Space, time and motion: From Newton to Einstein and Beyond

Mathematical Physics—Kon, Levichev & Stachel

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Options: 2012-2013 GUTS Funding, Volunteer Basis, Potential for UROP Funding, and Potential for Academic Credit

Math/physics students are invited to take on research projects under the supervision of the above BU mentors who have been awarded the BU 2012-2013 GUTS grant. Each of the mentors will present an approach to some current questions in a way which makes it possible for a motivated undergraduate to start working on a research project on one of these topics after a semester of studies. A (non-credit) BU course "Space, time and motion: From Newton to Einstein and Beyond" starts in the Spring 2013 semester. "Beyond" will include discussion of Unimodular Conformal Projective Relativity (UCPR) by Stachel, and of the DLF approach by Levichev. The class will meet once a week at a time to be agreed upon by the students.

Students considering this course may want to look at Stachel's "Albert Einstein: A Man for the Millenium?" http://math.bu.edu/people/levit/AlbertEinstein.pdf , which will be discussed at the first session.

Topics that will be covered in the course include:

Distinction between *geometry* and *algebra*

Groups and their representation as transformation groups

Klein approach: A geometry is defined by invariance under a group of transformations acting on the points of some space

Geometries: Consist of two distinct structures: metrics (invariant under local transformations at a point) and connections (invariant under global transformations between points), and compatibility conditions between them.

Distinction between *Mathematics* and *Physics*: Physics introduces *units*, and it is only the *ratio* between a physical quantity and its unit that can be treated as part of a mathematical structure.

Chrono-geometry: The properties of time and space are separate in Newtonian theory; special and general relativity lead to their combined representation by a pseudoRiemannian-metric

Inertio-gravitational field: Inertial motions and gravitational forces are separate in Newtonian throry: The equivalence principle leads to their combined representation by an affine connection in any physical theory.

Four space-time structures: Neither pseudo-metric nor affine connection is mathematically irreducible: pseudo-metric splits into conformal metric and scalar field; affine connection splits into projective connection and one form, leading to Unimodular Conformal Projective Relativity (UCPR).

Background-dependent theories: Space-time structures are fixed and given. Levichev and DLF theory. The D part of the theory is known as Segal's Chronometry. Here D refers to its space-time which has a Lie group structure. I. Segal (1918-1998) has long been known as one of the leading mathematicians of the 20th century. Around 2003 Dr. Levichev developed the DLF theory (where L and F are two other related space-times), the L and F parts of which are currently more conjectures than established mathematical theories (more details about the DLF approach can be found on http://math.bu.edu/people/levit). Professor Kon, who studied under and collaborated with Prof Segal, and Dr. Levichev are doing joint research on DLF theory.

Background-independent theories: Space-time structures themselves obey field equations, study of possible field equations for the four background-independent structures (more details about UCPR can be found in Stachel, " Quantum Gravity: A Heretical Vision," http://math.bu.edu/people/levit/QuantumGravity.pdf and Kaća Bradonjić, "Unimodular Conformal and Projective Relativity and the Compatibility of Causal and Dynamical Space-Time Structures" http://math.bu.edu/people/levit/40thAnn.pdf)