A Matter of Definition

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Abstract. Many significant problems in physics remain unsolved not merely for lack of clever mathematics or even a good theory, but for lack of a proper paradigm behind the mathematics. Therefore, this paper examines the definitions of several fundamental properties such as space, time, energy, field, force, mass, entropy and temperature, suggesting fundamentally new ways of understanding them all. Also the quadratic nature of energy defined as relationship naturally leads to a distinction between *self* energy *within* objects and *interaction* energy *between* objects. This distinction admits new definitions of entropy and temperature, based on the unavoidable cross terms inherent in any quadratic formulation. Further, the foundational concepts of the circuit and rotation are shown to be intimately connected with the very existence of particles and their structure. Certainly rotation plays a foundational and still overlooked role in explaining the energy relation $E = mc^2$ as well as the very nature of light as an interaction between particles.

Keywords: Definitions, Philosophy Of Science, Energy, Field Theory, Mass, Entropy, Temperature, Thermodynamics, Entanglement, Nonlocality, Rotation, Rotating Flows, Vortices, Superconductivity, Structure, Special Relativity, Light
PACS: 01.70.+w, 03.30.+p, 03.65.Ud, 05.70.-a, 11.10.-z, 21.10.Dr, 21.10.Gv, 32.10.-f, 33.15.-e, 42.50.Ct, 45.20.dh, 47.32.C-, 47.32.Ef, 74.20.-z

INTRODUCTION

As an editor of the World Science Database (www.worldsci.org), I have the pleasure of reading lots of innovative and original ideas in fundamental physics. I also observe many exchanges between independent scientists on various e-groups and during our weekly online meetings (live.worldsci.org or www.worldsci.org/php/index.php?tab0=Events). Through all of this, I notice certain patterns in the kinds of arguments presented, some healthy, some not. For the most part, everyone agrees that contemporary physics is a mess, but few agree on the details of what should be done. Many of them love to show how Einstein was wrong, Maxwell was wrong, Newton was wrong, their former physics professor was wrong, the last speaker was wrong, and they are right. No doubt you are wrong, too. Many claim to have discovered the "theory of everything", based on "one simple concept overlooked by everyone until now". Many thump their fist, insist on their ideas, and wonder why they don't receive more attention than they do. Many taut "experimental proof" that so-and-so's theory is wrong, when so-and-so himself regards the very same experiment as "proof" that he is right.

What should we make of all this? Are all of these "dissidents" crazy? No. Actually most, if not all, of their ideas have merit, even if not quite the "theory of everything" they proclaim. Then if they're really onto something, why don't they all agree? Well, they do agree on many things, though they vehemently insist on their particular take. They insist on their terminology.

In many cases the disagreements stem from completely different views about the meaning of words. Or perhaps from multiple, but inconsistent definitions. Indeed the problem arises before the argument even begins, in the very use of language, and its assumed relation to the physical concepts they try to convey. Often certain words trigger an unintended emotional response, as one person automatically turns off from a word or phrase like "aether", "neutrino", "zero point energy", or "Maxwell's Equations", while another begins nodding his head in agreement before he has any idea what's being promoted. Just because of words.

So how to get off the merry-go-round? How can we express ideas except via words? Perhaps the problem really is finding the right definitions for certain key words like "energy", "light", "motion", "temperature", and "entropy". Are these definitions arbitrary? Can we choose them to mean whatever we like, so long as we use them consistently? Surprisingly, no. Not if we're going to turn around and express these ideas in mathematical relationships. Can't we just use these words as they are "commonly" used among physicists? No, again. In fact, the common use of these words is precisely the problem. We must discover definitions that are consistent with the way these quantities are used in the mathematical equations of physics, yet also consistent with nature itself.

In short, getting the definitions right is a *BIG DEAL*. So big that it may be in fact *THE* problem with physics today. Yet most scientists, independent or mainstream, blithely assume that they know what "energy", "mass" and "temperature" really are, so long as they can write equations with symbols representing them. This paper challenges that assumption, and attempts to define some very basic concepts in ways fundamentally different than commonly accepted, yet hopefully both logically consistent and in harmony with nature, which holds the final trump card.

THINGS VS. PROPERTIES

Before we can even talk about anything in physics, we must first determine what sort of terms are merely ideas and what sort constitute nature itself. For example, is "energy" something that exists in nature itself, or is it just an idea that helps us account for things that are real? Please don't answer too quickly, because you limit yourself if you knee jerk a response. Try something else first, like "angular momentum" or "temperature". Can you go out and buy a truckload of angular momentum? No, clearly angular momentum is a property, measuring how much "spin" an object has relative to its environment. You can create angular momentum by spinning the object, but you can't put the angular momentum itself into your pocket. Likewise temperature measures the average relative motions of particles in a substance, but you can't eat a temperature sandwich. Only a hot or a cold sandwich. Temperature is not a thing, but a property.

Obvious as the distinction between things and properties of things may seem, believe it or not, failure to make this distinction is at the root of many misconceptions in physics today. Physicists and laymen alike carelessly assume that mass and energy are "things" that can be interchanged in some mysterious way via the famous equation attributed (incorrectly) to Einstein, $E = mc^2$. Moreover "light", a form of energy, is almost universally regarded as a thing that travels from source A to receiver B through another "thing" called space. In turn, according to general relativity, space is a thing that can be bent, contracted, and even quantized into tiny finite cells. But are we warranted in treating energy, mass, light, space and time as "things" or are they really only ideas, properties that help us describe relationships between real things? This paper explores the latter possibility.

MATTER, MOTION, SPACE AND TIME

Rather than champion this or that property (mass, energy, charge, etc.) as matter itself, let's start by assuming simply that something exists, and let's call this something "matter". Whatever properties matter has, it's the real deal, the true stuff, by definition. Now some ideas are so foundational they can't be proven and must be assumed. This is one. I won't argue with anyone who claims that nothing exists and everything is really just a thought, because I can't prove him wrong, nor can he prove me wrong in disagreeing. So for this paper, matter exists, regardless of what I or anyone thinks of it.

A second necessary assumption: matter moves relative to other matter. In fact, the motion of matter is only detectable and meaningful in relation to something else. This assumption requires some thought, and might even raise another knee jerk objection. Accept this assumption, and you may no longer determine motion with respect to space itself, but only wrt other objects in space. That is, the relationship between real things constitutes reality, not necessarily the "space" between them.

The foundational idea of matter-matter relationships is not new. Discussions of this sort began with the Greeks, and probably before. In the 1600s Leibnitz accused Newton of an absolutist take on physics, because Newton believed that motion could somehow be determined with respect to space itself rather than with respect to other matter, despite his famous equations that said otherwise. A little later, George Berkeley raised similar objections, influencing 18th century greats like Leonhard Euler and Ruđer Bošković. But the debate raged on, with the absolutists dominating the 19th century until Ernst Mach resurrected and extended the arguments of Bishop Berkeley. In fact, the idea that the motion of matter is only meaningful in relation to other matter is often called "Mach's Principle".

Incidentally there is a widespread misconception today that Einstein settled the matter once and for all in favor of the relational view. He did not. Einsteinian observer-based physics is kinematic, not relational or dynamic, as Einstein himself was well aware, especially in his later years. Clearly frictional effects are not relative to observer, but relative to the matter producing the friction. Moreover, the energy of an object is not relative to observer, but relative to the matter comprising the object's environment. Ironically most Einstein critics today argue that Einstein moved from absolutism to relationalism, when in fact his physics treats space very much the same as an absolutist, with only kinematic observer-based differences. For example, Einsteinian physics actually maintains that it is meaningful to compare velocities of objects separated by great distances or otherwise moving relative to completely different environments. In reality both objects "move" with respect to their own environments. But I digress. This paper is not a full attack of Einsteinian relativity.

So our fundamental assumptions are that matter exists and that the motion of matter is meaningful and measurable only with respect to other matter. For example, we can't just have gravity in an absolute sense, but gravity "of the earth" or "of the sun". We can't say that "mass m moves with velocity v", except at a velocity v with respect to the earth, a train, or the Milky Way. (I'll have more to say about mass m later.) We may not even say that a planet revolves or a top spins except in relation to a frame determined by the sun or earth, for example.

What does this say about space and time? If matter exists, it must exist in a place. The place is not matter itself, but a marker to identify its relationships with other matter. That's all space is, a place for matter. It has no other properties. You can't bend, expand or quantize it, though you can do all of those things to the matter in space. The point here is that matter is primary, not space. We never measure space directly, but only in terms of matter. For example, the ancient cubit measured the distance between elbow and fingertips, physical objects just like the "foot". These standard measures of space are called "rulers", which we use to compare with other matter. When we say that the earth is 93 million miles from the sun, we mean that the space from the earth to the sun measures the same as 93 million times the measure of a mile, which in turn measures 5280 times the standard "foot". And the standard foot ultimately derives from some physical foot, a pretty big one, I might add. Likewise the "meter" or "metre" was originally defined as one ten-millionth the distance from the earth's equator to the North Pole, though today defined in terms of light constant c. (And as we'll see, even c has more to do with matter than with space itself.) Thus, all measures of space ultimately derive from measures of the length, area or volume of real matter.

Another aside. If all matter in the universe is finite, and the physical laws of conservation suggest that this is so, then a non-preferred (that is, isotropic) distribution of matter in space itself must also be finite. Next, if there is no reason to prefer one reference frame over another, a "relativity principle" suggested by Galileo long before Einstein, then there can be no "boundary" to space. Else the frame in which the boundary remains stationary would be the preferred frame. Thus, you don't just tool along until you bump into the "space wall". Space itself has no such property. But a finite, unbounded space is **gasp** *NON-Euclidean* or **double gasp** *Riemannian*. Just as travel in a "straight line" on the surface of a globe isn't really "straight", neither does a truly "straight" line exist in a closed, finite space. Truly Euclidean space must either be infinite or bounded, and I just argued that it is neither.

But if you are a sworn Euclidian, don't stop reading now, or you'll miss the best part, since this is, after all, an aside, and what follows doesn't even depend on it. However, it does illustrate a very important point. Space itself doesn't bend or warp, because it's not a thing, but the relationships between matter in space do indeed form patterns of closure. An object can't move infinitely far away from another object in a finite space. Sooner or later, the objects again move closer together, or at least not further apart. So in fairness to the space benders and wormhole travelers, bending space relative to matter is mathematically similar to bending matter relative to a finite space. But that's not what's really going on. We don't bend space…

…And we don't warp time either. As we measure space by comparing matter with standard lengths of matter or "rulers", so we measure time by comparing cyclical motions of matter with standard cyclical motions or "clocks". You would never say that time itself "slows down" just because your watch runs slow, or because your biological processes slow down during hibernation. But that's exactly what many physicists do. The fact that a caesium atom oscillates faster in a satellite orbit, where gravity is neutralized, does not mean that time itself speeds up or slows down, only that a physical clock runs slower under the influence of earth's gravitational pull. And again, it doesn't matter from what reference frame you view the caesium atom, that is, how you look at it, only how the atom is influenced by its own environment. Indeed there are physical reasons why our standard "clocks" run slower under the stress of gravity or any other stress. That makes sense. But it doesn't mean that time itself "dilates" or is affected in any way. Time is not a thing. We must stop confusing time itself with its measurement or "clock".

I simply can't finish this diatribe on space and time without mentioning the connection between the two. There is none! The only reason for a supposed four-dimensional "space-time" arises from major misconceptions about the nature of light. From the "light cone" concept of Minkowski, whose work was otherwise brilliant, science has labored under the idea that light somehow travels through space along a space-time cone, independent of matter. This fundamental assumption is rarely even recognized as an assumption, much less questioned. But we must question it if we are to make progress in the fundamentals of physics. If light is a form of energy, and energy is not a "thing", can light itself be a "thing"?

ENERGY, FIELD, AETHER, AND FORCE

OK, if energy isn't a thing, then what is it? In his interesting book, Three Roads to Quantum Gravity (Smolin, 2002), Smolin compares the geometry of the universe with a sentence. By this analogy, "space" is the sentence itself while the "things" of the universe are the words in the sentence. He argues that you can't have a sentence without words, nor without relationships between words. While this is true enough, I suggest replacing "space" with "the universe", meaning all of reality and its laws, as the sentence itself. Then what are the relationships between words in this analogy? They represent energy. Energy measures the relationship between elements of matter (the words) in the universe (the sentence).

That's a pretty bold claim. Let's see if it makes sense. If energy measures relationship, then the more an object is "stressed" by its environment, the greater its energy. In the case of potential energy, this certainly works. A ball sitting on top of a hill has potential energy due to its position with respect to the earth. Take away the earth and the ball no longer has potential energy. What about the kinetic energy the ball gains after it rolls down the hill? Again take away the earth and how can you say whether it moves at all? This is the relational view of motion. In contrast, absolutists claim that the ball moves with respect to some mysterious frame provided by space itself; Einsteinian relativists claim that the ball moves kinematically (that is, arbitrarily) with respect to an observer. But there really is a right to the question, "How fast is the ball moving?" A child can tell you that the velocity is determined with respect to the earth, the dominant body in the environment. Thus, whether potential or kinetic, the energy of the ball is determined by its relationship with the earth.

So far, so good. How about a mathematical expression for "relationship"? Here we need to back up and talk about another concept desperately in need of clarification: the field. Even more than energy itself, this word carries a lot of emotional baggage. Some people love it and others hate it. But what is it? Let's start by noting that there's nothing else except what is, and remember that what is we defined as matter. According to the relational view, matter "moves" and has "stress" only in relation to other matter. But the other matter is physically located somewhere else, in another "place". Hmm. So the relational view tells us that matter here is influenced by other matter there. But the real surprise is that the relationship holds now. If this were not so, then there would have to be something else besides matter creating the relationship. But matter is all there is, by definition.

Sorry to have to keep interrupting, but it's time for another aside. If you are an aether lover, you may be thumping the table right now, thinking, "Doesn't he realize that aether is the something else that connects matter with matter? Otherwise the interactions between matter and matter would be instantaneous, and everybody knows that's impossible." Hopefully I hit the objection on the head. If this is you, I beg for your patience. In point of fact, I'm not an aether hater, I'm an aether definer. As the title of this paper suggests, the biggest problem with aether theories is lack of definition. These theories typically claim that the aether does this or that, flows here or there, bends space, warps time, does all sorts of incredible, yea even mystical, things. But they rarely nail down exactly what aether is, and even more rarely quantify it mathematically. I propose to do both momentarily, however my definition will be given in terms of matter, which I defined as the only stuff that truly exists, the only real "thing". Too many aether theories sweep problems under the rug by introducing a second kind of "thing" or matter, aether matter. You might guess (correctly) that the aether I propose is not a thing at all, any more than energy is. Aether thing theories are a bit like other universes theories or alien origins theories, where we sweep under the rug problems we can't solve in physics or life sciences in this universe by introducing another. The problems don't go away, they just get shuffled somewhere else where we can safely ignore them.

Now relax, I'm off my soapbox, and we're on our way toward defining fields, which in turn will quantify energy and define aether. Thus far we've established that matter moves only with respect to other matter, and yet the other matter is necessarily located somewhere else. So, if matter interacts with matter remotely, at a distance, we simply must have a mechanism in place to track the position and motion of all the other matter with respect to which each element of matter moves. That mechanism is the field. A field exists at each location in space because it tracks the position and motion of matter at other locations. Without matter there would be no field, or as Dr. Charles W. Lucas puts it, the field is permanently attached to matter. You can't have one without the other. Matter and its field are two inseparable parts of a whole. Yet another way to say it: all matter exerts influence on all other matter, and the field quantifies that influence. In the sense that matter's influence is actually part of matter itself, it exists not just locally, but throughout all space. That is, every element of matter exerts some influence, and thus has a field, at every point in space. All matter actually exists everywhere.

Before you accuse me of practicing voodoo and joining the Hare Krishnas, recognize that this definition of field has some very credible history to it. No less than Michael Faraday himself invented the field concept to explain the action-at-a-distance phenomenon of induction. Carl Freidrich Gauss recognized that the divergence of a field from a volume implied the existence of matter in that volume. James Clerk Maxwell further quantified and unified the field concept, giving it mathematical rigor. I don't think anyone denies the value of the field as a mathematical tool. The point of contention is in its definition. What does it really represent? In matter-based physics, the field has no meaning or existence apart from matter. You can't talk about the "field" as if it were something with an independent existence. Whether we say that it's a "real" attribute of matter or that it's merely a fictitious accounting system to track the real stuff is academic. Why? Because we don't access the "field" directly anyway, but only through matter. All of the detectors and scientific instruments, regardless of how precise, will always be made of matter, not of fields or aether. We simply don't access fields directly, however useful they may be. Moreover, we can argue that fields exist and are "real", but can never prove it, so the argument is futile at best. To argue that field X exists, but field Y doesn't is to completely miss the point. We use fields because they are unquestionably useful, end of story.

I just mentioned Gauss's Law as the connection between matter and its field. Mathematically this law states that a diverging or "spreading out" field indicates the presence of matter. Put another way, an outward pointing field represents the influence of the matter away from which it points. The rest of Maxwell's Equations tell us important things about how fields behave and interact, but Gauss' Law establishes the vital connection between matter and fields, and does so without any time dependence. In my paper, "The Meaning of Maxwell's Equations", I delve into the mathematical details of each of the four fundamental equations, and show how each expresses a fundamental physical principle. But let it now suffice that by "field" I do not mean a set of lines that move rigidly and statically with a body. There exist other solutions to Gauss' Law besides the static solution, and these dynamic solutions satisfy all four of Maxwell's Equation's simultaneously. (There will be more to say about dynamic fields later.)

Note that the idea of divergence or spreading out must be expressed by a vector, a mathematical quantity that has direction as well as magnitude for every point in space, since divergence inherently requires directional variation.

Thus, the "field" of an object is actually the vectoral sum of the fields of every component part of the object, with each infinitesimal part contributing infinitesimally to every point in space. This holds whether we're talking about an electric, gravitational or any other sort of field. The "total field" is then the vectoral sum of field contributions from all objects in the universe for every point. Obviously the objects nearest to any given point contribute greatest to the field at that point. Also it is possible for field contributions to cancel, resulting in points with zero magnitude, called "nodes".

A short caveat on two closely related, but not identical definitions for field. In a general sense, a "field" is any quantity that takes a continuum of values for all points in a space. It would be meaningless to take a gradient of something that's not a continuum, though physicists do it all the time without batting an eye. Anyway, the value assigned to each point may be scalar, vector, tensor, or higher-order. For example, the altitude on a topological map constitutes a "scalar field" in the 2D space of the map, since each location is assigned a single value. We could take the gradient at every point to establish a slope "vector field" in the same space. In 3D we could assign a temperature to every point in space to create a scalar field, or again a gradient at every point for a vector field, and so on. So while the definition for "field" is broad, it is also acceptable to define it more narrowly as the vector fields of electrodynamics and gravitation, as I've been doing.

Armed with this understanding of fields, we can now define energy in a more precise way than simply as "relationship" or "interaction". Actually this definition has been around for well over 100 years, and is credited to John Poynting. In 1883, Poynting derived a relationship from Maxwell's Equations equating the time change in energy density with the divergence of a radiation vector now called the "Poynting vector" in power per area. In his derivation, he found that energy density could be described as the dot product of two electric or magnetic fields. Now a dot product or inner product of vectors produces a scalar or number, whose magnitude and sign depend on the relative directions of the vectors. Thus, Poynting's energy density is a "scalar field" produced by an interaction between two vector fields. Then energy is the integral or sum of the contributions of this energy density field over all space.

But which two vector fields? Here's where I submit science has dropped the ball for over 100 years. In every application I've found, the interaction is expressed between the fields of an object with themselves. In other words, the energy density function results from the square of the field. This measures what I define as the "self energy" of the object, but says nothing about the relationship the object has with its environment. That is, every object has two kinds of energy: internal or self energy by virtue of interactions between the component parts of the object, and external or interaction energy by virtue of its interactions with other objects. As we'll soon see, the "self energy" is closely related to the "mass" of the object, whereas the "interaction energy" measures, for example, the potential or kinetic energy of our ball rolling down a hill. In practice, Poynting's concept of energy has been limited to the former, and seriously needs extending to the latter.

An object's total energy obviously includes its own self energy, but for many applications, this remains essentially constant. Of greater interest is its interaction energy, determined with respect to environment. This interaction energy may be kinetic or potential, as with the ball example above, depending on whether the object is free to move or constrained. However, the important point to remember is that an entirely different energy density function applies for every conceivable measure of energy. So the difficulty is in being very precise about which energy, and therefore which energy function you mean. Each object has its own self energy density function and total energy density function, one accounting for its interaction with body A and another with body B, one for potential, another for kinetic, etc. That's a lot of accounting.

Mathematically a Poynting electrodynamic definition of energy in terms of the interaction between the self fields $\vec{\mathbf{D}}$ and $\tilde{\mathbf{H}}$ of an object, and the fields $\vec{\mathbf{E}}$ and $\tilde{\mathbf{B}}$ of the environment reads $E \equiv \vec{\mathbf{D}} \cdot \vec{\mathbf{E}} + \tilde{\mathbf{H}} \cdot \tilde{\mathbf{B}}$. Only in the case of self energy are the object fields proportional to the environment fields $\vec{\mathbf{D}} = \varepsilon_0 \vec{\mathbf{E}}$ and $\tilde{\mathbf{B}} = \mu_0 \tilde{\mathbf{H}}$, and only in this case does the well-known factor $1/2$ arise.

At the risk of a knee jerk reaction, knowing full well the emotional attachment many people have to the term, I now propose my definition for "aether". It's embarrassingly simple, but consistent with the way it's been used since

Robert Boyle coined the term from the Greek αιθήρ, meaning to kindle, burn, or shine. The "aether" is nothing more nor less than the energy density function. Since there are multiple energy density functions, there can be multiple aethers, useful in multiple contexts, though THE aether refers to the energy density function created by the interaction of the fields of all matter in the universe with themselves. Then the aether through which a particular object passes is determined by the interaction between the object's fields and those of everything else in the universe. The stresses and strains in this aether help explain exactly why the object behaves as it does, the fundamental purpose of physics.

In many ways, the energy density function is also eerily similar to Richard Feynmann's probability amplitude function. The latter is supposed to tell us the probability that a particle resides in a particular region of space, but such a concept presupposes that particles are either entirely or not at all within the specified region. That is, the probability amplitude function presumes point particles, that either *are* or are *not* within any given region. In truth, finite particles can be partly within or partly outside, but they can exert their influence everywhere. One could equivalently conceive of Feynmann's function as a measure of the particle's influence in the region, effectively stating what percentage of the particle's total influence or energy density occurs therein. In this view, whether the particle is physically present in the region is of secondary importance.

Since this is not a rigorous mathematical treatment, I won't go into detail about how such a function explains the motion of an object, but we can understand the idea in principle. Just like our topological map, this function will have peaks and troughs, and thus gradients or slopes. In general the regions of greatest intensity and slope will be in the neighborhood of the object, where its own fields are strongest. If we add up all the contributions to slope, we can say whether the map as a whole "tilts" or not. In the case of energy density or aether, the slope represents force density and the sum of these contributions represents force. The overall "tilt" or slope of the energy density function depicts the force on the object. That is, the force acting on the object equals the integral sum of all the force densities defined by its interaction with environment. This is the proper definition of force. Mathematically, if P is the energy density or pressure function, or "aether" and $d\tau$ represents a volume element, the force $\tilde{\mathbf{F}}$ acting on the object is defined as $\tilde{\mathbf{F}} \equiv -\int \vec{\nabla} P \, d\tau$. Where the negative sign arises from the convention that the force acting on the object is opposite to the force the object exerts on the rest of the universe.

Sadly force is rarely defined in this way, but usually in terms of mass and acceleration via Newton's famous formula, $\tilde{\mathbf{F}} = m\vec{\mathbf{a}}$, $\tilde{\mathbf{F}} = q\vec{\mathbf{E}}$ or as the gradient of energy $\tilde{\mathbf{F}} = -\vec{\nabla} \int P \, d\tau = -\vec{\nabla} E$. Of course, Newton's formula is a marvel, and deserves its place in the formula Hall of Fame, but that does not make it fundamental. In fact, both mass and acceleration need some serious reconsidering, as we'll see shortly. But the point here is that force is inherently aggregate, an "extensive" integral sum rather than an "intensive" property associated with a single point. To obtain the finite force acting on a finite body, we must ultimately add all the contributions between every infinitesimal component of the body and every other body in the universe, not to mention all the interactions between the components within the body. Actually the problem is overwhelming, but amazingly we can reduce it to something manageable by imposing only a few simplifying assumptions. Assume that the body is "rigid", that its various parts do not move appreciably with respect to each other, then among other things its mass m remains essentially constant. Next assume that acceleration or gravitational field $\vec{\mathbf{a}}$ (again a field is not a "lumped" quantity) is more or less constant over the region in which the object's fields are significant, and treat it as constant as well. Under these assumptions $\tilde{\mathbf{F}} = m\vec{\mathbf{a}}$ works great, and definitely should be used. Similar assumptions for finite, "rigid" charge q in "constant" $\vec{\mathbf{E}}$ apply for $\tilde{\mathbf{F}} = q\vec{\mathbf{E}}$.

But these assumptions do not always hold, so these formulas are not always applicable. Worse yet, m and $\vec{\mathbf{a}}$ aren't necessarily even defined without a clearly defined body, as in the case of fluids. However, this isn't cause for despair. In virtually every case, we can make different, less restrictive assumptions about the internal characteristics of the body and about the external field in which the body resides. For example, the body might rotate as it translates, but otherwise remain rigid, it might expand and contract about its center of mass based on characteristics of its material, or the field might vary over the body in a manner that can be described mathematically. In truth, the art of doing physics is precisely the art of determining what approximations to make in order to solve each given problem. The point here is that our starting point must be with the infinitesimal, with the field. We then simplify by making appropriate assumptions. Thus, for example, while it may be acceptable to treat force as the gradient of the total energy, it's technically nonsense to do so. By definition a gradient expresses spatial changes "slopes" in a field, so it makes no sense to take the gradient of a function that has already been integrated. However, as a mathematical point, it often works just fine to do so, just as it's fine to use $\tilde{\mathbf{F}} = m\vec{\mathbf{a}}$.

MASS, SELF-ENERGY AND ZERO POINT ENERGY

I mentioned earlier that the best stuff was yet to come. In my opinion, the ideas in this and the next couple sections constitute the "best stuff", so I'm glad you're still with me.

Since Newton created the concept of mass, scientists have struggled with two seemingly different concepts of what mass actually measures: 1) amount of substance or "stuff" and 2) resistance to motion, or "inertia". You'll find both definitions in the dictionary, but the first is a "thing" and the second a "property". Mass as a "thing" is often called "gravitational mass", and shows up in Newton's famous equation $\tilde{\mathbf{F}} = G\frac{m_1 m_2}{r^2}\hat{\mathbf{r}}$. That is, the two "things" m_1 and m_2, whose centers are separated by distance *r*, exert a force on each other proportional to their product and inversely proportional to the r^2. But $\tilde{\mathbf{F}} = m\vec{\mathbf{a}}$ is associated with "inertial mass", the property of resistance to motion. But can mass be both a thing and a property? I leave it to you, but it makes no sense to me. Now which is it?

Since I spend a fair amount of time considering this very question in my paper, "The Meaning of Maxwell's Equations," I won't belabor it here. In that paper, I show that the interaction between two chunks of matter with diverging fields naturally *repel* rather than *attract*. Therefore, whatever mass is, it isn't a fundamental measure of matter, since mass *attracts*. In the next section, we'll delve into what holds matter together and why we even have particles, but for now it's important to emphasize that the ability to attract is not inherent in matter itself, but in its motion. Objects hold together due to a perfect balance of natural *repulsion* between like elements and *attraction* due to their relative motions. This concept is the key to unlocking many mysteries in physics. The sooner we dispense with the idea that mass is stuff that fundamentally attracts, the sooner we can get on with real understanding of how our universe works. It's a BIG deal!

All right, so if mass is simply the property of inertia or "resistance to motion", why does it behave as if it were an "amount of stuff"? To answer, imagine any object, say, an atom. The matter comprising the object is NOT static, but circulates so that the "magnetic" attraction due to motion balances the natural repulsion between the matter elements, holding the object together. In fact, all the elements within the object interact with each other, and their relative motions are what "bind" them together. Now here's a surprising conclusion: if two objects contain the same amount of matter (don't ignore this part), the one with a greater the degree of interaction between its elements will be denser and *smaller*, like a compressed spring. Thus, for example, a proton has the same amount of matter as an electron, but is much smaller, because the interactions between its parts are that much greater. So an object with a greater amount of interaction inside will be that much less affected by interactions from outside. Put another way, if the fields within the object are more intense, the addition of an external field will be less consequential. It will have greater "resistance to motion" or "mass".

Thus, mass is a property that depends on the dynamic geometry of an object's structure. Change the equilibrium of the structure, and its mass changes, even though its amount of substance remains constant. This understanding of mass agrees nicely with observed variations in mass in many nuclear reactions. For example, when a neutron decays into a proton and electron, no matter is created or destroyed, but its dynamic structure changes, and the combined "resistance to motion" of the released proton and electron is slightly less than the resistance to motion of the original neutron. Physicists often say that part of the neutron's *mass* was converted into *energy*, but this whole notion presupposes that mass and energy are "things", when in fact both are "properties".

Another great barrier to understanding is what I call the billiard ball concept of matter. Most physicists regard fundamental particles as indivisible, rigid chunks of matter rather than dynamic equilibrium structures. Thus, it remains a great mystery to them how one rigid object, the neutron, becomes two different rigid objects, the proton and electron. Also they invent mysterious "particles" like neutrinos to account for the lost energy in a reaction. It's certainly true that energy is conserved, but with a relational understanding of energy, it's not necessary to invent particles to account for these apparent losses. Instead, structure actually changes, so energy of structure (within the object) transforms into energy of environment (outside the object). That energy can be expressed as translation, as when an electron shoots off, or as rotation, as when a "gamma ray" or "neutrino" escapes. (We'll say more about rotation in the section on light.)

As a bonus, this concept of mass also demystifies the famous equation $E = mc^2$. It essentially quantifies what I've been saying, that an object's "resistance to motion" *m* is proportional to the amount of interaction energy *E* between the elements of the object. Since both *E* and *m* are properties of the object, we should expect proportionality constant c^2 to be a property of matter, NOT of space itself. In fact, by reinterpreting *c* in terms of matter rather than as a property of space, we begin to see how Einstein's postulate, that *c* remain constant in all frames, can hold without the need for redefining space and time. (More on this soon.)

Next we can understand "relativistic mass increase" naturally and simply, as the case in which environmental or external stresses are of an order of magnitude comparable with internal stresses within the object. That is, an object genuinely in translation with respect to environment, not merely kinematically with respect to some observer, actually experiences stress from that environment. Remember that its total energy is the integral sum of the interactions between the object field and the total field, including the object. Its "self energy" represents the interaction of the object field with itself, as it were. We determine whether and how much the object moves by how much its total energy exceeds its self energy, and call this difference "kinetic energy", provided the object is actually free to move. The ratio of the total to self energy is often called the gamma γ factor, as in $E = \gamma m_0 c^2$, where $m_0 c^2$ is the "rest energy".

However, there is an important distinction between "rest energy", as commonly used, and "self energy". An object is considered "at rest" with respect to translation only, with no thought to rotation. But actually a proton's or electron's stable rotation in the context of a structure may be quite different from the same particle's stable rotation left in isolation. We therefore need another factor to account for the ratio between the energy of an object, say an atom, and the sum of the energies of its constituent parts. Call this ratio delta, δ, corresponding to the relative rotations of its parts. Then, letting m_I represent the "inertial mass" of particles taken separately, the rest energy is $E_0 = m_0 c^2 = \delta m_I c^2$ and the total energy $E = \gamma \delta m_I c^2$.

At the risk of further derailment from the main argument, it's significant to mention here that rotational factor δ differs from translational factor γ in a simple, but very profound way. Since a body can never translate less than "not at all", $\gamma \geq 1$ and hence $E \geq E_0$ no matter what. But we'll soon see that fundamental particles must rotate just to exist. It is therefore possible that they rotate LESS than they would rotate if in isolation. Thus, δ could actually be less than unity, and in fact this is precisely the condition for a particle to remain bound within its structure. Given a small enough γ, i.e. at low enough temperatures where particles translate very little, the product $\gamma\delta$ could also slip under unity. In this case, the total energy *E* of the object would be LESS than the individual energies of the component parts. *The whole would be LESS than the sum of the parts.* I submit that this is the condition for superconductivity. In my soon-to-be-finished paper, "Theory of Entropy", I explore this connection in greater detail, and show that superconductivity in fact expresses the natural flow of stable structures.

Well, who'd have thought that a definition of mass would lead to a theory of superconductivity, but that's where we are. Mass defined strictly as "resistance to motion" must be proportional to "internal energy", which has both translational and rotational components. Further, mass is defined in terms of energy, not the reverse, while energy is defined in terms of relationship. When we consider the rotation of particles as well as translation, we understand how structures can actually possess less energy or mass than the sum of their components taken separately. This unusual condition occurs when translation energies, measured via temperature, are low enough to be offset by "binding energies" due to *decreased* rotations. I said earlier that this section contained some of the best stuff in this paper. Well, this is it. Of course, it's also the most controversial, and some of the concepts behind this conclusion will be explained in the next section. So I beg you to hang on to your objections a bit, and remain open to some new paradigms.

Now superconductivity is closely related to Zero Point Energy (ZPE), a term originally coined by Max Planck, defined as the energy remaining when temperature reaches zero. In recent years an almost mystical aura has surrounded ZPE, and the question of whether it can be tapped as usable energy. Actually it can be understood clearly and neatly in terms of self energy versus total energy. Take away the particle's environment, and all that remains is the particle's self energy, internal energy or energy of structure. In the next section, we'll consider temperature as a measure of interaction energy or environment energy. Thus, in zero temperature, only the energy sustaining a particle remains. This means that to "tap" ZPE, we must capture the energy released when the structure actually changes state, and becomes something else.

Of course, many nuclear reactions release structural energy, but thus far, hot fusion experiments have not produced more extractable energy than used to produce the reactions. Therefore, to extract usable amounts of ZPE, we must find something in nature that can be altered from a higher to a lower energy state in a controlled reaction. Better yet, we need to figure out a way to enlist nature's help to resonate molecules into higher energy states. Though this is not a paper on ZPE, I submit that nature will indeed help if we work with materials having a dipole-free state higher in energy than the corresponding dipole state. This is the case for water, which prefers an electric dipole state, and ferromagnets, which prefer a magnetic dipole. This is the basic reason these two materials are consistently considered for ZPE research.

ENTROPY AND TEMPERATURE

Believe it or not, we're now equipped to tackle a definition for entropy. This enigmatic property has been defined in numerous ways by numerous people, yet remains mysterious. An acceptable definition must answer for all the properties here listed:

1) Additive: twice as much of the same stuff in the same thermodynamic state has twice the entropy.
2) Defined by Boltzmann as $k_B \cdot \log W$, where *W* is the possible number of ways the particles in a system can be arranged to achieve a certain configuration.
3) Consistent with Claude Shannon's informational definition of entropy $-\sum p_n \cdot \log p_n$, where p_n represents the probability of the *nth* state.
4) Defined macroscopically as "heat" energy per temperature (*Q*/*T*).
5) Reaches a maximum for a given total energy or temperature when the velocities of all particles in a collection have a Gaussian distribution, and no net direction (Maxwell).
6) Reaches a maximum at equilibrium, defined as the most probable way of sharing a fixed amount of energy among a fixed number of structures.
7) Gives meaning to Ideal Gas Law Constant $R = k_B N_A$, where N_A is Avogadro's Number.
8) Defined as amount of change toward a more disordered state.
9) Defined as "degrees of freedom".
10) Quantifies the effects of friction and dissipation.
11) Accounts for the irreversibility of real processes.
12) Increases in real processes involving friction, surface tension, chemical reactions, etc.
13) Associated with the increase of "heat", or non-usable energy.
14) Measures the unavailability of a system's energy to do work ($G = H - ST$).
15) Explains the maximum efficiency (Carnot $\eta = 1 - T_C/T_H$) of a system.
16) Measures the dispersion or spreading of energy (Poynting's theorem).
17) Increases with time (the "arrow of time").
18) Approaches zero as temperature approaches zero (3^{rd} Law).
19) Increases with the mixing of different substances (Gibbs paradox).
20) Increases in spite of Poincare's Recurrence Theorem.
21) Follows Trouten's Rule for constant entropy of vaporization ($\Delta S_{vap} \approx 10.5R$).
22) Increases when more "radiation" is emitted than absorbed.
23) Associated with the loss of "mass" or "self" energy in the Universe.

24) Due to the finite size of particles.
25) Conserved in **some** form due to the existence of "constant" k_B.
26) Expressible as an equality, from which the Second Law "inequality" is derived.

You get the idea. To delve into these properties in greater detail, please see my paper, "Theory of Entropy", since I won't discuss them all here. We now seek a "covering definition" from which all of these other definitions and attributes can be derived. Does such a definition exist? Is there a covering concept that gets to the root of all the above, and tells us what entropy *IS*? *YES!*

In the simplest terms, entropy compares the whole to the sum of the parts. For a more precise definition, remember that ultimately all objects are composed of particles. Each particle has a total energy, determined in the context of environment, and a self energy, taken as if the particle were isolated. In general the two energies are not identical, but differ by the factor $\gamma\delta$ mentioned in the previous section. These factors represent a sort of entropy, expressing how much each particle is entangled with its environment. Physical entropy is simply scaled by Boltzmann's constant k_B, so that a mathematical definition is $S = k_B \sum \gamma_n \delta_n$ or $S' = k_B \sum (\gamma_n \delta_n - 1)$, summed over all particles in a system.

It's far from obvious at first glance that this simple definition actually satisfies all the above criteria, and admittedly this is the most radical proposal in this paper. (Relax, this is as radical as it will get.) Clearly it is additive, since more particles obviously imply greater entropy. But the logarithmic properties found in Boltzmann's and Shannon's definitions require some development. We must remember that the number of possible states W does not equal the number of particles N, and that particles are essentially interchangeable. I delve into these details in my "Theory of Entropy" papers, so will dispense with them for now.

Again this concept of entropy arises from distinguishing "self energy" E_S, within objects, from "external energy" or "interaction energy" E_E, between objects. Certainly their sum represents total energy $E_T = E_S + E_E$. And because energy arises from interactions between fields, it is inherently quadratic.

A simplified analogy illustrates why this is important. Let the "total field" at some point be $A + B$, composed of contributions from elements A and B. In a loose sense, ignoring physical units, then, the "total energy" at this point is $(A+B)^2$. But the "self energy" of A and B separately is $A^2 + B^2$. Therefore, the "interaction energy" is the difference between the two, namely $2AB$. This term is not attributable to A or B separately, but to their interaction. Such a measure of "entanglement" is an inevitable consequence of quadratic interactions, and thus inescapable. Now the entropy in this scenario is either $(A+B)^2 \big/ (A^2 + B^2)$ or $2AB \big/ (A^2 + B^2)$, depending on whether or not you want to include self energy in the equation. Since they differ by the constant "1", both expressions provide the same information. The first relates the whole to the sum of the parts, while the second relates the amount of entanglement $2AB$ to the sources $A^2 + B^2$.

Several crucial points result from this definition of entropy.

1) Finite objects (particles) must exist for "self energy" and hence entropy to be meaningful at all.
2) The measure of entropy will differ depending on the level at which "objects" are defined, i.e. as particles, molecules, planets, or solar systems.
3) Entropy is a consequence of the quadratic nature of interactions.
4) Increases in entropy are equivalent to reductions in "self energy", corresponding to "radiation" or irreversible changes of state.
5) The question, "Why does entropy exist?" is reduced to the question, "Why do particles exist?".

The quadratic nature of entropy demands that entropy exists if particles do. (We'll tackle the existence of particles in the next section).

Remember that energy was defined as an accounting tool. As with all such tools, we must obtain the same result regardless of how we account for it. This is the sacred "conservation of energy" principle. It means we must get the same total whether we count all the energy in space (the aether) or all the energy of objects. After all, it's the SAME energy. But because energy is quadratic, there will cross terms, and we can't simply add the energies of each object as if it were in isolation (billiard ball accounting) and obtain all of it. We must factor in the energy of environment for each object to get the two totals to agree. And therein enters entropy, which again measures the ratio of each object's total energy to its isolation energy E_{Self}. Close behind is temperature, which we'll examine next.

Moreover, this is a two-way street. While we often imagine energy as attributable to objects, we rarely if ever regard temperature, a form of energy, in this way. Instead, we usually conceive of "temperature" as a field quantity, with each location in space having its own unique value assigned to it. In fact, you may recall that I used precisely this case as an example to illustrate the concept of field. But are we justified in supposing that temperature is some sort of property of space? Shouldn't this, like all other properties, ultimately tell us something about the matter surrounding the space? In a way, the problem is opposite to the problem of mass, which we attribute to objects, but never to fields. Temperature we attribute to fields, but never to matter. But since both represent forms of energy, shouldn't both be attributable to both matter and fields, provided we don't double count? That is exactly my thesis.

Clearly temperature is an average of some kind. It measures the average interaction energy per particle, and tells us how much an average particle is entangled with its environment. So the field quantity should be defined in terms of energy density per particle density. This makes good sense at the macroscopic level, but what is the meaning of particle density at the level of particles? Either a region of space is occupied by a particle or it's not. Thus, particle density is often zero, rendering temperature meaningless. Only by "smearing" the field over a region of particles is the field concept of temperature meaningful. The bottom line is that we seriously need to reconsider the whole concept of temperature when dealing with individual particles.

Let's examine the possible meaning of the "temperature" of an individual particle or collection of particles. Can we in some sense say that the "temperature" of particle X is T? We can if we begin with the concept of energy, as we did with mass. Just as "mass" is proportional to energy, considered as "resistance to motion", so "temperature" is proportional to energy, considered as "entanglement". That is, the temperature of a single particle equals the amount of energy the particle has over and above its "isolation energy" or "self energy", divided by Boltzmann's proportionality constant k_B. The temperature of a collection of N particles is simply the average of the individual "temperatures". The following definitions refer to a collection of N particles.

Entropy:	$S \equiv k_B \sum_n \dfrac{E_{\text{Total-}n} - E_{\text{Self-}n}}{E_{\text{Self-}n}}$	Enthalpy:	$H \equiv E_{\text{Total}} - E_{\text{Rest}}$
		Heat:	$Q \equiv ST$
Temperature:	$T \equiv \dfrac{E_{\text{Total}} - E_{\text{Self}}}{k_B N}$	Gibb's Free Energy:	$G \equiv H - Q$

Note the distinction between self energy E_{Self} and rest energy E_{Rest}, differing by the δ factor. E_{Self} is the energy of each particle if it were in complete isolation, whereas E_{Rest} includes the particle's rotation energy, which could be more or less than what it would have in isolation. The difference constitutes the "binding energy" $E_{\text{Bind}} \equiv E_{\text{Rest}} - E_{\text{Self}}$. Thus, enthalpy H measures translational (billiard ball) energy only. Since rotations change significantly during structural or phase changes, and chemical or nuclear reactions, the difference between temperature and enthalpy, for example, can be substantial.

During "forward" phase changes like melting, boiling or ionization, energy increases result from changes in structure, E_{Self}, while E_{Rest} remains essentially constant. Thus, temperature doesn't rise, but enthalpy and entropy do. Actually it's a bit more complex than that, since a glance at the entropy definition might suggest that entropy actually decreases. However, as I explain in greater detail in "Theory of Entropy", during forward phase changes, shell electrons increase in entropy more than nucleons decrease. Likewise nucleons increase in energy more than shell electrons decrease. Thus total energy and entropy increase without increases in either total rest energy E_{Rest} or temperature T.

For many applications, however, we don't think in terms of particles, but in atoms, molecules, lattices, or other structures. The H_2 molecule, for example, consists of two protons and two electrons, for a total of four particles. And according to Bergman's (Bergman and Wesley, 1990) and other models, the neutron can be treated as two particles: a proton and electron in a modified equilibrium state. In this way, we can count the number of "particles" in virtually every isotope. Though we treat these structures as "billiard balls", in fact, the particles within them expand, contract, and generally slosh around. So when we refer to the velocity of an atom, we really mean the velocity of its "center of mass" (actually "center of energy"). Thus, the total translational kinetic energy or "enthalpy" H in a system consists of two parts: energy of the structures as a whole, or "work" W, plus the energy of particles relative to structures, or "internal energy" U. That is $H = W + U$.

All of these can be defined in greater mathematical detail, but the correspondence with well known thermodynamic properties remains. In fact, thermodynamic "pressure" P is simply the average work energy W over a given volume V, i.e. $W = PV$. Since they have identical units, the only difference between "pressure" and "energy density" is the convention that pressure represents an average.

An important special case is the Perfect Gas Law, which applies when two approximations hold.

1) Structures are nearly "rigid" (billiard balls). $U \ll W$
2) Binding energy E_{Bind} is small compared to E_{Self}.

The first tells us $H \approx W = PV$, and the second $H \approx Mk_B T$, where M is the number of structures in the system. Equating these two derives the Perfect Gas Law. Next, the law of "partial pressures" simply means we can add the energy of different structures within a system independently, each as if the other structures types were absent. This obviously holds when we can treat structures as if they were billiard balls, so that the energy of the whole equals the sum of the individual energies, as originally conceived by Maxwell and Boltzmann.

CIRCUITS, ROTATION AND PARTICLES

Several times in this paper I've mentioned rotation, suggesting connections between rotation, temperature and entropy. Like expansion / contraction, rotation inherently involves finite groups, since it is no more reasonable to consider the rotation of an infinitesimal amount of matter than to consider its expansion or contraction. No, the elements of an object rotate or expand with respect to other elements in the object, and thus require finite objects for any sort of meaning. Likewise, I've shown that the properties of entropy and temperature require the existence of particles to have meaningl. So why do we have particles, and what is their connection to the concept of rotation?

I noted earlier that matter fundamentally repels "like" matter, and that attraction is ultimately due to motion. The principle of binding via motion can be understood in terms of Ampere's Law, Bernoulli's Principle, and a host of related phenomena. To get the basic idea, imagine water flowing through a pipe or river. If the velocity increases (decreases), the channel constricts (expands), because the same amount of matter must pass through adjacent cross sections. If this were not so, matter would not be conserved, as expressed mathematically in the continuity equation. In fact, conservation of matter is the primary cause of these effects, not an incidental consequence. It demands that temporal changes in flow necessarily accompany spatial changes in the flow structure, either binding or separating elements of matter in the flow. Unquestionably this principle is profound, and for all its 300-year history, has not been fully appreciated. Attraction or suction of any and every kind is ultimately due to this principle. Indeed it is the fundamental reason why matter attracts and has "mass" at all.

But if finite structures of matter exist, then their internal motions must be confined to finite regions in space as well. Continuums of matter can't flow "off to infinity". They simply must circulate. That is, finite structures of matter must be ultimately composed of circuits. To repeat, their components must move relative to each other in order to create balanced structures, and the confinement of their motions in a finite space necessitates circulation. Particles exist because matter must circulate to have any sort of finite structure. The concept of the circuit is primary and fundamental to understanding the characteristics of particles. And the concept of rotation is inextricably linked with the concept of the circuit.

I submit that the principle of the closed-loop circuit relating to fundamental physics lies at the core of the next revolution in physics, and certainly at the core of the ideas discussed in this paper. Fortunately there even exists a historic parallel in the work of English court physician William Harvey (1578-1657). He was first to recognize not only the proper role of the heart as a pump, but of the very concept of a circulatory system. Through his ideas, physicians began contemplating the circulatory and other bodily systems as dynamic, rather than static. And the change from static to dynamic, from fixed functions to recycling processes was profound in the greatest sense of the word. Today the change from the static billiard ball concept of matter to a dynamic circulation system concept can be equally profound, and will certainly lead to a deeper understanding of the very fundamentals of the structure of matter.

In my paper, "Reference Frame Independent Dynamics", I argue that nothing is or even can be truly "static" in the sense of "not moving". The concept itself is flawed. Instead real objects experience "rest", or an absence of net force or torque, by appropriate orbit or circulation. The moon orbits the earth, the earth orbits the sun, the sun orbits the galaxy, etc. On the micro-scale, flows of matter circulate to create equilibria or states of "rest". Though we imagine a particle as a "static" chunk of matter, in truth it is "quasi-static" in the sense of circulating in such a way as to experience no net force or torque.

In 1842 British mathematician Earnshaw (1842) showed that no collection of static point charges (or point masses for that matter) could ever be arranged in a stable equilibrium configuration. (Earnshaw, 1842) And he was right. They can't. Sadly this fact is at the root of modern physics' rejection of classical mechanics relating to the structure of particles. This is the fundamental reason for Feynmann's oft-repeated mantra that there is no way to explain the behavior of elementary particles classically. And as long as we accept the concept of point charges or point masses, Earnshaw and Feynmann have an airtight case.

Hopefully, by now you expect me to chime in, thump my fist and shout, "Point charges are a fiction". Well… they *are*. Real particles are dynamic structures, held together by their own circulatory motions. Moreover dynamic structures *can* achieve stability, while idealized static particles *can't*.

It would be appropriate now to define precisely what stability means in terms of the fields defined several pages back. We must release the naïve notion of "static" fields every bit as much as static matter. In fact, physical particles are dynamic systems, not point particles, with the relative motions of their components demand dynamic fields, ever changing in time. In order for these fields to remain stable, they must change without changing in magnitude. How can this happen? They can change direction, but not magnitude. Indeed this is precisely the condition for stable structures, which have dynamic fields that change in direction, rather than magnitude at all locations in space. This condition is mathematically equivalent to the "orthogonality" condition, in which changes in a field are perpendicular to the given field.

$$\frac{d|\mathbf{A}|}{dt} = 0 \quad => \quad \frac{dA^2}{dt} = 0 \quad => \quad \mathbf{A} \cdot \frac{d\mathbf{A}}{dt} = 0$$

What sort of structures have flows whose fields satisfy this stringent orthogonality condition at all locations in space? A related question was asked and answered by Hicks and Hill in the late 1800s, when they determined the only two stable flow structures to be toroidal and spherical. (Hicks, 1881; 1884; 1885; 1899; Hill, 1884; 1894; Bergman and Wesley, 1990) Both flows exhibit helicity or handedness, a three-dimensional concept relating movement around a circuit with movement around a cross section. In the case of toroidal (doughnut-like) motion, right- or left-handed helicity results from the relationship between the simultaneous motions around the toroid and the torus cross section.

The case of spherical rotation is best described by imagining a plane travelling from the equator across the North Pole, back around to the other side of the world, thence on to the South Pole, and finally back to the point of beginning, all in exactly 24 hours (or 23 hours and 56 minutes sidereally). Viewed from outside the earth, the plane appears to return to its start position after only *12* hours, because the earth itself has rotated half way around. Thus, rather than a circle, the created path becomes a figure eight with a handedness depending on the relative rotations of the plane and the earth. Spherical rotation involves zillions of "planes", all flying along "circular" paths that pass through the poles. Interestingly, every element of matter in a continuum passes through both poles, yet the amount of matter passing into and out of each pole remains constant. Also we see that the 2 to 1 ratio of spherical rotation is a fundamental consequence of the interaction of orthogonal rotations. This 3D concept lies at the heart of the necessary 4π cycles of complex rotations.

THE NATURE OF LIGHT

Thus far, we've discussed the need for fundamental changes in our definitions of many common properties in physics, and of the primary importance of the circuit concept, even to the very existence of particles. However, there remain still more basic notions beyond the measurable physical properties that need closer examination.

To illustrate, consider the conception of "heat" as a "thing" called "caloric" commonly held in the 18^{th} century. Yes, people actually believed that when heat transferred from a hot body to a cold, this caloric "thing" literally moved from body A to body B. Today we smile at such a thought, smugly confident that heat is simply a measure of relative translations between the particles comprising the bodies. That is, heat is a form of energy or relationship that measures aggregate relative translation. Nothing could be more obvious.

But could we be guilty of a similar misconception with regard to light? I submit so. Future generations will smile just as indulgently upon our twentieth century conception of light as a "thing" that travels from A to B at special speed *c*. But if indeed particles exist because of the relative rotations of their component parts, then all particles must possess some fundamental frequency. This is evident in all known particles, which have characteristic spins, magnetic moments, or other rotation related quantities. After all, how could one have rotation without frequency? Or frequency without rotation? Then could "light" be nothing more than a measure of relative rotations between particles? Such a conception fits neatly and in good contrast with the conception of heat as relative translation. In fact, shouldn't we expect some form of energy to measure relative rotation in a manner analogous to heat's measure of translation? Is this what light really is?

Now if our concept of light as a thing that travels from A to B at speed *c* is actually misguided, then we have some serious rethinking in store. Indeed a major portion of twentieth century physics, including Einsteinian relativity and quantum mechanics is solidly based on this very concept. What could be more foundational than Einstein's second postulate, which states that "the speed of light is the same in all inertial reference frames"? Is it possible that the constant *c* is the same in all frames, yet is *not* the "speed of light"? Absolutely. The constant *c* could just as likely be the "speed of matter", representing the necessarily finite speed that elements of matter circulate in order to bind particles together. As argued earlier, without some finite motion, particles would simply cease to exist, exploding with no motion and imploding with infinite motion. In this case, *c* is a property of particles, just like all other constants *h*, *e*, *m*, *k*, etc., and not a property of space at all. Interestingly this is the sort of conception Poincare had, just prior to Einstein's 1905 papers, though such ideas were lost in the shuffle of early twentieth century physics.

But this is not a change to make lightly. The concept of light as a thing dates back at least as far as Fermat's empirical rule that light always travels the path of least time. Truly light does follow such a path, and in many instances does behave *as if* it were a thing that travels from source to receiver. Experimental results from Römer, Newton, and Bradley to Fitzeau, Michelson, Sagnac and Ives all support the idea that *something* travels between source and receiver at a speed near *c*. But in truth, none of these experiments prove or disprove the idea that light is a thing. All of these experiments can be explained equally well, possibly better, with a notion of light as a measure of relative rotations between particles.

So if both explanations work equally well, why switch? This returns us to the theme of this paper, that advances in the knowledge of physics and the resolution of many seeming contradictions and paradoxes will occur only through radically different conceptions of certain fundamental notions. Light may be one of those notions, if not *the* primary one. The difficulties a new conception of light can hope to resolve include, but are not limited to:

1) a rational understanding of space and time, and their necessary independence;

2) an interpretation of the constant c in terms of particles rather than of space itself;
3) physical models of elementary particles based on the fundamental circuit nature of motion;
4) a resolution of "action-at-a-distance" measurements connected with Bell's Inequality;
5) a fundamental understanding of gravity; and
6) a unification of the various branches of physics, including electrodynamics, optics, relativity theory, and thermodynamics.

With such a large potential benefit, surely it couldn't harm to admit that perhaps we don't really know what light is. Rather than continue to seek solutions under existing paradigms, just maybe some exploration of a new conception could provide the breakthroughs currently sought in physics.

If we acknowledge light as a form of energy, and energy as a measure of the relationship between elements of matter, then we should not expect light to be a thing in itself, but a measure of the relationship between things. Moreover, if light is always connected with frequency, and frequency ultimately connected with the rotation of physical objects, we should expect light in some sense to measure relative rotations of those objects, just as heat measures relative translations. We should also expect the net rotation from any given direction to in some sense equal the total rotational contributions from all objects in the universe. When we "see" an object from a certain direction, it's because all the rotational contributions from objects behind and beside it cancel exactly. They still contribute, they're still there, but they contribute no net rotation. Only when the contributions don't cancel exactly do we observe reflection, refraction, "Doppler shifts", and a host of optical phenomena. Finally, we should expect relative rotations to produce discontinuities or nodes, as particles literally lap each other as they spin with differing frequencies. In this way, light can be simultaneously wave like and particulate without appeal to metaphysics. And we find the seat of the wave in the rotating particle, not in space itself.

CONCLUSIONS

At the outset, this paper challenged the commonly accepted definitions and understandings of many basic notions in physics. By clearly delineating *things* versus *properties*, it showed that a relational understanding of energy creates a fundamentally new way of approaching physics, neither classical nor modern, Newtonian nor Einsteinian, absolute space-based nor observer-based. Physics built on matter-matter relationships necessarily employs "fields" to quantify those relationships and define not only energy, but other basic properties as well. Just as energy is defined in terms of the energy density field, so force is defined as the integral of the gradient of this field, and not as the gradient of an integral. By defining mass strictly as "resistance to motion", rather than as "amount of substance", the paper discovered interpretations of the famous equation $E = mc^2$ in terms of rotation as well as translation. Next, the quadratic nature of interaction inevitably involves cross terms, corresponding to the energy between objects, as opposed to self energy *within* objects. Both entropy and temperature are then defined in terms of the relations between self- and interaction energies. Closely connected is the concept of rotation, a group phenomenon shown to be foundational to the physical structure of particles. Finally, the paper drew an analogy between the 18th century caloric theory of heat and the current conception of light. In the same way we recognize heat as a measure of relative translations of particles, this paper suggests that light measures relative rotations. In summary, rather than accept conventional conceptions of many basic notions, perhaps it's time for science to explore new interpretations of old ideas.

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