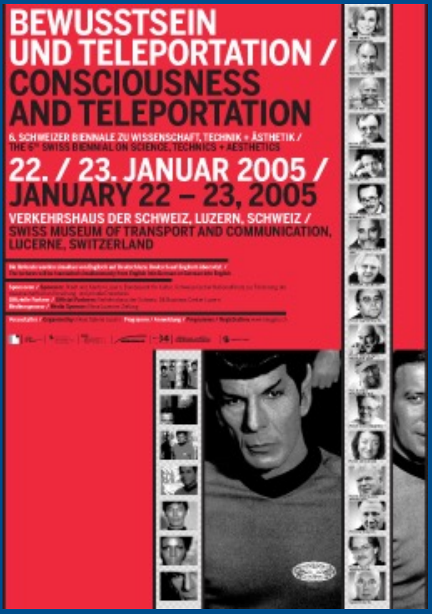

HOW DEEP INTO PHILOSOPHY HAS RECENT PHYSICS CARRIED US?

WIE TIEF IN DIE PHILOSOPHIE HINEIN REICHT DIE NEUE PHYSIK?

Abner Shimony (1928)

Boston University

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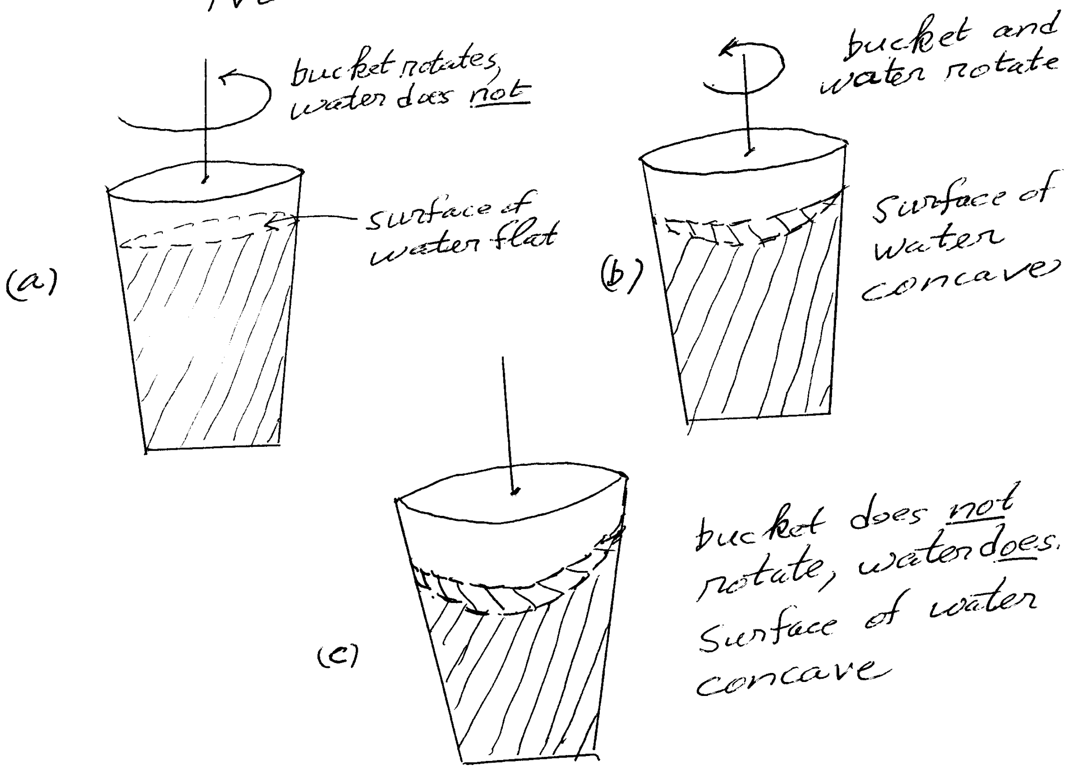
Newton's water-bucket experiment



Lorentz transformations from S to S′:

$$z' = (z - vt)/(1 - v^2/c^2)^{1/2}$$

$$x' = x$$

$$y' = y$$

$$t' = (t - Vz/c^2)/(1 - v^2/c^2)^{1/2} \qquad (1)$$

Newtonian transformations from S to S″:

$$z'' = (z - vt)$$

$$x'' = x$$

$$y'' = y$$

$$t'' = t. \qquad (2)$$

Spatial distance squared in S from P_1 to P_2

$$= (z_2 - z_1)^2 + (x_2 - x_1)^2 + (y_2 - y_1)^2$$

$$= (z''_2 - z''_1)^2 + (x''_2 - x''_1)^2 + (y''_2 - y''_1)^2$$

$$= \text{Spatial distance squared in } S''; \qquad (3)$$

hence, the spatial distance squared is preserved by the Newtonian transformation (2).

Spatial distance squared in S'

$$= (z_2 - z_1)^2/(1 - v^2/c^2) + (x_2 - x_1)^2 + (y_2 - y_1)^2 \qquad (4)$$

(calculated by the Lorentz transformations of Eq. (1)) is **not the same** as in S because of division by $(1 - v^2/c^2)$ in the first term.

What **is** preserved under the Lorentz transformation (1) is the **space-time interval squared**:

$$(z_2 - z_1)^2 + (x_2 - x_1)^2 + (y_2 - y_1)^2 - c^2(t_2 - t_1)^2 \equiv [\Delta(P_1,P_2)]^2 , \qquad (5)$$

Quantum state of a particle

Typically the state of a single particle is expressed in the position basis by a function $\psi(\mathbf{r})$, a part of whose meaning is that if the particle is subjected to a position measurement, the probability that it will be found in a small region $d\mathbf{r}$ about $\mathbf{r}$ is $|\psi(\mathbf{r})|^2 d\mathbf{r}$, which is the absolute value squared of the function $\psi(\mathbf{r})$ multiplied by the volume of the small region dr. But this rule does not exhaust the physical meaning of $\psi(\mathbf{r})$, because there are rules for extracting from it the probability of all possible results of all other properties which can be meaningfully ascribed to the particle; and furthermore, there is no information about its possible future behavior that is not implicit in the function $\psi(\mathbf{r})$.

Heisenberg on potentiality

The quantum state "contains statements about possibilities or better tendencies ('potentia' in Aristotelian philosophy), and these statements are completely objective, they do not depend on any observer."

There are three aspects of objectivity in the network of potentialities constituting a specific quantum state: objective indefiniteness (manifested when properties like position and momentum cannot be simultaneously precise according to the Uncertainty Principle; objective chance, when the outcome of an experiment performed on a system cannot in principle be predicted on the basis of complete knowledge of the system itself and of the apparatus with which it interacts; and objective probability, whereby the various possible outcomes are endowed with different tendencies to be actualized.

Schroedinger on entanglement

If σ_1 and σ_2 are two systems, each associated with a space of quantum states, the composite system $\sigma_1 + \sigma_2$ is associated with a space of quantum states constructed from quantum states of the constituents σ_1 and σ_2. A typical state of the composite system is $\varphi_i \times \psi_j$, where φ_i and ψ_j are respectively quantum states of the two constituents. Furthermore, a much larger class of quantum state of the composite system can be constructed by the superposition principle of QM, states of the form

$$\Psi = \Sigma_i \Sigma_j [\varphi_i \times \psi_j],$$

from which probabilities can be calculated by standard rules

Some of these states of a composite sytem are product states, expressible as a product of respective single states of the constituents. But the novel and metaphysically significant states of a composite system are those which cannot be expressed in any way whatever as a product. These were named "entangled states" by Schroedinger.

Peaceful Coexistence of Special Relativity Theory and Quantum Mechanics