

PHY 781 - High Energy Physics II

First Course Handout

Indian Institute of Technology, Kanpur

First Course Handout

High Energy Physics - II - PHY 781

Instructor: Joydeep Chakraborty (joydeep@iitk.ac.in)

Lectures: Tuesday and Friday (3:30 PM - 4:45 PM)

Evaluation: Mid Sem (20%), Final Sem (40%), Project (40%)

Topics

Broad Title	Topics
Regularisation	Ultraviolet divergences in QFT. Cutoff, Pauli-Villars, dimensional, lattice and heat-kernel/zeta-function regularisation. Regulators and symmetries (gauge invariance, chiral symmetry).
Renormalisation	Power counting; renormalisable and non-renormalisable theories. Counterterms and renormalisation schemes (on-shell, MS, MS-bar). Renormalisation of scalar theory, QED and non-abelian gauge theories. BRST symmetry and Slavnov-Taylor identities.
Renormalisation Group	Callan-Symanzik equation, beta functions and anomalous dimensions. Running couplings, asymptotic freedom, fixed points and critical exponents. Wilsonian renormalisation group and effective theories.
Anomalies	Axial (ABJ) anomaly via diagrams and the Fujikawa method. Trace anomaly. Gauge anomalies and their cancellation in the Standard Model. Wess-Zumino consistency conditions, 't Hooft anomaly matching, $\pi^0 \rightarrow \gamma\gamma$. Witten (global SU(2)) anomaly. Topological aspects of anomalies and the Atiyah-Singer index theorem.
Solitons	Topological charge and Bogomolny bound. Kinks and sine-Gordon model, vortices, 't Hooft-Polyakov monopole, skyrmions. Quantisation of soliton solutions.
Instantons	Tunnelling and Euclidean saddle points. BPST instanton in Yang-Mills theory, θ -vacua, fermion zero modes. $U(1)_A$ problem and the strong CP problem.

Recommended References

- 1 M. E. Peskin and D. V. Schroeder, An Introduction to Quantum Field Theory, Westview Press (1995).
- 2 S. Weinberg, The Quantum Theory of Fields, Vol. II: Modern Applications, Cambridge University Press (1996).
- 3 S. Coleman, Aspects of Symmetry, Cambridge University Press (1985).
- 4 R. Rajaraman, Solitons and Instantons, North-Holland (1982).

- 5 R. A. Bertlmann, *Anomalies in Quantum Field Theory*, Oxford University Press (1996).
- 6 K. Fujikawa and H. Suzuki, *Path Integrals and Quantum Anomalies*, Oxford University Press (2004).
- 7 N. Manton and P. Sutcliffe, *Topological Solitons*, Cambridge University Press (2004).
- 8 V. A. Rubakov, *Classical Theory of Gauge Fields*, Princeton University Press (2002).
- 9 J. Collins, *Renormalization*, Cambridge University Press (1984).
- 10 K. G. Wilson and J. Kogut, The renormalization group and the ϵ expansion, *Phys. Rep.* 12 (1974) 75–199.
- 11 J. Polchinski, Renormalization and effective Lagrangians, *Nucl. Phys. B* 231 (1984) 269–295.
- 12 A. Vandoren and P. van Nieuwenhuizen, Lectures on instantons, [arXiv:0802.1862](https://arxiv.org/abs/0802.1862).