# 2020 Enrollment


# Course List and Summary


# Master's Degree Program

# 授業科目表（MC）　List of Courses

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Language | 単位　Credit | | | 備考　Remarks |
|---|---|---|---|---|---|---|---|
| | | | | 必修<br>Required | 選択必修<br>Elective Required | 選択<br>Elective | |
| 専門基盤科目<br>Major Basic Subjects | 数値解析学 | 毎年<br>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.<br><br>A student has to earn 8 or more credits from the Major basic subjects listed in the left column. |
| | Numerical Analysis | 隔年<br>Every second year | E | | | | |
| | 確率モデル論<br>Probability Models | 毎年<br>Every year | JE | | 2 | | |
| | 基盤流体力学 | 毎年<br>Every year | J | | 2 | | |
| | Fluid Dynamics | 毎年<br>Every year | E | | | | |
| | 固体力学 | 毎年<br>Every year | J | | 2 | | |
| | Solid Mechanics | 毎年<br>Every year | E | | | | |
| | 熱科学・工学A | 隔年<br>Every second year | J | | 2 | | |
| | Thermal Science and Engineering A | 隔年<br>Every second year | E | | | | |
| | 熱科学・工学B | 隔年<br>Every second year | J | | 2 | | |
| | Thermal Science and Engineering B | 隔年<br>Every second year | E | | | | |
| | システム制御工学Ⅰ<br>System Control Engineering Ⅰ | 毎年<br>Every year | E | | 2 | | |
| | システム制御工学Ⅱ<br>System Control Engineering Ⅱ | 毎年<br>Every year | E | | 2 | | |
| | 材料化学<br>Materials Chemistry | 毎年<br>Every year | E | | 2 | | |
| | 計算機科学 | 隔年<br>Every second year | J | | 2 | | |
| | Computer Hardware Fundamentals | 隔年<br>Every second year | E | | | | |
| | 固体物理学<br>Solid State Physics | 毎年<br>Every year | E | | 2 | | |
| | 塑性力学<br>Mechanics of Plasticity | 毎年<br>Every year | E | | 2 | | |
| | 生物の構造と機能 | 隔年<br>Every second year | J | | 2 | | |
| | Structure and Function Living System | 隔年<br>Every second year | E | | | | |
| | ロボットビジョン<br>Robot Vision | 毎年<br>Every year | E | | 2 | | |
| | ディジタル信号処理 | 隔年<br>Every second year | J | | 2 | | |
| | Digital Signal Processing | 隔年<br>Every second year | E | | | | |
| | 力学と物理数学 | 隔年<br>Every second year | J | | 2 | | |
| | Introduction to Classical Mechanics and Physical Mathematics | 隔年<br>Every second year | E | | | | |
| | 連続体力学 | 隔年<br>Every second year | J | | 2 | | |
| | Continuum Mechanics | 隔年<br>Every second year | E | | | | |
| | 応用流体力学 | 隔年<br>Every second year | J | | 2 | | |
| | Applied Fluid Mechanics | 隔年<br>Every second year | E | | | | |
| | 構造力学 | 隔年<br>Every second year | J | | 2 | | |
| | Structural Mechanics | 隔年<br>Every second year | E | | | | |

# 授業科目表（MC）　List of Courses

| 区分 Category | 授業科目 Subject | 開講時期 Schedule | 使用言語 Language | 単位 Credit 必修 Required | 単位 Credit 選択必修 Elective Required | 単位 Credit 選択 Elective | 備考 Remarks |
|---|---|---|---|---|---|---|---|
| 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ても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．ただし，特別講義A，特別研修Aで修得した単位は2単位まで本要件に含めることができる．なお，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． |
| | 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 | | A student has to earn 2 or more credits from the major general subjects listed in the left colum. In addition, 12 or more credits in total are required to earn from the Major general subjects, Advanced seminar A, Special lecture A, and related subjects offered by other departments. However, a total of 2 credits at most, obtained from Advanced seminar A and Special lecture A, is included in this requirement. As an exception, a total of 8 credits obtained from Special lecture A is included in this requirement, when a student is enrolled in our double-dgree program or joint educationnal program. |
| | 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 | | |
| | 地殻システム設計学 | 隔年 Every second year | J | | 2 | | |
| | Earth Systems Design | 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 | | |
| 専門科目 Major General Subjects | 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 | | |
| | 環境技術政策論 Discussion on Environmental and Industrial Policy | 毎年 Every year | J | | 2 | | |
| | 工学と生命の倫理 Ethics of Engineering and Life | 隔年 Every year | JE | | 2 | | |
| | 融合領域研究合同講義 Interdisciplinary Research | 毎年 Every year | J | | 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 | | |
| | 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 | | 左記のセミナーのいずれかを履修し，2単位を修得すること． |
| | エネルギー学セミナー Seminar on Energy Systems Engineering | 毎年 Every year | JE | | 2 | | A student has to earn 2 credits from one of the seminar listed in the left column. |
| | 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 | | |

# 授業科目表（MC） List of Courses

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Language | 単位　Credit | | | 備考　Remarks |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | 必修<br>Required | 選択必修<br>Elective<br>Required | 選択<br>Elective | |
| 専門科目<br><br>Major General Subjects | 機械機能創成修士研修<br>Master Course Seminar on Mechanical Systems 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。開講年度等は授業時間割等で確認すること。
　　"Class 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 given in Japanese, with English explanations)
　J：日本語開講科目(Lectures given in Japanese)

| | |
|---|---|
| **Numerical Analysis**      2 credits | **Probability Models**      2 credits |
| Elective   Required<br>Professor   Naofumi Ohnishi<br><br>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. | Elective   Required<br>Associate Professor Reika Fukuizumi<br><br>Mathematical analysis is important for the understanding of random phenomenon appearing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications.<br>These lectures will be in Japanese in principle and an English resume will be distributed. |
| **Fluid Dynamics**      2 credits | **Solid Mechanics**      2 credits |
| Elective   Required<br>Professor   Keisuke Sawada<br>Professor   Soshi Kawai<br><br><br>This course covers the basics of both incompressible and compressible fluid dynamics.<br>1. Conservation laws and governing equations<br>2. Inviscid, incompressible flows<br>3. Viscous, incompressible flows<br>4. Inviscid, compressible flows | Elective   Required<br>Associate Professor Yoshiteru Aoyagi<br><br><br><br>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 | **Thermal Science and Engineering B**      2 credits |
| Elective   Required<br>Professor   Hideaki Kobayashi<br>Professor   Kaoru Maruta<br>Professor   Takashi Tokumasu<br>Associate Professor Hisashi Nakamura<br><br>In this course, students will master the basic physics of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and singular 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. | Elective   Required<br>Professor   Taku Ohara<br>Professor   Tetsushi Biwa<br>Professor   Atsuki Komiya<br>Associate Professor Gota Kikugawa<br><br>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 further deepen their understanding of the essence of thermal phenomena. |
| **System Control Engineering I**      2 credits | **System Control Engineering II**      2 credits |
| Elective   Required<br>Professor   Kazuya Yoshida<br>Professor   Yasuhisa Hirata<br><br>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. This class includes some exercises using MATLAB. | Elective   Required<br>Professor   Kazuhiro Kosuge<br>Professor   Koichi Hashimoto<br>Associate Professor   Shogo Arai<br><br>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 | Computer Hardware Fundamentals | 2 credits |
|---|---|---|---|

**Materials Chemistry**　　　　2 credits

Elective　Required
Professor　Yutaka Watanabe
Professor　Koji Amezawa
Professor　Eiji Akiyama
Associate Professor　Yoichi Takeda

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 VLSI technology and computer architecture will be lectured for better understanding of modern computer systems. First, CMOS-IC Technology, memory technologies, circuit architecture, high-level synthesis and integrated design technologies that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture that focuses 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 LSI technology and computer architecture will be also presented in the lecture.

**Solid State Physics**　　　2 credits

Elective　Required
Professor　Hiroo Yugami
Professor　Takahito Ono
Professor　Ying Chen

This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.

**Mechanics of Plasticity**　　　　2 credits

Elective　Required
Professor　Toshiyuki Hashida
Associate Professor　Yoshiteru Aoyagi

This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation.

**Structure and Function of Living System**　　　2 credits

Elective　Required
Professor　Yoichi Haga
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
Associate Professor Shingo Kagami
Associate 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 Classical 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

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

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

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

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
Professor  Hiroo Yugami
Associate Professor  Fumitada Iguchi

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<br><br>Elective　Required<br>Professor　Kazuhiro Ogawa<br>Associate Professor　Yoichi Takeda<br>Associate Professor　Ken Suzuki<br><br>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".<br>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<br><br>Elective　Required<br>Professor　Takehiko Sato<br>Associate Professor　Hidemasa Takana<br><br>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 process, energy equipment and other topics. |
| **Mechanical Systems Maintenance Engineering**　2 credits<br><br><br>Elective　Required<br>Professor　Tetsuya Uchimoto<br>Associate Professor　Hiroyuki Miki<br><br>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<br><br><br>Elective　Required<br>Professor　Koji Amezawa<br>Associate Professor　Takashi Nakamura<br><br>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<br><br>Elective　Required<br>Professor　Tunemoto Kuriyagawa<br>Associate Professor　Masayoshi Mizutani<br><br><br><br>The purpose of this course is to deepen understanding of Ultra-precision machining technology focusing on micro-mechanical machining or non-conventional processing. In the second half, this course aims to acquire extensive knowledge and identify a research issue of the technology through presentations and discussions in English. | **Manufacturing Systems**　　　2 credits<br><br>Elective　Required<br>Professor　Tunemoto Kuriyagawa<br>Associate Professor　Masayoshi Mizutani<br>Adjunct Instructor　Makoto Sano<br>Adjunct Instructor　Takashi Genma<br><br>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. |

| Earth Systems Design    2 credits | Neuromorphic Device Engineering    2 credits |
|---|---|
| Elective  Required<br>Professor  Toshiyuki Hashida<br><br><br>This course provides the fundamentals for the design of subsurface energy and materials systems such as geothermal heat extraction and $CO_2$ geological sequestration systems. The subsurface is an inner-space that includes a number of complex natural fractures.  One of the key issues in the design of the subsurface systems is how to control the complex natural fractures.  Hydraulic injection technologies play a crucial role in the formation of the subsurface energy and materials systems. First, a fracture mechanics model will be presented to analyze the mechanical response of a simple crack system subject to hydraulic injections.  Then, a fracture network model that is based on the fractal geometry will be described to characterize the mechanical behavior and fluid/heat transfer processes in a complex fracture systems.  This course then discusses an engineering methodology for designing complex fracture systems.  In the latter part of the lecture, a couple of journal papers will be read in turn to study applications of the fundamentals to the design of the subsurface energy and materials systems. | Elective  Required<br>Professor  Tetsu Tanaka<br>Associate Professor  Takafumi Fukushima<br><br>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:<br>・Understand the detail structures and functions of neurons as a basic neural element.<br>・Learn about neuromorphic devices and system integration concept/technology.<br>1st.  Introduction & elements of nervous systems<br>2nd. Neuronal potential and nervous excitement<br>3rd.  Mechanism of synapse transmission<br>4th.  Sensory systems<br>5th.  Neural network<br>6th.  Special talk<br>7th.  Neuromorphic devices 1<br>8th.  Neuromorphic devices 2<br>9th.  Neuromorphic system integration 1<br>10th. Neuromorphic system integration 2<br>11th. Neuromorphic system integration 3<br>12th. Special talk |
| **Physical Fluctuomatics**    2 credits | **Environmental and Technology Policy**    2 credits |
| Elective  Required<br>Professor  Kazuyuki Tanaka<br>Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing. | Elective  Required       Various teachers |

| | |
|---|---|
| **Ethics of Engineering and Life**        2 credits<br><br>Elective  Required<br>Professor  Tatsuo Yoshinobu<br>Adjunct Instructor  Seishi Kudo<br><br>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 an e-learning program, and  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. | **Interdisciplinary Research**           2 credits<br><br>Elective  Required       Various teachers |
| **Internship Training**            1 or 2 credits<br><br>Elective  Required       All teachers<br>Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training. | **International Scientific Internship Training**    1 or 2 credits<br><br>Elective  Required       All teachers<br>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**<br>1 or 2 credits<br><br>Elective  Required       Various teachers<br>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**<br>1 or 2 credits<br><br>Elective  Required       Various teachers<br>Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability. |
| **Seminar on Mechanical Systems**        2 credits<br><br>Elective  Required<br>Professor  Koshi Adachi<br>Professor  Tunemoto Kuriyagawa<br>Professor  Takahito Ono<br>Professor  Kazuhiro Ogawa<br>Professor  Toshiyuki Hashida<br>Professor  Tetsu Tanaka<br>Associate Professor Masayoshi Mizutani<br>Associate Professor Masaya Toda<br>Associate Professor Kazuhisa Sato<br>Associate Professor Takafumi Fukushima<br>Associate Professor Yuji Ichikawa<br><br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. | **Seminar on Energy Engineering**        2 credits<br><br>Elective  Required<br>Professor  Hiroo Yugami<br>Professor  Tetsushi Biwa<br>Professor  Kaoru Maruta<br>Professor Tetsuya Uchimoto<br>Professor  Yuka Iga<br>Professor  Koji Amezawa<br>Professor Atsuki Komiya<br>Associate Professor Fumitada Iguchi<br>Associate Professor Hidemasa Takana<br>Associate Professor Hisashi Nakamura<br>Associate Professor  Keiji Yashiro<br>Associate Professor  Hiroyuki Miki<br>Associate Professor  Takashi Nakamura<br><br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. |

| Seminar on Intelligent Mechano-Systems 2 credits | Master Course Seminar on Mechanical Systems Engineering 8 credits |
|---|---|
| Elective Required<br>Professor Takehiko Sato | Required Various teachers |
| By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. | 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

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Lang uage | 単位　Credit | | | 備考　Remarks |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | 必修<br>Required | 選択必修<br>Elective Required | 選択<br>Elective | |
| 専門基盤科目<br>Major Basic Subjects | 数値解析学 | 毎年<br>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．<br><br>A student has to earn 8 or more credits from the Major basic subjects listed in the left column. |
| | Numerical Analysis | 隔年<br>Every second year | E | | | | |
| | 確率モデル論<br>Probability Models | 毎年<br>Every year | JE | | 2 | | |
| | 基盤流体力学 | 毎年<br>Every year | J | | 2 | | |
| | Fluid Dynamics | 毎年<br>Every year | E | | | | |
| | 固体力学 | 毎年<br>Every year | J | | 2 | | |
| | Solid Mechanics | 毎年<br>Every year | E | | | | |
| | 熱科学・工学A | 隔年<br>Every second year | J | | 2 | | |
| | Thermal Science and Engineering A | 隔年<br>Every second year | E | | | | |
| | 熱科学・工学B | 隔年<br>Every second year | J | | 2 | | |
| | Thermal Science and Engineering B | 隔年<br>Every second year | E | | | | |
| | システム制御工学Ⅰ<br>System Control Engineering Ⅰ | 毎年<br>Every year | E | | 2 | | |
| | システム制御工学Ⅱ<br>System Control Engineering Ⅱ | 毎年<br>Every year | E | | 2 | | |
| | 材料化学<br>Materials Chemistry | 毎年<br>Every year | E | | 2 | | |
| | 計算機科学 | 隔年<br>Every second year | J | | 2 | | |
| | Computer Hardware Fundamentals | 隔年<br>Every second year | E | | | | |
| | 固体物理学<br>Solid State Physics | 毎年<br>Every year | E | | 2 | | |
| | 塑性力学<br>Mechanics of Plasticity | 毎年<br>Every year | E | | 2 | | |
| | 生物の構造と機能 | 隔年<br>Every second year | J | | 2 | | |
| | Structure and Function of Living System | 隔年<br>Every second year | E | | | | |
| | ロボットビジョン<br>Robot Vision | 毎年<br>Every year | E | | 2 | | |
| | ディジタル信号処理 | 隔年<br>Every second year | J | | 2 | | |
| | Digital Signal Processing | 隔年<br>Every second year | E | | | | |
| | 力学と物理数学 | 隔年<br>Every second year | J | | 2 | | |
| | Introduction to Classical Mechanics and Physical Mathematics | 隔年<br>Every second year | E | | | | |
| | 連続体力学 | 隔年<br>Every second year | J | | 2 | | |
| | Continuum Mechanics | 隔年<br>Every second year | E | | | | |
| | 応用流体力学 | 隔年<br>Every second year | J | | 2 | | |
| | Applied Fluid Mechanics | 隔年<br>Every second year | E | | | | |
| | 構造力学 | 隔年<br>Every second year | J | | 2 | | |
| | Structural Mechanics | 隔年<br>Every second year | E | | | | |

# 授業科目表（MC）　List of Courses

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Language | 単位　Credit | | | 備考　Remarks |
|---|---|---|---|---|---|---|---|
| | | | | 必修<br>Required | 選択必修<br>Elective Required | 選択<br>Elective | |
| 専門科目<br>Major General Subjects | 光計測<br>Optical Metrology | 隔年<br>Every second year | E | | 2 | | 左記の専門科目の内から少なくても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. ただし，特別講義A，特別研修Aで修得した単位は2単位まで本要件に含めることができる. なお，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.<br><br>A student has to earn 2 or more credits from the major general subjects listed in the left colum. In addition, 12 or more credits in total are required to earn from the Major general subjects, Advanced seminar A, Special lecture A, and related subjects offered by other departments. However, a total of 2 credits at most, obtained from Advanced seminar A and Special lecture A, is included in this requirement. As an exception, a total of 8 credits obtained from Special lecture A is included in this requirement, when a student is enrolled in our double-dgree program or joint educationnal program. |
| | 材料システム計測評価学 | 隔年<br>Every second year | J | | 2 | | |
| | Sensing and Evaluation of Materials System | 隔年<br>Every second year | E | | | | |
| | 超精密加工学 | 隔年<br>Every second year | J | | 2 | | |
| | Ultraprecision Machining | 隔年<br>Every second year | E | | | | |
| | ナノ・マイクロメカノプティクス<br>Nano/Micro Mechanoptics | 隔年<br>Every second year | E | | 2 | | |
| | ナノ・マイクロトライボロジー | 隔年<br>Every second year | J | | 2 | | |
| | Nano/Micro Tribology | 隔年<br>Every second year | E | | | | |
| | 微小破壊学 | 毎年<br>Every year | J | | 2 | | |
| | Strength and Reliability of Advanced Materials and Devices | 毎年<br>Every year | E | | | | |
| | グリーンナノテクノロジー<br>Green Nanotechnology | 隔年<br>Every second year | E | | 2 | | |
| | 地殻構造・エネルギー工学<br>Geo-technical and Energy Engineering | 隔年<br>Every second year | JE | | 2 | | |
| | 精密生産システム学<br>Manufacturing Systems | 毎年<br>Every year | J | | 2 | | |
| | 材料システム設計学 | 隔年<br>Every second year | J | | 2 | | |
| | Design of Materials System | 隔年<br>Every second year | E | | | | |
| 専門科目<br>Major General Subjects | バイオセンサ工学<br>Biosensor Engineering | 隔年<br>Every second year | E | | 2 | | 左記の専門科目の内から少なくても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. ただし，特別講義A，特別研修Aで修得した単位は2単位まで本要件に含めることができる. なお，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. |
| | バイオマイクロマシン工学<br>Bio-Micromachine Engineering | 隔年<br>Every second year | E | | 2 | | |
| | 生物流体工学 | 隔年<br>Every second year | J | | 2 | | |
| | Biofluid Mechanics | 隔年<br>Every second year | E | | | | |
| | バイオメカニクス特別講義Ⅰ<br>Special Lecture Series on Integrated Biomechanics Ⅰ | 隔年<br>Every second year | E | | 2 | | |
| | 知的メカノシステム解析学<br>Intelligent Mechanosystem Analysis | 隔年<br>Every second year | E | | 2 | | |
| | 物理フラクチュオマティクス論<br>Physical Fluctuomatics | 毎年<br>Every year | J | | 2 | | |
| | 環境技術政策論<br>Discussion on Environmental and Industrial Policy | 毎年<br>Every year | J | | 2 | | |
| | 工学と生命の倫理<br>Ethics of Engineering and Life | 隔年<br>Every year | JE | | 2 | | |
| | 融合領域研究合同講義<br>Interdisciplinary Research | 毎年<br>Every year | J | | 2 | | |
| | インターンシップ研修<br>Internship Training | | | | 1〜2 | | |
| | 国際学術インターンシップ研修<br>International Scientific Internship Training | | | | 1〜2 | | |
| | ファインメカニクス特別講義A<br>Special Lecture on Finemechanics A | | | | 1〜2 | | |
| | ファインメカニクス特別研修A<br>Advanced Seminar on Finemechanics A | | | | 1〜2 | | |
| 関連科目<br>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。<br>Those approved by the Educational Committee of the Graduate School of Engineering | | | | | | |

# 授業科目表（MC） List of Courses

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Language | 単位　Credit | | | 備考　Remarks |
|---|---|---|---|---|---|---|---|
| | | | | 必修<br>Required | 選択必修<br>Elective<br>Required | 選択<br>Elective | |
| 専門科目<br>Major General Subjects | 材料メカニクスセミナー<br>Seminar on Materials and Mechanics | 毎年<br>Every year | JE | | 2 | | 左記のセミナーのいずれかを履修し，2単位を修得すること．<br><br><br>A student has to earn 2 credits from one of the seminar listed in the left column. |
| | ナノメカニクスセミナー<br>Seminar on Nanomechanics | 毎年<br>Every year | JE | | 2 | | |
| | バイオメカニクスセミナー<br>Seminar on Biomechanics | 毎年<br>Every year | JE | | 2 | | |
| | 知的メカノシステム工学セミナー<br>Seminar on Intelligent Mechano-Systems | 毎年<br>Every year | JE | | 2 | | |
| 専門科目<br>Major General Subjects | ファインメカニクス修士研修<br>Master Course Seminar on 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。開講年度等は授業時間割等で確認すること。
   "Class 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 given in Japanese, with English explanations)
   J：日本語開講科目(Lectures given in Japanese)

| Numerical Analysis 2 credits | Probability Models 2 credits |
|---|---|
| Elective Required<br>Professor Naofumi Ohnishi<br><br>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. | Elective Required<br>Associate Professor Reika Fukuizumi<br><br>Mathematical analysis is important for the understanding of random phenomenon appearing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications.<br>These lectures will be in Japanese in principle and an English resume will be distributed. |
| Fluid Dynamics 2 credits | Solid Mechanics 2 credits |
| Elective Required<br>Professor Keisuke Sawada<br>Professor Soshi Kawai<br><br>This course covers the basics of both incompressible and compressible fluid dynamics.<br>1. Conservation laws and governing equations<br>2. Inviscid, incompressible flows<br>3. Viscous, incompressible flows<br>4. Inviscid, compressible flows | Elective Required<br>Associate Professor Yoshiteru Aoyagi<br><br><br>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 | Thermal Science and Engineering B 2 credits |
| Elective Required<br>Professor Hideaki Kobayashi<br>Professor Kaoru Maruta<br>Professor Takashi Tokumasu<br>Associate Professor Hisashi Nakamura<br><br>In this course, students will master the basic physics of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and singular 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. | Elective Required<br>Professor Taku Ohara<br>Professor Tetsushi Biwa<br>Professor Atsuki Komiya<br>Associate Professor Gota Kikugawa<br><br>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 further deepen their understanding of the essence of thermal phenomena. |
| System Control Engineering I 2 credits | System Control Engineering II 2 credits |
| Elective Required<br>Professor Kazuya Yoshida<br>Professor Yasuhisa Hirata<br><br>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. This class includes some exercises using MATLAB. | Elective Required<br>Professor Kazuhiro Kosuge<br>Professor Koichi Hashimoto<br>Associate Professor Shogo Arai<br><br>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　Yoichi Takeda

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 VLSI technology and computer architecture will be lectured for better understanding of modern computer systems. First, CMOS-IC Technology, memory technologies, circuit architecture, high-level synthesis and integrated design technologies that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture that focuses 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 LSI technology and computer architecture will be also presented in the lecture.

## Solid State Physics　　　　2 credits

Elective　Required
Professor　Hiroo Yugami
Professor　Takahito Ono
Professor　Ying Chen

This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.

## Mechanics of Plasticity　　　　2 credits

Elective　Required
Professor　Toshiyuki Hashida
Associate Professor　Yoshiteru Aoyagi

This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation.

## Structure and Function of Living System　　2 credits

Elective　Required
Professor　Yoichi Haga
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
Associate Professor Shingo Kagami
Associate 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 Classical 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.

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|---|---|
| **Continuum Mechanics**      2 credits<br>Elective Required<br>Professor Takuji Ishikawa<br><br>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<br>Elective Required<br>Professor Jun Ishimoto<br>Professor Yuka Iga<br><br>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<br>Elective Required<br>Professor Kanjuro Makihara<br><br>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<br>Elective Required<br>Professor Wei Gao<br>Associate Professor Yuki Shimizu<br><br>This course focuses on measurement methods and systems with nanometer resolution and accuracy for ultra-precision production, including measurement of displacement and vibrations, surface profiles, geometric forms and motions of precision machines. Fundamental theories and applications of sensor technologies, such as laser interferometer, linear encoder, laser displacement sensor, optical fiber sensor, as well as those of measuring instruments, such as scanning electron microscope, interference microscope, scanning probe microscope, mechanical stylus profiler will be learned through presentations and discussions. |
| **Sensing aand Evaluation of Materials System**      2 credits<br>Elective Required<br>Professor Hitoshi Soyama<br>Professor Hironori Tohmyoh<br><br>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<br>Elective Required<br>Professor Tunemoto Kuriyagawa<br>Associate Professor Masayoshi Mizutani<br><br>The purpose of this course is to deepen understanding of Ultra-precision machining technology focusing on micro-mechanical machining or non-conventional processing. In the second half, this course aims to acquire extensive knowledge and identify a research issue of the technology through presentations and discussions in English. |
| **Nano/Micro Mechanoptics**      2 credits<br>Elective Required<br>Professor Kazuhiro Hane<br>Professor Yoshiaki Kanamori<br><br>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<br>Elective Required<br>Professor Koshi Adachi<br><br>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.<br>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.<br>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. |

## Strength and Reliability of Advanced Materials and Devices   2 credits

Elective  Required
Professor  Hideo Miura

The Strain-induced changes of physical and chemical properties of various materials are discussed from the view point of the order of atom arrangement in the strained materials. The change of the free energy of materials due to strain energy causes the variation or fluctuation of various physical and chemical properties of the strained materials. Since nanotechnology enables us to create very complicated fine structures, large local strain occurs in the structures during manufacturing and operation because of lattice mismatch between nearby materials and higher density of the concentrated fields of strain and mechanical stress. The large local strain and stress accelerate the anisotropic diffusion of component elements, and thus, cause the change of micro texture of the materilas. Therefore,  deep understanding of the mechanism of the changes of variou sproperties of materials help us to evaluate the damage of the strained structures and devices and to design the optimum structures and their manufacturing methods. Some examples of fracture and/or failure mechanisms of products are also introduced based on the actual experience of the lecturer.
Hideo Miura:hmiura@rift.mech.tohoku.ac.jp

## Green Nanotechnology        2 credits

Elective  Required
Professor  Seiji Samukawa
Associate Professor  Tomohiro Kubota

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 nanoprocesses 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, microseismic 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  Tsunemoto Kuriyagawa
Associate Professor  Masayoshi Mizutani
 Senior Assistant Professor Makoto Sano
 Senior Assistant Professor 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  Kazuo Hokkirigawa
Associate Professor  Takeshi Yamaguchi

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
Associate Professor  Hirokazu Kaji

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 bioelements such as enzymes and antibodies. Biointerface engineering for integrating bioelements 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
Associate Professor  Hirokazu Kaji

The progress of Biomicromachine, 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 bioelements and the electric devices requires suitable biointerface 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. The cardiovascular, respiratory and digestive systems in the human body are lectured. Rheology of blood, flow in a flexible tube, mass transport, and heat transport in a body are explained using basic equations of mechanical engineering. Moreover, swimming microorganisms and fish as well as flying birds are explained. Finally the effects of mechanical environment on the biological functions are discussed.

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| **Special Lecture Series on Integrated Biomechanics　I**<br>2 credits<br><br>Elective　Required<br>Professor　Makoto Ohta<br>Associate Professor　Kenji Kikuchi<br><br>In terms of mechanics and functions on living things, we often describe them as continuum mechanics. Especially, fluid mechanics for blood flow and breath, statics and dynamics for soft materials as the muscle, the blood vessel, and the cell, and hard materials as skeletal system are treated for understanding of their fundamental mechanisms. We offer you basic concepts of measurement and visualization techniques for mechanical information on living things. | **Intelligent Mechanosystem Analysis**　　2 credits<br><br>Elective　Required<br>Professor　Toshiyuki Hayase<br>Associate Professor　Kenichi Funamoto<br><br>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. |
| **Physical Fluctuomatics**　　2 credits<br><br>Elective　Required<br>Professor　Kazuyuki Tanaka<br>Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing. | **Environmental and Technology Policy**　　2 credits<br><br>Elective　Required　　Various teachers |
| **Ethics of Engineering and Life**　　2 credits<br><br>Elective　Required<br>Professor　Tatsuo Yoshinobu<br>Adjunct Instructor　Seishi Kudo<br><br>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 an e-learning program, and  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. | **Interdisciplinary Research**　　2 credits<br><br>Elective　Required　　Various teachers |

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| **Internship Training**　　　　1 or 2 credits<br><br>Elective　Required　　All teachers<br>Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training. | **International Scientific Internship Training**　　1 or 2 credits<br><br>Elective　Required　　All teachers<br>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<br><br>Elective　Required　　Various teachers<br>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<br><br>Elective　Required　　Various teachers<br>Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability. |
| **Seminar on Materials and Mechanics**　　2 credits<br><br>Elective　Required<br>Professor　Kazuo Hokkirigawa<br>Professor　Hitoshi Soyama<br>Professor　Hideo Miura<br>Professor　Hironori Tohmyoh<br>Associate Professor　Takeshi Yamaguchi<br>Associate Professor　Yoshiteru Aoyagi<br>Associate Professor　Ken Suzuki<br>Associate Professor　Yoichi Takeda<br><br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. | **Seminar on Nanomechanics**　　2 credits<br><br>Elective　Required<br>Professor　Kazuhiro Hane<br>Professor　Wei Gao<br>Professor　Taku Ohara<br>Professor　Takashi Tokumasu<br>Professor　Seiji Samukawa<br>Professor　Yuji Takakuwa<br>Professor　Yoshiaki Kanamori<br>Associate Professor　Yuki Shimizu<br>Associate Professor　Shigeru Yonemura<br>Assistant Professor　Gota Kikugawa<br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. |
| **Seminar on Biomechanics**　　2 credits<br><br>Elective　Required<br>Professor　Matsuhiko Nishizawa<br>Professor　Takuji Ishikawa<br>Associate Professor　Hirokazu Kaji<br>Associate Professor　Kenji Kikuchi<br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. | **Seminar on Intelligent Mechano-Systems**　　2 credits<br><br>Elective　Required<br>Professor　Toshiyuki Hayase<br>Professor　Makoto Ohta<br>Associate Professor　Kenichi Funamoto<br><br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. |
| **Master Course Seminar on Finemechanics**　　8 credits<br><br>Required　Various teachers<br>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

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Language | 単位　Credit | | | 備考　Remarks |
|---|---|---|---|---|---|---|---|
| | | | | 必修<br>Required | 選択必修<br>Elective<br>Required | 選択<br>Elective | |
| 専門基盤科目<br><br>Major Basic Subjects | 数値解析学 | 毎年<br>Every year | J | | 2 | | |
| | Numerical Analysis | 隔年<br>Every second year | E | | | | |
| | 確率モデル論<br>Probability Models | 毎年<br>Every year | JE | | 2 | | |
| | 基盤流体力学 | 毎年<br>Every year | J | | 2 | | |
| | Fluid Dynamics | 毎年<br>Every year | E | | | | |
| | 固体力学 | 毎年<br>Every year | J | | 2 | | |
| | Solid Mechanics | 毎年<br>Every year | E | | | | |
| | 熱科学・工学A | 隔年<br>Every second year | J | | 2 | | |
| | Thermal Science and Engineering A | 隔年<br>Every second year | E | | | | |
| | 熱科学・工学B | 隔年<br>Every second year | J | | 2 | | |
| | Thermal Science and Engineering B | 隔年<br>Every second year | E | | | | |
| | システム制御工学Ⅰ<br>System Control Engineering Ⅰ | 毎年<br>Every year | E | | 2 | | |
| | システム制御工学Ⅱ<br>System Control Engineering Ⅱ | 毎年<br>Every year | E | | 2 | | |
| | 材料化学<br>Materials Chemistry | 毎年<br>Every year | E | | 2 | | |
| | 計算機科学 | 隔年<br>Every second 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.<br><br>A student has to earn 8 or more credits from the Major basic subjects listed in the left column. |
| | Computer Hardware Fundamentals | 隔年<br>Every second year | E | | | | |
| | 固体物理学<br>Solid State Physics | 毎年<br>Every year | E | | 2 | | |
| | 塑性力学<br>Mechanics of Plasticity | 毎年<br>Every year | E | | 2 | | |
| | 生物の構造と機能 | 隔年<br>Every second year | J | | 2 | | |
| | Structure and Function of Living System | 隔年<br>Every second year | E | | | | |
| | ロボットビジョン<br>Robot Vision | 毎年<br>Every year | E | | 2 | | |
| | ディジタル信号処理 | 隔年<br>Every second year | J | | 2 | | |
| | Digital Signal Processing | 隔年<br>Every second year | E | | | | |
| | 力学と物理数学 | 隔年<br>Every second year | J | | 2 | | |
| | Introduction to Classical Mechanics and Physical Mathematics | 隔年<br>Every second year | E | | | | |
| | 連続体力学 | 隔年<br>Every second year | J | | 2 | | |
| | Continuum Mechanics | 隔年<br>Every second year | E | | | | |
| | 応用流体力学 | 隔年<br>Every second year | J | | 2 | | |
| | Applied Fluid Mechanics | 隔年<br>Every second year | E | | | | |
| | 構造力学 | 隔年<br>Every second year | J | | 2 | | |
| | Structural Mechanics | 隔年<br>Every second year | E | | | | |

# 授業科目表（MC）　List of Courses

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Lang<br>uage | 単位　Credit | | | 備考　Remarks |
|---|---|---|---|---|---|---|---|
| | | | | 必修<br>Required | 選択必修<br>Elective<br>Required | 選択<br>Elective | |
| 専門科目<br><br>Major General<br>Subjects | 微小電気機械システム<br>Micro Electro Mechanical Systems | 毎年<br>Every year | E | | 2 | | 左記の専門科目の内から少なくても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．ただし，特別講義A，特別研修Aで修得した単位は2単位まで本要件に含めることができる．なお，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．<br><br>A student has to earn 2 or more credits from the major general subjects listed in the left colum. In addition, 12 or more credits in total are required to earn from the Major general subjects, Advanced seminar A, Special lecture A, and related subjects offered by other departments. However, a total of 2 credits at most, obtained from advanced seminar A and Special lecture A, is included in this requirement. As an exception, a total of 8 credits obtained from Special lecture A is included in this requirement, when a student is enrolled in our double-dgree program or joint educationnal program. |
| | ロボットシステム学<br>Robot Systems Engineering | 毎年<br>Every year | E | | 2 | | |
| | バイオメカトロニクス<br>Biomechatronics | 隔年<br>Every second year | J | | 2 | | |
| | 分子ロボティクス基礎 | 隔年<br>Every second year | J | | 2 | | |
| | Foundations of Molecular Robotics | 隔年<br>Every second year | E | | | | |
| | 知的メカノシステム解析学<br>Intelligent Mechanosystem Analysis | 隔年<br>Every second year | E | | 2 | | |
| | 固体イオニクス論<br>Introduction to Solid State Ionics | 隔年<br>Every second year | E | | 2 | | |
| | 人間－ロボット情報学<br>Human-Robot Informatics | 隔年<br>Every second year | E | | 2 | | |
| | 流体設計情報学<br>Fluid Design Informatics | 隔年<br>Every second year | E | | 2 | | |
| | ニューロロボティクス<br>Neuro Robotics | 隔年<br>Every second year | E | | 2 | | |
| | 知能制御システム学<br>Intelligent Control Systems | 隔年<br>Every second year | E | | 2 | | |
| | 物理フラクチュオマティクス論<br>Physical Fluctuomatics | 毎年<br>Every year | J | | 2 | | |
| | 機能性流体工学<br>Functional Fluids Engineering | 隔年<br>Every second year | E | | 2 | | |
| | 環境技術政策論<br>Discussion on Environmental and Industrial Policy | 毎年<br>Every year | J | | 2 | | |
| | 工学と生命の倫理<br>Ethics of Engineering and Life | 隔年<br>Every year | JE | | 2 | | |
| | 融合領域研究合同講義<br>Interdisciplinary Research | 毎年<br>Every year | J | | 2 | | |
| | インターンシップ研修<br>Internship Training | | | | 1〜2 | | A student has to earn 2 or more credits from the major general subjects listed in the left colum. In addition, 12 or more credits in total are required to earn from the Major general subjects, Advanced seminar A, Special lecture A, and related subjects offered by other departments. However, a total of 2 credits at most, obtained from Advanced seminar A and Special lecture A, is included in this requirement. As an exception, a total of 8 credits obtained from Special lecture A is included in this requirement, when a student is enrolled in our double-dgree program or joint educationnal program. |
| | 国際学術インターンシップ研修<br>International Scientific Internship Training | | | | 1〜2 | | |
| | ロボティクス特別講義A<br>Special Lecture on Robotics A | | | | 1〜2 | | |
| | ロボティクス特別研修A<br>Advanced Seminar on Robotics A | | | | 1〜2 | | |
| 関連科目<br>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。<br>Those approved by the Educational Committee of the Graduate School of Engineering | | | | | | |
| 専門科目<br><br>Major General<br>Subjects | ナノシステムセミナー<br>Seminar on Nano-Systems | 毎年<br>Every year | JE | | 2 | | 左記のセミナーのいずれかを履修し，2単位を修得すること．<br><br>A student has to earn 2 credits from one of the seminar listed in the left column. |
| | ロボットシステムセミナー<br>Seminar on Robot-Systems | 毎年<br>Every year | JE | | 2 | | |
| | ロボティクス修士研修<br>Master Course Seminar on 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。開講年度等は授業時間割等で確認すること。
　　"Class 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 given in Japanese, with English explanations)
　J：日本語開講科目(Lectures given in Japanese)

| Numerical Analysis 2 credits | Probability Models 2 credits |
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| Elective Required<br>Professor Naofumi Ohnishi<br><br>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. | Elective Required<br>Associate Professor Reika Fukuizumi<br><br>Mathematical analysis is important for the understanding of random phenomenon appearing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications.<br>These lectures will be in Japanese in principle and an English resume will be distributed. |
| **Fluid Dynamics** 2 credits | **Solid Mechanics** 2 credits |
| Elective Required<br>Professor Keisuke Sawada<br>Professor Soshi Kawai<br><br>This course covers the basics of both incompressible and compressible fluid dynamics.<br>1. Conservation laws and governing equations<br>2. Inviscid, incompressible flows<br>3. Viscous, incompressible flows<br>4. Inviscid, compressible flows | Elective Required<br>Associate Professor Yoshiteru Aoyagi<br><br><br>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 | Thermal Science and Engineering B 2 credits |
| Elective Required<br>Professor Hideaki Kobayashi<br>Professor Kaoru Maruta<br>Professor Takashi Tokumasu<br>Associate Professor Hisashi Nakamura<br><br>In this course, students will master the basic physics of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and singular 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. | Elective Required<br>Professor Taku Ohara<br>Professor Tetsushi Biwa<br>Professor Atsuki Komiya<br>Associate Professor Gota Kikugawa<br><br>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 further deepen their understanding of the essence of thermal phenomena. |
| System Control Engineering I 2 credits | System Control Engineering II 2 credits |
| Elective Required<br>Professor Kazuya Yoshida<br>Professor Yasuhisa Hirata<br><br>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. This class includes some exercises using MATLAB. | Elective Required<br>Professor Kazuhiro Kosuge<br>Professor Koichi Hashimoto<br>Associate Professor Shogo Arai<br><br>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 Yoichi Takeda

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 VLSI technology and computer architecture will be lectured for better understanding of modern computer systems. First, CMOS-IC Technology, memory technologies, circuit architecture, high-level synthesis and integrated design technologies that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture that focuses 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 LSI technology and computer architecture will be also presented in the lecture.

## Solid State Physics 2 credits

Elective Required
Professor Hiroo Yugami
Professor Takahito Ono
Professor Ying Chen

This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems.

## Mechanics of Plasticity 2 credits

Elective Required
Professor Toshiyuki Hashida
Associate Professor Yoshiteru Aoyagi

This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation.

## Structure and Function of Living System 2 credits

Elective Required
Professor Yoichi Haga
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
Associate Professor Shingo Kgami
Associate 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 Classical 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 | **Applied Fluid Mechanics**      2 credits |
| Elective  Required<br>Professor Takuji Ishikawa | Elective  Required<br>Professor Jun Ishimoto<br>Professor Yuka Iga |
| 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. | 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 | **Micro Electro Mechanical Systems**      2 credits |
| Elective  Required<br>Professor Kanjuro Makihara | Elective  Required<br>Professor  Shuji Tanaka<br>Associate Professor  Takashiro Tsukamoto |
| 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. | 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. |
| **Robot Systems Engineering**      2 credits | **Biomechatronics**      2 credits |
| Elective  Required<br>Professor  Kazuhiro Kosuge<br>Professor  Yasuhisa Hirata<br>Associate Professor  Shogo Arai | Elective  Required<br>Professor  Mami Tanaka |
| The robot is an advanced system that consists of mechanical parts, actuators, sensors, and controllers. By integrating the several systems and control methods effectively, the robot could realize required tasks in the real environment. In this lecture, the fundamental and advanced motion control methods of the robot will be given, and the recent applications developed by the integration of the robot technologies will be introduced. | |
| **Foundations of Molecular Robotics**      2 credits | **Intelligent Mechanosystem Analysis**      2 credits |
| Elective  Required<br>Professor  Satoshi Murata<br>Associate Professor  Shinichiro Nomura | Elective  Required<br>Professor  Toshiyuki Hayase<br>Associate Professor  Kenichi Funamoto |
| | 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 | **Human-Robot Informatics**      2 credits |
| Elective  Required<br>Professor  Koji Amezawa<br>Associate Professor  Takashi Nakamura | Elective  Required<br>Professor  Satoshi Tadokoro<br>Associate Professor  Masashi Konyo |
| 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. | |

| **Fluid Design Informatics**  2 credits | **Neuro Robotics**  2 credit |
|---|---|
| Elective  Required<br>Professor  Shigeru Obayashi<br>Associate Professor  Koji Shimoyama<br><br>This lecture aims to construct the theories, learn the methodologies, and see the real-world examples of fluid engineering design, which is based on computational fluid dynamics (CFD) combined with information science. The lecture outline is organized as 1. design optimization, 2. gradient method, 3. evolutionary computation, 4. surrogate model, 5. physics-based optimization, and 6. data mining. | Elective  Required<br>Professor  Mitsuhiro Hayashibe<br>Associate Professor Dai Owaki<br><br>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 | **Physical Fluctuomatics**  2 credits |
| Elective  Required<br>Professor  Koichi Hashimoto<br>Associate Professor  Shingo Kagami<br><br>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. | Elective  Required<br>Professor  Kazuyuki Tanaka<br><br>Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing. |
| **Functional Fluids Engineering**  2 credits | **Environmental and Technology Policy**  2 credits |
| Elective  Required<br>Professor  Takehiko Sato<br>Associate Professor Hidemasa Takana<br>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 process, energy equipment and other topics. | Elective  Required      Various teachers |

| Ethics of Engineeing and Life      2 credits | Interdisciplinary Research      2 credits |
|---|---|
| Elective  Required<br>Professor  Tatsuo Yoshinobu<br>Adjunct Instructor  Seishi Kudo<br><br>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 an e-learning program, and  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. | Elective  Required      Various teachers |
| Internship Training      1 or 2 credits | International Scientific Internship Training    1 or 2 credits |
| Elective  Required      All teachers<br>Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training. | Elective  Required      All teachers<br>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 | Advanced Seminar on Robotics A      1 or 2 credits |
| Elective  Required      Various teachers<br>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. | Elective  Required      Various teachers<br>Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability. |
| Seminar on Nano-Systems      2 credits | Seminar on Robot-Systems      2 credits |
| Elective  Required<br>Professor  Shuji Tanaka<br>Professor  Satoshi Murata<br>Professor  Yoichi Haga<br>Associate Professor  Shinichiro Nomura<br><br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. | Elective  Required<br>Professor  Kazuhiro Kosuge<br>Professor  Mami Tanaka<br>Professor  Mitsuhiro Hayashibe<br>Professor  Yasuhisa Hirata<br>Associate Professor  Shogo Arai<br>Associate Professor  Takeshi Okuyama<br>Associate Professor  Dai Owaki<br><br>By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. |
| Master Course Seminar on Robotics      8 credits<br><br><br>Required    Various teachers<br>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

| 区分 Category | 授業科目　Subject | 開講時期 Schedule | 使用言語 Language | 単位　Credit 必修 Required | 単位　Credit 選択必修 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 | | |
| | Numerical Analysis | 隔年 Every second year | E | | | | |
| | 確率モデル論 Probability Models | 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 | | 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. |
| | 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 Robot Vision | 毎年 Every year | E | | 2 | | |
| | 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 | | | | |

# 授業科目表（MC）　List of Courses

| 区分 Category | 授業科目 Subject | 開講時期 Schedule | 使用言語 Language | 単位 Credit 必修 Required | 選択必修 Elective Required | 選択 Elective | 備考 Remarks |
|---|---|---|---|---|---|---|---|
| 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ても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．ただし，特別講義A，特別研修Aで修得した単位は2単位まで本要件に含めることができる．なお，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 A student has to earn 2 or more credits from the major general subjects listed in the left colum. In addition, 12 or more credits in total are required to earn from the Major general subjects, Advanced seminar A, Special lecture A, and related subjects offered by other departments. However, a total of 2 credits at most, obtained from Advanced seminar A and Special lecture A, is included in this requirement. As an exception, a total of 8 credits obtained from Special lecture A is included in this requirement, when a student is enrolled in our double-dgree program or joint educationnal program. A student has to earn 2 or more credits from the major general subjects listed in the left colum. In addition, 12 or more credits in total are required to earn from the Major general subjects, Advanced seminar A, Special lecture A, and related subjects offered by other departments. However, a total of 2 credits at most, obtained from advanced seminar A and Special lecture A, is included in this requirement. As an exception, a total of 8 credits obtained from Special lecture A is included in this requirement, when a student is enrolled in our double-dgree program or joint educationnal program. |
| | 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 | | |
| | 航空宇宙流体力学 Aerospase Fluid Dynamics | 隔年 Every second year | E | | 2 | | |
| | 宇宙探査ロボティクス Robotics for Space Exploration | 毎年 Every year | E | | 2 | | |
| | 衛星工学 Spacecraft Engineering | 毎年 Every 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 | | |
| | 流体設計情報学 Fluid Design Informatics | 隔年 Every second 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 | | |
| | 環境技術政策論 Discussion on Environmental and Industrial Policy | 毎年 Every year | J | | 2 | | |
| | 工学と生命の倫理 Ethics of Engineering and Life | 隔年 Every year | JE | | 2 | | |
| | 融合領域研究合同講義 Interdisciplinary Research | 毎年 Every year | J | | 2 | | |
| | JAXA連携特別講義 Special Lecture in Cooperation with JAXA | 毎年 Every year | E | | 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 | | |
| | 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 | | 左記のセミナーのいずれかを履修し，2単位を修得すること． A student has to earn 2 credits from one of the seminar 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 | | |

# 授業科目表（MC）　List of Courses

| 区分<br>Category | 授業科目　Subject | 開講時期<br>Schedule | 使用言語<br>Language | 単位　Credit | | | 備考　Remarks |
|---|---|---|---|---|---|---|---|
| | | | | 必修<br>Required | 選択必修<br>Elective<br>Required | 選択<br>Elective | |
| 専門科目<br>Major General Subjects | 航空宇宙工学修士研修<br>Master Course Seminar on Aerospace 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。開講年度等は授業時間割等で確認すること。
　　"Class 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 given in Japanese, with English explanations)
　J：日本語開講科目(Lectures given in Japanese)

| | |
|---|---|
| **Numerical Analysis**　　　2 credits | **Probability Models**　　　2 credits |
| Elective　Required<br>Professor　Naofumi Ohnishi<br><br>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. | Elective　Required<br>Associate Professor Reika Fukuizumi<br><br>Mathematical analysis is important for the understanding of random phenomenon appearing in various fields of natural, life and social sciences, and the probabilistic approach is essential. We start with fundamental concepts in probability theory and learn basic tools for probabilistic models. In particular, for the time evolution of random phenomenon we study basic properties of random walks, Markov chains, Markov processes, and take a bird's-eye view of their wide applications.<br>These lectures will be in Japanese in principle and an English resume will be distributed. |
| **Fluid Dynamics**　　　2 credits | **Solid Mechanics**　　　2 credits |
| Elective　Required<br>Professor　Keisuke Sawada<br>Professor　Soshi Kawai<br><br>This course covers the basics of both incompressible and compressible fluid dynamics.<br>1. Conservation laws and governing equations<br>2. Inviscid, incompressible flows<br>3. Viscous, incompressible flows<br>4. Inviscid, compressible flows | Elective　Required<br>Associate Professor Yoshiteru Aoyagi<br><br><br>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 | **Thermal Science and Engineering B**　　　2 credits |
| Elective　Required<br>Professor　Hideaki Kobayashi<br>Professor　Kaoru Maruta<br>Professor　Takashi Tokumasu<br>Associate Professor Hisashi Nakamura<br><br>In this course, students will master the basic physics of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and singular 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. | Elective　Required<br>Professor　Taku Ohara<br>Professor　Tetsushi Biwa<br>Professor　Atsuki Komiya<br>Associate Professor Gota Kikugawa<br><br>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 further deepen their understanding of the essence of thermal phenomena. |
| **System Control Engineering I**　　　2 credits | **System Control Engineering II**　　　2 credits |
| Elective　Required<br>Professor　Kazuya Yoshida<br>Professor　Yasuhisa Hirata<br><br>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. This class includes some exercises using MATLAB. | Elective　Required<br>Professor　Kazuhiro Kosuge<br>Professor　Koichi Hashimoto<br>Associate Professor　Shogo Arai<br><br>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. |

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| **Materials Chemistry**      2 credits | **Computer Hardware Fundamentals**      2 credits |
| Elective  Required<br>Professor  Yutaka Watanabe<br>Professor  Koji Amezawa<br>Professor  Eiji Akiyama<br>Associate Professor  Yoichi Takeda | Elective  Required<br>Professor  Tetsu Tanaka<br>Professor  Hiroyuki Takizawa |
| 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. | Computers have become an indispensable part of modern society. In this course, both VLSI technology and computer architecture will be lectured for better understanding of modern computer systems. First, CMOS-IC Technology, memory technologies, circuit architecture, high-level synthesis and integrated design technologies that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture that focuses 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 LSI technology and computer architecture will be also presented in the lecture. |
| **Solid State Physics**      2 credits | **Mechanics of Plasticity**      2 credits |
| Elective  Required<br>Professor  Hiroo Yugami<br>Professor  Takahito Ono<br>Professor  Ying Chen | Elective  Required<br>Professor  Toshiyuki Hashida<br>Associate Professor  Yoshiteru Aoyagi |
| This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science. Following the chapter order in this text book, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid state physics and a broad perspective on the behavior of materials in engineering systems. | This lecture covers the concepts and analytical methods that form the basis of plastic deformation mechanics, including material strength and fracture, deformation processing and tribology, and learn how to apply these skills. Key themes will be (1) basic concepts in plastic deformation, (2) mechanical description of plastic deformations, (3) finite element analysis and (4) using case studies to consider applications to engineering. This lecture aims to have students understand and master basic concepts in and mechanical descriptions of plastic deformation. |
| **Structure and Function of Living System**      2 credits | **Robot Vision**      2 credits |
| Elective  Required<br>Professor  Yoichi Haga<br>Professor  Makoto Ohta<br>Professor  Takuji Ishikawa | Elective  Required<br>Professor Takayuki Okatani |
| In all types of engineering with a connection to the human body, a thorough understanding of the structure and function of the human body and other living systems is vital, as is consideration of systems geared to the special features of these living systems. This course covers the biology knowledge in terms of the basic functions and structures of living organisms that forms the basis of bioengineering. Particular emphasis will be placed on the basic knowledge and approaches necessary for deep exploration of the anatomy and physiology of the human body from the perspective of biomechanics. | This course 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 | **Introduction to Classical Mechanics and Physical Mathematics**<br>2 credits |
| Elective  Required<br>Associate Professor Shingo Kagami<br>Associate Professor Toshinori Kuwahara | Elective  Required<br>Professor Tomonaga Okabe |
| 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. | 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. |

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| **Continuum Mechanics**       2 credits | **Applied Fluid Mechanics**       2 credits |
| Elective  Required<br>Professor Takuji Ishikawa | Elective  Required<br>Professor Jun Ishimoto<br>Professor Yuka Iga |
| 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. | 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 | **Aerospace Systems**       2 credits |
| Elective  Required<br>Professor Kanjuro Makihara | Elective  Required<br>Professor  Naofumi Ohnishi<br>Adjunct Instructor Koichi Yonemoto<br>Adjunct Instructor Toshihiko Nakagawa<br>Adjunct Instructor Soichiro Yada |
| 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 Propulsion**       2 credits | **Computational Fluid Dynamics**       2 credits |
| Elective  Required<br>Professor  Naofumi Ohnishi | Elective  Required<br>Professor  Keisuke Sawada<br>Professr  Soshi Kawai |
| | Lectures on computational fluid dynamics for compressible flows are given.  Accuracy and errors of finite difference methods, finite volume discretization of conservation laws, upwind schemes based on nonlinear wave theory, -TVD stability theory, and recent high-order accurate numerical methods are given in the lectures. |
| **Aerospace Fluid Dynamics**       2 credits | **Robotics for Space Exploration**       2 credits |
| Elective  Required<br>Professor  Keisuke Asai<br>Associate Professor  Taku Nonomura | Elective  Required<br>Professor  Kazuya Yoshida |
| The accurate knowledge and comprehension for thermo fluid dynamics are required to understand the extreme flow phenomena in the aerospace engineering field and to design aircraft and spacecraft. In this course, from the viewpoint of experimental aerodynamics, 1)various experimental techniques in aerospace engineering fields such as wind-tunnel experiments are lectured with introducing latest examples, and 2)flow control techniques and applications for advanced aircraft and spacecraft are discussed. | 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.<br>As for the "orbital robotics," the following topics are lectured:<br>- Angular motion kinematics and attitude dynamics of a spacecraft,<br>- Multi-body dynamics and control of a free-flying space robot,<br>- Impact dynamics and post-impact control when a space robot captures a floating target.<br>As for the "lunar/planetary robotics," the following topics are lectured:<br>- Mission and system design for Lunar and asteroid exploration,<br>- Mobility system design and analysis for locomotion on the lunar/planetary surface,<br>- Sensing, planning, and navigation of a mobile robot.<br>All lectures are given in English. |

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| **Spacecraft Engineering**      2 credits | **Mathematical Modeling and Computation**      2 credits |
| Elective  Required<br>Professor  Kazuya Yoshida<br>Professor  Kanjuro Makihara<br>Professor  Hiroki Nagai<br>Associate Professor  Toshinori Kuwahara<br><br>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.<br>(1) Orbital mechanics for various space missions<br>(2) Attitude dynamics and control of spacecraft<br>(3) Design of space structures, vibration analysis and control<br>(4) Thermodynamics and thermal control of space systems<br>All lectures are given in English. | Elective  Required<br>Professor  Satoru Yamamoto<br><br>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 | **High Performance Computing**      2 credits |
| Elective  Required<br>Professor  Yuji Hattori<br>Associate Professor  Makoto Hirota<br><br>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. | Elective  Required<br>Professor  Hiroyuki Takizawa<br><br>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. |
| **Fluid Design Informatics**      2 credits | **Computer Architecture**      2 credits |
| Elective  Required<br>Professor  Shigeru Obayashi<br>Associate Professor  Koji Shimoyama<br><br>This lecture aims to construct the theories, learn the methodologies, and see the real-world examples of fluid engineering design, which is based on computational fluid dynamics (CFD) combined with information science. The outline of this lecture is organized as 1. design optimization, 2. gradient method, 3. evolutionary computation, 4. surrogate model, 5. physics-based optimization, 6. data mining, and 7. real-world applications. | Elective  Required<br>Professor  Hiroaki Kobayashi<br>Associate Professor  Masayuki Sato<br><br>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.<br>See the class web page<br>http://www.sc.isc.tohoku.ac.jp/class/architecture/ for more details.<br>(Contact instructors to have an access ID). |

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| **Physical Fluctuomatics**　　2 credits<br>Elective　Required<br>Professor　Kazuyuki Tanaka<br><br>Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the stand point of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods are reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum-mechanical extensions of probabilistic information processing. | **Environmental and Technology Policy**　　2 credits<br>Elective　Required　　Various teachers |
| **Ethics of Engineering and Life**　　2 credits<br>Elective　Required<br>Professor　Tatsuo Yoshinobu<br>Adjunct Instructor　Seishi Kudo<br><br>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 an e-learning program, and 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. | **Interdisciplinary Research**　　2 credits<br>Elective　Required　　Various teachers |
| **Special Lecture in Cooperation with JAXA**　　2 credits<br>Elective　Required<br>Visiting　Professor　Sadatake Tomioka<br>Visiting　Professor　Hideyuki Tanno<br><br>Visiting teachers from JAXA (Japan Aerospace Exploration Agency) make special lecture on future space transportation system.  Major topics are system and components of liquid rocket engines, hypersonic air-breathing engines including  combined cycle engine, as well as hypersonic aerodynamics for both hypersonic flight and re-entry. | **Internship Training**　　1 or 2 credits<br>Elective　Required　　All teachers<br><br><br>Practical training and research conducted at a company for around one week to one month in the first-year of masters program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training. |
| **International Scientific Internship Training**　　1 or 2 credits<br><br>Elective　Required　　All teachers<br>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**<br>1 or 2 credits<br>Elective　Required　　Various teachers<br>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<br>1 or 2 credits<br><br>Elective  Required        Various teachers | Seminar on Aero Systems            2 credits<br><br>Elective  Required<br>Professor  Keisuke Sawada<br>Professor  Tomonaga Okabe<br>Professor  Keisuke Asai<br>Professor  Shigeru Obayashi<br>Professor  Hiroki Nagai<br>Professor  Soushi Kawai<br>Associate Professor  Taku Nonomura<br>Associate Professor  Koji Shimoyama<br>Associate Professor  Go Yamamoto<br>Associate Professor  Keiichi Shirasu |
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| Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which students have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability. | By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. |
| Seminar on Space Systems        2 credits<br><br>Elective  Required<br>Professor  Naofumi Ohnishi<br>Professor  Kazuya Yoshida<br>Professor  Hideaki Kobayashi<br>Professor  Kanjuro Makihara<br>Visiting Professor Sadatake Tomioka<br>Visiting Professor Hideyuki Tanno<br>Associate Professor  Toshinori Kuwahara<br>Associate Professor Masayuki Takahashi | Master Course Seminar on Aerospace Engineering<br>8 credits<br>Required        Various teachers |
| By introducing and discussing key research papers in relation to their masters thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research. | 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. |