House of cards built one meter at a time

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Abstract: A physical law assumption is based upon a knowledge set extracted using observation and measurement techniques available at the time the assumption was made. An assumption can stifle scientific inquiry if it is allowed to become a protected paradigm, and thus, unchallengeable. Units of measure are a core element of physical law inquiry and an erroneous assumption used in selecting the base units can hinder the inquiry process significantly.

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Physical law assumption

The classical meaning of assumption is accepting something to be true or factual in order that it can be used as a starting point for a course of action or reasoning. Physical law assumptions are typically based upon observation and measurement to determine if the results are consistently repetitive and will withstand equivalent scrutiny. No assumption can be disassociated from an Earth-centric view, as we have no experiential background to form an assumption that is not Earth-centric. As a result, assumptions will have an Earth-centric bias, and it is difficult to ascertain, from our perspective, if the bias has introduced an egregious error.

This paper was prepared for an FQXi essay contest. This essay presents material on an assumption that does not make it on any obvious list of assumptions, fitting into the FQXi topic suggestion, "What are the implicit assumptions we tend to forget we have postulated, or that have become so ingrained that they have become unquestioned dogma?"[1] A Scientific American article about the FQXi Essay competition expanded on this type of assumption.[2] "In conferences, I see physicists go down the list of assumptions that underpin their theories. Each, it seems, is rock solid. But they can't all be right. Maybe one will, on closer inspection, prove to be not like the others. Or maybe physicists have left the culprit off their list because it is so deeply embedded in their way of thinking that they don't even recognize as an assumption." The concepts used to create units of measure are usually buried in a long drawn-out process extending over several centuries with seemingly little drama involved for those that use the units. The persistent use of a particular set of units by everybody you know normalizes their use in your mind such that you never question the assumptions that resulted in their creation.

System International (SI) base units are suitable for commerce, but there is a forced assumption that the same units are satisfactory for scientific units. Are the assumptions used two centuries ago, to create units of measure to be used in scientific inquiry, before the existence of electromagnetic fields were known, still valid today? Before any scientific assumption can be created, the two basic core elements of scientific inquiry have to be in place; a system of units and associated mathematical processes. Ideally, for scientific law formulation, the units used for scientific inquiry would have dimensions based upon the fundamental physical constants that they are intended to measure. The mathematical processes should be sufficiently robust that they can readily accommodate diverse methods of presenting physical law concepts in abstract and numeric form.

Observation and measurement devices have played a pivotal role in identifying physical law principles. Improvements in observation and measurement devices have been responsible for challenging and overturning what were thought to be valid assumptions. Unfortunately, the scientific community often traps itself into another corner by exclusively relying on an observation and measurement technique that proved valuable in establishing what appeared, over an extended period of time, to be an absolutely unassailable assumption. Thus, when advocates of a particular concept use the argument, “this is the way it has always been done,” or “there is no other way to do it,” that should raise a red flag in any area of inquiry, especially if it impacts the core concepts of physical law.

Also, it is one thing to write an article questioning the validity of the assumptions used to establish the base units of measure, but quite another thing to present an alternative process to create base units of measure that will pass peer review and be published in a traditional technical publication.

Assumptions become protected

It should be expected that contemporary physical law assumptions are subject to modification or can be declared erroneous. However, there is evidence that some physical law assumptions related to specific areas of physical law inquiry are protected from challenge. Why a physical law assumption becomes protected is not within the scope of this paper, but it is possible to identify some elements of the protection process by examining a physical law assumption that was overturned, which are discussed in the section *Toppling an Assumption*.

It is a normal process in every type of endeavor, whether producing a product or a new physical law theory, to proceed from some type of experiential process, such as observation and measurement that has relevance to the endeavor. In the normal sequence of events, challenges to the result, and more observations and measurements are involved in establishing a basis for a consistent repeatable result, which is then treated as an indisputable fact at the time the fact is established. An assumption can have application to a specific area of inquiry or affect a broad area of scientific inquiry. Overturning an assumption that is generally accepted can be either swift or a difficult chore. The characteristics of the scientific authority structure, a Professor Thomas S. Kuhn term, determines the level of difficulty encountered by those that challenge an assumption, or even an aspect of an assumption.[3] A paragraph from an article by William McComas discusses allegiance to the paradigm, “Myth 8. Scientists are Particularly Objective,” and how this leads to rejection of ideas outside of the paradigm.[4]

Peer review is a filter process that is used to screen the tens of thousands of papers that are submitted to various publications every year, far more papers than they can possibly publish. Once an assumption makes its way into the textbooks, multiple generations become indoctrinated to accept the textbook assumption without question, which then permeates the peer review process. Peer reviewers use the generally accepted assumptions as the first level of scrutiny, which is understandable, but this can eliminate a paper that identifies a valid concept that is outside of the assumptions. A person that has status in the scientific authority structure will be more successful passing peer review with material not contained in the textbooks, or challenging some aspect of an assumption, than a person without status.

Additionally, over time, with improved communications, the scientific community has tended to become more monolithic in defending particular assumptions. This has made it more difficult for those that challenge an established assumption to get articles published in traditional scientific journals.

Toppling an assumption

Recently, a long established physical assumption was challenged and overturned. Daniel Schecthman, the 2011 Nobel Prize winner in chemistry, found that identifying the structural form of quasicrystals, which he discovered in 1982, was the easy part. The hard part was overturning the crystal structure paradigm, the assumption that all crystals had to conform to specific forms, which are noted in the next paragraph. The crystal form assumption was a core aspect of the study of crystallography, but it is not a core concept that influences scientific inquiry outside of that discipline.

This is a good example of how using different equipment and method of observation changed an assumption. Before Schechtman’s quasicrystal discovery, all traditional research in crystallography was accomplished with x-ray diffraction. Daniel Schechtman used an electron diffraction technique that could reveal crystal structures using smaller sized crystals than required for x-ray diffraction. Several years later, large enough quasicrystals were grown to allow their form to be observable using x-ray diffraction.[5] A quote from the Royal Society of Chemistry (RSC) article, just cited, illustrates how the assumption about crystal forms was viewed: “Today, that a crystal can be icosahedral is accepted, but in 1982 it was blasphemy. Everyone was taught that crystals were ordered, repeating structures of equally spaced identical unit cells that fitted together to form a lattice, like honeycomb. Pentagons (five-fold symmetry) can't fit together in an ordered way, according to the textbooks the only symmetry you could have was two, three, four and six-fold.”

It took two years to get the paper by Schechtman and his research associates published. It was delayed by peer review, but that was just the first hurdle in getting the established crystallography authority to accept the results. Some individuals accepted the results immediately. The RSC article makes a note of Linus Pauling’s objection to quasicrystals. A quote from a Professor Kuhn obituary article sums up what it can take to overturn an assumption: “Paradigm change, or ‘revolutionary science’ as Kuhn called it, was more a matter of persuasion, personal influence, indirect influences from social changes and even propaganda, than it was a matter of logic.”[6] Some elements of the process just described were used to get the Schechtman, et.al., paper published, and then convince the existing authority in crystallography to accept the results.

The old crystal form paradigm was retained for almost a century because everyone was taught to use x-ray diffraction as the method to identify their forms. Even though the assumption that the quasicrystal structure form cannot exist has been corrected, this has not changed the way the scientific community creates and maintains assumptions.

Unchallengeable assumptions

Another quote from the Scientific American FQXi essay article describes how we become trapped in accepting an assumption: “As economist John Maynard Keynes wrote, ‘The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify... into every corner of our minds.’” A concept that is presented to us as children, and on into adulthood, becomes cemented into our thinking as something that we never question. Similarly, during our technical educations, we are expected to accept what is being taught as true, as our academic progress will depend upon our acceptance of what is presented. The manner in which a concept is presented can mask that it is an assumption, because we are never exposed to an information set that questions the concept.

When an assumption impacts a broad range of scientific inquiry, that can be a major impediment in getting material published that challenges the assumption. It is assumed that the scientific authority establishment guards against making assumptions that are considered unchallengeable, but this is easier to state than what history has shown.

Units of measure are a core element of scientific inquiry, and an erroneous assumption in this area impacts all physical law inquiry. The manner in which the base units of measure are selected hasn’t changed in many lifetimes, basically an Earth-centric approach. In the last century, definitions for the base units of measure have become cloaked in scientific language; however, if a unit is arbitrary to begin with, no amount of scientific language can correct its deficiencies.

Because SI units have been the official units of measure for many decades, it is difficult to find individuals that actually have a negative opinion about their characteristics. It was quite unexpected when an individual in a communications five years ago, in reference to the meter, kilogram, second and ampere, covered the major issues by stating, “They are totally anthropocentric, arbitrary, and non-natural base units, from the POV of physical law. From those four arbitrary definitions of quantity of stuff we get these weird numbers attached to such universal constants of c, G, hbar, and epsilon0.” It is these weird (unwieldy) numbers, with complex dimensions, that create problems in equations dealing with physical law. Various attempts to resolve the issue with the unwieldy numbers, usually by setting a physical constant equal to one, are summarized in a paper by K. Tomilin.[7]

Meter assumed a valid scientific unit of measure

I have examined a considerable number of definitions which describe units of measure and I never see an objection that the units used in commerce are suitable to use for scientific inquiry. The Bureau International des Poids et Mesures (BIPM) and the National Institute of Standards and Technology (NIST) never question the scientific suitability of the base units of measure, which are, the meter, kilogram, second, ampere, kelvin, mole and candela.[8][9] However, there is a scientific organization that has expressed its reservations on the manner in which units of measure have been defined.

The Consultative Committee on Units (CCU) of the International Union of Pure and Applied Physics (IUPAP) provides recommendations on how units are to be defined, as well as for CODATA values. In their 2005 report to the central IUPAP, the CCU provided the following statement: "*the consensus that now exists on the desirability of finding ways of defining all of the base units of the SI in terms of fundamental physical constants so that they are universal, permanent and invariant in time.*"[10] This is going to be very difficult to accomplish if the metrology groups insist that the same base units of measure are to be used in commerce. Otherwise, defining the core base units in terms of fundamental physical constants might be simpler than anyone in the metrology organizations have considered.

At one time, the meter length was precisely the length inscribed between two lines on a platinum-iridium bar. Now the meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second. The location of the vacuum is never stated. In the period 1960 to 1967, the official second was the ephemeris second , which was 1/86,400th time division of the rotation of a planet named Earth that orbits a particular star in one of many galaxies of stars. Now the second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom; the period counts closely match the duration of the ephemeris second.[11]

The populace has been conditioned to accept SI units as being the best possible system of units the world could produce. An electromagnetic (EM) approach to defining the base units was urged by James Clerk Maxwell, also mentioned in the Tomilin paper, who opposed the way the meter, kilogram and the second were to be defined as scientific units of measure. Maxwell stated, "If we wish to obtain standards of length, time and mass which shall be absolutely permanent, we must seek them not in the dimensions or the motion, or the mass of our planet, but in the wavelength, the period of vibration, and the absolute mass of this imperishable and unalterable and perfectly similar molecules." The atomic theory of the structure of matter had not been developed at the time Maxwell made his statement about units; thus, he was referring to the characteristics and EM emission of sodium, which were known.

The hyperfine frequency of neutral hydrogen, confirmed in 1951, became the final piece of information needed to identify a methodology that can achieve part of the desired consensus stated in the 2005 CCU report. The hyperfine discovery allowed the size of base units of measure to be determined using a fundamental EM principle, basic geometric form, and what are typically considered mathematical constants.[12][13] The concept presented in the cited paper allows the numeric value for the speed of light to be expressed in the form $2\pi\sqrt{2}\,(10^8)$, scaled to contemporary usage.

As noted in the section, *Toppling an Assumption*, getting a paper published in a traditional scientific publication that challenges a long established assumption does not mean it will be recognized by the scientific authority structure that controls a particular paradigm. The BIPM is the central authority on maintaining units, and, as a well entrenched bureaucracy, may not be inclined to entertain a mathematical method of identifying the base units of measure, as the BIPM would no longer be in control of maintaining the precision, a primary reason for their existence. A mathematical method establishing the size of the base units of measure would allow applications to dictate the desired precision.

Some conclusions

Units of measure are pervasive across all scientific disciplines, but it can be perfectly reasonable to use contemporary SI units for some physical science uses. However, when attempting to establish fundamental physical laws, identifying relationships among various physical laws, and establishing numeric values for physical constants, it would be imprudent to use SI base units, as their size was established first, and then some were redefined in terms of a physical constant, an afterthought.

Even though it is now possible to mutually define the size of the base units of measure mathematically, it doesn't mean the core scientific disciplines that should be using them will adopt the new units voluntarily. The last sentence in the Tomilin article states, "Sooner or later man will set some natural measures as fundamental and will correlate his practical measures with them." Unless a scientific organization that has an extended reach within the scientific community makes a directed effort to publicize the mathematical method of defining the base units of measure, I expect it will be much later.

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