Department of Mechanical Systems and Design

Numerical Analysis 2 credits Elective Required Professor Hisao Fukunaga Professor Hidetoshi Hashizume Professor Satoru Yamamoto Associate Professor Naofumi Ohnish Associate Professor Kanjuro Makihara	**Applied Analysis** 2 credits Elective Required Professor Nobuaki Obata
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Mathematical analysis is important for the understanding of random phenomenon apperaing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications. These lectures will be in Japanese in principle and an English resume will be distributed.
Fluid Dynamics 2 credits Elective Required Professor Keisuke Sawada	**Solid Mechanics** 2 credits Elective Required Professor Masumi Saka Professor Tomonaga Okabe
This course covers the basics of both incompressible and compressible fluid dynamics. 1. Conservation laws and governing equations 2. Inviscid, incompressible flows 3. Viscous, incompressible flows 4. Inviscid, compressible flows	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering 2 credits Elective Required Professor Katsuhide Ohira Professor Shigenao Maruyama Professor Hideaki Kobayashi Associate Professor Takashi Tokumasu	**System Control Engineering** 2 credits Elective Required Professor Kazuhiro Kosuge Professor Kazuya Yoshida Professor Koichi Hashimoto Associate Professor Yasuhisa Hirata
In this course, students will master the basic physics of thermal fluid science and thermal energy transformation and learn to link this knowledge to engineering applications. In particular, the course is designed to cover (1) microscopic approaches to thermal phenomena in molecular physics, (2) thermal phenomena involving chemical reactions such as combustion, (3) understanding and control of the various types of heat transfer, and (4) thermal and performance analyses of cryogenic systems such as refrigerators and liquefiers. Through these classes, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.
Materials Chemistry 2 credits Elective Required Professor Yutaka Watanabe Professor Koji Amezawa Professor Yuji Takakuwa Assistant Professor Yoichi Takeda	**Computer Hardware Fundamentals** 2 credits Elective Required Professor Tetsu Tanaka Assistant Professor Riyusuke Egawa
Most metals in the earth's atmosphere inevitably change into more thermodynamically stable compounds such as oxides or sulfides. To understand this principle more precisely, students will learn chemical and electro-chemical equilibrium theory, and kinetics theory in relation to corrosion and oxidation of metals. Practical examples will be used to explain the phenomena and theories of wet corrosion and high-temperature oxidation, deepening students' understanding of the chemical and electro-chemical reactions related to macro phenomena of corrosion and oxidation. This course will be offered in English with presentation and discussion style, using English-language materials. A detailed outline of the course will be presented during the first class.	Computers have become an indispensable part of modern society. This course addresses computers from the two angles of LSI (Large Scale Integrated circuit) technology and processor architecture. It looks in particular at CMOS-IC technology from the deep sub-micron generation to the deca-nano generation, memory, VLSI processor circuit architecture, high-level synthesis aimed at boosting performance and cutting power consumption, and integrated design technologies. Students will also learn the fundamentals of smart integrated systems enabling smart information processing.

Solid State Physics 2 credits Elective Required Professor Hiroo Yugami Professor Takahito Ono Professor Ying Chen	**Mechanics of Plasticity** 2 credits Elective Required Professor Toshimitsu Yokobori Associate Professor Riyuji Sugiura Associate Professor Yoshiteru Aoyagi
This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.	This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation.
Structure and Function of Living System 2 credits Elective Required Professor Yoichi Haga Associate Professor Makoto Ohta	**Intelligence and Systems Engineering** 2 credits Elective Required Professor Kazuo Hokkirigawa Associate Professor Takeshi Yamaguchi
In all types of engineering with a connection to the human body, a thorough understanding of the structure and function of the human body and other living systems is vital, as is consideration of systems geared to the special features of these living systems. This course covers the biology knowledge in terms of the basic functions and structures of living organisms that forms the basis of bioengineering. Particular emphasis will be placed on the basic knowledge and approaches necessary for deep exploration of the anatomy and physiology of the human body from the perspective of biomechanics.	This course will provide all students with the latest knowledge and concept associated with intelligent mechanical systems such as a continuously variable transmission and low noise and high precision positioning system. This course will also review recently-developed mechanical elements such as friction drive system and dry bearing system.
Design of Materials System 2 credits Elective Required Professor Kazuo Hokkirigawa Associate Professor Takeshi Yamaguchi	**Intelligent Machine Design** 2 credits Elective Required Various teachers
This course will provide all students with the fundamental knowledge of material design to develop intelligent mechanical systems with high performance. This course will also review the latest knowledge and concept associated with material system design.	
Nano/Micro/Tribology 2 credits Elective Required Professor Koshi Adachi	**Micro-Nanomechanical Architectonics** 2 credits Elective Required Professor Takahito Ono
Engineering of Fluid Systems 2 credits Elective Required Professor Yu Fukunishi Associate Professor Seiichirou Izawa	**Control of Thermal Energy** 2 credits Elective Required Professor Tetsushi Biwa
The objective of this lecture is to explain turbulent flow phenomena, which is very important fluid systems because they may lead to large energy loss. The lecture will cover from the basics of turbulence to the methods to control turbulence. The students will also learn about the past efforts to understand the complicated phenomena including the fundamental features of turbulence and the basic idea behind the ongoing attempts to control turbulence.	Transporting, converting and utilizing thermal energy constitute the fundamentals of engineering. It is required to understand the basics of heat transfer caused by various means, and learn the methods to enhance the heat transfer and to control it. The subject of this class focuses on the heat transfer caused by oscillatory flows like sound waves propagating in a gass-filled tube.
Energy Systems Engineering 2 credits Elective Required Professor Hiroo Yugami Associate Professor Shinichi Hashimoto	**Degradation in High Temperature Environments of Structures and Materials** 2 credits Elective Required Professor Kazuhiro Ogawa Associate Professor Yoichi Takeda
There are serious energy and environmental issues for the Earth and humanity. Solving the issues will demand effective usage of non-renewable energy sources and growth in the use of renewable energy generation systems. For such a purpose, new technologies for energy conversion and energy policy must be important. In this lecture, new energy conversion technologies such as fuel cells are introduced. Students also investigate energy technologies and energy policy. Based on the information, students will think current state of the energy system and the future through discussion.	Due to improve the operation efficiency, gas temperature of energy conversion systems, such as gas turbines and boilers, gradually increases. As a result, degradation of the structures, such as high-temperature creep, low cycle fatigue or high-temperature oxidation and corrosion, etc. may be occurred. These damages are called “aged deterioration” or “degradation”. In this lecture in the first half, the degradation in the energy conversion systems especially high-temperature oxidation is lectured, and the mechanism of high-temperature oxidation is explained. And in this lecture in the second half, presentation and discussion concerning high-temperature oxidation behavior of structures and materials are conducted.

Environmental Heat-Transfer Control 2 credits Elective Required Professor Shigenao Maruyama Associate Professor Atsuki Komiya	**Applied Energy Dynamics** 2 credits Elective Required Professor Kaoru Maruta
This class covers the heat transfer control and transport phenomena under extreme conditions such as a global and space environment. Especially, the emission, absorption and propagation of thermal radiation and the interaction of the light and matter will be introduced, and the issue of global warming is discussed. Also the reduction of carbon dioxide emission is studied and the efficient method of reduction is discussed at the viewpoint of heat and mass transfer.	
Electromagnetic Functional Flow Dynamics 2 credits Elective Required Professor Hideya Nishiyama Associate Professor Hidemasa Takana	**Mechanical Systems Maintenance Engineering** 2 credits Elective Required Professor Toshiyuki Takagi Associate Professor Tetsuya Uchimoto Associate Professor Hiroyuki Miki Adjunct Instructor Takayuki Aoki
This course focuses on the thermal and non-thermal plasma flows and electromagnetic fluids such as magnetic fluid, MR fluid, ER fluid and ionic liquid, whose functionality appears under the applied electromagnetic field. The flow functionalization associated with microscopic flow structure is explained from the physicochemical points of view. Furthermore, the governing equations for the functional fluids and diagnostic methods for the evaluation of their functionality will be discussed. The advanced engineering applications of the functional fluids to the environmental purification, energy devices, plasma processing are introduced. References: 1. errohydrodynamics,R.E.Rosensweig(1985),Cambridge University Press. 2. The Structure and Rehology of Complex Fluids, R.G.Larson(1999),Oxford University Press. 3. Partially Ionized Gases, M. Mitchner and C. H. Kruger, Jr., (1973). John Wiley & Sons. 4. Thermal Plasmas, Fundamentals and Applications, M. I. Boulos, P. Fauchais and E. Phender,Vol. 1, (1994), Plenum Press 5.Plasma Chemistry, A.Fridman(2008),Cambridge University Press.	In large-scale, complicated artifacts such as various industrial plants and airplanes, maintenance activities play an important role to prevent loss of function of the systems due to aging degradation. Optimization of the maintenance activities in view of both system safety and economic performance is placed as a major key challenge. In this course, we outlines the disciplines composing maintenance engineering such as reliability engineering, risk evaluation, nondestructive testing, failure analysis, and discuss the optimization of the maintenance activities.
Multiphase Flow Systems 2 credits Elective Required Professor Jun Ishimoto	**Introduction to Solid State Ionics** 2 credits Elective Required Professor Koji Amezawa Associate Professor Keiji Yashiro
This class covers the multiphase fluid mechanics. Especially, the research topics closely related to the cavitation and liquid atomization phenomena would be introduced. Furthermore, the numerical modeling, basic equations and computational simulation technique of multiphase fluid dynamics would be lectured. 1. Multiphase fluid flow pattern 2. Cavitation characteristics 3. Numerical analysis of cavitating flow 4. Computational method of dispersed multiphase flow 5. Cryogenic and magnetohydrodynamic multiphase fluid flow 6. Bubble dynamics 7. Microbubble dynamics 8. Computational method of free surface and interfacial flow 9. Atomization and spray dynamics 10. Numerical modeling of phase change and boiling phanemena	
Ultra-Highspeed Information Processing Algorithms 2 credits Elective Required Professor Hiroaki Kobayashi Associate Professor Hideaki Goto Associate Professor Hiroyuki Takizawa	**Computer Architecture** 2 credits Elective Required Professor Hiroaki Kobayashi Associate Professor Hiroyuki Takizawa

This course reviews supercomputing systems from both aspects of hardware and software. The course talks about the importance of parallel processing, parallel system architectures, parallel algorithm design, parallel programming, and performance evaluation methodologies. The course also discusses the memory systems necessary for supercomputing. See the class web page http://www.sc.isc.tohoku.ac.jp/class/uhsipa/ for more details. (Contact instructors to have an access ID)	The term "computer architecture" means the concept of designing computers and is also its philosophy. This course begins with the basic principles of computers, and then talks about instruction-level parallel processing, vector processing, parallel computing systems, and their control mechanisms. Supercomputing techniques such as vector systems and accelerators are also reviewed. See the class web page http://www.sc.isc.tohoku.ac.jp/class/architecture/ for more details. (Contact instructors to have an access ID).
Space Robotics 2 credits Elective Required Professor Kazuya Yoshida	**Ultraprecision Machining** 2 credits Elective Required Professor Tunemoto Kuriyagawa Associate Professor Masayoshi Mizutani
・Study engineering issues on space robotics. ・Fundamental knowledge on space environment and spacecraft designs are introduced, then some advanced topics are elaborated. ・Orbital mechanics, angular motion kinematics and attitude dynamics of a spacecraft are studied. ・ Multi-body dynamics and control issues for space robots and manipulators are elaborated. ・Advanced topics include (1) reaction dynamics and control of a free-flying space robot, (2) vibration dynamics and its suppression control of a flexible space robot, (3) impact dynamics and post-impact control when a space robot captures a floating target, (4) teleoperation and telepresence, and (5) mechanical simulation of micro-gravity environment. ・All lectures are given in English.	
Manufacturing Systems 2 credits Elective Required Professor Tunemoto Kuriyagawa Adjunct Instructor Tetuji Okuda Adjunct Instructor Takashi Genma	**Physical Fluctuomatics** 2 credits Elective Required Professor Kazuyuki Tanaka
	Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing.
Discussion on Environmental and Industrial Policy 2 credits Elective Required Various teachers	**Interdisciplinary Research** 2 credits Elective Required Various teachers
Project-Based Learning for Frontier of Mechanical Engineering 2 credits Elective Required Various teachers	**Internship Training** 1 or 2 credits Elective Required All teachers

In this study program, students will master a whole process of a project for mechanical design and system integration through practical hands-on experience. The first part comprises some classes on system integration, project management and safety management. The second part comprises project training, in which the students are expected to generate a project proposal and a conceptual design, undertake a design review and create a prototype. At the end, students must give a presentation on their results and write a report. This program is a prerequisite for students who wish to take the course entitled "Innovation Oriented Seminar on Mechanical Engineering."	Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training.
International Scientific Internship Training 1 or 2 credits Elective Required All teachers	**Special Lecture on Mechanical Systems and Design A** Elective Required Various teachers
When students have attended any lectures or practiced in a foreign academic organization or science program, one or two credits are given to them according to the content and the period.	A special lecture on leading-edge academic research in the major area, or on the creation and development of knowledge in relation to the major area.
Advanced Seminar on Mechanical Systems and Design A Elective Required Various teachers	**Seminar on Digital Design** 2 credits Elective Required Professor Kazuo Hokkirigawa Professor Tunemoto Kuriyagawa Professor Takahito Ono Professor Masaru Uchiyama Professor Kazuhiro Ogawa Associate Professor Takeshi Yamaguchi Associate Professor Masayoshi Mizutani Associate Professor Yoichi Takeda
Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability.	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Energy Systems Engineering 2 credits Elective Required Professor Hiroo Yugami Professor Yu Fukunishi Professor Tetsushi Biwa Professor Shigenao Maruyama Professor Hideya Nishiyama Professor Kaoru Maruta Professor Toshiyuki Takagi Professor Koji Amezawa Associate Professor Fumitada Iguchi Associate Professor Seiichiro Izawa Associate Professor Shinichi Hashimoto Assistant Professor Atsuki Komiya Assistant Professor Hidemasa Takana Assistant Professor Yuka Iga Assistant Professor Tetsuya Uchimoto Assistant Professor Keiji Yashiro Assistant Professor Hiroyuki Miki	**Innovation Oriented Seminar on Mechanical Engineering** 8 credits Elective Required Various teachers
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	In this course, students engage in experiments and seminars (including research presentations, discussion and literature reviews) on particularly innovation-oriented themes in leading-edge areas of mechanical engineering. To take this seminar, students must pass Project-Based Learning for Frontier of Mechanical Engineering and satisfy the other registration prerequisites. The eight credits are considered to be the equivalent of the eight credits for Masters Course Seminar in terms of masters program completion requirements. However, students earning credits through this seminar cannot simultaneously earn credits for Masters Course Seminar.
Master Course Seminar on Mechanical Systems and Design 8 credits Elective Required	
Students engage in experiments and seminars, including research presentations, discussion and literature reviews. Students who have acquired credits from the Innovation Oriented Seminar on Mechanical Engineering program do not need to take this course.	

Department of Nanomechanics

Numerical Analysis 2 credits Elective Required Professor Hisao Fukunaga Professor Hidetoshi Hashizume Professor Satoru Yamamoto Associate Professor Naofumi Ohnishi Associate Professor Kanjuro Makihara	**Applied Analysis** 2 credits Elective Required Professor Nobuaki Obata
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Mathematical analysis is important for the understanding of random phenomenon apperaing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications. These lectures will be in Japanese in principle and an English resume will be distributed.
Fluid Dynamics 2 credits Elective Required Professor Keisuke Sawada	**Solid Mechanics** 2 credits Elective Required Professor Masumi Saka Professor Tomonaga Okabe
This course covers the basics of both incompressible and compressible fluid dynamics. 1. Conservation laws and governing equations 2. Inviscid, incompressible flows 3. Viscous, incompressible flows 4. Inviscid, compressible flows	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering 2 credits Elective Required Professor Katsuhide Ohira Professor Shigenao Maruyama Professor Hideaki Kobayashi Associate Professor Takashi Tokumasu	**System Control Engineering** 2 credits Elective Required Professor Kazuhiro Kosuge Professor Kazuya Yoshida Professor Koichi Hashimoto Associate Professor Yasuhisa Hirata
In this course, students will master the basic physics of thermal fluid science and thermal energy transformation and learn to link this knowledge to engineering applications. In particular, the course is designed to cover (1) microscopic approaches to thermal phenomena in molecular physics, (2) thermal phenomena involving chemical reactions such as combustion, (3) understanding and control of the various types of heat transfer, and (4) thermal and performance analyses of cryogenic systems such as refrigerators and liquefiers. Through these classes, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.
Materials Chemistry 2 credits Elective Required Professor Yutaka Watanabe Professor Koji Amezawa Professor Yuji Takakuwa Assistant Professor Yoichi Takeda	**Computer Hardware Fundamentals** 2 credits Elective Required Professor Tetsu Tanaka Assistant Professor Riyusuke Egawa
Most metals in the earth's atmosphere inevitably change into more thermodynamically stable compounds such as oxides or sulfides. To understand this principle more precisely, students will learn chemical and electro-chemical equilibrium theory, and kinetics theory in relation to corrosion and oxidation of metals. Practical examples will be used to explain the phenomena and theories of wet corrosion and high-temperature oxidation, deepening students' understanding of the chemical and electro-chemical reactions related to macro phenomena of corrosion and oxidation. This course will be offered in English with presentation and discussion style, using English-language materials. A detailed outline of the course will be presented during the first class.	Computers have become an indispensable part of modern society. This course addresses computers from the two angles of LSI (Large Scale Integrated circuit) technology and processor architecture. It looks in particular at CMOS-IC technology from the deep sub-micron generation to the deca-nano generation, memory, VLSI processor circuit architecture, high-level synthesis aimed at boosting performance and cutting power consumption, and integrated design technologies. Students will also learn the fundamentals of smart integrated systems enabling smart information processing.
Solid State Physics 2 credits Elective Required Professor Hiroo Yugami Professor Takahito Ono Professor Ying Chen	**Mechanics of Plasticity** 2 credits Elective Required Professor Toshimitsu Yokobori Associate Professor Riyuji Sugiura Associate Professor Yoshiteru Aoyagi
This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals	This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will

of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.	be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation.
Structure and Function of Living System 2 credits Elective Required Professor Yoichi Haga Associate Professor Makoto Ohta	**Precision Nanometrology** 2 credits Elective Required Professor Wei Gao Associate Professor Yuki Shimizu
In all types of engineering with a connection to the human body, a thorough understanding of the structure and function of the human body and other living systems is vital, as is consideration of systems geared to the special features of these living systems. This course covers the biology knowledge in terms of the basic functions and structures of living organisms that forms the basis of bioengineering. Particular emphasis will be placed on the basic knowledge and approaches necessary for deep exploration of the anatomy and physiology of the human body from the perspective of biomechanics.	This course focuses on measurement methods and systems with nanometer resolution and accuracy for ultra-precision production, including measurement of displacement and vibrations, surface profiles, geometric forms and motions of precision machines. Fundamental theories and applications of sensor technologies, such as laser interferometer, linear encoder, laser displacement sensor, optical fiber sensor, as well as those of measuring instruments, such as scanning electron microscope, interference microscope, scanning probe microscope, mechanical stylus profiler will be learned through presentations and discussions.
Fundamentals of Damege Management 2 credits Elective Required Professor Toshimitu Yokobori Associate Professor Ryuji Sugiura	**Intelligent Sensing of Materials** 2 credits Elective Required Professor Hitoshi Soyama
	As evaluations of materials characteristics are very important to guarantee reliability of systems, and conventional method cannot be used in microstructures and microcomponents such as IC packages and micro/nano machine, a novel sensing method will be required to evaluate material properties for advanced systems. Lecture will deal with sensing of materials such as inverse analysis to evaluate strain, stress and strength, especially residual stress in polycrystalline metallic materials which affects strength and lifetime of machine components and plants.
Mechanics of Materials System 2 credits Elective Required Associate Professor Hironori Tohmyoh	**Fundamental Nano-Technology** 2 credits Elective Required Professor Hiroki Kuwano
Recently, materials system which is composed of various components has become more and more complex to produce a new functionality. To develop or operate safety such an advanced materials system, cross-cutting knowledge, which is related to various disciplines, is indispensable. In this lecture, the nondestructive evaluation techniques for advanced materials system, e.g., techniques for detecting a crack or materials degradation, etc., are treated. Also, we discuss the evaluation techniques for small-scale materials system and advanced electronic devices.	
Informative Nanosystem 2 credits Elective Required Professor Hiroki Kuwano Associate Professor Motoaki Hara	**Ultraprecision Machining** 2 credits Elective Required Professor Tunemoto Kuriyagawa Associate Professor Masayoshi Mizutani
Nano/Micro Mechanoptics 2 credits Elective Required Professor Kazuhiro Hane Associate Professor Yoshiaki Kanamori	**Nano/Micro/Tribology** 2 credits Elective Required Professor Koshi Adachi
Mechanoptics is the study of the fusion region of the optics and the mechanics. The fundamental and the application techniques in Nano/Micro Mechanoptics that is the study of Mechanoptics on the nano/micro meter scale are surveyed. In detail, the topics in the micrometer scale are spatial modulators for displays, micro mechanical systems for telecom applications, micro/nano optical sensor systems, and so on. The topics in the nanometer scale are wavelength-selective filters using subwavelength structures, devices for optical control of surface reflectance and light polarization, and nano-scale optics about subwavelength optics. Micro-fabrication techniques of nano/micro optic devices are studied. These latest papers are presented and discussed.	
Strength and Reliability of Microstructures and Devices 2 credits Elective Required Professor Hideo Miura	**Kinetic Theory of Gases** 2 credits Elective Required Associate Professor Shigeru Yonemura
The Strain-induced changes of physical properties of various materials are discussed from the view point of the atomic alignment in the strained materials. The change of the free energy of materials due to strain energy causes the variation or	In rarefied gas flows, or in micro/nanoscale gas flows around a nanostructured body, the frequency of intermolecular collisions is on the same order of the frequency of molecule-wall collisions, and therefore, gas molecules are in intense non-equilibrium.

fluctuation of various physical and chemical properties of the strained materials. Since nanotechnology enables us to create very complicated fine structures, large strain occurs in the structures during manufacturing and operation because of lattice mismatch between nearby materials and higher density of the concentrated fields of strain and mechanical stress. Since the changes of the designed performance and lifetime of products degrade their reliability, deep understanding of the mechanism of the changes help us to evaluate the damage of the strained structures and devices and to design the optimum structures and their manufacturing methods. Some examples of fracture and/or failure mechanisms of products are also introduced based on the actual experience of the lecturer. Hideo Miura:hmiura@rift.mech.tohoku.ac.jp	Such gases cannot be treated as a continuum, and hence, the governing equation of gas flows is not the Navier-Stokes equations but the Boltzmann equation. The molecular gas dynamics, i.e., the rarefied gas dynamics, which is based on the kinetic theory of gases, has been developed in the aerospace field, but recently, micro/nanoscale gas flows around a nanostructured body have also received attention due to the development of the microfabrication technology. The aim of this lecture is to discuss characteristics of gas molecules as a group and to learn about the Boltzmann equation.
Nano-Process Engineering 2 credits Elective Required Professor Seiji Samukama Associate Professor Tomohiro Kubota	**Nanoscale Thermal and Fluid Engineering** 2 credits Elective Required Professor Taku Ohara Senior Assistant Professor Gota Kikugawa
	Understanding of the phenomena and mechanism of nanoscale flow contributes to the establishment of basic theory for thermal and fluid flow to predict the phenomena in natural and artificial nanoscale structures. It also leads to fundamental technology that is important to control the interfacial phenomena such as wetting and friction and to explore novel machines invented by the biomimetic approach to transport phenomena in living bodies. In this class, basic theories of nanoscale thermal and fluid engineering, that span a wide range of physics and engineering from the molecular dynamics of thermofluid to the macroscopic thermophysical properties and flow characteristics determined by the molecular scale mechanism, are given in detail and comprehensibly.
Nano-Physics, Analysis and Control of Surfaces 2 credits Elective Required Professor Yuji Takakuwa Associate Professor Tadashi Abukawa	**Intelligent Control Systems** 2 credits Elective Required Professor Koichi Hashimoto Associate Professor Shingo Kagami
This lecture deals with various physical analysis methods to get atomic-scale information on the chemical composition, crystal structure, electronic states, and morphology of surfaces and thin films, which are inevitable for the Nanotechnology. The in-situ observation and control of the chemical reaction kinetics on surfaces and interfaces of solids present under a reactive gas atmosphere, which are explored by the real-time surface analysis methods, are described.	
Design of Crustal Complex Fracture Systems 2credits Elective Required Professor Toshiyuki Hashida	**Engineering for Geo-Energy Exploitation** 2 credits Elective Required Professor Takatoshi Ito Associate Professor Yuichi Moriya
Manufacturing Systems 2 credits Elective Required Professor Tunemoto Kuriyagawa Adjunct Instructor Tetuji Okuda Adjunct Instructor Takashi Genma	**Physical Fluctuomatics** 2 credits Elective Required Professor Kazuyuki Tanaka
	Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to

	probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing.
Discussion on Environmental and Industrial Policy 2 credits Elective Required Various teachers	**Ethics of Life for Young Engineers** 2 credits Elective Required Professor Seishi Kudoh Professor Tatsuo Yoshinobu
	Not only medical science but also engineering is closely related to "life". Applying some engineering technologies to various fields such as medicals and food productions, we undoubtedly face the matter of life and death in humans and other creatures. It is not negligible that environmental issues caused by excessive consumption of materials and energy are possible to scare us. Enormous information and innovative technologies are drastically changing the society, affecting the life style of human severely. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn rules on the ethics. We will invite experts who are engaging various fields every lecture. We will also arrange a day for observation tours in which attendees will be divided into several groups and visit hospitals, nursing homes or others.
Interdisciplinary Research 2 credits Elective Required Various teachers	**Project-Based Learning for Frontier of Mechanical Engineering** 2 credits Elective Required Various teachers
	In this study program, students will master a whole process of a project for mechanical design and system integration through practical hands-on experience. The first part comprises some classes on system integration, project management and safety management. The second part comprises project training, in which the students are expected to generate a project proposal and a conceptual design, undertake a design review and create a prototype. At the end, students must give a presentation on their results and write a report. This program is a prerequisite for students who wish to take the course entitled "Innovation Oriented Seminar on Mechanical Engineering."
Internship Training 1 or 2 credits Elective Required All teachers	**International Scientific Internship Training** 1 or 2 credits Elective Required All teachers
Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training.	When students have attended any lectures or practiced in a foreign academic organization or science program, one or two credits are given to them according to the content and the period.
Special Lecture on Nanomechanics A Elective Required Various teachers	**Advanced Seminar on Nanomechanics A** Elective Required Various teachers
A special lecture on leading-edge academic research in the major area, or on the creation and development of knowledge in relation to the major area.	Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability.
Seminar on Materials and Mechanics 2 credits Elective Required Professor Hitoshi Soyama Professor Masumi Saka Professor Toshimitsu Yokobori Professor Hideo Miura Associate Professor Hironori Tohmyoh Associate Professor Ryuji Sugiura Associate Professor Yoshiteru Aoyagi Associate Professor Ken Suzuki	**Seminar on Nanotechnology** 2 credits Elective Required Professor Kazuhiro Hane Professor Hiroki Kuwano Professor Wei Gao Professor Koshi Adachi Professor Taku Ohara Professor Seiji Samukawa Professor Yuji Takakuwa Associate Professor Yoshiaki Kanamori Associate Professor Yuki Shimizu Associate Professor Motoaki Hara Associate Professor Shigeru Yonemura Assistant Professor Takashi Tokumasu Assistant Professor Tomohiro Kubota Assistant Professor Tadashi Abukawa Senior Assistant Professor Gota Kikugawa
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area

and the position of their own research.	and the position of their own research.
Innovation Oriented Seminar on Mechanical Engineering 8 credits Elective Required Various teachers	**Master Course Seminar on Nanomechanics** 8 credits Elective Required
In this course, students engage in experiments and seminars (including research presentations, discussion and literature reviews) on particularly innovation-oriented themes in leading-edge areas of mechanical engineering. To take this seminar, students must pass Project-Based Learning for Frontier of Mechanical Engineering and satisfy the other registration prerequisites. The eight credits are considered to be the equivalent of the eight credits for Masters Course Seminar in terms of masters program completion requirements. However, students earning credits through this seminar cannot simultaneously earn credits for Masters Course Seminar.	Students engage in experiments and seminars, including research presentations, discussion and literature reviews. Students who have acquired credits from the Innovation Oriented Seminar on Mechanical Engineering program do not need to take this course.

Department of Aerospace Engineering

Numerical Analysis 2 credits Elective Required Professor Hisao Fukunaga Professor Hidetoshi Hashizume Professor Satoru Yamamoto Associate Professor Naofumi Ohnish Associate Professor Kanjuro Makihara	**Applied Analysis** 2 credits Elective Required Professor Nobuaki Obata
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Mathematical analysis is important for the understanding of random phenomenon apperaing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications. These lectures will be in Japanese in principle and an English resume will be distributed.
Fluid Dynamics 2 credits Elective Required Professor Keisuke Sawada	**Solid Mechanics** 2 credits Elective Required Professor Masumi Saka Professor Tomonaga Okabe
This course covers the basics of both incompressible and compressible fluid dynamics. 1. Conservation laws and governing equations 2. Inviscid, incompressible flows 3. Viscous, incompressible flows 4. Inviscid, compressible flows	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering 2 credits Elective Required Professor Katsuhide Ohira Professor Shigenao Maruyama Professor Hideaki Kobayashi Associate Professor Takashi Tokumasu	**System Control Engineering** 2 credits Elective Required Professor Kazuhiro Kosuge Professor Kazuya Yoshida Professor Koichi Hashimoto Associate Professor Yasuhisa Hirata
In this course, students will master the basic physics of thermal fluid science and thermal energy transformation and learn to link this knowledge to engineering applications. In particular, the course is designed to cover (1) microscopic approaches to thermal phenomena in molecular physics, (2) thermal phenomena involving chemical reactions such as combustion, (3) understanding and control of the various types of heat transfer, and (4) thermal and performance analyses of cryogenic systems such as refrigerators and liquefiers. Through these classes, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.
Materials Chemistry 2 credits Elective Required Professor Yutaka Watanabe Professor Koji Amezawa Professor Yuji Takakuwa Assistant Professor Yoichi Takeda	**Computer Hardware Fundamentals** 2 credits Elective Required Professor Tetsu Tanaka Assistant Professor Riyusuke Egawa
Most metals in the earth's atmosphere inevitably change	Computers have become an indispensable part of

into more thermodynamically stable compounds such as oxides or sulfides. To understand this principle more precisely, students will learn chemical and electro-chemical equilibrium theory, and kinetics theory in relation to corrosion and oxidation of metals. Practical examples will be used to explain the phenomena and theories of wet corrosion and high-temperature oxidation, deepening students' understanding of the chemical and electro-chemical reactions related to macro phenomena of corrosion and oxidation. This course will be offered in English with presentation and discussion style, using English-language materials. A detailed outline of the course will be presented during the first class.	modern society. This course addresses computers from the two angles of LSI (Large Scale Integrated circuit) technology and processor architecture. It looks in particular at CMOS-IC technology from the deep sub-micron generation to the deca-nano generation, memory, VLSI processor circuit architecture, high-level synthesis aimed at boosting performance and cutting power consumption, and integrated design technologies. Students will also learn the fundamentals of smart integrated systems enabling smart information processing.
Solid State Physics 2 credits Elective Required Professor Hiroo Yugami Professor Takahito Ono Professor Ying Chen	**Mechanics of Plasticity** 2 credits Elective Required Professor Toshimitsu Yokobori Associate Professor Riyuji Sugiura Associate Professor Yoshiteru Aoyagi
This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.	This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation.
Structure and Function of Living System 2 credits Elective Required Professor Yoichi Haga Associate Professor Makoto Ohta	**Aerospace Systems** 2 credits Elective Required Professor Hisao Fukunaga Adjunct Instructor Kouichi Yonemoto Adjunct Instructor Hirokage Okoshi Adjunct Instructor Atsutarou Watanabe
In all types of engineering with a connection to the human body, a thorough understanding of the structure and function of the human body and other living systems is vital, as is consideration of systems geared to the special features of these living systems. This course covers the biology knowledge in terms of the basic functions and structures of living organisms that forms the basis of bioengineering. Particular emphasis will be placed on the basic knowledge and approaches necessary for deep exploration of the anatomy and physiology of the human body from the perspective of biomechanics.	
Aerospace Propulsion 2 credits Elective Required Various teachers	**Computation Fluid Dynamics** 2 credits Elective Required Professor Keisuke Sawada
	Lectures on computational fluid dynamics for compressible flows are given. Finite volume discretization of conservation laws, upwind schemes based on nonlinear wave theory, and TVD stability theory for improving spatial accuracy are discussed.
Aerospace Structural Mechanics 2 credits Elective Required Professor Hisao Fukunaga Professor Tomonaga Okabe Associate Professor Kanjuro Makihara	**Aerospase Fluid Dynamics** 2 credits Elective Required Professor Keisuke Asai Professor Hiroki Nagai
This course covers the theories of mechanics and design of thin-walled structures used in aircrafts, rockets and space structures. 1. Structures and materials of aircrafts, rockets and space structures 2. Vibration analysis of aerospace structures 3. Dynamics of space structures 4. Vibration control of aerospace structures 5. Finite element analysis of structures 6. Damage modelling and simulation of composite structures	
Space Robotics 2 credits Elective Required Professor Kazuya Yoshida	**Space Engineering for Robotic Exploration** 2 credits Elective Required Professor Kazuya Yoshida Associate Professor Keiji Nagatani
l Study engineering issues on space robotics.	l Study engineering issues for space exploration

l Fundamental knowledge on space environment and spacecraft designs are introduced, then some advanced topics are elaborated. l Orbital mechanics, angular motion kinematics and attitude dynamics of a spacecraft are studied. l Multi-body dynamics and control issues for space robots and manipulators are elaborated. l Advanced topics include (1) reaction dynamics and control of a free-flying space robot, (2) vibration dynamics and its suppression control of a flexible space robot, (3) impact dynamics and post-impact control when a space robot captures a floating target, (4) teleoperation and telepresence, and (5) mechanical simulation of micro-gravity environment. l All lectures are given in English.	missions. l Fundamental knowledge on space environment and spacecraft designs are introduced, then some advanced topics are elaborated. l History of lunar/planetary exploration missions is introduced. l Mechanics and system design of mobile robots for exploration missions are elaborated. l Sensing, planning and navigation issues are also elaborated. l Advanced topics include (1) terra-mechanics (soil-wheel interaction mechanics), (2) visual odometry, (3) SLAM (simultaneous localization and mapping), (4) various motion planning algorithms, and (5) terrestrial field application of exploration robotics. l All lectures are given in English.
Aerospace Combustion Dynamics 2 credits Elective Required Professor Hideaki Kobayashi	**Cryogenic Physics and Engineering** 2 credits Elective Required Professor Katsuhide Ohira
In this course, the lecture is performed on turbulent combustion which is a fundamental process of aerospace propulsion systems. First, statistical parameters of turbulent flows are reviewed for weak and strong turbulence. The non-dimensional numbers which describe the relationship between turbulent flows and turbulent flame structures are explained, and then the scale relations predominant for determination of the turbulent combustion are demonstrated. The lecture is extended to the turbulent combustion models and elementally process highly related to the flamelet concept of turbulent combustion, as well as chemical reactions of combustion in the extreme conditions of the propulsion systems; i.e., high pressure and high temperature.	The lecture covers the fundamentals and application technologies of cryogenic fluids in advanced science utilizing cryogenic equipment. After learning thermo-physical properties of liquid hydrogen and liquid helium, and superfluidity of liquid helium, students further deepen their understanding of the applications of cryogenic fluid in space rocket, superconducting equipment and hydrogen energy system.
The Science of Shock Waves 2 credits Elective Required Associate Professor Mingyu Sun	**Mathematical Modeling and Computation** 2 credits Elective Required Professor Satoru Yamamoto Associate Professor Kentarou Sano
Applied Mathematical Fluid Dynamics 2 credits Elective Required Professor Yuji Hatsutori	**Fluid Design Informatics** 2 credits Elective Required Professor Shigeru Obyashi Associate Professor Koji Shimoyama
A number of ideas in applied mathematics, which include dynamical systems, differential geometry, Lie groups, and statistical mechanics, have been applied to fluid dynamics. Recent development in basic fluid dynamics is introduced and methods and ideas for attacking various problems in nonlinear dynamics are given. The lecture consists of three parts: (i) theory of hydrodynamics stability, (ii) statistical fluid dynamics, and (iii) topological fluid dynamics.	This lecture discusses a new framework of knowledge discovery by the fusion of the fluid engineering and the information technology. More specifically, the lecture explains techniques of the new computer-aided visualization using the data mining and methods of the knowledge discovery to conquer trade-offs for the fluid engineering problems that have various trade-offs such as environmental compatibility and economy by identifying the trade-off using the multi-objective optimization and visualizing the design information using the cluster analysis.
Physical Fluctuomatics 2 credits Elective Required Professor Kazuyuki Tanaka	**Discussion on Environmental and Industrial Policy** 2 credits Elective Required Various teachers
Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models	

in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing.	
Interdisciplinary Research 2 credits Elective Required Various teachers	**Special Lecture in Cooperation with JAXA** 2 credits Elective Required Visiting Professor Sadatake Tomioka Visiting Associate Professor Toshiya Kimura
	Visiting teachers from JAXA (Japan Aerospace Exploration Agency) make special lecture on future space transportation system. Major topics are liquid rocket engine with high performance and high reliability, as well as the rocket-based combined cycle engine, especially on their system and research on components.
Project-Based Learning for Frontier of Mechanical Engineering 2 credits Elective Required Various teachers	**Internship Training** 1 or 2 credits Elective Required All teachers
In this study program, students will master a whole process of a project for mechanical design and system integration through practical hands-on experience. The first part comprises some classes on system integration, project management and safety management. The second part comprises project training, in which the students are expected to generate a project proposal and a conceptual design, undertake a design review and create a prototype. At the end, students must give a presentation on their results and write a report. This program is a prerequisite for students who wish to take the course entitled "Innovation Oriented Seminar on Mechanical Engineering."	Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training.
International Scientific Internship Training 1 or 2 credits Elective Required All teachers	**Special Lecture on Aerospace Engineering A** Elective Required Various teachers
When students have attended any lectures or practiced in a foreign academic organization or science program, one or two credits are given to them according to the content and the period.	A special lecture on leading-edge academic research in the major area, or on the creation and development of knowledge in relation to the major area.
Advanced Seminar on Aerospace Engineering A Elective Required Various teachers	**Seminar on Simulation Science** 2 credits Elective Required Professor Keisuke Sawada Professor Tomonaga Okabe Professor Keisuke Asai Professor Shigeru Obyashi Associate Professor Naofumi Ohishi Associate Professor Hiroki Nagai Senior Assistant Professor Yuriko Takeshima
Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability.	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Spacetechnology 2 credits Elective Required Professor Hisao Fukunaga Professor Kazuya Yoshida Professor Hideaki Kobayashi Professor Katsuhide Ohira Visiting Professor Sadatake Tomioka Associate Professor Kanjuro Makihara Associate Professor Keiji Nagatani Associate Professor Mingyu Sun	**Innovation Oriented Seminar on Mechanical Engineering** 8 credits Elective Required Various teachers
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	In this course, students engage in experiments and seminars (including research presentations, discussion and literature reviews) on particularly innovation-oriented themes in leading-edge areas of mechanical engineering. To take this seminar, students must pass Project-Based Learning for Frontier of

	Mechanical Engineering and satisfy the other registration prerequisites. The eight credits are considered to be the equivalent of the eight credits for Masters Course Seminar in terms of masters program completion requirements. However, students earning credits through this seminar cannot simultaneously earn credits for Masters Course Seminar.
Master Course Seminar on AeroSpace Engineering 8 credits Elective Required	
Students engage in experiments and seminars, including research presentations, discussion and literature reviews. Students who have acquired credits from the Innovation Oriented Seminar on Mechanical Engineering program do not need to take this course.	

Department of Bioengineering and Robotics

Numerical Analysis 2 credits Elective Required Professor Hisao Fukunaga Professor Hidetoshi Hashizume Professor Satoru Yamamoto Associate Professor Naofumi Ohnishi Associate Professor Kanjuro Makihara	**Applied Analysis** 2 credits Elective Required Professor Nobuaki Obata
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Mathematical analysis is important for the understanding of random phenomenon apperaing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications. These lectures will be in Japanese in principle and an English resume will be distributed.
Fluid Dynamics 2 credits Elective Required Professor Keisuke Sawada	**Solid Mechanics** 2 credits Elective Required Professor Masumi Saka Professor Tomonaga Okabe
This course covers the basics of both incompressible and compressible fluid dynamics. 1. Conservation laws and governing equations 2. Inviscid, incompressible flows 3. Viscous, incompressible flows 4. Inviscid, compressible flows	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering 2 credits Elective Required Professor Katsuhide Ohira Professor Shigenao Maruyama Professor Hideaki Kobayashi Associate Professor Takashi Tokumasu	**System Control Engineering** 2 credits Elective Required Professor Kazuhiro Kosuge Professor Kazuya Yoshida Professor Koichi Hashimoto Associate Professor Yasuhisa Hirata
In this course, students will master the basic physics of thermal fluid science and thermal energy transformation and learn to link this knowledge to engineering applications. In particular, the course is designed to cover (1) microscopic approaches to thermal phenomena in molecular physics, (2) thermal phenomena involving chemical reactions such as combustion, (3) understanding and control of the various types of heat transfer, and (4) thermal and performance analyses of cryogenic systems such as refrigerators and liquefiers. Through these classes, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.
Materials Chemistry 2 credits Elective Required Professor Yutaka Watanabe Professor Koji Amezawa Professor Yuji Takakuwa Assistant Professor Yoichi Takeda	**Computer Hardware Fundamentals** 2 credits Elective Required Professor Tetsu Tanaka Assistant Professor Riyusuke Egawa
Most metals in the earth's atmosphere inevitably change into more thermodynamically stable compounds such as oxides or sulfides. To understand this principle more precisely, students will learn chemical and electro-chemical equilibrium theory, and kinetics theory in relation to corrosion and oxidation of metals. Practical examples will be used to explain the	Computers have become an indispensable part of modern society. This course addresses computers from the two angles of LSI (Large Scale Integrated circuit) technology and processor architecture. It looks in particular at CMOS-IC technology from the deep sub-micron generation to the deca-nano generation, memory, VLSI processor circuit architecture, high-level

phenomena and theories of wet corrosion and high-temperature oxidation, deepening students' understanding of the chemical and electro-chemical reactions related to macro phenomena of corrosion and oxidation. This course will be offered in English with presentation and discussion style, using English-language materials. A detailed outline of the course will be presented during the first class.	synthesis aimed at boosting performance and cutting power consumption, and integrated design technologies. Students will also learn the fundamentals of smart integrated systems enabling smart information processing.
Solid State Physics 2 credits Elective Required Professor Hiroo Yugami Professor Takahito Ono Professor Ying Chen	**Mechanics of Plasticity** 2 credits Elective Required Professor Toshimitsu Yokobori Associate Professor Riyuji Sugiura Associate Professor Yoshiteru Aoyagi
This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.	This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation.
Structure and Function of Living System 2 credits Elective Required Professor Yoichi Haga Associate Professor Makoto Ohta	**Biosensor Engineering** 2 credits Elective Required Professor Matsuhiko Nishizawa Associate Professor Hirokazu Kaji
In all types of engineering with a connection to the human body, a thorough understanding of the structure and function of the human body and other living systems is vital, as is consideration of systems geared to the special features of these living systems. This course covers the biology knowledge in terms of the basic functions and structures of living organisms that forms the basis of bioengineering. Particular emphasis will be placed on the basic knowledge and approaches necessary for deep exploration of the anatomy and physiology of the human body from the perspective of biomechanics.	
Bio-Micromachine Engineering 2 credits Elective Required Professor Matsuhiko Nishizawa Associate Professor Hirokazu Kaji	**Microengineering for Bio-mechanodevices** 2 credits Elective Required Professor Shiuji Tanaka
	This course deals with key components and microfabrication technology for bio-mechanodevices, which are used for human interface, advanced robotics, biomedical applications, wireless communication etc. Important key components such as sensors, actuators and packaging are overviewed together with related materials and typical applications. Microfabrication technology is explained in detail. The topics include wet/dry etching, physical/chemical vapor deposition, lithography, diffusion, oxidation, electroplating and wafer bonding. The lecture is given in practical aspects as well as fundamental aspects for who is studying microdevices and a wide range of related technology.
Neuroscience 2 credits Elective Required Professor Tetsu Tanaka	**Biofluid Mechanics** 2 credits Elective Required Professor Takuji Ishikawa
	In this lecture, we learn functions of biological flows in terms of fluid mechanics. The cardiovascular, respiratory and digestive systems in the human body are lectured. Rheology of blood, flow in a flexible tube, mass transport, and heat transport in a body are explained using basic equations of mechanical engineering. Moreover, swimming microorganisms and fish as well as flying birds are explained. Finally the effects of mechanical environment on the biological functions are discussed.
Biomechanics 2 credits Elective Required Professor Takuji Ishikawa Associate Professor Makoto Ohta	**Cell Engineering** 2 credits Elective Required Professor Yoichi Haga
This course will be opened for providing knowledge of biomechanical properties of tissues and biofluids such as blood flow. The knowledge will lead you to understand the relationship between the structures and the functions including remodeling. And the understandings are strongly related to biomedical engineering such as medical devices.	
Robot Systems Engineering 2 credits Elective Required Professor Kazuhiro Kosuge Associate Professor Yasuhisa Hirata	**Biomechatronics** 2 credits Elective Required Professor Mami Tanaka

The robot is an advanced system that consists of mechanical parts, actuators, sensors, and controllers. By integrating the several systems and control methods effectively, the robot could realize required tasks in the real environment. In this lecture, the fundamental and advanced motion control methods of the robot will be given, and the recent applications developed by the integration of the robot technologies will be introduced.	
Foundations of Molecular Robotics 2 credits Elective Required Professor Satoshi Murata Associate Professor Shinichiro Nomura	**Intelligent Mechanosystem Analysis** 2 credits Elective Required Professor Toshiyuki Hayase Associate Professor Atsushi Shirai
Introduction to Solid State Ionics 2 credits Elective Required Professor Koji Amezawa Associate Professor Keiji Yashiro	**Human-Robot Informatics** 2 credits Elective Required Professor Satoshi Tadokoro Associate Professor Masashi Konyo
Computer Vision 2 credits Elective Required Professor Takayuki Okatani	**Fluid Design Informatics** 2 credits Elective Required Professor Shigeru Obyashi Associate Professor Koji Shimoyama
This course covers methods for analyzing/recognizing images on a computer, methods for measuring physical quantities and controlling robots etc. by using visual information, and theories of recognizing and understanding three-dimensional scenes from images. Their applications to robot vision, medical image analysis, and image synthesis/computer graphics are also discussed.	This lecture discusses a new framework of knowledge discovery by the fusion of the fluid engineering and the information technology. More specifically, the lecture explains techniques of the new computer-aided visualization using the data mining and methods of the knowledge discovery to conquer trade-offs for the fluid engineering problems that have various trade-offs such as environmental compatibility and economy by identifying the trade-off using the multi-objective optimization and visualizing the design information using the cluster analysis.
Physical Fluctuomatics 2 credits Elective Required Professor Kazuyuki Tanaka	**Bio-Plasma Fluid Engineering** 2 credits Elective Required Professor Takehiko Sato
Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing.	Plasma medicine is now becoming one of new medical treatments since a plasma flow is capable of generating various stimuli such as heat, light, pressure, chemical species, charged particles and electric fields. The fundamental and applications of fluid, plasma and biological engineering for plasma medicine are main contents in this course. This course aims to introduce transportation phenomena, plasma generation phenomena, biological reaction phenomena, with measurement methods for the fluid, the plasma, and the biological reaction and to understand interactions of each phenomenon. Also, we will consider the present situation and the future of health problems facing humanity through plasma medicine.
Discussion on Environmental and Industrial Policy 2 credits Elective Required Various teachers	**Ethics of Life for Young Engineers** 2 credits Elective Required Professor Seishi Kudoh Professor Tatsuo Yoshinobu
	Not only medical science but also engineering is closely related to “life”. Applying some engineering technologies to various fields such as medicals and food productions, we undoubtedly face the matter of life and death in humans and other creatures. It is not negligible that environmental issues caused by excessive consumption of materials and energy are possible to scare us. Enormous information and innovative technologies are drastically changing the society, affecting the life style of human severely. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn

	rules on the ethics. We will invite experts who are engaging various fields every lecture. We will also arrange a day for observation tours in which attendees will be divided into several groups and visit hospitals, nursing homes or others.
Interdisciplinary Research 2 credits Elective Required Various teachers	**Project-Based Learning for Frontier of Mechanical Engineering** 2 credits Elective Required Various teachers
	In this study program, students will master a whole process of a project for mechanical design and system integration through practical hands-on experience. The first part comprises some classes on system integration, project management and safety management. The second part comprises project training, in which the students are expected to generate a project proposal and a conceptual design, undertake a design review and create a prototype. At the end, students must give a presentation on their results and write a report. This program is a prerequisite for students who wish to take the course entitled "Innovation Oriented Seminar on Mechanical Engineering."
Internship Training 1 or 2 credits Elective Required All teachers	**International Scientific Internship Training** 1 or 2 credits Elective Required All teachers
Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training.	When students have attended any lectures or practiced in a foreign academic organization or science program, one or two credits are given to them according to the content and the period.
Special Lecture on Bioengineering and Robotics A Elective Required Various teachers	**Advanced Seminar on Aeronautics and Space Engineering A** Elective Required Various teachers
A special lecture on leading-edge academic research in the major area, or on the creation and development of knowledge in relation to the major area.	Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability.
Seminar on Bio-Nanotechnology 2 credits Elective Required Professor Matsuhiko Nishizawa Professor Shuji Tanaka Professor Tetsu Tanaka Associate Professor Hirokazu Kaji	**Seminar on Biomechanics** 2 credits Elective Required Professor Yoichi Haga Professor Takuji Ishikawa Associate Professor Makoto Ohta
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Robotics 2 credits Elective Required Professor Kazuhiro Kosuge Professor Satoshi Murata Professor Mami Tanaka Associate Professor Yasuhisa Hirata Associate Professor Shinichiro Nomura	**Seminar on Intelligent Mechano-Systems** 2 credits Elective Required Professor Toshiyuki Hayase Professor Takehiko Sato Associate Professor Atsushi Shirai
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Innovation Oriented Seminar on Mechanical Engineering 8 credits Elective Required Various teachers	**Master Course Seminar on Bioengineering and Robotics** 8 credits Elective Required
In this course, students engage in experiments and seminars (including research presentations, discussion and literature reviews) on particularly innovation-oriented themes in leading-edge areas of mechanical engineering. To take this seminar, students must pass Project-Based Learning for Frontier of Mechanical Engineering and satisfy the other registration prerequisites. The eight credits are considered to be the equivalent of the eight credits for Masters Course Seminar in terms of masters program completion requirements. However, students earning credits through this seminar cannot simultaneously earn credits for Masters Course Seminar.	Students engage in experiments and seminars, including research presentations, discussion and literature reviews. Students who have acquired credits from the Innovation Oriented Seminar on Mechanical Engineering program do not need to take this course.

Department of Quantum Science and Energy Engineering

Numerical Analysis 2 credits Elective Required Professor Hisao Fukunaga Professor Hidetoshi Hashizume Professor Satoru Yamamoto Associate Professor Naofumi Ohnish Associate Professor Kanjuro Makihara	**Applied Analysis** 2 credits Elective Required Professor Nobuaki Obata
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Mathematical analysis is important for the understanding of random phenomenon appearing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications. These lectures will be in Japanese in principle and an English resume will be distributed.
Fluid Dynamics 2 credits Elective Required Professor Keisuke Sawada	**Solid Mechanics** 2 credits Elective Required Professor Masumi Saka Professor Tomonaga Okabe
This course covers the basics of both incompressible and compressible fluid dynamics. 1. Conservation laws and governing equations 2. Inviscid, incompressible flows 3. Viscous, incompressible flows 4. Inviscid, compressible flows	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering 2 credits Elective Required Professor Katsuhide Ohira Professor Shigenao Maruyama Professor Hideaki Kobayashi Associate Professor Takashi Tokumasu	**System Control Engineering** 2 credits Elective Required Professor Kazuhiro Kosuge Professor Kazuya Yoshida Professor Koichi Hashimoto Associate Professor Yasuhisa Hirata
In this course, students will master the basic physics of thermal fluid science and thermal energy transformation and learn to link this knowledge to engineering applications. In particular, the course is designed to cover (1) microscopic approaches to thermal phenomena in molecular physics, (2) thermal phenomena involving chemical reactions such as combustion, (3) understanding and control of the various types of heat transfer, and (4) thermal and performance analyses of cryogenic systems such as refrigerators and liquefiers. Through these classes, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.
Materials Chemistry 2 credits Elective Required Professor Yutaka Watanabe Professor Koji Amezawa Professor Yuji Takakuwa Associate Professor Yoichi Takeda	**Computer Hardware Fundamentals** 2 credits Elective Required Professor Tetsu Tanaka Associate Professor Riyusuke Egawa
Most metals in the earth's atmosphere inevitably change into more thermodynamically stable compounds such as oxides or sulfides. To understand this principle more precisely, students will learn chemical and electro-chemical equilibrium theory, and kinetics theory in relation to corrosion and oxidation of metals. Practical examples will be used to explain the phenomena and theories of wet corrosion and high-temperature oxidation, deepening students' understanding of the chemical and electro-chemical reactions related to macro phenomena of corrosion and oxidation. This course will be offered in English with presentation and discussion style, using English-language materials. A detailed outline of the course will be presented during the first class.	Computers have become an indispensable part of modern society. This course addresses computers from the two angles of LSI (Large Scale Integrated circuit) technology and processor architecture. It looks in particular at CMOS-IC technology from the deep sub-micron generation to the deca-nano generation, memory, VLSI processor circuit architecture, high-level synthesis aimed at boosting performance and cutting power consumption, and integrated design technologies. Students will also learn the fundamentals of smart integrated systems enabling smart information processing.
Solid State Physics 2 credits Elective Required Professor Hiroo Yugami Professor Takahito Ono Professor Ying Chen	**Science and Engineering of Particle Beam** 2 credits Elective Required Professor Keizo Ishii Guest Professor Tomihiro Kamiya Professor Manabu Tashiro Associate Professor Atsuki Terakawa Associate Professor Shigeo Matsuyama Associate Professor Keitaro Hitomi

This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.	
Quantum and Statistical Mechanics 2 credits Elective Required Professor Yasuyoshi Nagai Associate Professor Kenji Konashi Associate Professor Koji Inoue Associate Professor Keitaro Hitomi Professor Keizo Ishii	**Science and Engineering of Radiations** 2 credits Elective Required Professor Keizo Ishii Professor Hiroshi Watabe Guest Professor Iwao Kanno Guest Professor Kazutoshi Suzuki Associate Professor Atsuki Terakawa Associate Professor Shigeo Matsuyama Associate Professor Keitaro Hitomi Associate Professor Seong-Yun Kim
Fundamentals of quantum mechanics and statistical mechanics will be lectured. The main contents are: 1. General theory of quantum mechanics 2. Potential problems 3. Approximation methods 4. Identical particles and spin 5. Fermi-Dirac and Bose-Einstein statistics 6. Quantization of electromagnetic field 7. Others	
Fusion Reactor Materials 2 credits Elective Required Professor Akira Hasegawa Associate Professor Shiyuhei Nogami Guest Professor Takeo Muroga Guest Associate Professor Takuya Nagasaka	**Reduced-Activation System Design for Nuclear Applications** 2 credits Elective Required Professor Akira Hasegawa
Fusion Reactor Technology and Magneto Hydrodynamics 2 credits Elective Required Professor Hidetoshi Hashizume Associate Professor Shinji Ebara Associate Professor Noritaka Yusa Associate Professor Satoru Ito	**Environmental Perspective on the Energy Flow** 2 credits Elective Required Professor Yuichi Niibori Associate Professor Seong-Yun Kim
This lecture will introduce an outline of a magnetic confinement fusion power reactor, and deal with superconducting magnet and blanket systems and so on as one of the most challenging devices in terms of engineering feasibility. In addition, physics underlying those devices and these applications are lectured as well as some key issues related to the fusion power reactor design, especially to blanket systems. Moreover, the problematique existing in the fusion blanket systems, such as thermal-magneto-hydraulic problems with structural restriction and some measures will be shown.	
Neutron Device Engineering 2 credits Elective Required Professor Tomohiko Iwasaki Associate Professor Shinji Ebara	**Fusion Plasma Diagnostics** 2 credits Elective Required Associate Professor Sumio Kitajima
Neutron Device Engineering is the lecture on the behavior of neutron in the system and device such as fission and fusion reactor from the viewpoint of microscopic to macroscopic. The main topics of the lecture are “Transport of neutron in a medium” and “Dynamics and control of neutron in an energy system and device like nuclear reactor”. This lecture is compulsory for the student who pursues the license for chief engineer of reactor. Besides, it is desired that student takes the lecture of “Introduction to Neutron Transport” in undergraduate course.	Plasma diagnostics is one of important bases for the development of a nuclear fusion reactor. The aim of this course is to introduce basic concepts for equilibrium and transport of plasma confined by a magnetic field e.g. tokamak and stellarator and to give a brief overview of plasma heating methods. After introductions this course provides how to diagnose the core plasma in large experimental devices giving examples of current plasma diagnostic systems.
Energy Physics and Engineering Education 2 credits Elective Required Professor Keizo Ishii Associate Professor Atsuki Terakawa	**Particle Beam System Engineering** 2 credits Elective Required Professor Keizo Ishii Guest Professor Tomihiro Kamiya Associate Professor Atsuki Terakawa Associate Professor Shigeo Matsuyama Associate Professor Keitaro Hitomi
The lecture course presents and discusses the physics foundations of energy generation through nuclear fission and	

fusion reactions. Its aim is to provide the student with sufficient scientific knowledge to understand nuclear power generators.	
Safety Engineering of Nuclear Energy Systems 2 credits Elective Required Professor Makoto Takahashi	**Basics for Plant Life Management** 2 credits Elective Required Professor Yutaka Watanabe Associate Professor Tetsuya Uchimoto Associate Professor Noritaka Yusa
Applied Nuclear Medical Engineering 2 credits Elective Required Professor Hiroshi Ohtsu	**Quantum Energy Engineering** 2 credits Elective Required Various teachers
Engineering of Materials for Application in Irradiation Envi 2 credits Elective Required Associate Professor Shinji Nagata	**Materials for Nuclear Energy Systems** 2 credits Elective Required Professor Hiroaki Abe Professor Akira Hasegawa Associate Professor Yuki Sato
Nuclear Fuel Separation Engineering 2 credits Elective Required Professor Nobuaki Sato Associate Professor Akira Kirishima	**Nuclear Nano Materials Physics** 2 credits Elective Required Professor Yasuyoshi Nagai Associate Professor Kenji Konashi Associate Professor Koji Inoue
	The understanding of nano-scale atomic and electronic structures is increasingly important to study nuclear materials and their irradiation effects. In this lecture, the state-of-the-art methods to analyze the atomic scale defects induced by irradiation and the solute/impurity clustering in the nuclear materials, including three-dimensional atom probe method and positron annihilation spectroscopy, will be reviewed.
Engineering for Actinide Materials 2 credits Elective Required Professor Dai Aoki Associate Professor Kenji Konashi Associate Professor Tomoo Yamamura Associate Professor Fuminori Honda	**Accelerator Health Physics** 2 credits Elective Required Professor Hiroshi Watabe Professor Tomohiko Iwasaki Associate Professor Shigeo Matsuyama
	In response to the extension of accelerator application, it is important to understand the characteristics of radioactive ray occurred from accelerator, the interaction of ray with a medium, the behavior of ray in a medium and the effect of rays to human health for the safety and effective use of accelerator. In Accelerator Health Physics, we give a lecture on the various kinds of accelerator and its characteristics of radiation field, the transport of radioactive ray in a medium, the effect of radiation to human health and the shielding and protection from radiation through a perspective of their mathematical and statistical approach.
Experimental Nuclear System Engineering 2 credits Elective Required Professor Tomohiko Iwasaki Associate Professor Kenji Konashi	**Advanced Practical Nuclear Engineering** 1 credits Elective Required Various teachers
Student must participate in one practical experiment program of following #1 or #2. The recognition of credit on Experimental Nuclear System Engineering is evaluated on the basis of the contents of report in practical experiment program. #1 Nuclear reactor experiment and Operation control work of reactor by the use of critical assembly experiment facility at Kyoto University Reactor Research Institute #2 Experiment of actinide element and material for nuclear application at International Research Center for Nuclear Material Science, Institute for Materials Research, Tohoku University The credit of the lecture can be approved if student participates in an experiment or practical training on nuclear engineering system held at university or research institute in the country or overseas such as Japan Atomic Energy Agency. In this case, student must submit a certification of the experiment or training issued by concerned institute and a report on the experiment or training. The recognition of credit is evaluated on the basis of the report.	

Concrete for nuclear Power Plants 2 credits Elective Required Professor Makoto Hisada Associate Professor Hiroshi Minagawa	**Physical Fluctuomatics** 2 credits Elective Required Professor Kazuyuki Tanaka
	Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing.
Discussion on Environmental and Industrial Policy 2 credits Elective Required Various teachers	**Interdisciplinary Research** 2 credits Elective Required Various teachers
Internship Training 1 or 2 credits Elective Required All teachers	**International Scientific Internship Training** 1 or 2 credits Elective Required All teachers
Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training.	When students have attended any lectures or practiced in a foreign academic organization or science program, one or two credits are given to them according to the content and the period.
Special Lecture on Quantum Energy Engineering A Elective Required Various teachers	**Advanced Seminar on Quantum Energy Engineering A** Elective Required Various teachers
A special lecture on leading-edge academic research in the major area, or on the creation and development of knowledge in relation to the major area.	Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability.
Seminar on Advanced Nuclear Energy Engineering 2 credits Elective Required Professor Keizo Ishii	**Seminar on Safety Engineering of Nuclear Energy Systems** 2 credits Elective Required Professor Yutaka Watanabe Professor Yuichi Niibori Professor Makoto Takahashi Associate Professor Yohei Kikuchi Associate Professor Noritaka Yusa
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Energy Physics Engineering 2 credits Elective Required Professor Hidetoshi Hashizume Professor Tomohiko Iwasaki Associate Professor Shinji Ehara Associate Professor Sumio Kitajima Associate Professor Satoru Ito	**Seminar on Particle-Beam Engineering** 2 credits Elective Required Professor Hiroshi Ohtsu Professor Akira Hasegawa Associate Professor Atsuki Terakawa Associate Professor Shigeo Matsuyama Associate Professor Shiyuhei Nogami

By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Energy Chemical Engineering 2 credits Elective Required Professor Nobuaki Sato Associate Professor Akira Kirishima	**Seminar on Quantum Theoretic Material Engineering** 2 credits Elective Required Professor Dai Aoki Associate Professor Kenji Konashi Associate Professor Tomoo Yamamura Associate Professor Fuminori Honda
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Accelerator Radiation Science and Engineering 2 credits Elective Required Associate Professor Seong-Yun Kim Associate Professor Keitaro Hitomi	**Master Course Seminar on Quantum Energy Engineering** 8 credits Required
By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	Students engage in experiments and seminars, including research presentations, discussion and literature reviews. Students who have acquired credits from the Innovation Oriented Seminar on Mechanical Engineering program do not need to take this course.