midline. When m>n, balancing points are to the left. Except at limits points, multiple pairs of (m,n) hold the balance.

5. A tube for transport moves an object: encircling force devices tighten and relax in waves, with timings controlled by reverse triggering of an ensemble of bursters.

   a. A tube for transport is built from sections with a uniform design that combines a rigid tube, elastic materials and a Virtual Energy force device.

Movements in this design occur inside a rigid tube that is like a plumber's tube made of polyvinyl chloride (PVC). A toroidal form is symmetrical as to all portions (Fig. 28(a)); movements in a toroid are similar to movements at the central portion of a straight tube (Fig 28(b)). Straight tubes are simpler for figures and analysis.

Internally, a tube for transport is constructed from sections, each with two parts in an alternating sequence: active parts (red) are powered by Virtual Energy and passive parts (gray) have negligible energy values. (Fig. 28c, 28d.) Each part is a smaller toroid. Connected insides of parts/toroids form a central channel or ***lumen***. The lumen is internally bounded or covered by an elastic membrane that is attached to the insides of active and passive parts.

The closing force of an active part is opposed by elastic fibers that are attached to the inside of the rigid tube. A variable pulse-bust signal produces a variable contraction; an array of variable contractions can form a ***bulge*** that can move an object enclosed within, e.g., a ping pong ball.

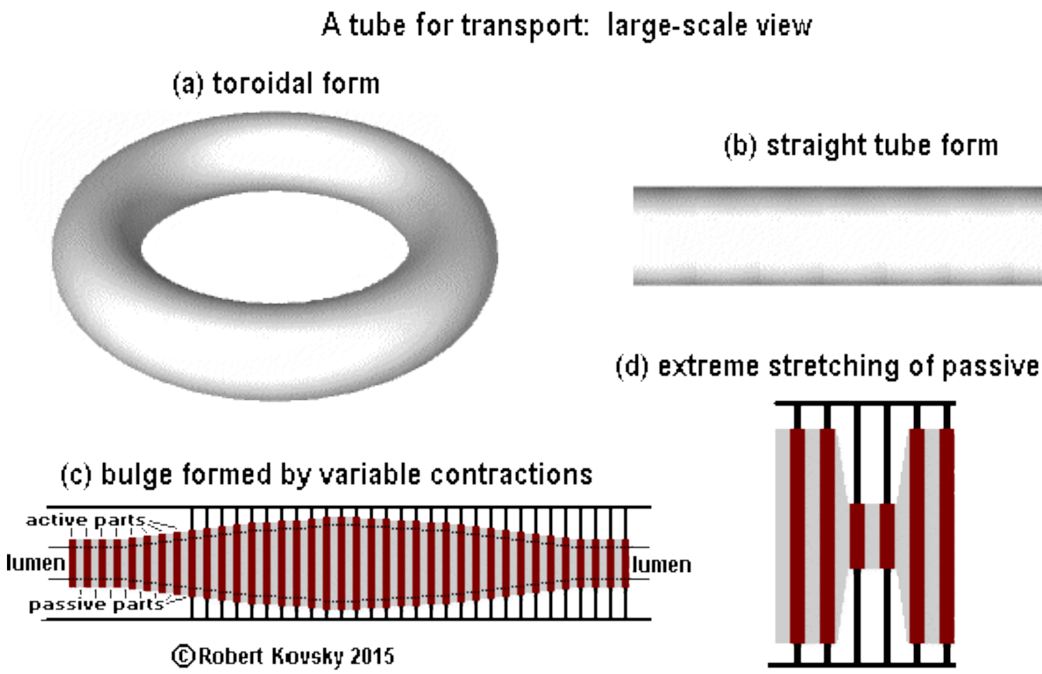


Fig. 28

A passive part stretches to accommodate movements of active parts on both sides. Extreme stretching results from the strongest contraction on one side and the weakest contraction on the other side. (Fig. 28.d.) To minimize stretching of passive parts in designs in this project, pulse numbers of burst signals differ by at most "one" between any active part and the next active part. Bulges are rather flat. Rounder bulges can be formed with greater stretching of passive parts.

b. Inside a tube for transport, the aperture opening of each section is set by a variable balance between elastic forces and forces from a Virtual Energy device.

As shown in Fig. 29(a), an active part in a tube for transport uses a duet force device (Fig. 9) modified into a circular force device with variable radius r. The duet produces centripetal contractile forces that are balanced by centrifugal forces produced by elastic fibers, each attached at one end to a sleeve around the duet and at the other end to the inside of the tube. Variable aperture openings form a linear series. (Fig. 29(b) views a bulge in 3-d from inside.) When an active part is in a fully relaxed condition, it has a pulse number of 0 and an aperture radius of r_1.

control of aperture in active part of a tube for transport

(a) operational design of aperture (b) sizes of pulse bursts and aperture openings

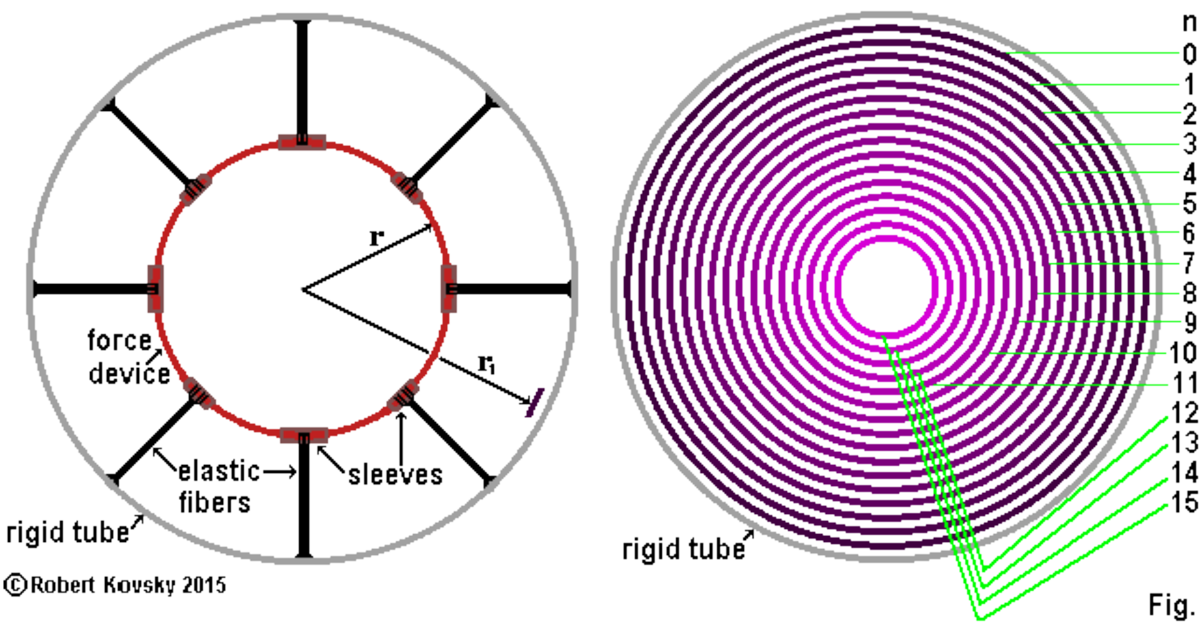


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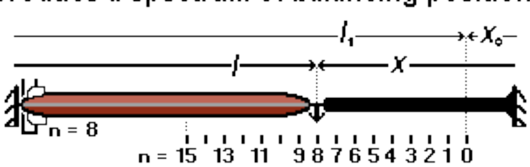
Fig. 29

Fig. 30 shows how a force produced by a force fiber duet opposes and balances a force produced by an elastic fiber, with a linear spectrum of balancing positions similar to that shown in Fig. 17. Note that there are 16 balancing positions in Figures 29 and 30 and 29 positions in Fig. 17.

Opposing VE forces and elastic forces produce a spectrum of balancing positions



©Robert Kovsky 2015 Fig. 30

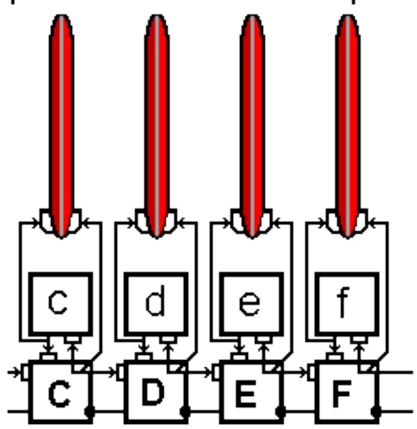
Balancing positions in Fig. 30 are defined by $nF_1 - j(l_1 - l) = k(x - x_0)$, where k is the "spring constant" of the fiber. Since $(l_1 - l) = (x - x_0)$, $l_1 - l = nF_1/(j+k)$. When n = 0, the elastic fiber is fully relaxed at $x = x_0$ and the force device is flaccid at $l = l_1$. Forces rise on both sides when n increases, but with a differential, and the balancing position shifts.

Application of the foregoing principles to the operational design of the aperture (Fig. 29(a)) leads to $r = r_1 - nF_1/(2\pi j + mk)$ where k is the "spring constant" for one elastic fiber and m is the number of elastic fibers, or m=8 in Fig. 29. It is convenient to hold mk fixed while the number of elastic fibers is increased. Conceptually, as the number of fibers increases, fibers become a membrane between sections with a continuous, elastic sleeve around the force device.

c. An ensemble of reverse-triggered bursters produces changes in aperture openings, moving objects (e.g., ping pong balls) through the lumen of a tube for transport.

A tube for transport moves an object enclosed in a bulge – e.g., a ping pong ball — by shifting a pattern of aperture openings. When a movement occurs: first, space opens in front of the object; next, the opening of space spreads back over the top; then, once over the top, opening becomes closing – and force devices near the back of the object push it forward into the open space. Reverse triggering is combined with forward projections to produce forward movements.

Bursters and force devices in a portion of a tube for transport



©Robert Kovsky 2015 Fig. 31

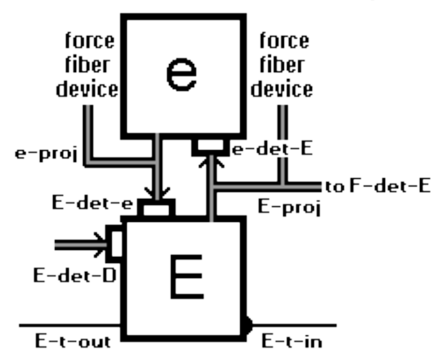
Fig. 31 shows an arrangement of VE force fiber devices and bursting devices in a portion of a tube for transport. Movements occur in four duets, which are pairs of force fibers that are driven by corresponding pairs of bursting devices C-c, D-d, E-e and F-f. The arrangement is continued to the left of C-c and to the right of F-f. Devices c, d, e and f are simple repeating bursters — R devices introduced in II.B.1 — while devices C, D, E and F are similar to R but modified to perform the shifting movements discussed herein. Operations of all bursters are tightly synchronized in the initial design but that constraint is relaxed in a later design. Each duet — e.g., E, e and the force fiber devices they drive — controls the aperture opening in an active part of a tube for transport.

Exemplary operations of bursters E and e are shown in Fig. 32 and in operational charts below. Signals arrive at e only through e's detector, labeled ***e-det-E***, that is reached by a projection from burster E that is labeled ***E-proj***.

In other words, pulse burst signals discharged by E and carried by E-proj arrive at e-det-E. In addition to carrying signals to e-det-E, E-proj sends signals to a force fiber device and to a detector on burster F, namely, ***F-det-E***. E may also receive a signal from D through detector ***E-det-D***.

Similarly, a pulse burst signal from e is carried on ***e-proj*** and arrives at a detector on E labeled ***E-det-e***. Such signal from e-proj also arrives at a force fiber device.

Burster pair and projections in a section of a tube for transport



©Robert Kovsky 2016 Fig. 32

E has two detectors, ***E-det-e*** and ***E-det-D***. During any cycle, one detector is receptive and the other detector is blocked. When E-det-e is receptive and E-det-D is blocked, aperture openings are kept steady. During such a steady cycle, E receives a pulse burst signal from e.

During a shifting cycle, the receptive detector is switched from E-det-e to E-det-D. E receives a pulse burst signal from D instead of from e. Such a shifting cycle in E begins with the arrival of a trigger pulse from F onto ***E-t-in*** and ends with the discharge of a trigger pulse onto D from ***E-t-out***. Two or more shifting operations can be performed in a sequence; in a sequence of shifts, E receives a pulse burst from D and passes it to F. Pulse bursts and trigger pulses travel in opposite directions.

The snippet of code below that is labeled “`shifts to`” represents a single shift step of movements in the cdef bank of bursters and force devices. Before the shift, signals are steady, with burst q in burster pair C-c, burst r in burster pair D-d, burst s in burster pair E-e and burst t in burster pair F-f. After a shift, signals are again steady, with burst q in burster pair D-d, burst r in pair E-e and burst s in pair F-f. A new burst signal p has shifted onto pair C-c from a burster B off the figure; and burst signal t has shifted off the Figure, onto G-g. That is, within the four focal pairs:

```
qrst shifts to
pqrs
```

In the operational chart for bursting device E below, the burster pair starts with reciprocal exchanges of signal NsN, detected as OsO. A trigger pulse arrives over the E-t-in line (~) and, eight ticks later, a trigger pulse is discharged over the E-t-out line (!). Between the trigger pulses, the receptive detector is switched from E-det-e to E-det-D for one cycle; and the new signal NrN, arriving through E-det-D, takes up occupancy in the E-e pair.

```
Operational chart for devices e and E (1 symbol, 1 tick)
e-det-E  NsNP    NsNP    NsNP    NsNP    NrNP   NrNP . . .
e-proj      POsOR   POsOR   POsOR   POrOR   POrOR    . . .
E-det-e      NsNP    NsNP    XXXX    NrNP   NrNP     . . .
E-proj   OsOR   POsOR   POsOR   POrOR   POrOR  POrOR . . .
E-det-D  XXXXXXXXXXXXXXXXXXXXNrNPXXXXXXXXXXXXXXXXXXX . . .
E-t-in                    ~
E-t-out                           !
```

The operational chart for e and E can be simplified through use of condensed code, The following chart is equivalent to the chart above. Prior to a shift, an s pulse burst is maintained in steady operations. Receipt of a trigger pulse (~) causes a switch in the receptive detector to E-det-e for one cycle, the detection through E-det-e of the r pulse burst and the establishment and maintenance of the r pulse burst in steady operations.

```
Operational chart for devices e and E (condensed code)
e-det-E  s s s s r r
e-proj    s s s r r
E-det-e   s s X r r
E-proj   s s s r r r
E-det-D  XXXXXr XXXX
E-t-in       ~
E-t-out        !
```

The movement of trigger pulses is in the direction that is opposite that of burst transmission and of actual movement of the object. Triggering is “reversed.” In other words, forward projection and reverse triggering both anticipate and control actual movement but in different ways. Forward projection controls the strength of the movement while reverse triggering controls the timing of the movement.

Condensed code is used in the operational chart below that tracks operations of sections C, D, E and F during a shifting operation. Note that the wave of trigger pulses moves in the reverse direction — from F to E to D to C — while the signal pattern p-q-r-s-t moves in the forward direction, from C to D to E to F. The actual movement of the object in the lumen defines the forward direction. Movement represented in the "`shifts to`" code snippet is thus produced.

```
qrst shifts to
pqrs
```

<u>`Operational chart for C-c, D-d, E-e and F-f (shift step)`</u>

```
C-t-out                    !
c-det-C  q q q q q q q q q p p p p p p p p p p p p p p p p p p p
c-proj    q q q q q q q q q p p p p p p p p p p p p p p p p p p
C-det-c   q q q q q q q q X p p p p p p p p p p p p p p p p p p
C-proj     q q q q q q q q p p p p p p p p p p p p p p p p p p p
C-det-B  XXXXXXXXXXXXXXXXXp XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C-t-in                   ~

D-t-out                  !
d-det-D  r r r r r r r r r q q q q q q q q q q q q q q q q q q q
d-proj    r r r r r r r r q q q q q q q q q q q q q q q q q q q
D-det-d   r r r r r r r X q q q q q q q q q q q q q q q q q q q
D-proj     r r r r r r r q q q q q q q q q q q q q q q q q q q q
D-det-C  XXXXXXXXXXXXXXXq XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
D-t-in                 ~

E-t-out                !
e-det-E  s s s s s s s r r r r r r r r r r r r r r r r r r r r r
e-proj    s s s s s s s r r r r r r r r r r r r r r r r r r r r
E-det-e   s s s s s s X r r r r r r r r r r r r r r r r r r r r
E-proj     s s s s s s r r r r r r r r r r r r r r r r r r r r r
E-det-D  XXXXXXXXXXXXXr XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
E-t-in               ~

F-t-out              !
f-det-F  t t t t t t s s s s s s s s s s s s s s s s s s s s s s
f-proj    t t t t t t s s s s s s s s s s s s s s s s s s s s s
F-det-f   t t t t t X s s s s s s s s s s s s s s s s s s s s s
F-proj     t t t t t s s s s s s s s s s s s s s s s s s s s s s
F-det-E  XXXXXXXXXXXs XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
F-t-in             ~
```

Each shift step is produced through a distinct wave. Separate shift steps can follow each other in an arbitrary fashion so long as 8 ticks (or a multiple thereof) pass between any two trigger pulses. The ***shifting episode*** set forth below is produced by 5 trigger pulses with 8 ticks between successive trigger pulses. As a result of the shifting episode, the "`shifts to`" code is:

```
qrst shifts to
lmno
```

Operational chart for C-c, D-d, E-e and F-f (shifting episode)

```
C-t-out                  ! ! ! ! !
c-det-C  q q q q q q q q q p o n m l l l l l l l l l l l l l
c-proj    q q q q q q q q q p o n m l l l l l l l l l l l l l
C-det-c   q q q q q q q q X X X X X l l l l l l l l l l l l l
C-proj     q q q q q q q q p o n m l l l l l l l l l l l l l
C-det-B  XXXXXXXXXXXXXXXXXp o n m l XXXXXXXXXXXXXXXXXXXXXXXXXXX
C-t-in                 ~ ~ ~ ~ ~

D-t-out                ! ! ! ! !
d-det-D  r r r r r r r r q p o n m m m m m m m m m m m m m m
d-proj    r r r r r r r r q p o n m m m m m m m m m m m m m m
D-det-d   r r r r r r r X X X X X m m m m m m m m m m m m m m
D-proj     r r r r r r r q p o n m m m m m m m m m m m m m m
D-det-C  XXXXXXXXXXXXXXXq p o n m XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
D-t-in               ~ ~ ~ ~ ~

E-t-out              ! ! ! ! !
e-det-E  s s s s s s s r q p o n n n n n n n n n n n n n n n
e-proj    s s s s s s s r q p o n n n n n n n n n n n n n n n
E-det-e   s s s s s s X X X X X n n n n n n n n n n n n n n n
E-proj     s s s s s s r q p o n n n n n n n n n n n n n n n
E-det-D  XXXXXXXXXXXXXr q p o n XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
E-t-in             ~ ~ ~ ~ ~

F-t-out            ! ! ! ! !
f-det-F  t t t t t t s r q p o o o o o o o o o o o o o o o o
f-proj    t t t t t t s r q p o o o o o o o o o o o o o o o o
F-det-f   t t t t t X X X X X o o o o o o o o o o o o o o o o
F-proj     t t t t t s r q p o o o o o o o o o o o o o o o o
F-det-E  XXXXXXXXXXXs r q p o XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
F-t-in           ~ ~ ~ ~ ~
```

The shifting episode set forth above embodies the most forceful kind of action that the module is capable of producing, subject to constraints imposed for purposes of this project.

D. Quad Net devices, critical moments and Shimmering Sensitivity

III. Foundations of Energy Constructions

A. Diversity of constructions.

A variety of foundational principles are used in constructions. Different constructions have different foundational principles. Some constructions use only one kind of such principles. In other constructions, two or more kinds work together. The principle of *actual life* is foundational in all new constructions and embodiments of freedom are their common aim.

Different sets of foundational principles implicitly limit each other. No single set of principles can be said to comprehend "everything." I hold to a general principle that human intelligence lacks capacities to comprehend, describe or control "everything." Of focal interest here is the incapacity of "modern science" to comprehend, describe or control bodily feelings and muscular movements of animals, e.g., feelings and movements of *itching and scratching*. I suggest that scientific models have only limited applications and introduce systemic errors. I suggest that alternative constructions can reach some important but neglected matters.

1. Rational constructions of physical paradigms

Physical paradigms in this project are examples of rational constructions in physics. Standard paradigms in part I employ Conserved Energy (CE) principles to construct Conserved Energy Thermodynamics (CET). New paradigms in part II employ Virtual Energy (VE) principles to construct Virtual Energy Thermodynamics (VET). All such paradigms, principles and constructions are set forth in a "rational style," similar to the "rational thermodynamics" of Josiah Willard Gibbs (1839-1903) and Clifford A. Truesdell III (1919-2000). Scientific systems of rational thermodynamics use rigid axioms and mathematical formalisms. Flexible principles of VET are different from rigid axioms of CET — but there are pervasive parallels. The VET paradigm of Shimmering Sensitivity in Quad Nets is based on the critical point paradigm in CET.

Other rational constructions in physics include Newton's corpuscular mechanics, Maxwell's electromagnetic fields, Dirac's quantum mechanics and vortices of Descartes and Rankine. Computers embody logical rationalism in operating devices. VET is foundationally different from such prior constructions but I follow a rational style in paradigmatic VET constructions.

A paradigmatic process of Shimmering Sensitivity begins by generating multiple fragments of device activity that potentially lead to multiple possible movements, each fragment leading to a different movement; initially, fragments co-exist in a "shimmering" condition that may include shifting combinations of fragments and competition between possibilities; next, the process passes through a critical moment and multiple possibilities change into a single actuality.

I suggest that processes of Shimmering Sensitivity are models for selections or choices in the lives of persons, such as choices made during ping pong games and in markets. During a critical moment in a selection, multiple possible next movements change into one actual next movement; and a change can depend on flowing influences, on material properties of body parts and on momentary sensitivities, as well as on happenstance events in the environment. When multiple devices with interactive processes of Shimmering Sensitivity are synchronized and pass through critical moments together, selections can be integrated and become one unified selection. In a supportive environment and directed at an achievable goal, a unified movement is produced by a ***whole body*** made of many body parts. In anticipated models of aquatic worms and eels, the whole body of the engineered organism, and each and all of many sensory-motor modules, participate in selections of movements.

2. Integrating constructions of psychology

Psychological constructions model a personality as made up of multiple parts, where each part operates independently and where parts also interact and engage in integrated activities. Freud's id-ego-superego model is similarly constructed and resembles a pelvic-manual-facial model in my approach, where personality parts are based in regions of the spine. Interacting independent parts sometimes work together and sometimes not. Integrations of activities of interacting parts are modeled through various constructions, including models of Piaget's "sensory-motor coordination of actions" discussed below and processes that involve Shimmering Sensitivity.

Different psychological models target different situations and use different kinds and numbers of personality parts. In a simple model of purposeful action, a personality is made of (1) muscular movements of "the body" and (2) images in "the mind." Bodily movements occur in actual time. Movements of mental images occur in actual time, detached time or controlled time. Rational activities, e.g., operations of physical paradigms, occur in detached time or controlled time.

In a body-mind model, integration of body and mind can sometimes be accomplished but not always. The two parts in the model have different characters. Muscular movements are brief and easily varied in many situations. A basic repertoire of muscular movements is produced in the person's only body and is adapted to different tasks; some tasks require practice and training of skills. Through training, muscular movements match an external form (as taught by ancient Athenians) or (following principles of Piaget), an internal ***action-scheme*** with a source, e.g., innate, habit, parent, teacher, command, goal, book, principle, law.

Images in the mind that signal, guide, train or control action-schemes have a character different from that of movements. Mental images occupy many different domains, sometimes with significant interactions with each other or with the body and also often with high degrees of independence. Images in domains such as "work," "family" and "play" compete for control of the body; the most powerful depend on permanent features and rigid demands.

In an enlarged psychological construction, addition of a third part of the personality, "emotions of the heart," might be suitable to model social activities where groups of individuals are formed on the basis of shared and/or conflicting *attractions* and *aversions* (emotions or movements of the heart). Shifting patterns of attractions and aversions generate shifting groups of individuals that resemble blocs in the Ising Model and clusters of movement in Quad Nets. In a psychology that includes emotions, formed and sustained movements of the heart — loves and hates — may strongly influence a person's selections involving domains of work, family and/or play.

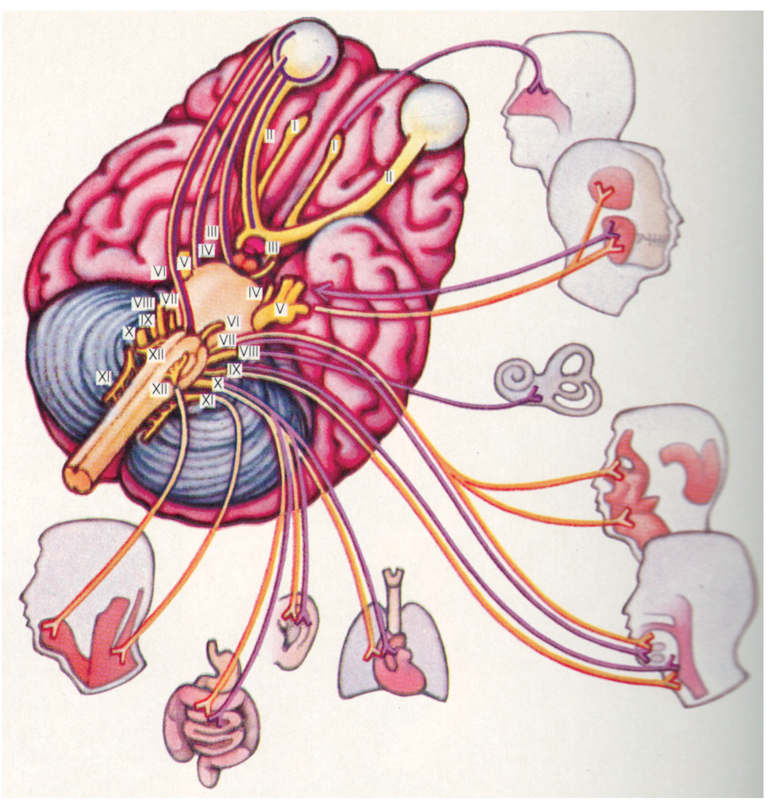
As to a psychology based on muscular movements, flowing patterns of movement in fish are produced by a spine made of an ordered array of modules. In a model of such patterns, a selection in one module is influenced by ongoing activities in its neighbors as well as by a wave of activation that travels along the array. In birds and mammals, spinal modules maintain capacities of flow first seen in fish, e.g., in flocks of birds in flight, or while climbing a tree or ladder. Modules also acquire distinct characters and particular additional capacities needed to operate limbs, feet and hands. Waves of flow can extend in a human being climbing a rope from feet moving between anchoring holds to up-reaching and up-pulling hands.

In a layered model of capacities of the human spine to produce movements, the "entire spine" extends physically down to the coccyx and through feelings down to the toes. It extends physically up through the brain stem and pons and includes the cranial nerves, e.g., nerves that signal sensations and movements of eyes, facial muscles and tongue. "The body" has "pelvic parts," "manual (hand/arm) parts," "cervical parts," "facial parts" and "ocular parts," each based in specific locations in the entire spine. Pelvic personality parts generate large-body movements and related bodily feelings that are based in the pelvis. Manual personality parts and ocular parts combine in constructions of small objects, structures and movements of external bodies. Facial parts operate during personal interactions and language functions that combine direct images, emotions and memories in verbal structures and that may even produce gestures with the hands. I suggest that the spine is the origin of sensation and the terminus of action and that both the cerebellum (generating "bodily awareness") and cerebrum (generating "the mind" and rational images) are perching outgrowths of the spine, connected to it through the cerebellar peduncles, midbrain, cerebral peduncles, thalamus, insula, etc.

An "entire spine" is implicit in the ***body plan*** ("bauplan") of flatworms that have a "ladder-like nervous system" — "with a well developed cerebral ganglion and longitudinal nerve cords connected by a transverse commissure." (Brusca & Brusca, *Inverterbates* (1990) 43, 294, 295.) I suggest that descendants of worms have similar entire spines incorporated in their body plans.

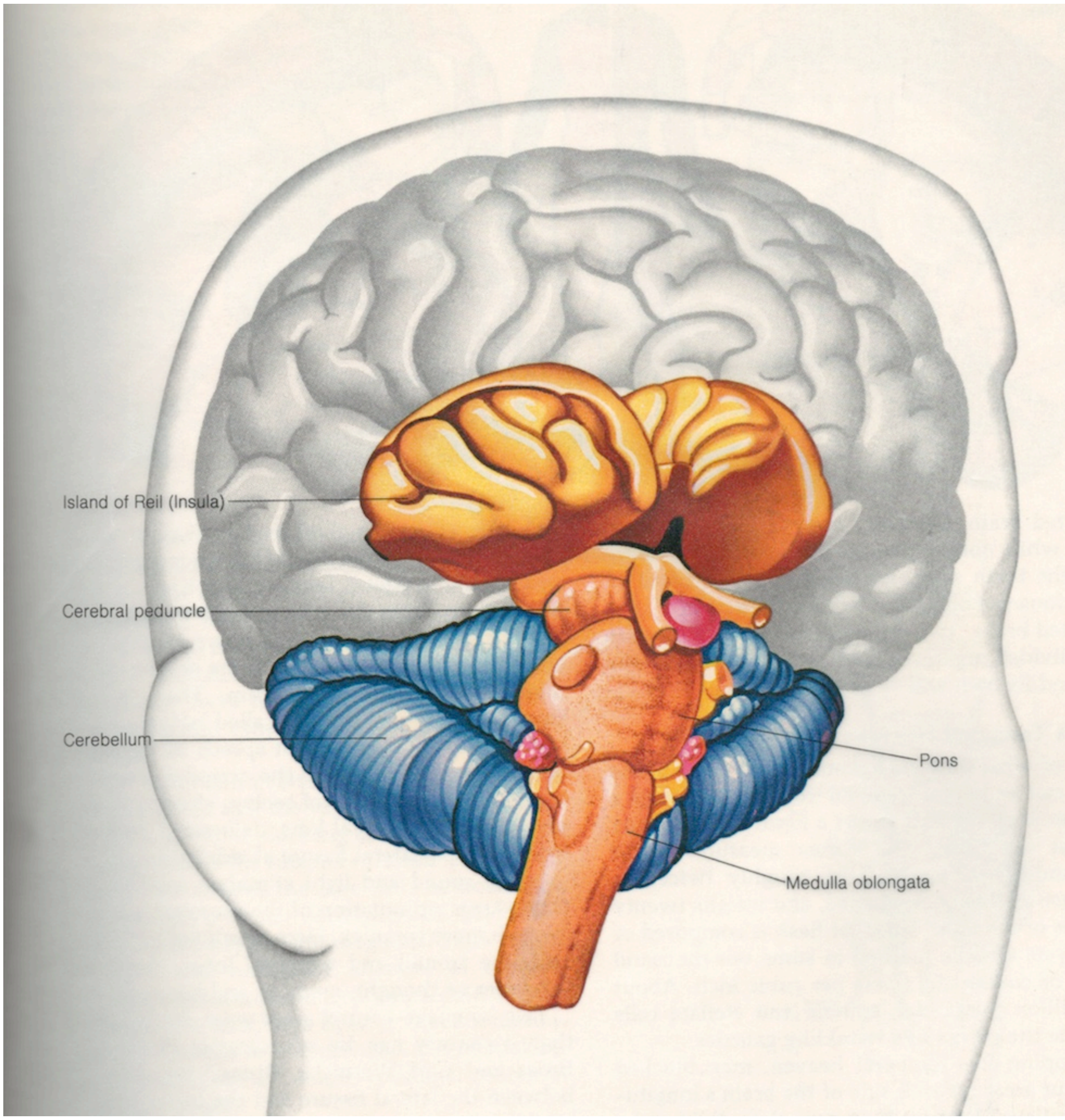
I suggest that parts of the human body have different levels of agility based in the entire spine, slowest in the pelvis and progressively quicker in hands, face, tongue and eyes. Body parts may interact with each other through cerebellar awareness or through the cerebral mind. Sometimes, certain parts are working together while other parts are inactive; e.g., while sitting at and playing an electronic piano keyboard, a person's hands, ears and mind are working together while pelvic parts are inactive and facial parts are operating independently and perhaps expressing emotions.

Images and text below are from J. Fincher, *The Brain: Mystery of Matter and Mind* (1981).



"Twelve pairs of cranial nerves branch from the brainstem, sending sensory (purple) and motor (orange) fibers to head and body organs. Spot illustrations (clockwise from top) show nasal path to olfactory nerve; trigeminal nerve endings in chewing muscles and sensory facial areas; acoustic nerve connections to the inner ear; facial-nerve motor fibers to face and scalp; sensory fibers from taste buds; wide-ranging vagus-nerve involvement in eardrum, lungs and stomach; and spinal-accessory nerve fibers that control head and shoulder movement; hypoglossal nerve leads to tongue." (The illustration list omits ocular nerves: sensory optic nerve and motor oculomotor, trochlear and abducens nerves.)

“From the medulla and adjacent areas radiate the twelve pairs of cranial nerves. They serve the sensory and motor needs of head, neck, chest and abdomen…[and] are known by both name and Roman numeral: olfactory (I), optic (II), oculomotor (III), trochlear (IV), trigeminal (V), abducens (VI), facial (VII), acoustic (VIII), glossopharyngeal (IX), vagus (X), spinal accessory (XI) and hypoglossal (XII).”



3. Polemical constructions opposing the modern scientific view

Polemical constructions use a principle of "type and anti-type" or "us vs. them," e.g., comparing and contrasting VET and CET paradigms. Shimmering Sensitivity, the physical principle of freedom, is contrasted with determinism and chance that are presumptions and goals of the modern scientific view. Flowing movements produced by flexible bodies of fish, birds, squirrels and children are contrasted with movements of rigid-body robots operated by computers.

As stated by computer intelligence advocate Marvin Minsky (*Society of Mind*, § 30.6):

> According to the modern scientific view, there is simply no room at all for 'freedom of the human will.' Everything that happens in our universe is either completely determined by what's already happened in the past or else depends, in part, on random chance. Everything, including that which happens in our brains, depends on these and only these:
>
> *A set of fixed, deterministic laws.* *A purely random set of accidents*
>
> There is no room on either side for any third alternative. Whatever actions we may 'choose,' they cannot make the slightest change in what might otherwise have been – *because those rigid, natural laws already caused the states of mind that caused us to decide that way.* And if that choice was in part made by chance – it still leaves nothing for us to decide.

I suggest that Minsky's statements are refuted by the bodily feelings and muscular movements of household chores. Living alone, I choose when to clean, what to clean and how thoroughly; and accidents happen through haste or negligence. VE paradigms and psychological constructions in this project provide further refutations. Such constructions are consistent with the actual life of chores and lead to a "third alternative" for consideration of events in our universe that do not conform to the rigid laws and closed-minded classifications of the modern scientific view.

In the modern scientific view, "energy" is defined as a real number that attaches to every point in space in our universe and to every particle of matter in our universe. All the energy in our universe can be added up — and the sum is a ***constant*** with an existence that lasts as long as our universe. Hence, as asserted by the modern scientific view, the principle of conservation of energy is universally and eternally real. The reality of conserved energy (CE) stands in the fore among the "rigid, natural laws" that are said to preclude freedom.

In contrast, virtual energy (VE) is a mental invention that has limited applications, chiefly to model rate-based processes in animal organisms where energy is supplied continually and to define similar processes in proposed electronics devices. VE can be conserved in storage bodies; but, in contrast to CE constructions, dissipations of VE participate in working operations during conversions and transformations. Continual dissipations are balanced by inflows of VE, leading to models with flowing integrated waves of transformational processes — instead of being bound to equipoise, quasi-static and equilibrium CE operations.

I suggest that VE has uses that reach beyond the modern scientific view, in which events are controlled by the "eternally constant universal sum" of conserved energy and its by-products "entropy" and "information." Instead, VE is generating multiple possible movements during transformational processes of Shimmering Sensitivity that lead to one actual movement; VE is dissipated in different ways that select and control actual movements; and such selections include production of flowing whole-body movements that require exercises of freedom.

B. Movements of and changes in animal bodies occur in actual time and make up the domain of actual life that establishes a foundation and goals for all constructions.

The ***domain of actual life*** serves as the foundation and standard for my constructions. The domain of actual life is prior to constructions and motivates constructions. For purposes here, the domain of actual life has a core made up of muscular movements and accompanying bodily feelings of persons. Core movements and bodily feelings exist prior to images of things, places or other persons. I presume first, that all healthy adult persons share a common foundation of muscular movements and related bodily feelings and that, more generally, birds and mammals have something similar. We all have personal bodily experience of itching and scratching. Dogs and cats stretch and scratch; and birds preen. Added to the common foundation, many persons, e.g., musicians, cooks and athletes, have additional movements specific to themselves.

In actual life, movements usually involve ***images*** of external things, places and other persons — and also memories of such images. At a traffic light, we stop on red and go on green. In actual life, images are significant when they are involved in movements; such images are included in the domain of actual life as needed. However, images detached from muscular movements and having a separate existence– e.g., algebra, TV, laws – are not included in initial constructions.

Persons share domains of actual life with other higher vertebrates such as dogs, cats, birds and squirrels. Of course, persons have movements of actual life that are additional to movements of such animals, such as movements used in card games and cooking. In all vertebrates, including fish, phenomena of actual life include possibilities of multiple different movements and relations between possible movements of choice, exclusion, triggering, emphasis, sequencing and/or causation. Human beings have further developed such relations using technology.

Psychological constructions seek to organize imagery connected to actual life. Psychologies based on the domain of actual life include both a general psychology and restricted psychologies.

Restricted psychologies aims to work with technical VE device constructions and VE concepts. In other words, specific constructions target specific activities of persons where psychological models fit VE device designs. Such activities are based on a "kit of parts" of specific repetitive movements and practiced repertoires of movements and courses of movements. By selecting movements from the kit and putting movements into practiced flowing patterns, a person follows mental forms, reaches goals and exercises freedom. Targeted activities might include certain sports contests, musical performances, parlor games, technologies and institutional decisions.

A general psychology of actual life is founded on actual muscular movements of persons in ordinary activities of life, e.g., eating, cooking, home-making, hygiene, sleep, travel, markets, socializing, exercise, consumer technology. Of special importance are whole-body movements and large-scale movements involving multiple spinal regions, e.g., scratching the left ankle with the right hand. Spontaneous, impulsive and precise whole-body movements of birds and squirrels resemble those of children and provide exemplars of exercises of freedom in actual life.

Overall psychological guidance is provided by Jean Piaget (1896-1980), who described a ***practical intelligence***, "an intelligence before language," that arises from and then controls ***sensory-motor coordination of actions***. A course of development is seen in which such sensory-motor coordination begins during infancy in reflexive actions and then develops in forms of practical intelligence during the first months and years of life before progressive reconstruction into mental forms that lead to operations in detached time . Viewing the initial stages of such development, Piaget and his close colleague Bärbel Inhelder (1913 – 1997) wrote (emphases added):

> Essentially ***practical*** – that is, aimed at getting results rather than at stating truths – this intelligence nevertheless succeeds in eventually solving numerous problems of action (such as reaching distant or hidden objects) by constructing a complex system of ***action-schemes*** and organizing reality in terms of spatio-temporal and causal structures. In the absence of language or symbolic function, however, these constructions are made with the sole support of perceptions and movements and thus by means of ***sensory-motor coordination of actions***, without the intervention of representation or thought.
>
> [Piaget & Inhelder, The Psychology of the Child (1969) at 4. "A ***scheme*** is the structure or organization of actions as they are transferred or generalized by repetition in similar or analogous circumstances."]

C. Constructions of images in rational domains initially arise in actual time but then repeat independently in detached time, co-existing with the domain of actual life and sometimes interacting with bodily movements and changes.

For purposes here, constructions in ***rational domains*** include mathematics, maps, expository language, codes, theories, device designs and other symbolic functions based in the mind. Traffic signals and words of command, in contrast, are connected to movements and belong to the domain of actual life. Rational domains are occupied by mental constructions but many activities in actual life do not require mental constructions. Persons initially encounter elements of such mental constructions through engagements with their environments, e.g., by playing with toys or reading a book. Such engagements occur in actual time, requiring eye movements for acquisition of images. Multiple engagements with permanent elements lead to a network of constructions in the mind that can be explored and elaborated in detached time.

Regardless of roots in the domain of actual life, rational domains are constructed in ways that are separate from and independent of muscular movements of actual life. Thus, a domain in the imagination of each adult person of ordinary intelligence is occupied by the counting numbers "1, 2, 3, 4" and so forth. The mental domain is independent of bodily experience although it was created during infancy in connection with bodily movements such as counting on fingers. In general, rational domains are independent of each other and of bodily movements. Important rational domains are shared by adults, e.g., domains of arithmetic and elementary mathematics, money, family relations, property, logic and, recently, computers. Such rational domains have independent and interactive existences in the imaginations of persons or in operations of computers — existences that may be represented by symbols on paper or on computer screens.

The division between the domain of actual life and rational domains corresponds to the division between body and mind. In a crude model, practical intelligence that controls muscular movements is located in the body and in the entire spine that extends up through the cranial nerves; while rational intelligence operates in the mind that is based in the cerebrum, which sits on top of the upper part of the whole spine and which interacts with the whole spine both directly and through intermediate parts such as the thalamus. Practical intelligence is also based in the cerebellum that sits on top of the lower spine, that can control its actions and that has more neurons than the sum of all the neurons in the rest of the brain and spine.

In actual life, bodily movements are often integrated with mental images. A simple example occurs during a weight-lifting session at the gym. Movements in the two domains are performed together. Each exercise ***set*** consists of an integral number of repeated cyclical movements; each cycle is called a ***repetition*** or ***rep***. Suppose that there are 8 reps to a set of bench press exercises, performed by lying on the back on a flat bench and raising dumbbells up from the chest, then lowering them under control. The person counts successive repetitive cycles as 1, 2, 3, 4, 5, 6, 7, 8 — thus coordinating the mental activity of counting with the bodily movements. In addition, there is a ***form*** of the exercise that prescribes details of movement, e.g., that the dumbbells should move smoothly, in parallel and in a vertical direction. The same methods of integration (counting reps and following forms) are applied to arm biceps curl exercises and to squats. Records of exercises, weights, sets and reps are used by an athlete to track and control progress. Similar rational methods are applied to activities of cooking and card games.

D. Movements of and changes in animal bodies that occur in actual time cannot be fully described or controlled by rational constructions that operate in detached time.

Successes of civilization are based on applying constructions in rational domains to the domain of actual life. For example, one ancient rational system, plane geometry and land surveying, successfully resolves boundary disputes, in contrast to animals and uncivilized peoples that engage in wars and feuds over such disputes. Other successes range from following a cake recipe to building a sewage plant or, in a legal case, enforcing the Uniform Commercial Code. Activities of actual life that are based on rational constructions are said to be ***rationalized***. Questions are presented: Can all matters in actual life be rationalized? If not, which matters in actual life can be rationalized? Which matters should be rationalized?

I suggest that there are clear limits to rationalizations. Rational forms are sited in specific mental domains, such as computation or commercial law; and each depends on specific principles. Rational forms do not generate new forms; rather, new forms are developed through exercises of human freedom, e.g., as a response to actual need. Human beings continually invent novel kinds of rational imagery in many activities of actual life, e.g., in internet culture, arts, international relations, clothing fashions and financial markets. In these activities, past rationalizations have had least success in predicting future events or future rationalizations.

Viewed more generally, activities of actual life often do not match or fit constructions in rational domains. Sometimes a better fit can achieved through practice, but, even then, only in limited ways. Muscular movements are of brief duration and easily varied, with a transient existence that is often difficult to repeat or to define exactly. Some practiced movements can be repeated and defined exactly, e.g., those used in 19th century ballet academies and performances; but such movements are in special categories and lack the spontaneous and flexible character of movements in ordinary activities of actual life. Spontaneous movements depend on momentary feelings more than on forms of practice. During spontaneous movements, changes occur in response to environmental interactions. Spontaneous movements occur in integrated flows.

In contrast to flowing movements in actual time, detached operations of computers use programmed forms and are subject to "interrupts." Historically, computer operations through the 1960's were not interrupted; jobs subject to "batch processing" had no interaction with a person. Interruptions became important when personal computers appeared in the 1970's; an historical review of PC programming languages begins with BASIC and develops to c to C++ to java to mobile app; such development involved progressively greater use of interrupts. In all computers, interrupts operate as part of programmed forms. Interrupted programs of computers and spontaneous flows of actual life do not fit together easily.

In contrast to transient movements of actual life, mental images such as numbers have a permanent, even an "eternal" character. A single name attaches to a person who grows and changes while developing from infancy to old age. Many mental images occur in definite, fixed structures, spaces and forms and are governed by rules that prohibit changes or deviations.

Attempts to apply detached operations and fixed mental images to transient, variable muscular movements are often frustrated by such systemic misfits. Frustration may be compounded when a person is presented with a new challenge or a new environment. Fortunately, human beings are sometimes able to invent means to overcome such frustrations.

E. The modern scientific view presumes full integration of rational domains with the domain of actual life.

In the modern scientific view, "Everything that happens in our universe" can be rationalized by means of "fixed deterministic laws" and "random chance." It is presumed that numerical values are attached to each point in space and to each particle of matter and that sums of values over the universe determine actual movements according to differential equations, e.g., equations based on Newton's Laws of Motion, Laws of Thermodynamics or Einstein's Field Equations.

A view similar to the modern scientific view was declared by Georg Wilhelm Friedrich Hegel (1770-1831), who wrote: "***What is rational, is actual; and what is actual is rational***." (Hegel, *Philosophy of Right*, Preface, Kaufmann trans. in *Discovering the Mind*, vol. I at 222.)

Hegel set forth a doctrine that ideas are real (*Philosophy of Right*, S. W. Dyde trans.):

> Against the doctrine that the idea is a mere idea, figment or opinion, philosophy preserves the more profound view that nothing is real except the idea. Hence arises the effort to recognize in the temporal and transient the substance, which is immanent, and the eternal, which is present. The rational is synonymous with the idea, because in realizing itself it passes into external existence. It thus appears in an endless wealth of forms, figures and phenomena. It wraps its kernel round with a robe of many colours, in which consciousness finds itself at home.

Hegel's constructions were popular during the 19^{th} and early 20^{th} centuries but have also been cited as a source of totalitarian ideologies. According to Karl R. Popper in *The Open Society and Its Enemies* (1950 rev. ed.), Hegel constructed a philosophy of "might is right" to ingratiate himself with the Prussian King. Hegel's construction conflated Plato's Forms or Ideas where "the Ideas alone are real" with "ideas in our minds" — "and this allows Hegel to maintain that everything that is reasonable must be real, and everything that is real must be reasonable, and that the development of reality is the same as that of reason."

Hegel wrote:

> Was vernünftig ist, das ist wirklich;
> und was wirklich ist, das ist vernünftig.

Translations differ on the English equivalent for "wirklich," choosing in some cases the word "actual" and in other cases the word "real." Similarly, "vernünftig" is alternatively translated as "rational" and "reasonable." Distinctions between actual and real or between rational and reasonable appear to be obscure in Hegel's philosophy. In a model of everything, where "vernünftig = wirklich," it seems hard to avoid real = rational = actual = reasonable.

Minsky's modern scientific view likewise declares that mathematical constructions, rational propositions and eternal certainties control "Everything that happens in our universe … including that which happens in our brains."

My alternative approach avoids such unlimited universals but rather suggests that "reality" may change when "rational" constructions in the mind fit and combine with "actual" movements of the body to make up an integrated, purposeful course of action. (Similarly, under the common law of England, in order to establish a criminal offense, a prohibited *actus reus* of the body must unite with a specific *mens rea* of the mind.) When mind and body are working together, something real is going on. I decline, however, to grant a metaphysical status to "reality."

F. To develop a new approach, three kinds of energy are constructed: actual, conserved and virtual.

Prior to its apotheosis as an eternal universal principle, "energy" had origins in Newtonian mechanics and mechanical paradigms such as Atwood's machine and Hooke's Law. In mechanics, energy is a capacity to generate forces and to produce certain movements of inanimate bodies. Forms of mechanical energy (kinetic, gravitational, elastic) are converted into each other according to general principles — in contrast to particular properties of material bodies and to particular phase changes that are investigated in thermodynamics.

In mechanics, changes in movements of bodies are easily rationalized as changes in energy. In thermodynamics, changes in properties of bodies are similarly rationalized and difficulties are glossed over. As shown in Part I of this project, thermodynamics rationalizations can match mechanics rationalizations when movements and changes are restricted to equipoise positions or equilibrium conditions operating in detached time. In such cases, matching elements make up a structure that covers both mechanics and thermodynamics. Certain restricted applications and constructions in actual time can be appended thereto, e.g., through invention of "enthalpy" used in conversions of flows of heat energy into flows of electrical energy. Such rationalizations have been inflated into the real system of Conserved Energy that is said to control the Universe.

Theories of Conserved Energy have had solid successes, such as rationalizing movements of celestial bodies and subatomic particles in *vacua* and movements of aeronautic and astronautic projectiles and vehicles. Conserved Energy principles provide important guidance in designs of power plants and automobile engines. Extensions of principles of Conserved Energy to chemical reactions have also had solid successes; but such chemical successes are limited to simple cases.

When attempts are made to apply principles of Conserved Energy to movements and changes of living animal bodies, however, the empirical results show major shortfalls and defects. Animal bodies ingest energy foods, expend energy through movements and discharge energy in the form of heat and excretions. These activities cannot be tracked with accuracy and cease only on death. Animal bodies are continually undergoing internal changes. While inanimate bodies are chiefly moved by external causes, internal stores of energy enable an animal body and each biological cell to move on its own. In contrast to robot bodies made of rigid elements, animal bodies have flexible elements and multiple uses for friction, viscosity and dissipation. Unlike chemical processes of Conserved Energy that are clearly defined only in equilibrium situations, chemical processes of living bodies occur in situations where equilibrium is not maintained and where the degree of disequilibrium is of major importance. In stating biochemical cycles — e.g., the citric acid cycle — scientists can articulate and quantify steps of energy change but not rates of change. As discussed in part I, CET operates in detached time regimes that are disconnected from actual movements that are based on such rates of change.

Chief styles of science include the empirical style and the rational style. (Yet another style, the experimental style, looks for errors in constructions made in other styles and also attempts to adapt empirical results to rational forms, e.g., looking for ways to produce materials that conform to Hooke's Law.) Empirical scientists classify natural phenomena and organize regularities that are observed. Empirical investigations of Linnaeus led to organized biological *taxa*, those of Mendel led to theories of genetic inheritance and those of Mendele'ev led to the Periodic Table of elements.

The domain of actual life can be approached by an empirical style. Investigations show the presence of regularities in diverse movements of diverse kinds of animals. It is possible to classify movements according to a temporal form (e.g., stationary, steady, saccadic, shimmering) or, in higher vertebrates, according to body area or areas (pelvic, manual, cervical, facial, ocular).

Empirical evidence suggests that there is something fundamental — I call it ***actual energy*** — that is a source of feelings in animal bodies and that produces, controls and integrates the various movements of a person or animal. In my approach, human beings lack a capacity to comprehend actual energy and actual energy is not denumerable; but conserved energy and virtual energy are useful approximations. On the largest scale, the empirical nature of actual energy in animal bodies might be described no better than by Hegel, as quoted above: that such energy appears in "an endless wealth of forms, figures and phenomena. It wraps its kernel round with a robe of many colours, in which consciousness finds itself at home." Other empirical descriptions are provided by yogic *prana* and by *qi* in Chinese practices of bodily discipline.

Further suggestions appropriate for a rational approach to actual energy were stated by Teilhard de Chardin in *The Phenomenon of Man* (1955, 1959 English transl.). In the following extracts, I would substitute "body" for his "atom" and omit "from the real evolutionary standpoint."

> …Energy is the measure of that which passes from one atom to another in the course of their transformations. A unifying power, then, but also, because the atom appears to become enriched or exhausted in the course of the exchange, the expression of structure.
>
> …Though never found in a state of purity, but always more or less corpuscular (even in light), energy nowadays represents for science the most primitive form of universal stuff. Hence we find our minds instinctively tending to represent energy as a kind of homogeneous, primordial flux in which all that has shape in the world is but a series of fleeting 'vortices.' From this point of view, the universe would find its stability and final unity *at the end of its decomposition*….
>
> Let us keep the proofs and indisputable measurements of physics. But let us not become bound to the perspective of the final equilibrium that they seem to suggest. …(pp. 42-43.)
>
> *First Principle*. During changes of a physico-chemical type, we do not detect any measurable appearance of new energy. …
>
> *Second Principle.* In every physico-chemical change, adds thermodynamics, a fraction of the available energy is irrevocably 'entropised,' lost, that is to say, in the form of heat. Doubtless it is possible to retain this degraded fraction symbolically in equations so as to express that in the operations of matter nothing is lost more than anything is created, but that is merely a mathematical trick. As a matter of fact, from the real evolutionary standpoint, something is finally burned in the course of every synthesis to pay for that synthesis. (pp. 50-51.)

A rational style of science based on axioms or on de Chardin's principles is more adventurous than the empirical style. In the rational style, mental constructions are invented for purposes of trying to apply them to actual events. Such attempted applications may or may not succeed, with results that may be variously judged e.g., solid, limited, speculative, trivial or trumped up.

Truesdell's style of rational thermodynamics invokes mathematical rigor and is highly focused and restrictive, expressly avoiding universal presumptions like those of Hegel. According to Truesdell, a rational construction has only a limited and specific range of applications. A conscientious construction necessarily includes statements of presumptions and limitations.

Truesdell's investigations, like those of other rational scientists, presume ***Conserved Energy*** as an axiom. Foundational paradigms start with the Ideal Gas. Another presumptive axiom leads to the definition of Entropy that is derived from Conserved Energy.

The modern scientific view presumes that there is a universal correspondence between rational constructions and actual events and calls this presumption "reality." In alternative constructions, I avoid the "reality" of Conserved Energy and, instead, construct ***Virtual Energy***.

The distinction between a "real" construction and a "virtual" construction is based on optics, the physics of light, where a "real optical image" is contrasted with a "virtual optical image." In rational constructions of geometrical optics, both kinds of images are made of many light rays. To form a real image, rays converge at a specific location or ***focus*** in space that is external to any person. E.g., real images appear on movie screens and inside cameras. In a virtual image, on the other hand, light rays do not converge in external space; rather, they converge and come to a focus inside an animal's eye that has lenses to modify rays for that purpose. Unlike a real image, a virtual image depends on the presence and orientation of an animal that sees the image.

Conserved Energy constructions presume identity between rational structures and actual movements. Like a real image, Conserved Energy is presumed to be independent of the particular body that holds or beholds it. Virtual Energy avoids such presumptions.

In actual development of VE designs, it should be noted, VE constructions have achieved progress by conforming to CE principles, e.g., by following the "quasi-static" path in burster development. In other words, VE constructions start in an overlap region shared with CE principles but without the commitments that CE requires, e.g., commitments to entropy and information. VE constructions are more conducive to modifications and develop into variant forms in different contexts, activations and domains. VE constructions sometimes contain ambiguous components in anticipation of future modifications and other potential changes. Any definition of VE is provisional, whether in the form of principles or in the form of device designs.

In modeling biological organisms by means of devices, general VE presumptions are that: "more than enough" energy is available for multiple kinds of operations but subject to operating principles of economy and efficiency; energy passes between forms and is subject to conversions and transformations; dissipations are common and useful.

VE operations may generate internal conflicts – e.g., through processes of Shimmering Sensitivity – that are overridden by the necessity of performing actual movements. Cyclical operations of Quad Net devices create "deadlines" for action. Meeting the deadline, a balanced condition is driven into a loss of balance, with the particular direction of loss depending on multiple, momentary influences. A course of movements based on overriding requires continual selections. Each whole-body selection may depend on fixed purposes, on sensations based in movements and in an environment, on competing dissipations that are based in memories and on momentary energetic interactions, activations and entrainments.

I suggest that such operations and selections in VE designs cannot be rationalized in terms of permanent images or numbers. In addition, if a course of movement is repeated in a fixed environment, e.g., practicing music, selections will show a ***character of patterns*** that is discerned by other persons and that cannot be rationalized as chance — just as the character of a snowflake cannot be rationalized by random variables of mathematical modeling.

General VE presumption are based on biological evidence. Mitochondria in cells produce plenty of "energy packets" (ATP). Movement proteins (actin and myosin) are present in all cells and in all structures of animal bodies, including not only large muscles but all bodily organs and connective tissues, even acting through tiny fibers between adjacent cells in an organ and extending in webs of tissue around organs.

I suggest that during a highly activated whole-body movement of actual life – e.g., during movements of dancing – essentially all the muscles, organs and trillions of cells located throughout the body participate energetically in the movements. Additionally, I presume that each animal body is unique in its material properties and in its balances of processes; and that descriptions and controls of movements of animal bodies are beyond full comprehension by models or control through rational structures of laws of governments.

In the technological domain, on the other hand, it appears that devices based on VE principles might be manufactured that closely conform to paradigms.

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