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Semiotic analysis of the observer in relativity, quantum mechanics, and a possible theory of everything

Abstract: Semiotic analysis of the role of the observer in the theory of relativity and in quantum mechanics shows the semiotic function of basic symmetries, such as symmetries under translation and rotation. How can semiotics be relevant to theories in physics? It is always human beings who form the theories. In the process of theory formation and communication, they rely on semiotic systems. Included among these systems is the semiotics involved in our pre-theoretical human understanding of space, time, and motion. Semiotic systems thereby have an influence on theories in physics. As a result, key concepts in fundamental physical theory have affinities with semiotics. In terms of Kenneth Pike's tagmemic theory, applied as a theory of theories, all symmetries take the form of distributional constraints. The additional symmetry under Lorentz transformations introduced by the special theory of relativity fits into the same pattern. In addition, constraints introduced by the addition of general relativity suggest the form and limitations that might be taken by a "theory of everything" encompassing general relativity and quantum field theory.

Keywords: theory of relativity, quantum mechanics, symmetry, theory of everything, perspectives, tagmemics

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A number of researchers have undertaken semiotic analysis of quantum mechanics (Christiansen 1985, Christiansen 2003; Dosch et al. 2005a; Dosch et al. 2005b; Januschke 2010; Prashant 2006). We wish to focus specifically on the problem of the *observer*. Semiotic analysis is relevant to understanding the role of the observer, because observers are people. And people presuppose and invoke semiotic systems as they form theories and communicate them. Moreover, in the twentieth century, physics was forced to wrestle with the involvement of observers in physical measurement, and this involvement

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actually became a key element in the formation and explication of theories in physics. Several distinct theories in physics now attribute a significant role to the observer: the special theory of relativity, the general theory of relativity, and quantum mechanics (together with its successor, quantum field theory). As we shall see, key elements in the semiotics of space, time, and motion have affinities with what we see coming out in the structure of fundamental physics. These affinities are not an accident, because the scientists are tacitly reckoning with semiotically structured knowledge in their theory formation.

1 Historical questions in quantum mechanics

The history of quantum mechanics shows the potential pertinence of semiotics. Nonrelativistic quantum mechanics received a stable mathematical formulation in the period 1925–1932 (Jammer 1966). Experimentally it was a success, but it entrained vexing questions about the nature of the observer's involvement with reality, questions that continue to be debated (Krips 2013; Laudisa and Rovelli 2013). Semiotics can analyze the nature of observer involvement. In the process, semiotically informed analysis may show how the scientific theories rely on semiotic systems being used by the scientists.

2 Symmetry

Classical mechanics, special relativity, general relativity, and quantum mechanics all utilize the concept of symmetry in their formulations. One of the most obvious symmetries in fundamental theories of physics is the symmetry related to rotations in space. A guiding assumption in theory formation is that fundamental physical laws should look the same no matter which direction one looks. A physicist can describe this property by saying that the laws are *invariant* under rotation.

Physical theories focus on the phenomena that they are investigating, not on the observer as such. But we can see that invariance under rotation presupposes a role for the observer. The variable direction to be used as a result of a rotation is the direction that the *observer* chooses. Or we might call it the direction that the *investigator* chooses. We are here not reducing observers merely to reading instruments and collecting data, as the concept of an "observer" sometimes occurs in quantum mechanical discussions of an "observation" of a quantum system. We are considering the observers as thinkers and theorizers as well. For this reason, we undertake our analysis using a specific semiotic framework that discusses observers, theories, and multiple theoretical perspectives (Pike 1976; Poythress 2013b). Our framework utilizes tagmemic theory as developed by Kenneth L. Pike (1967, 1982a, 1982b; Pike and Pike 1977).

3 Perspectives

Tagmemic theory specifically invokes the use of three interlocking perspectives or "views": the particle view, the wave view, and the field view (Pike 1959; Pike 1982; Poythress 2013b). The labels originated historically from Pike's interaction with physics and quantum mechanics (Pike 1959; Pike 1976: 99–100), but Pike adapted the labels to his own meanings. They are not to be equated with the use of terms within quantum mechanics.

The particle perspective focuses on "particles" or items that can be contrastively distinguished from other items around them. The fundamental probabilistic relation characteristic of particle analysis is mutual exclusion. For particle-like semiotic units A and B, the probability $\mathrm{P}(A \mathbin{\&} B)$ of joint occurrence is near 0. If units A and B are mutually exclusive, $\mathrm{P}(A \mathbin{\&} B) = 0$. But in typical semiotic contexts involving human investigators, we must be content with approximations. $\mathrm{P}(A \mathbin{\&} B)$ is near to 0, or approximately 0, which we write using the approximation symbol "~": $\mathrm{P}(A \mathbin{\&} B) \sim 0$. The wave perspective focuses on gradual variation, either in time or in conceptualization. The fundamental probabilistic relation characteristic of wave analysis is inclusion: $\mathrm{P}(A \mid B)$ is near 1, when B includes or presupposes A or extends A. The third perspective, the field perspective, focuses on multidimensional relationships, often relationships organized in cross-cutting arrays. The fundamental probabilistic relation characteristic of field analysis is probabilistic independence: $\mathrm{P}(A \mathbin{\&} B) \sim \mathrm{P}(A) \times \mathrm{P}(B)$, which is equivalent to proportionality relations: $\mathrm{P}(A \mathbin{\&} B)/\mathrm{P}(A) \sim \mathrm{P}(\text{not-}A \mathbin{\&} B)/\mathrm{P}(\text{not-}A)$, where not-$A$ is the event where A does not occur.

The three perspectives were originally developed in the context of analysis of language, but can be applied more broadly in the context of semiotic analysis (Pike 1967; Waterhouse 1974; Poythress 1982a, Poythress 1982b, Poythress 2013a, Poythress 2013b).

4 The physics of "translations"

So let us consider the investigator in physics from a semiotic point of view. From the particle perspective, the investigator can change his viewpoint by shifting to a new location. The new location is distinguishable from the old one: the two locations are mutually exclusive. This change is the kind of change that naturally gets classified as change of a particle kind. Linear measurements will take place with the new location treated as the origin. In terms of semiotic analysis, the investigator distinguishes the two locations and the two systems of measurements using the particle perspective.

In this context, the conception of changing location in the context of a *physical* theory depends on the deeper, *semiotic* conceptions of the investigator, who already has nontechnical intuitions about the nature of spatial location. Before the investigator becomes a theorist, he already has a pre-theoretical understanding of space and location. He has a heritage from his culture and from the sense of space given through his senses. He can talk about location through language or through gestures. Thus, space as conceptualized by the investigator already has a semiotic structure. Moreover, the two locations are distinguished *emically*, in a manner that is culturally meaningful, since the distinction is recognizable in an entire culture, not merely in a single individual.

Now consider a particular case of changing location. Suppose that measurements use three coordinate axes in three directions in space. The simplest form of change in location is a change in one coordinate axis, let us say the x-axis. Thus

$$x_{\text{new}} = x_{\text{old}} + c$$

Physicists customarily write this change in a more abbreviated form, by letting a symbol such as x' denote the new value and the symbol x denote the old value:

$$x' = x + c$$

From a semiotic viewpoint, the physicist has changed emic units, from an emic unit x in the old system to an emic unit x' in the new system. If we regard the two systems as first-order "theories," the change is a change of a particle kind in the sense indicated in the earlier work on theories of theories (Poythress 2013b).

This change in the semiotic viewpoint in the investigator is the intuitive basis for the theoretical concept of a *translation* in space. A translation in space is defined as a shift in the measurement system produced by placing the origin for measurement at a different location. The equation of transformation is precisely $x' = x + c$, if the translation is in the x-direction. General translations may shift in all three directions:

$$\begin{aligned} x' &= x + c_x \\ y' &= y + c_y \\ z' &= z + c_z \end{aligned}$$

Physicists expect the fundamental laws with look the same after a translation. This property is called *invariance under translation*. It is of course a theoretical constraint in the minds of physicists. But before it takes on that status, it has to be informally understood in the bodily experience of the investigator, and it has to be grasped mentally by means of a tacit reliance on the particle perspective (on tacit knowledge, see Polanyi 1964, Polanyi 1967). Thus, the concept of invariance also has a semiotic basis.

In addition, the investigator is tacitly relying on the semiotics involved in what Kenneth Pike (1982; 1967: 86–87) termed a *distributional* constraint (Poythress 2013b: 95–96). The physical laws remain the *same* when the location is *changed* by translation. Thus the location and the structure of the laws form two independent axes within a semiotic field.

5 Rotations

The investigator can also change his point of view not by moving to a new location, but by shifting his gaze, while remaining in the same location. This shift of gaze is the intuitive basis (pre-theoretical semiotic basis) for understanding the theoretical concept of rotation. Rotation automatically changes not one but two or three of the values of the coordinates. The general form of a rotation is

$$\begin{aligned} x' &= a_{11}x + a_{12}y + a_{13}z \\ y' &= a_{21}x + a_{22}y + a_{23}z \\ z' &= a_{31}x + a_{32}y + a_{33}z \end{aligned}$$

where the values a_{ij} are constants. The constants have to be chosen in such a way that lengths are preserved, and handedness is preserved (a figure shaped like a right hand is rotated into a figure of the same shape and orientation).

From a semiotic viewpoint, a rotation produces a whole new emic set of coordinates, which interlock with the old ones in a complex way. This wholesale replacement and wholesale interlock is a form of field-like change in the first-order "theory" that describes the physical system from only one fixed point of view. The fundamental physical laws are supposed to remain the same under rotation.

6 Motion

A third kind of shift in perspective can occur if the investigator starts moving. The classic illustration, used by Albert Einstein (1920: 14), imagines two observers. The first observer stands on the platform alongside a railroad track. The second observer is on a train moving along the track. The first observer, the one standing on the track, sees the train moving. From his point of view, the second observer is moving at the same speed as the train. And so is everything inside the train. If the second observer, seated in the train, regards his own position as fixed, he sees the scenery and the first observer moving relative to his position. That is, they are moving from his point of view.

So far, the situation with the train, and Einstein's description of it, involve realities that ordinary human beings understand, apart from any scientific training. They can understand, and they can communicate. They communicate through language or diagrams or pictures or invitations for others to stand alongside and experience the same observations. These common experiences obviously depend on the semiotic structures involved in language, gestures, pictures, and the ideas of "commonality" in experience.

Einstein's physical theory builds on these semiotically structured foundations. Einstein postulated that the two positions are equivalent from the standpoint of *physical* laws. If the observer on the train were to drop a ball, he would see the ball fall straight down toward the floor, the same as it would if the train were not moving along the track at all. Thus, the observer cannot tell that the train is moving unless he looks outside the train. And if another train passes on a parallel track, he cannot tell which train is moving relative to the ground without looking at the ground or at distant scenery. Such is the principle of *relativity*: motion is *relative* to the observer.

This change in motion is a third kind of change in perspective. It involves continual small adjustments in the position of the origin for measurement, when we compare two investigators. The small changes are a form of wave-like change in perspective (Poythress 2013b). Einstein's physical theory presupposes the underlying reality of semiotically structured understanding of motion.

Suppose that the train is moving with a fixed velocity v in the x-direction. Then what is the difference between the way in which things will be measured by the two observers, one on the platform and the other on the train? Before the work of Einstein, people could already conceive of such changes. They would have said that, as a result of the motion, the distance x' measured by the observer on the train in the direction of forward motion of the train would continually decrease relative to the distance measurement x by the observer on the platform. In a short time period t, the train covers a distance of vt. At the end of the time, x' is shortened by the amount vt relative to x. Thus:

$$x' = x - vt$$

Since the train is moving in the x-direction, the measurements in the directions of the other coordinate axes do not change:

$$y' = y;$$
$$z' = z$$

7 Multiple theories

A physical theory such as Newtonian mechanics that describes interactions from a single observational framework is a kind of first-order theory. The observational framework functions as a *perspective* on the physical world. But, as we have seen, the conceptual capabilities and semiotic capabilities of human nature allow us to consider multiple perspectives, and we may theorize within a second-order theory about the relationships between multiple perspectives. Traditional Newtonian mechanics in its more advanced forms already does this, and so it is a second-order theory from the semiotic point of view (Poythress 2013b: 89–96).

8 Galilean invariance

The investigator who is thinking about changes of perspective can rise above all the particularities of various observers. Having used all three perspectives, he may postulate that fundamental physical laws are *invariant* under translations (particle-like changes in perspective), rotations (field-like changes), and changes in velocity (wave-like changes). The third kind of change is also called a change in *inertial system* or *inertial frame*. The reference to *inertia* implies that the train (or other observation platform) must be moving at a constant velocity, rather than accelerating. An acceleration would be detectable, since the observer on the train would feel it (more precisely, he would feel the train seat pushing on him as it accelerates relative to the ground).

This threefold invariance – under translation, rotation, and motion at a constant velocity – is sometimes called *Galilean* invariance, in honor of Galileo Galilei. The corresponding transformations between different observational frameworks are *Galilean transformations* (Goldstein 1980: 276).

The assumption of invariance is a powerful one; it constrains the form that physical laws must take. With only a few more assumptions, it allows us to infer Newton's three laws of motion (Poythress 2013b: 89–96), which provide the basic framework for classical mechanics. As in the case of invariance under translation, the other kinds of invariance are distributional constraints (Poythress 2013b: 95–96).

9 The origins of the special theory of relativity

Albert Einstein worried about Galilean invariance, because it was not compatible with Maxwell's equations for light and electromagnetic radiation. Galilean invariance implied that the speed of light should change with the motion of the observer (Goldstein 1980: 276–277), and that an observer going sufficiently fast should be able to observe light in the form of standing waves rather than waves in motion. Einstein (1920: 21–24) therefore undertook to see whether the principle of Galilean invariance should be altered.

The process of alteration, we may observe, is a process of theory formation, and as such can be analyzed from a semiotic viewpoint. Einstein was motivated by empirical concerns. But these concerns overlap with concerns about the observer. Einstein (1920: 30–33) undertook a careful analysis of the process of measurement, through which he showed that the ideal of absolute Newtonian simultaneity in time, independent of all observers in all frames of reference, could not be observationally guaranteed. In particular, in order to synchronize clocks, observers on the station platform and on the train had to send signals, and the signals could not propagate faster than the speed of light. This constraint undermines any attempt to fix the measurement of time in a way independent of all observers.

An analogous conclusion might have been reached by observing from the standpoint of semiotics that particle and wave perspectives are always interlocked or entangled with one another. Investigators are always tacitly presupposing a variety of perspectives, and the presuppositions become even more evident when we erect a semiotic theory of theories, where we may be forced to become explicit about multiple perspectives in order to explain the multiplicity of possible theories about the same subject matter. If particle and wave perspectives are entangled, then in particular the particle perspective that differentiates frames of reference through translation in space is entangled with the wave perspective that differentiates frames of reference through relative motion. Translated back into physics, that entanglement suggests that space and time might be "entangled" rather than being perfectly separable in a manner independent of observer perspective.

The precise *way* that the two are entangled cannot be predicted without empirical observation. Since symmetries in translation and in rotation constrain the shape of classical mechanics, one might search for some additional symmetry that would constrain the shape of a revised form of mechanics, once the entanglement of space and time is allowed. Einstein postulated a particular symmetry, namely the constancy of the speed of light in a vacuum. This constancy would be shared by all observers, and would be independent of the frame in which an observer resided.

Given only this one additional assumption, Einstein was able to work out the relationships between observers and between observations of time and length made in two distinct inertial frames. This "working out" is the special theory of relativity.

Its key secret is a new "symmetry" – and symmetry is a characteristic distributional aspect of semiotic theories of theories (Poythress 2013b: 95–96). Given this key new symmetry, Einstein's new theory revises "Galilean invariance" to "Lorentz invariant" relativity, which again includes symmetries under rotation, under translation, and under changes in velocity. Lorentz invariance has equations that match Galilean invariance at low velocities, but deviate more and more as the velocity difference approaches the speed of light. This partial coalescence with Galilean invariance represents an instance in theory-making where a more complex theory (in this case, special relativity) includes a simpler, earlier theory (Newtonian mechanics) within it as a limit case (Poythress 2013b; also Dosch et al. 2005a: §5.1).

10 Quantum mechanics

Now consider elementary quantum mechanics. Symmetry principles play a central role in quantum mechanics, as well as in classical Newtonian mechanics and in the special theory of relativity. This use of symmetry again has an affinity with the distributional properties of emic units in a semiotic system.

As an example, consider a single, isolated atom. Since an atomic nucleus has a mass much greater than the surrounding electrons, the nucleus can be treated as approximately fixed in space. A single atom is then rotationally symmetric about its nucleus. The set of all possible rotational transformations with the nucleus as a center forms a mathematical group, the three-dimensional rotation group. The mathematical properties of the rotation group, together with the group of symmetries under interchange of two or more electrons, constrain many of the properties of the electron orbits and the atomic spectra related to them (Wigner 1959).

We can be more specific about relationships between semiotics and quantum mechanics. A natural probabilistic framework for studying semiotic systems treats as basic the probabilities for occurrence or non-occurrence of emic units A_1, A_2, A_3,... at specific times and places. The probabilities are then probabilities of the form $\mathrm{P}(A_i)$, or more precisely $\mathrm{P}(Q(A_i))$, where $Q(A_i)$ is the question, "Does the eme A_i occur at the specified time and place?" $\mathrm{P}(Q(A_i))$ is the probability, as estimated by the semiotic investigator, that $Q(A_i)$ will receive a "yes" answer.

This kind of probability analysis seems superficially to be different in texture from the probabilities associated with quantum mechanics, since measurements in quantum mechanics typically concern continuous observables like position and momentum. But Mackey (1963: 64–71) has shown that quantum mechanics can be reconfigured so that all questions about observables are translated into yes-no questions about whether the observable has a value falling within a (Borel) subset of the set of real numbers. Then all observables can be derived (constructed) from questions with yes-no answers. Mackey's reconfiguration is simply one form of an investigator's decision to switch to a new suite of observables (Poythress 2013b: §3). This switch is in fact a convenient one for dealing with all observables in a uniform way, since some observables (like the spin of elementary particles) cannot be treated as continuous.

Once the switch is made to questions, Mackey's formal structure for quantum mechanics has a structure parallel to the structure of a probabilistic theory of semiotics, with the questions in quantum mechanics being parallel to questions about the occurrence of emic units in semiotics. In fact, since Mackey's questions in the quantum mechanical context concern emic units within quantum theory, Mackey's questions are in fact *semiotic* questions from the standpoint of the semiotician, as well as being quantum mechanical questions from the standpoint of Mackey's view as a mathematical physicist. The usual symmetries that we have discussed for Newtonian mechanics have analogues in Mackey's structure, and they correspond to distributional constraints within semiotic theory.

Mackey needs one key postulate to get a theory that represents quantum mechanics rather than classical mechanics. The set of questions for quantum mechanics, with suitable partial ordering, is isomorphic to "all closed subspaces of a separable, infinite dimensional Hilbert space" (Mackey 1963: 71). Mackey understands that this additional postulate needs explanation, but the postulate is not as weird as it may seem at first. It is in fact the next simplest alternative to the situation where the questions form a Boolean algebra, which would result in classical mechanics. The decisive difference is that, in quantum mechanics, not all questions can be answered simultaneously. This restriction is an expression of the Heisenberg uncertainty principle, which says that one cannot have indefinitely precise measurements of both the position and the momentum of a single particle.

One can find a suggestive analog to the basic principle of quantum mechanics already lying within semiotics. As we saw above, the interlocking of perspectives within semiotics suggests the interlocking of the shifts in perspective through translation and through change in velocity. The same principle of interlocking can be applied to the suite of observables that belong to a single particle. In classical mechanics the observables for a single particle include three position observables (typically x, y, and z coordinates for the particle's location) and three velocity observables (typically v_x, v_y, v_z, the velocity components in the x-, y-, and z-directions).

The interlocking of particle and wave perspectives suggests the interlocking of location measurements (location being particle-like in its contrasts with other locations) and velocity measurements (velocity being wave-like in that it intrinsically involves comparison of neighboring values). This interlocking suggests in turn that there might be limits to simultaneous measurements of position and velocity. These limits would be analogous to the limits that special relativity postulates for observational simultaneity at high velocities (approaching the speed of light).

The constraint on simultaneous measurement implies that the structure of questions cannot form a Boolean algebra. The most regular alternative to a Boolean algebra is what Mackey's postulate chooses. Given this postulate, and the usual symmetries assumed in classical mechanics, Mackey is able to develop, with few extra assumptions, the entire structure leading to Schrödinger's equation and the results of nonrelativistic quantum mechanics. This result is in harmony with semiotic analysis that stresses the importance of a semiotic form of symmetry as a distributional constraint (Poythress 2013b).

11 Combining relativity and quantum mechanics

When physicists reckon with the special theory of relativity, the symmetries characterizing the fundamental laws have to be adjusted. The relevant symmetries include not only translations in space and time and rotations in space, but Lorentz boosts (Einstein 1920; Resnick 1968: 60). The range of symmetries is expressed in what is called the Poincaré group or the inhomogeneous Lorentz group, which plays a fundamental role in quantum field theory (Ryder 1996: 56). Judicious reasoning on the basis of these symmetries shows what are the viable possibilities for spin for elementary particles, and how the behavior of spin is highly constrained (Weinberg 1995: 49–106, 191–258). So even in this advanced form of quantum mechanics we can still see the influence of structures that originate with the semiotics of space, time, and motion.

12 A theory of everything?

Physics now confronts the challenge of integrating fundamental theories into a "theory of everything." Such a theory would include already established theories as first-order approximations. It would include the standard model for elementary particle physics, which is an expression of quantum field theory, based on the symmetries of special relativity and wave-particle duality in classical quantum mechanics. It would also include the general theory of relativity. This integration has proved not to be easy. As of 2013, the leading candidate for a theory of everything seems to be string theory, but there are complaints (Smolin 2007; Woit 2007), and some people are exploring alternatives.

The general theory of relativity postulates an additional invariant, beyond the ones that we have discussed. Physical law should be invariant under a change from a gravitational field to an acceleration. In developing the general theory of relativity, Einstein pictured a box whose occupants could not see outside the box in which they were confined. He postulated that, if they felt a force pulling them towards the floor, they would be unable to tell from any internal measurement whether the force was due to an acceleration in an elevator or to a gravitational field (Einstein 1920: 79–80). This constraint again depends on the role of the observer–in this case, the observer inside the box.

Mathematically, this invariance between gravitation and acceleration can be expressed by a transition to generalized coordinates, together with a generalized representation of the "metric" that measures distances using the chosen coordinate system. Generalized coordinates can be used not only for three spatial dimensions, but for the dimension of time as well, leading to a four-dimensional mathematical representation (Einstein 1920: 116).

13 Generalized coordinates

Generalized coordinates have proved useful in physics in other contexts besides general relativity, so it is worthwhile reflecting on their semiotic significance. The choice of a coordinate system is up to the investigator, as we have seen in discussing rotations and translations. Generalized coordinates function as one version of choice of a coordinate system, and thus fall under the semiotic analysis of theories of theories, and the semiotic analysis of multiple perspectives. Each choice of coordinate system is a choice of a suite of emic units, namely the units represented by the coordinate axes, together with a scale for measurement (such as meters in space and seconds in time). The translations, rotations, and Lorentz boosts involved in the special theory of relativity all involve linear equations of transformation, such as $x' = x + c$ for a translation of c units in the x-direction or

$$x' = ax + by$$
$$y' = cx + dy$$

for a rotation by a fixed angle about the z-axis. (For a rotation by a fixed angle θ, $a = cos\ \theta$, $b = sin\ \theta$, $c = -\ sin\ \theta$, and $d = cos\ \theta$.)

Generalized coordinates offer a distinct approach because the new coordinates need not be related to the old ones in a linear way. Nonlinearity means that the equations of motion in the new coordinate system may not look exactly like the old equations. Indeed, according to the principle of general relativity, the measured values definitely will not look the same in an accelerated system, because acceleration is equivalent to gravitation.

Even prior to Einstein's work on general relativity, generalized coordinates were used in physics in situations where the use of a nonlinear transformation simplified the mathematics or illumined the physical situation. The easiest case to illustrate is a case of cylindrical or spherical symmetry (note again the importance of symmetry, as a semiotic property). Suppose an engineer is studying or modeling the rotation of a cylindrical rod. The system is symmetrical around the central axis of the rod. So, instead of using the normal Cartesian coordinates x, y, and z, it may prove convenient to use cylindrical coordinates. Starting with an arbitrary system of Cartesian coordinates, it is possible by translation to locate the origin of the system at one end of the central axis of the rod. Then by rotation one can make the z-axis identical with the central axis of the rod. Finally, one introduces new "cylindrical" coordinates, z, r, and θ. z, as before, measures the distance from the origin in the direction of the z-axis, the axis of the rod. r measures the radial distance from any point to the z-axis, and θ measures the angle between the x-axis and the radial direction leading to the point in question. (See Figure 1.)

The coordinates r and θ are related to the older coordinates x and y in a nonlinear way, and the equations of motion in the new system of coordinates will look different. But the equations within the new system of coordinates may also be revealing, possibly by having no dependence on θ. Because of the cylindrical symmetry, the angle θ should not affect the behavior of the rod or of particles interacting with the rod. Likewise, when a system such as a ball or a single atom exhibits spherical symmetry, it is customary to using spherical coordinates r, θ, and φ, where r is the radial distance from the central point of symmetry and θ and φ measure angles between the radius and suitable fixed rays or planes.

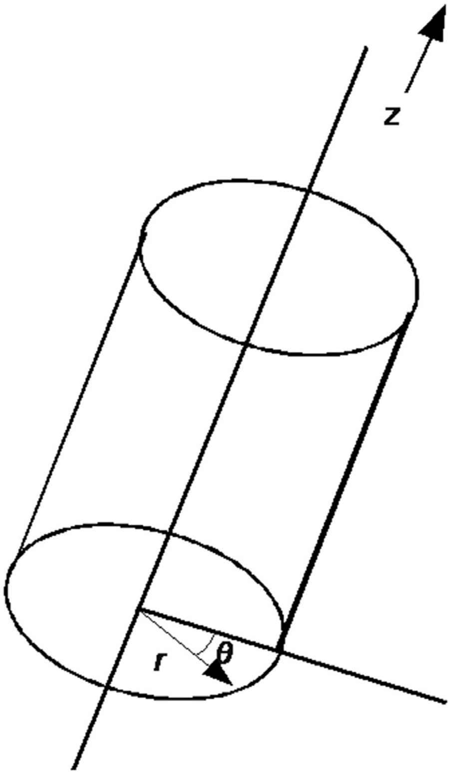

Figure 1: Cylindrical coordinates.

Within classical mechanics, when we use these nonlinear coordinate systems, the standard elementary Newtonian equation $F = ma$ does retain its standard form. But physicists have found that for many physical systems it was possible to write the equations in an invariant form. In fact, there are two different invariant forms, the Lagrangian and the Hamiltonian, depending on whether we choose to use generalized velocities or generalized momenta in addition to generalized position coordinates (Simon 1960: 365–368, 396–399). These formulations show the role of symmetries in classical mechanics, and by doing so affirm in addition the key role of distributional constraints in semiotic analyses of the theories.

However, in both the Lagrangian and Hamiltonian formulations within classical mechanics, time normally plays a very distinct, special role. Einstein's general theory of relativity removes this constraint: the fundamental equations treat time in a manner parallel to space, and indeed they must do so, in order to do justice to the fact that the concept of simultaneity and the measurement of the rate of passing of time vary with observer viewpoint.

14 Expectations for integration

The general theory of relativity includes the special theory of relativity as less comprehensive, special theory for dealing with "inertial frameworks" for measurement. The special theory serves as a first-order approximation for the general theory.

By analogy, a "theory of everything" would encompass both the general theory of relativity and the standard model for relativistic quantum mechanics within a more comprehensive theory, which would have these subordinate theories as first-order approximations. But it would not literally be a theory of absolutely *everything* because it needs an investigator or theorist. The theorist can rise above both the more comprehensive theory and the simpler theories encompassed by it, and can articulate the semiotic relations between the theories (Poythress 2013b). Gödel's results concerning incompleteness in arithmetic (Nagel and Newman 2008) suggest by analogy that no theory sufficiently complex to include arithmetic can provide robust resources for theorizing about *itself* without engendering contradiction or paradox. The same is suggested by the semiotic analysis of theories, according to which we can postulate an indefinitely ascending series of theories, each of which is analyzing the theories below it in the series.

In a semiotically oriented theory of theories, the symmetries and invariants of physical theories are analyzed as a distributional constraint. But distribution is entangled with contrast and variation. The independence of observables postulated as a distributional ideal is indeed an ideal, only approximated and not actually completely realized in real systems. This entanglement suggests a lesson for physical theory, namely that the invariances postulated by fundamental theories will be approximate rather than exact. Elementary particle theory is already familiar with this approximate invariance in the form of "symmetry breaking." Special relativity turns out to be an approximation, since no real physical system is ever completely isolated from distant gravitational interaction.

The search for a theory of everything theorizes that general relativity in turn is only an approximation. Might it be the case that the supposed equivalence between acceleration and gravity is only approximate? Or we could consider even more radical deviations from symmetry. Might it be that the invariance of physical theory under translation or rotation is only approximate?

That sounds like an outlandish proposal, until one realizes that no small physical system is completely isolated from the rest of the matter/energy in the universe. Cosmologists postulate a roughly uniform spread of matter/energy for the sake of simplicity in their models. But the distribution of matter in the universe is not completely uniform either under translation or rotation. So at the level of a theory encompassing the entire universe, no real invariance exists. One must postulate an invariance for the fundamental equations, but not for the distribution of matter/energy that the equations are designed to describe. Since the equations can only be tested with reference to the actual universe, which is not completely symmetrical, there is no final way of deciding whether failure in symmetry in test results is due to the asymmetry of the universe or to a failure of the equations to include asymmetry in the laws. Thus, a theory of "everything" fails literally to be absolutely final because of entanglement between theory and constraints in observation.

Or, to put in a way that is oriented to the investigator, the investigator can never honestly eliminate alternative hypotheses, because he cannot eliminate multiple perspectives on the meaning of his investigation. This limitations has a semiotic dimension: semiotics includes the potential for multiple perspectives.

15 Discrete or continuous

In trying to develop a "theory of everything," researchers confront the question whether the ultimate "stuff" of the universe is discrete or continuous. The currently favored option of string theory postulates that the ultimate nature of things should be represented by the spatial structure of a multidimensional manifold, which mathematically is continuous, not discrete. However, minority options include discrete models, where, for instance, the ultimate constituents are discrete quantum computations (Lloyd 2006; Lloyd 2007) or discrete causal structures (Markopoulou 2000a, Markopoulou 2000b). Let us consider the question from the standpoint of tagmemic theory, treated as a semiotic theory.

In tagmemic theory, the particle view treats semiotic systems as discrete collections of particles, while the wave view treats the same systems as continuous waves that develop and interact. These two viewpoints interlock; moreover, each is equally ultimate (Pike 1982: 19–29).

Now consider current physical theory. Almost all current theories in physics use differential equations, which presuppose a backdrop of continuous space and time. This is true even in solid state physics, where the researchers know full well that the solid state is discrete at the atomic level. But they customarily represent it at the macrolevel using a continuous model, for the sake of simplicity and solvability.

Mathematically, the representation of a continuum in space or time presupposes points on the continuum, and from an observer point of view each point is discrete. Conversely, each discrete point is identifiable in terms of its location within a continuum. So, observationally speaking, we can see a mutual dependence. Newtonian mechanics embodies a physical form of this mutuality. Discrete point particles move in continuous space, and are identifiable partly by location. As in other cases, the understanding of both discreteness and continuity relies on pretheoretical experience, which involves semiotic structure applied to space and time.

The rise of quantum mechanics partially dissolves the discreteness of particles, because subatomic "particles" are not completely localized in space. Quantum field theory further dissolves the materiality of "particles" because they pop in and out of existence, and the times for their existence are not completely localized. Yet the theory still retains indispensable ties with observation, and observation still has the form of discrete events located within a spacetime framework that is modeled as continuous. The theory includes discrete observables like spin, and discrete energy states in the atom, but the mathematical models still have their basis in the mathematics of the continuum.

The interlocking of discrete and continuous within the world of the observer suggests that any theory that ultimately gets tested by means of correlations between theory and observation must contain within itself a mutual dependence of the discrete and the continuous. One can ask whether this mutuality is modeled to some extent within quantum mechanics by the ability to shift from an analysis based on waves, using momentum eigenstates, and an analysis based on particle position, using position as the observable distinguishing the states. A theory of everything necessarily encompasses ordinary quantum mechanics, as a first-order approximation. So the interlocking of discrete and continuous, and the ability to express the theory in terms of both kinds of observer viewpoint, would be desirable.

16 Conclusion

We cannot dictate what form a final theory would take, because as observers we deal with a world outside ourselves. At the same time, we as observers are informed by semiotic structures. The forms of interlocking in these structures suggest useful heuristic constraints on the final theory. In addition, semiotic analysis makes visible ways in which semiotic structures inform existing theories in physics.

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Bionote

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