Graduate Major in Mathematical and Computing Science

【Master's Degree Program】

1. Outline

Master's Degree Program in Mathematical and Computing Science offers a broad range of advanced courses in the field of mathematical science and computer science. Our students develop skills and originality to contribute to the progress of mathematical science and computer science. They also enhance practical problem-solving skills to formulate mathematical models for modern, advanced, and complicated problems in global society and to solve the problems with advanced computer systems.

2. Competencies Developed

After completing the program, students will acquire the following competencies:

- Knowledge and skills relating to mathematical science
- Ability to accurately grasp the mathematical structures of research objects and logically describe them
- Ability to grasp a complicated real-life problem within a clear, mathematical framework and also realize its solution as an algorithm
- Knowledge and skills relating to computer science such as computer architecture and software systems
- Ability to propose an approach that fuses mathematical science and computer science
- Communication skills for writing, discussion, and presentation in a logical manner

3. Learning Goals

The master's degree program provides a curriculum to acquire the "Competencies Developed" mentioned above in an efficient and organized way. Through the curriculum, students are expected to:

A) Learn mathematical structures in practical problems and computer-aided approaches for mathematical researches

B) Learn mathematical models to formulate various problems and operational methods to solve them

C) Obtain deep knowledge and high expertise in computer science, including mathematical logic, algorithm, theory of computation, computer architecture, and software systems

D) Cultivate wide scopes and study proactively:

Acquire skills to study proactively through (1) small-group seminars in discussion styles with professors and other graduate students, (2) frequent communications among research groups, and (3) the process to complete the master's thesis.

E) Enhance communication skills:

Acquire writing abilities to write the master's thesis and develop abundant abilities for presentations through seminars in a research group and communications in joint researches.

4. IGP Completion Requirements

The following requirements must be met to complete the Master's Degree Program of this major.

1. Attain a total of 30 credits or more from 400- and 500-level courses.
2. A minimum of five credits acquired from Liberal Arts and Basic Science Courses (Three credits from Humanities and Social Science Courses of which two credits must be from 400-level courses and one credit from 500-level courses, and two credits from Career Development Courses).
3. From the courses specified in the Graduate Major in Mathematical and Computing Science curriculum,
   - four credits acquired from 400-level Research Seminars and four credits acquired from 500-level Research Seminars;
   - two credits acquired from Advanced Exercises and Experiments in Mathematical and Computing Science I and II; and
   - a minimum of eight credits acquired from Major Courses.

   Consequently, a minimum of 18 credits acquired from Core Courses.
4. Pass the master's thesis review and defense.

Table M1 shows course categories and the number of credits required to complete the Master's Degree Program of this major. It also shows the required minimum credits in each course category and points to be noted when selecting the required courses and electives.

The learning goals to be obtained by students through courses are listed as “associated learning goals”. Prior to registering courses, students need to fully understand the course goals.

Table M1. Graduate Major in Mathematical and Computing Science Completion Requirements

Course category		<Required courses> Required credits	<Electives> Minimum credits required	Minimum credits required	Associated learning goals	Comments
Liberal arts and basic science courses	Humanities and social science courses		•2 credits from 400-level •1 credit from 500-level	5 credits	D	
	Career development courses		2 credits		D,E	All Graduate Attributes (GA) should be acquired. (Refer to Section 7 for the definition of GA.)
	Other courses					
Core courses	Research seminars	Seminar on Mathematical and Computing Science S1 Seminar on Mathematical and Computing Science F1 Seminar on Mathematical and Computing Science S2 Seminar on Mathematical and Computing Science F2 A total of 8 credits, 2 credits each from the above courses.		18 credits	A,B,C,D,E	
	Research-related courses	Advanced Exercises and Experiments in Mathematical and Computing Science I Advanced Exercises and Experiments in Mathematical and Computing Science II A total of 2 credits, 1 credit each from the above courses.			A,B,C,D,E	
	Major courses		8 credits		A,B,C,D	
	Major courses and Research-related courses <u>outside</u> the					

	Graduate Major in Mathematical and Computing Science standard curriculum					
Total required credits	**A minimum of 30 credits including those attained according to the above conditions**					
Note	**・Japanese Language and Culture Courses offered to international students can be recognized as equivalent to the Humanities and Social Science Courses of the corresponding course level.** **・For details of the Liberal Arts and Basic Science Courses, please refer to the relevant sections.**					

5. IGP Courses

Table M2 shows the Core Courses of the Master's Degree Program in this major. Graduate Majors listed in the Comments column offer core courses that are recognized as equivalent to the corresponding Major Courses or Research-related Courses in the standard curriculum of this major.

Table M2. Core Courses of the Graduate Major in Mathematical and Computing Science

Course category		Course number	Course title			Credits	Competencies	Learning goals	Comments
Research seminars	**400 level**	MCS.Z491.R	◎		Seminar on Mathematical and Computing Science S1	0-0-2	1,2,3,4,5	A,B,C,D,E	
		MCS.Z492.R	◎		Seminar on Mathematical and Computing Science F1	0-0-2	1,2,3,4,5	A,B,C,D,E	
	500 level	MCS.Z591.R	◎		Seminar on Mathematical and Computing Science S2	0-0-2	1,2,3,4,5	A,B,C,D,E	
		MCS.Z592.R	◎		Seminar on Mathematical and Computing Science F2	0-0-2	1,2,3,4,5	A,B,C,D,E	
Research-related courses	**400 level**	MCS.U471.L			Internship A (Computing)	0-0-2	2,4,5	D,E	【School of Computing】(XCO.U471)
		MCS.U481.R	◎		Advanced Exercises and Experiments in Mathematical and Computing Science I	0-0-1	1,2,3,4,5	A,B,C,D,E	
		MCS.U482.R	◎		Advanced Exercises and Experiments in Mathematical and Computing Science II	0-0-1	1.2,3,4,5	A,B,C,D,E	
	500 level	MCS.U571.L			Internship B (Computing)	0-0-2	2,4,5	D,E	【School of Computing】(XCO.U571)

Major courses		MCS.U472.L			English Presentation Skills A (Computing)	2-0-0	2	E	【School of Computing】(XCO.U472)
		MCS.T496.L		E	Advanced Topics in Computing AE	2-0-0	1,2,3	A,B,C,D,E	【School of Computing】(XCO.T496)
		MCS.T497.L		O	Advanced Topics in Computing AO	2-0-0	1,3	A,B,C,D,E	【School of Computing】(XCO.T497)
		MCS.T498.L		E	Advanced Topics in Computing BE	2-0-0	1,2,3	A,B,C,D,E	【School of Computing】(XCO.T498)
		MCS.T499.L		O	Advanced Topics in Computing BO	2-0-0	1,3	A,B,C,D,E	【School of Computing】(XCO.T499)
	400 level	MCS.T401.L		O	Analysis on Continuous Systems	2-0-0	3	A	
		MCS.T402.L			Mathematical Optimization: Theory and Algorithms	2-0-0	3	B	
		MCS.T403.L			Statistical Learning Theory	2-0-0	3,5	B	
		MCS.T405.L		O	Theory of Algorithms	2-0-0	3	C	
		MCS.T406.L		E	Distributed Systems	2-0-0	3,5	C	
		MCS.T407.L		O	High Performance Computing	2-0-0	1,2,3,4	C	
		MCS.T408.L		E	Discrete, Algebraic and Geometric Structures I	2-0-0	1,3,4,5	A	Not offered in AY 2018
		MCS.T409.L		O	Applied Functional Analysis	2-0-0	3,5	A	
		MCS.T410.L		E	Applied Probability	2-0-0	3,5	B	
		MCS.T411.L			Computational Complexity Theory	2-0-0	3	C	Not offered in AY 2018
		MCS.T416.L		E	Logic and Computation	2-0-0	3	C	
		MCS.T418.L		O	Practical Parallel Computing	2-0-0	3,5	C	
		MCS.T419.L		E	Stochastic Differential Equations	2-0-0	3,5	B	
	500 level	MCS.T502.L			Functional Programming	2-0-0	3	C	
		MCS.T503.L		O	Programming Language Design	2-0-0	2,3	C	

		MCS.T504.L		E	Topics in Geometry	2-0-0	1,3,5	A	
		MCS.T505.L		O	Discrete, Algebraic and Geometric Structures II	2-0-0	3,4,5	A	Not offered in AY 2018
		MCS.T507.L		O	Theory of Statistical Mathematics	2-0-0	3,4	B	
		MCS.T509.L		O	Software Verification	2-0-0	3	C	

Note：

• ◎：Required course， O：odd academic years， E ：even academic years

• Competencies: 1 = Intercultural skills; 2 = Communication skills; 3 = Specialist skills; 4 = Critical thinking skills; 5 = Practical and/or problem-solving skills

•【 】Course offered by another graduate major

6. IGP Courses That Can Be Counted as Humanities and Social Science Courses

None

7. IGP Courses That Can Be Counted as Career Development Courses

In order to fulfill the completion requirements for the master's degree program, students must attain at least 2 credits in Career Development Courses, and should satisfy all of the Graduate Attributes (GA) specified in Table MA-1 of the "Career Development Courses" (Liberal Arts and Basic Science Courses) in the Guide to Graduate Education and International Graduate Program. Students will be evaluated in regards to GA achievements at the time of their degree completion. As to the courses with more than one GA, the number of GA stipulated for the courses is considered to be acquired regardless of the credits received for the courses.

Major Courses that enable students to acquire GA and that are recognized as equivalent to Career Development Courses are listed in Table M3 below.

However, it must be noted that credits attained from these courses cannot be counted more than once as Major Courses or Career Development Courses towards the completion requirements for the master's degree program.

For Graduate Attributes, refer to the Guide to the Career Development Courses.
The Graduate Attributes of the Master's Degree Program are listed in Table MA-1 as follows:

C0M: Able to delineate one's career plan clearly and recognize the skills necessary to materialize the plan, also considering its relations to the society

C1M: Able to utilize its own expertise to the development of academia and technology, and work with others with different expertise to contribute to problem-solving

Table M3. Courses of the Graduate Major in Mathematical and Computing Science recognized as equivalent to Career Development Courses

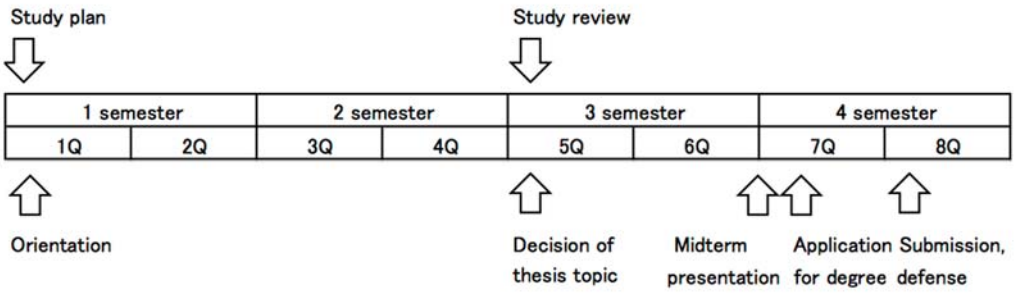
Course category	Course number	Course title	Credits	GA*	Learning goals	Comments
Courses that can be counted as Career Development Courses	MCS.U471.L	Internship A (Computing)	0-0-2	C0M, C1M	D,E	
	MCS.U472.L	English Presentation Skills A (Computing)	2-0-0	C1M	E	
	MCS.U571.L	Internship B (Computing)	0-0-2	C0M, C1M	D,E	

Credits in Career Development Courses must be attained from among the above-listed courses and those listed as such in the Liberal Arts and Basic Science Courses Guide.

＊GA: Graduate Attributes

8. Research Related to the Completion of Master Theses

・A relevant research time line is shown in the following diagram.



・Criteria for thesis examination

Master's thesis should include new knowledge in the fields of mathematical science and computer science or useful knowledge contributing to developments of those fields. Each student should write his or her thesis by him- or herself and the thesis should contain his or her original ideas.

・Procedure for thesis examination

The examination committee is comprised of 3 or more referees. After the peer review by the referees done in advance, an oral presentation is made and a final examination and evaluation are performed. Examinations of candidates for the doctor’s program are performed by 5 referees.

【Doctoral Degree Program】

1. Outline

We develop talent who can deepen and start their own research based on a firm understanding and knowledge of mathematical science and computer science, and who have the research skills to propose and lead new approaches for solving various problems of modern society, as well as capable talent who open and drive forward new frontiers of science and technology as leaders who can succeed internationally in research institutes and companies.

2. Competencies Developed

After completing the program, students will acquire the following competencies:

- The advanced insight and broad, systematic knowledge of an expert in mathematical science and computer science
- The flexible and diverse ideas, inquisitive spirit, and originality to continuously deepen and expand research topics
- The creativity to pioneer and promote new research topics
- The daring spirit to propose solutions to problems beleaguering our information society through research, and the high, professional ethical values to contribute to society
- The ability to publish one's own research findings in the forms of academic papers, conference presentations, and participation in various competitions, as well as the ability to compose papers and present and argue one's findings convincingly

3. Learning Goals

The doctoral degree program provides a curriculum to acquire the “Competencies Developed” mentioned above based on the competencies developed in the master’s degree program. Through the curriculum, students are expected to:

A) Deepen their understanding of mathematical structures in practical problems and computer-aided approaches for mathematical researches.

B) Obtain ability to construct advanced mathematical models to analyze various problems and design methods to solve them

C) Enhance knowledge and expertise in computer science, including mathematical logic, algorithm, theory of computation, computer architecture, and software systems

D) Cultivate wide scopes and study proactively:

Acquire skills to study proactively through discussion with advisors and communications with domestic and international researchers and to launch a new research project.

E) Enhance communication skills:

Acquire writing abilities to compose the doctoral thesis and develop abundant abilities for presentations through communication with international researchers and presentation at seminars and conferences.

4. IGP Completion Requirements

The following requirements must be met to complete the Doctoral Degree Program of this major.

1. Attain a total of 24 credits or more from 600-level courses.
2. A minimum of six credits acquired from 600-level Liberal Arts and Basic Science Courses (Two credits from Humanities and Social Science Courses and four credits from Career Development Courses).
3. From the courses specified in the Graduate Major in Mathematical and Computing Science curriculum, 12 credits acquired from 600-level Research Seminars.
4. Pass the doctoral dissertation review and defense.

Table D1 shows course categories and the number of credits required to complete the Doctoral Degree Program of this major. It also shows the required minimum credits in each course category and points to be noted when selecting the required courses and electives.

The learning goals to be obtained by students through courses are listed as “associated learning goals”. Prior to registering courses, students need to fully understand the course goals.

Table D1. Graduate Major in Mathematical and Computing Science Completion Requirements

Course category		<Required courses> Required credits	<Electives> Minimum credits required	Minimum credits required	Associated learning goals	Comments
Liberal arts and basic science courses	Humanities and social science courses		2 credits	6 credits	D	
	Career development courses		4 credits		D,E	All Graduate Attributes (GA) should be acquired. (Refer to Section 7 for the definition of GA.)
	Other courses					
Core courses	Research seminars	Seminar on Mathematical and Computing Science S3 Seminar on Mathematical and Computing Science F3 Seminar on Mathematical and Computing Science S4 Seminar on Mathematical and Computing Science F4 Seminar on Mathematical and Computing Science S5 Seminar on Mathematical and Computing Science F5 A total of 12 credits, 2 credits each from the above courses.		12 credits	A,B,C,D,E	
	Research-related courses					
	Major courses					
	Major Courses and Research-related courses <u>outside</u> the Graduate Major in Mathematical and Computing Science					

	standard curriculum					
Total required credits		**A minimum of 24 credits including those attained according to the above conditions**				
Note		**・Japanese Language and Culture Courses offered to international students can be recognized as equivalent to the Humanities and Social Science Courses of the corresponding course level.** **・For details of the Liberal Arts and Basic Science Courses, please refer to the relevant sections.**				

5. IGP Courses

Table D2 shows the Core Courses of the Doctoral Degree Program of this major. Graduate Majors listed in the Comments column offer core courses that are recognized as equivalent to the corresponding Major Courses or Research-related Courses in the standard curriculum of this major.

Table D2. Core Courses of the Graduate Major in Mathematical and Computing Science

Course category		**Course number**			**Course title**	**Credits**	**Competencies**	**Learning goals**	**Comments**
Research seminars	**600 level**	MCS.Z691.R	◎		Seminar on Mathematical and Computing Science S3	0-2-0	1,2,3,4,5	A,B,C,D,E	
		MCS.Z692.R	◎		Seminar on Mathematical and Computing Science F3	0-2-0	1,2,3,4,5	A,B,C,D,E	
		MCS.Z693.R	◎		Seminar on Mathematical and Computing Science S4	0-2-0	1,2,3,4,5	A,B,C,D,E	
		MCS.Z694.R	◎		Seminar on Mathematical and Computing Science F4	0-2-0	1,2,3,4,5	A,B,C,D,E	
		MCS.Z695.R	◎		Seminar on Mathematical and Computing Science S5	0-2-0	1,2,3,4,5	A,B,C,D,E	
		MCS.Z696.R	◎		Seminar on Mathematical and Computing Science F5	0-2-0	1,2,3,4,5	A,B,C,D,E	
Research-related courses	**600 level**	MCS.U671.L			Internship C (Computing)	0-0-2	2,4,5	D,E	【School of Computing】(XCO.U671)
		MCS.U672.L			English Presentation Skills B (Computing)	2-0-0	2	E	【School of Computing】(XCO.U672)
		MCS.U681.L			Forum on Mathematical and Computing Science S3	0-0-1	1,2,4,5	A,B,C,D,E	
		MCS.U682.L			Forum on Mathematical and Computing Science F3	0-0-1	1,2,4,5	A,B,C,D,E	

		MCS.U683.L			Forum on Mathematical and Computing Science S4	0-0-1	1,2,4,5	A,B,C,D,E	
		MCS.U684.L			Forum on Mathematical and Computing Science F4	0-0-1	1,2,4,5	A,B,C,D,E	
		MCS.U685.L			Forum on Mathematical and Computing Science S5	0-0-1	1,2,4,5	A,B,C,D,E	
		MCS.U686.L			Forum on Mathematical and Computing Science F5	0-0-1	1,2,4,5	A,B,C,D,E	
Major courses	**600 level**	MCS.T601.L			Presentation Exercises on Mathematical and Computing Science I	0-1-0	1,2,3	D,E	
		MCS.T602.L			Presentation Exercises on Mathematical and Computing Science II	0-1-0	1,2,3	D,E	
		MCS.T603.L			Tutorial Exercises on Mathematical and Computing Science I	0-1-0	1,2,3	D,E	
		MCS.T604.L			Tutorial Exercises on Mathematical and Computing Science II	0-1-0	1,2,3	D,E	
		MCS.T673.L			Advanced Topics in Computing C	2-0-0	1,2,3	A,B,C,D,E	【School of Computing】(XCO.T673)
		MCS.T674.L			Advanced Topics in Computing D	2-0-0	1,2,3	A,B,C,D,E	【School of Computing】(XCO.T674)

Note：

• ◎：Required course，O：odd academic years，E：even academic years

• Competencies: 1 = Intercultural skills; 2 = Communication skills; 3 = Specialist skills; 4 = Critical thinking skills; 5 = Practical and/or problem-solving skills

•【 】Course offered by another graduate major

6. IGP Courses That Can Be Counted as Humanities and Social Science Courses

None

7. IGP Courses That Can Be Counted as Career Development Courses

In order to fulfill the completion requirements for the doctoral degree program, students must attain at least 4 credits in Career Development Courses, and should satisfy all of the Graduate Attributes (GA) specified in Table A-1 or A-2 of the "Career Development Courses" (Liberal Arts and Basic Science Courses) in the Guide to Graduate Education and International Graduate Program. Students will be evaluated in regards to GA achievements at the time of their degree completion. As to the courses with more than one GA, the number of GA stipulated for the courses is considered to be acquired regardless of the credits received for the courses.

Major Courses that enable students to acquire GA and that are recognized as equivalent to Career Development Courses are listed in Tables D3-1 and D3-2 below.

However, it must be noted that credits attained from these courses cannot be counted more than once as Major Courses or Career Development Courses towards the completion requirements for the doctoral degree program.

For Graduate Attributes, refer to the Guide to the Career Development Courses.
The Graduate Attributes of the Academic Leader Program (ALP) are listed in Table A-1 as follows:

A0D: You will be able to precisely draw your own career plan and self-train yourself to acquire the skills required for attaining your goals in the academic field

A1D: You will be able to ascertain the true nature of phenomena, master the secret of learning, and lead the pioneering of a new academic discipline or research area

A2D: You will be able to understand the position of academia in society, and adequately explain the academic progress to members of society, which is the stakeholder

A3D: You will be able to nurture junior students in educational institutions, inculcating in them an interest in academics and enabling them to later join in the pioneering of new academic disciplines or research areas

The Graduate Attributes of the Productive Leader Program (PLP) are listed in Table A-2 as follows:

P0D: You will be able to precisely draw your own career plan and self-train yourself to acquire the skills required for attaining your goals in the industry, etc.

P1D: You will be able to precisely grasp the needs of society and detect its problems, and lead the future developments in science and technology

P2D: While leading teams consisting of members with varied specialties and value systems, you will be able to create products and enterprises that bring forth new values in the society

P3D: Through the project, you will be able to nurture junior students, enabling them to later join in the development of next generation society and industry

Table D3-1. Courses of the Graduate Major in Mathematical and Computing Science recognized as equivalent to Career Development Courses in the Academic Leader Program (ALP)

Course category	Course number	Course title			Credits	GA*	Learning goals	Comments
Courses that can be counted as Career Development Courses	MCS.U671.L			Internship C (Computing)	0-0-2	A1D, A2D, A3D	D,E	
	MCS.U672.L			English Presentation Skills B (Computing)	2-0-0	A2D, A3D	E	
	MCS.U681.L			Forum on Mathematical and Computing Science S3	0-0-1	A0D, A1D, A2D	A,B,C,D,E	
	MCS.U682.L			Forum on Mathematical and Computing Science F3	0-0-1	A1D, A2D, A3D	A,B,C,D,E	

	MCS.U683.L			Forum on Mathematical and Computing Science S4	0-0-1	A0D, A1D, A2D	A,B,C,D,E	
	MCS.U684.L			Forum on Mathematical and Computing Science F4	0-0-1	A1D, A2D, A3D	A,B,C,D,E	
	MCS.U685.L			Forum on Mathematical and Computing Science S5	0-0-1	A0D, A1D, A2D	A,B,C,D,E	
	MCS.U686.L			Forum on Mathematical and Computing Science F5	0-0-1	A1D, A2D, A3D	A,B,C,D,E	
Credits in Career Development Courses must be attained from among the above-listed courses and those listed as such in the Liberal Arts and Basic Science Courses Guide. **＊GA: Graduate Attributes**								

Table D3-2. Courses of the Graduate Major in Mathematical and Computing Science recognized as equivalent to Career Development Courses in the Productive Leader Program (PLP)

Course category	Course number	Course title			Credits	GA*	Learning goals	Comments
Courses that can be counted as Career Development Courses	MCS.U671.L			Internship C (Computing)	0-0-2	P1D, P2D, P3D	D,E	
	MCS.U672.L			English Presentation Skills B (Computing)	2-0-0	P2D, P3D	E	
	MCS.U681.L			Forum on Mathematical and Computing Science S3	0-0-1	P0D, P1D, P2D	A,B,C,D,E	
	MCS.U682.L			Forum on Mathematical and Computing Science F3	0-0-1	P1D, P2D, P3D	A,B,C,D,E	
	MCS.U683.L			Forum on Mathematical and Computing Science S4	0-0-1	P0D, P1D, P2D	A,B,C,D,E	
	MCS.U684.L			Forum on Mathematical and Computing Science F4	0-0-1	P1D, P2D,	A,B,C,D,E	

						P3D		
	MCS.U685.L			Forum on Mathematical and Computing Science S5	0-0-1	P0D, P1D, P2D	A,B,C,D,E	
	MCS.U686.L			Forum on Mathematical and Computing Science F5	0-0-1	P1D, P2D, P3D	A,B,C,D,E	
Credits in Career Development Courses must be attained from among the above-listed courses and those listed as such in the Liberal Arts and Basic Science Courses Guide. **＊GA: Graduate Attributes**								

Students enrolled in the educational program for leading graduate schools or in the Tokyo Tech Academy for Leadership (ToTAL) may be offered courses recognized as equivalent to Career Development Courses besides those listed as such in the "Liberal Arts and Basic Science Courses" in the Guide to Graduate Education and International Graduate Program. For details about available courses or completion requirements, please refer to the Study Guide of the Academy that offers the relevant program.

8. Research Related to the Completion of Doctoral Theses

・Criteria for thesis examination

Doctoral thesis must contain novelty, originality, and enough academic contribution in the field of mathematical science and computer science. The thesis must be published or contain enough contribution to be published in an international-level journal or elsewhere.

・Procedure for thesis examination

The examination committee is comprised of 5 or more referees, preferably including external referees from other universities and research institutes. After passing an interim evaluation and a preliminary thesis examination, a student must submit his or her thesis and give oral presentation. After the peer review by the referees done in advance, a final examination and evaluation are performed. In the final examination, the committee assesses knowledge and understanding on the research field by asking the examinee to explain related works.