Skoltech

Course Syllabus

Course Title	Introduction to Two-Dimensional Conformal Field Theory
Course Title (in Russian)	Введение в двумерную конформную теорию поля
Lead Instructor	Litvinov, Alexey

1. Annotation

Course Description

Conformal field theories are relatively simple quantum field theories that serve as starting points for perturbation theory for more generic quantum field theories with the mass gap. In two dimensions, unlike higher dimensions, the algebra of conformal transformations is infinite-dimensional. As a result, it has been possible to exactly solve certain nontrivial two-dimensional conformal field theories. This course provides introduction to basic concepts of two-dimensional conformal field theory. We will review basic ideas of the bootstrap approach to quantum field theory and describe the mathematical structures that appear in conformal field theory: representation theory of the Virasoro algebra, differential equations of correlation functions, conformal blocks etc.

Course Description (in Russian)

Конформные теории поля — это относительно простые квантовые теории поля, которые служат стартовой точкой для теории возмущений для более общих квантовых теорий поля с массовой щелью. В двух измерениях, в отличие от высших измерений, алгебра конформных преобразований бесконечномерна. В результате удается точно решить некоторые нетривиальные двумерные конформные теории поля. В этом курсе мы введем основные понятия двумерной конформной теории поля. Мы рассмотрим основные идеи бутстрапного подхода в квантовой теории поля и опишем математические структуры, возникающие в конформной теории поля: теорию представлений алгебры Вирасоро, дифференциальные уравнения на корреляционные функций, конформные блоки и т. д.

2. Basic Information

Course Academic Level MSc PhD

Number of ECTS credits 6

Type of Assessment Graded

Mapping from grades to percentage:

A: 86

B: 76

C: 66

D: 56

E: 46

F: 0

Term Term 1-2

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

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

Maximum Number of Students

	Maximum Number of Students
Overall:	30
Per Group (for seminars and labs):	30

3. Course Content

Topic	Summary of Topic	Contact Hours: Lectures	Contact Hours: Seminars	Contact Hours: Labs	Non-contact Hours: Student's Independent Study
Basics of 2D conformal field theory	Classical field theory, Noether theorem, stress-energy tensor, scaling and conformal invariances, conformal group, conformal Ward identities, conformal families, Virasoro algebra, representation theory of Virasoro algebra, null-vectors, free bosonic CFT, free fermionic CFT, operator algebra in CFT, conformal blocks, Zamolodchikov recursion formula, BPZ differential equation and three-point function	20	20		52
Minimal models of conformal field theory	Fusion rules, truncation of operator algebra, Ising model, Tricritical Ising model, N = 1 SUSY CFT, Potts model, W −algebras, parafermionic CFT, Friedan Qiu and Shenker theorem, modular bootstrap for free theories and minimal models, ADE classification of	15	15		40

4. Learning Outcomes

Skoltech Learning Outcomes are indicated as per Skoltech Learning Outcomes Framework.

1. FUNDAMENTAL KNOWLEDGE

1.1. KNOWLEDGE OF MATHEMATICS AND NATURAL SCIENCES

2.1. COGNITION AND MODES OF REASONING

2.1.1. Analytical reasoning and problem solving

2.1.3. Creative thinking

2.1.4. Decision making (with ambiguity, urgency etc.)

2.2. ATTITUDES AND LEARNING PROCESS

2.2.2. Willingness to make decisions in the face of uncertainty

2.2.3. Responsibility, intensity, perseverance, urgency and will to deliver

2.2.4. Resourcefulness, flexibility and an ability to adapt

2.2.5. Self-awareness and a commitment to self-improvement, lifelong learning and educating

2.2.6. Development and support of teaching and learning community

2.3. ETHICS, EQUITY AND OTHER RESPONSIBILITIES

2.3.6. Commitment to social and professional behavior

3.1. COMMUNICATIONS IN INTERNATIONAL ENVIRONMENTS

3.1.2. Written, electronic and graphical communication

3.1.3. Oral presentation and discussion

3.1.4. Inquiry, listening and dialogue

3.1.5. Communications in English in scientific, business and social settings

3.2. TEAMWORK AND LEADERSHIP

3.2.1. Forming effective teams

3.3. COLLABORATION AND CHANGE

3.3.1. Establishing diverse connections and networking

4.1. MAKING SENSE OF GLOBAL SOCIETAL ENVIRONMENTAL AND BUSINESS CONTEXT

4.1.1. Appreciating the potential and limitations of science and technology, their role in society and society's role in their evolution

4.3. VISIONING — CONCEIVING AND DESIGNING SUSTAINABLE SYSTEMS

4.3.1. Identifying stakeholders need and wants

4.3.2. Identifying and formulating objectives and goals

4.4. DELIVERING ON THE VISION — IMPLEMENTING AND OPERATING

4.4.2. Manufacturing and supply chain operations

5. Assignments and Grading

Physical Attendance Requirement (% of classes) 80

Assignment Type	Assignment Summary	% of Final Course Grade
Final Exam	Oral exam	50
Problem Set	Homeworks	25
Presentation	Oral presentation on material of the lectures	25

6. Assessment Criteria

Assignment 1 Type Final Exam

Sample of Assignment 1

Derive differential equation on four-point correlation function with Phi13 field

Assessment Criteria for Assignment 1

The maximal number of points can be achieved by correct use of conformal Ward identities, representation theory of Virasoro algbera with the correct answer. Reductions can be made for technical mistakes, or misunderstanding of general concepts of conformal field theory.

Assignment 2 Type

Problem Set

Sample of Assignment 2

1. Using the Jacobi triple identity, prove the character identities for Ising CFT.
2. Derive differential equation satisfied by 4-point correlation function with one degenerate field in N=1 superconformal filed theory.
3. Derive the isomorphism between the product of 2 minimal models M25 and M310 minimal model of series D.

Student who correctly solve all problem will receive highest score. Ehe fewer tasks solved, the lower the final score.

Assignment 3 Type

Presentation

Sample of Assignment 3

Task: give a lecture instead of the professor using lecture materials.

Assessment Criteria for Assignment 3

The student must understand all the intricacies of the lecture to receive full credit.

7. Textbooks and Internet Resources

You can request at most two required textbooks. Additionaly, you can suggest up to nine recommended textbooks.

Required Textbooks	ISBN-13 (or ISBN-10)
Conformal Field Theory, Philippe Francesco , Pierre Mathieu , David Sénéchal, Graduate Texts in Contemporary Physics, 1997	

8. Facilities

Software
Wolfram Mathematica

Labs for Education

Laboratory of integrable systems and turbulence

NRU HSE-Skoltech International Laboratory of Representation Theory and Mathematical Physics

9. Additional Notes

The proposed course 1) has explicit academic content and requirements for receiving credits, 2) is in alignment with the program's learning outcomes, 3) adheres to policies and Skoltech regulations.

Lead Instructor confirms