Subject Code	SM11130011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Algebraic StructuresI		
Subject Number	SAMAL1505		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Masaaki Furusawa		
Main Theme of the Subject	A lecturer at another university gives intensive courses in one week on recent topics in structure and representation theory of algebraic systems. The theme is taken, by an expert, mainly from ring theory, algebraic number theory and representation theory		
Goal of the Subject	Will be announced separately.		
Contents of the Subject /Subject Plan	Will be announced separately.		
Preparation and Review	Will be announced separately.		
Evaluation Method	Report, etc.		
Comments to Students	Will be announced separately.		
Teaching Materials	Will be announced separately.		
Remarks1			

Subject Code	SM11140011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Algebraic StructuresII		
Subject Number	SAMAL1506		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Masaaki Furusawa		
Main Theme of the Subject	A lecturer at another university gives intensive courses in one week on recent topics in structure and representation theory of algebraic systems. The theme is taken, by an expert, mainly from ring theory, algebraic number theory and representation theory		
Goal of the Subject	Will be announced separately.		
Contents of the Subject /Subject Plan	Will be announced separately.		
Preparation and Review	Will be announced separately.		
Evaluation Method	Report, etc.		
Comments to Students	Will be announced separately.		
Teaching Materials	Will be announced separately.		
Remarks1			

Subject Code	SM11170011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Geometric StructuresI		
Subject Number	SAMGE1505		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Hiroshi Tamaru		
Main Theme of the Subject	Professor Megumi Harada (McMaster University, Canada) who is working on topology and algebraic geometry will introduce recent topics on the area.		
Goal of the Subject	To be announced		
Contents of the Subject /Subject Plan	To be announced		
Preparation and Review	To be announced		
Evaluation Method	Attendance and report.		
Comments to Students	The lectures will be given in English, so that you can learn English as well.		
Teaching Materials	None		
Remarks1			

Subject Code	SM11180011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Geometric StructuresII		
Subject Number	SAMGE1506		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Hiroshi Tamaru		
Main Theme of the Subject	Professor Megumi Harada (McMaster University, Canada) who is working on topology and algebraic geometry will introduce recent topics on the area.		
Goal of the Subject	To be announced		
Contents of the Subject /Subject Plan	To be announced		
Preparation and Review	To be announced		
Evaluation Method	Attendance and report, etc.		
Comments to Students	To be announced		
Teaching Materials	To be announced		
Remarks1			

Subject Code	SM11430011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Topics in Mathematical Structures 1		
Subject Number	SAMMS1501		
Credit(s)	2 Credits	Teaching Method	Lecture／Seminar
Lecturer(s)	Masato Okado,Takamichi Sano		
Main Theme of the Subject	Introduction to recent research topics and results in algebra by the faculty members in algebra.		
Goal of the Subject	This course is intended to learn recent research topics and results in algebra guided by the faculty members and by giving presentations. We hope to raise the level of the knowledge of the students to the research level.		
Contents of the Subject /Subject Plan	For example, in order to learn the theory of the category of modules using homological algebra, the following is a possibility. Lecture 1: Artinian rings Lecture 2: Modules over Artinian rings Lecture 3: Category of modules over Artinian rings Lecture 4: Injective objects Lecture 5: Differential complexes Lecture 6: Homology Lecture 7: Projective objects Lecture 8: Generators Lecture 9: Morita equivalence Lecture 10: Triangulated categories Lecture 11: Localization Lecture 12: Derived equivalence Lecture 13: Quasi-Frobenius rings Lecture 14: Derived equivalence concerning modules over groups		
Preparation and Review	To read and to understand the assigned materials.		
Evaluation Method	The grade is given based on the presentations and the attendance.		
Comments to Students	The format, the level and the contents of the course are subject to change according to the areas of specialty and the interests of the students and the faculty members.		
Teaching Materials	The materials and the references are assigned by the faculty members.		
Remarks1	Those who plan to register this course are required to contact the appropriate faculty member beforehand.		

Subject Code	SM11440011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Topics in Mathematical Structures 2		
Subject Number	SAMMS1502		
Credit(s)	2 Credits	Teaching Method	Lecture／Seminar
Lecturer(s)	Hirotaka Akiyoshi,Masamichi Yoshida		
Main Theme of the Subject	Recent topics in geometric topology are introduced.		
Goal of the Subject	Researchers in the field of topology introduce recent research results and research subjects related to topological geometry. Students also present them under the direction of the supervisor.		
Contents of the Subject /Subject Plan	Basic notions in classical knot theory. Some topics in classical knot theory. Recent topics in classical knot theory. Basic notions in 4-dimensional knot theory. Some topics in 4-dimensional knot theory. Recent topics in 4-dimensional knot theory. Topological invariants in knot theory; basic notions related to (co)homology theory ;recent topics related to (co)homology. Basic notions in graph theory related to topology. Some topics in graph theory related to topology. Recent topics in graph theory related to topology. Basic notions in spatial graph theory. Some topics in spatial graph theory.		
Preparation and Review	Learning is expected to deepen the understanding of the topics and research results by reading the literature and its references.		
Evaluation Method	Comprehensively evaluated by presentations and/or reports.		
Comments to Students	The contents, progress and form of the course may be changed depending on the specialized field of the supervisor, the research field of the students, the research situation, etc.		
Teaching Materials	Will be introduced during the class		
Remarks1	Students who who wish to take this course should contact the supervisor in advance.		

Subject Code	SM11450011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Topics in Mathematical Structures 3		
Subject Number	SAMMS1503		
Credit(s)	2 Credits	Teaching Method	Lecture／Seminar
Lecturer(s)	Masaaki Furusawa,Shunsuke Yamana		
Main Theme of the Subject	Introduction to recent research topics and results in algebra by the faculty members in algebra.		
Goal of the Subject	This course is intended to learn recent research topics and results in algebra guided by the faculty members and by giving presentations. We hope to raise the level of the knowledge of the students to the research level.		
Contents of the Subject /Subject Plan	As an example, the following is a possibility. Lecture 1: Commutative rings Lecture 2: Affine algebraic varieties Lecture 3: Schemes Lecture 4: Lie algebras Lecture 5: Semisimple Lie algebras Lecture 6: Representation theory of Lie algebras Lecture 7: Lie groups Lecture 8: Compact Lie groups Lecture 9: Semisimple Lie groups Lecture 10: Symmetric spaces Lecture 11: Hermitian symmetric spaces Lecture 12: Analysis on symmetric spaces Lecture 13: Iwasawa theory Lecture 14: Non-commutative Iwasawa theory		
Preparation and Review	To read and to understand the assigned materials.		
Evaluation Method	The grade is given based on the presentations and the attendance.		
Comments to Students	The format, the level and the contents of the course are subject to change according to the areas of specialty and the interests of the students and the faculty members.		
Teaching Materials	The materials and the references are assigned by the faculty members.		
Remarks1	Those who plan to register this course are required to contact the appropriate faculty member beforehand.		

Subject Code	SM11460011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Topics in Mathematical Structures 4		
Subject Number	SAMMS1504		
Credit(s)	2 Credits	Teaching Method	Lecture／Seminar
Lecturer(s)	Hirotaka Akiyoshi,Hiroshi Tamaru		
Main Theme of the Subject	This course deals with recent topics in topology.		
Goal of the Subject	At the end of the course, the participants are expected to acquire the necessary knowledge of topology needed to start their own study.		
Contents of the Subject /Subject Plan	Recent topics and results are introduced by researchers. Students also give oral presentations on the topics assigned. Lesson 1. Basics of Fuchsian groups Lesson 2. Topics in Fuchsian groups Lesson 3. Basics of the mapping class groups of surfaces Lesson 4. Topics in the mapping class groups of surfaces Lesson 5. Recent developments in the mapping class groups of surfaces Lesson 6. Basics of Heegaard splittings and Dehn surgeries of 3-manifolds Lesson 7. Topics in Heegaard splittings and Dehn surgeries of 3-manifolds Lesson 8. Recent developments in Heegaard splittings and Dehn surgeries of 3-manifolds Lesson 9. Basics of Kleinian groups Lesson 10. Topics in Kleinian groups Lesson 11. Recent developments in Kleinian groups Lesson 12. Basics of 3-dimensional geometric structures Lesson 13. Topics in 3-dimensional geometric structures Lesson 14. Recent developments in 3-dimensional geometric structures Course contents may change according to the attendants in the lectures.		
Preparation and Review	Carefully read through and understand the contents of the references.		
Evaluation Method	Evaluated based on class attendance and quality of oral presentations.		
Comments to Students	Course contents may change according to the attendants in the lectures.		
Teaching Materials	Will be introduced in the class.		
Remarks1	この科目の履修希望者は事前に担当教員に連絡をとること。		

Subject Code	SM11470011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Advanced Algebra I		
Subject Number	SAMAL1501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Mitsuyasu Hashimoto		
Main Theme of the Subject	Basics on algebraic geometry		
Goal of the Subject	Learning basics on affine algebraic varieties, in particular, Hilbert's Nullstellensatz. By gluing affine algebraic varieties locally, we understand general algebraic varieties. Especially, we shall study projective varieties.		
Contents of the Subject /Subject Plan	1. Affine algebraic varieties 2. Noetherian rings 3. Hilbert's basis theorem 4. Modules over a commutative ring 5. Hilbert's Nullstellensatz. 6. Coordinate rings and morphisms 7. Affine algebraic varieties revisited 8. Zariski topology 9. Irreducible components 10. Ringed spaces 11. Algebraic varieties 12. Projective spaces 13. Projective varieties 14. Tangent spaces and dimensions 15. Application		
Preparation and Review	Prereading is not necesary for the lecture. However, it is necessary for a participant to polish his or her understanding on the past lectures.		
Evaluation Method	Scored by reports, exams, etc.		
Comments to Students	Require basic knowledge: Algebra II, Algebra III, Algebra IV		
Teaching Materials	No specified text book.		
Remarks1			

Subject Code	SM11490011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Advanced Algebra III		
Subject Number	SAMAL1503		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Hyohe Miyachi		
Main Theme of the Subject	Lean some basics in Galois Theory.		
Goal of the Subject	The goal is to lean the fundamental theorem of Galois theory and its applications.		
Contents of the Subject /Subject Plan	1. Ring theory basics 2. Finite extension and algebraic extension 3. Separable extension 4. Norm and trace 5. Normal extension and Galois extension 6. The fundamental theorem of Galois theory 7. Lifting theorem for extensions 8. Cohomology 9. Cyclotomic field 10. Constructible numbers and pictures 11. Kummer theory 12. Solvable groups 13. Quintics 14. The fundamental theorem of algebra 15. Artin-Schreier theory		
Preparation and Review	Recall Algebra I, II, III and IV.		
Evaluation Method	The grading is based on your reports.		
Comments to Students	The knowledge in Algebra I, II, III and IV is prerequisite.		
Teaching Materials	There is no particular one.		
Remarks1			

Subject Code	SM11510011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Advanced Geometry I		
Subject Number	SAMGE1501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Hiroshi Tamaru		
Main Theme of the Subject	We will introduce fundamental notions and facts on Lie groups and Lie algebras. Roughly speaking, a Lie group is "manifold and group", and a Lie algebra is "vector space with product (with some conditions)". In this lecture, we explain these two notions correspond, with describing explicit examples. In particular, matrix groups play fundamental roles.		
Goal of the Subject	The students will study fundamental notions and facts on Lie groups and Lie algebras, and learn them through explicit examples.		
Contents of the Subject /Subject Plan	1st-4th: Matrix groups and matrix Lie algebras 5th-9th: Fundamental notions and facts on Lie groups and Lie algebras 10th-15th: The correspondence between Lie groups and Lie algebras		
Preparation and Review	Read the resume distributed in the lecture, and understand the story. Solve the problems in the resume. Consider several examples which are not appeared in the lecture.		
Evaluation Method	Evaluated by mainly reports. Possibly there are exams.		
Comments to Students	It is hard to understand a general theory without explicit examples. Since many fundamental examples of Lie groups and Lie algebras can be expressed by matrices, it is recommended to touch and get used to such examples.		
Teaching Materials	The resume will be distributed in the lecture. The references will be announced in the lecture if necessarily.		
Remarks1			

Subject Code	SM11530011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Advanced Geometry III		
Subject Number	SAMGE1503		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Shin Kato		
Main Theme of the Subject	Although the minimal surface in the Euclidean 3-space is one of the classical research object in geometry, new significant results have been discovered also in recent years. In this course, the teacher will introduce basic facts and recent topics on minimal surfaces, and surfaces in the Lorentzian 3-space also.		
Goal of the Subject	Students are expected to understand the basic theory of minimal surfaces and its related topics, and to acquire skills for researches on differential geometry.		
Contents of the Subject /Subject Plan	1- 3 Curvatures of surfaces in the Euclidean 3-space 4- 6 Minimal surfaces and variational problems 7- 9 Minimal surfaces and their flux 10-12 Spacelike maximal surfaces and timelike minimal surfaces in the Lorentzian 3-space 13-15 Introduction to recent researches		
Preparation and Review	Students are encouraged to read and understand suggested research papers.		
Evaluation Method	Reporting assignments, etc..		
Comments to Students	Before the registration to this course, students must contact to the teacher.		
Teaching Materials	The teacher will suggest the related references to students.		
Remarks1			

Subject Code	SM11550011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Mathematical Analysis 1		
Subject Number	SAMMA1501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Sachiko Hamano		
Main Theme of the Subject	We shall introduce some topics on the complex analysis, the probability theory, the potential theory, the partial differential equations, et al.		
Goal of the Subject	You should obtain the knowledge on the complex analysis, the probability theory, the potential theory, the partial differential equations, et al.		
Contents of the Subject /Subject Plan	The following is an example: 1st The Riemann surfaces 2nd The holomorphic differential 3rd The quasi-conformal mappings 4th The mathematical statistics 5th The 2 dimensional hyperbolic geometry 6th The Fuchsian groups 7th The probability theory 8th The stochastic processes 9th The dynamics on the circle 10th The asymptotic Teichmuller spaces 11th The partial differential equations 12th The variational methods 13th The harmonic functions 14th The potential theory		
Preparation and Review	You should read carefully and understand some papers.		
Evaluation Method	Wright reports.		
Comments to Students	Show those on the board.		
Teaching Materials	It will be suggested by each lerctures.		
Remarks1	You should contact us.		

Subject Code	SM11560011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Mathematical Analysis 2		
Subject Number	SAMMA1502		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Shin Kato,Hideyuki Ishi		
Main Theme of the Subject	Several classical and modern topics selected from differential geometry and geometric analysis, especially geometric variational problems will be lectured.		
Goal of the Subject	This lecture aims to learn the foundations of differential geometry and related mathematics. Recent progress and research topics in differential geometry are presented by some lecturers.		
Contents of the Subject /Subject Plan	The lecture plan will be concretely shown in class. For example, Submanifolds in Euclidean spaces Vector bundles and connections Lie groups, classical groups and Lie algebras Riemannian manifolds Geodesics and variational formulas Morse theory over manifolds Isometry groups and holonomy groups Curvatures Riemannian manifolds of constant curvatures Curvatures and topology of manifolds Curvatures and spectrum of Laplace operator Minimal submanifolds Harmonic maps Symplectic manifoldsetc.		
Preparation and Review	Read and try to understand the books or papers suggested in advance or in class.		
Evaluation Method	Evaluated by the attendance, reports etc. to the lectures.		
Comments to Students	The contents, progress and style of the lectures are possible to be changed, depending on the speciality of lecturers and research field and interests of students.		
Teaching Materials	It will be suggested by each lerctures.		
Remarks1	A student who wants to attend this lecture must take contact to a main lecturer in advance.		

Subject Code	SM11570011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Analysis 3		
Subject Number	SAMMA1503		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Takayuki Koike,Hideaki Sunagawa		
Main Theme of the Subject	The focus of this course is an introduction to mathematical analysis in general: complex analysis, probability theory, potential theory, partial differential equations, dynamical systems, harmonic analysis, mathematical statistics and so on.		
Goal of the Subject	Understand the basics of mathematical analysis in general: complex analysis, probability theory, potential theory, partial differential equations, dynamical systems, harmonic analysis, mathematical statistics and so on.		
Contents of the Subject /Subject Plan	Introduction to mathematical analysis in general: I. Complex analysis, II. Probability theory, III. Potential theory, IV. Partial differential equations, V. Dynamical systems, VI. Harmonic analysis, VII. Mathematical statistics, and so on.		
Preparation and Review	Students are expected to read a text book and references carefully.		
Evaluation Method	Attendance and report		
Comments to Students	It will be presented separately.		
Teaching Materials	Contents will be announced separately.		
Remarks1	この科目の履修希望者は事前に担当教員に連絡をとること。		

Subject Code	SM11580011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Analysis 4		
Subject Number	SAMMA1504		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Hiroshi Tamaru,Yoshihiro Ohnita		
Main Theme of the Subject	Introduction to recent topics on differential geometry.		
Goal of the Subject	To know recent topics and to understand recent results on differential geometry.		
Contents of the Subject /Subject Plan	Recent topics and recent results on differential geometry. [1] Basic facts on geometry of submanifolds [2] Topics on geometry of submanifolds [3] Recent results on geometry of submanifolds [4] Basic facts on symmetric spaces and Lie groups [5] Topics on symmetric spaces and Lie groups [6] Recent results on symmetric spaces and Lie groups [7] Basic facts on harmonic maps and minimal surfaces [8] Topics on harmonic maps and minimal surfaces [9] Recent results on harmonic maps and minimal surfaces [10] Basic facts on Riemannian geometry [11] Topics on Riemannian geometry [12] Recent results on Riemannian geometry [13] Basic facts on symplectic geometry and moment maps [14] Topics on symplectic geometry and moment maps [15] Recent results on symplectic geometry and moment maps		
Preparation and Review	Students attending this lecture are expected to read original papers on the topics introduced and to understand them deeply.		
Evaluation Method	Report etc..		
Comments to Students	Contact the lecturer before taking the registration for this lecture.		
Teaching Materials	Not specified.		
Remarks1			

Subject Code	SM11590011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Advanced Analysis I		
Subject Number	SAMAN1501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Futoshi Takahashi		
Main Theme of the Subject	Title: Introduction to the infinite dimensional critical point theory		
Goal of the Subject	To understand the basics on the critical point theory developed in the infinite dimensional function spaces and to apply it to concrete problems.		
Contents of the Subject /Subject Plan	1st：Frechet derivative and Gateau derivative 2nd : Nemetski operator 3rd：Gradient flow and the deformation theorem (1) 4th：Gradient flow and the deformation theorem (2) 5th：Mountain Pass Theorem 6th：Application to semilinear elliptic PDE (1) 7th：Application to semilinear elliptic PDE (2) 8th：Symmetry and compactness 9th：Symmetric solitary wave 10th：Non-symmetric solitary wave 11th：Critical Sovolev inequality 12th：Quantitative deformation theorem 13th：Ekeland's variational principle 14th：General min-max theorem		
Preparation and Review	Review of each lecture.		
Evaluation Method	Report : subject of report is to be announced.		
Comments to Students	This lecture will be given in English.		
Teaching Materials	Michel Willem ``Minimax Theorems'' (Birkhauser, PLNDE 34). Others will be announced in the course.		
Remarks1			

Subject Code	SM11610011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Advanced Analysis III		
Subject Number	SAMAN1503		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Ken Abe		
Main Theme of the Subject	We consider holomorphic functions and harmonic functions. After recalling the fundamental properties of those functions, I shall explain some topics with relation to Fourier analysis and partial differential equations.		
Goal of the Subject	You should recall fundamental properties of holomorphic and harmonic functions, and understand some relations with Fourier series and partial differential equations.		
Contents of the Subject /Subject Plan	1st Holomorphic functions 2nd Cauchy-Riemann equation 3rd The Taylor expansion 4th Harmonic functions 5th Power series expansion 6th The Laplace equation 7th The wave equation 8th The heat equation 9th Fundamental solutions 10th Hypo-ellipticity 11th Analytic hypo-ellipticity 12th The Fourier series 13th The Hardy spaces 14th The Bergman space		
Preparation and Review	You should possibly recall fundamental properties on the complex analysis, the functional analysis, and the Lebesgue integral.		
Evaluation Method	You should write some reports.		
Comments to Students	You should ask some questions.		
Teaching Materials	I shall show some bibliography in the class.		
Remarks1			

Subject Code	SM11630011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Introduction to MathematicsI		
Subject Number	SAMIN1501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Ken Abe,Masato Okado,Hiroshi Tamaru,Shunsuke Yamana,Shin Kato,Masaharu Nishio,Hideaki Sunagawa,Masaaki Furusawa,Takayuki Koike		
Main Theme of the Subject	This is an omnibus course of introductions on latest frontiers of mathematics. A half of the faculties introduce a topic of their research subjects by one or two lectures. The another half faculties are in charge of the introduction of mathematics II.		
Goal of the Subject	The goal is to realize latest frontiers of mathematics and learn various mathematical perspectives through introductions on research subjects of faculties in an omnibus form.		
Contents of the Subject /Subject Plan	(1) An introduction on a topic of the representation theory (2) An introduction on a topic of the algebraic groups (3) An introduction on a topic of the number theory (4) An introduction on a topic of the ring theory (5) An introduction on a topic of the knot theory (6) An introduction on a topic of the 3- and 4-dimensional topology (7) An introduction on a topic of the geometry of transformation groups (8) An introduction on a topic of the differential geometry (9) An introduction on a topic of the variational methods (10) An introduction on a topic of the nonlinear partial differential equations (11) An introduction on a topic of the complex analysis (12) An introduction on a topic of the potential theory (13) An introduction on a topic of the ergodic theory (14) An introduction on a topic of the probability theory (15) An introduction on a topic of the statistics The above is one example. The order of the course contents may be different.		
Preparation and Review	Closely read and understand indicated literatures and their references.		
Evaluation Method	Attendance and reports		
Comments to Students	Faculties in charge and schedules are announced at the beginning of April.		
Teaching Materials	A particular text book is not designated. A handout is freely given.		
Remarks1	The course starts biennially at an odd year.		

Subject Code	SM11650011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in AnalysisI		
Subject Number	SAMAN1505		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Hideaki Sunagawa		
Main Theme of the Subject	Recent topics on global analysis and differential geometry, including boundary areas such as partial differential equation, geometric measure theory and the theory on metric measure spaces, will be lectured by an expert from another university.		
Goal of the Subject	To be announced.		
Contents of the Subject /Subject Plan	To be announced.		
Preparation and Review	To be announced.		
Evaluation Method	Based on attendance record, reports, and so on.		
Comments to Students	To be announced.		
Teaching Materials	To be announced.		
Remarks1			

Subject Code	SM11660011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Analysis II		
Subject Number	SAMAN1506		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Hideaki Sunagawa		
Main Theme of the Subject	Recent topics on global analysis and differential geometry, including boundary areas such as partial differential equation, geometric measure theory and the theory on metric measure spaces, will be lectured by an expert from another university.		
Goal of the Subject	To be announced.		
Contents of the Subject /Subject Plan	To be announced.		
Preparation and Review	To be announced.		
Evaluation Method	Based on attendance record, reports, and so on.		
Comments to Students	To be announced.		
Teaching Materials	To be announced.		
Remarks1			

Subject Code	SM12010011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Quantum Field Theory		
Subject Number	SAPL11501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Masaki Arima,Nobuhito Maru		
Main Theme of the Subject	Two instructors will give lectures. Prof. Arima will give a lecture on the basics of quantum field theory, whose final goal is the perturbation theory based on the canonical quantization for the scalar field and the electromagnetic field. Prof. Maru will give a lecture on the basics of quantum field theory, whose final goal is the perturbation theory and renormalization based on the path integral quantization.		
Goal of the Subject	Learning about the free field theory and interacting field theory through the canonical quantization and the path integral quantization.		
Contents of the Subject /Subject Plan	Arima 1 Review of classical field theory 2 Conservation law 3 On neutral scalar field: Hamiltonian 4 On neutral scalar field: Canonical quantization 5 On neutral scalar field: Examples of conservation law 6 On charged scalar field 7 On electromagnetic field: Differences between the scalar field and the electromagnetic field 8 On electromagnetic field: Difficulties in quantization 9 On electromagnetic field: Gauge fixing and quantization 10 On interactions of fields: Interaction representation 11 On interactions of fields: Wick's theorem 12 On interactions of fields: Application to the scalar field theory 13 On interactions of fields: Interaction with the gauge field 14 Introduction of renormalization: Higher order perturbations and divergence 15 Introduction of renormalization: Prescription for renormalization Maru 1 Path integral in quantum mechanics 2 Path integral of scalar field: Introduction 3 Path integral of scalar field: Green functions 4 Path integral of scalar field: Generating functional 5 Perturbation theory: Formulation 6 Perturbation theory: Feynman rules 7 Renormalization: Regularization 8 Renormalization: Φ4 theory 9 Renormalization: Φ3 theory, scalar QED, renormalizability 10 Effective action: Effective potential 11 Effective action: Dynamical symmetry breaking 12 Path integral of spinor field 13 Path integral of electromagnetic field 14 Renormalization group: Perturbative renormalization group 15 Renormalization group: Winsonian renormalization group		
Preparation and Review	It is desirable to confirm the content of the previous lecture before the lecture. It is required to check again the content of the lecture by yourself after the lecture.		
Evaluation Method	The grading is evaluated by attendance and a take-home exam. For those who take both lectures, the grading is evaluated by better scored one.		
Comments to Students	Prof. Arima's lecture will be held in the second period on Tuesday at the science building B105. Prof. Maru's lecture will be held in the third period on Tuesday at the science building B105. Students can take either or both classes depending on the contents of the lecture. Attendance will be required. Questions about the lecture are welcome.		
Teaching Materials	Greiner & Reinhardt, “Field Quantization”, Springer (Arima) Peskin & Schroeder, “An Introduction to Quantum Field Theory” (Maru)		

Subject Code	SM12020011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Theory of Elementary Particles		
Subject Number	SAPL11502		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Nobuhito Maru		
Main Theme of the Subject	In this lecture, the basics and problems of the electroweak unified theory in particle physics are discussed. Grand unified theory as an example of physics beyond the Standard Model is also introduced.		
Goal of the Subject	In this lecture, the physics of the electroweak theory and the grand unified theory will be discussed.		
Contents of the Subject /Subject Plan	1 Spontaneous Symmetry Breaking: Discrete Symmetry 2 Spontaneous Symmetry Breaking: Abelian Symmetry, Goldstone Model 3 Spontaneous Symmetry Breaking: Non-Abelian Symmetry 4 Nambu-Goldstone's Theorem 5 Spontaneous Symmetry Breaking of Gauge Symmetry: Higgs Mechanism 6 Spontaneous Symmetry Breaking of Chiral Symmetry: Nambu-Jona-Lasino Model 7 Spontaneous Symmetry Breaking of Chiral Symmetry: Pion as a Nambu-Goldstone Particle 8 Weinberg-Salam model, Electroweak Symmetry Breaking 9 Lepton sector: Yukawa Coupling, Charged Current, Neutral Current 10 Quark sector: Yukawa Coupling, CKM Matrix 11 Quark sector:GIM Mechanism 12 Quark scetor: CP Violation 13 Neutrino Oscillation 14 Grand Unified Theory: SU(5) Model, Gauge Coupling Unification 15 Grand Unified Theory: Proton Decay, SO(10) Model		
Preparation and Review	Before attending a lecture, the content of the previous lecture should be checked. After the lecture, the calculations done in the lecture should be checked again by yourself.		
Evaluation Method	The grading is evaluated by a take-home exam.		
Comments to Students	Do not hesitate to ask if you have a question about the lectures. It is desirable to have knowledge of the basics of the special relativity and the quantum field theory.		
Teaching Materials	It will be announced in the lecture.		
Remarks1			

Subject Code	SM12060011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Relativistic Theory of Gravitation		
Subject Number	SAPL11506		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Hideki Ishihara,Ken-ichi Nakao		
Main Theme of the Subject	Basic knowledge about general relativity as a theory of gravity and its application.		
Goal of the Subject	To acquire basic knowledge about general relativity as a theory of gravity and to understand typical physical processes in our universe through general relativity.		
Contents of the Subject /Subject Plan	1. Geometrical quantities 1: vectors and tensors 2. Geometrical quantities 2: metric tensor and curvature 3. Parallel transport and connection 4. Geodesics in curved spacetime 5. Geodesic deviation equation 6. Equation for gravity: the Einstein equations 7. Newtonian limit of gravity 8. Asymptotically flat spacetime 9. Gravitational collapse 10. Black holes 11. Massive and massless particles in a black hole spacetime 12. Relativistic model of the universe 13. Time evolution of the universe 14. Gravitational waves		
Preparation and Review	Reading the introduced textbook before and after each lecture.		
Evaluation Method	A grade for class participation.		
Comments to Students	Active discussions are desirable.		
Teaching Materials	Useful articles will be introduced in lectures.		
Remarks1			

Subject Code	SM12080011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Nuclear Physics I		
Subject Number	SAPL11508		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Yohei Chiba, Sangin Shim		
Main Theme of the Subject	This course deals with basic properties of atomic nuclei as quantum many-body systems and introductory nuclear structure and reaction theories. Through the course, students understand the role and importance of nuclear physics in modern physics.		
Goal of the Subject	The goal is to understand the concepts of models of nuclear structure and reaction. The following topics are covered in this course; * Nuclear structure: basic properties (nuclear size, shape, binding energy...), single-particle picture and nuclear shell model, collective model, and mean-field theory * Nuclear reaction: quantum scattering theory, elastic scattering and optical model, and reaction models on direct reaction process (DWBA, channel-coupling method...)		
Contents of the Subject /Subject Plan	1. Discovery of atomic nucleus, measurement of nuclear size and binding energy 2. Electron scattering and nuclear charge density 3. Properties of nuclear force and effective interaction 4. Mean field and single-particle picture, shell model 5. Nuclear collective motion (vibration, rotation and giant resonance) 6. Microscopic models on nuclear collective motion I (Hartree-Fock method, Time-dependent Hartree-Fock method and RPA) 7. Microscopic models on nuclear collective motion II (quasi-particles, Hartree-Fock-Bogoliubov theory, density functional theory) 8. Basics of nuclear reaction 9. Quantum scattering theory and scattering states 10. Elastic scattering and Optical model 11. Multiple scattering and effective interaction, optical potential 12. Models of direct reaction I (DWBA) 13. Models of direct reaction II (Coupled channel method) 14. Unstable nuclei and break-up process, many-body scattering problem		
Preparation and Review	Students are expected to review each class for roughly one hour, look over references introduced in the class, and submit some reports if necessary.		
Evaluation Method	Grading will be based on submitted reports, attendance, questions, and contribution to discussion in classes.		
Comments to Students	Depending the number of students, the course may be given in a seminar style.		
Teaching Materials	Textbooks and materials relevant to the lecture will be introduced in the class. Some examples are as follows: "Nuclear Structure", K. Takada and K. Ikeda (Asakura Shoten) [原子核構造論（高田健次郎、池田清美、朝倉書店）], "The Nuclear Many-body Problems", P, Ring and P. Schuck (Springer), "Introduction to quantum scattering theory", K. Oagata (Kyoritsu Shuppan) [量子散乱理論への招待（緒方一介、共立出版）], Nuclear Reactions for Astrophysics (Thompson, Nunes, Cambridge).		
Remarks1			

Subject Code	SM12090011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Nuclear Physics II		
Subject Number	SAPL11509		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Masaki Arima		
Main Theme of the Subject	The "Hadron" is the name for the smallest 'visible' particles. The nucleon, which composes the nucleus, is a member of the hadrons. This lecture will explore the hadronic phenomena in terms of the field theory with reference to their properties of internal symmetry.		
Goal of the Subject	This lecture aims to give an overview of the hadron world, and to understand the roll of the internal symmetry in the hadron physics		
Contents of the Subject /Subject Plan	1. Review of the field theory; Basic process of quantization 2. Review of the field theory; Internal degree of freedom 3. Review of the field theory; Conservation law 4. Examples of the symmetry; Gauge symmetry 5. Examples of the symmetry; Chiral symmetry 6. Hadrons and the symmetry; Nuclear phenomena 7. Hadrons and the symmetry; Isospin symmetry 8. Hadrons and the symmetry; Weak interaction 9. SU(3) symmetry; "Strange" phenomena 10. SU(3) symmetry; Strangeness 11. SU(3)XSU(3) symmetry; Weak interaction and Parity violation 12. SU(3)XSU(3) symmetry; Chiral symmetry 13. Phenomenological model of Hadrons; Quark model I 14. Phenomenological model of Hadrons; Quark model II 15. Phenomenological model of Hadrons; Skyrme model		
Preparation and Review	It is desirable to check the contents of the last lecture every time. Take the contents of every lesson in a notebook. Check each formulas, and/or equations shown in the lecture by yourself so as to understand their meanings correctly.		
Evaluation Method	The grade is evaluated by the attendance and the reports.		
Comments to Students	Attend every lesson seriously.		
Teaching Materials	G. Reinhardt, “Field quantization”, Springer I.J.R. Aitchison, “An informal introduction to gauge field theories”		
Remarks1			

Subject Code	SM12140011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Fundamental PhysicsIII		
Subject Number	SAPI11505		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Hideki Ishihara		
Main Theme of the Subject	Lectures on recent topics of fundamental physics are given by experts in other Universities.To acquire basic knowledge and basic skill about fundamental physics.		
Goal of the Subject	To acquire basic knowledge and basic skill about various fields of fundamental physics.		
Contents of the Subject /Subject Plan	To be announced separately.		
Preparation and Review	To be announced separately.		
Evaluation Method	Class participation.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM12150011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	High Energy Physics I		
Subject Number	SAPL21501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Kazuhiro Yamamoto		
Main Theme of the Subject	We review the particle physics, and aim to obtain the basic and advanced knowleges which are necessary to study the particle phisics.		
Goal of the Subject	We aim to obtain the clear understandings of vearious sort of quantum numbers and behavior of particles, while comparing between the accumulated experimental results for far and the theory which explains them in order to understand the particle physics.		
Contents of the Subject /Subject Plan	The 1st lecture: Review of elementary earticles The 2nd lecrure: Review of four tyes of forces The 3rd lecture: Interactions and fields The 4th lecture: Behavior of particles in the field The 5th lecture: Invariant principle and conservation low The 6th lecture: Spin and parity The 7th lecture: Charge conjugation and time reversal The 8th lecture: Isospin The 9th lecture: Hadrons containing heavy quarks The 10th lecture: Classification of baryons The 11th lecture: Classification od of mesons The 12th lecture: Electron-positron pair annihilation process The 13th lecture: Deep inelastic scattering The 14th lecture: Interactions between quark The 15th lecture: Quantum Chromodynamics		
Preparation and Review	The prior leanings are not necessarily required, but the review of the lecture note after the lectures are required.		
Evaluation Method	The score is evaluated the attendance to lectures and the term paper.		
Comments to Students	To be announced separately.		
Teaching Materials	Reference: “Introduction to High Energy Physics; 4th edition”, D. H. Perkins, Cambridge		
Remarks1			

Subject Code	SM12160011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	High Energy Physics II		
Subject Number	SAPL21502		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Yoshihiro Seiya		
Main Theme of the Subject	Reviews on how the weak interactions were understood based on experimental and theoretical developments and were combined with the electromagnetic interactions to form the Weinberg-Salam theory. Also, the standard model of the elementary particle physics including the strong interactions and beyond are briefly introduced.		
Goal of the Subject	Understanding weak interaction phenomenology and basics of the standard model of the elementary particle physics.		
Contents of the Subject /Subject Plan	1. Brief history of the elementary particle physics and review of the four forces. 2. Dirac equation. Helicity and spin polarization of Dirac particles. 3. Basics of the quantum field theory. Gauge symmetry. 4. Calculation of cross sections. 5. Weak interactions and quarks. GIM mechanism. Kobayashi-Maskawa mass matrix. 6. Weinberg-Salam theory. Charged, Neutral, electromagnetic current. 7. Higgs particle and spontaneous symmetry breaking. 8. Masses of gauge bosons. 9. Masses of fermions and Kobayashi-Maskawa mass matrix. 10. Production of Higgs particles and detection. 11. Strong interactions. Structure functions of hadrons. 12. QCD corrections of the tructure functions of hadrons. 13. Beyond the standard model of the elementary particle physics. 14. Uncertainty, probability, statistics. 15. Current status of the experimental elementary particle physics.		
Preparation and Review	To be announced separately.		
Evaluation Method	Attendance status, reports, and other overall performance.		
Comments to Students	Announced when necessary.		
Teaching Materials	・”Introduction to High Energy Physics; 4th edition”, D. H. Perkins, Cambridge. ・”Quarks and Leptons: An Introductory Course in Modern Particle Physics”, F. Halzen and A. D. Martin, Wiley		
Remarks1			

Subject Code	SM12180011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Cosmic Ray Physics II		
Subject Number	SAPL21504		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Shoichi Ogio		
Main Theme of the Subject	Review of the theoretical and the experimental studies of the cosmic ray physics covering very wide energy range, from low energies measured with satellite-borne detectors to ultra high energies. Particularly, this lecture is specially focused on the standard theories, basic experimental techniques, recent results and unsettled questions.		
Goal of the Subject	The first goal is to learn the theoretically and experimentally established "standards". The second goal is to deepen your knowledge of recent results and to develop your ability to study current and unsolved problems on the firm foundation for the standards,		
Contents of the Subject /Subject Plan	Day 1. Cosmic rays Day 2. Energy spectrum and chemical composition of low energy cosmic rays Day 3. Transport equation for the cosmic ray propagation Day 4. Leaky box model Day 5. Acceleration of cosmic rays Day 6. Fermi acceleration Day 7. Air shower phenomenon Day 8. Several methods for air shower observations Day 9. On going projects and recent results for the studies of cosmic rays below 10 PeV Day 10. Future plans for studies on cosmic rays below 10 PeV Day 11. Observations of TeV gamma rays Day 12. Propagation of ultra high energy cosmic rays Day 13. Possible sources of ultra high energy cosmic rays Day 14. On going projects and recent results for the studies of ultra high energy cosmic rays Day 15. Future plans for the studies of ultra high energy cosmic rays		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on discussions in the classes and reports.		
Comments to Students	It is recommended to complete "Cosmic ray physics I".		
Teaching Materials	T. K. Gaisse, "Cosmic Rays and Particle Physics", Cambridge University Press		
Remarks1			

Subject Code	SM12210011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Astrophysics		
Subject Number	SAPL21508		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Nobuyuki Kanda,Kazuhiro Yamamoto,Yoshiki Tsunesada		
Main Theme of the Subject	Astrophysics and cosmology are described by general relativity in its macroscopic aspects, and by particle physics in its microscopic aspects. Astronomical observations in multi-wavelengths since the 20th century revealed various phenomena in the universe, and our general pictures and understandings about the universe have been continuously updated with improved observational techniques and refined theoretical models. This course deals with the basics of astrophysics, and discusses the frontier of astrophysics and cosmology, i.e. the recent discoveries, perspectives, long-standing mysteries, and newly recognized puzzles.		
Goal of the Subject	We learn about the foundation of cosmology, interactions of elementary particles and gravity in the early universe, the big bang and inflation model. We explain the modern topics such as dark matter and dark energy. In addition, we will review the hierarchy of the universe such as stars, galaxies and the large-scale structure of the cosmos. In the lecture, we will explain the latest observations and experimental results of not only the theory but also various astronomical phenomenon, e.g., high-energy astronomical objects, cosmic rays, gravitational waves, accelerators, and explain how they contribute to the understanding of the universe.		
Contents of the Subject /Subject Plan	1. General Relativity and Expanding Universe 2. Big Bang and Cosmic Microwave Background 3. Cosmological Parameters 4. Cosmological Constant and Dark Energy 5. Large-scale Structure of the Cosmos 6. Galaxy 7. Evolution of Stars 8. Death of Stars (Blackhole, Neutron Star, Supernova) 9. High-Energy Astronomical Phenomenon 10. Dark matter (Astronomical) 11. Dark matter (CDM) 12. Early Universe and Particle Physics 13. Nucleosynthesis 14. Dark Matter 15. Neutrino Astronomy		
Preparation and Review	Students have to study the references and prepare for each item. We pick up some of lecture contents for a report.		
Evaluation Method	We evaluate using a report on the term-end and attendance, questions in the class.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM12230011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Astro and High EnergyPhysics II		
Subject Number	SAPI21502		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Yoshiki Tsunesada		
Main Theme of the Subject	Topics on astrophysics and/or high energy physics are given as an intensive course by an expert from other institution.		
Goal of the Subject	Announced when the course is given.		
Contents of the Subject /Subject Plan	Announced when the course is given.		
Preparation and Review	Announced when the course is given.		
Evaluation Method	Attendance status and reports.		
Comments to Students	Announced when the course is given.		
Teaching Materials	Announced when the course is given.		
Remarks1			

Subject Code	SM12260011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Particle Physics II		
Subject Number	SAPI21505		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Yoshihiro Seiya		
Main Theme of the Subject	In this intensive course, recent topics on particle physics will be lectured by an expert from another university.		
Goal of the Subject	To be announced separately.		
Contents of the Subject /Subject Plan	To be announced separately.		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on attendance and reports.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM12280011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Condensed Matter Physics I		
Subject Number	SAPL31501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Osamu Ishikawa		
Main Theme of the Subject	This course provides the understandings of the electron's behavior of metal, in which atoms are arranged periodically, on the basis of quantum mechanics, statistical mechanics and electromagnetism which are principal subjects in modern physics. And by introducing the Fermi liquid theory, it also provides the understandings of the behavior of many particle's interacting with each other. We will study the outlines of superconductivity in metal and superfluidity in liquid He.		
Goal of the Subject	The goals to be accomplished are to understand the electronic physical properties, like the electric resistance, as electron motions in the lattice which consists of atoms to be arranged periodically and to understand macroscopic properties of many particles with or without interaction and to understand the coherent state in superconducting state and superfluid state.		
Contents of the Subject /Subject Plan	Part 1 Basic properties of conduction electrons (waves in lattice, classical electric conduction and scattering time) Part 2 (free electron model, periodic boundary condition) Part 3 (Fermi energy level, Fermi degenerate) Part 4 (electronic conduction as free electrons, specific heat of electrons, and Pauli susceptibility) Part 5 Interacting Fermi particles system (Fermi liquid theory and quantum statistical mechanics) Part 6 (quasiparticle distribution function and energy change of the system) Part 7 (spin of electron and Landau parameters) Part 8 (some properties in an equilibrium state; specific heat, magnetic susceptibility, effective mass, compressibility) Part 9 Motion of electrons and transport property (viscosity, thermal conductivity, spin diffusion in Fermi liquid theory) Part 10 (Landau quantization) Part 11 (Hall effect, Quantum Hall effect) Part 12 (other transport phenomena) Part 13 Coherent state Part 14 Superconductivity and superfluidity Part 15 Review		
Preparation and Review	In advance you should review some relating subjects which you studied in statistical mechanics and quantum mechanics as an undergraduate. After the class, you should review the contents of a lecture and reflect them on your homework.		
Evaluation Method	We will evaluate the score totally by an evaluation of several homework and a student's attendance record.		
Comments to Students	It will be good for a student to master an basic approach of thinking, when considering the motion of electrons of metal.		
Teaching Materials	Reference book C. Kittel "Introduction of Solid State Physics"		
Remarks1	学部で物性物理学１の単位をすでに取得したものは履修不可		

Subject Code	SM12290011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Condensed Matter Physics II		
Subject Number	SAPL31502		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Mitsuru Sugisaki		
Main Theme of the Subject	This course is intended to coherently understand various physical phenomena in materials. In general, condensed matter physics deals with the large collections of atoms that compose both ordinary and exotic materials. Following Condensed Matter Physics I, this course provides a survey of electrical, optical, and magnetic properties of matter.		
Goal of the Subject	The aim of this course is to understand the origin of magnetism based upon the relativistic electron theory. Themes also include: ferromagnetism and antiferromagnetism where the electron-electron interaction is important, while paramagnetism can be understood simply by introducing the interaction with an external magnetic field; the concept of elementary excitations, such as magnon, plasmon, phonon, exciton, etc. Students are expected to gain an understanding of physical properties of elementary excitations in external fields.		
Contents of the Subject /Subject Plan	1. Electron in a magnetic field; Paramagnetism and diamagnetism 2. Dirac equation 3. Spin–orbit interaction 4. Exchange interaction and Hund's rules 5. Ferromagnetism and antiferromagnetism 6. Magnetic anisotropy and domains 7. Magnon 8. X-ray crystallography 9. Lattice vibration and phonon 1: acoustic and optical modes 10. Lattice vibration and phonon 2: second quantization 11. Density of states; Lattice heat capacity; Anharmonic potential 12. Drude model; Reflection and refraction 13. Plasmon, exciton, polaron, and polariton 14. Nonlinear optical response		
Preparation and Review	Prerequisite: fundamentals of quantum mechanics, statistical mechanics, and electromagnetism. Students are expected to pursue extended projects provided at the class.		
Evaluation Method	Grading scheme: Class participation + Assignments + Research Paper Report		
Comments to Students	Preferred prerequisite: Condensed Matter Physics I		
Teaching Materials	J.R. Hook and H.E. Hall, "Solid State Physics, 2nd Edition", Chichester, 1995, John Wiley & Sons. S. Nakajima, Y Toyozawa, and R. Abe, “The Physics of Elementary Exacitations”, Berlin, 1980, Springer.		
Remarks1	Exclusion: students who have the credits of Condensed Matter Physics 2 for undergraduate students, offered from Faculty of Science, OCU.		

Subject Code	SM12300011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Quantum Statistical Physics I		
Subject Number	SAPL31503		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Makoto Tsubota,Hiromitsu Takeuchi		
Main Theme of the Subject	We will learn the basics of theory of condensed matter physics, low temperature physics. In particular, we will learn the basics of quantum hydrodynamics.		
Goal of the Subject	Students will be able to read the papers by themselves and make some simple analytical and numerical calculations on this topics.		
Contents of the Subject /Subject Plan	1st Introduction 2nd Quantum condensation 3rd Superfluidity 4th Quantized vortex 5th Quantized vortex in superfluid helium 6th Dynamics of quantized vortex (1) 7th Dynamics of quantized vortex (2) 8th Classical turbulence 9th Quantum turbulence: history 10th Quantum turbulence: statistical laws 11th Atomic Bose-Einstein condensate(BEC) 12th Quantized vortex in atomic BECs 13th Quantum turbulence in atomic BECs 14th Multicomponent BECs		
Preparation and Review	Students should read papers and solve problems proposed in classes.		
Evaluation Method	Students submit the reports for the problems proposed in classes. The course grade will be based on the reports.		
Comments to Students	Students can learn from basics to advanced contents of low temperature physics.		
Teaching Materials	M. Tsubota, M. Kobayashi, H. Takeuchi, Physics Reports 522, 191 (2013)		
Remarks1			

Subject Code	SM12330011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Optical Properties of Condensed Matter		
Subject Number	SAPL31506		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Katsuichi Kanemoto,Mitsuru Sugisaki		
Main Theme of the Subject	The course concentrates on optical properties of condensed matters, especially functional materials, and their underlying physics. Main topics to be covered: Bacterial photoreceptors, Optical functional materials, and Opto-electronic devices. Recent progresses in the field of optical condensed matter physics will be also surveyed.		
Goal of the Subject	The goals of this lecture are to deeply understand the optical physics of condensed matter and modern laser spectroscopy. The course especially focuses upon photophysics of organic solids and photoreceptor proteins. Topics to be covered include: exciton, motional narrowing, exciton-phonon interaction, self-trapping, photo-induced nucleation, photoinduced electron transfer, dephasing, optically forbidden transition and energy transfer, and atomic spin of transition metals.		
Contents of the Subject /Subject Plan	1. Fundamentals of optical processes in materials: absorption and fluorescence. 2. Introduction to group theory and its relationship with linear optical responses. 3. Time evolution operator in Hilbert space; introduction to density operator. 4. Nonlinear polarizability in Liouville space. 5. Relationship between double-sided Feynman diagrams and nonlinear optical responses. 6. Ultra-fast phenomena in biological organelles. 7. Examples of nonlinear optical response in photosynthetic systems 1: photon echo and vibronic interaction. 8. Examples of nonlinear optical response in photosynthetic systems 2: 2-dimensional spectroscopy and electronic coherence. 9. Spectral evaluation of electron-phonon interaction. 10. Nonlinear susceptibility of one-dimensional materials. 11. Dynamics of photoexcitations in organic semiconductors. 12. Photo-induced spin dynamics in semiconductors. 13. Physics of solar cells. 14. Physics and operating principles of optoelectronic devices. 15. Semiconductor lasers and pseudo laser phenomena.		
Preparation and Review	Prerequisite: studying fundamentals of optics and solid state physics.		
Evaluation Method	Grading scheme: Class participation + Assignments + Research Paper Report		
Comments to Students	Original text booklets and supplemental materials should be read in advance.		
Teaching Materials	References: S. Mukamel, Nonlinear Optical Spectroscopy, New York, 1999, Oxford Univesity Press; W. W. Parson, Modern Optical Spectroscopy, Berlin, 2015, Springer.		
Remarks1			

Subject Code	SM12350011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Low Temperature Solid State Physics		
Subject Number	SAPL31508		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Hideo Yano		
Main Theme of the Subject	The course will deepen your understanding of quantum solid systems appearing at low temperature, such as exchange interaction due to the zero point motion of an atom, quantum statistics of bosonic helium 4 or fermionic helium 3, and nuclear magnetism of solid helium 3.		
Goal of the Subject	The course aims at giving students the fundamentals of low temperature physics starting from a microscopic quantum statistics approach. The primary goal of the course is to prepare students for research in low temperature physics and materials science.		
Contents of the Subject /Subject Plan	1. Physical properties and magnetism at very low temperature 2. Nuclear spin ordering at very low temperature 3. Characteristics of helium 4. Quantum statistics of solid helium 5. Phase diagram of helium 6. Cooling techniques and experimental methods 7. Exchange interaction in solid helium 4 (Boson system) 8. Exchange interaction in solid helium 3 (Fermion system) 9. Solid helium 3: Nuclear spin interaction 10. Solid helium 3: Crystal structure and effective 11. HamiltonianSolid helium 3: Magnetic properties at high temperatures and nuclear magnetic transition 12. Solid helium 3: Nuclear spin resonance and spin structure 13. Vacancies in solid helium 14. Quantum statistics and superfluidity of liquid helium 4 15. Exchange interaction and momentum distribution in superfluid helium 4		
Preparation and Review	Students are encouraged to discuss the lectures and homework material.		
Evaluation Method	The grade will be determined by the attendance rate and the homework.		
Comments to Students	Students are encouraged to review the previous lectures, to deepen your understanding.		
Teaching Materials	"The Frontia of Physics 3: Solid Helium at Very Low Temperature (Japanese)", Y. Nagaoka, Kyoritsu Shuppan "Superconductivity, Superfluids and Condensates", J. F. Annett, Oxford University Press		
Remarks1			

Subject Code	SM12370011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Solid State PhysicsIB		
Subject Number	SAPI31502		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Katsuichi Kanemoto		
Main Theme of the Subject	In this intensive course, recent topics on solid sate physics will be lectured by experts from other universities.		
Goal of the Subject	Understand the concept of state-of-the-art research on solid state physics.		
Contents of the Subject /Subject Plan	To be announced separately.		
Preparation and Review	After the lecture, prepare a report related to the content of the class.		
Evaluation Method	Grading will be given based on attendance and reports.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM12410011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Condensed MatterPhysics IB		
Subject Number	SAPI31506		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Makoto Tsubota		
Main Theme of the Subject	In this intensive course, recent topics on condensed matter physics will be lectured by lecturers from other universities.		
Goal of the Subject	Understand the concept of state-of-the-art research on condensed matter physics.		
Contents of the Subject /Subject Plan	To be announced separately.		
Preparation and Review	After the lecture, prepare a report related to the content of the class.		
Evaluation Method	Grading will be given based on attendence and reports.		
Comments to Students	To be annouced separately.		
Teaching Materials	To be annouced separately.		
Remarks1			

Subject Code	SM12440011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Experimental Physics of Cosmic-rays and Elementary ParticlesI		
Subject Number	SAPL21505		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Eiichi Nakano		
Main Theme of the Subject	The measurement technologies which are necessary for cosmic rays observation and elementary particle experiment are explained.		
Goal of the Subject	The aim of this class is to understand foundations and techniques of measuring devices for cosmic rays observation and an elementary particle experiment.		
Contents of the Subject /Subject Plan	The interaction between particle and materials, principles of particle detectors, history of detector developments, making and usage of detectors and electronics circuits for signal readout are explained. And accelerators and beam optics are mentioned. 1. interaction between particle and material 2. energy loss (dE/dx) 3. proportional chamber 4. drift chamber 5. Multi Wire Proportional/Drift Chamber (MWPC/MWDC) 6. Micro Pattern Gaseous Detector（MPGD） 7. resistive plate chamber, Geiger-Muler counter 8. semi-conductor detector 9. Cherenkov detector, transition radiation detector 10. scintillation counter 11. calorimeter, neutron detector 12. muon detector, neutrino detector 13. electronics circuit I (analogue) 14. electronics circuit II (transfer circuit, digital) 15. accelerator		
Preparation and Review	The term paper is necessary		
Evaluation Method	The grade is evaluated based on lecturing reply and term paper.		
Comments to Students	It is desirable that electromagnetism and special theory of relativity are understood.		
Teaching Materials	Reference : Introduction to experimental particle physics, R.C. Fernow, Cambridge university press (1986)		
Remarks1			

Subject Code	SM12450011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Experimental Physics of Cosmic-rays and Elementary ParticlesII		
Subject Number	SAPL21506		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Masako Iwasaki		
Main Theme of the Subject	This course deals with the basic concepts of the data analysis, and data acquisition for the cosmic-rays and elementary particle experiments. It also enhances the development of students' skill in the programming.		
Goal of the Subject	The goals of this course are to - understand the data analysis and data acquisition for the cosmic-rays and elementary particle experiments - be able to use C++ and Python for programming.		
Contents of the Subject /Subject Plan	1. Introduction: LINUX and Xwindow 2. Introduction: Data analysis in cosmic-rays and elementary particle experiments 3. C++ programming: Introduction 4. C++ programming: Class 5. C++ programming: Inheritance 6. ROOT programming: Introduction, histogram 7. ROOT programming: Random number generation, fitting 8. ROOT programming: Event generation with PYTHIA 9. ROOT programming: Physics analysis 10. Python programming introduction (1) 11. Python programming introduction (2) 12. Introduction: Data acquisition in cosmic-rays and elementary particle experiments 13. DAQ programming: Introduction 14. DAQ programming: Distributed detector control system 15. DAQ programming: User Interface		
Preparation and Review	There will be home work in the class, and it should be solved by the next class.		
Evaluation Method	Your overall grade in the class will be decided based on class attendance, usual performance, programming performance, and homework.		
Comments to Students	There will be programming excises using PC in the class.		
Teaching Materials	Text will be distributed in the class.		
Remarks1			

Subject Code	SM13060011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Mathematical Physics I		
Subject Number	SAMPL1504		
Credit(s)	2 Credits	Teaching Method	Lecture／Seminar
Lecturer(s)	Hiroshi Itoyama		
Main Theme of the Subject	To be announced separately.		
Goal of the Subject	To be announced separately.		
Contents of the Subject /Subject Plan	To be announced separately.		
Preparation and Review	To be announced separately.		
Evaluation Method	To be announced separately.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM13070011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Physics II		
Subject Number	SAMPL1505		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Sanefumi Moriyama		
Main Theme of the Subject	This class aims to study non-abelian gauge theory, which is utilized to describe modern particle physics.		
Goal of the Subject	After recapitulating path integral quantization and renormalization group, we study gauge fixing in quantization and asymptotic freedom.		
Contents of the Subject /Subject Plan	1. gauge principle 2. non-abelian gauge symmetry 3. Yang-Mills theory 4. path integral quantization 5. gauge fixing 6. BRST symmetry 7. Faddeev-Popov gauge fixing 8. renormalization group 9. beta function 10. asymptotic freedom 11. conformal symmetry 12. quantum anomaly 13. anomalous dimension 14. Wess-Zumino condition		
Preparation and Review	Students are expected to read the textbook carefully in advance and lead or join actively the discussions.		
Evaluation Method	The evaluation is based on the activity in the study.		
Comments to Students	This class aims to deepen the contents introduced in Mathematical Physics I. The contents are subject to change depending on the study progress of students. Students should contact in advance.		
Teaching Materials	Michael E. Peskin, Daniel V. Schroeder, An Introduction to Quantum Field Theory, Perseus Books		
Remarks1			

Subject Code	SM13080011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Mathematical Physics III		
Subject Number	SAMPL1506		
Credit(s)	2 Credits	Teaching Method	Lecture／Seminar
Lecturer(s)	Hideki Ishihara		
Main Theme of the Subject	Invariance and covariance in physics.		
Goal of the Subject	To understand that invariance and covariance are most fundamental concepts for costruction of theories in physics.		
Contents of the Subject /Subject Plan	1. Spacetime and manifold 2. Vectors and 1-forms; basis of general relativity 3. Metric space 4. Parallel transport and covariant derivative 5. Geodesic equations 6. Lie derivative 7. Isometry and Killing vector 8. Symmetry of spacetime and conservation law 9. Canonical formalism of relativistic particles 10. Mechanics of Nambu-Goto string 11. Mechanical system with constraint conditions 12. Constraint and symmetry 13. First and second class of constraint 14. Symmetry of general relativity		
Preparation and Review	To be announced in the lecture.		
Evaluation Method	A grade for class participation.		
Comments to Students	To be announced in the lecture.		
Teaching Materials	To be announced in the lecture.		
Remarks1			

Subject Code	SM13090011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Physics IV		
Subject Number	SAMPL1507		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Sanefumi Moriyama		
Main Theme of the Subject	This class aims to study supersymmetry which is a major attempt beyond the standard model.		
Goal of the Subject	After studying four-dimensional supersymmetry algebra and its representation, we study supersymmetric multiplets and supersymmetric theories from the viewpoint of superspace.		
Contents of the Subject /Subject Plan	1. bosons and fermions 2. Poincare symmetry 3. Coleman-Mandula theorem 4. four-dimensional supersymmetry algebra 5. supersymmetry transformation 6. chiral multiplet 7. vector multiplet 8. superspace, superfield 9. chiral superfield 10. vector superfield 11. extended supersymmetry 12. supersymmetric algebra in other dimensions 13. maximally supersymmetric theories 14. supergravity		
Preparation and Review	Students are expected to read the textbook carefully in advance and lead or join actively the discussions.		
Evaluation Method	The evaluation is based on the activity in the study.		
Comments to Students	This class aims to deepen the contents introduced in Mathematical Physics I. The contents are subject to change depending on the study progress of students. Students should contact in advance.		
Teaching Materials	This class aims to deepen the contents introduced in Mathematical Physics I. The contents are subject to change depending on the study progress of students. Students should contact in advance.		
Remarks1			

Subject Code	SM13100011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Computational Science		
Subject Number	SAMPL1508		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Nobuyuki Kanda,Yousuke Itoh		
Main Theme of the Subject	In this lecture, we study basics of information theory and logic. Structure and history of computers are briefly reviewed. We learn a few but useful numerical methods using computers. In the latter half, we learn probability and statistics, and how to properly handle data in natural science.		
Goal of the Subject	The aim of the first part of this lectures is to understand boolean algebra and its usage, basics of information, numerical representations of data on a computer, and basics of operation circuits. Students are also expected to gain a sense on history of development of computers. They are supposed to master basics of probability theory and statistics. They are expected to get familiar with numerical algorithms such as Fast Fourier Transform and Markov-Chain Monte-Carlo using or developing simple programs on their own computers.		
Contents of the Subject /Subject Plan	1. Computer science and information theory, boolean algebra 2. Computers and their history 3. Numerical figures on a computer 4. Basics of operation circuits 5. Numerical calculation and programming language 6. Random number 7. Monte-Carlo method 8. Numerical integration, solution of an equation. 9. Fast Fourier Transform 10. Probability theory, Bayes theorem 11. Basics of statistics, error propagation 12. Chi-square and regression 13. Maximum likelihood 14. Goodness of fit		
Preparation and Review	Using standard textbooks, students are expected to be familiar with basics of a computer (how to use one), probability theory and statistics in advance. Homework will be given after lectures, to complete which students need to use their own computers.		
Evaluation Method	Weighted average of results of reports, attendances, and quizzes.		
Comments to Students	For writing reports and programming hands-on session, students are requested to prepare computers by themselves or to obtain ones from their laboratories, or to have rights to use ones in the Osaka-City University Media Center. An editor software or a graph plotter of preference should be installed in the computers.		
Teaching Materials			
Remarks1			

Subject Code	SM13130011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Selected Topics in Mathematical PhysicsIII		
Subject Number	SAMPI1507		
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Hiroshi Itoyama		
Main Theme of the Subject	Experts from other universities explain recent hot topics in mathematical physics.		
Goal of the Subject	This class aims to help students to acquire knowledge and methods in various areas of mathematical physics.		
Contents of the Subject /Subject Plan	It will be announced separately. Contact for more information.		
Preparation and Review	It will be announced separately.		
Evaluation Method	Based on attendance record and homework.		
Comments to Students	It will be announced separately.		
Teaching Materials	It will be announced separately.		
Remarks1			

Subject Code	SM13140011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Sciences A		
Subject Number	SAMPL1501		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Ryo Kanda		
Main Theme of the Subject	The main theme of this course is abelian categories. As we consider linear maps for vector spaces, or continuous maps for topological spaces, it is common to consider structure-respecting maps for structured sets. The notion of categories is a framework t		
Goal of the Subject	The goal of this course is to understand basic notions and results about abelian categories so that you can apply them to concrete abelian categories.		
Contents of the Subject /Subject Plan	Lectures 1-2: The definition of categories and examples Lectures 3-4: Functors and natural transformations Lectures 5-6: Adjoint functors and equivalence of categories Lecture 7: Limits and colimits Lecture 8: Additive categories Lectures 9-10: Abelian categories Lecture 11: Grothendieck categories Lectures 12-13: Localization of categories and embedding theorems Lectures 14-15: Applications and advanced topics The topics are subject to change according to the level of understanding among students.		
Preparation and Review	Review the contents of previous lectures before each lecture.		
Evaluation Method	Grades are based on reports and other factors if any.		
Comments to Students	Knowledge of commutative algebra (equivalent to Algebra III) is desirable. If you miss the first lecture, send an email to the lecturer before the second lecture.		
Teaching Materials	No textbook. References will be introduced during lectures.		
Remarks1			

Subject Code	SM13150011	Offering Academic Year/Semester	2021 First Semester
Subject Name(English)	Mathematical Sciences B		
Subject Number	SAMPL1502		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Takayuki Koike		
Main Theme of the Subject	The Lie group SU(1,1) acts on the unit disk in the complex plane transitively as linear fractional transformations. Because of this group action, we can develop rich geometry and analysis over the unit disk. Bounded symmetric domains and bounded homogene		
Goal of the Subject	Through observations of geometry over homogeneous spaces, students will learn how to make use of Lie groups and Lie algebras as tools to study mathematical objects.		
Contents of the Subject /Subject Plan	[1] Introduction and overview [2] Geometry of classical domains (type I) [3] Geometry of classical domains (type II and III) [4] Geometry of classical domains (type IV) [5] Borel embeddings of bounded symmetric domains [6] Harish-Chandra realizations of bounded symmetric domains [7] Siegel domains and Cayley transforms [8] Examples of symmetric Siegel domains [9] Bounded homogeneous domains [10] Normal j-algebras [11] Examples of homogeneous Siegel domains [12] Bergman mappings and representative domains [13] Equivariant imbeddings of homogeneous Siegel domains [14] Matrix realizations of homogeneous Siegel domains [15] Toward a classification of bounded homogeneous domains		
Preparation and Review	Students attending this lecture are expected to read original papers on the topics introduced and to understand them deeply.		
Evaluation Method	Report etc..		
Comments to Students	Contact the lecturer before taking the registration for this lecture.		
Teaching Materials	Related literatures are introduced in the lecture.		
Remarks1			

Subject Code	SM13160011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Sciences C		
Subject Number	SAMPL1503		
Credit(s)	2 Credits	Teaching Method	Lecture
Lecturer(s)	Sachiko Hamano		
Main Theme of the Subject	This course serves advanced complex analysis such as the uniformization theorem.		
Goal of the Subject	Students will be accustomed to dealing with basic complex analysis.		
Contents of the Subject /Subject Plan	I. Introduction for basic complex analysis II. Harmonic functions III. Analytic continuation and Riemann surfaces IV. Conformal mappings		
Preparation and Review	Students are expected to review after every lecture for understanding technical terms and theorems in each lecture.		
Evaluation Method	Reports mainly. Fulfill the omitted discussion and computations in the lecture.		
Comments to Students	Required knowledge is the courses Complex Analysis I and Complex Analysis II or corresponding knowledge.		
Teaching Materials	Elias M. Stein & Rami Shakarchi: Complex Analysis (Princeton Lectures in Analysis), Princeton University Press, 2003. L. V. Ahlfors: Complex Analysis, McGraw-Hill, 1966.		
Remarks1			

Subject Code	SM13230011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Physics V		
Subject Number	SAMPL1509		
Credit(s)	2 Credits	Teaching Method	
Lecturer(s)	Takahiro Nishinaka		
Main Theme of the Subject	Conformal field theories have nice characteristic properties and are related to various physical phenomena. In this class, we learn the basics of four-dimensional conformal field theories and their supersymmetric versions.		
Goal of the Subject	We learn the characteristic properties of four-dimensional conformal and superconformal field theories.		
Contents of the Subject /Subject Plan	1. The basics of quantum field theories 2. Four-dimensional conformal symmetry 3. State-operator map 4. Primary and descendant fields 5. Unitary representations and unitarity bounds 6. Operator product expansions 7. Correlation functions 8. Conformal blocks 9. The conformal bootstrap 10. Supersymmetry algebra 11. Four-dimensional superconformal symmetry 12. Unitary representations of the superconformal algebra 13. Examples of 4d N=1 superconformal field theories 14. Superconformal index 15. Seiberg dualities of super QCD		
Preparation and Review	Students are expected to confirm understanding of the material lectured in each class session. It is encouraged to ask questions whenever they arise.		
Evaluation Method	The evaluation is based on the activity in class.		
Comments to Students	This class aims to deepen the contents introduced in Mathematical Physics I. The content of this class is subject to change, depending on what students are interested in and have studied already. Students should contact in advance.		
Teaching Materials	A textbook or lecture note will be introduced in class.		
Remarks1			

Subject Code	SM13240011	Offering Academic Year/Semester	2021 Second Semester
Subject Name(English)	Mathematical Physics VI		
Subject Number	SAMPL1510		
Credit(s)	2 Credits	Teaching Method	
Lecturer(s)	Takahiro Nishinaka		
Main Theme of the Subject	String theory is not only a theory including quantum gravity, but a powerful tool to understand the non-perturbative behaviors of quantum field theories. In this class, we learn D-branes in type IIA/IIB string theory and quantum field theories arising from these branes.		
Goal of the Subject	We learn string theory, D-branes and quantum field theories arising from D-branes.		
Contents of the Subject /Subject Plan	1. Bosonic strings 2. Mass spectrum 3. Circle compactification and T-duality 4. T-duality of open strings and branes 5. Field theories on branes 6. type IIA/IIB string theory 7. Massless spectrum 8. The low-energy effective action 9. T-duality of type IIA/IIB string theory and D-branes 10. Corresponding supergravity solutions 11. S-duality of type IIB string theory 12. NS5-branes 13. NS5/D4-system and 4d N=2 gauge theories 14. M-theory and M2/M5-branes 15. MQCD and Seiberg-Witten curves		
Preparation and Review	Students are expected to confirm understanding of the material lectured in each class session. It is encouraged to ask questions whenever they arise.		
Evaluation Method	The evaluation is based on the activity in class.		
Comments to Students	This class aims to deepen the contents introduced in Mathematical Physics I. The content of this class is subject to change, depending on what students are interested in and have studied already. Students should contact in advance.		
Teaching Materials	Clifford V. Johnson, “D-branes”		
Remarks1			

Subject Code	SM14030013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Mathematical Structures(M1)		
Subject Number	SAMEX1501		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Masaaki Furusawa,Hirotaka Akiyoshi,Masato Okado,Masamichi Yoshida,Hiroshi Tamaru,Shunsuke Yamana,Ken Abe,Mitsuyasu Hashimoto,Hideyuki Ishi,Futoshi Takahashi,Shin Kato, Hideaki Sunagawa,Takamichi Sano,Hyohe Miyachi,Sachiko Hamano,Yoshihiro Ohnita,Takayuki Koike		
Main Theme of the Subject	To present and to discuss some selected recent research papers in the theory of mathematical structures in the seminar and to report progress on own research.		
Goal of the Subject	To deepen and to broaden the understanding of some areas in the theory of mathematical structures.		
Contents of the Subject /Subject Plan	To be assigned later.		
Preparation and Review	To be assigned later.		
Evaluation Method	The grade is given based on the presentations and the participations in the seminar.		
Comments to Students	To be communicated later.		
Teaching Materials	To be assigned later.		
Remarks1			

Subject Code	SM14040013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Mathematical Structures(M2)		
Subject Number	SAMEX1601		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Masaaki Furusawa,Hirotaka Akiyoshi,Masato Okado,Masamichi Yoshida,Hiroshi Tamaru,Shunsuke Yamana,Ken Abe,Mitsuyasu Hashimoto,Hideyuki Ishi,Futoshi Takahashi,Shin Kato, Hideaki Sunagawa,Takamichi Sano,Hyohe Miyachi,Sachiko Hamano,Yoshihiro Ohnita,Takayuki Koike		
Main Theme of the Subject	To present and to discuss some selected recent research papers in the theory of mathematical structures in the seminar and to report progress on own research.		
Goal of the Subject	To deepen and to broaden the understanding of some areas in the theory of mathematical structures.		
Contents of the Subject /Subject Plan	To be assigned later.		
Preparation and Review	To be assigned later.		
Evaluation Method	The grade is given based on the presentations and the participations in the seminar.		
Comments to Students	To be communicated later.		
Teaching Materials	To be assigned later.		
Remarks1			

Subject Code	SM14050013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Mathematical Analysis(M1)		
Subject Number	SAMEX1502		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Futoshi Takahashi,Hirotaka Akiyoshi,Masato Okado,Masamichi Yoshida,Hiroshi Tamaru,Shunsuke Yamana,Ken Abe,Mitsuyasu Hashimoto,Hideyuki Ishi,Shin Kato, Hideaki Sunagawa,Takamichi Sano,Masaaki Furusawa,Hyohe Miyachi,Sachiko Hamano,Yoshihiro Ohnita,Takayuki Koike		
Main Theme of the Subject	To present and to discuss some selected recent research papers in mathematical analysis in the seminar and to report progress on own research.		
Goal of the Subject	To deepen and to broaden the understanding of some areas in mathematical analysis.		
Contents of the Subject /Subject Plan	To be assigned later.		
Preparation and Review	To be assigned later.		
Evaluation Method	The grade is given based on the presentations and the participations in the seminar.		
Comments to Students	To be communicated later.		
Teaching Materials	To be assigned later.		
Remarks1			

Subject Code	SM14060013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Mathematical Analysis(M2)		
Subject Number	SAMEX1602		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Futoshi Takahashi,Hirotaka Akiyoshi,Masato Okado,Masamichi Yoshida,Hiroshi Tamaru,Shunsuke Yamana,Ken Abe,Mitsuyasu Hashimoto,Hideyuki Ishi,Shin Kato, Hideaki Sunagawa,Takamichi Sano,Masaaki Furusawa,Hyohe Miyachi,Sachiko Hamano,Yoshihiro Ohnita,Takayuki Koike		
Main Theme of the Subject	To present and to discuss some selected recent research papers in mathematical analysis in the seminar and to report progress on own research.		
Goal of the Subject	To deepen and to broaden the understanding of some areas in mathematical analysis.		
Contents of the Subject /Subject Plan	To be assigned later.		
Preparation and Review	To be assigned later.		
Evaluation Method	The grade is given based on the presentations and the participations in the seminar.		
Comments to Students	To be communicated later.		
Teaching Materials	To be assigned later.		
Remarks1			

Subject Code	SM14070013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Fundamental Physics(M1)		
Subject Number	SAPE11501		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Nobuhito Maru, Hiroyuki Sakuragi, Sanefumi Moriyama, Hiroshi Itoyama, Masaki Arima, Ken-ichi Nakao, Hideki Ishihara		
Main Theme of the Subject	Review and discuss journal articles on recent research results on fundamental physics. Report on progress of ones own research projects and have a group discussion.		
Goal of the Subject	In addition to developing the understanding of each specialized topic in the field of fundamental physics, we aim to acquire a wide range of knowledge applicable to entire field of physics. If necessary, read research papers and solve problem sets.		
Contents of the Subject /Subject Plan	The plan of class will be announced by each instructor.		
Preparation and Review	It will be announced in the class.		
Evaluation Method	The grade evaluation is based on attendance, report and discussion in a seminar.		
Comments to Students	It will be announced in the class.		
Teaching Materials	It will be announced in the class.		
Remarks1			

Subject Code	SM14080013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Fundamental Physics(M2)		
Subject Number	SAPE11601		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Nobuhito Maru, Hiroyuki Sakuragi, Sanefumi Moriyama, Hiroshi Itoyama, Masaki Arima, Ken-ichi Nakao, Hideki Ishihara		
Main Theme of the Subject	Review and discuss journal articles on recent research results on fundamental physics. Report on progress of ones own research projects and have a group discussion.		
Goal of the Subject	In addition to developing the understanding of each specialized topic in the field of fundamental physics, we aim to acquire a wide range of knowledge applicable to entire field of physics. If necessary, read research papers and solve problem sets.		
Contents of the Subject /Subject Plan	The plan of class will be announced by each instructor.		
Preparation and Review	It will be announced in the class.		
Evaluation Method	The grade evaluation is based on attendance, report and discussion in a seminar.		
Comments to Students	It will be announced in the class.		
Teaching Materials	It will be announced in the class.		
Remarks1			

Subject Code	SM14090013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Astro and High Energy Physics(M1)		
Subject Number	SAPE21501		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Yoshiki Tsunesada,Nobuyuki Kanda,Eiichi Nakano,Kazuhiro Yamamoto,Masako Iwasaki,Yoshihiro Seiya,Yousuke Itoh,Shoichi Ogio		
Main Theme of the Subject	Review and discuss journal articles on recent research results on astrophysics and high energy physics. Report on progress of ones own research projects and have a group discussion.		
Goal of the Subject	In addition to developing the understanding of each specialized topic in the field of astrophysics and high energy physics, we aim to acquire a wide range of knowledge applicable to entire field of physics.		
Contents of the Subject /Subject Plan	Read research papers and solve problem sets.		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on attendance, reports, and discussions in the class.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM14100013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Astro and High Energy Physics(M2)		
Subject Number	SAPE21601		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Yoshiki Tsunesada,Nobuyuki Kanda,Eiichi Nakano,Kazuhiro Yamamoto,Masako Iwasaki,Yoshihiro Seiya,Yousuke Itoh,Shoichi Ogio		
Main Theme of the Subject	Review and discuss journal articles on recent research results on astrophysics and high energy physics. Report on progress of ones own research projects and have a group discussion.		
Goal of the Subject	In addition to developing the understanding of each specialized topic in the field of astrophysics and high energy physics, we aim to acquire a wide range of knowledge applicable to entire field of physics.		
Contents of the Subject /Subject Plan	Read research papers and solve problem sets.		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on attendance, reports, and discussions in the class.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM14110013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Condensed Matter Physics(M1)		
Subject Number	SAPE31501		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Katsuichi Kanemoto,Hideo Yano,Shin Inouye,Osamu Ishikawa,Akira Oguri,Ken Obara,Hiromitsu Takeuchi,Mitsuru Sugisaki,Yunori Nishikawa,Makoto Tsubota		
Main Theme of the Subject	Review and discuss journal articles on recent research results on condensed matter physics. Report on progress of ones own research projects and have a group discussion.		
Goal of the Subject	In addition to developing the understanding of each specialized topic in the field of condensed matter physics, we aim to acquire a wide range of knowledge applicable to entire field of physics. If necessary, read research papers and solve problem sets.		
Contents of the Subject /Subject Plan	To be assigned by faculty.		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on attendance, reports, and discussions in the class.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM14120013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Exercises in Condensed Matter Physics(M2)		
Subject Number	SAPE31601		
Credit(s)	4 Credits	Teaching Method	Seminar
Lecturer(s)	Katsuichi Kanemoto,Hideo Yano,Shin Inouye,Osamu Ishikawa,Akira Oguri,Ken Obara,Hiromitsu Takeuchi,Mitsuru Sugisaki,Yunori Nishikawa,Makoto Tsubota		
Main Theme of the Subject	Review and discuss journal articles on recent research results on condensed matter physics. Report on progress of ones own research projects and have a group discussion.		
Goal of the Subject	In addition to developing the understanding of each specialized topic in the field of condensed matter physics, we aim to acquire a wide range of knowledge applicable to entire field of physics. If necessary, read research papers and solve problem sets		
Contents of the Subject /Subject Plan	To be assigned by faculty.		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on attendance, reports, and discussions in the class.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM14130013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Advanced Research Course for Master's Thesis of Mathematics I		
Subject Number	SAARC1501		
Credit(s)	6 Credits	Teaching Method	Seminar／Laboratory
Lecturer(s)	Mitsuyasu Hashimoto,Hirotaka Akiyoshi,Masato Okado,Masamichi Yoshida,Hiroshi Tamaru,Shunsuke Yamana,Ken Abe,Hideyuki Ishi,Futoshi Takahashi,Shin Kato ,Hideaki Sunagawa,Takamichi Sano,Masaaki Furusawa,Hyohe Miyachi,Sachiko Hamano,Yoshihiro Ohnita,Takayuki Koike		
Main Theme of the Subject	Fundamental theory of each specialty.		
Goal of the Subject	To understand systematically fundamentals of the theory which is necessary to solve the research problem for the master thesis.		
Contents of the Subject /Subject Plan	Each student is expected to gain the systematic understanding of fundamentals of the theory to solve the research problem for the master thesis. For that purpose, each student is assigned reading materials and is expected to formulate and to solve the research problem for the master thesis under the guidance of his or her adviser.		
Preparation and Review	To be assigned later.		
Evaluation Method	The grade is given based on the presentations and participations in his or her seminar.		
Comments to Students	To be communicated later.		
Teaching Materials	To be assigned later.		
Remarks1			

Subject Code	SM14140013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Advanced Research Course for Master's Thesis of Mathematics II		
Subject Number	SAARC1601		
Credit(s)	6 Credits	Teaching Method	Seminar／Laboratory
Lecturer(s)	Mitsuyasu Hashimoto,Hirotaka Akiyoshi,Masato Okado,Masamichi Yoshida,Hiroshi Tamaru,Shunsuke Yamana,Ken Abe,Hideyuki Ishi,Futoshi Takahashi,Shin Kato, Hideaki Sunagawa,Takamichi Sano,Masaaki Furusawa,Hyohe Miyachi,Sachiko Hamano,Yoshihiro Ohnita,Takayuki Koike		
Main Theme of the Subject	Fundamental theory of each specialty.		
Goal of the Subject	To understand systematically fundamentals of the theory which is necessary to solve the research problem for the master thesis.		
Contents of the Subject /Subject Plan	Each student is expected to gain the systematic understanding of fundamentals of the theory to solve the research problem for the master thesis. For that purpose, each student is assigned reading materials and is expected to formulate and to solve the research problem for the master thesis under the guidance of his or her adviser.		
Preparation and Review	To be assigned later.		
Evaluation Method	The grade is given based on the presentations and participations in his or her seminar.		
Comments to Students	To be communicated later.		
Teaching Materials	To be assigned later.		
Remarks1			

Subject Code	SM14150013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Advanced Research Course for Master's Thesis of Physics I		
Subject Number	SAARC1501		
Credit(s)	6 Credits	Teaching Method	Seminar／Laboratory
Lecturer(s)	Eiichi Nakano, Hiroyuki Sakuragi, Nobuyuki Kanda, Katsuichi Kanemoto, Sanefumi Moriyama, Nobuhito Maru, Hiroshi Itoyama, Hideo Yano, Masaki Arima, Shin Inouye, Osamu Ishikawa, Akira Oguri, Kazuhiro Yamamoto, Ken Obara, Masako Iwasaki, Hiromitsu Takeuchi, Mitsuru Sugisaki, Yoshihiro Seiya, Yousuke Itoh, Ken-ichi Nakao, Yunori Nishikawa, Hideki Ishihara, Yoshiki Tsunesada, Shoichi Ogio, Makoto Tsubota		
Main Theme of the Subject	Acquiring the systematic knowledge and techniques about theories and experiments leading to the writing of the Master's thesis.		
Goal of the Subject	We aim to acquire systematic knowledge and techniques about theories and experiments leading to the writing of the Master's thesis.		
Contents of the Subject /Subject Plan	Discuss research program leading to the writing of the Master's thesis. Special emphasis will be placed on encouraging students to make research plans, to read textbooks and journal articles, and to acquire the experimental skills.		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on attendance, reports, and discussions in the class.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM14160013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	Advanced Research Course for Master's Thesis of Physics II		
Subject Number	SAARC1601		
Credit(s)	6 Credits	Teaching Method	Seminar／Laboratory
Lecturer(s)	Eiichi Nakano, Hiroyuki Sakuragi, Nobuyuki Kanda, Katsuichi Kanemoto, Sanefumi Moriyama, Nobuhito Maru, Hiroshi Itoyama, Hideo Yano, Masaki Arima, Shin Inouye, Osamu Ishikawa, Akira Oguri, Kazuhiro Yamamoto, Ken Obara, Masako Iwasaki, Hiromitsu Takeuchi, Mitsuru Sugisaki, Yoshihiro Seiya, Yousuke Itoh, Ken-ichi Nakao, Yunori Nishikawa, Hideki Ishihara, Yoshiki Tsunesada, Shoichi Ogio, Makoto Tsubota		
Main Theme of the Subject	Acquiring the systematic knowledge and techniques about theories and experiments leading to the writing of the Master's thesis.		
Goal of the Subject	We aim to acquire systematic knowledge and techniques about theories and experiments leading to the writing of the Master's thesis.		
Contents of the Subject /Subject Plan	Discuss research program leading to the writing of the Master's thesis. Special emphasis will be placed on encouraging students to make research plans, to read textbooks and journal articles, and to acquire the experimental skills.		
Preparation and Review	To be announced separately.		
Evaluation Method	Grading will be given based on attendance, reports, and discussions in the class.		
Comments to Students	To be announced separately.		
Teaching Materials	To be announced separately.		
Remarks1			

Subject Code	SM40010013	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	International Advanced Research Course for Master's Thesis of Science 1		
Subject Number			
Credit(s)	1 Credit	Teaching Method	Lecture
Lecturer(s)	Mitsuyasu Hashimoto,Hirotaka Akiyoshi,Masato Okado,Masamichi Yoshida,Hiroshi Tamaru,Shunsuke Yamana,Ken Abe,Hideyuki Ishi,Futoshi Takahashi,Shin Kato, Hideaki Sunagawa,Takamichi Sano,Masaaki Furusawa,Hyohe Miyachi,Sachiko Hamano,Yoshihiro Ohnita,Takayuki Koike		
Main Theme of the Subject	International research experience through research activities and scholarly exchanges abroad.		
Goal of the Subject	Each student is expected not only to make advancements in research towards the master thesis, but also to participate in the international scientific community.		
Contents of the Subject /Subject Plan	Each student will be advised on where to go and what to do there and also on how to give a research presentation in English, by the adviser. After returning to Japan, it is expected to present a research report.		
Preparation and Review	To be assigned individually. Also each student is expected to seek research problems actively.		
Evaluation Method	The grade is assigned based on the advancements in research and also on the improvements of the skill in research presentation and scientific communication in the international setting.		
Comments to Students	It is required to consult the adviser before registering this course.		
Teaching Materials	To be assigned later.		
Remarks1			

Subject Code	SM40010023	Offering Academic Year/Semester	2021 First Semester 2021 Second Semester
Subject Name(English)	International Advanced Research Course for Master's Thesis of Science 1		
Subject Number			
Credit(s)	1 Credit	Teaching Method	Seminar
Lecturer(s)	Eiichi Nakano, Hiroyuki Sakuragi, Nobuyuki Kanda, Katsuichi Kanemoto, Sanefumi Moriyama, Nobuhito Maru, Hiroshi Itoyama, Hideo Yano, Masaki Arima, Shin Inouye, Osamu Ishikawa, Akira Oguri, Kazuhiro Yamamoto, Ken Obara, Masako Iwasaki, Hiromitsu Takeuchi, Mitsuru Sugisaki, Yoshihiro Seiya, Yousuke Itoh, Ken-ichi Nakao, Yunori Nishikawa, Hideki Ishihara, Yoshiki Tsunesada, Shoichi Ogio, Makoto Tsubota		
Main Theme of the Subject	Students are expected to experience research in international fields through research activities and academic exchanges outside Japan.		
Goal of the Subject	Through research activities outside Japan, we aim to make progress in research plans of the Master's thesis, to achieve research goals, and to participate in international scientific communities of students and researchers in each research field.		
Contents of the Subject /Subject Plan	The university or research institute to be dispatched and research plans will be determined through discussion with the supervisor. Encourage students to make research proposal and plan, and to acquire the presentation of research (in English) or experimental skills. After returning to Japan, research results are to be reported.		
Preparation and Review	To be assigned by faculty. In addition, students are encouraged to make research subjects by oneself and to study actively the subject before and after the project.		
Evaluation Method	Grading will be given based on research results and progress of research. Improvement of overseas presentation and communication skills is also confirmed.		
Comments to Students	Regarding international research plans, etc., consult with the supervisor before registering for the course.		
Teaching Materials	To be announced separately.		
Remarks1			