LPS 241: Foundations of Classical Field Theory
Winter & Spring 2017

Instructor: Jim Weatherall
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Lectures: Tu/Th 3:30pm-4:50pm in SSL 171
Office Hours: Th 11:00am-12:00pm

Description: This two-quarter sequence will provide an introduction to differential geometry and classical field theory, including general relativity and Yang-Mills theory. If time permits we will also cover the geometrized formulation of Newtonian gravitation or other special topics, depending on class interest. 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 will include the logical structure of the theories; the geometrical significance 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 and theories of force and matter.

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

Course Website: https://eee.uci.edu/17w/66730 (password: kretschmann)

Course Texts:
Topics in the Foundations of General Relativity and Newtonian Gravitation Theory, by David B. Malament.

Classical Field Theory Lecture Notes (available online).

Notes on Reading: Much of the course will follow Malament's book closely (with some minor rearrangement). However, I will supplement it in some places to discuss additional topics. In these instances, my presentation will follow my Classical Field Theory Lecture Notes. 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; in cases where these are available online, they will be linked to.

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. I prefer typed problem sets and value careful presentations that show your work. (Learn Latex.) 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, classical Yang-Mills theory, and other special topics. 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 cover a sub- or superset of these topics.

Syllabus date: January 6, 2017

Winter Quarter

Week 1		
	Tuesday	Introduction; manifolds
	Thursday	Manifolds (cont.); smooth maps and diffeomorphisms
Week 2		
	Tuesday	Tangent vectors
	Thursday	Vector fields and integral curves
Week 3		
	Tuesday	Covectors and tensor fields
	Thursday	Covectors and tensor fields (cont.)
Week 4		
	Tuesday	**No class**
	Thursday	**No class**
Week 5		
	Tuesday	Pushforward and pullback maps; submersions and immersions; submanifolds
	Thursday	Fiber bundles
Week 6		
	Tuesday	Bundle morphisms; cross sections and lifts
	Thursday	Lie derivatives; Covariant derivative operators
Week 7		
	Tuesday	Covariant derivative operators (cont); exterior derivatives
	Thursday	Ehresmann connections
Week 8		
	Tuesday	Parallel transport and holonomy
	Thursday	Curvature
Week 9		
	Tuesday	Metrics
	Thursday	Metrics (cont.); metric submanifolds; volume elements
Week 10		
	Tuesday	Lie groups and Lie algebras
	Thursday	Principal and associated bundles
Week 11		
	TBD	Connections and curvature on principal bundles

Spring Quarter

Week 1

Tuesday	Relativistic spacetimes; temporal orientation and causal connectibility
Thursday	Proper time; space-time decomposition; particle dynamics

Week 2

Tuesday	The energy-momentum field
Thursday	Einstein's equation

Week 3

Tuesday	Fluids
Thursday	FLRW Spacetimes

Week 4

Tuesday	Killing fields & conserved quantities
Thursday	Electromagnetic fields

Week 5

Tuesday	Electromagnetic fields (cont.)
Thursday	Yang-Mills fields

Week 6

Tuesday	Matter fields
Thursday	Lagrangian field theory

Week 7

Tuesday	Lagrangian field theory
Thursday	**No class**

Week 8

Tuesday	Hyperbolic systems
Thursday	**No class**

Week 9

Tuesday	Hyperbolic systems
Thursday	Initial value formulation

Week 10

Tuesday	Classical Spacetimes
Thursday	Geometrized Newtonian Gravitation