London Theory Institute
Lectures Series

Nadav Drukker

“ An Introduction to Observables in Gauge Theories”

Informations
Pre-recorded Lectures :
Youtube
Live Tutorial :
Monday 15th of
November, 10h30

Abstract

Gauge theories are ubiquitous in theoretical physics, not to mention that the standard model is one. It is therefore of utmost importance to know what the observables of these theories are, quantities that can be calculated and measured. I start with a long discussion based on the most familiar gauge theory, Maxwell's electromagnetism, where a lot of computations can be done explicitly. I then take the lessons from that to non-abelian gauge theories. The observables covered are local, Wilson loops, and briefly 't Hooft loops and surface operators.

Introduction to Observables in Gauge Theories

Nadav Drukker

Exercises

1. a) For Maxwell theory in 4d take a contour that is a straight line along the x^0 axis and solve the equations of motion with the source $\int A_0\, dt$.

   b) For Maxwell theory in 2d, where there is only one component of F, say F_{12}, take $\mathcal{C}$ to be any simple closed curve in the plane and solve for F requiring that it goes to zero at infinity.

2. a) Reevaluate the parallel lines Wilson loop using propagators.

   b) Reevaluate the circular Wilson loop using classical electrostatics (it is useful to remember that Maxwell theory in 4d is conformal).

3. a) Evaluate the cusp at angle ϕ by exponentiating the propagator.

   b) Do it by using electrostatics.

4. Plaquette: Consider a Wilson loop along a an arbitrary contour $\mathcal{C}$ in Yang-Mills theory. Assume that it passes the point $x^\mu = 0$ along the x^1 axis. Consider a deformation of the contour, which adds a small bump going first a distance ϵ in the x^2 axis, then ϵ in the x^1 direction and then back in the $-x^2$ directions and connect to the original line.

   Express the new Wilson loop with a plaquette in terms of the original Wilson loop with an operator inserted to order ϵ^2.

5. a) Define operator insertions into an 't Hooft loop. What are the simplest insertions?

   b) Likewise for the surface operator.

References

A lot of the material is based on my own redoing of classic results you can find in any E&M and QFT books.

I highly recommend the original papers of Wilson and 't Hooft

1. Wilson, K. (1974). "Confinement of quarks". Physical Review **D10** (8): 2445. DOI:10.1103/PhysRevD.10.2445.

2. G.'t Hooft (1974). "A planar diagram theory for strong interactions". Nucl. Phys. **B72**(3), 461–473. DOI:10.1016/0550-3213(74)90154-0.

3. G.'t Hooft (1974). "On the phase transition towards permanent quark confinement". Nucl. Phys. **B138**(3), 1–25. DOI:10.1016/0550-3213(78)90153-0.

4. A. Kapustin (2006) "Wilson-'t Hooft operators in four-dimensional gauge theories and S-duality". Phys. Rev. **D74** 025005, hep-th/0501015.

5. N. Drukker and V. Forini (2011) "Generalized quark-antiquark potential at weak and strong coupling". JHEP **06** 131, arXiv:1105.5144.