Master in Mathematical and Theoretical Physics

Supersymmetry & Supergravity
Mini-Project HT2025

Topic: Extended Supersymmetry in Gauge Theories

Write a report on $\mathcal{N} > 1$ supersymmetric gauge theories. Your report should cover the points:

- For general $\mathcal{N} > 1$ supersymmetric theories, analyse the case of massive representations with non-vanishing central charges, including short supermultiplets and BPS states.

For $\mathcal{N} = 2$ supersymmetry:

- Derive super Yang-Mills (SYM) theory, namely its Lagrangian density. You should also discuss the supermultiplets and relevant R-symmetry.
- Add short massive hypermultiplets to SYM theory. Describe the additional supermultiplets. Derive with a reasoned explanation the most general possible renormalizable superpotential, and compute the total Lagrangian density.
- Choose one of the following options:
    1. Conduct a complete analysis of supersymmetry and gauge symmetry breaking in SYM theory. Then specify to the case of $SU(3)$ gauge group, and provide a detailed discussion of the symmetry breaking.
    2. Provide a detailed discussion of any pertinent R-symmetry in the theory of SYM with short massive hypermultiplets.

These topics are described in various textbooks, online lecture notes, and original research papers cited therein, for example:

- M. Bertolini, Supersymmetry From the Basics to Exact Results in Gauge Theories, ch. 6
- S. Weinberg, The Quantum Theory of Fields Vol III Supersymmetry, ch. 27
- P. West, Introduction to Supersymmetry and Supergravity (2nd Edition), ch. 12

The report should be 10–15 pages with 1 inch margins, using 11 point font. For your report you may assume and make use of results and techniques in quantum field theory, general relativity, etc., that are covered in Master's level courses, such as those of the MTP program.

The report should not be merely a repetition of some lecture notes or follow a single textbook's treatment. Rather, you should consult and build on several sources, and ideally, original references or research literature. In your report indicate explicitly which ideas come from existing sources, and if appropriate, which are original. You should also make proper attribution for all of your sources. Your report need not contain original research done by yourself.