Classical Field Theory - Video course

COURSE OUTLINE

The course introduces the student to relativistic classical field theory. The basic object is a field (such as the electromagnetic field) which possesses infinite degrees of freedom. The use of local and global symmetries (such as rotations) forms an underlying theme in the discussion.

Concepts such as conservation laws, spontaneous breakdown of symmetry, Higgs mechanism etc. are discussed in this context. Several interesting solutions to the Euler-Lagrange equations of motion such as kinks, vortices, monopoles and instantons are discussed along with their applications.

The Standard Model of particle physics is used to illustrate how the various concepts discussed in this course are combined in real applications. All necessary mathematical background is provided to make the course self-contained. This course may also be considered as a prelude to Quantum Field Theory.

COURSE DETAIL

Topics **(Mathematical topics are given in parentheses)**	**No. of Lectures** **1 hr each**
Review of Classical Mechanics: Hamiltonians and Lagrangians. Legendre transforms and their properties. Euler-Lagrange equations. Principle of least action. (Functional calculus.) What is classical field theory?	1
Vectors and Tensors: Group theory from invariances of classical equations. Newton's equations and the Galilean group. Maxwell's equations. Special Relativity and the Lorentz group. Vectors and tensors of the rotation and Lorentz groups. (Basics of group theory: definition, discrete groups and matrix groups.)	4
Basics of CFT: Systems with infinite degrees of freedom. Locality in space and time. Lagrangian densities for real and complex scalar fields. Euler-Lagrange (EL) equations. Functional calculus revisited. Hamiltonian density. The energy-momentum tensor.	3
Solutions to the EL equations:	4

NP-TEL

NPTEL

http://nptel.iitm.ac.in

Physics

Pre-requisites:

1. Classical Mechanics, Electromagnetism (and possibly the special theory of relativity).

Additional Reading:

1. A. Zee, *Fearful Symmetry: The Search for Beauty in Modern Physics*, Princeton Univ. Press (2007).

Hyperlinks:

1. http://sgovindarajan.wikidot.com/cftontheweb

Coordinators:

Prof. Suresh Govindarajan
Department of PhysicsIIT Madras

Finite-energy time-independent solutions -- classical vacua. Kinks in the Sine-Gordon and φ^4 theories. Green functions as singular solutions. Boundary conditions.	
Symmetries and Conservation Laws: Discrete and continuous symmetries. Noether's theorem: the energy momentum tensor, the generalized angular momentum and the electromagnetic current. (Lie groups and Lie algebras. Representations of groups.)	4
The massless vector field: The Lagrangian density. Gauge invariance and the electromagnetic field strength. Maxwell's equations. Lorentz invariants of the field strength. The symmetrized energy-momentum tensor. The generalized angular momentum and the spin of the photon.	3
Secret Symmetry: Global symmetries. Spontaneous breakdown of symmetry. Goldstone's theorem. (Coset spaces in group theory.)	3
Solitons: Solitons as finite-energy solutions. Derrick's theorem. Getting around Derrick's theorem. Local symmetries and gauge fields. Abelian vortices. The Dirac monopole as a singular solution of Maxwell's equations. Dirac quantization.	4
Local Symmetries: Abelian gauge fields. Covariant derivatives and minimal coupling. The abelian Higgs model. Vortex solutions (in type II superconductors). Topological conservation laws. The abelian Higgs mechanism.	4
Non-abelian gauge theories: Covariant derivatives; The Yang--Mills field strength; Coupling matter to non-abelian gauge fields; Higgs mechanism - $SU(2) \to U(1)$ and $SO(3) \to U(1)$; Weinberg's theorem. The 't Hooft-Polyakov monopole as a non-singular solution. Julia-Zee dyons; the Bogomolnyi-Prasad-Sommerfield(BPS) limit. Dirac quantization for dyons.	6
The Standard Model of Particle Physics as a CFT: Basic forces in nature. Symmetry breaking in the electroweak sector. Quantum Chromodynamics and the quark model.	2

Instantons: Instantons as finite action solutions to the EL equations.The 't Hooft solution. Nahm and Bogomolnyi equations from dimensional reduction.	2

References:

1. L. D. Landau and E. M. Lifshitz, *The Classical Theory of Fields*, Pergamon (1975).
2. M. R. Spiegel, *Vector Analysis*, Schaum Outline Series, McGraw-Hill (1974).
3. M. Carmeli, *Classical Fields*, Wiley (1982).
4. A. O. Barut, *Electrodynamics and Classical Theory of Fields*, Chap. 1,Macmillan (1986).
5. C. Itzykson and J. B. Zuber, *Quantum Field Theory*, Chap. 1, McGraw-Hill (1986).
6. S. Coleman, *Aspects of Symmetry*, Cambridge Univ. Press.
7. R. Rajaraman, *Solitons and Instantons*, North-Holland.