Skoltech
Skolkovo Institute of Science and Technology

Course Syllabus

Course Title (in English)	Supersymmetric Gauge Theories and Integrable Systems
Course Title (in Russian)	Суперсимметричные калибровочные теории и интегрируемые системы
Lead Instructor(s)	Gavrylenko, Pavlo Marshakov, Andrei

Status of this Syllabus	The syllabus is a final draft waiting for form approval
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1. Annotation

Course Description

The course will be devoted to the study of N=2 supersymmetric gauge theories and related topics. It turns out that comparing to the N=1 theories, N=2 allows to compute much more quantities. In particular, low-energy effective action can be described in terms of single function, prepotential. Seiberg-Witten solution of the N=2 theory gives explicit description of the prepotential in terms of periods of some meromorphic differentials on algebraic curves. It turns out that this description is deeply related to classical integrable systems.

During the course we will learn basics of the N=2 theories, classical solutions, holomorhy arguments, and so on, study Seiberg-Witten exact solution, and then its underlying integrable systems. We are also going to learn some modern developments of this topic, like Nekrasov instanton computations and AGT relation.

Course Prerequisites	Knowledge of quantum mechanics and classical field theory. Basic knowledge of quantum field theory. Basics of N=1 supersymmetry.

2. Structure and Content

Course Academic Level	Master-level course suitable for PhD students

Number of ECTS credits	6

Topic	Summary of Topic	Lectures (# of hours)	Seminars (# of hours)	Labs (# of hours)
Basics of N=2 SUSY	1) N=2 SUSY & lagrangians 2) N=2 algebra, superfields 3) Classical solutions: monopoles, instantons 4) Central charges			
Physicsl properties of N=2 theories	1) Vacua 2) Anomalies 3) 1-loop holomorphy			
Seiberg-Witten exact solution				
Integrable system	1) Simplest example of SU(2) pure gauge theory 2) Spectral curves and Seiberg-Witten theory			
Instantons and Nekrasov functions				
AGT duality				

3. Assignments

Assignment Type	Assignment Summary
Homework	There will be two tests (homeworks). One will be devoted to the basics of N=2 supersymmetry: supersymmetry algebra representations, Lagrangians, classical solutions. Another one will be devoted to classial integrable systems: compatibility of Seiberg-Witten equations, Lax matrices, separation of variables.

4. Grading

Type of Assessment	Graded

Grade Structure		
	Activity Type	**Activity weight, %**
	Attendance	50
	Homework Assignments	50

Grading Scale

A:	86
B:	76
C:	66
D:	56
E:	46
F:	0
Attendance Requirements	Optional with Exceptions

5. Basic Information

Students of Which Programs do You Recommend to Consider this Course as an Elective?

Masters Programs	PhD Programs
Mathematical and Theoretical Physics	Mathematics and Mechanics Physics

Course Tags	Math Physics

6. Textbooks and Internet Resources

Papers	DOI or URL
L. Alvarez-Gaume, S.F. Hassan, Introduction to S-Duality in N=2 Supersymmetric Gauge Theory. (A pedagogical review of the work of Seiberg and Witten)	https://arxiv.org/abs/hep-th/9701069
Adel Bilal, Duality in N=2 SUSY SU(2) Yang-Mills Theory: A pedagogical introduction to the work of Seiberg and Witten	https://arxiv.org/abs/hep-th/9601007
Monopole Condensation, And Confinement In N. Seiberg, E. Witten, N=2 Supersymmetric Yang-Mills Theory	https://arxiv.org/abs/hep-th/9407087
A. Marshakov, A. Yung, Strong versus Weak Coupling Confinement in N=2 Supersymmetric QCD	https://arxiv.org/abs/0912.1366

7. Facilities

8. Learning Outcomes

Knowledge
Seiberg-Witten of exact solution of N=2 supersymmtric gauge theory

Skill
Ability to perform computations on algebraic curves

9. Assessment Criteria

Input or Upload Example(s) of Assigment 1:

Select Assignment 1 Type	Homework Assignments
Input Example(s) of Assignment 1 (preferable)	

Sample problems:

1) Compute Poisson bracket of super-charges in the field theory and derive expression for the central charge. Compute its value on the monopole solution.

2) Write explicit component expansion of the Lagrangian in the Abelian N=2 sigma model.

3) Check that the derivative formula $dF/dz_i = \mathrm{res}_{z_i} (dS)^2/dz$ is compatible with Seiberg-Witten equations.

4) Compute the dimension of the Higgs branch in some simple SU(2) N=2 theory.

5) Compute derivatives of Seiberg-Witten differential in $N_c=2$, $N_f=4$ Seiberg-Witten theory. Which of them are meromorphic, and which can be made holomorphic by addition of some df?

Assessment Criteria for Assignment 1	Enough number of problems should be solved

Input or Upload Example(s) of Assigment 2:

Input or Upload Example(s) of Assigment 3:

Input or Upload Example(s) of Assigment 4:

Input or Upload Example(s) of Assigment 5:

10. Additional Notes

Upload a File (if needs to be)	https://ucarecdn.com/3725ea57-ab93-4210-87c9-572a3c0c1d94/