LPS 241: Foundations of Classical Field Theory (Fall & Winter 2013–14)
Draft Syllabus of November 12, 2013

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Lectures: Tu/Th 3:30-4:50 in SSL 152
Office Hours: Th 11:00-12:00

Description: This two-quarter sequence will provide an introduction to differential geometry and classical field theory, including general relativity, Newtonian gravitation, and Yang-Mills theory. Our presentation will differ from a course on these topics offered in a physics or mathematics department in that the emphasis throughout will be on the "foundations" of these physical theories. Some specific topics to be covered may include the logical structure of the theories; the geometrical interpretations of Einstein's equation, the Yang-Mills equation, and "gauge" potentials; the status, interpretation, and relations between various principles of symmetry and conservation; the causal and topological structure of spacetime; and the relationships between general relativity, the "geometrized" formulation of Newtonian gravitation, and theories of force and matter.

Prerequisites: Though there are no formal prerequisites for this course, I will mostly take for granted a background in basic undergraduate mathematics and physics, including calculus in several variables, point-set topology, abstract algebra, special relativity, and Newtonian gravitational theory.

Course Website: https://eee.uci.edu/13f/66339 (password: kretschmann)

Course Texts:
Topics in the Foundations of General Relativity and Newtonian Gravitation Theory, by David Malament.
Notes on Fiber Bundles, Connections, and the Foundations of Classical Field Theories (available online).

Notes on Reading: Most of the course will follow Malament's book closely (with some minor rearrangement). However, I plan to supplement it in some places to discuss additional topics. In these instances, my presentation will follow my Notes on Fiber Bundles, Connections, and the Foundations of Classical Field Theories. This latter document is constantly evolving, but I will alert you when I make significant changes. A bibliography of supplementary texts will be maintained on the course website.

Requirements: Auditors are welcome; all that is required for an S is regular attendance and occasional participation. If you would like a grade, you will need to submit written work. The requirements for the first quarter will be problems from Malament (2012) and from my lecture notes, as I will describe in class. For the second quarter, the requirement will be a ∼10-15 page paper, the topic of which will need to be approved in advance. (Ideally, we will work closely on the paper before you submit it.)

Collaboration: You are encouraged to collaborate on the problem sets, though everyone needs to produce his or her own write-up. If you do collaborate, you should indicate as much on top of the problem set before turning it in. Also, while working on the problems, please feel free to talk with me as much as you like.

Course Schedule: The basic structure will be that the first quarter will be devoted to mathematical topics in differential geometry and the second quarter will be devoted to general relativity, Newtonian gravitation, and classical Yang-Mills theory. A more precise (though still-rough) outline is below; however, I do not intend to force the pace of the course to stick to a particular schedule and so we may not reach all of the topics mentioned here (and we may have time for additional topics).

Fall Quarter

Fall Week 0	
Thursday	Introduction; manifolds
Fall Week 1	
Tuesday	Manifolds (cont.)
Thursday	Manifolds (cont.); smooth maps and diffeomorphisms
Fall Week 2	
Tuesday	Tangent vectors
Thursday	Tangent vectors
Fall Week 3	
Tuesday	Vector fields and integral curves
Thursday	Tensors and tensor fields; abstract index notation
Fall Week 4	
Tuesday	Pushforward and pullback maps; submersions and immersions
Thursday	(Embedded) submanifolds; fiber bundles
Fall Week 5	
Tuesday	Bundle morphisms; cross sections and lifts
Thursday	Lie derivatives
Fall Week 6	
Tuesday	Covariant derivative operators; exterior derivatives
Thursday	Ehresmann connections
Fall Week 7	
Tuesday	Ehresmann connections (cont.); parallel transport and holonomy
Thursday	Curvature
Fall Week 8	
Tuesday	Metrics
Thursday	Metrics (cont.)
Fall Week 9	
Tuesday	Metric submanifolds; volume elements
Thursday	Lie groups
Fall Week 10	
Tuesday	Lie algebras
Thursday	Principal and associated bundles
Fall Week 11	
Extra session (TBD)	Connections and curvature on principal bundles

Winter Quarter

Winter Week 1	
Tuesday (1 October 2013)	Relativistic spacetimes
Thursday (3 October 2013)	Temporal orientation and causal connectibility
Winter Week 2	
Tuesday (8 October 2013)	Proper time; particle dynamics
Thursday (10 October 2013)	The energy-momentum field
Winter Week 3	
Tuesday (15 October 2013)	Einstein's equation
Thursday (17 October 2013)	Einstein's equation (cont.)
Winter Week 4	
Tuesday (22 October 2013)	Fluid flow
Thursday (24 October 2013)	Cosmological solutions
Winter Week 5	
Tuesday (29 October 2013)	Electromagnetic fields
Thursday (31 October 2013)	Yang-Mills fields
Winter Week 6	
Tuesday (5 November 2013)	Yang-Mills fields
Thursday (7 November 2013)	Klein-Gordon fields; the Aharanov-Bohm effect
Winter Week 7	
Tuesday (12 November 2013)	Lagrangian field theory
Thursday (14 November 2013)	Lagrangian field theory
Winter Week 8	
Tuesday (19 November 2013)	Lagrangian field theory
Thursday (21 November 2013)	Symmetries and conserved quantities
Winter Week 9	
Tuesday (26 November 2013)	Classical spacetimes
Thursday (28 November 2013)	Geometrized Newtonian gravitation
Winter Week 10	
Tuesday (3 December 2013)	Geometrized Newtonian gravitation (cont.)
Thursday (5 December 2013)	Classical cosmology