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Quantum Ontology of de Broglie and Bohm with Reflections on the Meaning of Probability

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TOPICS of this LECTURE

- PHILOSOPHICAL STARTING POINTS
- STRUCTURE OF CONSERVATION LAWS --- PHYSICAL (QUALITATIVE) AND MATHEMATICAL (QUANTITATIVE)
- QUANTUM THEORY AND ONTOLOGY ---
- SUMMARY

VERY BRIEF PHILOSOPHICAL CONSIDERATIONS METAPHYSICS (study of being *as such*) & EPISTEMOLOGY

- My web site ---- "Philosophy: Everybody has one (implicitly or explicitly!)"
- Examples of Physicists with more **explicit** philosophy: Albert **Einstein** (belief in the external world existing independently of us; causation) and Max **Planck** (belief in necessity of an "ideal and omniscient Spirit" for tracking causal influences) and Ernst **Mach** (expressed belief that all we can know are *appearances*; influenced by Kant who held that we cannot know the *thing in itself* or *das Ding an sich;* admits that consciousness has an identity but thereby acts as a distorter of the external world, assumes a "diaphanous" (non-interaction) model of world for true knowledge of it ---- Kant is an Idealist)
- Generally different views in Epistemology and in Metaphysics Hume (necessity is not seen in causal interactions), Locke (knowledge is based on mind's assembling sense data), Berkeley, Descartes, Kant, Mach, Planck & Einstein vs Bohr & Heisenberg

Metaphysics and Epistemology

- Philosophical Axioms ---- principles such that one must use them in any attempt to deny them
- EXAMPLES from ----
- <u>Metaphysics</u> there is an *external world* independent of one's consciousness (note difference from Einstein's *belief* in such a world). *Law of Identity* "A is A"
- <u>Epistemology</u> Regarding Consciousness one is conscious (Descartes is correct in that respect; but note that to be conscious is to be conscious *of* some *other* thing). *Law of Non-Contradiction* (not both A and not-A)
- EXTENSIVE DISCUSSION of the preceding with a novel theory of <u>direct</u> perception (which draws on the work of J.J. Gibson) can be found in *The Evidence of the Senses* by David Kelley (see the detailed review by Stephen Hicks which cites key topics along with their page numbers)



How about when "Tennis Balls" are used instead of "Water" ?

NO

How about when "Euros" are used instead of "Water" ?

NO

How about when "Energy" is used instead of "Water"?

YES !

Balance Laws Laws of Continuity Less General Conservation Laws The physical property is quantified. For example a volume of 5 m³ of water. OUTSIDE Region INSIDE Region OUTSIDE Region

Conservation Law: However much of the quantity starts on the INSIDE continues to remain on the INSIDE. For Example: For the INSIDE — There may be 3 m^3 of water near the <u>right side</u> and 2 m^3 of water near the <u>left side</u> at one time and 5 m^3 of water near the <u>center</u> of the cylinder at another time. But the <u>total</u> amount of water within the cylinder <u>does not change</u>.

Law of Continuity: However much of the quantity leaves (or goes into) the INSIDE will continuously appear on (or disappear from) the OUTSIDE. For Example: If 3 m^3 of water <u>disappears</u> from the <u>INSIDE</u> during some time interval then 3 m^3 of water must <u>flow through</u> the surface to the <u>OUTSIDE</u>.

Balance Law: If the amount of the quantity that is disappearing from the INSIDE is <u>not</u> equal to the amount that is appearing on the OUTSIDE then a balance would require that there is an <u>additional</u> "SOURCE" or "SINK". For Example: If 5 m^3 of water <u>remains</u> on the <u>INSIDE</u> while 3 m^3 of water <u>flows to</u> the <u>OUTSIDE</u> then 3 m^3 of water must <u>flow into</u> the <u>INSIDE</u> from some <u>SOURCE</u>.

The field of physics appears to be dominated by *deterministic causal theories* (DCTs). More specifically, most theories of physics (the so-called "classical theories") are formulated using mathematical equations predicated on the idea that, given certain well-posed initial conditions of the system, the time development of the system is specifiable. This means that if the values of an appropriate set of variables are specified at one instant throughout some region of space then the system's fundamental equations can in principle be utilized to. This can be seen in the striking successes --- predict the values of those variables at any later time in that regions --- of Newtonian mechanics, special relativity, general relativity, electromagnetic theory, and even in classical thermodynamics.

De Broglie and Bohm and Ontology

EINSTEIN ----- "Wave to Particle"

De Broglie ---- "Particle to Wave"

Phase Wave Animation

De Broglie -- Particle and Wave Speeds



Figure I. A sketch showing the Slits (A and B) through which electrons pass on their way to the Screen. The Intensity pattern results from quantum interference and emerges after a large enough number of electrons have struck the screen. Where the "intensity" at a point on the screen is large there is a relatively large number of electrons. There is one place on the screen, at about the center, where the intensity is largest. The next-largest intensity occurs at about the same distance on each side of the center. [An actual build-up of such an interference pattern, when successively larger numbers of electrons is used, has been shown in the American Journal of Physics article by A. Tonomura, *et al.*, February 1989 issue.]

Electrons passed through a Double **Slit: Experimental Results showing** Pattern of landings on Screen by Tanamura



So...:Between the Slits and Screen: (1) Where is each Particle? and (2) How Fast and in What Direction is it moving? (3) Usual Answer **İS...**

Double-Slit Experimental Results

"Great Smoky Dragon"



Figure 2.* The (edited) "smoky dragon" of J. A. Wheeler. [From "Niels Bohr: A Centenary Volume", ed. by A. P. French and P. J. Kennedy (Harvard University Press, Cambridge, 1985), p. 151. Drawing is by Field Gilbert.] Besides shading in the head and tail somewhat I have also inserted a ? into the dragon's smoke to emphasize that this region is a mystery so far as a particle's position and momentum values are concerned. **Arkhimedes* paper

APPLICATIONS: LOCAL*

Applications come from the domain of nonrelativistic quantum theory.

• A Local Case

One form of an "equation of motion" is the (usual) local Schrödinger equation

$$\begin{array}{ccc} & \mathcal{K}\mathcal{E} & \mathcal{F}\mathcal{E} \\ \mathcal{E} & \mathcal{P}\mathcal{E} \\ -\frac{\hbar^2}{2M} \nabla^2 \phi - i\hbar \partial_4 \phi + U \phi = 0 \end{array} \tag{4.1}$$

where D^* stands for the **4-dimensional region** and ϕ is a function of x

[standing for $(x^k; k=1, 2, 3, 4)$], ϕ is the Schrödinger wave function, U is a local potential, ∂_4 is

the **partial derivative with respect to the time** coordinate x⁴, and **M** is the **particle's mass**,

 $\hbar = \text{Planck's constant}/2\pi$, and $i = \sqrt{-1}$. A result of the Bohm-de Broglie formalism is.

^{*} L.I. Gould (1989), "Nonlocal Conserved Quantities, Balance Laws, and Equations of Motion", International Journal of Theoretical Physics **28**, No. 3



Figure 3. The quantum potential for the two-slit experiment. [From D. Bohm and B.J. Hiley, "The Ontological Basis for the Quantum Theory", "I. Non relativistic particle systems", Phys. Reports 144, 32 (1987).]



Notice the valleys get

Quantum Potential at Screen

INCREASING DISTANCE FROM DOTS RESULTS IN APPARENT <u>INCREASE</u> IN HEIGHTS OF MOUNTAINS AND RIDGES (and VICE VERSA)

Central Mountain Peak

here ____

1st Circular Valley surrounding Mountain Peak approx.

here

2nd Circular Valley Surrounding 1st Circular Valley approx. here



Figure 4. Rings of Mountains and Valleys Seen from Above [from *Tiede 2000* (May 1992); I thank Professor Stig Stenholm (Research Institute for Theoretical Physics, University of Helsinki) for bringing this picture to my attention and Dr. Paavo Pylkkänen (Philosophy Department, University of Helsinki) for translating the title].

Quantum Potential In Action



Figure 5. Trajectories from a random distribution of electrons emerging from the two slits (at A and B). [From "The Undivided Universe" (Ref. 1) which refers to the original paper by C. Philippidis, C. Dewdney, and B. J. Hiley} Nuovo Cimento **52B**, 15 (1979).]

Does one now have a Deterministic Causal Theory?

Bohm considers the wave function in a state of random fluctuation arising from a deeper subquantum-mechanical level. ----> Each trajectory shown due to the average motion arising from the particle's tiny fluctuations caused by those nondeterminable (at least so far!) fluctuations. So, as Bohm mentions, his "interpretation, while being *causal,* is not strictly *deterministic*."¹²

¹²David Bohm and F. David Peat, "Science, Order, and Creativity" (Bantam Books, New York, 1987), p. 97. Further discussion at a somewhat technical level can be found in Ch. 4 of David Bohm, "Wholeness and the hnplicate Order" (Routledge & Kegan Paul, London, 1980).

The Wave Function as a Measure of Probability or...?

 $\int \psi(x)\psi^*(x)dx = 1$ "MATTER" WAVE FUNCTION

CAUSALITY (part of Metaphysics)

- Conservation of Energy is a principle of physics which has causality built in. The principle states that In a closed system the total amount of energy remains constant in time. So if you find you're missing some energy, you have to look further, for the "energy books" must be balanced. Note this explains why and how a stone dropped from one's hand speeds up as it falls toward Earth.
- Probability as a measure of one's lack of knowledge. Probability, per se, is not observed in nature. It is an estimate of <u>our</u> view of an event's frequency based on our view of the <u>constraints</u> under which the event may occur. That is true for the coins as well as for particles which nature distributes according to B-E or F-D statistics. You don't see the distribution directly. You see the results predicted by one or the other statistics.
- **Bohm-de Broglie:** Probability does not propagate. The matter wave propagates

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- CAUSALITY & PROBABILITY

References [portions of the preceding have been freely taken from the following references, each by L.I. Gould]

"Noether's Invisible Hand — A way of *Directly* Relating Both Local and Nonlocal Dynamical Laws to their Associated Conservation Laws" for *Symmetry: Culture and Science* **29**, No. 4, pp. 487 – 505 (2018)

"Towards a More Causal Interpretation of Quantum Mechanics: The Ontological Interpretation of David Bohm," *Arkhimedes* **45**, No. 2, 144 - 157 (1993)