# 2025 Enrollment

Course List and Summary

Master's Degree Program

	T	_	1		anical Sy	stems Engineerin
授業科目 Subject	開講時期 Schedule	使用 言語 Langu age	必須 Required	単位 Credit 選択必須 Elective Required	選択 Elective	備考 Remarks
数值解析学	毎年 Every year	$\mathbf{J}$		0		
Numerical Analysis	隔年 Every second year	Е		2		
統計的モデリング Statistical modeling	毎年 Every year	JE		2		
基盤流体力学	毎年	J				
Fluid Dynamics	毎年	Е		2		
固体力学	毎年	$\mathbf{J}$		_		
Solid Mechanics	毎年	Е		2		
熱科学・工学A	隔年	J				
Thermal Science and Engineering A	隔年	Е		2		
熱科学・工学B	隔年	$\mathbf{l}$				
Thermal Science and Engineering B	隔年	Е		2		
システム制御工学 I System Control Engineering	毎年 Every year	Е		2		左記の専門基盤科目の 内から4科目以上選邦 履修し、8単位以上値 得すること. A student has to earn 8 or more credits from
システム制御工学 II System Control Engineering	毎年 Every year	Е		2		
材料化学	毎年 Factor	Е		2		
計算機科学	隔年	J				the Major basic subjects listed in the
Computer Hardware	隔年	Е		2		left column.
固体物理学	毎年	Е		2		
塑性力学	毎年	Е		2		
Mechanics of Plasticity 生物の構造と機能	隔年	J				
Structure and Function	隔年	Е		2		
Living System ロボットビジョン	隔年	J				
Robot Vision	隔年	Е		2		
ディジタル信号処理	隔年	J				
Digital Signal Processing	隔年	Е		2		
 力学と物理数学	隔年	J				
Introduction to Classical Mechanics and Physical	Every second year 隔年 Every second year	E		2		
	Subject数値解析学Numerical Analysis統計的モデリングStatistical modeling基盤流体力学Fluid Dynamics固体力学Solid Mechanics熱科学・工学AThermal Science and Engineering A熱科学・工学BThermal Science and Engineering Bシステム制御工学 I System Control Engineering Iシステム制御工学 I System Control Engineering I財料化学 Materials Chemistry計算機科学Computer Hardware Fundamentals固体物理学 Solid State Physics塑性力学 Mechanics of Plasticity生物の構造と機能Structure and Function Living SystemロボットビジョンRobot Visionディジタル信号処理Digital Signal Processing 力学と物理数学Introduction to Classical	SubjectSchedule数値解析学毎年 Every yearNumerical Analysis隔年 Every second year就計的モデリング毎年Statistical modelingEvery year基盤流体力学毎年 Every yearFluid Dynamics毎年 Every year圖体力学毎年 Every yearSolid Mechanics毎年 Every year熟科学・工学A隔年 Every second yearThermal Science and Engineering A隔年 Every second yearThermal Science and Engineering B毎年 Every second yearジステム制御工学 I System Control Engineering I毎年 Every yearジステム制御工学 I System Control Engineering I毎年 Every year村料化学毎年 Every second year計算機科学隔年 Every yearIシンテム制御工学 I Every 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$ \vec{\pi}   \vec{\pi}   \vec{n}   \vec{n}  $	Intelligent Machine Design			2	
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Mace Nanomechanical Architectonics $                                    $	Nano/Micro Tribology		Е	2	
Energy Systems Engineering Registing $\nabla x 7 \mu \lambda r \overline{r} \eta \lambda r \overline{r}$ Every second year $\overline{E}$ $2$ $\overline{R}$ Right $\overline{g}$ $\overline{G}$ Structures and Materials $\overline{R}$ Engineering Machanical Systems $\overline{R}$ $\overline{R}$ $\overline{E}$ very second year $\overline{E}$ $\overline{E}$ $2$ $\overline{L}$ $\overline$	Micro-Nanomechanical Architectonics		Е	2	
$             \mathbb{R} = \frac{1}{2}             $ <td></td> <td></td> <td>Е</td> <td>2</td> <td></td>			Е	2	
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$ \begin{split} & \mathbb{R}^{\mathbb{N}^{\mathbb{N}}}}\mathbb{N}}}}}}}}}}$	Temperature Environments		Е	2	左記の専門科目の内か ら少なくとも1科目以
$\bar{\mathfrak{g}}$ $\bar{\mathfrak{h}}$ Mechanical Systems Maintenance Engineering $\bar{\mathfrak{h}}$ Every second year $E$ 2 $\mathcal{K}$ 	Functional Fluids		Е	2	上を修得するととも に,左記の科目,特別
$\bar{p}$ mpt find Major General 	Mechanical Systems		Е	2	及び関連科目を選択履 修し,全体で12単位
General Subjects超精密加工学開幕年 Every second yearJ2the Major general subjects listed in th 	 Introduction to Solid State		Е	2	Students must earn at
Ultraprecision Machining $\stackrel{\text{in} \# +}{\text{Every second year}}$ EIleft column. $\stackrel{\text{Here}}{\text{Here}}$ $\stackrel{\text{Here}}{\text{Manufacturing Systems}}$ $\stackrel{\text{Here}}{\text{Every year}}$ $\stackrel{\text{J}}{\text{Supersond year}}$ $\stackrel{\text{L}}{\text{Supersond year}}$ $\stackrel{\text{L}}{S$	超精密加工学		J		the Major general
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自然エネルギーデザイン学隔年 Every second yearJ2earn from the Major general subjects, Special Lecture A, Advanced Seminar and related subjectDesign of Natural Energy隔年 Every second yearJ2earn from the Major general subjects, Special Lecture A, Advanced Seminar and related subject $= = - \Box = U - U - U - U - U - U - U - U - U - U$			$\mathbf{J}$	2	In total 12 or more
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Neuromorphic Device Engineering隔年 Every second yearEbngフラクチュオマティクス 論 Physical Fluctuomatics毎年 Every yearJ2環境行政論 Environmental Administration毎年 Every yearJ2工学と生命の倫理 Ethics of Engineering and Life毎年 Every yearJE2インターンシップ研修 Internship Trainingー1~2国際学術インターンシップ研1~2			$\mathbf{J}$		and related subjects.
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工学と生命の倫理 Ethics of Engineering and Life毎年 Every yearJE2インターンシップ研修 Internship Training1~21~2国際学術インターンシップ研11	環境行政論 Environmental	毎年	J	2	1
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International Scientific 1~2	国際学術インターンシップ研 修 International Scientific			1~2	

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	機械機能創成特別講義A Special Lecture on Mechanical Systems Engineering A				1~2	<ul> <li>特別講義 A, 特別研修 A</li> <li>で修得した単位は 2 単</li> <li>位まで専門科目の要件</li> <li>の 12 単位に含めること</li> <li>ができる.</li> <li>なお, ダブルディグリー</li> <li>プログラム, 共同教育プ</li> <li>ログラムの学生に限り,</li> <li>特別講義 A の単位を 8</li> <li>単位まで本要件に含め</li> <li>ることができる.</li> <li>A total of 2 credits at</li> </ul>
	機械機能創成特別研修A Advanced Seminar on Mechanical Systems Engineering A				1~2	In total of 2 credits atmost, obtained fromSpecial Lecture Aand/orAdvancedSeminar A, can beincluded in therequirement of 12credits.As an exception,students enrolled inthedouble-degreeprogram or jointeducationalprogram can includeup to 8 credits fromSpecial Lecture A.
関連科目 Related Subjects of Other Majors	本研究科委員会において関連科 Those approved by the Educat			ate School c	f Engineering	
	機能システム学セミナー Seminar on Mechanical Systems	毎年 Every year	JE		2	左記のセミナーのうち から,指導教員の所属す るセミナー2単位を修
専門科目	エネルギー学セミナー Seminar on Energy Engineering	毎年 Every year	JE		2	得すること. Students must earn 2 credits from one of
Major General Subjects	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	their supervisor's seminars listed in the left column.
	機械機能創成修士研修 Master's Research Training in Mechanical Systems and Engineering			8		

1, 上記科目の単位数を合わせて 30 単位以上を修得すること。

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

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

"Schedule" is currently tentative and may be subject to change.

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

3,「使用言語」欄のアルファベット記号について

Language Key

E:英語開講科目(Lectures given in English)

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

Numerical Analysis2 creditsElective RequiredProfessor Naofumi Ohnishi	Statistical modeling2 creditsElective RequiredProfessor Yuko Araki
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Statistical modeling is widely used in various fields of natural and social sciences to extract information from data and to solve problems. In this lectures, we will start from the basic theory underlying statistical modeling of phenomena , and then focuses on (1) how to set up flexible models, (2)how to estimate parameters of models, and (3) how to select optimal models in order to efficiently extract information from recent data with complex and diverse structures. Background knowledge on elementary probability and statistics are required.
Fluid Dynamics     2 credits       Elective Required     Professor Masaya Shigeta	Solid Mechanics     2 credits       Elective Required     Associate Professor Yoshiteru Aoyagi
Students acquire the intuition and knowledge of the nature of fluid motion by studying the fundamentals of Fluid Dynamics with not only theories but also visualized images, observation videos, and computer graphic animations. The goal is for students to be able to predict the fluid motion and to design the control methods in aerodynamic and material processing applications. Students can also improve their abilities of scientific discussion and international communication. Keywords: Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility, Conservation laws, Bernoulli's theorem, Viscosity and diffusivity, Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number, Strouhal number and Kármán's vortex street, Navier-Stokes and wave equations, Analogy with heat and mass transfers, and Plasma as high- temperature chemically-reactive electromagnetic fluid.	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering A       2 credits         Elective Required       Professor Kaoru Maruta         Professor Takashi Tokumasu       Professor Takashi Nakamura         Associate Professor Akihiro Hayakawa       In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	Thermal Science and Engineering B2 creditsElective RequiredProfessor Taku OharaProfessor Tetsushi BiwaProfessor Atsuki KomiyaProfessor Gota KikugawaAssociate Professor Eita ShojiAssociate Professor Surblys DonatasThe students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating- flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.
System Control Engineering I       2 credits         Elective Required       Professor Koichi Hashimoto         Professor Yasuhisa Hirata       New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.	System Control Engineering II       2 credits         Elective Required       Professor Kazuya Yoshida         Associate Professor Yusuke Tamura       This course gives an advanced lecture based on the contents of "System Control Engineering I." This lecture introduces the analysis and design methods of control systems used for designing motion control for increasingly advanced and complex mechanical systems. Students will learn fundamental concepts for state and output feedback in the state space, state observer and Kalman filter, and response analysis of control systems. This class includes some exercises using MATLAB.

Materials Chemistry 2 cre	-	are Fundamentals	2 credits
Elective Required	Elective Required		
Professor Yutaka Watanabe	Professor Tetsu T		
Professor Koji Amezawa	Professor Hiroyul	xi Takizawa	
Professor Eiji Akiyama			
Associate Professor Hiroshi Abe	Computers have	become an indispensable part of n	nodern society. In
	this course, both	IC technology and computer are	chitecture will be
Most metals in the earth's atmosphere inevitably change in thermodynamically stable compounds such as oxides or sul		er understanding of modern compu	ter systems. First,
understand this principle more precisely, students will learn		ology, memory technology, and 2	2D/3D integration
and electro-chemical equilibrium theory, and kinetics the		upport a remarkable evolution of	computer systems
relation to corrosion and oxidation of metals. Practical exam	over the past let	decades will be introduced. Then, th	ne topics will move
be used to explain the phenomena and theories of wet corro	to computer arc	hitecture focusing on the struct	ture of computer
high-temperature oxidation, deepening students' understandi chemical and electro-chemical reactions related to macro pho-	avatoma jaguag	and tradeoffs involved in the de	sign of computer
of corrosion and oxidation. This course will be offered in Engl		re, and high-performance computi	ng. Also, research
a lecture and practice style, using English-language mate	als. A topics on state-of-	the-art IC technology and compute	r architecture will
detailed outline of the course will be presented during the first	class. be presented in th	ne lecture.	
Solid State Physics 2 cre	ts Mechanics of Plas	sticity	2 credits
Elective Required	Elective Required		/
Professor Takahito Ono	Associate Profess	or Yoshiteru Aoyagi	
Professor Wataru Yashiro	38.3.5.5.		1
Associate Professor Makoto Shimizu	-	sticity is an extended subject of meanics of elasticity, continuum mecha	
This course targets students from mechanical engineering	1	ecture aims to understand the mec	
engineering and a wide range of other specialized areas	system and a	astic deformation," a fundamental j	
Introduction to Solid State Physics (Charles Kittel, Eighth Ed	ion) as as the strength as	nd fracture of materials, forming p	rocess, and
the main text, it focuses on the fundamentals of material		master a deformation analysis met	
Following the chapter order in this textbook, each class will a		cture covers 1) basic concepts of pla escription of plastic deformation, 3	
content associated with that chapter. The course aims to students from a wide range of areas with an understandir	101140	finite element method, and 4) app	
basics concept of solid-state physics and a broad perspectiv		· • •	
behavior of materials in engineering systems.			
Structure and Function of Living System 2 cre			
•••	ts Robot Vision		2 credits
Elective Required	ts <b>Robot Vision</b> Elective Required	l	2 credits
Elective Required Professor Yoichi Haga			2 credits
Elective Required Professor Yoichi Haga Professor Makoto Ohta	Elective Required		2 credits
Elective Required Professor Yoichi Haga	Elective Required Professor Takayu		
Elective Required Professor Yoichi Haga Professor Makoto Ohta Professor Takuji Ishikawa	Elective Required Professor Takayu This course expla vision. The proble	ki Okatani	itions in computer
Elective Required Professor Yoichi Haga Professor Makoto Ohta Professor Takuji Ishikawa In all types of engineering with a connection to the human	elective Required Professor Takayu This course expla vision. The proble	ki Okatani ins various problems and their solu	ations in computer in which we wish
Elective Required Professor Yoichi Haga Professor Makoto Ohta Professor Takuji Ishikawa In all types of engineering with a connection to the human thorough understanding of the structure and function of the	ody, a numan	ki Okatani ins various problems and their solu ems are basically inverse problems	ations in computer in which we wish a scene from their
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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 Mechanics2 creditsElective Required	Applied Fluid Mechanics     2 credits       Elective Required       Professor Jun Ishimoto       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 Mechanics2 creditsElective RequiredProfessor Kanjuro MakiharaAssociate Professor Keisuke OtsukaThis lecture gives a fundamental knowledge on the structuralanalysis and the structural design of mechanical structures. Maintopics of this lecture are deformation and stress analyses of fuselageand 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 analysisof mechanical structures. (4) Structural identification and structuralhealth monitoring (5) Structural mechanics for aerospace	
engineering. Nano/Micro Tribology 2 credits Elective Required Professor Koshi Adachi Associate Professor Motoyuki Murashima	Micro-Nanomechanical Architectonics       2 credits         Elective Required         Professor Takahito Ono         Associate Professor Masaya Toda         Associate Professor Nguyen Van Toan
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.	Designing of mechanical system based on nanotechnology is an intellectual task combining large amount of information and wide experimental knowledge. In this class, the fundamental knowledge and designing theories of the highly developed micro machines for each process of their planning, fabrication and evaluation are presented. The processes to combine mechanics, electronics, fluidics, and optical components in the design of micro mechanics, the examples of modelling, simulation and fabrication of the devices, and the evaluation and the optimization of design are lectured with several trial examples of actual designs.

Energy Systems Engineering       2 credits         Elective Required       Associate Professor Makoto Shimizu         There are serious energy and environmental issues for the Earth and humanity. Solving the issues will demand effective usage of non-renewable energy sources and growth in the use of renewable energy generation systems. For such a purpose, new technologies for energy conversion and energy policy must be important. In this lecture, new energy conversion technologies such as fuel cells are introduced. Students also investigate energy technologies and energy policy. Based on the information, students will think current state of the energy system and the future through discussion.	Oxidation in High Temperature Environments of Structures and Materials       2 credits         Elective Required       2 credits         Professor Kazuhiro Ogawa       Professor Ken Suzuki         Due to improve the operation efficiency, gas temperature of energy conversion systems, such as gas turbines and boilers, gradually increases. As a result, degradation of the structures, such as high- temperature creep, low cycle fatigue or high-temperature oxidation and corrosion, etc. may be occurred. These damages are called "aged deterioration" or "degradation".         In this lecture in the first half, the degradation in the energy conversion systems especially high-temperature oxidation is lectured, and the mechanism of high-temperature oxidation is explained. And in this lecture in the second half, presentation and discussion concerning high-temperature oxidation behavior of structures and materials are conducted.
Functional Fluids Engineering       2 credits         Elective Required       Professor Takehiko Sato         Professor Masaya Shigeta       Professor Masaya Shigeta         Professor Masaya Shigeta       Professor Masaya Shigeta         Professor Hidemasa Takana       This course covers fluids that express functionality depending by external fields. We discuss fundamentals of fluids' structure, mechanism of exhibiting the functionalities, transport phenomena, governing equations, and diagnostic method for the functional fluids such as plasma fluid, magnetic fluid, MR or ER fluids, ionic liquid. Also, regarding advanced applications using functionalities of those fluids, we outline plasma medicine, environmental remediation, material processing, energy equipment and other topics.         Introduction to Solid State Ionics       2 credits         Elective Required       Professor Kaji Amezawa         Associate Professor Kazuhisa Sato       1n 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	Mechanical Systems Maintenance Engineering       2 credits         Elective Required       Professor Tetsuya Uchimoto         In large-scale, complicated artifacts such as various industrial plants and airplanes, maintenance activities play an important role to prevent loss of function of the systems due to aging degradation. Optimization of the maintenance activities in view of both system safety and economic performance is placed as a major key challenge. In this course, we outline the disciplines composing maintenance engineering such as reliability engineering, materials degradation, risk evaluation, nondestructive testing, failure analysis. In addition, recent works will be introduced: such as a novel health monitoring system, a vibration control system, and so on.         Ultraprecision Machining       2 credits         Elective Required       Professor Masayoshi Mizutani         Focusing on description of the principles, technologies and applications achieving both the ultra-precise form accuracy and ultra-smooth surface roughness. The purpose of this course, especially, is to deepen understanding of Ultra-precision machining technology focusing on micro-mechanical machining, non-conventional processing, or additive manufacturing.
introduced.         Manufacturing Systems       2 credits         Elective Required         Professor Masayoshi Mizutani         Adjunct Instructor Makoto Sano         Adjunct Instructor Takashi Genma         This class is included two topics. One is focusing on description of the fundamental principles and applications for intelligent CNC machining centers and industrial robots for industrial production.         Machining center, Control system of CNC machine, Mechanisms and control for robot, Sensing system for robot, Software and language for robot, CAD/CAM and FMS, ultra-precision machine. The other is focusing on an optical instrument for LSI manufacturing systems.	Design of Natural Energy       2 credits         Elective Required       Associate Professor Anna Suzuki         Diffusion of renewable energy technologies must deal with complex and uncertain nature, which is beyond human control. This course surveys trends in renewable energy development and study design methodologies for sustainable use of energy from natural systems. The course also explores better ways to use natural energy in society and develops into designs for co-creation in the communities.

Design and manufacture of optical lenses, Mechanisms and control of AF/AE camera, Microscope and telescope, Laser interferometer measuring instrument, LSI production, Stepper.	
Neuromorphic Device Engineering       2 credits         Elective Required       Professor Tetsu Tanaka         Professor Takafumi Fukushima	Physical Fluctuomatics2 creditsElective RequiredProfessor Kazuyuki TanakaApplications to many fields in engineering like control, signalprocessing etc. and in information sciences are in mind through thelecture course for the basic knowledge of statistical machine learningtheory as well as stochastic processes. Brief introduction will be givento methods for applications like statistical estimation etc., and to therelationship with statistical-mechanical informatics. We first lectureprobability and statistics and their fundamental properties andexplain the basic frameworks of Bayesian estimation and maximumlikelihood estimation. Particularly, we show EM algorithm as one offamiliar computational schemes to realize the maximum likelihoodestimation and EM algorithm from observed data. We show someuseful probabilistic models which are applicable to probabilisticinformation processing in the standpoint of Bayesian estimation. Wemention that some of these models can be regarded as physicalmodels in statistical mechanics. Fundamental structure of beliefpropagation methods is reviewed as powerful key algorithms tocompute some important statistical quantities, for example, averages,variances and covariances. Particularly, we clarify the relationshipbetween belief propagations and some approximate methods instatistical mechanics. As ones of application to probabilisticinformation processing based on Bayesian estimation and maximumlikelihood estimations, we show probabilistic image processing andpropagation methods is reviewed as powerful key algorithms to<
Environmental Administration       2 credits         Elective Required       Various teachers         The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively.         In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies.         In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.	Ethics of Engineering and Life2 creditsElective RequiredProfessor Tetsutaro HattoriWe 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 

Internship Training 1 or 2 credits	International Scientific Internship Training 1 or 2 credits
Elective Required	Elective Required
All teachers	All teachers
Practical training and research conducted at a company for around one week to one month in the first year of master's program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training.	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	Advanced Seminar on Mechanical Systems Engineering A
1 or 2 credits	1 or 2 credits
Elective Required	Elective Required
Various teachers	Various teachers
A special lecture on leading-edge academic research in the major	Addressing leading-edge academic research in the major area, this
area, or on the creation and development of knowledge in relation to	course comprises seminars on a subject which student have chosen
the major area.	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	Seminar on Energy Engineering 2 credits
Elective Required	Elective Required Professor Tetsushi Biwa
Professor Koshi Adachi	Professor Masaya Shigeta
Professor Takahito Ono Professor Kazuhiro Ogawa	Professor Kaoru Maruta
Professor Tetsu Tanaka	Professor Tetsuya Uchimoto
Professor Masavoshi Mizutani	Professor Yuka Iga
Professor Takafumi Fukushima	Professor Koji Amezawa
Associate Professor Masaya Toda	Professor Atsuki Komiya
Associate Professor Kazuhisa Sato	Professor Hidemasa Takana
Associate Professor Yuji Ichikawa	Associate Professor Junnosuke Okajima
Associate Professor Motoyuki Murashima	Associate Professor Makoto Shimizu
Associate Professor Nguyen Van Toan	Associate Professor Anna Suzuki
	Associate Professor Yuta Kimura Associate Professor Hitoshi Muneoka
By introducing and discussing key research papers in relation to their	By introducing and discussing key research papers in relation to their
master's thesis, as well as the background to and interim results of	master's thesis, as well as the background to and interim results of
their own research. Through this seminar, students will identify	their own research. Through this seminar, students will identify
research trends in their particular area and the position of their own	research trends in their particular area and the position of their own
research.	research.
Seminar on Intelligent Mechano-Systems 2 credits	Master's Research Training in Mechanical Systems and Engineering
Elective Required	8 credits
Professor Takehiko Sato	Required
By introducing and discussing how account reporting in relation to their	Various teachers
By introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of	Students engage in experiments and seminars, including research
their own research. Through this seminar, students will identify	presentations, discussion, and literature reviews. Students who have
research trends in their particular area and the position of their own	acquired credits from the Innovation Oriented Seminar on
research.	Mechanical Engineering program do not need to take this course.

Department of Finemechanics

				1		partmen	t of Finemechanic
			使用		単位 Credit	1	
区分	授業科目	開講時期	言語	必須	選択必須	選択	備考
Category	Subject	Schedule	Langu age	Required	Elective Required	Elective	Remarks
	数値解析学	毎年	J		-		
		Every year 隔年			2		
	Numerical Analysis	Every second year	Е				
	統計的モデリング	毎年	ID		0		
	Statistical modeling	Every year	JE		2		
	基盤流体力学	毎年 Every year	$\mathbf{J}$				
	Fluid Dynamics	毎年 Every year	Е		2		
		毎年					
		Every year	J	-	2		
	Solid Mechanics	毎年 Every year	Е				
	熱科学・工学A	隔年 Every second year	<b>1</b>				
	Thermal Science and	隔年		-	2		
	Engineering A	Every second year	Е				
	熱科学・工学B	隔年 Every second year	$\mathbf{J}$				
	Thermal Science and	隔年	_	-	2		
	Engineering B	Every second year	Е				
	システム制御工学 I	毎年		2			左記の専門基盤科目の
	System Control	卅十 Every year	Е		2		内から4科目以上選択
	Engineering I	livery year					履修し、8単位以上修
専門基盤科目	システム制御工学 II System Control	毎年	n		2		得すること. A student has to earn
Major Basic	Engineering II	Every year	Е				
Subjects	材料化学	毎年	-				8 or more credits from
	Materials Chemistry	Every year	Е		2		the Major basic
	計算機科学	隔年	$\mathbf{J}$				subjects listed in the
		Every second year	3	-	2		left column.
	Computer Hardware	隔年	Е				
	Fundamentals 固体物理学	Every second year 毎年					
	Solid State Physics	Every year	Е		2		
	塑性力学 Mechanics of Plasticity	毎年	Е		2		
		Every year 隔年					
	生物の構造と機能	Every second year	$\mathbf{J}$		0		
	Structure and Function	隔年	Е		2		
	Living System	Every second year	-				
	ロボットビジョン	隔年 Every second year	J				
	Robot Vision	隔年 Every second year	Е		2		
	ディジタル信号処理	隔年	J				
	Digital Signal Processing	Every second year 隔年	Е		2		
		Every second year					
	力学と物理数学	隔年 Every second year	$\mathbf{J}$				
	Introduction to Classical			1	2		
	Mechanics and Physical	隔年 Every second year	Е				
	Mathematics	Livery second year					

		隔年	-			
	連続体力学	Every second year	$\mathbf{J}$	2		
	Continuum Mechanics	隔年 Every second year	Е	2		
	応用流体力学	隔年 Every second year	$\mathbf{J}$	2		
	Applied Fluid Mechanics	隔年 Every second year	Е	2		
	構造力学	隔年 Every second year	J			
	Structural Mechanics	隔年 Every second year	Е	2		
	光計測 Optical Metrology	隔年 Every second year	Е	2		
	材料システム計測評価学	隔年 Every second year	J			-
	Sensing and Evaluation of Materials System	隔年 Every second year	Е	2		
	超精密加工学	隔年 Every second year	J			-
	Ultraprecision Machining	隔年 Every second year	Е	2		
	ナノ・マイクロメカノプテ ィクス	隔年	Е	2		-
	Nano/Micro Mechanoptics ナノ・マイクロトライボロ	Every second year 隔年	т			-
	ジー N 04: 10:111	Every second year 隔年	J	2		左記の専門科目の内か ら少なくとも1科目以
	Nano/Micro Tribology グリーンナノテクノロジー	Every second year 隔年	Е			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.
	Green Nanotechnology	Every second year	Е	2		
	地殻構造・エネルギー工学 Geo-technical and Energy Engineering	隔年 Every second year	JE	2		
	精密生産システム学 Manufacturing Systems	毎年 Every year	J	2		
専門科目 Major	材料システム設計学	隔年 Every second year	J	2		Students must earn a least 2 credits from
General Subjects	Design of Materials System	隔年 Every second year	Е	2		the Major general subjects listed in the
	バイオセンサ工学 Biosensor Engineering	隔年 Every second year	Е	2		left column.
	バイオマイクロマシン工学 Bio-Micromachine	隔年 Every second year	Е	2		In total 12 or more credits are required to earn from the Major
	Engineering       生物流体工学	隔年 Every second year	J			general subjects, Special Lecture A,
	Biofluid Mechanics	隔年 Every second year	Е	2		Advanced Seminar A, and related subjects.
	バイオメカニクス特別講義 I	隔年 Every second year	J			
	Special Lecture Series on Integrated Biomechanics I	隔年 Every second year	Е	2		
	知的メカノシステム解析学 Intelligent Mechanosystem	隔年 Every second year	Е	2		-
	Analysis 表面ナノ・マイクロ計測制 御学 Nano-and Micro-Surface Metrology and Engineering	隔年 Every second year	Е	2		
	物理フラクチュオマティク ス論 Physical	毎年 Every year	J	2		

	Fluctuomatics					
	環境行政論 Environmental	毎年				
	Administration	Every year	$\mathbf{J}$		2	
	工学と生命の倫理 Ethics of	毎年	$_{ m JE}$		2	
	Engineering and Life	Every year	011			
	インターンシップ研修				1~2	
	Internship Training					
	国際学術インターンシップ 研修 International					
	Scientific				$1 \sim 2$	
	InternshipTraining					
	ファインメカニクス特別講 義A Special Lecture on Finemechanics A				1~2	<ul> <li>特別講義 A, 特別研修 A</li> <li>で修得した単位は2単</li> <li>位まで専門科目の要件</li> <li>の12単位に含めること</li> <li>ができる.</li> <li>なお,ダブルディグリー</li> <li>プログラム,共同教育プ</li> <li>ログラムの学生に限り,</li> <li>特別講義 A の単位を8</li> <li>単位まで本要件に含めることができる.</li> <li>A total of 2 credits at</li> </ul>
						most, obtained from Special Lecture A and/or Advanced Seminar A, can be included in the requirement of 12 credits.
	ファインメカニクス特別研 修A Advanced Seminar on Finemechanics A				1~2	As an exception, students enrolled in the double-degree program or joint educational program can include up to 8 credits from Special Lecture A.
関連科目 Related Subjects of Other Majors	本研究科委員会において関連 Those approved by the Educa			te School of	Engineering	
	材料メカニクスセミナー Seminar on Materials and Mechanics	毎年 Every year	JE		2	左記のセミナーのうち から,指導教員の所属す
	ナノメカニクスセミナー Seminar on Nanomechanics	毎年 Every year	JE		2	るセミナー2単位を修 得すること.
専門科目 Major	バイオメカニクスセミナー Seminar on Biomechanics	毎年 Every year	JE		2	Students must earn 2 credits from one of their supervisor's
General Subjects	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	seminars listed in the left column.
	ファインメカニクス修士研 修 Master's Research Training in Finemechanics			8		

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

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

"Schedule" is currently tentative and may be subject to change.

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

3,「使用言語」欄のアルファベット記号について

#### Language Key

E:英語開講科目(Lectures given in English)

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

Numerical Analysis       2 credits         Elective Required       Professor Naofumi Ohnishi         Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Statistical modeling2 creditsElective RequiredProfessor Yuko ArakiStatistical modeling is widely used in various fields of natural and socialsciences to extract information from data and to solve problems. In thislectures, we will start from the basic theory underlying statisticalmodeling of phenomena , and then focuses on (1) how to set up flexiblemodels, (2)how to estimate parameters of models, and (3) how to selectoptimal models in order to efficiently extract information from recentdata with complex and diverse structures.Background knowledge on elementary probability and statistics arerequired.
Fluid Dynamics2 creditsElective RequiredProfessor Masaya ShigetaStudents acquire the intuition and knowledge of the nature of fluidmotion by studying the fundamentals of Fluid Dynamics with not onlytheories but also visualized images, observation videos, and computergraphic animations. The goal is for students to be able to predict the fluidmotion and to design the control methods in aerodynamic and materialprocessing applications. Students can also improve their abilities ofscientific discussion and international communication. Keywords:Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility,Conservation laws, Bernoulli's theorem, Viscosity and diffusivity,Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number,Strouhal number and Kármán's vortex street, Navier-Stokes and waveequations, Analogy with heat and mass transfers, and Plasma as high-temperature chemically-reactive electromagnetic fluid.	Solid Mechanics       2 credits         Elective Required       Associate Professor Yoshiteru Aoyagi         This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering A       2 credits         Elective Required       Professor Kaoru Maruta         Professor Takashi Tokumasu       Professor Takashi Nakamura         Associate Professor Akihiro Hayakawa       In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	Thermal Science and Engineering B       2 credits         Elective Required       Professor Taku Ohara         Professor Taku Ohara       Professor Tetsushi Biwa         Professor Atsuki Komiya       Professor Gota Kikugawa         Associate Professor Eita Shoji       Associate Professor Surblys Donatas         The students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating-flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.

System Control Engineering I       2 credits         Elective Required         Professor Koichi Hashimoto         Professor Yasuhisa Hirata         New mechanical systems using advanced mechanisms are be         developed in a range of areas for medical care and welfare, sp         exploration, disaster rescue purposes and so on. This course focuses         motion control design of increasingly advanced and comp         mechanical systems. Students will learn fundamentals for non-lin         system analysis and control system design methods. First, phase pla         analysis methods and Lyapunov methods are introduced as the m         ways to analyze non-linear systems. Next, non-linear feedback comp         system design methods that can be used for mechanical comp         system design methods.	ace s on olex ear ane ain trol trol	System Control Engineering II       2 credits         Elective Required         Professor Kazuya Yoshida         Associate Professor Yusuke Tamura         This course gives an advanced lecture based on the contents of "Syste         Control Engineering I." This lecture introduces the analysis and desi         methods of control systems used for designing motion control         increasingly advanced and complex mechanical systems. Students w         learn fundamental concepts for state and output feedback in the state space, state observer and Kalman filter, and response analysis         control systems. This class includes some exercises using MATLAB	ign for will ate of
Materials Chemistry2 creditsElective RequiredProfessor Yutaka WatanabeProfessor Koji Amezawa		Computer Hardware Fundamentals2 creditsElective RequiredProfessor Tetsu TanakaProfessor Hiroyuki Takizawa	
Professor Eiji Akiyama Associate Professor Hiroshi Abe Most metals in the earth's atmosphere inevitably change into m thermodynamically stable compounds such as oxides or sulfides. understand this principle more precisely, students will learn chemi and electro-chemical equilibrium theory, and kinetics theory relation to corrosion and oxidation of metals. Practical examples to be used to explain the phenomena and theories of wet corrosion a high-temperature oxidation, deepening students' understanding of chemical and electro-chemical reactions related to macro phenome of corrosion and oxidation. This course will be offered in English w a lecture and practice style, using English-language materials detailed outline of the course will be presented during the first class <b>Solid State Physics</b> 2 credits Elective Required Professor Takahito Ono Professor Wataru Yashiro Associate Professor Makoto Shimizu This course targets students from mechanical engineering, syst engineering and a wide range of other specialized areas. Us Introduction to Solid State Physics (Charles Kittel, Eighth Edition) the main text, it focuses on the fundamentals of material scient Following the chapter order in this textbook, each class will cover content associated with that chapter. The course aims to prov students from a wide range of areas with an understanding of basics concept of solid-state physics and a broad perspective on behavior of materials in engineering systems.	To ical in will and the ena vith . A ss. eem sing ) as nce. the vide the	Computers have become an indispensable part of modern society. this course, both IC technology and computer architecture will lectured for a better understanding of modern computer systems. Fin CMOS-IC technology, memory technology, and 2D/3D integrati- technology that support a remarkable evolution of computer syste- over the past few decades will be introduced. Then, the topics will not to computer architecture focusing on the structure of compu- systems, issues and tradeoffs involved in the design of compu- system architecture, and high-performance computing. Also, resear topics on state-of-the-art IC technology and computer architecture we be presented in the lecture. <b>Mechanics of Plasticity</b> 2 credits Elective Required Associate Professor Yoshiteru Aoyagi Mechanics of plasticity is an extended subject of mechanics of materials, mechanics of elasticity, continuum mechanics, and solid mechanics. This lecture aims to understand the mechanical description of "plastic deformation," a fundamental phenomenon su as the strength and fracture of materials, forming process, and tribology, and to master a deformation analysis method based on plasticity. This lecture covers 1) basic concepts of plastic deformatio 2) a mechanical description of plastic deformation, 3) a simulation method using the finite element method, and 4) applications to engineering through examples.	be rst, ion ms ove tter rch will
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 thorough understanding of the structure and function of the hum body and other living systems is vital, as is consideration of systegeared to the special features of these living systems. This cour covers the biology knowledge in terms of the basic functions a structures of living organisms that forms the basis of bioengineerin Particular emphasis will be placed on the basic knowledge a approaches necessary for deep exploration of the anatomy a physiology of the human body from the perspective of biomechanics	nan ems urse and ing. and and	Robot Vision       2 credits         Elective Required         Professor Takayuki Okatani         This course explains various problems and their solutions in computivision. The problems are basically inverse problems in which we will to estimate some information about an object or a scene from the image(s), such as the three-dimensional shape of a scene or to categories of object. Students will first learn a series of fundament concepts, and then study a number of approaches to the problems computer vision, where the main focus is on the recently developed deep learning methods.	ish ieir the ital 3 of

Digital Signal Processing 2 credits	Introduction to Mechanics and Physical Mathematics 2 credits
Elective Required	Elective Required
Professor Shingo Kagami	1
Professor Toshinori Kuwahara	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 includ discrete-time signals, discrete-time and discrete Fourier transformations, sampling, digital frequency analysis, discrete-tim systems, z transformation, digital filtering, and some more advance topics.	universality and do not always provide new ideas directly. But, we often need such a background to make the theoretical models.
Continuum Mechanics 2 credits	Applied Fluid Mechanics 2 credits
Elective Required	Elective Required
Professor Takuji Ishikawa	Professor Jun Ishimoto
Associate Professor Toshihiro Omori	Professor Yuka Iga
Materials may be regarded as continuum at the macroscopic scale. this lecture, we aim to mathematically understand the motion and deformation of materials, such as solid and fluid, at the macroscop scale. We first explain the concepts of continuum and stress as wel as vector/tensor analysis. We then derive basic equations describin the motion and deformation of continuum, such as equilibrium equation, constitutive equation and boundary conditions. This lect 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
Structural Mechanics 2 credits	
Elective Required	
Professor Kanjuro Makihara	
Associate Professor Keisuke Otsuka	
This lecture gives a fundamental knowledge on the structural analysis and the structural design of mechanical structures. Main topics of this lecture are deformation and stress analyses of fuselag 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 analy of mechanical structures. (4) Structural identification and structure health monitoring (5) Structural mechanics for aerospace engineering.	rsis

Oratical Maturals and	2 credits	Sensing and Evaluation of Materials System	2 credits
Optical Metrology Elective Required	2 creatts	Elective Required	2 creatts
Professor Wei Gao		Professor Hitoshi Soyama	
Associate Professor Hiraku Matsukuma		Professor Hironori Tohmyoh	
hosociate i fotossor imaka matsakama			
This course focuses on precision metrology b measuring methods and systems for ultrapr including measurement of displacement and profiles, geometric forms and motions of pre Fundamental theories of geometrical optics applications of optical sensor technologies, s autocollimator, laser triangulation sensor, la as well as those of 3D measuring instrumen interferometer, interference microscope, opt vision, etc., will be learned through presenta Precision optical metrology based on ultrash optical frequency comb will also be treated.	ecision manufacturing, l vibrations, surface cision machines. and wave optics and uch as linear encoder, aser interferometer, etc., ts, such as surface ical scanner, machine ations and discussions.	Advanced materials system composed of the v produces various functions. To operate such a without failure for realizing a safe socie understanding of the system, which requires conventional methodologies, is indispensable. addition to the error theory, which is the basis of the inverse problem analysis for identifying the the evaluation of residual strain, which exists in structures, is treated. Moreover, the methods for material degradation in advanced materials sys scales from electronic devices to various plants are	a materials system ty, comprehensive trials not tied to In this course, in f measurement, and physical quantities, various devices and evaluating cracks or tem having various
Ultraprecision Machining	2  credits	Nano/Micro Mechanoptics	2 credits
Elective Required		Elective Required	
Professor Masayoshi Mizutani		Professor Yoshiaki Kanamori	
Focusing on description of the principles, tea		Associate Professor Naoki Inomata	
applications achieving both the ultra-precise smooth surface roughness. The purpose of th deepen understanding of Ultra-precision ma focusing on micro-mechanical machining, no processing, or additive manufacturing.	is course, especially, is to chining technology	Mechanoptics is the fusional research field of optic Nano/Micro mechanoptics is a research field of me nano/micrometer scales. Fundamental technologie in the field are surveyed. The topics on micromete modulators for displays, micromechanical systems telecommunication, optical sensors, etc. The topics scale are wavelength-selective optical filters using mechanical structures, optical devices for controlli reflectance and light polarization, and structural of the subwavelength optics. Micro/Nanometer scale technologies for micro/nano mechanoptics are also papers relating to the above are also presented an	chanoptics on es and applications r scale are spatial s for optical s on nanometer r subwavelength ang surface optical optics smaller than fabrication s studied. The latest
Nano/Micro Tribology	2 credits	Green Nanotechnology	2 credits
Elective Required		Elective Required	
Professor Koshi Adachi Associate Professor Motoyuki Murashima		Professor Kazuhiko Endo	
Many contact interfaces exist in one machin strong effects on the performance of the mac Performance of machines and devices are so contact interfaces. Microscopic design of contact interfaces becon necessary as the size of a machine or device thinner together with higher performance as Principal properties of surfaces and contact explained in this lecture for such needs, and	hine or device. metimes limited by such ones important and becomes smaller or nd accuracy. interfaces will be	Nanofabrication (etching, deposition, and surface advanced devices such as ULSIs, nanomachines, or bio chips are realized by means of reactive plasma tunneling microscope (STM) and so on, via interact device material and microscopic particles such as ions, radicals, and photons. This lecture will intro- interaction of such microscopic particles in process plasma, beam, and atom/molecule handling which advanced technologies. Measurement methods of will be explained. Examples of advanced green na processes used in these devices advanced industrie	pptical devices, and as, scanning tion between the atoms, molecules, duce behavior and ses such as reactive are basis of such interactions nodevices and nano

Geo-technical and Energy Engineering Elective Required	2 credits		redits
Professor Takatoshi Ito		Elective Required	
Professor Hirokazu Moriya		Professor Masayoshi Mizutani	
Associate Professor Kiyotoshi Sakaguchi		Adjunct Instructor Makoto Sano	
Associate Professor Myotosin Sakagucin		Adjunct Instructor Takashi Genma	
This course provides an introduction to geomechanics	and	This class is included two topics. One is focusing on descrip	tion of the
engineering techniques for exploitation of geo-energy,	especially	fundamental principles and applications for intelligent CNC	
geothermal energy. The class will explore the status a	nd origin of	centers and industrial robots for industrial production.	-
temperature and stress fields in subsurface rocks, hyd	raulic	center, Control system of CNC machine, Mechanisms and	-
fracturing techniques used for creating fractures and	improving	robot, Sensing system for robot, Software and language	
hydraulic properties of rocks, micro seismic imaging a	nd event	CAD/CAM and FMS, ultra-precision machine. The other is for	
analysis used for determining geometry and character	istics of	an optical instrument for LSI manufacturing systems. D	-
fractures, and well testing carried out for determining	; well and	manufacture of optical lenses, Mechanisms and control	-
reservoir performance.		camera, Microscope and telescope, Laser interferometer	
		instrument, LSI production, Stepper.	incasaring
Design of Materials System	2 credits	Biosensor Engineering 2 c	redits
Elective Required		Elective Required	
Professor Takeshi Yamaguchi		Professor Matsuhiko Nishizawa	
Associate Professor Toshiaki Nishi			
		Biological molecular systems for transduction of inform	ation and
This course will provide all students with the fundame	ental knowledge	energy will be briefly lectured, followed by the lectu	re of the
of material design to develop intelligent mechanical sy	stems with high	construction, mechanism, and technical trends on biosensor	rs utilizing
performance. This course will also review the latest	knowledge and	bio elements such as enzymes and antibodies. Bio	interface
concept associated with material system design.		engineering for integrating bio elements with the electric d	evices will
		also be lectured for educating ability for engineering	innovative
		biosensors for advanced medicines.	
Bio-Micromachine Engineering	2 credits		redits
Elective Required		Elective Required	
Professor Matsuhiko Nishizawa		Professor Takuji Ishikawa	
The progress of Bio micro machine, which is the fusion	of biotechnology	In this lecture, we learn functions of biological flows in term	ms of fluid
and micromachine technology, will be fully lectured,	assuming their	mechanics. Flow field at the cellular scale can be regarded	an Stokon
	assuming men		as blokes
use for advanced medicines. The processing of bio		flow. We learn basic characteristics and mathematical desc	
use for advanced medicines. The processing of bio materials is important content of this lecture because	ocompatible soft		riptions of
	ocompatible soft the fusion of bio	flow. We learn basic characteristics and mathematical desc	riptions of organisms,
materials is important content of this lecture because	ocompatible soft the fusion of bio	flow. We learn basic characteristics and mathematical desc Stokes flow. Flow generated by flagella, swimming micros	riptions of organisms, piofluids is
materials is important content of this lecture because elements and the electric devices requires suitable	ocompatible soft the fusion of bio	flow. We learn basic characteristics and mathematical desc Stokes flow. Flow generated by flagella, swimming microc motions of vesicles and cells are discussed. Rheology of b	riptions of organisms, piofluids is n a human
materials is important content of this lecture because elements and the electric devices requires suitable	ocompatible soft the fusion of bio	flow. We learn basic characteristics and mathematical desc Stokes flow. Flow generated by flagella, swimming micro motions of vesicles and cells are discussed. Rheology of b explained by introducing various constitutive laws. Flow in	priptions of organisms, biofluids is a a human spots are
materials is important content of this lecture because elements and the electric devices requires suitable	ocompatible soft the fusion of bio	flow. We learn basic characteristics and mathematical desc Stokes flow. Flow generated by flagella, swimming microc motions of vesicles and cells are discussed. Rheology of b explained by introducing various constitutive laws. Flow in body, flying birds, swimming fish and fluid mechanics in	priptions of organisms, biofluids is a a human spots are
materials is important content of this lecture because elements and the electric devices requires suitable	ocompatible soft the fusion of bio	flow. We learn basic characteristics and mathematical desc Stokes flow. Flow generated by flagella, swimming microc motions of vesicles and cells are discussed. Rheology of b explained by introducing various constitutive laws. Flow in body, flying birds, swimming fish and fluid mechanics in lectured. We show fluid mechanics can be a strong tool to u	priptions of organisms, biofluids is a a human spots are
materials is important content of this lecture because elements and the electric devices requires suitable	ocompatible soft the fusion of bio	flow. We learn basic characteristics and mathematical desc Stokes flow. Flow generated by flagella, swimming microc motions of vesicles and cells are discussed. Rheology of b explained by introducing various constitutive laws. Flow ir body, flying birds, swimming fish and fluid mechanics in lectured. We show fluid mechanics can be a strong tool to u biological functions.	priptions of organisms, biofluids is a a human spots are
materials is important content of this lecture because elements and the electric devices requires suitabl techniques utilizing smart biomaterials.	ocompatible soft the fusion of bio le bio interface	flow. We learn basic characteristics and mathematical desc Stokes flow. Flow generated by flagella, swimming microc motions of vesicles and cells are discussed. Rheology of b explained by introducing various constitutive laws. Flow ir body, flying birds, swimming fish and fluid mechanics in lectured. We show fluid mechanics can be a strong tool to u biological functions.	riptions of organisms, piofluids is a a human spots are nderstand
materials is important content of this lecture because elements and the electric devices requires suitabl techniques utilizing smart biomaterials. Special Lecture Series on Integrated Biomechanics I	ocompatible soft the fusion of bio le bio interface	flow. We learn basic characteristics and mathematical descStokes flow. Flow generated by flagella, swimming microormotions of vesicles and cells are discussed. Rheology of beexplained by introducing various constitutive laws. Flow inbody, flying birds, swimming fish and fluid mechanics inlectured. We show fluid mechanics can be a strong tool to ubiological functions.Intelligent Mechanosystem Analysis2 cm	riptions of organisms, piofluids is a a human spots are nderstand
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#### Nano-and Micro-Surface Metrology and Engineering 2 credits

Elective Required

Professor Wataru Yashiro

#### **Physical Fluctuomatics**

2 credits

**Elective Required** Professor Kazuyuki Tanaka

Measurement and control are the two wheels of manufacturing. The aim of this lecture is to learn the history of the development of conventional techniques for measurement and control methods covering a wide range of spatial scales from atomic to macroscopic scales of surfaces and interfaces that govern the function of materials. The ultimate goal of this lecture is to develop the ability to analyze for oneself what the limits of conventional measurement and control techniques are, and what problems have been essentially solved to open up new frontiers.	Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the standpoint of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods is reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantum- mechanical extensions of probabilistic information processing.
Environmental Administration 2 credits	Ethics of Engineering and Life 2 credits
Elective Required	Elective Required Professor Tetsutaro Hattori
Various teachers	
The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively. In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies. In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.	We will study wide range of ethical issues including "research ethics", which are important for researchers and engineers. Not only medical science but also engineering is closely related to "life". Applying some engineering technologies to various fields such as medicine and food productions, we undoubtedly face the matter of life and death in humans and other creatures. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn the ethical norm. We will invite experts engaged in various fields to give lectures. We will also arrange group discussion and presentation. *Note for foreign students: Lectures are given in Japanese. In slides and handouts, some lecturers give titles etc. both in Japanese and English, but others do not.
Internship Training 1 or 2 credits	International Scientific Internship Training 1 or 2 credits
Elective Required	Elective Required
All teachers	All teachers
Practical training and research conducted at a company for around one week to one month in the first year of master's program. Through this training, students learn how to apply the basic research at	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.

Practical training and research one week to one month in the 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.

Special Lecture on Finemechanics A1 or 2 creditsElective RequiredVarious teachers	Advanced Seminar on Finemechanics A       1 or 2 credits         Elective Required       Various teachers
A special lecture on leading-edge academic research in the major area, or on the creation and development of knowledge in relation to the major area.	Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which student have chosen themselves as well as training in and beyond the university. Integrating these advanced specialist knowledge helps to develop students' problem-posing ability.
Seminar on Materials and Mechanics2 creditsElective RequiredProfessor Hitoshi SoyamaProfessor Hitonori TohmyohProfessor Takeshi YamaguchiProfessor Ken SuzukiAssociate Professor Yoshiteru AoyagiAssociate Professor Keiichi ShirasuAssociate Professor Toshiaki NishiBy introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	Seminar on Nanomechanics       2 credits         Elective Required       Professor Wei Gao         Professor Taku Ohara       Professor Taku Ohara         Professor Takashi Tokumasu       Professor Takashi Tokumasu         Professor Kazuhiko Endo       Professor Gota Kikugawa         Associate Professor Hiraku Matsukuma       Associate Professor Daichi Chiba         Associate Professor Hikaru Nomura       Associate Professor Surblys Donatas         By introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Biomechanics       2 credits         Elective Required         Professor Matsuhiko Nishizawa         Professor Takuji Ishikawa         Associate Professor Kenji Kikuchi         Associate Professor Toshihiro Omori         By introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	Seminar on Intelligent Mechano-Systems       2 credits         Elective Required       Professor Makoto Ohta         Professor Kenichi Funamoto       Associate Professor Hitomi Anzai         By introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Master's Research Training in Finemechanics       8 credits         Required       Various teachers         Students engage in experiments and seminars, including research presentations, discussion, and literature reviews. Students who have acquired credits from the Innovation Oriented Seminar on Mechanical Engineering program do not need to take this course.	

### Department of Robotics

	1	•	1	•		Depa	artment of Robotics
			使用		単位 Credit		
区分	授業科目	開講時期	言語	必須	選択必須	選択	備考
Category	Subject	Schedule	Langu	必須 Required	Elective	選択 Elective	Remarks
			age	inquited	Required	LICCUVE	
	数值解析学	毎年	J				
		Every year		-	2		
	Numerical Analysis	隔年	Е				
		Every second year	+				
	統計的モデリング	每年 F	JE		2		
	Statistical modeling	Every year 毎年					
	基盤流体力学	毋平 Every year	$\mathbf{J}$				
		由 Keiy year 每年			2		
	Fluid Dynamics	Every year	E				
		—————————————————————————————————————	_				
	固体力学	Every year	$\mathbf{J}$				
		毎年	5	1	2		
	Solid Mechanics	Every year	Е				
	熱科学・工学A	隔年	т				
	ボイヤチ・上子A	Every second year	J		2		
	Thermal Science and	隔年	F		2		
	Engineering A	Every second year	Е				
	熱科学・工学B	隔年	J				
		Every second year	0	-	2		
	Thermal Science and	隔年	Е		<b>–</b>		
	Engineering B	Every second year					
	システム制御工学I	毎年	_				左記の専門基盤科目の
	System Control	Every year	Е		2		内から4科目以上選択
	Engineering I						履修し,8単位以上修 得中ステレ
市田甘酔シロ	システム制御工学 II System Control	毎年	Е		2		得すること.
専門基盤科目 Major Basic	Engineering II	Every year	E		-		A student has to earn
Subjects	材料化学						8 or more credits from
Subjecto	和和北子 Materials Chemistry	毋平 Every year	Е		2		the Major basic
		Reference in the second secon					subjects listed in the
	計算機科学	隋年 Every second year	$\mathbf{J}$				left column.
	Computer Hardware	區 Kery second year	1	1	2		
	Fundamentals	Every second year	Е				
	固体物理学	毎年	† _				
	Solid State Physics	Every year	Е		2		
	塑性力学	毎年	F		9		
	Mechanics of Plasticity	Every year	Е		2		
	生物の構造と機能	隔年	J				
		Every second year	0	-	2		
	Structure and Function	隔年	Е		-		
	Living System	Every second year					
	ロボットビジョン	隔年	J				
		Every second year		-	2		
	Robot Vision	隔年	Е				
	 	Every second year					
	ディジタル信号処理	隔年 Every second year	$\mathbf{J}$				
		Every second year 隔年		-	2		
	Digital Signal Processing	啼牛 Every second year	Е				
		Every second year 隔年					
	力学と物理数学	Every second year	$\mathbf{J}$				
	Introduction to Classical			-	2		
	Mechanics and Physical	隔年 Every second year	Е				
				•	1		1

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

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

1, 上記科目の単位数を合わせて 30 単位以上を修得すること。

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

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

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

3,「使用言語」欄のアルファベット記号について

Language Key

E:英語開講科目(Lectures given in English)

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

Numerical Analysis2 creditsElective RequiredProfessor Naofumi Ohnishi	Statistical modeling2 creditsElective RequiredProfessor Yuko Araki
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Statistical modeling is widely used in various fields of natural and social sciences to extract information from data and to solve problems. In this lectures, we will start from the basic theory underlying statistical modeling of phenomena, and then focuses on (1) how to set up flexible models, (2)how to estimate parameters of models, and (3) how to select optimal models in order to efficiently extract information from recent data with complex and diverse structures. Background knowledge on elementary probability and statistics are required.
Fluid Dynamics     2 credits       Elective Required     Professor Masaya Shigeta	Solid Mechanics 2 credits Elective Required Associate Professor Yoshiteru Aoyagi
Students acquire the intuition and knowledge of the nature of fluid motion by studying the fundamentals of Fluid Dynamics with not only theories but also visualized images, observation videos, and computer graphic animations. The goal is for students to be able to predict the fluid motion and to design the control methods in aerodynamic and material processing applications. Students can also improve their abilities of scientific discussion and international communication. Keywords: Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility, Conservation laws, Bernoulli's theorem, Viscosity and diffusivity, Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number, Strouhal number and Kármán's vortex street, Navier-Stokes and wave equations, Analogy with heat and mass transfers, and Plasma as high- temperature chemically-reactive electromagnetic fluid.	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering A       2 credits         Elective Required       Professor Kaoru Maruta         Professor Takashi Tokumasu       Professor Takashi Nakamura         Associate Professor Akihiro Hayakawa       In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	Thermal Science and Engineering B2 creditsElective RequiredProfessor Taku OharaProfessor Taku OharaProfessor Tetsushi BiwaProfessor Atsuki KomiyaProfessor Gota KikugawaAssociate Professor Eita ShojiAssociate Professor Surblys DonatasThe students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating- flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.
System Control Engineering I       2 credits         Elective Required         Professor Koichi Hashimoto         Professor Yasuhisa Hirata         New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.	System Control Engineering II       2 credits         Elective Required       Professor Kazuya Yoshida         Associate Professor Yusuke Tamura       This course gives an advanced lecture based on the contents of "System Control Engineering I." This lecture introduces the analysis and design methods of control systems used for designing motion control for increasingly advanced and complex mechanical systems. Students will learn fundamental concepts for state and output feedback in the state space, state observer and Kalman filter, and response analysis of control systems. This class includes some exercises using MATLAB.

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Materials Chemistry2 creditsElective RequiredProfessor Yutaka WatanabeProfessor Yutaka WatanabeProfessor Koji AmezawaProfessor Eiji AkiyamaAssociate Professor Hiroshi AbeMost metals in the earth's atmosphere inevitably change into morethermodynamically stable compounds such as oxides or sulfides. Tounderstand this principle more precisely, students will learn chemicaland electro-chemical equilibrium theory, and kinetics theory inrelation to corrosion and oxidation of metals. Practical examples willbe used to explain the phenomena and theories of wet corrosion andhigh-temperature oxidation, deepening students' understanding of thechemical and electro-chemical reactions related to macro phenomenaof corrosion and oxidation. This course will be offered in English witha lecture and practice style, using English-language materials. Adetailed outline of the course will be presented during the first class.Solid State Physics2 creditsElective RequiredProfessor Takahito OnoProfessor Wataru YashiroAssociate Professor Makoto ShimizuThis course targets students from mechanical engineering, systemengineering and a wide range of other specialized areas. UsingIntroduction to Solid State Physics (Charles Kittel, Eighth Edition) asthe main text, it focuses on the fundamentals of material science.Following the chapter order in this textbook, each class will cover thecontent associated with that chapter. The course aims to providestudents from a wide range of areas with an understanding of the<	Computer Hardware Fundamentals2 creditsElective RequiredProfessor Tetsu TanakaProfessor Tetsu TanakaProfessor Hiroyuki TakizawaComputers have become an indispensable part of modern society. In this course, both IC technology and computer architecture will be lectured for a better understanding of modern computer systems. First, CMOS-IC technology, memory technology, and 2D/3D integration technology that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture focusing on the structure of computer systems, issues and tradeoffs involved in the design of computer system architecture, and high-performance computing. Also, research topics on state-of-the-art IC technology and computer architecture will be presented in the lecture.Mechanics of Plasticity Elective Required Associate Professor Yoshiteru AoyagiMechanics of plasticity is an extended subject of mechanics, and solid mechanics. This lecture aims to understand the mechanical description of "plastic deformation," a fundamental phenomenon such as the strength and fracture of materials, forming process, and tribology, and to master a deformation analysis method based on plasticity. This lecture covers 1) basic concepts of plastic deformation, 2) a mechanical description of plastic deformation, 3) a simulation method using the finite element method, and 4) applications to engineering through examples.
Structure and Function of Living System       2 credits         Elective Required       Professor Yoichi Haga         Professor Makoto Ohta       Professor Takuji Ishikawa         In all types of engineering with a connection to the human body, a thorough understanding of the structure and function of the human body and other living systems is vital, as is consideration of systems geared to the special features of these living systems. This course covers the biology knowledge in terms of the basic functions and structures of living organisms that forms the basic 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	Introduction to Mechanics and Physical Mathematics	2 credits
Elective Required		Elective Required	
Professor Shingo Kagami		*	
Professor Toshinori Kuwahara		Professor Tomonaga Okabe	
This lecture covers fundamentals of digital signal proprovides a foundation for sensing, control, communic processing, image processing, and so forth. Related s discrete-time signals, discrete-time and discrete Fou transformations, sampling, digital frequency analysi systems, z transformation, digital filtering, and some topics.	ation, voice ubjects include rier s, discrete-time	In the modeling of classical mechanics, we often meet to mathematics, such as differential geometry or manifol. These have been developed from the viewpoint of math universality and do not always provide new ideas direct often need such a background to make the theoretical. Furthermore, symbols and calculations developed in the not commonly used by general engineering students on students of engineering, and this is considered to be an learning them. In this lecture, I am going to introduce mathematical expressions as simple as possible, so that can employ the advanced mathematics in the general free engineering field. This course can also be considered as introduction to the tools of physical mathematics.	ds theory. nematical ctly. But, we models. nese fields are graduate n obstacle for those at the students mechanical
Continuum Mechanics	2 credits	Applied Fluid Mechanics	2 credits
Elective Required Professor Takuji Ishikawa		Elective Required	
Associate Professor Toshihiro Omori		Professor Jun Ishimoto	
Associate Professor Toshihiro Omori		Professor Yuka Iga	
Materials may be regarded as continuum at the mac this lecture, we aim to mathematically understand the deformation of materials, such as solid and fluid, at the scale. We first explain the concepts of continuum and as vector/tensor analysis. We then derive basic equate the motion and deformation of continuum, such as ex- equation, constitutive equation and boundary condit is the basis of solid and fluid mechanics, which is rec- students who want to establish a whole picture of bo	he motion and the macroscopic d stress as well tions describing quilibrium ions. This lecture commended to	This lecture will be given on the fundamentals and multiphase fluid dynamics and numerical analysis rela- dynamic phenomena with heterogeneous interfaces, phase flow, phase change, cavitation, and the fundam type fluid machinery such as pumps and turbines. Th be understand are as follows. 1) Flow pattern and classis of gas-liquid two-phase flow, 2) Fundamentals of two Modeling of dispersed multi-phase flow and numeri Modeling of liquid atomization 5) Classification an machinery 6) Generation of cavitation in pumps.	ated to the fluid gas-liquid two- entals of turbo- e main topics to ification method offluid model, 3) cal analysis, 4)
<b>Structural Mechanics</b> Elective Required Professor Kanjuro Makihara Associate Professor Keisuke Otsuka	2 credits		
This lecture gives a fundamental knowledge on the s analysis and the structural design of mechanical stru- topics of this lecture are deformation and stress anal and wing structures subjected to bending, twisting a Fundamental of mechanical structure and material s Vibration analysis for structures. (3) Applied load an of mechanical structures. (4) Structural identification health monitoring (5) Structural mechanics for aeros engineering.	uctures. Main yses of fuselage nd shear. (1) strength. (2) ud stress analysis n and structural		

Micro Electro Mechanical Systems 2 credits	Advanced Robotics 2 credits
Elective Required	Elective Required
Professor Shuji Tanaka	Professor Yasuhisa Hirata
Associate Professor Takashiro Tsukamoto	Associate Professor Yusuke Tamura
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.	The robot is an advanced system that consists of mechanical parts, actuators, sensors, and controllers. By integrating the several systems and control methods effectively, the robot could realize required tasks in the real environment. In this lecture, the fundamental and advanced motion control methods of the robot will be given, and the recent applications developed by the integration of the robot technologies will be introduced.
Biomechatronics 2 credits	Foundations of Molecular Robotics 2 credits
Biomechatronics 2 credits Elective Required	Foundations of Molecular Robotics 2 credits Elective Required
Professor Mami Tanaka	Professor Satoshi Murata
I IVICOOVI MIAIIII I AIIAKA	Associate Professor Shinichiro Nomura
	Molecular robotics is a technology for creating systems by combining logically designed molecules. The basis of molecular robotics are DNA nanotechnology and artificial cell engineering. DNA nanotechnology is used to create various nanostructures and molecular computers for molecular robot by designing the sequences of nucleic acid molecules such as DNA. Artificial cell engineering is a methodology to embed various functional molecules in vesicles called liposomes to create a cellular molecular robot. In addition, synthetic biology, which is a closely related subject to molecular robotics, will also be explained.
Intelligent Mechanosystem Analysis 2 credits	Introduction to Solid State Ionics 2 credits
Elective Required	Elective Required
Professor Kenichi Funamoto	Professor Koji Amezawa
Associate Professor Hitomi Anzai	Associate Professor Kazuhisa Sato
Associate Professor Takuya Mabuchi	
Intelligent mechano-systems are generally modeled as infinite- dimensional nonlinear dynamical systems. As a basis of modern control theory to deal with such systems, we first study basic concepts of function spaces, dual spaces, and linear operators, and understand basic theories of optimization from intuitive geometrical point of view. Next, mathematical modeling of mechano-systems is discussed for fluid control systems focusing on the relationship between the structure of differential equations and physical phenomena. It is preferable to have basic background on fluid dynamics, control engineering, linear algebra, and analysis.	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.
<b>Embodied Intelligence and Robotics</b> 2 credits	Neuro Robotics 2 credits
Elective Required	Elective Required
Professor Kazunori Ohno	Professor Mitsuhiro Hayashibe
Professor Masashi Konyo	Associate Professor Dai Owaki
Lectures and investigation study on the following themes.	This serves deals with her deals of the New Dillet 111
1) Disaster response robotics	This course deals with key elements for Neuro-Robotics which is new
2) Haptic interface	scientific field to use robotics for neuroscience and use neuroscience for
3) Field robotics	robotics. We learn robotics computation aspect and neuroscience
4) Advanced mechanisms	knowledge to understand human functionality with the view of robotics, and robotics modeling and computation technology which is useful to understand human system of motor control and motor learning. It may include machine learning, neural network, Kalman filtering, control methods for computation aspect. The lecture is given

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

#### Physical Fluctuomatics

2 credits

Elective Required Professor Kazuyuki Tanaka

Applications to many fields in engineering like control, signal processing etc. and in information sciences are in mind through the lecture course for the basic knowledge of statistical machine learning theory as well as stochastic processes. Brief introduction will be given to methods for applications like statistical estimation etc., and to the relationship with statistical-mechanical informatics. We first lecture probability and statistics and their fundamental properties and explain the basic frameworks of Bayesian estimation and maximum likelihood estimation. Particularly, we show EM algorithm as one of familiar computational schemes to realize the maximum likelihood estimation. As one of linear statistical models, we introduce Gaussian graphical model and show the explicit procedure for Bayesian estimation and EM algorithm from observed data. We show some useful probabilistic models which are applicable to probabilistic information processing in the standpoint of Bayesian estimation. We mention that some of these models can be regarded as physical models in statistical mechanics. Fundamental structure of belief propagation methods is reviewed as powerful key algorithms to compute some important statistical quantities, for example, averages, variances and covariances. Particularly, we clarify the relationship between belief propagations and some approximate methods in statistical mechanics. As ones of application to probabilistic information processing based on Bayesian estimation and maximum likelihood estimations, we show probabilistic image processing and probabilistic reasoning. Moreover, we review also quantummechanical extensions of probabilistic information processing.

#### **Environmental Administration**

Elective Required Various teachers

The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively. In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies.

In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.

Ethics of Engineering and Life	2 credits	Internship Training	1 or 2 credits
Elective Required		Elective Required	
Professor Tetsutaro Hattori		All teachers	
We will study wide range of ethical issues ind which are important for researchers and eng science but also engineering is closely related engineering technologies to various fields suc productions, we undoubtedly face the matter humans and other creatures. The intrinsic in huge, which requires us to acquire sophistica the ethical norm. We will invite experts enga give lectures. We will also arrange group disc *Note for foreign students: Lectures are giver and handouts, some lecturers give titles etc. I English, but others do not.	neers. Not only medical to "life". Applying some h as medicine and food of life and death in fluence of engineering is ted knowledge and learn ged in various fields to ussion and presentation.	Practical training and research conduct one week to one month in the first year this training, students learn how to ap university to a real industrial technolo students gain on-site experience and u planning, surveys and research, product and product management, etc., in comp students take this training. One or two according to the content and the period	r of master's program. Through ply the basic research at gy setting. Additionally, nderstand the realities of ct development, manufacturing panies. It is desirable that all o credits are given to them
International Scientific Internship Training	1  or  2  credits	Special Lecture on Robotics A	1 or 2 credits
Elective Required		Elective Required	
All teachers		Various teachers	
When students have attended any lectures or academic organization or science program, or given to them according to the content and th	e or two credits are	A special lecture on leading-edge acade area, or on the creation and developme the major area.	•

Advanced Seminar on Robotics A 1 or 2 credits	Seminar on Nano-Systems 2 credits
Elective Required	Elective Required
Various teachers	Professor Shuji Tanaka
	Professor Satoshi Murata
Addressing leading edge academic research in the major area, this course comprises seminars on a subject which student have chosen	Professor Yoichi Haga
themselves as well as training in and beyond the university.	Professor Yoshiaki Kanamori
Integrating these advanced specialist knowledge helps to develop	Associate Professor Shinichiro Nomura
students' problem-posing ability.	Associate Professor Takaki Tsukamoto
	Associate Professor Naoki Inomata
	Associate Professor Takuya Mabuchi
	By introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.
Seminar on Robot-Systems 2 credits	Master's Research Training in Robotics 8 credits
Elective Required	Required
Professor Mami Tanaka	Various teachers
Professor Mitsuhiro Hayashibe	
Professor Yasuhisa Hirata	Students engage in experiments and seminars, including research
Professor Kimitoshi Yamazaki	presentations, discussion, and literature reviews. Students who have
Associate Professor Takeshi Okuyama	acquired credits from the Innovation Oriented Seminar on
Associate Professor Dai Owaki	Mechanical Engineering program do not need to take this course.
Associate Professor Yusuke Tamura	
By introducing and discussing key research papers in relation to their	
master's thesis, as well as the background to and interim results of	
their own research. Through this seminar, students will identify	
research trends in their particular area and the position of their own	
research.	

				De	epartmen	t of Aer	ospace Engineering
区分 Category	授業科目 Subject	開講時期 Schedule	使用 言語 Langu age	必須 Required	単位 Credit 選択必須 Elective Required	選択 Elective	備考 Remarks
	数值解析学	毎年 Every year	J		2		
	Numerical Analysis	隔年 Every second year	Е		-		
	統計的モデリング Statistical modeling	毎年 Every year	JE		2		
	基盤流体力学	毎年 Every year	J		2		
	Fluid Dynamics	毎年 Every year	Е				
	固体力学	毎年 Every year	J		2		
	Solid Mechanics	毎年 Every year	Е		2		
	熱科学・工学A	隔年 Every second year	$\mathbf{J}$				
	Thermal Science and Engineering A	隔年 Every second year	Е		2		
	熱科学・工学B	隔年 Every second year	J		_		
	Thermal Science and Engineering B	隔年 Every second year	Е		2		
	システム制御工学 I System Control Engineering I	毎年 Every year	Е		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
専門基盤科目 Major Basic	システム制御工学 II System Control Engineering II	毎年 Every year	Е		2		
Subjects	材料化学 Materials Chemistry	毎年 Every year	Е		2		8 or more credits from the Major basic
	計算機科学	隔年 Every second year	J			subjects listed left column.	subjects listed in the left column.
	Computer Hardware Fundamentals	隔年 Every second year	Е		2		
	固体物理学 Solid State Physics	毎年 Every year	Е		2		
	塑性力学 Mechanics of Plasticity	毎年 Every year	Е		2		
	生物の構造と機能	隔年 Every second year	J				
	Structure and Function Living System	隔年 Every second year	Е		2		
	ロボットビジョン	隔年 Every second year	J				
	Robot Vision	隔年 Every second year	Е		2		
ディジタ	ディジタル信号処理	隔年 Every second year	J				
	Digital Signal Processing	隔年 Every second year	Е		2		
	力学と物理数学	隔年 Every second year	J				
	Introduction to Classical Mechanics and Physical Mathematics	隔年 Every second year	Е		2		

	連続体力学	隔年 Every second year	J		
	Continuum Mechanics	隔年 Every second year	Е	2	
	応用流体力学	隔年 Every second year	J		
	Applied Fluid Mechanics	隔年 Every second year	Е	2	
	構造力学	隔年 Every second year	1	2	
	Structural Mechanics	隔年 Every second year	Е	2	
	航空宇宙システム工学 Aerospace Systems	毎年 Every year	J	2	
	航空宇宙推進工学	隔年 Every second year	J	2	
	Aerospace Propulsion	隔年 Every second year	Е	2	
	数値流体力学 Computational Fluid Dynamics	隔年 Every second year	Е	2	
	宇宙探査ロボティクス Robotics for Space Exploration	隔年 Every second year	Е	2	左記の専門科目の内か ら少なくとも1科目以
	衛星工学 Spacecraft Engineering	隔年 Every second year	Е	2	上選択履修し2単位以     上を修得するととも
	計算数理科学 Mathematical Modeling and Computation	毎年 Every year	Е	2	<ul> <li>ニションドナ ふととも</li> <li>に、左記の科目、特別</li> <li>講義 A,特別研修 A,</li> <li>及び関連科目を選択履</li> </ul>
	数理流体力学	隔年 Every second year	J		修し、全体で12単位 以上を修得すること.
専門科目 Maian	Applied Mathematical Fluid Dynamics	隔年 Every second year	Е	2	Students must earn at
Major General Subjects	高性能計算論 High Performance Computing	毎年 Every year	Е	2	least 2 credits from the Major general subjects listed in the left column.
	アーキテクチャ学 Computer Architecture	毎年 Every year	Е	2	In total 12 or more
	物理フラクチュオマティク ス論 Physical Fluctuomatics	毎年 Every year	J	2	credits are required to earn from the Major general subjects,
	環境行政論 Environmental Administration	毎年 Every year	J	2	Special Lecture A, Advanced Seminar A,
	工学と生命の倫理 Ethics of Engineering and Life	毎年 Every year	JE	2	and related subjects.
	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	て 在 の か た フ に 朱 単 る - - - - - - - - - - - - - - - - -	<ul> <li>特別講義 A, 特別研修 A</li> <li>56得した単位は2単</li> <li>なまで専門科目の要件</li> <li>012単位に含めること</li> <li>いた、ダブルディグリー</li> <li>パブラム,共同教育プログラム,共同教育プログラムの学生に限り、</li> <li>特別講義 A の単位を 8</li> <li>4位まで本要件に含め</li> <li>ちことができる.</li> <li>4 total of 2 credits at</li> </ul>
	航空宇宙工学特別研修A Advanced Seminar on Aerospace Engineering A				1~2	S a S in r c A s t t t p e e p u	nost, obtained from pecial Lecture A nd/or Advanced eminar A, can be ncluded in the equirement of 12 redits. As an exception, tudents enrolled in ne double-degree rogram or joint ducational rogram can include p to 8 credits from pecial Lecture A.
関連科目 Related Subjects of Other Majors	本研究科委員会において関連 Those approved by the Educa			te School of	Engineering		
	航空システムセミナー Seminar on Aero Systems	毎年 Every year	JE		2	カ	E記のセミナーのうち いら,指導教員の所属す らセミナー2単位を修 計すること.
専門科目 Major General Subjects	宇宙システムセミナー Seminar on Space Systems	毎年 Every year	JE		2	c: tl s	tudents must earn 2 redits from one of neir supervisor's eminars listed in the eft column.
	航空宇宙工学修士研修 Master's Research Training in Aeronautics and Space Engineering			8			

1, 上記科目の単位数を合わせて 30 単位以上を修得すること。

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

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

"Schedule" is currently tentative and may be subject to change.

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

3,「使用言語」欄のアルファベット記号について

Language Key

E:英語開講科目(Lectures given in English)

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

Numerical Analysis2 creditsElective RequiredProfessor Naofumi Ohnishi	Statistical modeling2 creditsElective RequiredProfessor Yuko Araki
Students will be taught the numerical analysis techniques which provide the basis for analysis in fluid dynamics, thermodynamics, mechanics, electromagnetics and measurement and control engineering, etc., and learn how to apply these skills. Classes will focus in particular on (1) numerical solutions for ordinary differential equations (2) the finite difference method and the finite element method for partial differential equations, and (3) linear algebra and numerical optimization methods, covering the basics of numerical analysis and their engineering applications.	Statistical modeling is widely used in various fields of natural and social sciences to extract information from data and to solve problems. In this lectures, we will start from the basic theory underlying statistical modeling of phenomena , and then focuses on (1) how to set up flexible models, (2)how to estimate parameters of models, and (3) how to select optimal models in order to efficiently extract information from recent data with complex and diverse structures. Background knowledge on elementary probability and statistics are required.
Fluid Dynamics2 creditsElective RequiredProfessor Masaya Shigeta	Solid Mechanics2 creditsElective RequiredAssociate Professor Yoshiteru Aoyagi
Students acquire the intuition and knowledge of the nature of fluid motion by studying the fundamentals of Fluid Dynamics with not only theories but also visualized images, observation videos, and computer graphic animations. The goal is for students to be able to predict the fluid motion and to design the control methods in aerodynamic and material processing applications. Students can also improve their abilities of scientific discussion and international communication. Keywords: Vortex, Stream/Path/Streak lines, Incompressibility/Compressibility, Conservation laws, Bernoulli's theorem, Viscosity and diffusivity, Boundary layer, Aerodynamic force, Laws of similarity, Reynolds number, Strouhal number and Kármán's vortex street, Navier-Stokes and wave equations, Analogy with heat and mass transfers, and Plasma as high- temperature chemically-reactive electromagnetic fluid.	This class is designed to provide students with a comprehensive understanding of deformation of solids and covers the fundamentals of continuum solid mechanics. It focuses on two-dimensional elasticity in infinitesimal strain theory, the concept of strain and stress, and the introduction of general methods of solving the boundary value problems through the specific problems. Moreover, this class also covers the fundamentals of finite deformation theory, which is used for addressing the large deformations of solids.
Thermal Science and Engineering A       2 credits         Elective Required       Professor Kaoru Maruta         Professor Takashi Tokumasu       Professor Takashi Nakamura         Associate Professor Akihiro Hayakawa       In this course, students will master the fundamentals of reactive flows in thermal fluid science. In particular, the course is designed to cover flame behaviors and peculiar phenomena in laminar and turbulent combustion, the basic concept of chemical kinetics and the understanding of reaction phenomena of electrochemistry on the standpoint of thermal science. Through the class, students will further deepen their understanding of the essence of thermal phenomena and will become able to apply this to practical devices.	Thermal Science and Engineering B       2 credits         Elective Required       Professor Taku Ohara         Professor Taku Ohara       Professor Tetsushi Biwa         Professor Tetsushi Biwa       Professor Atsuki Komiya         Professor Gota Kikugawa       Associate Professor Eita Shoji         Associate Professor Surblys Donatas       Associate Professor Surblys Donatas         The students will master the basic physics of thermal energy conversion and heat transfer in both micro and macroscopic scales and learn to link this knowledge to engineering applications. More specifically, the series lectures: i) the Molecular Dynamics and molecular-scale analyses of thermo-fluid phenomena, ii) oscillating-flow based heat transfer and energy conversion, iii) visualization and control of multi-scale heat and mass transfer, and iv) statistical mechanics regarding interface phenomena will be done. Students are expected to further deepen their understanding of the essence of thermal phenomena.
System Control Engineering I       2 credits         Elective Required         Professor Koichi Hashimoto         Professor Yasuhisa Hirata         New mechanical systems using advanced mechanisms are being developed in a range of areas for medical care and welfare, space exploration, disaster rescue purposes and so on. This course focuses on motion control design of increasingly advanced and complex mechanical systems. Students will learn fundamentals for non-linear system analysis and control system design methods. First, phase plane analysis methods and Lyapunov methods are introduced as the main ways to analyze non-linear systems. Next, non-linear feedback control system design methods that can be used for mechanical control systems with non-linear dynamics. Finally, students look at several control system design methods.	System Control Engineering II       2 credits         Elective Required         Professor Kazuya Yoshida         Associate Professor Yusuke Tamura         This course gives an advanced lecture based on the contents of "System         Control Engineering I." This lecture introduces the analysis and design         methods of control systems used for designing motion control for         increasingly advanced and complex mechanical systems. Students will         learn fundamental concepts for state and output feedback in the state         space, state observer and Kalman filter, and response analysis of         control systems. This class includes some exercises using MATLAB.

Materials Chemistry       2 credits         Elective Required       Professor Yutaka Watanabe         Professor Koji Amezawa       Professor Eiji Akiyama         Associate Professor Hiroshi Abe       Most metals in the earth's atmosphere inevitably change into more thermodynamically stable compounds such as oxides or sulfides. To understand this principle more precisely, students will learn chemical and electro-chemical equilibrium theory, and kinetics theory in relation to corrosion and oxidation of metals. Practical examples will be used to explain the phenomena and theories of wet corrosion and high-temperature oxidation, deepening students' understanding of the chemical and electro-chemical reactions related to macro phenomena of corrosion and oxidation. This course will be offered in English with a lecture and practice style, using English-language materials. A detailed outline of the course will be presented during the first class.         Solid State Physics       2 credits         Elective Required       2 credits         Professor Takahito Ono       Professor Makoto Shimizu         This course targets students from mechanical engineering, system engineering and a wide range of other specialized areas. Using Introduction to Solid State Physics (Charles Kittel, Eighth Edition) as the main text, it focuses on the fundamentals of material science.         Following the chapter order in this textbook, each class will cover the content associated with that chapter. The course aims to provide students from a wide range of areas with an understanding of the basics concept of solid-state physics and a broad perspective on the behavior of materials in engineering systems.	Computer Hardware Fundamentals       2 credits         Elective Required       Professor Tetsu Tanaka         Professor Tetsu Tanaka       Professor Hiroyuki Takizawa         Computers have become an indispensable part of modern society. In this course, both IC technology and computer architecture will be lectured for a better understanding of modern computer systems. First, CMOS-IC technology, memory technology, and 2D/3D integration technology that support a remarkable evolution of computer systems over the past few decades will be introduced. Then, the topics will move to computer architecture focusing on the structure of computer systems, issues and tradeoffs involved in the design of computer system architecture, and high-performance computing. Also, research topics on state-of-the-art IC technology and computer architecture will be presented in the lecture.         Mechanics of Plasticity       2 credits         Elective Required       Associate Professor Yoshiteru Aoyagi         Mechanics of plasticity is an extended subject of mechanics of materials, mechanics of elasticity, continuum mechanics, and solid mechanics. This lecture aims to understand the mechanical description of "plastic deformation," a fundamental phenomenon such as the strength and fracture of materials, forming process, and tribology, and to master a deformation analysis method based on plasticity. This lecture covers 1) basic concepts of plastic deformation, 2) a mechanical description of plastic deformation, 3) a simulation method using the finite element method, and 4) applications to engineering through examples.
Structure and Function of Living System       2 credits         Elective Required       Professor Yoichi Haga         Professor Makoto Ohta       Professor Takuji Ishikawa         In all types of engineering with a connection to the human body, a thorough understanding of the structure and function of the human body and other living systems is vital, as is consideration of systems geared to the special features of these living systems. This course covers the biology knowledge in terms of the basic functions and structures of living organisms that forms the basis of bioengineering. Particular emphasis will be placed on the basic knowledge and approaches necessary for deep exploration of the anatomy and physiology of the human body from the perspective of biomechanics.	Robot Vision       2 credits         Elective Required       Professor Takayuki Okatani         This course explains various problems and their solutions in computer vision. The problems are basically inverse problems in which we wish to estimate some information about an object or a scene from their image(s), such as the three-dimensional shape of a scene or the categories of object. Students will first learn a series of fundamental concepts, and then study a number of approaches to the problems of computer vision, where the main focus is on the recently developed deep learning methods.

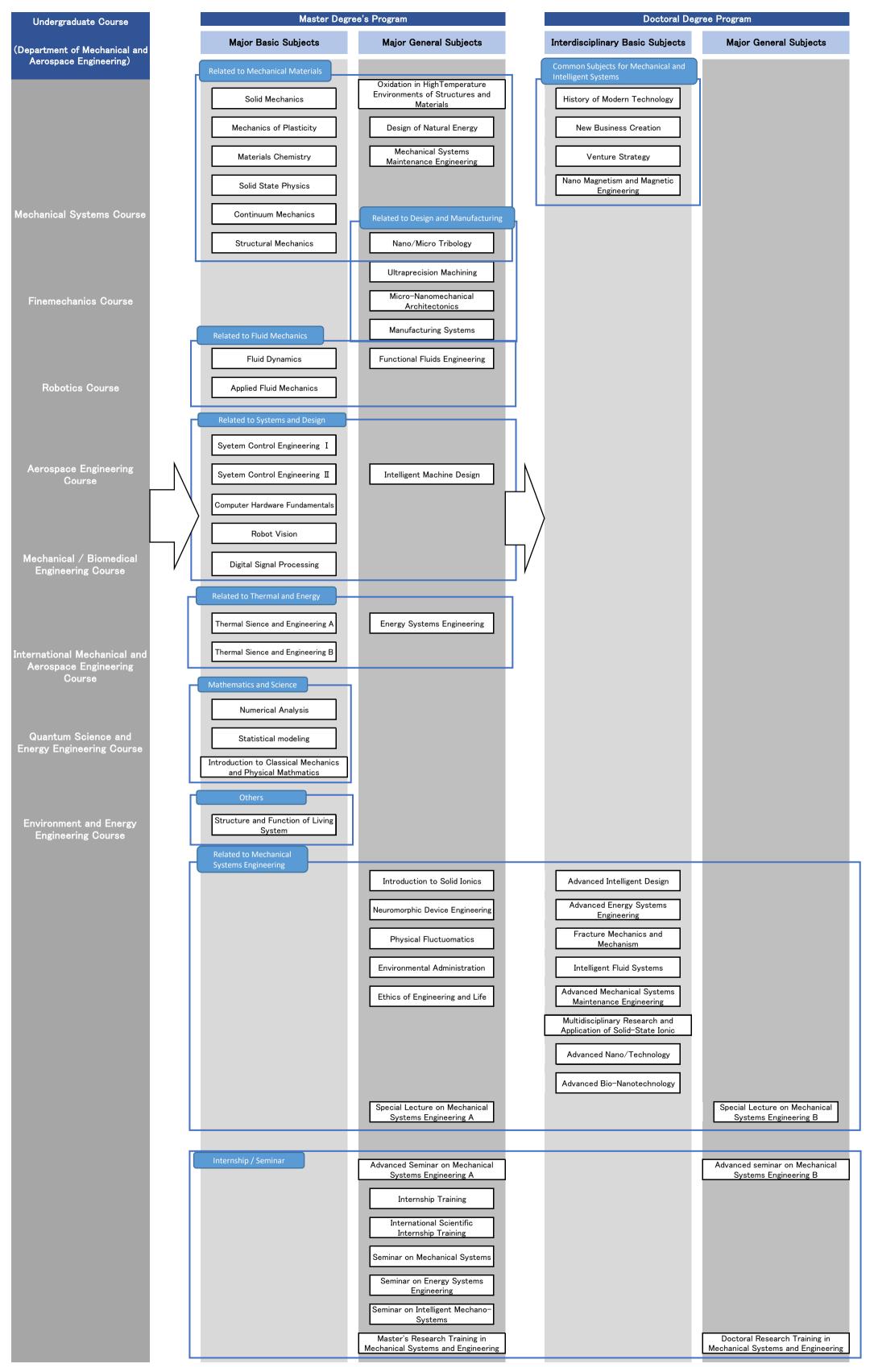
Digital Signal Processing	2 credits	Introduction to Mechanics and Physical Mathematics	2 credits
Elective Required	2 0104105	Elective Required	2 0104105
Professor Shingo Kagami			
Professor Toshinori Kuwahara		Professor Tomonaga Okabe	
This lecture covers fundamentals of digital signal provides a foundation for sensing, control, communi processing, image processing, and so forth. Related a discrete-time signals, discrete-time and discrete Fourtransformations, sampling, digital frequency analysis systems, z transformation, digital filtering, and some topics.	cation, voice subjects include trier is, discrete-time	In the modeling of classical mechanics, we often meet the mathematics, such as differential geometry or manifold. These have been developed from the viewpoint of mathe- universality and do not always provide new ideas direct often need such a background to make the theoretical m Furthermore, symbols and calculations developed in the not commonly used by general engineering students or students of engineering, and this is considered to be an learning them. In this lecture, I am going to introduce t mathematical expressions as simple as possible, so that can employ the advanced mathematics in the general m engineering field. This course can also be considered as introduction to the tools of physical mathematics.	ematical ematical ely. But, we nodels. ese fields are graduate obstacle for hose the students nechanical
Continuum Mechanics	2 credits	Applied Fluid Mechanics	2 credits
Elective Required		Elective Required	
Professor Takuji Ishikawa		Professor Jun Ishimoto	
Associate Professor Toshihiro Omori		Professor Yuka Iga	
Materials may be regarded as continuum at the mat this lecture, we aim to mathematically understand to deformation of materials, such as solid and fluid, at scale. We first explain the concepts of continuum an as vector/tensor analysis. We then derive basic equa the motion and deformation of continuum, such as e equation, constitutive equation and boundary condi- is the basis of solid and fluid mechanics, which is re students who want to establish a whole picture of bo	the macroscopic d stress as well tions describing quilibrium tions. This lecture commended to	This lecture will be given on the fundamentals and a multiphase fluid dynamics and numerical analysis relat dynamic phenomena with heterogeneous interfaces, g phase flow, phase change, cavitation, and the fundame type fluid machinery such as pumps and turbines. The be understand are as follows. 1) Flow pattern and classif of gas-liquid two-phase flow, 2) Fundamentals of two- Modeling of dispersed multi-phase flow and numeric Modeling of liquid atomization 5) Classification and machinery 6) Generation of cavitation in pumps.	ted to the fluid gas-liquid two- entals of turbo- e main topics to fication method fluid model, 3) al analysis, 4)
Structural Mechanics	2  credits		
Elective Required			
Professor Kanjuro Makihara Associate Professor Keisuke Otsuka			
Associate Professor Kelsuke Utsuka			
This lecture gives a fundamental knowledge on the	structural		
analysis and the structural design of mechanical str			
topics of this lecture are deformation and stress ana	•		
and wing structures subjected to bending, twisting a			
Fundamental of mechanical structure and material	0		
Vibration analysis for structures. (3) Applied load an			
of mechanical structures. (4) Structural identification			
health monitoring (5) Structural mechanics for aero engineering.	space		
engmeering.			

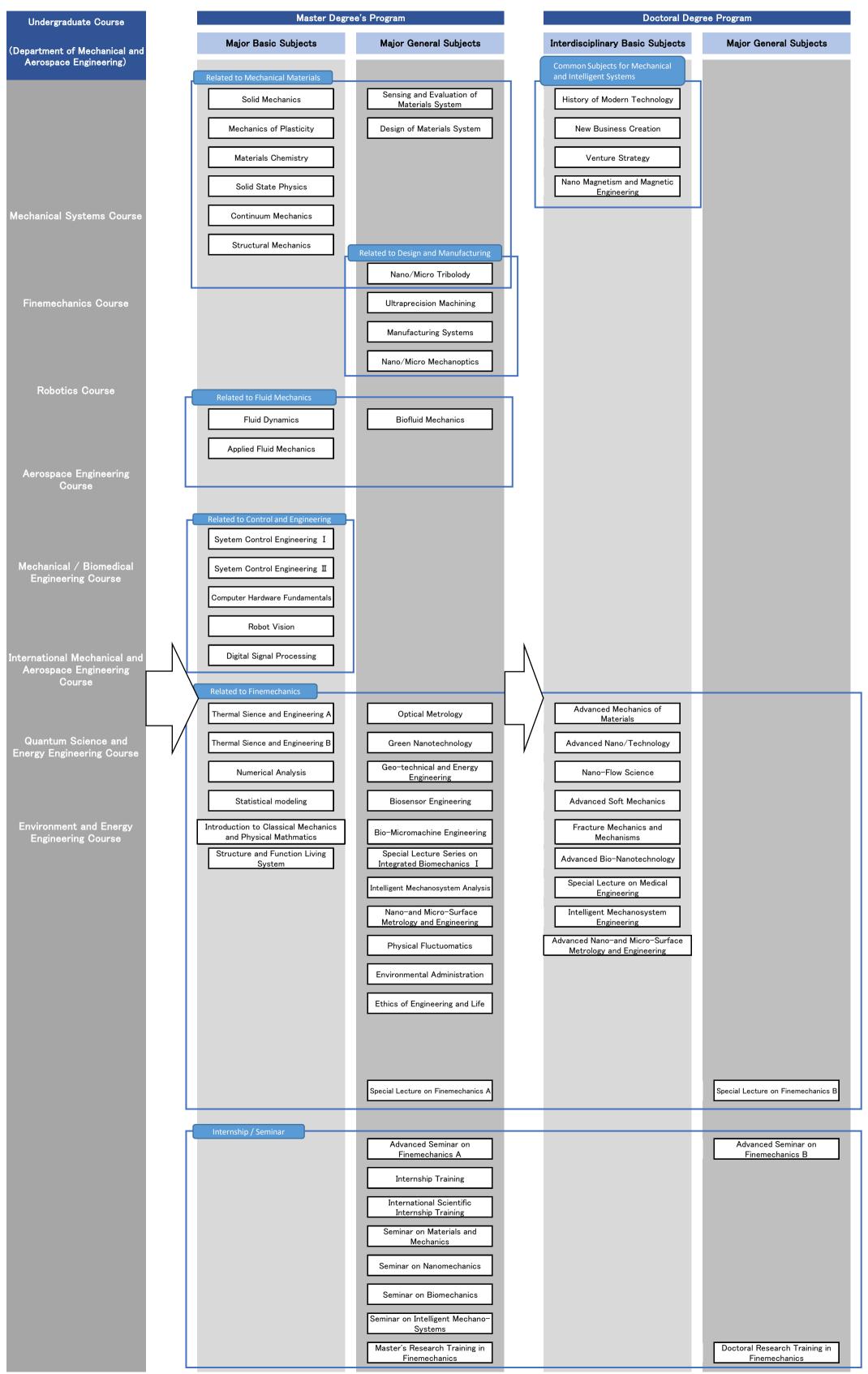
Aerospace Systems       2 credits         Elective Required       Professor Naofumi Ohnishi         Adjunct Instructor Toshihiko Nakagawa       Adjunct Instructor Soichiro Yada         Lectures give the system concept of aircraft and rocket and discuss the basic design planning and the performance of these flight vehicles.	Aerospace Propulsion       2 credits         Elective Required       Professor Naofumi Ohnishi         Associate Professor Masayuki Takahashi       2         Lectures on principles of thrust generation of jet engine and rocket       engine which propel vehicles in air and space are given, including         structure of the engines and methods for improving their       performance. Non-chemical propulsion schemes are also introduced, including physics of plasma.
Computational Fluid Dynamics2 creditsElective RequiredProfessor Soshi Kawai	Robotics for Space Exploration2 creditsElective RequiredProfessor Kazuya Yoshida
This course provides the basic and advanced fundamentals and theories of modern computational fluid dynamics (CFD) methods for compressible flows. Also, we will provide lectures on the programming of numerical methods discussed in this course.	Robotics technology is useful for space development and exploration activities. In this course, the subject of Space Robotics is elaborated on the application to orbital servicing missions and lunar/planetary exploration. As for the "orbital robotics," the following topics are lectured: • Angular motion kinematics and attitude dynamics of a spacecraft, • Multi-body dynamics and control of a free-flying space robot, • Impact dynamics and post-impact control when a space robot captures a floating target. As for the "lunar/planetary robotics," the following topics are lectured: • Mission and system design for Lunar and asteroid exploration, • Mobility system design and analysis for locomotion on the lunar/planetary surface, • Sensing, planning, and navigation of a mobile robot. All lectures are given in English.
Spacecraft Engineering2 creditsElective RequiredProfessor Kazuya YoshidaProfessor Kanjuro MakiharaProfessor Hiroki NagaiProfessor Toshinori KuwaharaIn this course, the fundamental engineering issues are lectured in the following four parts for the design and development of spacecraft and space flight systems.(1) Orbital mechanics for various space missions(2) Attitude dynamics and control of spacecraft(3) Design of space structures, vibration analysis and control(4) Thermodynamics and thermal control of space systemsAll lectures are given in English.	Mathematical Modeling and Computation       2 credits         Elective Required       Professor Satoru Yamamoto         This lecture introduces typical mathematical models on some       physical and social problems observed in nature and in events which are basically formulated by a system of nonlinear partial-differential         equations, and also teaches the numerical methods based on the finite-difference method for solving the mathematical models. Each student is subjected to make his own mathematical model and submits the computational result as the final report.
Applied Mathematical Fluid Dynamics       2 credits         Elective Required       Professor Yuji Hattori         Associate Professor Makoto Hirota       A number of ideas in applied mathematics, which include dynamical systems, differential geometry, Lie groups, and statistical mechanics, have been applied to fluid dynamics. Recent development in basic fluid dynamics is introduced and methods and ideas for attacking various problems in nonlinear dynamics are given. The lecture consists of three parts: (i) theory of hydrodynamics stability, (ii) statistical fluid dynamics, and (iii) topological fluid dynamics.	High Performance Computing       2 credits         Elective Required       Professor Hiroyuki Takizawa         This course reviews high-performance computing systems from both aspects of hardware and software. The course talks about the importance of parallel processing, parallel system architectures, parallel algorithm design, parallel programming, and performance evaluation methodologies. The course also discusses the memory systems necessary for high-performance computing.

Computer Architecture	2 credits	Physical Fluctuomatics	2 credits
Elective Required		Elective Required	
Professor Hiroaki Kobayashi		Professor Kazuyuki Tanaka	
Associate Professor Masayuki Sato The term "computer architecture" means the concept computers and is also its philosophy. This course beg basic principles of computers, and then talks about in parallel processing, vector processing, parallel compu and their control mechanisms. Supercomputing tech- vector systems and accelerators are also reviewed. See the class web page for more details. http://www.sc.isc.tohoku.ac.jp/class/architecture/ (Contact instructors to have an access ID).	tins with the nstruction-level ating systems,	Applications to many fields in engineering lik processing etc. and in information sciences ar lecture course for the basic knowledge of stati theory as well as stochastic processes. Brief in to methods for applications like statistical est relationship with statistical-mechanical infor probability and statistics and their fundament explain the basic frameworks of Bayesian est likelihood estimation. Particularly, we show I familiar computational schemes to realize the estimation. As one of linear statistical models graphical model and show the explicit proced estimation and EM algorithm from observed of useful probabilistic models which are applical information processing in the standpoint of I mention that some of these models can be reg in statistical mechanics. Fundamental struct methods is reviewed as powerful key algor important statistical quantities, for example, covariances. Particularly, we clarify the reli- propagations and some approximate methods As ones of application to probabilistic informat Bayesian estimation and maximum likelihoo probabilistic image processing and probabilistic	e in mind through the astical machine learning ntroduction will be given imation etc., and to the matics. We first lecture tal properties and imation and maximum EM algorithm as one of e maximum likelihood a, we introduce Gaussian ure for Bayesian data. We show some ble to probabilistic Bayesian estimation. We arded as physical models ure of belief propagation ithms to compute some averages, variances and ationship between belief in statistical mechanics. tion processing based on od estimations, we show tic reasoning. Moreover,
		information processing.	
Environmental Administration	2 credits	Ethics of Engineering and Life Elective Required	2 credits
Elective Required Various teachers		Professor Tetsutaro Hattori	
The Graduate School of Environmental Studies has had a cooperation agreement with Miyagi Prefecture and Sendai City, respectively. In this lecture, students learn about current status and issues related to environmental policies of Miyagi Prefecture and Sendai City (about climate change such as global warming, promotion of waste reduction and recycling including plastic recycling, and environment-related laws) to achieve environmental conservation and sustainable society and learn about environmental policies and environmental technologies. In addition to lectures, this course can help students acquire practical knowledge and develop their ability to think about how to respond to environmental issues through exercise and facility tour.		We will study wide range of ethical issues including "research ethics", which are important for researchers and engineers. Not only medical science but also engineering is closely related to "life". Applying some engineering technologies to various fields such as medicine and food productions, we undoubtedly face the matter of life and death in humans and other creatures. The intrinsic influence of engineering is huge, which requires us to acquire sophisticated knowledge and learn the ethical norm. We will invite experts engaged in various fields to give lectures. We will also arrange group discussion and presentation. *Note for foreign students: Lectures are given in Japanese. In slides and handouts, some lecturers give titles etc. both in Japanese and English, but others do not.	
Internship Training	1 or 2 credits	International Scientific Internship Training	1 or 2 credits
Elective Required All teachers		Elective Required All teachers	
Practical training and research conducted at a company for around one week to one month in the first year of master's program. Through this training, students learn how to apply the basic research at university to a real industrial technology setting. Additionally, students gain on-site experience and understand the realities of planning, surveys and research, product development, manufacturing and product management, etc., in companies. It is desirable that all students take this training. One or two credits are given to them according to the content and the period of the training.		When students have attended any lectures or academic organization or science program, on given to them according to the content and th	e or two credits are

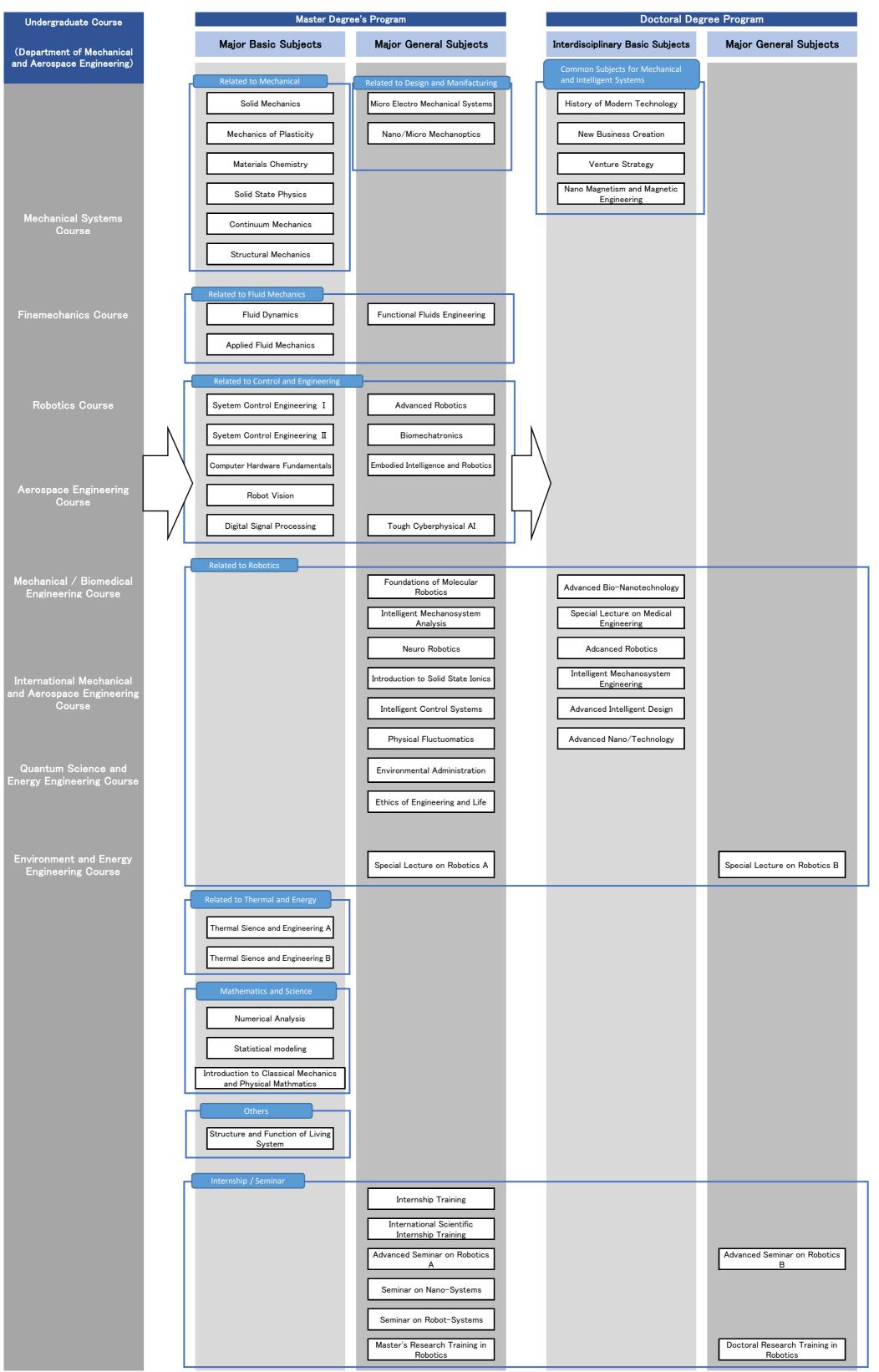
Special Lecture on Aerospace Engineering A 1 or 2 credits Elective Required Various teachers A special lecture on leading-edge academic research in the major area, or on the creation and development of knowledge in relation to the major area.	Advanced Seminar on Aerospace Engineering A       1 or 2 credits         Elective Required       Various teachers         Addressing leading-edge academic research in the major area, this course comprises seminars on a subject which student have chosen themselves as well as training in and beyond the university.         Integrating these advanced specialist knowledge helps to develop students' problem-posing ability.	
Seminar on Aero Systems2 creditsElective RequiredProfessor Tomonaga OkabeProfessor Tomonaga OkabeProfessor Hiroki NagaiProfessor Soshi KawaiProfessor Hisashi NakamuraAssociate Professor Go YamamotoAssociate Professor Yoshiaki AbeAssociate Professor Aiko YakenoAssociate Professor Kai FukamiBy introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	Seminar on Space Systems       2 credits         Elective Required       Professor Naofumi Ohnishi         Professor Kazuya Yoshida       Professor Kazuya Yoshida         Professor Hideaki Kobayashi       Professor Kanjuro Makihara         Professor Toshinori Kuwahara       Associate Professor Masayuki Takahashi         Associate Professor Keisuke Otsuka       Associate Professor Akihiro Hayakawa         By introducing and discussing key research papers in relation to their master's thesis, as well as the background to and interim results of their own research. Through this seminar, students will identify research trends in their particular area and the position of their own research.	
Master's Research Training in Aeronautics and Space Engineering 8 credits Required Various teachers Students engage in experiments and seminars, including research presentations, discussion, and literature reviews. Students who have acquired credits from the Innovation Oriented Seminar on Mechanical Engineering program do not need to take this course.		

# Department of Mechanical Systems Engineering





# **Department of Finemechanics**



## **Department of Robotics**

# **Department of Aerospace Engineering**

