2025 Enrollment

Course List and Summary

Master’s Degree Program

授業科目表（MC）List of Courses

Department of Mechanical Systems Engineering

区分 Category	授業科目 Subject	開講時期 Schedule	使用言語 Language	単位 Credit 必須 Required	単位 Credit 選択必須 Elective Required	単位 Credit 選択 Elective	備考 Remarks
専門基盤科目 Major Basic Subjects	数値解析学	毎年 Every year	J		2		左記の専門基盤科目の内から４科目以上選択履修し，８単位以上修得すること． A student has to earn 8 or more credits from the Major basic subjects listed in the left column.
	Numerical Analysis	隔年 Every second year	E				
	統計的モデリング Statistical modeling	毎年 Every year	JE		2		
	基盤流体力学	毎年 Every year	J		2		
	Fluid Dynamics	毎年 Every year	E				
	固体力学	毎年 Every year	J		2		
	Solid Mechanics	毎年 Every year	E				
	熱科学・工学A	隔年 Every second year	J		2		
	Thermal Science and Engineering A	隔年 Every second year	E				
	熱科学・工学B	隔年 Every second year	J		2		
	Thermal Science and Engineering B	隔年 Every second year	E				
	システム制御工学Ⅰ System Control Engineering Ⅰ	毎年 Every year	E		2		
	システム制御工学Ⅱ System Control Engineering Ⅱ	毎年 Every year	E		2		
	材料化学 Materials Chemistry	毎年 Every year	E		2		
	計算機科学	隔年 Every second year	J		2		
	Computer Hardware Fundamentals	隔年 Every second year	E				
	固体物理学 Solid State Physics	毎年 Every year	E		2		
	塑性力学 Mechanics of Plasticity	毎年 Every year	E		2		
	生物の構造と機能	隔年 Every second year	J		2		
	Structure and Function Living System	隔年 Every second year	E				
	ロボットビジョン	隔年 Every second year	J		2		
	Robot Vision	隔年 Every second year	E				
	ディジタル信号処理	隔年 Every second year	J		2		
	Digital Signal Processing	隔年 Every second year	E				
	力学と物理数学	隔年 Every second year	J		2		
	Introduction to Classical Mechanics and Physical Mathematics	隔年 Every second year	E				

	連続体力学	隔年 Every second year	J		2		
	Continuum Mechanics	隔年 Every second year	E				
	応用流体力学	隔年 Every second year	J		2		
	Applied Fluid Mechanics	隔年 Every second year	E				
	構造力学	隔年 Every second year	J		2		
	Structural Mechanics	隔年 Every second year	E				
専門科目 Major General Subjects	知的機械設計学 Intelligent Machine Design				2		左記の専門科目の内から少なくとも１科目以上選択履修し２単位以上を修得するとともに，左記の科目，特別講義 A，特別研修 A，及び関連科目を選択履修し，全体で１２単位以上を修得すること． Students must earn at least 2 credits from the Major general subjects listed in the left column. In total 12 or more credits are required to earn from the Major general subjects, Special Lecture A, Advanced Seminar A, and related subjects.
	ナノ・マイクロトライボロジー	隔年 Every second year	J		2		
	Nano/Micro Tribology	隔年 Every second year	E				
	微小機械構成学 Micro-Nanomechanical Architectonics	隔年 Every second year	E		2		
	エネルギーシステム学 Energy Systems Engineering	隔年 Every second year	E		2		
	環境強度システムデザイン学	隔年 Every second year	J		2		
	Oxidation in High Temperature Environments of Structures and Materials	隔年 Every second year	E				
	機能性流体工学 Functional Fluids Engineering	隔年 Every second year	E		2		
	機械システム保全学 Mechanical Systems Maintenance Engineering	隔年 Every second year	E		2		
	固体イオニクス論 Introduction to Solid State Ionics	隔年 Every second year	E		2		
	超精密加工学	隔年 Every second year	J		2		
	Ultraprecision Machining	隔年 Every second year	E				
	精密生産システム学 Manufacturing Systems	毎年 Every year	J		2		
	自然エネルギーデザイン学	隔年 Every second year	J		2		
	Design of Natural Energy	隔年 Every second year	E				
	ニューロモルフィックデバイス工学	隔年 Every second year	J		2		
	Neuromorphic Device Engineering	隔年 Every second year	E				
	物理フラクチュオマティクス論 Physical Fluctuomatics	毎年 Every year	J		2		
	環境行政論 Environmental Administration	毎年 Every year	J		2		
	工学と生命の倫理 Ethics of Engineering and Life	毎年 Every year	JE		2		
	インターンシップ研修 Internship Training				1~2		
	国際学術インターンシップ研修 International Scientific Internship Training				1~2		

	機械機能創成特別講義A Special Lecture on Mechanical Systems Engineering A				1~2		特別講義 A, 特別研修 A で修得した単位は 2 単位まで専門科目の要件の 12 単位に含めることができる. なお, ダブルディグリープログラム, 共同教育プログラムの学生に限り, 特別講義 A の単位を 8 単位まで本要件に含めることができる. A total of 2 credits at most, obtained from Special Lecture A and/or Advanced Seminar A, can be included in the requirement of 12 credits. As an exception, students enrolled in the double-degree program or joint educational program can include up to 8 credits from Special Lecture A.
	機械機能創成特別研修A Advanced Seminar on Mechanical Systems Engineering A				1~2		
関連科目 Related Subjects of Other Majors	本研究科委員会において関連科目として認められたもの。 Those approved by the Educational Committee of the Graduate School of Engineering						
専門科目 Major General Subjects	機能システム学セミナー Seminar on Mechanical Systems	毎年 Every year	JE		2		左記のセミナーのうちから, 指導教員の所属するセミナー 2 単位を修得すること. Students must earn 2 credits from one of their supervisor's seminars listed in the left column.
	エネルギー学セミナー Seminar on Energy Engineering	毎年 Every year	JE		2		
	知的メカノシステム工学セミナーSeminar on Intelligent Mechano-Systems	毎年 Every year	JE		2		
	機械機能創成修士研修 Master's Research Training in Mechanical Systems and Engineering			8			

1, 上記科目の単位数を合わせて 30 単位以上を修得すること。

Students must acquire 30 or more credits from the subjects above.

2,『開講時期』については、現時点におけるものであり、変更になることもある。開講年度などは授業時間割などで確認すること。

“Schedule” is currently tentative and may be subject to change.

Make sure to check the fiscal years when each class is offered with the time schedule of the classes, program syllabus, etc.

3,「使用言語」欄のアルファベット記号について

Language Key

E:英語開講科目（Lectures given in English）

JE:準英語開講科目（Lectures basically given in Japanese, with English explanations）

J:日本語開講科目（Lectures given in Japanese）

Numerical Analysis 2 credits

Elective Required

Professor Naofumi Ohnishi

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.

Statistical modeling 2 credits

Elective Required

Professor Yuko Araki

Statistical modeling is widely used in various fields of natural and social sciences to extract information from data and to solve problems. In this lectures, we will start from the basic theory underlying statistical modeling of phenomena , and then focuses on (1) how to set up flexible models, (2)how to estimate parameters of models, and (3) how to select optimal models in order to efficiently extract information from recent data with complex and diverse structures.
Background knowledge on elementary probability and statistics are required.

Fluid Dynamics 2 credits

Elective Required

Professor Masaya Shigeta

Students acquire the intuition and knowledge of the nature of fluid motion by studying the fundamentals of Fluid Dynamics with not only theories but also visualized images, observation videos, and computer graphic animations. The goal is for students to be able to predict the fluid motion and to design the control methods in aerodynamic and material processing applications. Students can also improve their abilities of scientific discussion and international communication. Keywords: Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility, Conservation laws, Bernoulli's theorem, Viscosity and diffusivity, Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number, Strouhal number and Kármán's vortex street, Navier-Stokes and wave equations, Analogy with heat and mass transfers, and Plasma as high-temperature chemically-reactive electromagnetic fluid.

Solid Mechanics 2 credits

Elective Required

Associate Professor Yoshiteru Aoyagi

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 A 2 credits

Elective Required

Professor Kaoru Maruta

Professor Takashi Tokumasu

Professor Hisashi Nakamura

Associate Professor Akihiro Hayakawa

In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.

Thermal Science and Engineering B 2 credits

Elective Required

Professor Taku Ohara

Professor Tetsushi Biwa

Professor Atsuki Komiya

Professor Gota Kikugawa

Associate Professor Eita Shoji

Associate Professor Surblys Donatas

The students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating-flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.

System Control Engineering I 2 credits

Elective Required

Professor Koichi Hashimoto

Professor Yasuhisa Hirata

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.

System Control Engineering II 2 credits

Elective Required

Professor Kazuya Yoshida

Associate Professor Yusuke Tamura

This course gives an advanced lecture based on the contents of "System Control Engineering I." This lecture introduces the analysis and design methods of control systems used for designing motion control for increasingly advanced and complex mechanical systems. Students will learn fundamental concepts for state and output feedback in the state space, state observer and Kalman filter, and response analysis of control systems. This class includes some exercises using MATLAB.

Materials Chemistry 2 credits

Elective Required

Professor Yutaka Watanabe

Professor Koji Amezawa

Professor Eiji Akiyama

Associate Professor Hiroshi Abe

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 a lecture and practice style, using English-language materials. A detailed outline of the course will be presented during the first class.

Computer Hardware Fundamentals 2 credits

Elective Required

Professor Tetsu Tanaka

Professor Hiroyuki Takizawa

Computers have become an indispensable part of modern society. In this course, both IC technology and computer architecture will be lectured for a better understanding of modern computer systems. First, CMOS-IC technology, memory technology, and 2D/3D integration technology that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture focusing on the structure of computer systems, issues and tradeoffs involved in the design of computer system architecture, and high-performance computing. Also, research topics on state-of-the-art IC technology and computer architecture will be presented in the lecture.

Solid State Physics 2 credits

Elective Required

Professor Takahito Ono

Professor Wataru Yashiro

Associate Professor Makoto Shimizu

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 textbook, 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.

Mechanics of Plasticity 2 credits

Elective Required

Associate Professor Yoshiteru Aoyagi

Mechanics of plasticity is an extended subject of mechanics of materials, mechanics of elasticity, continuum mechanics, and solid mechanics. This lecture aims to understand the mechanical description of "plastic deformation," a fundamental phenomenon such as the strength and fracture of materials, forming process, and tribology, and to master a deformation analysis method based on plasticity. This lecture covers 1) basic concepts of plastic deformation, 2) a mechanical description of plastic deformation, 3) a simulation method using the finite element method, and 4) applications to engineering through examples.

Structure and Function of Living System 2 credits

Elective Required

Professor Yoichi Haga

Professor Makoto Ohta

Professor Takuji Ishikawa

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.

Robot Vision 2 credits

Elective Required

Professor Takayuki Okatani

This course explains various problems and their solutions in computer vision. The problems are basically inverse problems in which we wish to estimate some information about an object or a scene from their image(s), such as the three-dimensional shape of a scene or the categories of object. Students will first learn a series of fundamental concepts, and then study a number of approaches to the problems of computer vision, where the main focus is on the recently developed deep learning methods.

Digital Signal Processing 2 credits

Elective Required

Professor Shingo Kagami

Professor Toshinori Kuwahara

This lecture covers fundamentals of digital signal processing that provides a foundation for sensing, control, communication, voice processing, image processing, and so forth. Related subjects include discrete-time signals, discrete-time and discrete Fourier transformations, sampling, digital frequency analysis, discrete-time systems, z transformation, digital filtering, and some more advanced topics.

Introduction to Mechanics and Physical Mathematics 2 credits

Elective Required

Professor Tomonaga Okabe

In the modeling of classical mechanics, we often meet the applied mathematics, such as differential geometry or manifolds theory. These have been developed from the viewpoint of mathematical universality and do not always provide new ideas directly. But, we often need such a background to make the theoretical models. Furthermore, symbols and calculations developed in these fields are not commonly used by general engineering students or graduate students of engineering, and this is considered to be an obstacle for learning them. In this lecture, I am going to introduce those

	mathematical expressions as simple as possible, so that the students can employ the advanced mathematics in the general mechanical engineering field. This course can also be considered as an introduction to the tools of physical mathematics.
Continuum Mechanics 2 credits Elective Required Professor Takuji Ishikawa Associate Professor Toshihiro Omori Materials may be regarded as continuum at the macroscopic scale. In this lecture, we aim to mathematically understand the motion and deformation of materials, such as solid and fluid, at the macroscopic scale. We first explain the concepts of continuum and stress as well as vector/tensor analysis. We then derive basic equations describing the motion and deformation of continuum, such as equilibrium equation, constitutive equation and boundary conditions. This lecture is the basis of solid and fluid mechanics, which is recommended to students who want to establish a whole picture of both subjects.	**Applied Fluid Mechanics** 2 credits Elective Required Professor Jun Ishimoto Professor Yuka Iga This lecture will be given on the fundamentals and applications of multiphase fluid dynamics and numerical analysis related to the fluid dynamic phenomena with heterogeneous interfaces, gas-liquid two-phase flow, phase change, cavitation, and the fundamentals of turbo-type fluid machinery such as pumps and turbines. The main topics to be understand are as follows. 1) Flow pattern and classification method of gas-liquid two-phase flow, 2) Fundamentals of two-fluid model, 3) Modeling of dispersed multi-phase flow and numerical analysis, 4) Modeling of liquid atomization 5) Classification and role of fluid machinery 6) Generation of cavitation in pumps.
Structural Mechanics 2 credits Elective Required Professor Kanjuro Makihara Associate Professor Keisuke Otsuka This lecture gives a fundamental knowledge on the structural analysis and the structural design of mechanical structures. Main topics of this lecture are deformation and stress analyses of fuselage and wing structures subjected to bending, twisting and shear. (1) Fundamental of mechanical structure and material strength. (2) Vibration analysis for structures. (3) Applied load and stress analysis of mechanical structures. (4) Structural identification and structural health monitoring (5) Structural mechanics for aerospace engineering.	
Nano/Micro Tribology 2 credits Elective Required Professor Koshi Adachi Associate Professor Motoyuki Murashima Many contact interfaces exist in one machine or device, and they have strong effects on the performance of the machine or device. Performance of machines and devices are sometimes limited by such contact interfaces. Microscopic design of contact interfaces becomes important and necessary as the size of a machine or device becomes smaller or thinner together with higher performance and accuracy. Principal properties of surfaces and contact interfaces will be explained in this lecture for such needs, and fundamentals and applications of friction and wear will be introduced.	**Micro-Nanomechanical Architectonics** 2 credits Elective Required Professor Takahito Ono Associate Professor Masaya Toda Associate Professor Nguyen Van Toan Designing of mechanical system based on nanotechnology is an intellectual task combining large amount of information and wide experimental knowledge. In this class, the fundamental knowledge and designing theories of the highly developed micro machines for each process of their planning, fabrication and evaluation are presented. The processes to combine mechanics, electronics, fluidics, and optical components in the design of micro mechanics, the examples of modelling, simulation and fabrication of the devices, and the evaluation and the optimization of design are lectured with several trial examples of actual designs.

Energy Systems Engineering 2 credits

Elective Required
Associate Professor Makoto Shimizu

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.

Oxidation in High Temperature Environments of Structures and Materials 2 credits

Elective Required
Professor Kazuhiro Ogawa
Professor Ken Suzuki

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.

Functional Fluids Engineering 2 credits

Elective Required
Professor Takehiko Sato
Professor Masaya Shigeta
Professor Hidemasa Takana

This course covers fluids that express functionality depending by external fields. We discuss fundamentals of fluids’ structure, mechanism of exhibiting the functionalities, transport phenomena, governing equations, and diagnostic method for the functional fluids such as plasma fluid, magnetic fluid, MR or ER fluids, ionic liquid. Also, regarding advanced applications using functionalities of those fluids, we outline plasma medicine, environmental remediation, material processing, energy equipment and other topics.

Mechanical Systems Maintenance Engineering 2 credits

Elective Required
Professor Tetsuya Uchimoto

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 outline the disciplines composing maintenance engineering such as reliability engineering, materials degradation, risk evaluation, nondestructive testing, failure analysis. In addition, recent works will be introduced: such as a novel health monitoring system, a vibration control system, and so on.

Introduction to Solid State Ionics 2 credits

Elective Required
Professor Koji Amezawa
Associate Professor Kazuhisa Sato

In this lecture, ionic transport phenomena in solids will be discussed. Ions in ceramics, ionic crystals, and inorganic glasses can move in varying degrees. Particularly solids showing excellent ionic conduction are called as solid-state ionic conductors, and utilized as electrolytes or electrodes of fuel cells, batteries, and electrochemical sensors. In this lecture, basics of solid-state Ionics, such as mechanisms of ionic conduction in solid, will be first explained, and then advanced applications of solid-state ionic conductors will be introduced.

Ultraprecision Machining 2 credits

Elective Required
Professor Masayoshi Mizutani

Focusing on description of the principles, technologies and applications achieving both the ultra-precise form accuracy and ultra-smooth surface roughness. The purpose of this course, especially, is to deepen understanding of Ultra-precision machining technology focusing on micro-mechanical machining, non-conventional processing, or additive manufacturing.

Manufacturing Systems 2 credits

Elective Required
Professor Masayoshi Mizutani
Adjunct Instructor Makoto Sano
Adjunct Instructor Takashi Genma

This class is included two topics. One is focusing on description of the fundamental principles and applications for intelligent CNC machining centers and industrial robots for industrial production. Machining center, Control system of CNC machine, Mechanisms and control for robot, Sensing system for robot, Software and language for robot, CAD/CAM and FMS, ultra-precision machine. The other is focusing on an optical instrument for LSI manufacturing systems.

Design of Natural Energy 2 credits

Elective Required
Associate Professor Anna Suzuki

Diffusion of renewable energy technologies must deal with complex and uncertain nature, which is beyond human control. This course surveys trends in renewable energy development and study design methodologies for sustainable use of energy from natural systems. The course also explores better ways to use natural energy in society and develops into designs for co-creation in the communities.

Design and manufacture of optical lenses, Mechanisms and control of AF/AE camera, Microscope and telescope, Laser interferometer measuring instrument, LSI production, Stepper.

Neuromorphic Device Engineering 2 credits

Elective Required
Professor Tetsu Tanaka
Professor Takafumi Fukushima

High-performance and highly efficient signal processing is performed in the human brain, compared with that in conventional Neumann-type computing. In this course, from the point of view of signal processing systems beyond the present computing, we will review brain and nervous systems. The students will be able to:
・Understand the detail structures and functions of neurons as a basic neural element.
・Learn about neuromorphic devices and system integration concept/technology.
1st. Introduction & elements of nervous systems
2nd. Neuronal potential and nervous excitement
3rd. Mechanism of synapse transmission
4th. Sensory systems
5th. Neural network
6th. Special talk
7th. Neuromorphic devices 1
8th. Neuromorphic devices 2
9th. Neuromorphic system integration 1
10th. Neuromorphic system integration 2
11th. Neuromorphic system integration 3
12th. Special talk

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 standpoint 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 is 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 also review quantum-mechanical extensions of probabilistic information processing.

Environmental Administration 2 credits

Elective Required
Various teachers

The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively.
In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies.
In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.

Ethics of Engineering and Life 2 credits

Elective Required
Professor Tetsutaro Hattori

We will study wide range of ethical issues including "research ethics", which are important for researchers and engineers. Not only medical science but also engineering is closely related to “life”. Applying some engineering technologies to various fields such as medicine and food productions, we undoubtedly face the matter of life and death in humans and other creatures. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn the ethical norm. We will invite experts engaged in various fields to give lectures. We will also arrange group discussion and presentation.
*Note for foreign students: Lectures are given in Japanese. In slides and handouts, some lecturers give titles etc. both in Japanese and English, but others do not.

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 master's 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

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 Mechanical Systems Engineering A

1 or 2 credits

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.

Advanced Seminar on Mechanical Systems Engineering A

1 or 2 credits
Elective Required
Various teachers

Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which student 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 Mechanical Systems 2 credits

Elective Required
Professor Koshi Adachi
Professor Takahito Ono
Professor Kazuhiro Ogawa
Professor Tetsu Tanaka
Professor Masayoshi Mizutani
Professor Takafumi Fukushima
Associate Professor Masaya Toda
Associate Professor Kazuhisa Sato
Associate Professor Yuji Ichikawa
Associate Professor Motoyuki Murashima
Associate Professor Nguyen Van Toan

By introducing and discussing key research papers in relation to their master's 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 Engineering 2 credits

Elective Required
Professor Tetsushi Biwa
Professor Masaya Shigeta
Professor Kaoru Maruta
Professor Tetsuya Uchimoto
Professor Yuka Iga
Professor Koji Amezawa
Professor Atsuki Komiya
Professor Hidemasa Takana
Associate Professor Junnosuke Okajima
Associate Professor Makoto Shimizu
Associate Professor Anna Suzuki
Associate Professor Yuta Kimura
Associate Professor Hitoshi Muneoka

By introducing and discussing key research papers in relation to their master's 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 Intelligent Mechano-Systems 2 credits

Elective Required
Professor Takehiko Sato

By introducing and discussing key research papers in relation to their master's 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.

Master's Research Training in Mechanical Systems and Engineering 8 credits

Required
Various teachers

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.

授業科目表（MC）List of Courses

Department of Finemechanics

区分 Category	授業科目 Subject	開講時期 Schedule	使用言語 Language	単位 Credit 必須 Required	選択必須 Elective Required	選択 Elective	備考 Remarks
専門基盤科目 Major Basic Subjects	数値解析学	毎年 Every year	J		2		左記の専門基盤科目の内から４科目以上選択履修し，８単位以上修得すること． A student has to earn 8 or more credits from the Major basic subjects listed in the left column.
	Numerical Analysis	隔年 Every second year	E				
	統計的モデリング Statistical modeling	毎年 Every year	JE		2		
	基盤流体力学	毎年 Every year	J		2		
	Fluid Dynamics	毎年 Every year	E				
	固体力学	毎年 Every year	J		2		
	Solid Mechanics	毎年 Every year	E				
	熱科学・工学A	隔年 Every second year	J		2		
	Thermal Science and Engineering A	隔年 Every second year	E				
	熱科学・工学B	隔年 Every second year	J		2		
	Thermal Science and Engineering B	隔年 Every second year	E				
	システム制御工学Ⅰ System Control Engineering Ⅰ	毎年 Every year	E		2		
	システム制御工学Ⅱ System Control Engineering Ⅱ	毎年 Every year	E		2		
	材料化学 Materials Chemistry	毎年 Every year	E		2		
	計算機科学	隔年 Every second year	J		2		
	Computer Hardware Fundamentals	隔年 Every second year	E				
	固体物理学 Solid State Physics	毎年 Every year	E		2		
	塑性力学 Mechanics of Plasticity	毎年 Every year	E		2		
	生物の構造と機能	隔年 Every second year	J		2		
	Structure and Function Living System	隔年 Every second year	E				
	ロボットビジョン	隔年 Every second year	J		2		
	Robot Vision	隔年 Every second year	E				
	ディジタル信号処理	隔年 Every second year	J		2		
	Digital Signal Processing	隔年 Every second year	E				
	力学と物理数学	隔年 Every second year	J		2		
	Introduction to Classical Mechanics and Physical Mathematics	隔年 Every second year	E				

	連続体力学	隔年 Every second year	J		2		
	Continuum Mechanics	隔年 Every second year	E				
	応用流体力学	隔年 Every second year	J		2		
	Applied Fluid Mechanics	隔年 Every second year	E				
	構造力学	隔年 Every second year	J		2		
	Structural Mechanics	隔年 Every second year	E				
専門科目 Major General Subjects	光計測 Optical Metrology	隔年 Every second year	E		2		左記の専門科目の内から少なくとも１科目以上選択履修し２単位以上を修得するとともに，左記の科目，特別講義 A，特別研修 A，及び関連科目を選択履修し，全体で１２単位以上を修得すること． Students must earn at least 2 credits from the Major general subjects listed in the left column. In total 12 or more credits are required to earn from the Major general subjects, Special Lecture A, Advanced Seminar A, and related subjects.
	材料システム計測評価学	隔年 Every second year	J		2		
	Sensing and Evaluation of Materials System	隔年 Every second year	E				
	超精密加工学	隔年 Every second year	J		2		
	Ultraprecision Machining	隔年 Every second year	E				
	ナノ・マイクロメカノプティクス Nano/Micro Mechanoptics	隔年 Every second year	E		2		
	ナノ・マイクロトライボロジー	隔年 Every second year	J		2		
	Nano/Micro Tribology	隔年 Every second year	E				
	グリーンナノテクノロジー Green Nanotechnology	隔年 Every second year	E		2		
	地殻構造・エネルギー工学 Geo-technical and Energy Engineering	隔年 Every second year	JE		2		
	精密生産システム学 Manufacturing Systems	毎年 Every year	J		2		
	材料システム設計学	隔年 Every second year	J		2		
	Design of Materials System	隔年 Every second year	E				
	バイオセンサ工学 Biosensor Engineering	隔年 Every second year	E		2		
	バイオマイクロマシン工学 Bio-Micromachine Engineering	隔年 Every second year	E		2		
	生物流体工学	隔年 Every second year	J		2		
	Biofluid Mechanics	隔年 Every second year	E				
	バイオメカニクス特別講義 I	隔年 Every second year	J		2		
	Special Lecture Series on Integrated Biomechanics I	隔年 Every second year	E				
	知的メカノシステム解析学 Intelligent Mechanosystem Analysis	隔年 Every second year	E		2		
	表面ナノ・マイクロ計測制御学 Nano-and Micro-Surface Metrology and Engineering	隔年 Every second year	E		2		
	物理フラクチュオマティクス論 Physical	毎年 Every year	J		2		

	Fluctuomatics						
	環境行政論 Environmental Administration	毎年 Every year	J		2		
	工学と生命の倫理 Ethics of Engineering and Life	毎年 Every year	JE		2		
	インターンシップ研修 Internship Training				1~2		
	国際学術インターンシップ研修 International Scientific InternshipTraining				1~2		
	ファインメカニクス特別講義A Special Lecture on Finemechanics A				1~2		特別講義 A, 特別研修 A で修得した単位は 2 単位まで専門科目の要件の 12 単位に含めることができる. なお, ダブルディグリープログラム, 共同教育プログラムの学生に限り, 特別講義 A の単位を 8 単位まで本要件に含めることができる. A total of 2 credits at most, obtained from Special Lecture A and/or Advanced Seminar A, can be included in the requirement of 12 credits. As an exception, students enrolled in the double-degree program or joint educational program can include up to 8 credits from Special Lecture A.
	ファインメカニクス特別研修A Advanced Seminar on Finemechanics A				1~2		
関連科目 Related Subjects of Other Majors	本研究科委員会において関連科目として認められたもの。 Those approved by the Educational Committee of the Graduate School of Engineering						
専門科目 Major General Subjects	材料メカニクスセミナー Seminar on Materials and Mechanics	毎年 Every year	JE		2		左記のセミナーのうちから, 指導教員の所属するセミナー 2 単位を修得すること. Students must earn 2 credits from one of their supervisor's seminars listed in the left column.
	ナノメカニクスセミナー Seminar on Nanomechanics	毎年 Every year	JE		2		
	バイオメカニクスセミナー Seminar on Biomechanics	毎年 Every year	JE		2		
	知的メカノシステム工学セミナー Seminar on Intelligent Mechano-Systems	毎年 Every year	JE		2		
	ファインメカニクス修士研修 Master's Research Training in Finemechanics			8			

1, 上記科目の単位数を合わせて 30 単位以上を修得すること。

Students must acquire 30 or more credits from the subjects above.

2,『開講時期』については、現時点におけるものであり、変更になることもある。開講年度などは授業時間割などで確認すること。

“Schedule” is currently tentative and may be subject to change.

Make sure to check the fiscal years when each class is offered with the time schedule of the classes, program syllabus, etc.

3,「使用言語」欄のアルファベット記号について

Language Key

E:英語開講科目（Lectures given in English）

JE:準英語開講科目（Lectures basically given in Japanese, with English explanations）

J:日本語開講科目（Lectures given in Japanese）

Numerical Analysis 2 credits

Elective Required

Professor Naofumi Ohnishi

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.

Statistical modeling 2 credits

Elective Required

Professor Yuko Araki

Statistical modeling is widely used in various fields of natural and social sciences to extract information from data and to solve problems. In this lectures, we will start from the basic theory underlying statistical modeling of phenomena , and then focuses on (1) how to set up flexible models, (2)how to estimate parameters of models, and (3) how to select optimal models in order to efficiently extract information from recent data with complex and diverse structures.
Background knowledge on elementary probability and statistics are required.

Fluid Dynamics 2 credits

Elective Required

Professor Masaya Shigeta

Students acquire the intuition and knowledge of the nature of fluid motion by studying the fundamentals of Fluid Dynamics with not only theories but also visualized images, observation videos, and computer graphic animations. The goal is for students to be able to predict the fluid motion and to design the control methods in aerodynamic and material processing applications. Students can also improve their abilities of scientific discussion and international communication. Keywords: Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility, Conservation laws, Bernoulli’s theorem, Viscosity and diffusivity, Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number, Strouhal number and Kármán’s vortex street, Navier-Stokes and wave equations, Analogy with heat and mass transfers, and Plasma as high-temperature chemically-reactive electromagnetic fluid.

Solid Mechanics 2 credits

Elective Required

Associate Professor Yoshiteru Aoyagi

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 A 2 credits

Elective Required

Professor Kaoru Maruta

Professor Takashi Tokumasu

Professor Hisashi Nakamura

Associate Professor Akihiro Hayakawa

In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.

Thermal Science and Engineering B 2 credits

Elective Required

Professor Taku Ohara

Professor Tetsushi Biwa

Professor Atsuki Komiya

Professor Gota Kikugawa

Associate Professor Eita Shoji

Associate Professor Surblys Donatas

The students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating-flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.

System Control Engineering I 2 credits

Elective Required

Professor Koichi Hashimoto
Professor Yasuhisa Hirata

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.

System Control Engineering II 2 credits

Elective Required

Professor Kazuya Yoshida
Associate Professor Yusuke Tamura

This course gives an advanced lecture based on the contents of "System Control Engineering I." This lecture introduces the analysis and design methods of control systems used for designing motion control for increasingly advanced and complex mechanical systems. Students will learn fundamental concepts for state and output feedback in the state space, state observer and Kalman filter, and response analysis of control systems. This class includes some exercises using MATLAB.

Materials Chemistry 2 credits

Elective Required

Professor Yutaka Watanabe
Professor Koji Amezawa
Professor Eiji Akiyama
Associate Professor Hiroshi Abe

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 a lecture and practice style, using English-language materials. A detailed outline of the course will be presented during the first class.

Computer Hardware Fundamentals 2 credits

Elective Required

Professor Tetsu Tanaka
Professor Hiroyuki Takizawa

Computers have become an indispensable part of modern society. In this course, both IC technology and computer architecture will be lectured for a better understanding of modern computer systems. First, CMOS-IC technology, memory technology, and 2D/3D integration technology that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture focusing on the structure of computer systems, issues and tradeoffs involved in the design of computer system architecture, and high-performance computing. Also, research topics on state-of-the-art IC technology and computer architecture will be presented in the lecture.

Solid State Physics 2 credits

Elective Required
Professor Takahito Ono
Professor Wataru Yashiro
Associate Professor Makoto Shimizu

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 textbook, 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.

Mechanics of Plasticity 2 credits

Elective Required
Associate Professor Yoshiteru Aoyagi

Mechanics of plasticity is an extended subject of mechanics of materials, mechanics of elasticity, continuum mechanics, and solid mechanics. This lecture aims to understand the mechanical description of "plastic deformation," a fundamental phenomenon such as the strength and fracture of materials, forming process, and tribology, and to master a deformation analysis method based on plasticity. This lecture covers 1) basic concepts of plastic deformation, 2) a mechanical description of plastic deformation, 3) a simulation method using the finite element method, and 4) applications to engineering through examples.

Structure and Function of Living System 2 credits

Elective Required

Professor Yoichi Haga
Professor Makoto Ohta
Professor Takuji Ishikawa

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.

Robot Vision 2 credits

Elective Required

Professor Takayuki Okatani

This course explains various problems and their solutions in computer vision. The problems are basically inverse problems in which we wish to estimate some information about an object or a scene from their image(s), such as the three-dimensional shape of a scene or the categories of object. Students will first learn a series of fundamental concepts, and then study a number of approaches to the problems of computer vision, where the main focus is on the recently developed deep learning methods.

Digital Signal Processing 2 credits

Elective Required
Professor Shingo Kagami
Professor Toshinori Kuwahara

This lecture covers fundamentals of digital signal processing that provides a foundation for sensing, control, communication, voice processing, image processing, and so forth. Related subjects include discrete-time signals, discrete-time and discrete Fourier transformations, sampling, digital frequency analysis, discrete-time systems, z transformation, digital filtering, and some more advanced topics.

Introduction to Mechanics and Physical Mathematics 2 credits

Elective Required
Professor Tomonaga Okabe

In the modeling of classical mechanics, we often meet the applied mathematics, such as differential geometry or manifolds theory. These have been developed from the viewpoint of mathematical universality and do not always provide new ideas directly. But, we often need such a background to make the theoretical models. Furthermore, symbols and calculations developed in these fields are not commonly used by general engineering students or graduate students of engineering, and this is considered to be an obstacle for learning them. In this lecture, I am going to introduce those mathematical expressions as simple as possible, so that the students can employ the advanced mathematics in the general mechanical engineering field. This course can also be considered as an introduction to the tools of physical mathematics.

Continuum Mechanics 2 credits

Elective Required
Professor Takuji Ishikawa
Associate Professor Toshihiro Omori

Materials may be regarded as continuum at the macroscopic scale. In this lecture, we aim to mathematically understand the motion and deformation of materials, such as solid and fluid, at the macroscopic scale. We first explain the concepts of continuum and stress as well as vector/tensor analysis. We then derive basic equations describing the motion and deformation of continuum, such as equilibrium equation, constitutive equation and boundary conditions. This lecture is the basis of solid and fluid mechanics, which is recommended to students who want to establish a whole picture of both subjects.

Applied Fluid Mechanics 2 credits

Elective Required
Professor Jun Ishimoto
Professor Yuka Iga

This lecture will be given on the fundamentals and applications of multiphase fluid dynamics and numerical analysis related to the fluid dynamic phenomena with heterogeneous interfaces, gas-liquid two-phase flow, phase change, cavitation, and the fundamentals of turbo-type fluid machinery such as pumps and turbines. The main topics to be understand are as follows. 1) Flow pattern and classification method of gas-liquid two-phase flow, 2) Fundamentals of two-fluid model, 3) Modeling of dispersed multi-phase flow and numerical analysis, 4) Modeling of liquid atomization 5) Classification and role of fluid machinery 6) Generation of cavitation in pumps.

Structural Mechanics 2 credits

Elective Required
Professor Kanjuro Makihara
Associate Professor Keisuke Otsuka

This lecture gives a fundamental knowledge on the structural analysis and the structural design of mechanical structures. Main topics of this lecture are deformation and stress analyses of fuselage and wing structures subjected to bending, twisting and shear. (1) Fundamental of mechanical structure and material strength. (2) Vibration analysis for structures. (3) Applied load and stress analysis of mechanical structures. (4) Structural identification and structural health monitoring (5) Structural mechanics for aerospace engineering.

Optical Metrology 2 credits
Elective Required
Professor Wei Gao
Associate Professor Hiraku Matsukuma

This course focuses on precision metrology based on optical measuring methods and systems for ultraprecision manufacturing, including measurement of displacement and vibrations, surface profiles, geometric forms and motions of precision machines. Fundamental theories of geometrical optics and wave optics and applications of optical sensor technologies, such as linear encoder, autocollimator, laser triangulation sensor, laser interferometer, etc., as well as those of 3D measuring instruments, such as surface interferometer, interference microscope, optical scanner, machine vision, etc., will be learned through presentations and discussions. Precision optical metrology based on ultrashort pulse laser and optical frequency comb will also be treated.

Sensing and Evaluation of Materials System 2 credits
Elective Required
Professor Hitoshi Soyama
Professor Hironori Tohmyoh

Advanced materials system composed of the variety of materials produces various functions. To operate such a materials system without failure for realizing a safe society, comprehensive understanding of the system, which requires trials not tied to conventional methodologies, is indispensable. In this course, in addition to the error theory, which is the basis of measurement, and the inverse problem analysis for identifying the physical quantities, the evaluation of residual strain, which exists in various devices and structures, is treated. Moreover, the methods for evaluating cracks or material degradation in advanced materials system having various scales from electronic devices to various plants are lectured.

Ultraprecision Machining 2 credits
Elective Required
Professor Masayoshi Mizutani

Focusing on description of the principles, technologies and applications achieving both the ultra-precise form accuracy and ultra-smooth surface roughness. The purpose of this course, especially, is to deepen understanding of Ultra-precision machining technology focusing on micro-mechanical machining, non-conventional processing, or additive manufacturing.

Nano/Micro Mechanoptics 2 credits
Elective Required
Professor Yoshiaki Kanamori
Associate Professor Naoki Inomata

Mechanoptics is the fusional research field of optics and mechanics. Nano/Micro mechanoptics is a research field of mechanoptics on nano/micrometer scales. Fundamental technologies and applications in the field are surveyed. The topics on micrometer scale are spatial modulators for displays, micromechanical systems for optical telecommunication, optical sensors, etc. The topics on nanometer scale are wavelength-selective optical filters using subwavelength mechanical structures, optical devices for controlling surface optical reflectance and light polarization, and structural optics smaller than the subwavelength optics. Micro/Nanometer scale fabrication technologies for micro/nano mechanoptics are also studied. The latest papers relating to the above are also presented and discussed.

Nano/Micro Tribology 2 credits
Elective Required
Professor Koshi Adachi
Associate Professor Motoyuki Murashima

Many contact interfaces exist in one machine or device, and they have strong effects on the performance of the machine or device. Performance of machines and devices are sometimes limited by such contact interfaces.
Microscopic design of contact interfaces becomes important and necessary as the size of a machine or device becomes smaller or thinner together with higher performance and accuracy.
Principal properties of surfaces and contact interfaces will be explained in this lecture for such needs, and fundamentals and applications of friction and wear will be introduced.

Green Nanotechnology 2 credits
Elective Required
Professor Kazuhiko Endo

Nanofabrication (etching, deposition, and surface modification) of advanced devices such as ULSIs, nanomachines, optical devices, and bio chips are realized by means of reactive plasmas, scanning tunneling microscope (STM) and so on, via interaction between the device material and microscopic particles such as atoms, molecules, ions, radicals, and photons. This lecture will introduce behavior and interaction of such microscopic particles in processes such as reactive plasma, beam, and atom/molecule handling which are basis of advanced technologies. Measurement methods of such interactions will be explained. Examples of advanced green nanodevices and nano processes used in these devices advanced industries will be introduced.

Geo-technical and Energy Engineering 2 credits

Elective Required
Professor Takatoshi Ito
Professor Hirokazu Moriya
Associate Professor Kiyotoshi Sakaguchi

This course provides an introduction to geomechanics and engineering techniques for exploitation of geo-energy, especially geothermal energy. The class will explore the status and origin of temperature and stress fields in subsurface rocks, hydraulic fracturing techniques used for creating fractures and improving hydraulic properties of rocks, micro seismic imaging and event analysis used for determining geometry and characteristics of fractures, and well testing carried out for determining well and reservoir performance.

Manufacturing Systems 2 credits

Elective Required
Professor Masayoshi Mizutani
Adjunct Instructor Makoto Sano
Adjunct Instructor Takashi Genma

This class is included two topics. One is focusing on description of the fundamental principles and applications for intelligent CNC machining centers and industrial robots for industrial production. Machining center, Control system of CNC machine, Mechanisms and control for robot, Sensing system for robot, Software and language for robot, CAD/CAM and FMS, ultra-precision machine. The other is focusing on an optical instrument for LSI manufacturing systems. Design and manufacture of optical lenses, Mechanisms and control of AF/AE camera, Microscope and telescope, Laser interferometer measuring instrument, LSI production, Stepper.

Design of Materials System 2 credits

Elective Required
Professor Takeshi Yamaguchi
Associate Professor Toshiaki Nishi

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.

Biosensor Engineering 2 credits

Elective Required
Professor Matsuhiko Nishizawa

Biological molecular systems for transduction of information and energy will be briefly lectured, followed by the lecture of the construction, mechanism, and technical trends on biosensors utilizing bio elements such as enzymes and antibodies. Bio interface engineering for integrating bio elements with the electric devices will also be lectured for educating ability for engineering innovative biosensors for advanced medicines.

Bio-Micromachine Engineering 2 credits

Elective Required
Professor Matsuhiko Nishizawa

The progress of Bio micro machine, which is the fusion of biotechnology and micromachine technology, will be fully lectured, assuming their use for advanced medicines. The processing of biocompatible soft materials is important content of this lecture because the fusion of bio elements and the electric devices requires suitable bio interface techniques utilizing smart biomaterials.

Biofluid Mechanics 2 credits

Elective Required
Professor Takuji Ishikawa

In this lecture, we learn functions of biological flows in terms of fluid mechanics. Flow field at the cellular scale can be regarded as Stokes flow. We learn basic characteristics and mathematical descriptions of Stokes flow. Flow generated by flagella, swimming microorganisms, motions of vesicles and cells are discussed. Rheology of biofluids is explained by introducing various constitutive laws. Flow in a human body, flying birds, swimming fish and fluid mechanics in spots are lectured. We show fluid mechanics can be a strong tool to understand biological functions.

Special Lecture Series on Integrated Biomechanics I 2 credits

Elective Required
Professor Makoto Ohta
Associate Professor Kenji Kikuchi

The mechanical function and structure of living organisms will be described in detail from the standpoint of continuum mechanics. In particular, we will establish understanding for future research, such as fluid dynamics of blood flow and airflow, muscles, blood vessels, and cells as soft materials, and static and dynamics of skeletal systems as hard materials. Then, we will explain the measurement and visualization methods of the information from the living body and learn the principles of measurements for biological information and its application.

(Note) This course is offered in Japanese and English every other year.

Intelligent Mechanosystem Analysis 2 credits

Elective Required
Professor Kenichi Funamoto
Associate Professor Hitomi Anzai
Associate Professor Takuya Mabuchi

Intelligent mechano-systems are generally modeled as infinite-dimensional nonlinear dynamical systems. As a basis of modern control theory to deal with such systems, we first study basic concepts of function spaces, dual spaces, and linear operators, and understand basic theories of optimization from intuitive geometrical point of view. Next, mathematical modeling of mechano-systems is discussed for fluid control systems focusing on the relationship between the structure of differential equations and physical phenomena. It is preferable to have basic background on fluid dynamics, control engineering, linear algebra, and analysis.

Nano-and Micro-Surface Metrology and Engineering 2 credits

Elective Required
Professor Wataru Yashiro

Measurement and control are the two wheels of manufacturing. The aim of this lecture is to learn the history of the development of conventional techniques for measurement and control methods covering a wide range of spatial scales from atomic to macroscopic scales of surfaces and interfaces that govern the function of materials. The ultimate goal of this lecture is to develop the ability to analyze for oneself what the limits of conventional measurement and control techniques are, and what problems have been essentially solved to open up new frontiers.

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 standpoint 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 is 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.

Environmental Administration 2 credits

Elective Required
Various teachers

The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively.
In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies.
In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.

Ethics of Engineering and Life 2 credits

Elective Required
Professor Tetsutaro Hattori

We will study wide range of ethical issues including "research ethics", which are important for researchers and engineers. Not only medical science but also engineering is closely related to “life”. Applying some engineering technologies to various fields such as medicine and food productions, we undoubtedly face the matter of life and death in humans and other creatures. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn the ethical norm. We will invite experts engaged in various fields to give lectures. We will also arrange group discussion and presentation.
*Note for foreign students: Lectures are given in Japanese. In slides and handouts, some lecturers give titles etc. both in Japanese and English, but others do not.

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 master’s 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

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 Finemechanics A 1 or 2 credits

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.

Advanced Seminar on Finemechanics A 1 or 2 credits

Elective Required
Various teachers

Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which student 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 Hironori Tohmyoh
Professor Takeshi Yamaguchi
Professor Ken Suzuki
Associate Professor Yoshiteru Aoyagi
Associate Professor Keiichi Shirasu
Associate Professor Toshiaki Nishi

By introducing and discussing key research papers in relation to their master's 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 Nanomechanics 2 credits

Elective Required
Professor Wei Gao
Professor Taku Ohara
Professor Takashi Tokumasu
Professor Wataru Yashiro
Professor Kazuhiko Endo
Professor Gota Kikugawa
Associate Professor Hiraku Matsukuma
Associate Professor Daichi Chiba
Associate Professor Hikaru Nomura
Associate Professor Surblys Donatas

By introducing and discussing key research papers in relation to their master's 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 Biomechanics 2 credits

Elective Required
Professor Matsuhiko Nishizawa
Professor Takuji Ishikawa
Associate Professor Kenji Kikuchi
Associate Professor Toshihiro Omori

By introducing and discussing key research papers in relation to their master's 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 Intelligent Mechano-Systems 2 credits

Elective Required
Professor Makoto Ohta
Professor Kenichi Funamoto
Associate Professor Hitomi Anzai

By introducing and discussing key research papers in relation to their master's 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.

Master's Research Training in Finemechanics 8 credits

Required
Various teachers

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.

授業科目表（MC）List of Courses

Department of Robotics

区分 Category	授業科目 Subject	開講時期 Schedule	使用言語 Language	単位 Credit 必須 Required	単位 Credit 選択必須 Elective Required	単位 Credit 選択 Elective	備考 Remarks
専門基盤科目 Major Basic Subjects	数値解析学	毎年 Every year	J		2		左記の専門基盤科目の内から４科目以上選択履修し，８単位以上修得すること． A student has to earn 8 or more credits from the Major basic subjects listed in the left column.
	Numerical Analysis	隔年 Every second year	E				
	統計的モデリング Statistical modeling	毎年 Every year	JE		2		
	基盤流体力学	毎年 Every year	J		2		
	Fluid Dynamics	毎年 Every year	E				
	固体力学	毎年 Every year	J		2		
	Solid Mechanics	毎年 Every year	E				
	熱科学・工学A	隔年 Every second year	J		2		
	Thermal Science and Engineering A	隔年 Every second year	E				
	熱科学・工学B	隔年 Every second year	J		2		
	Thermal Science and Engineering B	隔年 Every second year	E				
	システム制御工学Ⅰ System Control Engineering Ⅰ	毎年 Every year	E		2		
	システム制御工学Ⅱ System Control Engineering Ⅱ	毎年 Every year	E		2		
	材料化学 Materials Chemistry	毎年 Every year	E		2		
	計算機科学	隔年 Every second year	J		2		
	Computer Hardware Fundamentals	隔年 Every second year	E				
	固体物理学 Solid State Physics	毎年 Every year	E		2		
	塑性力学 Mechanics of Plasticity	毎年 Every year	E		2		
	生物の構造と機能	隔年 Every second year	J		2		
	Structure and Function Living System	隔年 Every second year	E				
	ロボットビジョン	隔年 Every second year	J		2		
	Robot Vision	隔年 Every second year	E				
	ディジタル信号処理	隔年 Every second year	J		2		
	Digital Signal Processing	隔年 Every second year	E				
	力学と物理数学	隔年 Every second year	J		2		
	Introduction to Classical Mechanics and Physical Mathematics	隔年 Every second year	E				

	連続体力学	隔年 Every second year	J		2		
	Continuum Mechanics	隔年 Every second year	E				
	応用流体力学	隔年 Every second year	J		2		
	Applied Fluid Mechanics	隔年 Every second year	E				
	構造力学	隔年 Every second year	J		2		
	Structural Mechanics	隔年 Every second year	E				
専門科目 Major General Subjects	微小電気機械システム Micro Electro Mechanical Systems	毎年 Every year	E		2		左記の専門科目の内から少なくとも１科目以上選択履修し２単位以上を修得するとともに，左記の科目，特別講義 A，特別研修 A，及び関連科目を選択履修し，全体で１２単位以上を修得すること． Students must earn at least 2 credits from the Major general subjects listed in the left column. In total 12 or more credits are required to earn from the Major general subjects, Special Lecture A, Advanced Seminar A, and related subjects.
	アドバンスドロボティクス Advanced Robotics	隔年 Every second year	E		2		
	バイオメカトロニクス Biomechatronics	隔年 Every second year	J		2		
	分子ロボティクス基礎	隔年 Every second year	J		2		
	Foundations of Molecular Robotics	隔年 Every second year	E				
	知的メカノシステム解析学 Intelligent Mechanosystem Analysis	隔年 Every second year	E		2		
	固体イオニクス論 Introduction to Solid State Ionics	隔年 Every second year	E		2		
	身体性知能ロボット学 Embodied Intelligence and Robotics	隔年 Every second year	E		2		
	ニューロロボティクス Neuro Robotics	隔年 Every second year	E		2		
	知能制御システム学 Intelligent Control Systems	隔年 Every second year	E		2		
	機能性流体工学 Functional Fluids Engineering	隔年 Every second year	E		2		
	ナノ・マイクロメカノプティクス Nano/Micro Mechanoptics	隔年 Every second year	E		2		
	タフ・サイバーフィジカル AI 学 Tough Cyberphysical AI	隔年 Every second year	J		2		
	物理フラクチュオマティクス論 Physical Fluctuomatics	毎年 Every year	J		2		
	環境行政論 Environmental Administration	毎年 Every year	J		2		
	工学と生命の倫理 Ethics of Engineering and Life	毎年 Every year	JE		2		
	インターンシップ研修 Internship Training				1~2		
	国際学術インターンシップ研修 International Scientific InternshipTraining				1~2		

	ロボティクス特別講義A Special Lecture on Robotics A				1~2		特別講義 A, 特別研修 A で修得した単位は 2 単位まで専門科目の要件の 12 単位に含めることができる. なお, ダブルディグリープログラム, 共同教育プログラムの学生に限り, 特別講義 A の単位を 8 単位まで本要件に含めることができる. A total of 2 credits at most, obtained from Special Lecture A and/or Advanced Seminar A, can be included in the requirement of 12 credits. As an exception, students enrolled in the double-degree program or joint educational program can include up to 8 credits from Special Lecture A.
	ロボティクス特別研修A Advanced Seminar on Robotics A				1~2		
関連科目 Related Subjects of Other Majors	本研究科委員会において関連科目として認められたもの。 Those approved by the Educational Committee of the Graduate School of Engineering						
専門科目 Major General Subjects	ナノシステムセミナー Seminar on Nano-Systems	毎年 Every year	JE		2		左記のセミナーのうちから, 指導教員の所属するセミナー 2 単位を修得すること. Students must earn 2 credits from one of their supervisor's seminars listed in the left column.
	ロボットシステムセミナー Seminar on Robot-Systems	毎年 Every year	JE		2		
	ロボティクス修士研修 Master's Research Training in Robotics			8			

1, 上記科目の単位数を合わせて 30 単位以上を修得すること。

Students must acquire 30 or more credits from the subjects above.

2,『開講時期』については、現時点におけるものであり、変更になることもある。開講年度などは授業時間割などで確認すること。

“Schedule” is currently tentative and may be subject to change.

Make sure to check the fiscal years when each class is offered with the time schedule of the classes, program syllabus, etc.

3,「使用言語」欄のアルファベット記号について

Language Key

E:英語開講科目（Lectures given in English）

JE:準英語開講科目（Lectures basically given in Japanese, with English explanations）

J:日本語開講科目（Lectures given in Japanese）

Numerical Analysis 2 credits

Elective Required

Professor Naofumi Ohnishi

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.

Statistical modeling 2 credits

Elective Required

Professor Yuko Araki

Statistical modeling is widely used in various fields of natural and social sciences to extract information from data and to solve problems. In this lectures, we will start from the basic theory underlying statistical modeling of phenomena , and then focuses on (1) how to set up flexible models, (2)how to estimate parameters of models, and (3) how to select optimal models in order to efficiently extract information from recent data with complex and diverse structures.
Background knowledge on elementary probability and statistics are required.

Fluid Dynamics 2 credits

Elective Required

Professor Masaya Shigeta

Students acquire the intuition and knowledge of the nature of fluid motion by studying the fundamentals of Fluid Dynamics with not only theories but also visualized images, observation videos, and computer graphic animations. The goal is for students to be able to predict the fluid motion and to design the control methods in aerodynamic and material processing applications. Students can also improve their abilities of scientific discussion and international communication. Keywords: Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility, Conservation laws, Bernoulli's theorem, Viscosity and diffusivity, Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number, Strouhal number and Kármán's vortex street, Navier-Stokes and wave equations, Analogy with heat and mass transfers, and Plasma as high-temperature chemically-reactive electromagnetic fluid.

Solid Mechanics 2 credits

Elective Required

Associate Professor Yoshiteru Aoyagi

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 A 2 credits

Elective Required
Professor Kaoru Maruta
Professor Takashi Tokumasu
Professor Hisashi Nakamura
Associate Professor Akihiro Hayakawa

In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.

Thermal Science and Engineering B 2 credits

Elective Required
Professor Taku Ohara
Professor Tetsushi Biwa
Professor Atsuki Komiya
Professor Gota Kikugawa
Associate Professor Eita Shoji
Associate Professor Surblys Donatas

The students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating-flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.

System Control Engineering I 2 credits

Elective Required

Professor Koichi Hashimoto
Professor Yasuhisa Hirata

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.

System Control Engineering II 2 credits

Elective Required

Professor Kazuya Yoshida
Associate Professor Yusuke Tamura

This course gives an advanced lecture based on the contents of "System Control Engineering I." This lecture introduces the analysis and design methods of control systems used for designing motion control for increasingly advanced and complex mechanical systems. Students will learn fundamental concepts for state and output feedback in the state space, state observer and Kalman filter, and response analysis of control systems. This class includes some exercises using MATLAB.

Materials Chemistry 2 credits

Elective Required

Professor Yutaka Watanabe

Professor Koji Amezawa

Professor Eiji Akiyama

Associate Professor Hiroshi Abe

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 a lecture and practice style, using English-language materials. A detailed outline of the course will be presented during the first class.

Computer Hardware Fundamentals 2 credits

Elective Required

Professor Tetsu Tanaka

Professor Hiroyuki Takizawa

Computers have become an indispensable part of modern society. In this course, both IC technology and computer architecture will be lectured for a better understanding of modern computer systems. First, CMOS-IC technology, memory technology, and 2D/3D integration technology that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture focusing on the structure of computer systems, issues and tradeoffs involved in the design of computer system architecture, and high-performance computing. Also, research topics on state-of-the-art IC technology and computer architecture will be presented in the lecture.

Solid State Physics 2 credits

Elective Required

Professor Takahito Ono

Professor Wataru Yashiro

Associate Professor Makoto Shimizu

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 textbook, 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.

Mechanics of Plasticity 2 credits

Elective Required

Associate Professor Yoshiteru Aoyagi

Mechanics of plasticity is an extended subject of mechanics of materials, mechanics of elasticity, continuum mechanics, and solid mechanics. This lecture aims to understand the mechanical description of "plastic deformation," a fundamental phenomenon such as the strength and fracture of materials, forming process, and tribology, and to master a deformation analysis method based on plasticity. This lecture covers 1) basic concepts of plastic deformation, 2) a mechanical description of plastic deformation, 3) a simulation method using the finite element method, and 4) applications to engineering through examples.

Structure and Function of Living System 2 credits

Elective Required

Professor Yoichi Haga

Professor Makoto Ohta

Professor Takuji Ishikawa

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.

Robot Vision 2 credits

Elective Required

Professor Takayuki Okatani

This course explains various problems and their solutions in computer vision. The problems are basically inverse problems in which we wish to estimate some information about an object or a scene from their image(s), such as the three-dimensional shape of a scene or the categories of object. Students will first learn a series of fundamental concepts, and then study a number of approaches to the problems of computer vision, where the main focus is on the recently developed deep learning methods.

Digital Signal Processing 2 credits

Elective Required

Professor Shingo Kagami

Professor Toshinori Kuwahara

This lecture covers fundamentals of digital signal processing that provides a foundation for sensing, control, communication, voice processing, image processing, and so forth. Related subjects include discrete-time signals, discrete-time and discrete Fourier transformations, sampling, digital frequency analysis, discrete-time systems, z transformation, digital filtering, and some more advanced topics.

Introduction to Mechanics and Physical Mathematics 2 credits

Elective Required

Professor Tomonaga Okabe

In the modeling of classical mechanics, we often meet the applied mathematics, such as differential geometry or manifolds theory. These have been developed from the viewpoint of mathematical universality and do not always provide new ideas directly. But, we often need such a background to make the theoretical models. Furthermore, symbols and calculations developed in these fields are not commonly used by general engineering students or graduate students of engineering, and this is considered to be an obstacle for learning them. In this lecture, I am going to introduce those mathematical expressions as simple as possible, so that the students can employ the advanced mathematics in the general mechanical engineering field. This course can also be considered as an introduction to the tools of physical mathematics.

Continuum Mechanics 2 credits

Elective Required

Professor Takuji Ishikawa

Associate Professor Toshihiro Omori

Materials may be regarded as continuum at the macroscopic scale. In this lecture, we aim to mathematically understand the motion and deformation of materials, such as solid and fluid, at the macroscopic scale. We first explain the concepts of continuum and stress as well as vector/tensor analysis. We then derive basic equations describing the motion and deformation of continuum, such as equilibrium equation, constitutive equation and boundary conditions. This lecture is the basis of solid and fluid mechanics, which is recommended to students who want to establish a whole picture of both subjects.

Applied Fluid Mechanics 2 credits

Elective Required

Professor Jun Ishimoto

Professor Yuka Iga

This lecture will be given on the fundamentals and applications of multiphase fluid dynamics and numerical analysis related to the fluid dynamic phenomena with heterogeneous interfaces, gas-liquid two-phase flow, phase change, cavitation, and the fundamentals of turbo-type fluid machinery such as pumps and turbines. The main topics to be understand are as follows. 1) Flow pattern and classification method of gas-liquid two-phase flow, 2) Fundamentals of two-fluid model, 3) Modeling of dispersed multi-phase flow and numerical analysis, 4) Modeling of liquid atomization 5) Classification and role of fluid machinery 6) Generation of cavitation in pumps.

Structural Mechanics 2 credits

Elective Required

Professor Kanjuro Makihara

Associate Professor Keisuke Otsuka

This lecture gives a fundamental knowledge on the structural analysis and the structural design of mechanical structures. Main topics of this lecture are deformation and stress analyses of fuselage and wing structures subjected to bending, twisting and shear. (1) Fundamental of mechanical structure and material strength. (2) Vibration analysis for structures. (3) Applied load and stress analysis of mechanical structures. (4) Structural identification and structural health monitoring (5) Structural mechanics for aerospace engineering.

Micro Electro Mechanical Systems 2 credits
Elective Required
Professor Shuji Tanaka
Associate Professor Takashiro Tsukamoto

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.

Advanced Robotics 2 credits
Elective Required
Professor Yasuhisa Hirata
Associate Professor Yusuke Tamura

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.

Biomechatronics 2 credits
Elective Required
Professor Mami Tanaka

Foundations of Molecular Robotics 2 credits
Elective Required
Professor Satoshi Murata
Associate Professor Shinichiro Nomura

Molecular robotics is a technology for creating systems by combining logically designed molecules. The basis of molecular robotics are DNA nanotechnology and artificial cell engineering. DNA nanotechnology is used to create various nanostructures and molecular computers for molecular robot by designing the sequences of nucleic acid molecules such as DNA. Artificial cell engineering is a methodology to embed various functional molecules in vesicles called liposomes to create a cellular molecular robot. In addition, synthetic biology, which is a closely related subject to molecular robotics, will also be explained.

Intelligent Mechanosystem Analysis 2 credits
Elective Required
Professor Kenichi Funamoto
Associate Professor Hitomi Anzai
Associate Professor Takuya Mabuchi

Intelligent mechano-systems are generally modeled as infinite-dimensional nonlinear dynamical systems. As a basis of modern control theory to deal with such systems, we first study basic concepts of function spaces, dual spaces, and linear operators, and understand basic theories of optimization from intuitive geometrical point of view. Next, mathematical modeling of mechano-systems is discussed for fluid control systems focusing on the relationship between the structure of differential equations and physical phenomena. It is preferable to have basic background on fluid dynamics, control engineering, linear algebra, and analysis.

Introduction to Solid State Ionics 2 credits
Elective Required
Professor Koji Amezawa
Associate Professor Kazuhisa Sato

In this lecture, ionic transport phenomena in solids will be discussed. Ions in ceramics, ionic crystals, and inorganic glasses can move in varying degrees. Particularly solids showing excellent ionic conduction are called as solid state ionic conductors, and utilized as electrolytes or electrodes of fuel cells, batteries, and electrochemical sensors. In this lecture, basics of solid state ionics, such as mechanisms of ionic conduction in solid, will be first explained, and then advanced applications of solid state ionic conductors will be introduced.

Embodied Intelligence and Robotics 2 credits
Elective Required
Professor Kazunori Ohno
Professor Masashi Konyo

Lectures and investigation study on the following themes.
1) Disaster response robotics
2) Haptic interface
3) Field robotics
4) Advanced mechanisms

Neuro Robotics 2 credits
Elective Required
Professor Mitsuhiro Hayashibe
Associate Professor Dai Owaki

This course deals with key elements for Neuro-Robotics which is new scientific field to use robotics for neuroscience and use neuroscience for robotics. We learn robotics computation aspect and neuroscience knowledge to understand human functionality with the view of robotics, and robotics modeling and computation technology which is useful to understand human system of motor control and motor learning. It may include machine learning, neural network, Kalman filtering, control methods for computation aspect. The lecture is given

	in practical aspects as well as fundamental aspects for students who study neurorobotics and its related applications.
Intelligent Control Systems 2 credits Elective Required Professor Koichi Hashimoto Professor Shingo Kagami The aim of this lecture is to obtain the basics knowledge and to know the latest trend for intelligent control systems. Lectures on robot kinematics, robot vision, and feedback control theory will be given. Lectures on building blocks for robot vision systems such as image sensors, image processing and visual tracking will also be given.	**Functional Fluids Engineering** 2 credits Elective Required Professor Takehiko Sato Professor Masaya Shigeta Professor Hidemasa Takana This course covers fluids that express functionality depending by external fields. We discuss fundamentals of fluids' structure, mechanism of exhibiting the functionalities, transport phenomena, governing equations, and diagnostic method for the functional fluids such as plasma fluid, magnetic fluid, MR or ER fluids, ionic liquid. Also, regarding advanced applications using functionalities of those fluids, we outline plasma medicine, environmental remediation, material processing, energy equipment and other topics.
Nano/Micro Mechanoptics 2 credits Elective Required Professor Yoshiaki Kanamori Associate Professor Naoki Inomata Mechanoptics is the fusional research field of optics and mechanics. Nano/Micro mechanoptics is a research field of mechanoptics on nano/micrometer scales. Fundamental technologies and applications in the field are surveyed. The topics on micrometer scale are spatial modulators for displays, micromechanical systems for optical telecommunication, optical sensors, etc. The topics on nanometer scale are wavelength-selective optical filters using subwavelength mechanical structures, optical devices for controlling surface optical reflectance and light polarization, and structural optics smaller than the subwavelength optics. Micro/Nanometer scale fabrication technologies for micro/nano mechanoptics are also studied. The latest papers relating to the above are also presented and discussed.	**Tough Cyberphysical AI** 2 credits Elective Required Professor Kazunori Ohno The importance of cyberphysical AI that operates in the real world with embodiment is rapidly growing. In order to contribute to solving issues that our society faces such as SDGs and disasters, with the central issues of system robustness, flexibility, adaptability, and wide applicability, this course will give lectures, exercises, and discussions on advanced research of tough cyberphysical AI such as tough robotics, intelligence operating in extreme environments, and their advancement.

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 standpoint 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 is 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.

Environmental Administration 2 credits

Elective Required

Various teachers

The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively.
In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies.
In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.

Ethics of Engineering and Life 2 credits

Elective Required

Professor Tetsutaro Hattori

We will study wide range of ethical issues including "research ethics", which are important for researchers and engineers. Not only medical science but also engineering is closely related to “life”. Applying some engineering technologies to various fields such as medicine and food productions, we undoubtedly face the matter of life and death in humans and other creatures. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn the ethical norm. We will invite experts engaged in various fields to give lectures. We will also arrange group discussion and presentation.
*Note for foreign students: Lectures are given in Japanese. In slides and handouts, some lecturers give titles etc. both in Japanese and English, but others do not.

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 master’s 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

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 Robotics A 1 or 2 credits

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.

Advanced Seminar on Robotics A 1 or 2 credits
Elective Required
Various teachers

Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which student 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 Nano-Systems 2 credits
Elective Required
Professor Shuji Tanaka
Professor Satoshi Murata
Professor Yoichi Haga
Professor Yoshiaki Kanamori
Associate Professor Shinichiro Nomura
Associate Professor Takaki Tsukamoto
Associate Professor Naoki Inomata
Associate Professor Takuya Mabuchi

By introducing and discussing key research papers in relation to their master's 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 Robot-Systems 2 credits
Elective Required
Professor Mami Tanaka
Professor Mitsuhiro Hayashibe
Professor Yasuhisa Hirata
Professor Kimitoshi Yamazaki
Associate Professor Takeshi Okuyama
Associate Professor Dai Owaki
Associate Professor Yusuke Tamura

By introducing and discussing key research papers in relation to their master's 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.

Master's Research Training in Robotics 8 credits
Required
Various teachers

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.

授業科目表（MC）List of Courses

Department of Aerospace Engineering

区分 Category	授業科目 Subject	開講時期 Schedule	使用言語 Language	単位 Credit 必須 Required	単位 Credit 選択必須 Elective Required	単位 Credit 選択 Elective	備考 Remarks
専門基盤科目 Major Basic Subjects	数値解析学	毎年 Every year	J		2		左記の専門基盤科目の内から４科目以上選択履修し，８単位以上修得すること． A student has to earn 8 or more credits from the Major basic subjects listed in the left column.
	Numerical Analysis	隔年 Every second year	E				
	統計的モデリング Statistical modeling	毎年 Every year	JE		2		
	基盤流体力学	毎年 Every year	J		2		
	Fluid Dynamics	毎年 Every year	E				
	固体力学	毎年 Every year	J		2		
	Solid Mechanics	毎年 Every year	E				
	熱科学・工学A	隔年 Every second year	J		2		
	Thermal Science and Engineering A	隔年 Every second year	E				
	熱科学・工学B	隔年 Every second year	J		2		
	Thermal Science and Engineering B	隔年 Every second year	E				
	システム制御工学Ⅰ System Control Engineering Ⅰ	毎年 Every year	E		2		
	システム制御工学Ⅱ System Control Engineering Ⅱ	毎年 Every year	E		2		
	材料化学 Materials Chemistry	毎年 Every year	E		2		
	計算機科学	隔年 Every second year	J		2		
	Computer Hardware Fundamentals	隔年 Every second year	E				
	固体物理学 Solid State Physics	毎年 Every year	E		2		
	塑性力学 Mechanics of Plasticity	毎年 Every year	E		2		
	生物の構造と機能	隔年 Every second year	J		2		
	Structure and Function Living System	隔年 Every second year	E				
	ロボットビジョン	隔年 Every second year	J		2		
	Robot Vision	隔年 Every second year	E				
	ディジタル信号処理	隔年 Every second year	J		2		
	Digital Signal Processing	隔年 Every second year	E				
	力学と物理数学	隔年 Every second year	J		2		
	Introduction to Classical Mechanics and Physical Mathematics	隔年 Every second year	E				

	連続体力学	隔年 Every second year	J		2		
	Continuum Mechanics	隔年 Every second year	E				
	応用流体力学	隔年 Every second year	J		2		
	Applied Fluid Mechanics	隔年 Every second year	E				
	構造力学	隔年 Every second year	J		2		
	Structural Mechanics	隔年 Every second year	E				
専門科目 Major General Subjects	航空宇宙システム工学 Aerospace Systems	毎年 Every year	J		2		左記の専門科目の内から少なくとも１科目以上選択履修し２単位以上を修得するとともに，左記の科目，特別講義 A，特別研修 A，及び関連科目を選択履修し，全体で１２単位以上を修得すること． Students must earn at least 2 credits from the Major general subjects listed in the left column. In total 12 or more credits are required to earn from the Major general subjects, Special Lecture A, Advanced Seminar A, and related subjects.
	航空宇宙推進工学	隔年 Every second year	J		2		
	Aerospace Propulsion	隔年 Every second year	E				
	数値流体力学 Computational Fluid Dynamics	隔年 Every second year	E		2		
	宇宙探査ロボティクス Robotics for Space Exploration	隔年 Every second year	E		2		
	衛星工学 Spacecraft Engineering	隔年 Every second year	E		2		
	計算数理科学 Mathematical Modeling and Computation	毎年 Every year	E		2		
	数理流体力学	隔年 Every second year	J		2		
	Applied Mathematical Fluid Dynamics	隔年 Every second year	E				
	高性能計算論 High Performance Computing	毎年 Every year	E		2		
	アーキテクチャ学 Computer Architecture	毎年 Every year	E		2		
	物理フラクチュオマティクス論 Physical Fluctuomatics	毎年 Every year	J		2		
	環境行政論 Environmental Administration	毎年 Every year	J		2		
	工学と生命の倫理 Ethics of Engineering and Life	毎年 Every year	JE		2		
	インターンシップ研修 Internship Training				1~2		
	国際学術インターンシップ研修 International Scientific Internship Training				1~2		

	航空宇宙工学特別講義A Special Lecture on Aerospace Engineering A				1~2		特別講義 A, 特別研修 A で修得した単位は 2 単位まで専門科目の要件の 12 単位に含めることができる. なお, ダブルディグリープログラム, 共同教育プログラムの学生に限り, 特別講義 A の単位を 8 単位まで本要件に含めることができる. A total of 2 credits at most, obtained from Special Lecture A and/or Advanced Seminar A, can be included in the requirement of 12 credits. As an exception, students enrolled in the double-degree program or joint educational program can include up to 8 credits from Special Lecture A.
	航空宇宙工学特別研修A Advanced Seminar on Aerospace Engineering A				1~2		
関連科目 Related Subjects of Other Majors	本研究科委員会において関連科目として認められたもの。 Those approved by the Educational Committee of the Graduate School of Engineering						
専門科目 Major General Subjects	航空システムセミナー Seminar on Aero Systems	毎年 Every year	JE		2		左記のセミナーのうちから, 指導教員の所属するセミナー 2 単位を修得すること. Students must earn 2 credits from one of their supervisor's seminars listed in the left column.
	宇宙システムセミナー Seminar on Space Systems	毎年 Every year	JE		2		
	航空宇宙工学修士研修 Master's Research Training in Aeronautics and Space Engineering			8			

1, 上記科目の単位数を合わせて 30 単位以上を修得すること。

Students must acquire 30 or more credits from the subjects above.

2,『開講時期』については、現時点におけるものであり、変更になることもある。開講年度などは授業時間割などで確認すること。

“Schedule” is currently tentative and may be subject to change.

Make sure to check the fiscal years when each class is offered with the time schedule of the classes, program syllabus, etc.

3,「使用言語」欄のアルファベット記号について

Language Key

E:英語開講科目（Lectures given in English）

JE:準英語開講科目（Lectures basically given in Japanese, with English explanations）

J:日本語開講科目（Lectures given in Japanese）

Numerical Analysis 2 credits

Elective Required

Professor Naofumi Ohnishi

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.

Statistical modeling 2 credits

Elective Required

Professor Yuko Araki

Statistical modeling is widely used in various fields of natural and social sciences to extract information from data and to solve problems. In this lectures, we will start from the basic theory underlying statistical modeling of phenomena , and then focuses on (1) how to set up flexible models, (2)how to estimate parameters of models, and (3) how to select optimal models in order to efficiently extract information from recent data with complex and diverse structures.
Background knowledge on elementary probability and statistics are required.

Fluid Dynamics 2 credits

Elective Required

Professor Masaya Shigeta

Students acquire the intuition and knowledge of the nature of fluid motion by studying the fundamentals of Fluid Dynamics with not only theories but also visualized images, observation videos, and computer graphic animations. The goal is for students to be able to predict the fluid motion and to design the control methods in aerodynamic and material processing applications. Students can also improve their abilities of scientific discussion and international communication. Keywords: Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility, Conservation laws, Bernoulli's theorem, Viscosity and diffusivity, Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number, Strouhal number and Kármán's vortex street, Navier-Stokes and wave equations, Analogy with heat and mass transfers, and Plasma as high-temperature chemically-reactive electromagnetic fluid.

Solid Mechanics 2 credits

Elective Required

Associate Professor Yoshiteru Aoyagi

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 A 2 credits

Elective Required
Professor Kaoru Maruta
Professor Takashi Tokumasu
Professor Hisashi Nakamura
Associate Professor Akihiro Hayakawa

In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.

Thermal Science and Engineering B 2 credits

Elective Required
Professor Taku Ohara
Professor Tetsushi Biwa
Professor Atsuki Komiya
Professor Gota Kikugawa
Associate Professor Eita Shoji
Associate Professor Surblys Donatas

The students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating-flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.

System Control Engineering I 2 credits

Elective Required

Professor Koichi Hashimoto
Professor Yasuhisa Hirata

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.

System Control Engineering II 2 credits

Elective Required

Professor Kazuya Yoshida
Associate Professor Yusuke Tamura

This course gives an advanced lecture based on the contents of "System Control Engineering I." This lecture introduces the analysis and design methods of control systems used for designing motion control for increasingly advanced and complex mechanical systems. Students will learn fundamental concepts for state and output feedback in the state space, state observer and Kalman filter, and response analysis of control systems. This class includes some exercises using MATLAB.

Materials Chemistry 2 credits

Elective Required

Professor Yutaka Watanabe

Professor Koji Amezawa

Professor Eiji Akiyama

Associate Professor Hiroshi Abe

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 a lecture and practice style, using English-language materials. A detailed outline of the course will be presented during the first class.

Computer Hardware Fundamentals 2 credits

Elective Required

Professor Tetsu Tanaka

Professor Hiroyuki Takizawa

Computers have become an indispensable part of modern society. In this course, both IC technology and computer architecture will be lectured for a better understanding of modern computer systems. First, CMOS-IC technology, memory technology, and 2D/3D integration technology that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture focusing on the structure of computer systems, issues and tradeoffs involved in the design of computer system architecture, and high-performance computing. Also, research topics on state-of-the-art IC technology and computer architecture will be presented in the lecture.

Solid State Physics 2 credits

Elective Required

Professor Takahito Ono

Professor Wataru Yashiro

Associate Professor Makoto Shimizu

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 textbook, 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.

Mechanics of Plasticity 2 credits

Elective Required

Associate Professor Yoshiteru Aoyagi

Mechanics of plasticity is an extended subject of mechanics of materials, mechanics of elasticity, continuum mechanics, and solid mechanics. This lecture aims to understand the mechanical description of "plastic deformation," a fundamental phenomenon such as the strength and fracture of materials, forming process, and tribology, and to master a deformation analysis method based on plasticity. This lecture covers 1) basic concepts of plastic deformation, 2) a mechanical description of plastic deformation, 3) a simulation method using the finite element method, and 4) applications to engineering through examples.

Structure and Function of Living System 2 credits

Elective Required

Professor Yoichi Haga

Professor Makoto Ohta

Professor Takuji Ishikawa

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.

Robot Vision 2 credits

Elective Required

Professor Takayuki Okatani

This course explains various problems and their solutions in computer vision. The problems are basically inverse problems in which we wish to estimate some information about an object or a scene from their image(s), such as the three-dimensional shape of a scene or the categories of object. Students will first learn a series of fundamental concepts, and then study a number of approaches to the problems of computer vision, where the main focus is on the recently developed deep learning methods.

Digital Signal Processing 2 credits

Elective Required

Professor Shingo Kagami

Professor Toshinori Kuwahara

This lecture covers fundamentals of digital signal processing that provides a foundation for sensing, control, communication, voice processing, image processing, and so forth. Related subjects include discrete-time signals, discrete-time and discrete Fourier transformations, sampling, digital frequency analysis, discrete-time systems, z transformation, digital filtering, and some more advanced topics.

Introduction to Mechanics and Physical Mathematics 2 credits

Elective Required

Professor Tomonaga Okabe

In the modeling of classical mechanics, we often meet the applied mathematics, such as differential geometry or manifolds theory. These have been developed from the viewpoint of mathematical universality and do not always provide new ideas directly. But, we often need such a background to make the theoretical models. Furthermore, symbols and calculations developed in these fields are not commonly used by general engineering students or graduate students of engineering, and this is considered to be an obstacle for learning them. In this lecture, I am going to introduce those mathematical expressions as simple as possible, so that the students can employ the advanced mathematics in the general mechanical engineering field. This course can also be considered as an introduction to the tools of physical mathematics.

Continuum Mechanics 2 credits

Elective Required

Professor Takuji Ishikawa

Associate Professor Toshihiro Omori

Materials may be regarded as continuum at the macroscopic scale. In this lecture, we aim to mathematically understand the motion and deformation of materials, such as solid and fluid, at the macroscopic scale. We first explain the concepts of continuum and stress as well as vector/tensor analysis. We then derive basic equations describing the motion and deformation of continuum, such as equilibrium equation, constitutive equation and boundary conditions. This lecture is the basis of solid and fluid mechanics, which is recommended to students who want to establish a whole picture of both subjects.

Applied Fluid Mechanics 2 credits

Elective Required

Professor Jun Ishimoto

Professor Yuka Iga

This lecture will be given on the fundamentals and applications of multiphase fluid dynamics and numerical analysis related to the fluid dynamic phenomena with heterogeneous interfaces, gas-liquid two-phase flow, phase change, cavitation, and the fundamentals of turbo-type fluid machinery such as pumps and turbines. The main topics to be understand are as follows. 1) Flow pattern and classification method of gas-liquid two-phase flow, 2) Fundamentals of two-fluid model, 3) Modeling of dispersed multi-phase flow and numerical analysis, 4) Modeling of liquid atomization 5) Classification and role of fluid machinery 6) Generation of cavitation in pumps.

Structural Mechanics 2 credits

Elective Required

Professor Kanjuro Makihara

Associate Professor Keisuke Otsuka

This lecture gives a fundamental knowledge on the structural analysis and the structural design of mechanical structures. Main topics of this lecture are deformation and stress analyses of fuselage and wing structures subjected to bending, twisting and shear. (1) Fundamental of mechanical structure and material strength. (2) Vibration analysis for structures. (3) Applied load and stress analysis of mechanical structures. (4) Structural identification and structural health monitoring (5) Structural mechanics for aerospace engineering.

Aerospace Systems 2 credits
Elective Required
Professor Naofumi Ohnishi
Adjunct Instructor Toshihiko Nakagawa
Adjunct Instructor Soichiro Yada

Lectures give the system concept of aircraft and rocket and discuss the basic design planning and the performance of these flight vehicles.

Aerospace Propulsion 2 credits
Elective Required
Professor Naofumi Ohnishi
Associate Professor Masayuki Takahashi

Lectures on principles of thrust generation of jet engine and rocket engine which propel vehicles in air and space are given, including structure of the engines and methods for improving their performance. Non-chemical propulsion schemes are also introduced, including physics of plasma.

Computational Fluid Dynamics 2 credits
Elective Required
Professor Soshi Kawai

This course provides the basic and advanced fundamentals and theories of modern computational fluid dynamics (CFD) methods for compressible flows. Also, we will provide lectures on the programming of numerical methods discussed in this course.

Robotics for Space Exploration 2 credits
Elective Required
Professor Kazuya Yoshida

Robotics technology is useful for space development and exploration activities. In this course, the subject of Space Robotics is elaborated on the application to orbital servicing missions and lunar/planetary exploration.
As for the "orbital robotics," the following topics are lectured:
- Angular motion kinematics and attitude dynamics of a spacecraft,
- Multi-body dynamics and control of a free-flying space robot,
- Impact dynamics and post-impact control when a space robot captures a floating target.
As for the "lunar/planetary robotics," the following topics are lectured:
- Mission and system design for Lunar and asteroid exploration,
- Mobility system design and analysis for locomotion on the lunar/planetary surface,
- Sensing, planning, and navigation of a mobile robot.
All lectures are given in English.

Spacecraft Engineering 2 credits
Elective Required
Professor Kazuya Yoshida
Professor Kanjuro Makihara
Professor Hiroki Nagai
Professor Toshinori Kuwahara

In this course, the fundamental engineering issues are lectured in the following four parts for the design and development of spacecraft and space flight systems.
(1) Orbital mechanics for various space missions
(2) Attitude dynamics and control of spacecraft
(3) Design of space structures, vibration analysis and control
(4) Thermodynamics and thermal control of space systems
All lectures are given in English.

Mathematical Modeling and Computation 2 credits
Elective Required
Professor Satoru Yamamoto

This lecture introduces typical mathematical models on some physical and social problems observed in nature and in events which are basically formulated by a system of nonlinear partial-differential equations, and also teaches the numerical methods based on the finite-difference method for solving the mathematical models. Each student is subjected to make his own mathematical model and submits the computational result as the final report.

Applied Mathematical Fluid Dynamics 2 credits
Elective Required
Professor Yuji Hattori
Associate Professor Makoto Hirota

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.

High Performance Computing 2 credits
Elective Required
Professor Hiroyuki Takizawa

This course reviews high-performance computing 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 high-performance computing.

Computer Architecture 2 credits

Elective Required

Professor Hiroaki Kobayashi

Associate Professor Masayuki Sato

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 for more details.

http://www.sc.isc.tohoku.ac.jp/class/architecture/

(Contact instructors to have an access ID).

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 standpoint 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 is 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.

Environmental Administration 2 credits

Elective Required

Various teachers

The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively.
In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies.
In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.

Ethics of Engineering and Life 2 credits

Elective Required

Professor Tetsutaro Hattori

We will study wide range of ethical issues including "research ethics", which are important for researchers and engineers. Not only medical science but also engineering is closely related to “life”. Applying some engineering technologies to various fields such as medicine and food productions, we undoubtedly face the matter of life and death in humans and other creatures. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn the ethical norm. We will invite experts engaged in various fields to give lectures. We will also arrange group discussion and presentation.
*Note for foreign students: Lectures are given in Japanese. In slides and handouts, some lecturers give titles etc. both in Japanese and English, but others do not.

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 master’s 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

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 Aerospace Engineering A 1 or 2 credits

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.

Advanced Seminar on Aerospace Engineering A 1 or 2 credits

Elective Required
Various teachers

Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which student 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 Aero Systems 2 credits

Elective Required
Professor Tomonaga Okabe
Professor Hiroki Nagai
Professor Soshi Kawai
Professor Hisashi Nakamura
Associate Professor Go Yamamoto
Associate Professor Yoshiaki Abe
Associate Professor Aiko Yakeno
Associate Professor Kai Fukami

By introducing and discussing key research papers in relation to their master's 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 Space Systems 2 credits

Elective Required
Professor Naofumi Ohnishi
Professor Kazuya Yoshida
Professor Hideaki Kobayashi
Professor Kanjuro Makihara
Professor Toshinori Kuwahara
Associate Professor Masayuki Takahashi
Associate Professor Keisuke Otsuka
Associate Professor Akihiro Hayakawa

By introducing and discussing key research papers in relation to their master's 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.

Master's Research Training in Aeronautics and Space Engineering 8 credits

Required
Various teachers

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 Mechanical Systems Engineering

Undergraduate Course

(Department of Mechanical and Aerospace Engineering)

- Mechanical Systems Course
- Finemechanics Course
- Robotics Course
- Aerospace Engineering Course
- Mechanical / Biomedical Engineering Course
- International Mechanical and Aerospace Engineering Course
- Quantum Science and Energy Engineering Course
- Environment and Energy Engineering Course

Master Degree's Program

Major Basic Subjects

Related to Mechanical Materials

- Solid Mechanics
- Mechanics of Plasticity
- Materials Chemistry
- Solid State Physics
- Continuum Mechanics
- Structural Mechanics

Related to Fluid Mechanics

- Fluid Dynamics
- Applied Fluid Mechanics

Related to Systems and Design

- Syetem Control Engineering Ⅰ
- Syetem Control Engineering Ⅱ
- Computer Hardware Fundamentals
- Robot Vision
- Digital Signal Processing

Related to Thermal and Energy

- Thermal Sience and Engineering A
- Thermal Sience and Engineering B

Mathematics and Science

- Numerical Analysis
- Statistical modeling
- Introduction to Classical Mechanics and Physical Mathmatics

Others

- Structure and Function of Living System

Related to Mechanical Systems Engineering

Internship / Seminar

- Internship Training
- International Scientific Internship Training

Major General Subjects

- Oxidation in HighTemperature Environments of Structures and Materials
- Design of Natural Energy
- Mechanical Systems Maintenance Engineering

Related to Design and Manufacturing

- Nano/Micro Tribology
- Ultraprecision Machining
- Micro-Nanomechanical Architectonics
- Manufacturing Systems
- Functional Fluids Engineering
- Intelligent Machine Design
- Energy Systems Engineering

Related to Mechanical Systems Engineering

- Introduction to Solid Ionics
- Neuromorphic Device Engineering
- Physical Fluctuomatics
- Environmental Administration
- Ethics of Engineering and Life
- Special Lecture on Mechanical Systems Engineering A

Internship / Seminar

- Advanced Seminar on Mechanical Systems Engineering A
- Seminar on Mechanical Systems
- Seminar on Energy Systems Engineering
- Seminar on Intelligent Mechano-Systems
- Master's Research Training in Mechanical Systems and Engineering

Doctoral Degree Program

Interdisciplinary Basic Subjects

Common Subjects for Mechanical and Intelligent Systems

- History of Modern Technology
- New Business Creation
- Venture Strategy
- Nano Magnetism and Magnetic Engineering

Related to Mechanical Systems Engineering

- Advanced Intelligent Design
- Advanced Energy Systems Engineering
- Fracture Mechanics and Mechanism
- Intelligent Fluid Systems
- Advanced Mechanical Systems Maintenance Engineering
- Multidisciplinary Research and Application of Solid-State Ionic
- Advanced Nano/Technology
- Advanced Bio-Nanotechnology

Major General Subjects

Related to Mechanical Systems Engineering

- Special Lecture on Mechanical Systems Engineering B

Internship / Seminar

- Advanced seminar on Mechanical Systems Engineering B
- Doctoral Research Training in Mechanical Systems and Engineering

Department of Finemechanics

Undergraduate Course

(Department of Mechanical and Aerospace Engineering)

- Mechanical Systems Course
- Finemechanics Course
- Robotics Course
- Aerospace Engineering Course
- Mechanical / Biomedical Engineering Course
- International Mechanical and Aerospace Engineering Course
- Quantum Science and Energy Engineering Course
- Environment and Energy Engineering Course

Master Degree's Program

Major Basic Subjects

Related to Mechanical Materials

- Solid Mechanics
- Mechanics of Plasticity
- Materials Chemistry
- Solid State Physics
- Continuum Mechanics
- Structural Mechanics

Related to Fluid Mechanics

- Fluid Dynamics
- Applied Fluid Mechanics

Related to Control and Engineering

- Syetem Control Engineering Ⅰ
- Syetem Control Engineering Ⅱ
- Computer Hardware Fundamentals
- Robot Vision
- Digital Signal Processing

Related to Finemechanics

- Thermal Sience and Engineering A
- Thermal Sience and Engineering B
- Numerical Analysis
- Statistical modeling
- Introduction to Classical Mechanics and Physical Mathmatics
- Structure and Function Living System

Major General Subjects

- Sensing and Evaluation of Materials System
- Design of Materials System

Related to Design and Manufacturing

- Nano/Micro Tribolody
- Ultraprecision Machining
- Manufacturing Systems
- Nano/Micro Mechanoptics

Related to Fluid Mechanics

- Biofluid Mechanics

- Optical Metrology
- Green Nanotechnology
- Geo-technical and Energy Engineering
- Biosensor Engineering
- Bio-Micromachine Engineering
- Special Lecture Series on Integrated Biomechanics Ⅰ
- Intelligent Mechanosystem Analysis
- Nano-and Micro-Surface Metrology and Engineering
- Physical Fluctuomatics
- Environmental Administration
- Ethics of Engineering and Life
- Special Lecture on Finemechanics A

Internship / Seminar

- Advanced Seminar on Finemechanics A
- Internship Training
- International Scientific Internship Training
- Seminar on Materials and Mechanics
- Seminar on Nanomechanics
- Seminar on Biomechanics
- Seminar on Intelligent Mechano-Systems
- Master's Research Training in Finemechanics

Doctoral Degree Program

Interdisciplinary Basic Subjects

Common Subjects for Mechanical and Intelligent Systems

- History of Modern Technology
- New Business Creation
- Venture Strategy
- Nano Magnetism and Magnetic Engineering

Related to Finemechanics

- Advanced Mechanics of Materials
- Advanced Nano/Technology
- Nano-Flow Science
- Advanced Soft Mechanics
- Fracture Mechanics and Mechanisms
- Advanced Bio-Nanotechnology
- Special Lecture on Medical Engineering
- Intelligent Mechanosystem Engineering
- Advanced Nano-and Micro-Surface Metrology and Engineering

Major General Subjects

- Special Lecture on Finemechanics B

Internship / Seminar

- Advanced Seminar on Finemechanics B
- Doctoral Research Training in Finemechanics

Department of Robotics

Undergraduate Course

(Department of Mechanical and Aerospace Engineering)

Mechanical Systems Course

Finemechanics Course

Robotics Course

Aerospace Engineering Course

Mechanical / Biomedical Engineering Course

International Mechanical and Aerospace Engineering Course

Quantum Science and Energy Engineering Course

Environment and Energy Engineering Course

Master Degree's Program

Major Basic Subjects

Related to Mechanical

- Solid Mechanics
- Mechanics of Plasticity
- Materials Chemistry
- Solid State Physics
- Continuum Mechanics
- Structural Mechanics

Related to Fluid Mechanics

- Fluid Dynamics
- Applied Fluid Mechanics

Related to Control and Engineering

- Syetem Control Engineering Ⅰ
- Syetem Control Engineering Ⅱ
- Computer Hardware Fundamentals
- Robot Vision
- Digital Signal Processing

Related to Robotics

Related to Thermal and Energy

- Thermal Sience and Engineering A
- Thermal Sience and Engineering B

Mathematics and Science

- Numerical Analysis
- Statistical modeling
- Introduction to Classical Mechanics and Physical Mathmatics

Others

- Structure and Function of Living System

Internship / Seminar

Major General Subjects

Related to Design and Manifacturing

- Micro Electro Mechanical Systems
- Nano/Micro Mechanoptics

Related to Fluid Mechanics

- Functional Fluids Engineering

Related to Control and Engineering

- Advanced Robotics
- Biomechatronics
- Embodied Intelligence and Robotics
- Tough Cyberphysical AI

Related to Robotics

- Foundations of Molecular Robotics
- Intelligent Mechanosystem Analysis
- Neuro Robotics
- Introduction to Solid State Ionics
- Intelligent Control Systems
- Physical Fluctuomatics
- Environmental Administration
- Ethics of Engineering and Life
- Special Lecture on Robotics A

Internship / Seminar

- Internship Training
- International Scientific Internship Training
- Advanced Seminar on Robotics A
- Seminar on Nano-Systems
- Seminar on Robot-Systems
- Master's Research Training in Robotics

Doctoral Degree Program

Interdisciplinary Basic Subjects

Common Subjects for Mechanical and Intelligent Systems

- History of Modern Technology
- New Business Creation
- Venture Strategy
- Nano Magnetism and Magnetic Engineering

Related to Robotics

- Advanced Bio-Nanotechnology
- Special Lecture on Medical Engineering
- Adcanced Robotics
- Intelligent Mechanosystem Engineering
- Advanced Intelligent Design
- Advanced Nano/Technology

Major General Subjects

Related to Robotics

- Special Lecture on Robotics B

Internship / Seminar

- Advanced Seminar on Robotics B
- Doctoral Research Training in Robotics

Department of Aerospace Engineering

Undergraduate Course

(Department of Mechanical and Aerospace Engineering)

- Mechanical Systems Course
- Finemechanics Course
- Robotics Course
- Aerospace Engineering Course
- Mechanical / Biomedical Engineering Course
- International Mechanical and Aerospace Engineering Course
- Quantum Science and Energy Engineering Course
- Environment and Energy Engineering Course

Master Degree's Program

Major Basic Subjects

Related to mechanical

- Solid Mechanics
- Mechanics of Plasticity
- Materials Chemistry
- Solid State Physics
- Continuum Mechanics
- Structural Mechanics

Related to Fluid Mechanics

- Fluid Dynamics
- Applied Fluid Mechanics

Related to Control and Engineering

- Syetem Control Engineering Ⅰ
- Syetem Control Engineering Ⅱ
- Computer Hardware Fundamentals
- Robot Vision
- Digital Signal Processing

Related to Thermal and Energy

- Thermal Sience and Engineering A
- Thermal Sience and Engineering B

Mathematics and Science

- Numerical Analysis
- Statistical modeling
- Introduction to Classical Mechanics and Physical Mathmatics

Other

- Structure and Function of Living System

Major General Subjects

General Subjects

- Environmental Administration
- Ethics of Engineering and Life

- Computational Fluid Dynamics
- Applied Mathematical Fluid Dynamics

- Mathematical Modeling and Computaion
- High Performance Computing
- Computer Architecture

Related to Aerospace

- Aerospace Systems
- Aerospace Propulsion
- Robotics for Space Exploration
- Spacecraft Engineering
- Special Lecture on Aerospace Engineering A

- Physical Fluctuomatics

Internship / Seminar

- Internship Training
- International Scientific Internship Training
- Advanced Seminar on Aerospace Engineering A
- Seminar on Aero Systems
- Seminar on Space Systems
- Master's Research Training in Aeronautics and Space Engineering

Doctoral Degree Program

Interdisciplinary Basic Subjects

Common subjects for Mechanics and Intelligent Systems

- History of Modern Technology
- New Business Creation
- Venture Strategy
- Nano Magnetism and Magnetic Engineering

- Advanced Aero Systems Ⅰ
- Advanced Aero Systems Ⅱ
- Advanced Space Systems Ⅰ
- Advanced Space Systems Ⅱ
- Advanced Aerospace Fluid Dynamics

Major General Subjects

- Special Lecture on Aerospace Engineering B
- Advanced Seminar onAerospace Engineering B
- Doctoral Research Training in Aeronautics and Space Engineering