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PHYSICS IN THE THEOLOGICAL SEMINARY

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The Trinity and the hypostatic union are among the most difficult doctrines in systematic theology. The difficulties originate from several sources: The doctrines are distinctive of theology, they are a mystery beyond human comprehension, adequate methodology to study them is lacking, and no effective analogies have existed for comparison.

A renewed study combining physics and theology shows that it is possible to identify effective and thought-provoking analogies to the Trinity and the hypostatic union. In this paper I explore the relationship between (1) the triple point and the Trinity, and (2) complementarity and the hypostatic union. Awareness of such similarities has value for both physicists and theologians. For the physicist, the existence of analogy with theology is intellectually satisfying and shows that physics can be useful in a wholly diverse area of inquiry. For the theologian, the use of analogy stimulates new perspectives and provides an epistemic counterpart from which to view complicated points of theology.

I. ANALOGICAL REASONING DEFINED

Considered as a noun, analogy may be defined as a point-by-point comparison of one thing to another. Considered as a verb, it may be defined as a form of inference where it is reasoned that if two things correspond in one or more respects, they will likely correspond in other respects. To quote Barbour:

> Analogy is the extension of patterns of relationship drawn from one area of experience to coordinate other types of experience. . . . An analogy is never a total identity or a comprehensive description, but only a simplified comparison of limited aspects.[1]

It is in this sense that I view analogy. Common examples abound in physics. Perhaps the most familiar is the water-flow analogy to electric current in a wire. Familiarity with flowing water enables one to better understand the behavior of electrons in a circuit, behavior that is difficult to visualize without the aid of analogy.

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[1] I. G. Barbour, *Issues in Science and Religion* (New York: Harper, 1966) 158–161.

II. THE TRIPLE POINT AND THE TRINITY

The triple point[2] is defined as the point where the solid, liquid, and gaseous forms of a substance coexist in a state of dynamic equilibrium. The important considerations are that three states of matter coexist, the equilibrium is dynamic, and the phases have distinct properties despite being one and the same substance.

The three states of matter (solid, liquid, gas) are commonly called phases, and the law that governs their behavior is the phase rule. The phase rule specifies which state of matter a substance will exhibit depending on its temperature and pressure. For example, water at normal atmospheric pressure will exist in liquid form if its temperature is between 32° F and 212° F. At lower pressures, however, such as in a vacuum chamber or on a mountaintop, water will exist as a liquid only under a smaller range of temperatures, say between 70° F and 150° F. The lower pressure makes it easier for water to evaporate by lowering its boiling point, and it is less capable of sustaining the liquid state.

Application of the phase rule to a substance results in a phase diagram that shows the possible forms of matter available to a substance at varying temperatures and pressures. The temperature and pressure are customarily plotted on a two-dimensional graph with appropriate regions representing solid, liquid, and gas. A common example is water, whose phase diagram is reproduced in Figure 1. Coexistence between two phases occurs along the mutual boundary of the phase regions, and coexistence between all three phases exists at the intersection of the regions. This intersection is the triple point. The triple point for water means that coexistence of ice, water, and steam occurs at only one specific temperature (0.01° C) and one specific pressure (0.006 atmosphere, or 6/1000 below normal atmospheric pressure). Changing these parameters destroys the coexistence, and water exists in whichever state of matter the phase diagram directs.

The phase rule governs the behavior of states of matter at equilibrium, meaning that the substance possesses properties that are independent of time. At the triple point, equilibrium requires rigorous control of pressure and temperature to maintain the triple point indefinitely. The equilibrium is dynamic rather than static, with transitions occurring continuously between the coexisting phases but so that no apparent change is evident with the naked eye. This means that, at the triple point, boiling and condensing, melting and freezing, and subliming and freezing of gas are all going on simultaneously.

It is noteworthy that the triple point is not equivalent to the mere existence of three forms of matter but rather defines a unique relationship between the solid, liquid, and gaseous phases. Mere existence of three

[2] G. J. Van Wylen, *Thermodynamics* (New York: Wiley, 1959); M. W. Zemansky, *Heat and Thermodynamics* (New York: Wiley, 1968); T. L. Brown and H. E. LeMay, *Chemistry: The Central Science* (Englewood Cliffs: Prentice-Hall, 1977).

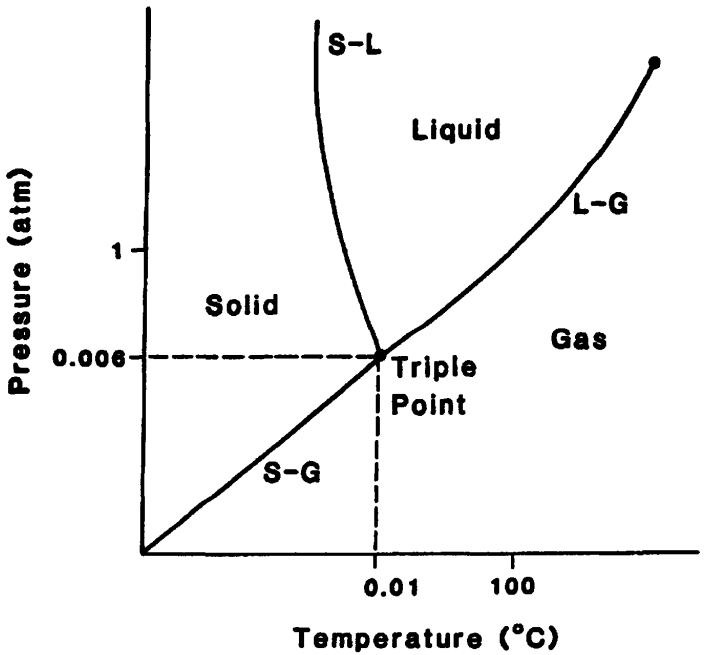

Fig. 1. The triple point. The phase diagram of water, showing the possible phases available to H_2O at varying pressures and temperatures.

phases of matter is trimodal and therefore unsuitable for analogy to the Trinity.

In summary, the triple point shows how one substance can exist in three fundamental forms concurrently, each fully the same in nature yet clearly distinct to the extent of having a real interaction with each other, different properties, and different applications.

The triple point shares a number of common elements with the Trinity, including a singular nature shared by three coequal but distinct subsistences, economical properties, and ontological properties. Further, it preserves the distinctions among the trinitarian, tritheistic and trimodal formulations. These rigorous requirements have been difficult to satisfy in previous analogies.[3] It is possible to identify at least seven points of likeness between the triple point and the Trinity.

1. *The triple point and the Trinity both possess a singular nature with three coequal but distinct subsistences.* The triple point and the Trinity

[3] C. Hodge, *Popular Lectures on Theological Themes* (Philadelphia: Presbyterian Board of Publication, 1887); A. H. Leitch, *Interpreting Basic Theology* (Great Neck: Channel, 1961); J. O. Buswell, *What Is God?* (Grand Rapids: Zondervan, 1937).

have a singular essence and possess three subsistences having real distinctions among them. While the three states of matter at the triple point are conjoined by a common molecular structure, the phases are quite different when viewed macroscopically. The differences are manifested by the distinct physical properties held by the different forms of matter, such as compressibility, thermal and electrical conductivity, energy, and so forth. This fact leads to the union of three into one without loss of identity of the phases. The Godhead is also considered to be a single essence containing three subsistences that are able to merge without loss of identity. There is thus an infusion of three-into-one in both models, the satisfaction of which constitutes a minimum requirement for establishment of an effective analogy to the Trinity.

2. *The triple point and the Trinity are both equilibrium states.* Equilibrium is that condition in a thermodynamic system when the properties of the system do not change with time. The dynamic equilibrium at the triple point occurs when equilibrium is maintained by equal rates of forward and reverse reactions, as opposed to equilibrium maintained by the absence of reaction. Transitions are continually occurring among the phases, and no net change in the relative amounts of liquid, solid, and gas is measurable. The analogous property of the Godhead is the principle of immutability, meaning that the nature and attributes of the persons of the Trinity are invariant with time.

3. *Neither the triple point nor the Trinity is a tritheism.* The triple point preserves the distinction between tritheistic and trinitarian viewpoints of the Trinity. Tritheism holds that there are three Gods rather than three persons in one God. The persons of the tritheistic God refer to three deified beings and deny the unity of the divine essence. The triple point is incompatible with tritheism because, at the triple point, there are not three phases in the sense of taking solid, liquid, and gas from separate locations and combining them mechanically. There is unity of essence at the triple point, with the phases tied together at a particular set of thermodynamic conditions. The triple point of water, for example, does not represent the existence of three "waters" united merely by purpose. There is something more in the union of the three phases at the triple point than merely the sum of phases. The same is true of the conjoined persons of the Trinity.

4. *Neither the triple point nor the Trinity is a trimodality.* Trimodalism holds that the Godhead is a trinity of revelation rather than a trinity of persons and denies the reality of the trinitarian persons. A trimodal God refers to three aspects or manifestations of one God, with no internal distinctions within the divine substance. The triple point is not trimodal because the thermodynamic phases possess distinct and unique properties and are not merely different manifestations of the same thing. For ex-

ample, although composed of identical molecules, ice is manifestly different from steam and water and exhibits different physical properties. Further, the phases of the triple point are locked together in a state of dynamic equilibrium, which prohibits manifestation of the individual states of matter except by destruction of the triple point. This means that once the triple point is established, simultaneous exercise of the three concurrent phases is guaranteed. No grounds exist for the action of one phase apart from another. By contrast, a trimodal God could manifest only a single mode at a given time.

5. *The phase relationships at the triple point are similar to relationships between the trinitarian persons.* The interdependence of phases at the triple point is reminiscent of the relationships evident between members of the Trinity. No one state of matter is more fundamental than another, nor does the thermodynamic substance lose its identity because it exists in three concurrent forms. Thermodynamically, each phase at the triple point derives and sustains its character by mutual collaboration with the other two phases. The triple point phases cannot exist independently but are interlocked at equilibrium. The blending is similar to the relations between the persons of the Godhead. Trinitarian doctrine holds that the Godhead is sustained by a self-contained mutuality of relations and that no one person of the Trinity is or can be without the others. There is a coequal sharing of the singular divine nature without intrinsic subordination of any person. The undivided essence belongs equally to each of the persons and each possesses all the attributes of deity. No one state of matter is more fundamental than another, nor does the thermodynamic substance lose its identity because it exists in three concurrent forms.

6. *The triple point and the Trinity both have ontological properties.* There is a structural resemblance between the thermodynamic phases at the triple point and the ontological Trinity. Ontologically, the persons of the Trinity have an internal number system given by the Biblical dictum: The Father is the first person who neither proceeds from nor is begotten, the Son is the second person who is begotten by the Father, the Spirit is the third person who proceeds from both Father and Son. There is similarly a natural ordering of phase relations, specified by nature's universal desire to seek the state of lowest energy. During energy minimization, phase changes may occur and one phase may be considered to "beget" or "proceed from" another. While it is difficult to attach the designation "first" to the solid phase, a fundamental concept exists that allows for phase ordering in a way suggestive of the trinitarian ordering.

7. *The triple point and the Trinity both have economic properties.* The economic Trinity expresses the view that, while the entire Godhead is involved in external divine acts, usually one member of the triad is featured.

Similar behavior is displayed by the states of matter of most substances. For example, in the case of water, steam is used to drive locomotives and heat buildings, ice is an effective coolant and friction reducer, and water sustains the human body. While such applications are normally carried out far from equilibrium and no need exists for maintaining three coexistent phases at the triple point, use of a substance at its triple point is not ruled out in principle. In a triple-point skating rink, for example, the joint operation of all three phases contributes to the maintenance of lubrication while the solid phase is featured. Under idealized conditions it is possible for the triple point to be involved in applications that depend on the joint effort of all three phases but where only one phase is featured.

III. COMPLEMENTARITY AND THE HYPOSTATIC UNION

The principle of complementarity addresses the true nature of matter at its most basic level. The central issue is whether objects in nature are fundamentally waves or particles. The answer is that all objects have both wave and particle characteristics that are exhibited to various degrees depending on the method of observation. In other words, nature is both particle and wave, just as Christ is both God and man.

The complementarity principle, first enunciated by the physicist Niels Bohr in 1928, is an attempt to accommodate the classically irreconcilable wave and particle concepts. By "classical" we mean the traditional physics of large, low-speed objects (e.g. cannonballs, falling objects) familiar to physicists of the last century. This is in contrast to quantum physics, which is the physics of small, fast-moving objects (e.g. an electron in an atom). The controversy over waves and particles arose during experiments indicating that small, fast-moving objects were found to exhibit both particle and wave properties. The simultaneous exhibition of both aspects is incompatible unless traditional views of waves and particles are modified.

Traditionally, a particle describes an object with a definite location in space, such as a baseball. It is an object distinguished by the fact that it is localized. A particle occupies a well-defined region of space, it moves from one region of space to another, and you always know where it is. It exists at one place only at any given time. Waves are different. They are not localized but are spread over wide regions of space and can, in fact, occupy any region of space containing many locations at the same time, such as a water wave on the surface of a lake. The two ideas are mutually exclusive. How a synthesis is possible is what complementarity addresses.

In the twentieth century, when classical physics was superseded by quantum physics, waves and particles were found to be reconcilable if our traditional views of waves and particles are abandoned. The statement of this reconciliation is the complementarity principle. In the complementarian viewpoint, both wave and particle properties are necessary for a full description of nature, each revealing a complementary aspect of matter. A given experiment may emphasize one of the properties. Neither nature is

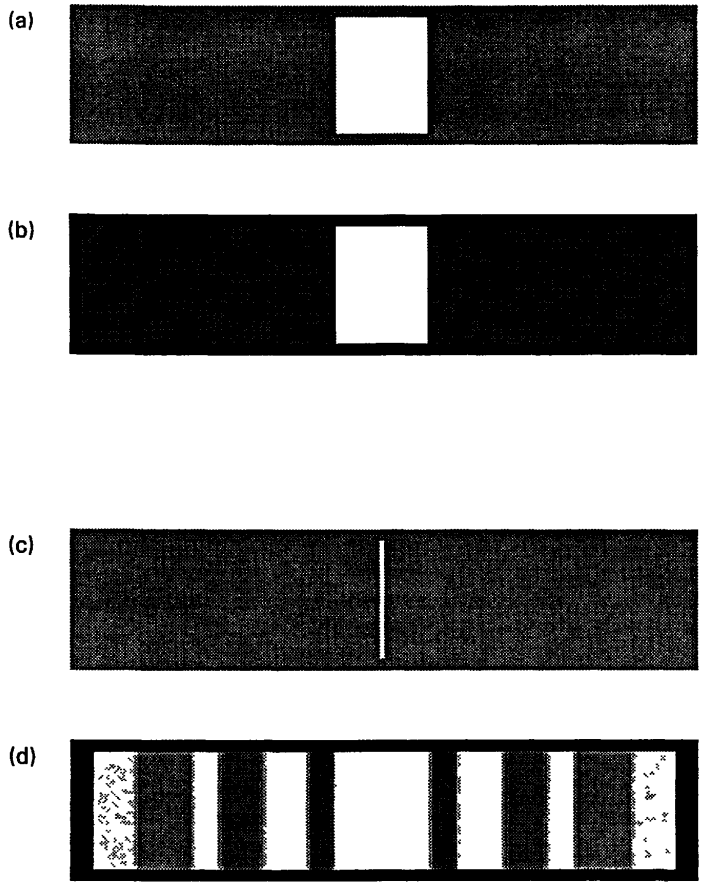

Fig. 2. The complementarity principle. The single-slit experiment shows that electrons can be made to act either as particles or waves depending on the choice of experimental conditions. When particles are incident from the rear of the wide single slit (a) the transmitted light pattern seen by the naked eye (b) is formed by straight-line motion of particles. When particles are incident from the rear of the narrow single slit (c) the transmitted light pattern seen by the naked eye (d) is formed by diffraction effects characteristic of wave behavior.

lost or destroyed, but either waves or particles are featured depending on the observation method.

The classic demonstration of this behavior is given by the single-slit experiment (see Figure 2). A beam of particles such as electrons is incident upon an opaque screen with a small slit cut into it. Before reaching the screen the electrons may be verified to act as particles. They have a definite

position in space, form bright spots on phosphor screens, and obey the laws of particle physics. After passing through the slit, however, an interference pattern is formed that is distinctively a wave phenomenon, shown by the alternating pattern of light and dark fringes. A similar pattern can be observed by looking at a bright light source through two fingers placed together to form a narrow slit.

The quantitative expression of complementarity is given by the Heisenberg uncertainty principle:[4]

$$(\text{wave nature}) \times (\text{particle nature}) \geq h$$

The symbol h is a numerical value called Planck's constant, and the quantities enclosed in parentheses are known as conjugate properties. The uncertainty principle shows that if one tries to squeeze matter into displaying its particle aspect, the wave aspect becomes less pronounced. This is because when the quantity (particle nature) increases in the uncertainty principle, the quantity (wave nature) must decrease in order to keep the right side of the equation ≥ h. The quantities on the left side of the equation may vary but can never be zero.

The uncertainty principle states that although wave information is hidden when the position of an electron is measured to be at a precise location, it is not lost. It is only suppressed. Both wave and particle attributes are inseparably united, and it is the observation technique that determines which attribute is featured. A full description of matter is incomplete with only one nature. A complete description requires both wave and particle natures whose relative appearance in a given environment is specified by the uncertainty principle. To summarize, classical physics states that particles and waves cannot exist together because they are mutually exclusive concepts. Quantum physics states that particles and waves can and must exist together. It is simply that one or the other is featured when observed.

The relevance for theology lies in the coexistence of dual natures, which should be mutually incompatible but are not. For waves and particles the paradox is resolved by the deeper understanding of quantum physics. A similar reconciliation of the dual nature of Christ is given by the hypostatic union, which holds that Christ was both fully man and fully God. Just as the Scriptures represent Christ to possess both divine and human natures, each undivested of its distinct attributes, they also represent Christ as a single, undivided personality in whom the two natures are inseparably united.

It is possible to identify at least seven points of likeness between the hypostatic union and the complementary view of waves and particles.

1. *Both models have two natures in a single entity.* The wave-particle duality and the hypostatic union possess two natures integrated into a

[4] Discussed in any general college physics textbook; cf. e.g. D. Halliday and R. Resnick, *Fundamentals of Physics* (New York: Wiley, 1988).

single entity. The wave and particle natures pertain to a single entity properly called the wave-particle, while the divine and human natures pertain to a single person properly called the God-man. The coexisting natures are fully integrated, cannot be separated, and at a certain level appear to be incompatible. This is due, however, to the unjustified transferral of concepts familiar in one domain into another. For example, when experimental techniques developed to the point where small, fast-moving objects could be observed, physicists of the last century continued to insist upon using classical terminology to explain what was truly quantum physics. The classical terminology eventually had to be abandoned when experiments demonstrated both wave and particle properties in a single entity. By a refined view of what is wave-like and what is particle-like the paradox of having both particles and waves in a single entity was resolved. Likewise the hypostatic union states that the dual nature of Christ appears incompatible because of our limited understanding of what is human and what is divine. At a deeper level the concepts are reconcilable.

2. *The wave-particle and the God-man have properties that transcend each individual nature.* Combining two natures into one gives the resulting entity new properties not held by either nature individually. Without the dual nature of electrons, for example, it is difficult to explain the phenomena of scattering, diffraction, barrier penetration, and so on. Likewise the dual nature of Christ is the indispensable foundation upon which other broader theological doctrines such as atonement, redemption, and the incarnation are based. There is no possibility of explaining physical phenomena by purely wave or purely particle concepts, nor is there any flexibility in the hypostatic union to account for Christ's resurrection in purely human terms.

3. *The wave-particle duality and the hypostatic union have characteristics described by conjugate properties that obey an uncertainty principle.* Conjugate properties occur in both the hypostatic union and the wave-particle duality. The description of an entity in either realm proceeds by specification of a pair of complementary quantities.

In physics, this corresponds to trying to squeeze a wave into a small region of space to force it to look like a particle. Since waves are not easily localized in space, measurement of its position is subject to uncertainty, making it difficult to tell how wave-like or particle-like the resulting phenomenon is. In any experiment performed to isolate either the wave or particle aspect, an unavoidable interference takes place that frustrates the attempt (cf. Figure 2). A given experiment will emphasize the details of only one conjugate property at a time, depending on the choice of observation technique.

It is equally difficult to perceive both human and divine natures at the same time in the God-man. Either the divine or the human nature is featured, depending on the interaction of the person of Christ with the universe. It may be possible to formulate a relation similar to the uncertainty principle that describes the combination of divine and human in the

God-man. In symbols, (divine nature) × (human nature) ≥ C, where now the conjugate properties represent an attempt to specify the divine and human natures of the God-man simultaneously and C is a constant. Such a relation shows that absolute precision in the specification of the divine nature of Christ is accompanied by complete uncertainty in his human nature and provides a possible explanation of how the person of Christ could possess both divine and human attributes at the same time. One cannot squeeze the God-man into a situation where only the human nature is present, because the divine nature is never absent. It is therefore difficult to tell how divine-like and human-like the person of Christ is. At a certain level the conjugate properties appear dualistic and incompatible. Both descriptions, however, are necessary to fully characterize the properties of the God-man.

4. *Viewing the conjugate properties as classical entities leads to absurdities.* According to Bohr and nineteenth-century physicists, physical phenomena had to be expressed in classical terminology. The point of quantum physics, however, is that quantum entities cannot be described in classical terms without leading to absurdities. By making a classification according to traditional views of waves or particles, we force a classical description on things that are by nature unclassical. Physical objects do not obey the laws of classical physics. They obey the laws of quantum physics.

In the same way, to press the hypostatic union into a classical description of what is divine and what is human leads to the same logical absurdities. For example, it is impossible to explain how Christ could turn water into wine and rise from the dead based on our limited classical view of what constitutes humanity. On the other hand, from a classical view of what constitutes deity it is difficult to explain why a divine being could experience pain or would need to eat and sleep. The paradox is reconciled by the existence of conjugate natures that cannot be viewed in all detail at all times. In a given situation either the divine or the human nature is featured, depending on the interaction of the God-man with the world. At a deeper level the two natures of Christ are not incompatible. The paradox merely reflects the inadequacy of our limited notions of what is human and what is divine.

5. *The conjugate properties discriminate against alternate models of the hypostatic union.* An effective analogy to the hypostatic union should be capable of discriminating against other forms of the doctrine. Showing that the wave-particle duality is unlike one thing does not prove that it is like something else, but the corroborative support is satisfying.

There are at least eight alternative models that have been proposed for the union of the God-man. These theories differ from the traditional doctrine in that they deny either (1) the reality of the two natures (Ebionism and docetism), (2) the integrity of the two natures (Arianism, Apollinarianism, and the theory of incomplete humanity), or (3) the union of the na-

tures in one person (Nestorianism, Eutychianism, and the theory of gradual incarnation).

Conjugate properties are incompatible with the alternate models for the following reasons. First, the uncertainty relation governing the conjugate properties is an explicit statement that there is reality to particle and wave interpretations of matter. Second, there is no subordination or loss of nature implied in the statement that matter has a dual nature. Third, there is no incomplete integration of the wave and particle nature. Waves or particles are featured depending on the experiment, but the wave-particle has not given up any of its wave or particle nature during the integration. The measurement has merely dictated whether waves or particles are observed. Matter at its most fundamental level is both wave and particle, just as Christ is both God and man. There is no provision in either the wave-particle duality or the hypostatic union for a half-wave/half-particle or a half-God/half-man.

6. *In spite of the union, the two natures are retained in both models.* In the hypostatic union the two natures are unchanged by the union. The argument: If divine attributes are conferred to man, man ceases to be man. Therefore the divine and human natures are not mixed to form a third nature that is neither one nor the other. The humanity in Christ is not deified, nor is the deity of Christ humanized.

Can the same be said of particles and waves—that is, are wave or particle natures changed by the dualism? In both classical and quantum views of waves and particles, the answer is no. In classical physics, particles and waves are mutually exclusive concepts, so there is no integration of the natures. In quantum physics, either the particle or wave nature may be suppressed but never destroyed. For example, in the single-slit experiment as the slit is opened the diffraction pattern shrinks and begins to look as if it is caused by the straight-line motion of particles through the slit. As the wave nature of the electrons appears to vanish as the slit is opened, however, it still must be present to produce the interference pattern, which can only arise by wave interference. Hence while one complementary nature is featured the other is suppressed but not changed into something other than a wave or particle. There may seem to be less of one nature during the measurement, but the wave and particle natures themselves are unchanged. This is similar to what theologians mean when they say that the hypostatic union occurs without corruption of the natures.

7. *Reconciliation of the hypostatic union and the wave-particle duality is dependent on the role of human perception.* Whether an object such as an electron appears as a wave or a particle depends on the nature of the measurement that is made. The wave-like or particle-like character of an object lies only in the eye of the beholder, and no one can really say when a wave has been localized enough to be considered a particle. A similar situation occurs when viewing a three-dimensional cube drawn on paper.

A paradox arises when the observer is asked to specify which side of the cube is facing forward. Some individuals see the "back" surface as forward, some see the "front" surface as forward. In forcing a notion of meaning upon a series of lines, or in pressing matter to fit a classical model of either particles or waves, an antinomy is created that forces us to conclude that the universe is by nature dualistic. In other words, we as observers are the true source of the paradox due to our insistence on describing things by particular models. In the case of the hypostatic union, the God-man seems impossible because of our deep-seated convictions of what is divine and what is human. In our insistence on preconceived views of humanity and deity we tend to regard the hypostatic union as paradoxical and dualistic. This no longer needs to be the case since the complementarity principle successfully resolves a similar paradox in science.

IV. CONCLUSIONS AND QUESTIONS

It is intriguing that such fundamental theories in physics and theology have so many common elements. A useful exercise for theology students is to consider further similarities between the analogies or to describe some of the deficiencies of the analogies. For example, a chief deficiency of both analogies is the inability of inanimate quantities (such as phases, waves, and particles) to approximate traits best described as personal. This is because personhood in the Trinity refers to distinct individual existences that possess the properties of reason and self-determination as well as the capability of expressing love, feelings and emotion. Obviously the phases of the triple point are not self-determining but are controlled by the applied thermodynamic conditions. A second deficiency in the triple-point analogy is that all matter is compound in structure, composed of smaller and smaller particles, while the Godhead is singular and indivisible.

Notwithstanding these and other deficiencies, the chief value in the analogies is to stimulate renewed thought concerning the Trinity and the hypostatic union. For example, given the view that the Godhead may be crudely represented in a divine phase diagram, how would one label the axes? In other words, what X- and Y-variables determine the actions of the Godhead? Can the trinitarian equilibrium be upset? What is the mechanism by which the members of the Trinity share the divine essence? What do the bounding surfaces between the members of the Trinity consist of? Can the complementarity principle resolve other Scriptural difficulties, such as the coexistence of divine sovereignty and human free will? It is difficult to envision a better method for generating questions apart from analogy. Such questions can then be tested by independent methods and are subjects for further theological study.[5]

[5] I wish to express appreciation to the theology faculty at Western Conservative Baptist Seminary in Portland, Oregon, for many stimulating discussions during my graduate studies in theology. In particular I want to thank W. R. Cook, N. Thornton and J. Wood for offering constructive comments on the manuscript.