Article Outlines

Barrett, T. W. (2008). Topological Foundations Of Electromagnetism. Hackensack, NJ: World Scientific.

Motivation

Maxwell’s equations are foundational to electromagnetic theory. They are the cornerstone of electrostatics. However, there are some phenomena that cannot be explained by the conventional Maxwell theory. The conventional Maxwell theory must be extended, or generalized, to a non-Abelian form. It explains, the majority of cases in electromagnetism, however it is the topology of the spatiotemporal situation that can explain the outlying effects. The most basic explanation of electromagnetic phenomena and their physical models lies not in differential calculus or group theory, but in the topological description of the (spatiotemporal) situation.

Anomalous Electromagnetic Phenomena not explained by Maxwell’s Equations

Field(s)→free electron(F→FE), field(s)→conducting electron(F→CE), field(s)→particle(F→P), wave guide→field (WG→F), conducting electron→field(s (CE→F), and rotating frame→field(s)(RF→F)interactions.

1. The Aharonov–Bohm and Altshuler–Aronov–Spivak effects. Ehrenberg and Siday, Aharonov and Bohm,and Altshuler, Aronov and Spivak predicted experimental results by attributing physical effects to the potentials. Most commentaries in classical field theory still show these potentials as mathematical conveniences without gauge invariance and with no physical significance.
2. The topological phase effects of Berry, Aharonov, Anandan, Pan-charatnam, Chiao and Wu (WG→F and F→P). In the WG→F version, the polarization of light is changed by changing the spatial trajectory adiabatically. The Berry–Aharonov–Anandan phase has also been demonstrated at the quantum as well as the classical level. This phase effect in parameter (momentum) space is the correlate of the Aharonov–Bohm effect in metric (ordinary) space, both involving adiabatic transport.
3. The Josephson effect (CE→F). At both the quantum and the macro physical level, the free energy of the barrier is defined with respect to an potential variable (phase)
4. The quantum Hall effect(F→CE). Gauge invariance of the vector potential, being an exact symmetry, forces the addition of a flux quantum to result in an excitation without dependence on the electron density.
5. The De Haas–Van Alphen effect(F→CE). The periodicity of oscillations in this effect is determined by potential dependency and gauge invariance.
6. 6.The Sagnac effect (RF→F). Exhibited in the well-known and well-used ring laser gyro, this effect demonstrates that the Maxwell theory, as presently formulated, does not make explicit the constitutive relations of free space, and does not have a built-in Lorentz invariance as its field equations are independent of the metric  
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The potentials have been demonstrated to be physically meaningful constructs at the quantum level, at the classical level.