CHED MEMORANDUM ORDER
No. 48
Series of 2017

SUBJECT: POLICIES, STANDARDS AND GUIDELINES FOR THE BACHELOR OF SCIENCE IN MATHEMATICS (BS MATH) AND BACHELOR OF SCIENCE IN APPLIED MATHEMATICS (BS APPLIED MATH) PROGRAMS

In accordance with the pertinent provisions of Republic Act (RA) No. 7722 otherwise known as the "Higher Education Act of 1994", in pursuance of an outcomes-based quality assurance system as advocated under CMO No. 46, series of 2012, in light of the addition of two years to basic education as provided by Republic Act (RA) 10533 otherwise known as the "Enhanced Basic Education Act of 2013", in view of the new General Education Curriculum, promulgated under CMO 20 s. 2013, and for the purpose of rationalizing mathematics education in the country by virtue of Commission en banc Resolution No. 231-2017 dated March 28, 2017, the following policies, standards and guidelines, revising CMO No. 19, series of 2007, are hereby adopted and promulgated by the Commission.

ARTICLE I
INTRODUCTION

Section 1. Rationale

Based on the Guidelines for the Implementation of CMO No. 46, series of 2012, this PSG implements the "shift to learning competency-based standards/outcomes-based education." It specifies the 'core competencies' expected of BS Mathematics and BS Applied Mathematics graduates "regardless of the type of HEI they graduate from." However, in "recognition of the spirit of outcomes-based education and...of the typology of HEIs," this PSG also provides "ample space for HEIs to innovate in the curriculum in line with the assessment of how best to achieve learning outcomes in their particular contexts and their respective missions."

Specifically, CHED strongly advocates a shift from a teaching- or instruction-centered paradigm in higher education to one that is learner- or student-centered, within a lifelong learning framework. The learner- or student-centered paradigm shifts from a more input-oriented curricular design based on the description of course content, to outcomes-based education in which the course content is developed in terms of learning outcomes. In this paradigm, students are made aware of what they ought to know, understand and be able to do after completing a unit of study. Teaching and assessment are subsequently geared towards the acquisition of appropriate knowledge and skills and the building of student competencies.

On the other hand, teachers remain crucial to the learning process as catalyst and facilitators of learning. Learning environment such as laboratories, facilities, libraries, shape the learning experience of students and are deemed important since a good environment will enable the development and assessment of student learning competencies. The development and acquisition of the target learning competencies is the expected outcome of each academic program.

Revisions to the basic education curriculum (RA 10533), specifically the addition of senior high school (Grades 11 and 12), and the approval of the new CHED General Education Curriculum (CMO No. 20 s. 2013) necessitate additional revisions to the current Policies, Standards, and Guidelines for the BS Mathematics and BS Applied Mathematics curricula.

This document shall serve as a guide and standard for the transformation of the current Bachelor of Science in Mathematics (BS Math) and Bachelor of Science in Applied Mathematics (BS Applied Math) curricula (CMO No. 19 s. 2007) towards a learner- or student-centered approach, incorporating the provisions of the new General Education curriculum. The revised curricula take into account the College Readiness Standards prepared by the CHED for General Education and approved by the Commission en banc on 28 October 2011.

Each higher education institution (HEI) shall be given ample space to innovate the curriculum in line with their assessment of how best to achieve the set learning outcomes in their particular contexts and their respective missions. The main objective for each of the HEIs is the achievement of learning outcomes through different strategies.

ARTICLE II
AUTHORITY TO OPERATE

Section 2. Government Authority

All private higher education institutions (PHEIs) intending to offer Bachelor of Science in Mathematics (BS Math) and Bachelor of Science in Applied Mathematics (BS Applied Math) must first secure proper authority from the Commission in accordance with this PSG. All PHEIs with existing BS Math and BS Applied Math program are required to shift to an outcomes-based approach. State universities and colleges (SUCs), and local colleges and universities (LUCs) should likewise strictly adhere to the provisions in these policies and standards.

ARTICLE III
GENERAL PROVISIONS

Per Section 13 of R.A. 7722, the higher education institutions shall exercise academic freedom in its curricular offerings but must comply with the minimum requirements for specific academic programs, the general education distribution requirements and the specific professional courses.

Section 3. The Articles that follow give minimum standards and other requirements and prescriptions. The minimum standards are expressed as a minimum set of desired program outcomes that are given in Article IV, Section 6. The Commission designed a sample curriculum to attain such outcomes. This curriculum is shown in Article V, Section 9. The number of units of this curriculum is herein prescribed as the "minimum unit requirement" under Section 13 of RA 7722. In designing the curriculum the Commission employed curriculum mapping. Annex A exhibits a sample curriculum map.

Using a learner-centered/outcomes-based approach the Commission also determined appropriate curriculum delivery methods shown in Article V, Section 11. The sample course syllabi given in Article V, Section 12 show some of these methods.

Based on the curriculum and the means of its delivery, the Commission determined the physical resource requirements for the library, laboratories and other facilities and the human resource requirements in terms of administration and faculty. See Article VI.

Section 4. The HEIs are allowed to design curricula suited to their own contexts and missions provided that they can demonstrate that the same leads to the attainment of the required minimum set of outcomes. In the same vein, they have latitude in terms of curriculum delivery and in terms of specification and deployment of human and physical resources as long as they can show that the attainment of the program outcomes and satisfaction of program educational objectives can be assured by the alternative means they propose.

The HEIs can use the CHED Implementation Handbook for Outcomes-Based Education (OBE) and the Institutional Sustainability Assessment (ISA) as a guide in making their submissions. See Article VII, Section 19.

ARTICLE IV
PROGRAM SPECIFICATIONS

Section 5. Program Description

5.1 Degree Name

The degree program described herein shall be called Bachelor of Science in Mathematics (BS Math) or Bachelor of Science in Applied Mathematics (BS Applied Math).

5.2 Nature of the Field of Study

Mathematics is often described as the science of patterns. Mathematicians seek to discover, analyze and classify patterns in both abstract objects and natural phenomena. The traditional domains of study are quantity (arithmetic), structure (algebra), space (geometry) and change (analysis). Mathematics offers distinctive and powerful modes of thought such as abstraction, generalization, deduction, inference, use of symbols and the axiomatic method. Mathematical truth is established through logical analysis and proof. As a universal discipline it is rich in both theory and applications.

Mathematics is used as an essential tool in many fields, including the natural sciences, engineering, medicine, finance and the social sciences. Apart from being the language of the physical sciences, mathematics shares much in common with the former, notably in the exploration of logical consequences of assumptions. Mathematics is also regarded as an art, having an aesthetic and creative side. The special role of mathematics in education (being part of the curricula from primary school to college) is a consequence of its foundational nature and universal applicability.

Mathematicians engage in pure mathematics or mathematics for its own sake, without having, at least initially or intentionally, application or utility in mind. Applied mathematics, on the other hand, is the branch of mathematics concerned with application of mathematical theories and methods to other fields. Applied mathematicians are academics, researchers, or professionals who work on practical problems, often involving the formulation, analysis, and use of mathematical models. In turn, their work inspires and motivates new mathematical discoveries that may lead to the development of new mathematical disciplines, as in the case of operations research or game theory, or mathematics-based disciplines, such as statistics and finance. There is no clear line separating pure and applied mathematics.

5.3 Trends and Developments in Mathematics in the 21st Century

The legacy of classical mathematical theory, discovery of modern mathematical theories and techniques, and emergence of efficient computing methods, robust symbolic mathematical software and powerful computers, have broadened the landscape of mathematics and have led to many advancements in mathematics and science in general.

Mathematical theories and techniques have become essential in many areas, notably finance and the life sciences. Experimental and computational mathematics continue to grow in importance within mathematics. Computation, simulation and visualization are playing increasing roles in both science and mathematics. The overlap between applied mathematics and statistics and other decision sciences has become more significant, especially with the recognition of the stochastic nature of varied phenomena. Mathematical models and quantitative methods are increasingly being used in many fields, and new and powerful models are needed to address global problems and issues like climate change, disaster mitigation, risk management, food, water, and population.

5.4 Program Goals

The BS Math/ Applied Math graduates shall be equipped with enhanced mathematical and critical thinking skills. Graduates are expected to have developed deeper appreciation and understanding of the importance of mathematics in history and the modern world. They will be able do research or perform jobs that require analytical thinking and quantitative skills.

The program provides students with substantial exposure to the breadth and depth of mathematics, from classical to contemporary, and from theoretical to applied. The curriculum covers foundational courses in core areas of mathematics/applied mathematics as well as advanced courses that will help prepare graduates to pursue higher studies or work in a variety of fields.

5.5 Professions/careers/occupations for BS Math/ Applied Math graduates

Graduates of BS Math/ Applied Math often obtain jobs in education (teaching high school math courses or tertiary level elementary/service courses), statistics, actuarial science, operations research, risk management, business and economics, banking and finance, and computing and information technology.

5.6 Allied Fields

Mathematics/ applied mathematics is closely related to the fields of statistics, physics, computer science, and engineering.

Section 6. Program Outcomes

The minimum standards for the Bachelor of Science in Mathematics/ Bachelor of Science in Applied Mathematics program are expressed in the following minimum set of learning outcomes:

6.1 Common to all baccalaureate programs in all types of institutions

The graduates have the ability to:

a) Articulate the latest developments in their specific field of practice. (PQF level 6 descriptor)

b) Effectively communicate orally and in writing using both English and Filipino languages.
c) Work effectively and independently in multi-disciplinary and multi-cultural teams. (PQF level 6 descriptor)
d) Demonstrate professional, social, and ethical responsibility, especially in practicing intellectual property rights and sustainable development.
e) Preserve and promote *"Filipino historical and cultural heritage"*(based on RA 7722).

6.2 Common to the Science and Mathematics Discipline

f) Demonstrate broad and coherent knowledge and understanding in the core areas of physical and natural sciences.
g) Apply critical and problem solving skills using the scientific method.
h) Interpret relevant scientific data and make judgments that include reflection on relevant scientific and ethical issues.
i) Carry out basic mathematical and statistical computations and use appropriate technologies in the analysis of data.
j) Communicate information, ideas problems and solutions, both, orally and in writing, to other scientists, decision makers and the public.
k) Relate science and mathematics to the other disciplines.
l) Design and perform safe and responsible techniques and procedures in laboratory or field practices.
m) Critically evaluate input from others.
n) Appreciate the limitations and implications of science in everyday life.
o) Commit to the integrity of data.

6.3 Specific to BS Math/ BS Applied Math

p) Gain mastery in the core areas of mathematics: algebra, analysis, and geometry.
q) Demonstrate skills in pattern recognition, generalization, abstraction, critical analysis, synthesis, problem-solving and rigorous argument.
r) Develop an enhanced perception of the vitality and importance of mathematics in the modern world including inter-relationships within math and its connection to other disciplines.
s) Appreciate the concept and role of proof and reasoning and demonstrate knowledge in reading and writing mathematical proofs.
t) Make and evaluate mathematical conjectures and arguments and validate their own mathematical thinking.
u) Communicate mathematical ideas orally and in writing using clear and precise language.

6.4 Common to a horizontal type as defined in CMO No. 46, series of 2012

- For professional institutions: a service orientation in one's profession
- For colleges: an ability to participate in various types of employment, development activities, and public discourses particularly in response to the needs of the communities one serves
- For universities: an ability to participate in the generation of new knowledge or in research and development projects

Graduates of state universities and colleges must, in addition, have the competencies to support "national, regional and local development plans" (RA 7722).

The HEIs, at its option, may adopt mission-related program outcomes that are not included in the minimum set.

Section 7. Sample Performance Indicators

Performance indicators (PIs) assist in the evaluation of student learning or the achievement of the program outcomes. These are demonstrable traits developed not only through the core or discipline-specific courses but also more importantly through their collective experiences.

To achieve the program outcomes, graduates of the BS Mathematics/ BS Applied Mathematics program are expected to possess a wide range of knowledge, values and skills. The performance indicators presented even for the baccalaureate and science and mathematics graduates are evaluated in the context of a BS Mathematics/ BS Applied Mathematics graduate.

Graduates of all Baccalaureate Programs

Program Outcomes	Performance Indicators
a) Articulate the latest developments in their specific field of practice.	• Participate in continuing education and professional development in the specific field of practice.
b) Effectively communicate orally and in writing using both the English/Filipino language.	• Demonstrate effective oral and written communication using both English and Filipino languages. • Exhibit adequate technical writing and oral communication abilities.
c) Work effectively in multi-disciplinary and multi-cultural teams.	• Work effectively as a member of multi-disciplinary and multi-cultural teams. • Display good judgment of people, actions and ideas and communicate them efficiently. • Demonstrate effective leadership, coordination and decision-making skills. • Demonstrate productive project management skills.
d) Demonstrate professional, social, and ethical responsibility, especially in practicing intellectual property rights.	• Articulate the contribution of one's profession to society and nation building. • Articulate the responsibilities of a Filipino citizen in relation to the rest of the world. • Demonstrate respect for intellectual property rights. • Explain professional knowledge and ethical responsibilities.
e) Preserve and promote Filipino historical and cultural heritage based on RA 7722.	• Articulate one's possible contributions to society and nation building.

Graduates of Science and Mathematics Programs

Program Outcomes	Performance Indicators
f) Demonstrate broad and coherent knowledge and understanding in the core areas of the physical and natural sciences and mathematics.	• Discuss extensively and articulate information in the core areas of science and mathematics.
g) Apply critical and problem solving skills using the scientific method.	• Employ problem-solving skills using the scientific method. • Demonstrate critical thinking skills in solving problems. • Apply scientific reasoning.
h) Interpret scientific data and reflect on relevant scientific and ethical issues.	• Recognize the importance of relevant scientific data. • Summarize information using reflection on important scientific and ethical issues.
i) Carry out basic mathematical and statistical computations and use appropriate technologies in the analysis of data.	• Perform appropriate suitable mathematical and statistical computations in data analysis.
j) Communicate information, ideas problems and solutions both, orally and in writing, to other scientists, decision makers and the public.	• Demonstrate technical writing and public speaking abilities. • Disseminate information, ideas, problems and solutions to fellow scientists, decision makers and the public. • Participate actively in scientific forum and public discussions.
k) Connect science and math to the other disciplines.	• Apply scientific advancements in ways that are meaningful to other disciplines. • Propose solutions to environmental problems based on interdisciplinary knowledge.
l) Design and perform techniques and procedures following safe and responsible laboratory or field practices.	• Practice responsible laboratory and field practices that follow proper techniques and procedures. • Demonstrate precision in making observations and in distinguishing differences between samples and events. • Employ appropriate and correct experimental design. • Follow industry standards and national laws.
m) Accepts and critically evaluates input from others.	• Discern significant inputs from other disciplines. • Critically evaluate data and information.
n) Appreciate the limitations and implications of science in everyday life.	• Acknowledge scientific facts as part of everyday life.
o) Commit to the integrity of data.	• Adhere to data integrity. • Report results and data as honestly as possible.

Graduates of BS Mathematics/ Applied Mathematics

Program Outcomes	Performance Indicators
p) Gain mastery in the core areas of mathematics: algebra, analysis, and geometry.	• Undertake an independent study of an unfamiliar topic and present an accurate and in-depth discussion of the results of the investigation both orally and in writing. • Represent a given problem by a mathematical model and use this to obtain a solution to the given problem.
q) Demonstrate skills in pattern recognition, generalization, abstraction, critical analysis, synthesis, problem-solving and rigorous argument.	• Apply the appropriate techniques in solving mathematical problems. • Break down a complicated problem into simpler parts • Adapt known methods and tools in solving new problems.
r) Develop and enhance perception of the vitality and importance of mathematics in the modern world including inter-relationship within math and its connection to other disciplines.	• Discuss the mathematical concepts behind well-known solutions to real-life problems. • Discuss important breakthroughs in the solution of real-world problems where mathematics played a significant role.
s) Appreciate the concept and role of proof and reasoning and demonstrate knowledge in reading and writing mathematical proofs.	• Submit a paper or thesis that contains proofs of mathematical statements based on rules of logic. • Assess the validity of the mathematical reasoning in the works of others and identify errors and gaps, if any.
t) Make and evaluate mathematical conjectures and arguments and validate their own mathematical thinking.	• Given a true mathematical statement, questions and investigates truth of the converse or inverse statements. • Able to propose conjectures, investigate their truth or falsity, and write rigorous proofs of the investigation. • Given a survey, expository or research paper, is able to recreate proofs and arguments contained in the paper, provide examples or give illustrations, and propose generalizations of results.
u) Communicate mathematical ideas orally and in writing using clear and precise language.	• Able to prepare a well-written research paper (thesis or special project paper) that organizes and presents a body of mathematics in a detailed, interesting and original manner. • Able to give an oral presentation of results of the research paper before peers and teachers.

ARTICLE V
CURRICULUM

Section 8. Curriculum Description

The curriculum for the BS Math/BS Applied Math program is built around a traditional base of foundational and core courses in the major areas of mathematics and applied mathematics with the inclusion of specialized courses in mathematics, applied mathematics, relevant disciplines, and emerging areas.

Since the mathematics department of different schools will have their particular strengths and orientation, there is a provision for elective courses that will allow for flexibility and accommodate the department's special interests. HEIs may offer courses beyond those specified in the recommended courses, according to their faculty expertise, institutional resources, and thrusts.

A BS Mathematics/ BS Applied Mathematics program offering a minor or specialization must include at least 15 units of relevant courses and electives for the specific area of specialization. Minors or specializations may include actuarial science, computing, operations research or statistics, among others. HEIs offering minors or specializations must possess the necessary faculty resources and facilities.

Based on the guidelines of the Mathematical Association of America's Committee on Undergraduate Programs in Mathematics, the following recommendations are given for designing the curricula for the BS Mathematics and BS Applied Mathematics programs:

8.1 Develop mathematical thinking and communication skills

Courses designed for mathematics/applied mathematics majors should ensure that students:

- Progress from a procedural/computational understanding of mathematics to a broad understanding encompassing logical reasoning, generalization, abstraction, and formal proof;
- Gain experience in careful analysis of data;
- Become skilled at conveying their mathematical knowledge in a variety of settings, both orally and in writing.

8.2 Provide a broad view of the mathematical sciences

All majors should have significant experience working with ideas representing the breadth of the mathematical sciences. In particular, students should see a number of contrasting but complementary points of view:

- Continuous and discrete;
- Algebraic and geometric;
- Deterministic and stochastic; and
- Theoretical and applied.

Majors should understand that mathematics is an engaging field, rich in beauty, with powerful applications to other subjects, and a wide range of contemporary open questions.

8.3 Require study in depth

All majors should be required to:

- Study a single area in depth, drawing on ideas and tools from previous coursework and making connections, by completing two related courses or a year-long sequence at the upper level;
- Work on a senior-level project that requires them to analyze and create mathematical arguments and leads to a written and an oral report.

8.4 Develop skill with a variety of technological tools

All majors should have experiences with a variety of technological tools, such as computer algebra systems, visualization software, statistical packages, and computer programming languages

Section 9. Sample Curricula

9.1 Curriculum Components

The components of the BS Math/ Applied Math curriculum are listed in Table 1a and 1b together with the **minimum** number of units in each component.

Table 1a. Components of the BS Math curriculum and their corresponding units.

COMPONENTS	UNITS
a. General Education Curriculum	36
b. Core Courses	51
c. Non-math Foundational Courses	10
d. Electives	
Math Electives	9
Qualified Electives/Cognates	6
Free Electives	6
e. Thesis/Special Problem	3
f. Physical Education (PE)	8
g. National Service Training Program (NSTP)	6
Total	**135**

May also be chosen from the list of math electives with approval of program adviser.

+Any academic course in any discipline freely chosen by the student.

Table 1b. Components of the BS Applied Math curriculum and their corresponding units.

COMPONENTS	UNITS
a. General Education Curriculum	36
b. Core Courses	51
c. Non-math Foundational Courses	10
d. Electives	
Math Electives Qualified Electives/Cognates* Free Elective+	9 6 6
e. Thesis/Special Problem	3
h. Physical Education (PE)	8
i. National Service Training Program (NSTP)	6
Total	**135**

**May also be chosen from the list of math electives with approval of program adviser.*

+Any academic course in any discipline freely chosen by the student.

a. General Education (GE) Courses

CHED Memorandum Order No. 20 series of 2013 prescribes the set of courses comprising the General Education Program, consisting of eight (8) required core courses, three (3) GE elective courses and the legislated course on the Life and Works of Rizal. The list of GE courses is given in Table 2a and a suggested sequence is given in Table 2b. The GE courses may be taught in English or Filipino.

GE electives are courses that conform to the philosophy and goals of General Education as contained in CMO No 20, s. 2013. Each elective course must apply an inter- or cross-disciplinary perspective and draw materials, cases or examples from Philippine realities and experiences. The electives must cover at least any two domains. For BS Mathematics and BS Applied Mathematics students, at least one GE elective must come from the Math, Science and Technology domain.

Table 2a. The GE courses and their corresponding units.

	Domain	**Required Courses**	Units
1	Social Sciences and Philosophy	Understanding the Self/ *Pag-unawa sa Sarili*	3
2		Readings in Philippine History/ *Mga Babasahin hinggil sa Kasaysayan ng Pilipinas*	3
3		The Contemporary World/ *Ang Kasalukuyang Daigdig*	3
4		Ethics/Etika	3
5	Math, Science and Technology	Mathematics in the Modern World/ *Matematika sa Makabagong Daigdig*	3
6		Science, Technology, and Society/ *Agham, Teknolohiya, at Lipunan*	3
7	Arts and Humanities	Purposive Communication/ *Malayuning Komunikasyon*	3
8		Art Appreciation/ *Pagpapahalaga sa Sining*	3
		Mandated Course	
9		Life and Works of Rizal / *Buhay at mga Likha ni Rizal*	3

		Elective GE Courses	
10	GE Electives*	GE Elective 1	3
11		GE Elective 2	3
12		GE Elective 3	3
		TOTAL	**36**

**To be taken from at least two domains; one GE elective should be an MST course. Remedial courses (such as algebra and trigonometry) cannot be credited as part of the GE or program electives.*

Table 2b. Suggested sequence of GE courses and mandated Rizal course.

	1st Semester	2nd Semester
Year 1	Mathematics in the Modern World	Readings in Philippine History
	Purposive Communication	Art Appreciation
	GE Elective 1	Understanding the Self
Year 2	GE Elective 2	Ethics
Year 3	The Contemporary World	Life and Works of Rizal
Year 4	Science, Technology, and Society	GE Elective 3

b. Core Courses (51 units)

The following core courses found in Tables 3a and 3b comprise the minimum requirements of the BS Math and BS Applied Math programs.

Table 3a. Core courses for the BS Mathematics program.

PROGRAM: BS MATHEMATICS	
DESCRIPTIVE TITLE	UNITS
a. Abstract Algebra I	3
b. Advanced Calculus I	3
c. Advanced Course in Analysis or Algebra+	3
d. Calculus I, II, III *	12 (4,4,4)
e. Complex Analysis	3
f. Differential Equations I	3
g. Fundamental Concepts of Mathematics	3
h. Fundamentals of Computing I	3
i. Linear Algebra	3
j. Modern Geometry	3
k. Numerical Analysis or Mathematical Modeling	3
l. Probability	3
m. Statistical Theory	3
n. Topology or Elementary Number Theory	3
TOTAL	**51**

+This course may be one of the following: Advanced Calculus II, Real Analysis, or Abstract Algebra II.

**Calculus I, II, III may be offered as a series of courses with a minimum 12 units provided all the topics in the recommended syllabi are covered.*

Table 3b. Core courses for the BS Applied Mathematics program.

PROGRAM: BS APPLIED MATHEMATICS	
DESCRIPTIVE TITLE	UNITS
a. Advanced Calculus I	3
b. Calculus I, II, III *	12 (4,4,4)
c. Differential Equations I	3
d. Discrete Mathematics	3
e. Fundamental Concepts of Mathematics	3
f. Fundamentals of Computing I	3
g. Fundamentals of Computing II	3
h. Linear Algebra	3
i. Mathematical Modeling	3
j. Numerical Analysis	3
k. Operations Research	3
l. Probability	3
m. Statistical Theory	3
n. Theory of Interest	3
TOTAL	**51**

** Calculus I, II, III may be offered as a series of courses with a minimum 12 units provided all the topics in the recommended syllabi are covered.*

c. Non-math Foundational Courses (10 units)

These refer to courses specific to a discipline outside mathematics that are not part of the general education program. HEIs may offer these courses to provide additional skills and foundation for advanced courses.

Table 4. List of non-math foundational courses

	Required Non-Math Foundational Courses	UNITS
1	General Physics I (Mechanics) with laboratory	4
2	Biology/General Chemistry I/General Physics II (with or without lab)	3
3	To be determined by HEI*	3
	TOTAL	**10**

**Such as additional/higher course in computing, statistics, communications, language, economics.*

d. Qualified Electives/Cognates (6 units)

Qualified electives or cognates are any academic courses offered in allied or relevant fields in the HEI chosen by a student and approved by the program adviser. Together with the math/applied math electives, these courses serve to incorporate a research focus or specialization to the student's program. In combination with or in lieu of qualified electives or cognates, the student, with approval of the program adviser may also choose from the list of math/applied math electives to satisfy this requirement. They comprise six (6) units of the curricula for the BS Math and BS Applied Math programs.

e. Mathematics Electives (9 units)

Electives may be chosen from the recommended list of math/applied math courses below (see Tables 5a and 5b).

Table 5a. List of recommended elective courses for the BS Math program.

PROGRAM: BS MATHEMATICS	
DESCRIPTIVE TITLE	UNITS
a. Abstract Algebra II	3
b. Actuarial Mathematics I	3
c. Actuarial Mathematics II	3
d. Advanced Calculus II	3
e. Algebraic Geometry	3
f. Differential Equations II	3
g. Differential Geometry	3
h. Discrete Mathematics	3
i. Dynamical Systems	3
j. Fundamentals of Computing II	3
k. Graph Theory and Applications	3
l. History and Development of Fundamental Ideas in Mathematics	3
m. Mathematical Biology	3
n. Mathematical Finance	3
o. Mathematical Modeling	3
p. Numerical Analysis	3
q. Operations Research I	3
r. Operations Research II	3
s. Partial Differential Equations	3
t. Projective Geometry	3
u. Real Analysis	3
v. Set Theory	3
w. Theory of Interest	3

Table 5b. List of recommended elective courses for the BS Applied Math program.

PROGRAM: BS APPLIED MATHEMATICS	
DESCRIPTIVE TITLE	UNITS
a. Actuarial Mathematics I	3
b. Actuarial Mathematics II	3
c. Applied Multivariate Analysis	3
d. Automata and Computability Theory	3
e. Computational Complexity	3
f. Convex Analysis	3
g. Data Structures and Algorithms	3
h. Differential Equations II	3
i. Dynamical Systems	3
j. Graph Theory and Applications	3
k. History and Development of Fundamental Ideas in Mathematics	3
l. Linear Models	3
m. Linear Programming	3
n. Mathematical Biology	3
o. Mathematical Finance	3
p. Nonlinear programming	3

q. Operations Research II	3
r. Partial Differential Equations	3
s. Real Analysis	3
t. Risk Theory	3
u. Sampling Theory	3
v. Simulation	3
w. Time Series Analysis	3
x. Theory of Databases	3

f. Free Electives (6 units)

Free electives are academic courses in any discipline offered in the HEI freely chosen by a student. They comprise six (6) units of the curricula for the BS Math and BS Applied Math programs.

g. Thesis or Special Problem (3 units)

Each student in the BS Mathematics or BS Applied Mathematics program is required to complete a 3-unit Thesis or Special Problem course. The course provides opportunities for students to conduct research on a mathematics topic that builds on areas covered by the core and elective courses.

The thesis/special problem involves activities that include independent reading from mathematical literature and other sources, as well as problem solving. The final paper should contain, organize and present a body of mathematics or a solution to a mathematical problem in a detailed, coherent and original manner.

9.2 Sample Program of Study

The sample program of study with the recommended sequence of courses is given in Tables 6a and 6b. Institutions may modify the curriculum to suit their particular requirements and thrusts. Certain courses may be offered during the summer.

Table 6a. Sample program of study for BS Math and recommended sequence of courses.

BS MATHEMATICS (135 units)								
	First Semester				**Second Semester**			
Year	**Descriptive Title**	**Units**			**Descriptive Title**	**Units**		
I								
	Calculus I	4		4	Calculus II	4		4
	Fundamentals of Computing 1	3		3	Fundamental Concepts of Math	3		3
	GE Course 1	3		3	GE Course 4	3		3
	GE Course 2	3		3	GE Course 5	3		3
	GE Course 3	3		3	GE Course 6	3		3
	PE I		2	0	PE II		2	0
	NSTP		3	0	NSTP		3	0
	Total	**16**	**5**	**21**	**Total**	**16**	**5**	**21**

BS MATHEMATICS (continued)								
Year	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
II								
	Calculus III	4		4	Advanced Calculus I	3		3
	Abstract Algebra I	3		3	Linear Algebra	3		3
	General Physics I Lec and Laboratory	3	1	4	Probability	3		3
	Non-math Foundational Course	3		3	Biology or General Physics II or General Chemistry I	3		3
	GE Course 7	3		3	GE Course 8	3		3
	PE III		2	2	PE IV		2	3
	Total	**16**	**3**	**19**	**Total**	**15**	**2**	**17**

Year	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
III								
	Advanced Course in Algebra or Analysis*	3		3	Modern Geometry	3		3
	Differential Equations I	3		3	Topology or Elementary Number Theory	3		3
	Math Elective 1	3		3	Numerical Analysis or Mathematical Modeling	3		3
	Statistical Theory	3		3	Math Elective 2	3		3
	GE Course 9	3		3	GE Course 10	3		3
	Total	**15**	**(0)**	**15**	**Total**	**15**	**(0)**	**15**

Year	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
IV								
	Complex Analysis	3		3	Qualified Elective / Cognate 2	3		3
	Math Elective 3	3		3	Free Elective 2	3		3
	Qualified Elective / Cognate 1	3		3	GE Course 12	3		3
	Free Elective 1	3		3	Thesis or Special Problem	3		3
	GE Course 11	3		3				
	Total	**15**	**(0)**	**15**	**Total**	**12**	**(0)**	**12**

**May be one of the following: Advanced Calculus II, Real Analysis, or Abstract Algebra II*

Note: GE courses include Life and Works of Rizal (mandated subject).

Table 6b. Sample program of study for BS Applied Math and recommended sequence.

BS APPLIED MATHEMATICS (135 units)								
Year	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
I	Calculus I	4		4	Calculus II	4		4
	Fundamentals of Computing 1	3		3	Fundamentals of Computing II	3		3
	GE Course 1	3		3	GE Course 4	3		3
	GE Course 2	3		3	GE Course 5	3		3
	GE Course 3	3		3	GE Course 6	3		3
	PE I		2	0	PE II		2	0
	NSTP		3	0	NSTP		3	0
	Total	**16**	**5**	**21**	**Total**	**16**	**5**	**21**
II	Calculus III	4		4	Differential Equations I	3		3
	Fundamental Concepts of Mathematics	3		3	Linear Algebra	3		3
	General Physics I Lec and Laboratory	3	1	4	Probability	3		3
	Non-math Foundational Course	3		3	Biology or General Physics II or General Chemistry I	3		3
	GE Course 7	3		3	GE Course 8	3		3
	PE III		2	0	PE IV		2	3
	Total	**16**	**3**	**19**	**Total**	**15**	**2**	**17**
III	Discrete Mathematics	3		3	Numerical Analysis	3		3
	Advanced Calculus I	3		3	Operations Research	3		3
	Math Elective 1	3		3	Theory of Interest	3		3
	Statistical Theory	3		3	Math Elective 2	3		3
	GE Course 9	3		3	GE Course 10	3		3
	Total	**15**	**(0)**	**15**	**Total**	**15**	**(0)**	**15**
IV	Mathematical Modeling	3		3	Qualified Elective / Cognate 2	3		3
	Math Elective 3	3		3	Free Elective 2	3		3
	Qualified Elective / Cognate 1	3		3	GE Course 12	3		3
	Free Elective 1	3		3	Thesis or Special Problem	3		3
	GE Course 11	3		3				
	Total	**15**	**(0)**	**15**	**Total**	**12**	**(0)**	**12**

**May be one of the following: Advanced Calculus II, Real Analysis, or Abstract Algebra II*

Note: GE courses include Life and Works of Rizal (mandated subject).
NSTP and PE courses are not included in the total number of units.

Section 10. Curriculum Map and Course Map

Based on the required minimum set of program outcomes, the CHED has determined a program of study that leads to the attainment of the outcomes. This program of study specifies a set of courses sequenced based on flow of content, with each course having a specified title, description, course outcome and credit unit. For this purpose, a sample curriculum map is included as part of the PSG. It is a matrix of all courses and the minimum set of program outcomes showing which outcome each course addresses and in what way. The map also determines whether the outcomes are aligned with the curriculum.

Higher education institutions shall formulate its curriculum map based on its own set of program outcomes and courses. A sample curriculum map is given in Annex A.

Section 11. Sample Means of Curriculum Delivery

A range of instructional methods can be employed that can also become means of assessing outcomes. These include lecture and discussion, problem-solving, individual or group reports, problem-sets, computing and programming exercises, computer simulations and visualization. Suggested teaching strategies and assessment activities are indicated in the course syllabus of each course.

Section 12. Sample Syllabi for Core Mathematics Courses

The course specifications provided in this CMO in Annex B apply only to the core courses and indicate the minimum topics to be covered in each area. The HEIs shall formulate the syllabus for all the courses in their respective BS Math/ Applied Math program.

HEIs may follow their own course specification s in the implementation of the program but must not be less than those specified for major courses.

ARTICLE VI
REQUIRED RESOURCES

Section 13. Administration

The minimum qualifications for the head of the unit offering the degree program are the following:

13.1 Dean of the college/unit

The dean of a college/unit must be at least a master's degree holder in any of the disciplines for which the unit/college offers a program; and a holder of a valid certificate of registration and professional license, where applicable.

13.2 Head of the mathematics department/unit

The head of the unit/department must be at least a master's degree holder in the discipline for which the unit/department offers a program or in an allied field (cf. Article IV Section 5.6).

Section 14. Faculty

14.1 Qualification of faculty

a. Faculty teaching in a BS Mathematics/ BS Applied Mathematics program must be at least a master's degree holder in mathematics or in an allied field (cf. Section 5.5).

b. All undergraduate mathematics courses in the recommended program of study for the BS Mathematics/ BS Applied Mathematics program starting from the 2nd year must be taught by at least an MS degree holder in Mathematics/ Applied Mathematics. Specialized courses in the program (e.g. actuarial science, computing, operations research, and statistics) must be taught by at least an MS degree holder in the appropriate field, or by an expert with equivalent qualifications (e.g. Fellow / Associate of the Actuarial Society of the Philippines).

14.2 Full time faculty members

The institution shall maintain at least 50% of the faculty members teaching in the BS Mathematics/ Applied Mathematics program as full time.

14.3 Teaching load

Teaching load requirements for the BS Mathematics/ Applied Mathematics program shall be as follows:

a. Full time faculty members should not be assigned more than four (4) different courses/subjects within a semester.
b. In no instance should the aggregate teaching load of a faculty member exceed 30 units per semester (inclusive of overload and teaching loads in other schools).
c. Teaching hours per day should not exceed the equivalent of 6 lecture hours.

14.4 Faculty Development

The institution must have a system of faculty development. It should encourage the faculty to:

a. pursue graduate studies in mathematics/ applied mathematics especially at the PhD level;
b. undertake research activities and publish their research output;
c. give lectures and present papers in national/ international conferences, symposia and seminars; and,
d. attend seminars, symposia and conferences for continuing education.

The institution must provide opportunities and incentives such as:

a. tuition subsidy for graduate studies;
b. study leave with pay;
c. deloading to finish a thesis or to carry out research activities;
d. travel grants for academic development activities such as special skills training and attendance in national/ international conferences, symposia and seminars; and,
e. awards and recognition.

Section 15. Library

Library personnel, facilities and holdings should conform to existing requirements for libraries which are embodied in a separate CHED issuance.

The HEI is likewise encouraged to maintain journals and other non-print materials to aid the faculty and students in their academic work. CD-ROMs could complement a library's book collection but should not be considered as a replacement for the same.

Internet access is encouraged but should not be made a substitute for book holdings and/or on-line subscription to books and journals.

Libraries shall participate in inter-institutional activities and cooperative programs whereby resource sharing is encouraged.

Section 16. Laboratories and Classrooms

16.1 Laboratory requirements

The institution or unit should provide a computer laboratory or computing facilities that can be used by students for their research and computing requirements.

Laboratories should conform to existing requirements as specified by law (RA 6541, "The National Building Code of the Philippines" and Presidential Decree 856, "Code of Sanitation of the Philippines").

16.2 Classroom requirements

a. For lecture classes, ideal size is 30 students per class, maximum is 50.
b. For laboratory and research classes, class size shall be 20-25 students per class.
c. Special lectures with class size more than 50 may be allowed as long as the attendant facilities are provided.

16.3 Educational technology centers

The institution should provide facilities to allow preparation, presentation and viewing of audio-visual materials to support instruction.

ARTICLE VII
QUALITY ASSURANCE

Section 17. Assessment and Evaluation

The institution/department shall have in place a program assessment and evaluation system. The HEI must show this in their syllabi and catalogue. Institutions may refer to the CHED Implementation Handbook for Outcome-Based Education (OBE) and the Institutional Sustainability assessment (ISA) for guidance.

Section 18. Continuous Quality Improvement (CQI) Systems

The HEI shall maintain at all times a high standard of instruction and delivery through the establishment of a program level Continuous Quality Improvement system. Institution/department must show organizational and process plans, and implementation strategies. Institutions may refer to the CHED Implementation Handbook for Outcome-Based Education (OBE) and the Institutional Sustainability assessment (ISA) for guidance.

Section 19. CHED Monitoring and Evaluation

The CHED, in harmony with existing guidelines on monitoring and evaluation, shall conduct regular monitoring on the compliance of respective HEIs to this PSG. An outcomes-based assessment instrument shall be used during the conduct of monitoring and evaluation.

Using the CHED Implementation Handbook for OBE and ISA as reference, an HEI shall develop the following items to be submitted to CHED when they apply for a permit for a new program:

1. The complete set of program outcomes, including its proposed additional program outcomes.
2. Its proposed curriculum, and its justification including a curriculum map.
3. Proposed performance indicators for each outcome. Proposed measurement system for the level of attainment of each indicator.
4. Proposed outcomes-based syllabus for each course.
5. Proposed system of program assessment and evaluation
6. Proposed system of program Continuous Quality Improvement (CQI).

ARTICLE VIII
TRANSITORY, REPEALING AND EFFECTIVITY PROVISIONS

Section 20. Transitory Provision

All private HEIs, state universities and colleges (SUCs) and local universities and colleges (LUCs) with existing authorization to operate the Bachelor of Science in Mathematics and Bachelor of Science in Applied Mathematics programs are hereby given a period of three (3) years from the effectivity thereof to fully comply with the requirements in this CMO. However, the prescribed minimum curricular requirements in this CMO shall be implemented starting Academic Year 2018-2019.

Section 21 Repealing Clause

All CHED issuances, rules and regulations or parts thereof, which are inconsistent with the provisions of this CMO, are hereby repealed.

Section 22 Effectivity Clause

This CMO shall take effect fifteen (15) days after its publication in the Official Gazette, or in a newspaper of general circulation. This CMO shall be implemented beginning Academic Year 2018-2019.

Quezon City, Philippines, May 18 2017.

For the Commission,

PATRICIA B. LICUANAN, Ph.D.
Chairperson

Attachments:

Annex A – Curriculum Mapping
Annex B – Course Specifications
Annex C – Sample Examinations

ANNEX A. CURRICULUM MAPPING

BS MATH/APPLIED MATH PROGRAM OUTCOMES

At the end of this program, the students are expected to be able to:

A. Common to all programs in all types of schools

a) Engage in lifelong learning and understanding of the need to keep abreast of the developments in the specific field of practice. (PQF level 6 descriptor)
b) Communicate effectively thru oral and in writing using both English and Pilipino.
c) Perform effectively and independently in multi-disciplinary and multi-cultural teams. (PQF level 6 descriptor)
d) Recognize professional, social, and ethical responsibility.
e) Appreciate the "*Filipino historical and cultural heritage*" (based on RA 7722).

B. Common to the discipline

f) Demonstrate broad and coherent knowledge and understanding in the core areas of mathematics.
g) Apply analytical, critical and problem solving skills using the scientific method.
h) Interpret relevant scientific data and make judgments that include reflection on relevant scientific and ethical issues.
i) Carry out basic mathematical and statistical computations and use appropriate technologies in the analysis of data.
j) Communicate information, ideas problems and solutions both, orally and in writing, to other scientists, decision makers and the public.
k) Connect science and mathematics to the other disciplines.
l) Design and perform techniques and procedures following safe and responsible laboratory or field practices.
m) Accept and critically evaluate input from others.
n) Appreciate the limitations and implications of science in everyday life.
o) Commitment for the integrity of data.

C. Specific to BS Math/Applied Math

p) Gain mastery in the core areas of mathematics: algebra, analysis, geometry
q) Demonstrate skills in pattern recognition, generalization, abstraction, critical analysis, synthesis, problem-solving and rigorous argument
r) Develop an enhanced perception of the vitality and importance of mathematics in the modern world including inter-relationship within math and its connection to other disciplines
s) Appreciate the concept and role of proof and reasoning and demonstrate knowledge in reading and writing mathematical proofs
t) Make and evaluate mathematical conjectures and arguments and validate their own mathematical thinking
u) Communicate mathematical ideas orally and in writing using clear and precise language

BS MATH/APPLIED MATH

SAMPLE CURRICULUM MAP

COURSES	RELATIONSHIP OF COURSES TO PROGRAM OUTCOME																				
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
A. GE Program Courses																					
Understanding the Self/ *Pag-unawa sa Sarili*																					
Readings in Philippine History/ *Mga Babasahin hinggil sa Kasaysayan ng Pilipinas*																					
The Contemporary World/ *Ang Kasalukuyang Daigdig*																					
Ethics/Etika																					
Mathematics in the Modern World/ *Matematika sa Makabagong Daigdig*																					
Science, Technology, and Society/ *Agham, Teknolohiya, at Lipunan*																					
Purposive Communication/ *Malayuning Komunikasyon*																					
Art Appreciation/ *Pagpapahalaga sa Sining*																					
Life and Works of Rizal / *Buhay at mga Likha ni Rizal*																					
GE Elective 1																					
GE Elective 2																					
GE Elective 3																					
B. Others																					
P.E. 1, 2, 3, 4			*P*	*P*	*P*								*P*		*P*						
NSTP 1, 2			*P*	*P*	*P*								*P*		*P*						
C. Mathematics Core Courses																					
Abstract Algebra I						*I*	*P*		*P*	*P*						*P*	*P*	*P*	*P*	*P*	*P*
Advanced Calculus I						*I*	*P*		*P*		*P*						*P*	*P*	*P*	*P*	*P*
Advanced Course in Analysis/ Algebra						*I*	*P*		*P*		*P*						*P*	*P*	*P*	*P*	*P*
Calculus I, II, III						*I*	*P*	*I*	*P*	*P*	*I*					*P*	*P*	*P*	*I*	*I*	*P*
Complex Analysis						*P*	*P*		*P*	*P*			*P*	*P*		*P*	*P*	*P*	*P*	*P*	*P*
Differential Equations I						*P*	*P*	*I*	*P*	*P*	*I*					*P*	*P*	*P*	*I*	*I*	*P*
Elementary Number Theory						*I*	*P*		*P*	*P*						*P*	*P*	*P*	*P*	*P*	*P*
Fundamental Concepts of Mathematics						*I*	*I*		*I*				*I*			*I*	*I*		*I*		*I*
Fundamentals of Computing I							*P*		*P*	*P*	*I*					*P*	*P*	*P*			*P*
Linear Algebra						*P*	*P*		*P*	*P*	*P*		*P*	*P*		*P*	*P*	*P*	*P*	*P*	*P*
Modern Geometry						*I*	*P*		*P*		*I*						*P*	*I*	*P*	*P*	*P*

Numerical Analysis (or Mathematical Modeling)						*P*	*P*	*P*	*P*	*P*	*I*		*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
Probability							*I*		*P*				*I*				*I*	*I*	*I*		*I*
Statistical Theory							*P*	*P*	*P*	*P*	*I*		*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
Topology							*P*		*P*		*P*						*P*	*P*	*P*	*P*	*P*
D. Applied Mathematics Core Courses																					
Advanced Calculus I							*P*		*P*		*P*						*P*	*P*	*P*	*P*	*P*
Calculus I, II, III						*I*	*P*	*I*	*P*	*P*	*I*					*P*	*P*	*P*	*I*	*I*	*P*
Differential Equations I						*P*	*P*	*I*	*P*	*P*	*I*					*P*	*P*	*P*	*I*	*I*	*P*
Discrete Mathematics						*I*	*P*									*P*	*P*	*P*	*P*	*P*	*P*
Fundamental Concepts of Mathematics						*I*	*I*		*I*				*I*			*I*	*I*		*I*		*I*
Fundamentals of Computing I							*P*		*P*	*P*	*I*					*P*	*P*	*P*			*P*
Linear Algebra						*P*	*P*		*P*	*P*	*I*		*P*	*P*		*P*	*P*	*P*	*P*	*P*	*P*
Mathematical Modeling						*P*	*P*	*P*	*P*	*P*	*I*		*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
Numerical Analysis						*P*	*P*	*P*	*P*	*P*	*I*		*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
Operations Research I							*P*		*P*	*I*	*P*			*I*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
Probability							*I*		*P*				*I*				*I*	*I*	*I*		*I*
Statistical Theory							*P*	*P*	*P*	*P*	*I*		*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
Theory of Interest							*P*		*P*		*I*		*P*				*P*	*P*	*P*	*P*	*P*
E. Non-math Foundational Courses																					
Gen. Physics I (lecture and lab)						*P*	*P*	*P*	*P*	*P*	*P*		*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*	*P*
F. Elective Courses																					
G. Free Electives																					
H. Thesis or Special Problem																					
Thesis	*P*	*D*													*P*		*D*		*D*	*D*	*D*
Special Problem	*P*	*D*							*P*	*P*	*P*				*P*		*P*	*P*	*P*	*P*	*D*

I: *INTRODUCED – The student gets introduced to concepts/principles.*

P: *PRACTISED – The student practices the competencies with supervision.*

D: *DEMONSTRATED – The student practices the competencies across different settings with minimal supervision.*

ANNEX B. COURSE SPECIFICATIONS

BS Mathematics / Applied Mathematics

ABSTRACT ALGEBRA I

A. Course Details

COURSE NAME	**Abstract Algebra I**
COURSE DESCRIPTION	This course covers groups, subgroups, cyclic groups, permutation groups, abelian groups, normal subgroups, quotient groups and homomorphisms and isomorphism theorems, rings, integral domains, fields, ring homomorphisms, ideals, and field of quotients.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Fundamental Concepts of Mathematics

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
state with precision the definition of a group, a subgroup, a ring, a field, etc.						✓				✓						✓					✓
determine if a given set with given operation/s is a group, a subgroup, a ring, a field, etc.						✓	✓		✓	✓						✓	✓		✓	✓	
apply definitions and theorems to carry out computations and constructions involving different algebraic structures						✓	✓		✓	✓						✓	✓	✓	✓		
apply definitions and theorems to prove properties that are satisfied by all groups, subgroups, rings, etc						✓	✓		✓	✓						✓	✓		✓	✓	✓
recall the definitions and the basic properties of certain examples of groups, e.g. dihedral, symmetric, alternating						✓				✓						✓		✓			✓

recall the definition and basic properties of other objects such as homomorphism, isomorphism, kernel, direct product of groups, quotient groups, etc.						✓				✓						✓		✓			✓

C. Course Outline

Week	Topics
1-2	Preliminaries • Sets • Equivalence Relations • Functions • Binary Operations • Division Algorithm in Z and Modular Operations
3-4	Groups • Definition and elementary properties • Group tables • Order of a group • Subgroups • Isomorphism of groups
5-6	Cyclic Groups and Cosets • Definition, Order of an element • Structure of cyclic groups • Cosets • Lagrange's Theorem
7-8	Permutation Groups • Permutations • The symmetric and alternating groups • Dihedral group • Cayley's Theorem
9-10	Direct Product and Generating Sets • The direct product • Subgroup generated by a subset • Fundamental theorem of finitely generated abelian groups
11-12	Quotient Groups and Homomorphisms • Normal subgroup • Quotient group • Homomorphisms and basic properties • Isomorphism theorems
13-14	Rings • Definition and basic properties • Subring • The group of units of a ring • Ideal • Quotient ring
15-16	Ring Homomorphisms, Integral Domains, Fields • Basic properties of ring homomorphism • Ring isomorphism theorems • Zero divisors, integral domains • Fields • Field of quotients of an integral domain

D. Suggested Teaching Strategies

- Lectures, exercises, group discussion, individual inquiry

E. Suggested Assessment/Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. Textbooks/References:

- J. A. Gallian, Contemporary Abstract Algebra (7th ed.), Houghton Mifflin, 2010.
- J. Fraleigh, A First Course in Abstract Algebra (5th ed), Addison-Wesley, 2000.
- I. Herstein, Abstract Algebra *(2nd ed),* Collier Macmillan, 1990.
- T. Hungerford, Abstract Algebra, an Introduction *(2nd ed),* Saunders College, 1993

ABSTRACT ALGEBRA II

A. Course Details

COURSE NAME	**Abstract Algebra II**
COURSE DESCRIPTION	This course covers rings of polynomials, fundamental theorem of field theory, extension fields, algebraic extensions, finite fields, geometric constructions, fundamental theorem of Galois theory, illustrations of Galois theory.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Abstract Algebra I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
calculate effectively in polynomial rings over various rings.									✓							✓	✓				
determine irreducibility of polynomials over a field using a variety of techniques.									✓							✓	✓		✓	✓	
determine whether an integral domain is a UFD.									✓							✓	✓		✓	✓	

explain connection between primes and irreducibles in arbitrary rings.									✓							✓	✓		✓	✓	
construct extension fields given an irreducible polynomial over the field.									✓							✓	✓				
determine the irreducible polynomial of an algebraic element over a field.									✓							✓	✓				
determine the index of a field in an extension field and a basis for the extension									✓							✓	✓		✓	✓	
give examples and non-examples of constructible real numbers.									✓							✓	✓		✓	✓	
describe the basic structure of finite fields and its subfields.									✓							✓	✓				
describe the splitting field and algebraic closure of a given field.									✓							✓	✓		✓	✓	
illustrate the Fundamental Theory of Galois Theory for small extensions.									✓							✓	✓		✓	✓	

C. Course Outline

Week	Topics
1	Introduction • Historical background • Solution of quadratic, cubic, quartic equations
2	Rings • Review of basic concepts on rings • Characteristic of a ring • Prime subfield • Prime ideal, maximal Ideal, principal ideal
3-4	Rings of Polynomials • Division algorithm in F[x] (F a field) • Ideal structure in F[x] • Divisibility conditions in ideal form • Irreducible polynomials • Tests for irreducibility
5-6	Factorization in Commutative Rings* • Unique factorization domains • Euclidean domains • Gaussian integers • Multiplicative norms

7-8	Extension Fields • Fundamental theorem of field theory (Kronecker's Theorem) • Algebraic and transcendental elements • Irreducible polynomial of an algebraic element • Extension fields as vector spaces
9	Finite Fields • Cyclic structure of group of units • Subfield structure • Frobenius automorphism
10-12	Special Extension Fields • Finite extensions • Algebraic extensions • Splitting fields • Algebraically closed fields, algebraic closure
13	Geometric Constructions • Constructible numbers • Trisecting an angle, doubling the cube
14	Some Important Theorems • Primitive element theorem • Isomorphism extension theorem
15-16	The Fundamental Theorem of Galois Theory* • The Galois group • The Galois correspondence (sketch of proof) • Normal extensions • Illustrations of Galois theory: finite fields, cyclotomic fields • *Insolvability of the quintic*

**If time permits. Italicized items are optional topics*

D. Suggested Teaching Strategies

- Lectures, exercises, group discussion

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References
- Fraleigh. A First Course in Abstract Algebra
- Galllian. Contemporary Abstract Algebra
- Herstein. Abstract Algebra

A. Course Details

COURSE NAME	**Advanced Calculus I**
COURSE DESCRIPTION	Advanced Calculus I is the first of two courses that provides an introduction to mathematical analysis beyond the calculus series. Topics include the real number system, point set topology, limits and continuity, the derivatives, multivariable differential calculus, implicit functions and extremum problems.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Calculus III

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
prove completeness and topological properties of the real number system and R^n									✓							✓	✓		✓	✓	
prove convergence and divergence of a sequence of real numbers using the ϵ-δ definitions and theorems									✓							✓	✓		✓	✓	
identify and prove basic facts about continuity, derivatives, and their properties.									✓							✓	✓		✓	✓	
explain the differential for functions of one and several variables and apply to approximation									✓							✓	✓		✓	✓	
explain the Mean Value Theorem and its consequences									✓							✓	✓		✓	✓	
review of the technique of implicit differentiation for functions of a single variable and for functions of several variables.									✓							✓	✓		✓	✓	
investigate the validity of the technique and proof of the Implicit Function Theorem.									✓							✓	✓		✓	✓	
express the derivative and differential of a function as a matrix									✓							✓	✓		✓	✓	

C. Course Outline

Week	Topics
1	R as a Complete Ordered Field • Countable and uncountable sets
2-4	Point Set Topology • Euclidean space R^n • Open and closed sets in R^n • Accumulation points • Bolzano-Weiestrass Theorem • Heine-Borel Theorem • Compactness of R^n • Metric spaces • Compact subsets of a metric space • Boundary of a set
5-8	Limits and Continuity • Convergent sequences in a metric space • Cauchy sequences • Complete metric spaces • Limit of a function • Continuous functions • Continuity of composite functions • Examples of continuous functions • Continuity and inverse images of open or closed sets • Functions continuous on compact sets • Topological mappings • Uniform continuity and compact sets • Discontinuities of real-valued functions • Monotonic functions
9-11	Derivatives • Derivatives and continuity • The chain rule • One-sided derivatives • Rolle's theorem • The mean-value theorem for derivatives • Taylor's formula with remainder
12-14	Multivariable Differential Calculus • Rolle's theorem The directional derivative • Differential of functions of several variables • Jacobian matrix • The chain rule • Matrix form of chain rule • The mean-value theorem for differentiable functions • A sufficient condition for differentiability • A sufficient condition for equality of mixed partial derivatives • Taylor's formula for functions from R^n to R
15-16	Implicit Functions and Extremum Problems • Functions with nonzero Jacobian determinant • The inverse function theorem • The implicit function theorem • Extrema of real-valued functions of one variable • Extrema of real-valued functions of several variables

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Apostol. Mathematical Analysis
- Rudin. Principles of Mathematical Analysis
- Protter and Morrey. A First Course in Real Analysis
- Lang. Undergraduate Analysis
- Ross. Elementary Analysis: The Theory of Calculus

ADVANCED CALCULUS II

A. Course Details

COURSE NAME	**Advanced Calculus II**
COURSE DESCRIPTION	This course is a continuation of Advanced Calculus I. Topics include the convergence of sequences and series of real numbers, sequences and series of functions, uniform convergence, power series, functions of bounded variation and rectifiable curves, Riemann-Stieltjes integrals, interchanging of limit operations, multiple integration, improper integrals, transformations.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Advanced Calculus I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
prove convergence and divergence of series of real numbers									✓							✓	✓		✓	✓	
define the Riemann integral on R and R^n using upper sums, lower sums, and/or limits									✓							✓	✓			✓	
use the definition to compute integral values in elementary cases									✓							✓	✓			✓	
identify sufficient and necessary conditions for									✓							✓	✓		✓	✓	

existence of the integral and prove theorems and properties of single and multiple integrals																					
explain Jacobian of a transformation and change of variable in multiple integrals.									✓							✓	✓			✓	
use transformations to "simplify" regions.									✓							✓	✓				
prove convergence and divergence of a sequence of real-valued functions									✓							✓	✓		✓	✓	
differentiate between pointwise and uniform convergence									✓							✓	✓		✓	✓	
prove convergence and properties of a series of functions									✓							✓	✓		✓	✓	
identify the interval of convergence of a power series									✓							✓	✓				
prove the Cauchy-Hadamard Theorem and explain its relevance									✓							✓	✓		✓	✓	
explain transformations and transformations defined implicitly by systems of equations									✓							✓	✓		✓	✓	
evaluate double integrals over more complicated regions of the plane.									✓							✓	✓				
define and give examples of vector and scalar fields, including directional derivatives, gradient, divergence and curl.									✓							✓	✓				
evaluate line integrals using definition and vector formulation									✓							✓	✓				
differentiate between path dependent and path independent line integrals									✓							✓	✓				
state and apply Green's theorem and Stoke's Theorem.									✓							✓	✓		✓	✓	

C. Course Outline

Week	Topics
1-3	Infinite Series • Limit superior and limit inferior of a sequence of real numbers • Infinite series • Alternating series • Absolute and conditional convergence • Tests for convergence of series • Dirichlet's test and Abel's test

	• Rearrangement of series • Double series and rearrangement theorem for double series • Multiplication of series
4-7	Riemann-Stieltjes Integral • Functions of bounded variation • Curves and paths • Rectifiable curves and arc length • Definition of Riemann-Stieltjes integral • Sufficient and necessary conditions for the existence of Riemann-Stieltjes integrals • Differentiation under the integral sign • Interchanging the order of integration • Multiple integrals and improper integrals
8-12	Sequences of Functions • Pointwise convergence of sequences of functions • Uniform convergence and continuity • Uniform convergence of infinite series of functions • Uniform convergence and Riemann-Stieltjes integration • Uniform convergence and differentiation • Power series
13	Green's Theorem for Rectangles and Regions
14	Review of Vector Fields
15-16	Surfaces • Surface area • Integrals over curves and surfaces • Stokes' Theorem, Gauss' Theorem

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Apostol. Mathematical Analysis
- Rudin. Principles of Mathematical Analysis
- Protter and Morrey. A First Course in Real Analysis
- Lang. Undergraduate Analysis
- Ross. Elementary Analysis: The Theory of Calculus

CALCULUS I

A. Course Details

COURSE NAME	**Calculus I**
COURSE DESCRIPTION	This is a first course in calculus. It covers limits, continuity, derivatives of algebraic and transcendental functions (exponential, logarithmic, trigonometric, hyperbolic and their inverses), applications of derivatives, differentials; antiderivatives, definite integrals, Fundamental Theorem of Calculus, and applications of definite integrals.
NUMBER OF UNITS	4 units (Lec)
PREREQUISITE	Pre Calculus Mathematics (Algebra and Trigonometry)

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
evaluate the limit of a function using the limit theorems.						✓	✓		✓	✓						✓	✓				
define continuity at a point and on an interval.						✓				✓						✓			✓		✓
distinguish between continuous and discontinuous functions						✓	✓			✓						✓			✓	✓	
use the definition to get the derivative of a function.						✓			✓	✓						✓					
apply the differentiation rules on various types of functions.						✓	✓		✓	✓						✓	✓				
apply the derivative tests to find maxima/minima of a function, graph functions and solve optimization problems.						✓	✓		✓	✓	✓					✓	✓	✓			
compute antiderivatives of various functions and definite integrals						✓	✓		✓	✓						✓	✓				
solve problems involving areas of regions, volumes of solids of revolution, arc lengths of curve and differential equations.						✓	✓		✓	✓	✓	✓				✓	✓				

C. Course Outline

Week	Topics
1-3	Limits and Continuity • Definition of limits and limit theorems (ε-δ definition optional) • One-sided limits, infinite limits, and limits at infinity • Continuity of a function and the Intermediate Value Theorem • The Squeeze Theorem and limits and continuity
4-7	Derivatives and Differentiation • The Derivative of a function • Formulas for differentiation of algebraic and transcendental functions • Chain Rule, implicit differentiation, higher-order derivatives • Indeterminate forms and L'Hopital's Rule • Increasing and decreasing functions and the 1st Derivative Test • Concavity and the 2nd Derivative Test • Sketching graphs of functions • Mean Value Theorem
8-11	Other Applications of Differentiation • Local linear approximation and differentials • Absolute extrema, Extreme Value Theorem, and optimization • Rectilinear motion • Related rates
12-16	Antiderivatives, Indefinite Integrals, and Applications • Antiderivatives and formulas of antidifferentiation • Integration by substitution • The definite integral • The Mean Value Theorem for integration • The Fundamental Theorem of Calculus • Area of a plane region • Arc length of a plane curve • Volumes by slicing, disks/washers, and cylindrical shells

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Anton, H., Bivens, I.C., and Davis, S., Calculus Early Transcendentals, 10th Edition, Wiley, *2011*.
- Anton, H., Bivens, I.C., and Davis, S., Calculus, 10th Edition, Wiley, *2012*.
- Edwards, Jr., C.H. and Penney, E., Calculus, Early Transcendentals, 7th Edition, Prentice Hall, 2007.
- Etgen, G., S. Salas and E. Hille, Calculus : One and Several Variables, 9th Ed., John Wiley and Sons, Inc., 2003.
- Leithold, Louis, The Calculus *7*, Harper Collins, 1996.
- Stewart, J., Calculus: Early Transcendentals, 7th Edition, Brooks/Cole, 2011.
- Thomas, G.B., Weir, M.D. and Hass, J.L., Thomas' Calculus, 12th Edition., Pearson, 2009.

- Thomas, G.B., Weir, M.D. and Hass, J.L., Thomas' Calculus Early Transcendentals, 12th Edition., Pearson, 2009.
- Varberg, D., Purcell, E.J., and Rigdon, S.E., Calculus Early Transcendentals, 1st Edition, Pearson, 2006.
- Varberg, D., Purcell, E.J., and Rigdon, S.E., Calculus, 9th Edition, Pearson, 2006

CALCULUS II

A. Course Details

COURSE NAME	Calculus II
COURSE DESCRIPTION	This course is the second of a series of three calculus courses. It covers techniques of integration, parametric equations and polar coordinates, cylindrical surfaces, surfaces of revolution, and quadric surfaces; vectors and vector-valued functions; functions of several variables; limits and continuity of functions of several variables; partial derivatives and the total differential; directional derivative; relative and absolute extrema of functions of several variables
NUMBER OF UNITS	4 units (Lec)
PREREQUISITE	Calculus I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
evaluate integrals using the basic techniques of integration						✓	✓		✓							✓	✓				
evaluate improper integrals						✓	✓		✓							✓	✓				
sketch graphs of equations in polar coordinates						✓	✓		✓							✓	✓				
identify and sketch graphs in space of lines, planes, cylindrical surfaces, surfaces of revolution and quadric surfaces						✓	✓		✓		✓					✓	✓	✓			
use calculus of vector-valued functions to analyze motion in space						✓	✓		✓		✓					✓	✓	✓			
evaluate limits and analyze the continuity of functions of several variables						✓	✓		✓							✓	✓				
find partial derivatives and directional derivatives of functions of several variables						✓			✓							✓					

solve problems involving the total differential						✓	✓		✓		✓					✓	✓	✓			✓
find relative and absolute extrema of functions of several variables						✓	✓		✓		✓					✓	✓				
apply the Lagrange multipliers method on constrained optimization problems						✓	✓		✓		✓					✓	✓	✓			✓

C. Course Outline

Week	Topics
	Techniques of Integration and Improper Integrals • Review of formulas of integration and integration by substitution • Integration by parts • Trigonometric integrals and integration by trigonometric substitution • Integration of rational functions by partial fractions • Improper integrals
	Parametric Curves, Polar Coordinates, and Surfaces • Parametric curves and the calculus of parametric curves • Polar coordinates and graphs of equations in polar coordinates • Tangent lines to, areas enclosed by, and arc length of polar curves • The three-dimensional Cartesian coordinate system • Cylindrical surfaces • Review of conic sections and quadric surfaces • Surfaces of revolution
	Vectors, Lines and Planes in Space, Vector-Valued Functions • Vectors in the plane and in space • Magnitude and direction angles • Vector operations • Dot and cross products of vectors • Scalar and vector projections • Lines and planes in space • Vector-valued functions • Calculus of vector-valued functions • Arc length and parametrization using arc length • Motion in space and normal and tangential components of acceleration • Curvature
	Differential Calculus of Functions of Several Variables • Functions of several variables, level curves, and level surfaces • Limits and continuity of functions of several variables • Partial derivatives • Higher-order derivatives, the total differential, and tangent plane approximation • The Chain Rule and implicit differentiation • Directional derivatives and gradients • Tangent planes to level surfaces • Relative extrema and the Second Derivatives Test • Absolute extrema and the method of Lagrange multipliers • Parametric surfaces and surfaces of revolution

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Same as Calculus I

CALCULUS III

A. Course Details

COURSE NAME	**Calculus III**
COURSE DESCRIPTION	This course covers sequences and series; double and triple integrals; applications of multiple integrals; vector fields; line and surface integrals.
NUMBER OF UNITS	4 units (Lec)
PREREQUISITE	Calculus II

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
apply the various tests for convergence and divergence of series;						✓	✓		✓							✓	✓		✓		
obtain the radius and interval of convergence of power series						✓			✓							✓					
evaluate double and triple integrals						✓			✓							✓					
solve problems involving applications of double and triple integrals						✓			✓							✓	✓				✓
evaluate line and surface integrals						✓			✓							✓					
solve problems involving applications of line and surface integrals						✓	✓		✓							✓	✓	✓			
define the curvature and geometry of plane and space curves						✓										✓					✓

define a vector field, its divergence, and curl						✓										✓					✓
perform a combination of gradient, divergence or curl operations on fields						✓	✓		✓							✓	✓				
evaluate line and surface integrals						✓	✓		✓							✓	✓				
state and apply Green's Theorem, Gauss' Divergence Theorem, and Stokes' Theorem						✓	✓		✓							✓		✓			✓
discuss the relationships between Green's Theorem, Gauss' Divergence Theorem, and Stokes' Theorem						✓				✓						✓					✓

C. Course Outline

Week	Topics
	Sequences and Series • Sequences • Series of constant terms and the n^{th}-term Test for Divergence • The Integral, Comparison, and Limit Comparison Tests • The Alternating Series, Ratio, and Root Tests • Power series and radius and interval of convergence of power series • Differentiation and integration of power series • Taylor, Maclaurin, and binomial series • Approximation using Taylor polynomials
	Multiple Integration • Double integrals • Double integrals in polar coordinates • Applications of double integrals (area, volume, mass, surface area) • Triple integrals • Triple integrals in cylindrical and spherical coordinates • Applications of triple integrals (volume, mass)
	Vector Fields and Line and Surface integrals • Vector fields • Curl and divergence • Line integrals of scalar and vector fields • The Fundamental Theorem of Line Integrals • Independence of path • Green's Theorem • Surface integrals of scalar and vector field • Stokes' Theorem and Gauss' Divergence Theorem

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Same as Calculus I and II

COMPLEX ANALYSIS

A. Course Details

COURSE NAME	**Complex Analysis**
COURSE DESCRIPTION	This course involves a study of the algebra of complex numbers, analytic functions, elementary complex functions, complex integration, and the residue theorem and its applications.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Advanced Calculus I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
perform operations on complex numbers using the appropriate properties.						✓										✓	✓		✓		
use the appropriate tests to determine if a given function of a complex number is analytic.						✓	✓						✓			✓	✓	✓	✓	✓	✓
compare the properties of elementary functions of complex numbers with their real counterparts.						✓	✓						✓			✓	✓	✓	✓	✓	✓
use the appropriate theorems to evaluate the integral of a function of complex numbers.						✓	✓						✓			✓	✓		✓	✓	✓
represent a given analytic function by a specified series.						✓	✓				✓		✓			✓	✓		✓		✓
use the residue theorem to evaluate complex integrals and improper integrals.						✓	✓				✓		✓			✓	✓	✓	✓		✓

C. Course Outline

Week	Topics
1-2	The algebra of complex numbers • Cartesian, geometric and polar representations of complex numbers • Powers and roots • Stereographic projection
3-4	Functions of a complex variable • Limits and Continuity

	• Derivatives • Analytic functions and the Cauchy-Riemann equations in Cartesian and polar form • Harmonic functions
5-7	Elementary complex functions • Exponential functions and their properties • Complex trigonometric and hyperbolic functions • Complex logarithmic functions • Multiple valued functions and their branches • Complex exponents • Inverse trigonometric functions
8-9	Mappings of Elementary functions • Linear, reciprocal and linear fractional transformations • The power function and exponential function • Successive transformations
10-12	Complex Integration • Contours and Line Integrals • The Cauchy-Goursat Theorem • Cauchy's Integral Theorem and integral formula • Derivatives of functions • Morera's Theorem and the Fundamental Theorem of Algebra • Maximum moduli
13-15	Residues and Poles • Residues and the Residue Theorem • Laurent Series • The principal part of a function • Poles • Quotients of analytic functions • Improper integrals • Integration around a branch point

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Pennisi. Elements of Complex Variables
- Churchill, Brown, and Verhey. Complex Variables and Applications
- Lang. Complex Analysis
- Spiegel. Theory and Problems of Complex Variables

A. Course Details

COURSE NAME	**Differential Equations I**
COURSE DESCRIPTION	This is an introductory course in ordinary differential equations (ODEs). It focuses primarily on techniques for finding explicit solutions to linear ODEs. Topics include first order ordinary differential equations, linear differential equations, linear equations with constant coefficients, nonhomogeneous equations, undetermined coefficients and variation of parameters, linear systems of equations; the existence and uniqueness of solutions.
NUMBER OF UNITS	3 units (Lec/Lab)
PREREQUISITE	Calculus III

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
solve ordinary differential equations by separation of variables, if applicable						✓	✓		✓	✓						✓	✓				
solve first-order ordinary differential equations						✓	✓		✓	✓						✓	✓				
solve second-order linear ordinary differential equations with constant coefficients and extend the technique to similar equations of higher order						✓	✓		✓	✓						✓	✓				
use Laplace transforms to solve linear ordinary differential equations and systems						✓	✓		✓	✓						✓	✓				
use the matrix exponential function to solve the linear system x'=Ax, where A is a 2x2 matrix with constant entries						✓	✓		✓	✓						✓	✓				
use qualitative analysis to sketch the solution curves of autonomous first-order ordinary differential equations						✓	✓		✓	✓						✓	✓				
use qualitative analysis to sketch the phase portrait of linear system x'=Ax, where A						✓	✓		✓	✓						✓	✓				

is a 2x2 matrix with constant entries																					
use linearization to describe the nature and stability properties of the fixed points of a non-linear autonomous system of order 2						✓	✓		✓	✓						✓	✓				
sketch the phase portrait of non-linear autonomous system of order 2 having a first integral						✓	✓		✓	✓						✓	✓				
submit a group report on an application of mathematical modelling using ordinary differential equations in economics, physics, engineering, or other areas.*						✓	✓	✓	✓	✓	✓					✓	✓	✓		✓	✓

*optional

C. Course Outline

Week	Topics
1-2	Basic Denitions and Existence Theorems • Classification of ordinary differential equations and systems • Solutions and basic existence theorems • Direction field
3-7	Some Techniques of Solving Ordinary Differential Equations • Separation of variables • Leibniz's formula for first-order linear equations • Second-order linear ordinary differential equations with constant coefficients • Jordan canonical forms for 2 x 2 real matrices • The matrix exponential function; solutions of the linear system x'=Ax
8-13	Qualitative Analysis of Autonomous Differential Equation • First-order autonomous equations • Autonomous systems • Phase portraits of canonical linear systems in the plane • Phase portraits of non-canonical linear systems in the plane • Linearization at a fixed point • First integrals
14-16	Laplace Transforms • Definition and Examples • Properties of the Laplace Transform • Inverse Laplace Transform • Solving Initial Value Problems • Convolution

*optional

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. Textbooks:

- Rainville, E.D., Bedient, P.E., and Bedient, R.E., Elementary Differential Equations, 8th Edition, Pearson, 1996.
- Edwards, C.H. and Penney, D.E. Elementary Differential Equations, 6th Edition, Pearson, 2007.
- Edwards, C.H. and Penney, D.E. Elementary Differential Equations with Boundary Value Problems, 6th Edition, Pearson, 2007.
- Polking, J., Boggess, A., and Arnold, D. Differential Equations and Boundary Value Problems, 2nd Edition, Pearson, 2005.
- Polking. J., Ordinary Differential Equations using Matlab, 3rd Edition, Pearson, 2003.
- Zill, D.G, Advanced Engineering Mathematics, 4th Edition, Jones and Bartlett, 2011
- Blanchard, Differential Equations, Thomson/Brooks/Cole, 2007
- Arrowsmith, D.K. & Place, C.M., Dynamical Systems, Chapman & Hall, 1992
- Coddington, E.A. & Levinson, N., Theory of Ordinary Differential Equations, McGraw-Hill, 1976
- Nagle, R.K., Saff, E.B., and Snider, A.D., Fundamentals of Differential Equations and Boundary Value Problems, Addison-Wesley, 2000
- Verhulst, F., Nonlinear Differential Equations and Dynamical Systems, Springer-Verlag, 2000.

DISCRETE MATHEMATICS

A. Course Details

COURSE NAME	**Discrete Mathematics**
COURSE DESCRIPTION	This is a course that covers the fundamentals of logic, proving, functions and sets, basic counting techniques, and advanced counting techniques.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Precalculus

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
Translate mathematical statements from common English to formal logic and vice-versa						✓	✓			✓						✓		✓			✓

Verify the validity of an argument using rules of inference						✓	✓			✓						✓	✓	✓	✓	✓	✓
Identify the difference among the various types of proof: direct proof, proof by contraposition, proof by contradiction, and proof by cases; and use an appropriate method in proving mathematical statements.						✓	✓			✓						✓	✓		✓	✓	✓
Use the proper notations on sets and functions and perform operations on them						✓										✓		✓			
Apply the basic and advanced counting techniques to solve counting problems						✓	✓		✓	✓	✓					✓	✓	✓			
Solve problems involving recurrence relations, generating functions and inclusion-exclusion principle						✓	✓		✓	✓	✓					✓	✓	✓	✓	✓	✓

C. Course Outline

Week	Topics
1-3	Propositional Logic • Propositional Equivalences • Predicates and Quantifiers • Nested Quantifiers • Rules of Inference
4-7	Introduction to Proofs • Proof Methods and Strategy • Sets • Set Operations • Functions
8-11	Counting • The Basics of Counting • The Pigeonhole Principle • Permutations and Combinations • Binomial Coefficients • Generalized Permutations and Combinations
12-15	Advanced Counting Techniques • Recurrence Relations • Solving Linear Recurrence Relations • Generating Functions • Inclusion-Exclusion Principle

D. Suggested Teaching Strategies
- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation
- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Rosen, K.H., Discrete Mathematics and Applications, 6th Edition, McGraw-Hill, 2007.
- Grimaldi. R.P., Discrete and Combinatorial Mathematics, 5th Edition, Pearson, 2003.
- Ross, K.A., Discrete Mathematics, 5th Edition, Pearson, 2002.
- Johnsonbaugh. R., Discrete Mathematics, 7th Edition, Pearson, 2007.

ELEMENTARY NUMBER THEORY

A. Course Details

COURSE NAME	**Elementary Number Theory**
COURSE DESCRIPTION	Properties of integers; divisibility; primes and unique factorization; solutions of congruences and residue systems; linear Diophantine equations, primitive roots; quadratic reciprocity law.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Fundamental Concepts of Mathematics

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
Understand the logic and methods behind the major proofs in Number Theory						✓	✓									✓	✓		✓	✓	✓
Construct mathematical proofs of statements and find counterexamples to false statements in number theory						✓	✓		✓								✓		✓	✓	✓
collect and use numerical data to form conjectures about the integers								✓	✓								✓				✓
Prove results involving divisibility and greatest common divisors						✓	✓		✓								✓		✓	✓	✓
Solve systems of linear congruences							✓		✓								✓		✓	✓	✓

Find integral solutions to specified linear Diophantine equations							✓		✓								✓		✓	✓	✓
Apply Euler-Fermat's Theorem to prove relations involving prime numbers and integers							✓		✓								✓		✓	✓	✓
Apply Wilson's theorem							✓		✓								✓		✓	✓	✓
Demonstrate knowledge of the Legendre symbol and quadratic reciprocity law							✓		✓								✓		✓	✓	✓

C. Course Outline

Time Allotment	Topics
6 hrs	Unit I: Preliminaries • The Number System • Review of Principle of Mathematical Induction and Pigeonhole Principle • Divisibility; division algorithm, GCD, Euclidean algorithm • Bezout's identity; relatively prime; LCM
12 hrs	Unit II: Primes • Fundamental Theorem of Arithmetic • Prime distributions • Fermat and Mersenne primes • Linear Diophantine equations • Primality Testing and Factorization
1.5 hrs	Exam 1
12 hrs	Unit III: Congruences, Roots and Indices • Modular Arithmetic, congruences and congruence classes • Simultaneous congruences and the Chinese Remainder Theorem • Wilson's Theorem and Fermat's Little Theorem • Euler phi-function • Primitive Roots and Indices • Computing powers and roots
1.5 hrs	Exam 2
12 hrs	Unit IV: Quadratic Reciprocity and Other Topics • Quadratic residues • Legendre symbol • Reciprocity laws • Arithmetic functions • Pythagorean triples • Which primes are sums of two powers? • No fourth power is the sum of two fourth powers
	Special Topics* • Elliptic curves and Fermat's Last Theorem • Some unsolved problems in Number Theory
1.5 hrs	Exam 3

*optional

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

References

- K. H. Rosen, Elementary Number Theory and its Applications
- G. Jones and M. Jones, Elementary Number Theory

Further reading

- I. Niven and H. Zuckerman, An Introduction to the Theory of Numbers
- G.H. Hardy and E.M. Wright, An Introduction to the Theory of Numbers
- C. Vanden Eynden, Elementary Number Theory
- K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory
- G.H. Hardy, A Mathematician's Apology
- Lewis Carroll, Alice in Wonderland

FUNDAMENTAL CONCEPTS OF MATHEMATICS

A. Course Details

COURSE NAME	**Fundamental Concepts of Mathematics**
COURSE DESCRIPTION	This course covers sets, principles of logic, methods of proof, relations, functions, integers, binary operations, complex numbers, matrices and matrix operations, and an introduction to mathematical systems.
NUMBER OF UNITS (Lec)	3 units (Lec)
PREREQUISITE	Precalculus

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
determine whether two propositions or predicates are logically equivalent							✓									✓				✓	
construct truth tables							✓									✓					
use and interpret set notation correctly							✓		✓							✓	✓				

construct and understand proofs of mathematical propositions which use some standard proof techniques							✓		✓							✓	✓		✓	✓	✓
determine whether a given relation is an equivalence relation							✓									✓			✓	✓	✓
obtain the equivalence classes that arise from an equivalence relation							✓		✓							✓	✓		✓		
determine whether a given function is injective, surjective or bijective.							✓		✓							✓	✓		✓		
determine whether a given set is finite, countably infinite or uncountable							✓		✓							✓	✓		✓		
determine the cardinality of a given set							✓		✓							✓	✓		✓		

C. Course Outline

Week	Topics
1-2	Sets • Basic definitions and notation • Set operations, algebra of sets • Venn diagrams • Counting properties of finite sets
3-4	Principles of Logic • Statements, logical connectives • Validity, truth table • Tautologies • Quantifiers
5-7	Methods of Proof • Direct proof • Indirect proof • Proof by specialization and division into cases • Mathematical induction
8-9	Relations • Definition • Equivalence relations • Equivalence classes and partitioning • Partial ordering
10-11	Functions • Injection, surjection, bijection • Image, inverse image • Inverse function • Cardinal number of a set • Counting principles • Countable and uncountable sets

12-13	Integers • Divisibility • Division algorithm, Euclidean algorithm • Fundamental Theorem of Arithmetic
14-15	Binary Operations • Definition • Modular operations • Operations on matrices • Operations on complex numbers
16	Introduction to Mathematical Systems • Semigroup • Group • Ring • Field

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Morash. Bridge to Abstract Mathematics
- Gerstein. Introduction to Mathematical Structures and Proofs
- Rotman. Journey to Mathematics
- Kurtz. Foundations of Abstract Mathematics
- Sundstrom. Mathematical Reasoning: Writing and Proofs
- Chartrand, Polimeni and Zhang. Mathematical Proofs: A transition to advanced mathematics

FUNDAMENTALS OF COMPUTING I

A. Course Details

COURSE NAME	**Fundamentals of Computing I**
COURSE DESCRIPTION	This course introduces fundamental programming constructs: types, control structures, functions, I/O, basic data structures using the C programming language. In-class lectures and discussions are supplemented by computer hands-on sessions.
NUMBER OF UNITS	3 units (Lec/Lab)
PREREQUISITE	Precalculus

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
write simple programs in C or other programming language, using the correct syntax, commands, functions, etc.									✓									✓			
design and complete a program to solve a nontrivial mathematical problem.							✓		✓									✓			

C. Course Outline

Week	Topics
1-2	Introduction to Computer Programming • Basic components of a computer • Overview of programming languages • Number systems and conversions • Overview of command shell • Problem-solving on a computer Introduction to C Language • Syntax and semantics • Elements of a C program • Basic I/O: printf, scanf
3-5	Basic DataTypes Identifiers, Keywords, Variables, Constants Operators and Precedence • Arithmetic • Boolean • Relational • Increment/Decrement
6-7	Type Conversions Control Structures • Statements and blocks • Conditional: if-else, switch, ternary operator • Looping: while, do-while, for • Others: break, continue
8-9	Functions Procedures
10-12	Arrays and Strings Pointers User-Defined Data Types
13-14	Manipulating Files Searching and Sorting • Linear search • Binary search • Bubble search

D. Suggested Teaching Strategies

- Lectures, case studies, programming exercises, group discussions, computer demonstrations

E. Suggested Assessment / Evaluation

- Quizzes, midterm exam, final exam, machine problems, programming project

F. Learning Resources

a. Textbooks/References
   - Kernighan and Ritchie. The C Programming Language
   - Kelly and Pohl. C by Dissection-The Essentials of C Programming
   - Goldstein and Gritz. Hands-on Turbo C

FUNDAMENTALS OF COMPUTING II

A. Course Details

COURSE NAME	**Fundamentals of Computing II**
COURSE DESCRIPTION	This course covers advanced programming concepts and techniques using Java, C++ or other suitable object-oriented programming languages. Topics include recursion, abstract data types, advanced path structures, programming interfaces, object-oriented programming, inheritance, polymorphism, event handling, exception handling, API programming. In-class lectures and discussions are supplemented by computer hands-on sessions.
NUMBER OF UNITS	3 units (Lec/Lab)
PREREQUISITE	Fundamentals of Computing I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
recall the correct usage of the various functions and keywords of the programming language																					
write short programs using the appropriate functions and procedures of the language									✓								✓	✓			
determine if a completed program, or a part of it, runs according to the specified requirements									✓								✓				

design and complete a working program that combines several parts and modules to solve a mathematical problem							✓		✓								✓	✓			
analyze the efficiency of a completed program							✓		✓								✓				

C. Course Outline

Week	Topics
1-2	The way of the program • The Python programming language • What is a program? • What is debugging? • Formal and natural language Variables, expressions and statements • Values and types • Variables • Variable names and keywords • Statements • Operators and operands • Expressions • Order of operations • String operations Functions • Function calls • Type conversion functions • Math functions • Composition • Adding new functions • Definitions and uses • Flow of execution • Parameters and argument
3-5	Conditionals and recursion • Modulus operator • Boolean expressions • Logical operators • Conditional execution • Alternative execution • Chained conditionals • Nested conditionals • Recursion • Stack diagrams for recursive functions • Infinite recursion • Keyboard input Fruitful functions • Return values • Incremental development • Composition • Boolean functions • More recursion

	Iteration • Multiple assignment • Updating variables • The while statement • Break Strings • A string is a sequence • Traversal with a for loop • String slices • Strings are immutable • Searching • Looping and counting • String methods • The in operator • String comparison
6-8	Lists • A list is a sequence • Lists are mutable • Traversing a list • List operations • List slices • List methods • Map, filter and reduce • Deleting elements • Lists and strings • Objects and values • Aliasing • List arguments Dictionaries • Dictionary as a set of counters • Looping and dictionaries • Reverse lookup • Dictionaries and lists • Memos • Global variables Tuples • Tuples are immutable • Tuple assignment • Tuples as return values • Variable-length argument tuples • Lists and tuples • Dictionaries and tuples • Comparing tuples • Sequences of sequence
9-12	Files • Persistence • Reading and writing • Format operator • Filenames and paths • Catching exceptions • Databases • Pickling

	• Pipes • Writing modules Classes and objects • User-defined types • Attributes • Rectangles • Instances as return values • Objects are mutable • Copying Classes and functions • Time • Pure functions • Modifiers • Prototyping versus planning Classes and methods • Object-oriented features • Printing objects • The init method • The str method • Operator overloading Type-based dispatch • Polymorphis • Inheritance • Card objects • Class attributes • Comparing cards • Decks • Printing the deck • Add, remove, shuffle and sort • Inheritance • Class diagrams

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry, programming exercises, computer lab sessions

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Downey, Allen. Think Python. O'Reilly Media. 2012. Also accessible at http://faculty.stedwards.edu/mikek/python/thinkpython.pdf
- Zelle, John. Python Programming: An Introduction to Computer Science, 2nd Edition. Franklin, Beedle and Associates Inc. 2010.
- "The Python Tutorial". Docs.Python.Org. October, 2013. <docs.python.org/3/tutorial/index.html>
- "Non-Programmer's Tutorial for Python 3". Wikibooks. October, 2013 < http://en.wikibooks.org/wiki/Non-Programmer%27s_Tutorial_for_Python_3>

A. Course Details

COURSE NAME	**Linear Algebra**
COURSE DESCRIPTION	This course covers matrices, systems of linear equations, vector spaces, linear independence, linear transformations, determinants, eigenvalues and eigenvectors, diagonalization, and inner product spaces.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Fundamental Concepts of Mathematics
COREQUISITE	Abstract Algebra I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
define and illustrate basic concepts in Linear Algebra.						✓							✓			✓					✓
apply the appropriate tools of Linear Algebra to obtain the solutions to a given problem.						✓	✓		✓				✓			✓	✓	✓	✓		
construct a basis for a given vector space or subspace.						✓	✓		✓				✓			✓			✓		
represent linear transformations and quadratic forms with matrices, and describe properties of these functions based on the matrix representation.						✓	✓		✓				✓			✓	✓	✓	✓		
determine the eigenvalues and associated eigenvectors of a matrix/linear transformation							✓		✓		✓		✓			✓		✓			
use the Gram-Schmidt orthonormalization process to construct an orthonormal basis for a given inner product space						✓	✓		✓		✓		✓			✓	✓	✓			

C. Course Outline

Week	Topics
1	• Matrices • Matrix operations and their properties • Transpose of a matrix
2	• Special types of square matrices • The echelon form of a matrix • Elementary matrices and row equivalence
3	• Systems of linear equations • The Inverse of a Matrix
4-5	• Determinants and their properties • Cofactors • The adjoint of a matrix • Cramer's rule
6-8	• Vector Spaces: Definition and examples • Subspaces • Linear Combinations and spanning sets • Linear Independence • Basis and dimension • Rank of a matrix
9-11	• Isomorphism of vector spaces • Linear transformations: definitions and examples • Kernel of a linear transformation • Range, nullity and rank • Dimension Theorem • Nonsingular linear transformations • Matrix of a linear transformation • Similarity
12-13	• Eigenvalues and eigenvectors • Characteristic polynomial • Hamilton-Cayley theorem • Diagonalization
14-15	• Inner product spaces • Orthogonal basis • Gram-Schmidt orthogonalization • Diagonalization of symmetric matrices
16	• Quadratic forms • Positive definite matrices

D. Suggested Teaching Strategies

- Lectures, exercises, group discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, long exams, midterm, final exam, exploration (real-life application of linear algebra)

F. Learning Resources

A. References

- Kolman. Elementary Linear Algebra
- Finkbeiner. Introduction to Matrices and Linear Transformations
- Herstein. Topics in Algebra
- Lang. Linear Algebra

A. Course Details

COURSE NAME	**Mathematical Modeling**
COURSE DESCRIPTION	This course is an application of mathematics to various fields. It introduces discrete and continuous models, model fitting and optimization. Applications involve real-world problems from business, engineering, and life sciences. Lectures are supplemented by computer laboratory sessions.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Fundamentals of Computing I, Differential Equations I, Linear Algebra

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
identify a problem involving a physical system						✓	✓	✓			✓		✓	✓		✓	✓	✓		✓	✓
make assumptions on a physical system and develop a mathematical model						✓	✓	✓	✓		✓		✓	✓		✓	✓	✓		✓	✓
apply appropriate mathematical tools to solve the problem						✓	✓	✓	✓		✓			✓		✓	✓	✓			
analyze and validate the model						✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		
rework the model, if necessary						✓	✓	✓	✓		✓		✓			✓	✓	✓		✓	
assess and articulate what type of modeling techniques are appropriate for a given physical system						✓	✓	✓	✓	✓	✓		✓			✓	✓	✓		✓	✓
make predictions of the behavior of a given physical system based on the analysis of its mathematical model						✓	✓	✓	✓	✓	✓				✓	✓	✓	✓		✓	✓

C. Course Outline

Week	Topics
1-4	Discrete Models • Linear models • Discrete models • Systems
5-7	Model Fitting • Fitting model to data graphically • Analytical methods of model fitting • Applying the least-squares criterion • Choosing a best model
8-10	Optimization of Discrete Models • Linear Programming I – geometric solutions • Linear Programming II – algebraic solutions • Linear Programming III – the simplex method
11-16	Continuous Models • Linear models • Nonlinear models • Systems

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, computer sessions, group work, individual inquiry

E. Suggested Assessment / Evaluation

- Problem sets, seatwork, final exam

F. Learning Resources

A. References

- Frank R. Giordano, William P. Fox and Steven B. Horton. A first Course in Mathematical Modeling, 5th Ed., Cengage Learning, 2014.
- Linda S.J. Allen, An Introduction to Mathematical Biology, Pearson-Prentice Hall, 2007..
- Leah Edelstein-Keshet, Mathematical Models in Biology, SIAM (Society for Industrial and Applied Mathematics), Philadelphia (reprint), 2004.
- Cleve Moler, Experiments with MATLAB, MathWorks, Inc., 2001, http: //mathworks.com/moler
- Douglas D. Mooney and Randall J. Swift, A Course in Mathematical Modeling, Mathematical Association of America, 1999.

MODERN GEOMETRY (EUCLIDEAN AND NON-EUCLIDEAN GEOMETRY)

A. Course Details

COURSE NAME	**Modern Geometry (Euclidean and Non-Euclidean Geometry)**
COURSE DESCRIPTION	The first part of the course focuses on Euclidean and affine geometry on the plane. The second half may continue with Euclidean geometry on the sphere; alternatively, an introduction to finite geometries and to the non-Euclidean hyperbolic and elliptic geometries may be given. This course interrelates and makes use of tools from Geometry, Linear Algebra and Abstract Algebra.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Linear Algebra and Abstract Algebra I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
prove geometric statements using a variety of methods (e.g. synthetic, analytic) with appropriate logical arguments and mathematical rigor.						✓			✓							✓	✓		✓	✓	
identify desirable features of axiomatic and deductive systems such as consistency and completeness.						✓			✓							✓	✓		✓	✓	
describe the basic transformations (e.g. Euclidean, affine, orthogonal)						✓			✓							✓	✓		✓	✓	
explain the significance of Euclid's Fifth Postulate and construct equivalent statements						✓			✓							✓	✓		✓	✓	
describe some models of non-euclidean geometries and finite geometries						✓			✓							✓	✓		✓	✓	
identify properties of small finite geometries						✓			✓							✓	✓		✓	✓	
evaluate the role and contributions of geometry to mathematics, culture and society						✓			✓	✓						✓	✓	✓	✓	✓	

C. Course Outline

Week	Topics

1-5	A. Plane Euclidean Geometry
	• Review
	    ○ Coordinate Plane
	    ○ The Vector Space R^2
	    ○ The Inner-Product Space R^2
	    ○ The Euclidean Plane E^2
	• Lines
	• Orthonormal pairs
	• Equation of a line
	• Perpendicular lines
	• Parallel and intersecting lines
	• Reflections
	• Congruence and isometries
	• Symmetry groups
	• Translations, Rotations, Glide reflections
	• Structure of the isometry group
	• *Fixed points and fixed lines of isometries*

6-8	B. Affine Transformations in the Euclidean Plane* • Affine transformations • Fixed lines • The 2-dimensional affine group • Fundamental theorem of affine geometry • Affine reflections • Shears • Dilatations • Similarities • Affine symmetries
9-11	C. Geometry on the Sphere* • Preliminaries from 3-dimensional Euclidean space • The cross-product • Orthogonal bases • Planes • Incidence geometry of the sphere • The triangle inequality • Parametric representation of lines • Perpendicular lines • Motions of the sphere • Orthogonal transformations of Euler's theorem • Isometries • *Fixed points and fixed lines of isometries*

9-11	D. Finite Geometries*
	• Introduction to finite geometries
	    ○ Axiomatic systems
	    ○ Four-line and four point geometries
	• Finite geometries of Fano and Young
	• Finite geometries of Pappus and Desargues
	• Finite geometries as linear spaces
	    a. Near-linear and linear spaces

	b. Incidence matrices c. Numerical properties • Finite projective planes and projective spaces • *Finite affine spaces*
12-16	E. Non-euclidean geometries • Euclid's Fifth Postulate • Introduction to hyperbolic geometry ○ Fundamental postulate of hyperbolic geometry ○ Ideal points and omega triangles ○ Quadrilaterals and triangles • Introduction to elliptic geometry ○ Characteristic postulate of elliptic geometry ○ Quadrilaterals and triangles

Note: *Two of the three main topics in weeks 6 to 11 may be chosen.* *Italicized items are optional.*

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam, individual/group project

F. Learning Resources

A. References

- Ryan. Euclidean and Non-Euclidean Geometry (for weeks 1, 2 and 3)
- Wald. Geometry: An Introduction
- Greenberg. Euclidean and Non–Euclidean Geometries: Development & History
- Batten, Combinatorics of Finite Geometries (for week 4)
- Smart, Modern Geometries (for week 5)

MODERN GEOMETRY (PROJECTIVE GEOMETRY)

A. Course Details

COURSE NAME	**Modern Geometry (Projective Geometry)**
COURSE DESCRIPTION	This course covers projective planes, projectivities, analytic projective geometry, cross ratio and harmonic sequences, geometric transformations, and isometries.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Linear Algebra

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
show how projective geometry relates to Euclidean geometry									✓							✓	✓		✓	✓	
describe the properties of projective geometry and projective planes									✓							✓	✓		✓	✓	
illustrate the principle of duality									✓							✓	✓		✓	✓	
define the terms "point at infinity (or ideal point)" and "line at infinity."									✓							✓	✓		✓	✓	
outline the proofs and consequences of the theorems of Pappus and Desargues									✓							✓	✓		✓	✓	
illustrate the concepts of "perspective from a line" and "perspective from a point"									✓							✓	✓		✓	✓	
compute the cross ratio and illustrate its projective invariance									✓							✓	✓				
illustrate harmonic sets, harmonic conjugates and complete quadrangles									✓							✓	✓				
work effectively with homogeneous coordinates									✓							✓	✓				

C. Course Outline

Week	Topics
1	Introduction and Historical Background • From Euclidean geometry to non-Euclidean geometry • Some geometries: hyperbolic, elliptic, inversive and projective
2-3	The Projective Plane • Axioms of the projective plane • Principle of duality • Number of points/lines n a finite projective plane • Applications
4-5	Triangles and Quadrangles • Definitions • Desarguesian plane • Harmonic sequence of points/lines
6-7	Projectivities • Central perspectivity • Projectivity • Fundamental theorem of projective geometry • Theorem of Pappus

8-9	Analytic Projective Geometry • Projective plane determined by a three-dimensional vector space over a field • Homogeneous coordinates of points/lines • Line determined by two points • Point determined by two lines • Collinearity, concurrency
10-11	Linear Independence of Points/Lines • Definition • Analytic proof of some theorems like Desargues' Theorem
12	The Real Projective Plane • Ideal points • Ideal line
13	Matrix Representation of Projectivities • Derivation of matrix representation • Fundamental theorem of projective geometry (analytic approach)
14	Geometric Transformations* • Affine transformations and the affine plane • Similarity transformation • Homothetic transformation
15-16	Isometries* • Types of isometries • Products of isometries • Application of isometries to the solution of some geometric problems

*If time permits

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Coxeter and Greitzer. Geometry Revisited
- Smart. Modern Geometry
- Hughes and Piper. Projective Planes

A. Course Details

COURSE NAME	**Numerical Analysis**
COURSE DESCRIPTION	This is an introductory course that covers error analysis, solutions of linear and nonlinear equations and linear systems, interpolating polynomials, numerical differentiation and integration, numerical approximations of eigenvalues, and numerical solutions of ordinary differential equations.
NUMBER OF UNITS	3 units (Lec/Lab)
PREREQUISITE	Differential Equations I and Linear Algebra

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
choose and use the appropriate method to obtain a numerical solution to a given mathematical problem.						✓	✓		✓				✓				✓				
implement a specified numerical method using available software.							✓		✓									✓			
compute the error of the estimate provided by a given numerical method.																					
compare the accuracy of the estimates provided by different numerical methods for solving a given problem.							✓	✓	✓				✓				✓	✓		✓	✓
discuss a real-life application of a numerical method.							✓	✓	✓		✓		✓				✓	✓			✓

C. Course Outline

Time Allotment	Topics
2 hours	Mathematical Preliminaries • Intermediate Value Theorem • Extreme Value Theorem • Rolle's Theorem and the Mean Value Theorem • Taylor's Theorem

4 hours	Error Analysis and Computer Arithmetic • Floating point arithmetic • Error • Accuracy • Convergence of solutions
7 hours	Solutions of Nonlinear Equations • Bracketing methods • Fixed Point methods • Newton's method • Secant method
6 hours	Solutions of Linear Systems • Gaussian elimination • LU-Decomposition • Gauss-Seidel method • Gauss-Jacobi method
8 hours	Numerical Interpolation • Lagrange Interpolation • Divided differences • Interpolation at equally spaced points: Newton's and Gauss' formulas • Cubic splines
8 hours	Numerical Differentiation and integration • Newton's formulas • Finite differences • Trapezoidal rule • Simpson's rules • Romberg integration • Gaussian integrals

8 hours	Numerical Solutions of Ordinary Differential Equations
	• One-step methods
	    ○ Euler's method
	    ○ Taylor series method
	    ○ Runge-Kutta methods
	• Multi-step methods
	    ○ Adams' corrector-predictor formulas
	    ○ Milne's method

5 hours	Numerical Approximation of Eigenvalues and Eigenvectors • Power method • Inverse power and shifted power method • Rayleigh quotients • QR-Algorithm

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry, computer lab sessions,

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Atkinson. Elementary Numerical Analysis
- Gerald and Wheatley. Applied Numerical Analysis
- Kreysig. Advanced Engineering Mathematics
- Sastry. Introductory Methods of Numerical Analysis
- Scheid. Theory and Problems of Numerical Analysis

OPERATIONS RESEARCH I

A. Course Details

COURSE NAME	Operations Research I
COURSE DESCRIPTION	This course is an introduction to linear programming. It covers basic concepts, problem formulation, graphical solution for two-variable problems, simplex algorithm and other algorithms for special LP problems, duality and sensitivity analysis. In-class lectures and discussions are supplemented by computer hands-on sessions.
NUMBER OF UNITS	3 units (Lec/Lab)
PREREQUISITE	Linear Algebra

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
determine appropriateness of linear programming (LP) modeling as framework to investigate real-world problems								✓	✓		✓					✓	✓			✓	
develop LP models that consider key elements of real world problems								✓	✓							✓	✓		✓	✓	
solve the models for their optimal solutions									✓							✓	✓		✓	✓	
interpret the models' solutions and infer solutions to the real-world problems								✓	✓							✓	✓		✓	✓	
illustrate proficiency in the use of the simplex method and its variants and extensions									✓							✓	✓		✓	✓	

apply the principle of duality in solving LP problems									✓							✓	✓		✓	✓	
demonstrate proficiency in using appropriate mathematical software in solving problems.									✓							✓	✓		✓	✓	
apply parametric and integer programming whenever appropriate.								✓	✓							✓	✓		✓	✓	
develop a report that describes the formulation of a model, its solution, and analysis, with recommendations in language understandable to decision-makers		✓				✓		✓	✓							✓	✓		✓	✓	✓

C. Course Outline

Week	Topics

1	Overview of Operations Research
	• Definition of OR
	• The general optimization problem
	    ○ Survey of applications and introduction to some classical LP models
	    ○ The product mix problem
	    ○ The diet problem
	    ○ The transportation problem
	    ○ The fluid bending problem
	    ○ The caterer's problem

2	Linear Programming (LP)
	• Definition of linear programming
	• Formulation of verbal problems into LPs
	• Assumptions/Limitations:
	    ○ Proportionality
	    ○ Additivity
	    ○ Divisibility
	    ○ Nonnegativity
	    ○ Certainty
	    ○ Single objective

3	Geometry of LP in Two Variables • Graphing of linear inequalities • The feasible region as a convex polyhedral area • Geometric interpretation of convex combination • The extreme points • The objective function as a family of parallel lines
4	Review of Linear Algebra • Systems of linear equations • Canonical forms • Basic solutions • Basic feasible solution • Degenerate solutions • Inconsistent systems

F. Learning Resources

A. References

- Taha. Operations Research: An Introduction
- Gass. Linear Programming (Methods and Applications)
- Gillet. Introduction to Operations Research

PROBABILITY

A. Course Details

COURSE NAME	**Probability**
COURSE DESCRIPTION	This is an introductory course in probability covering axiomatic probability space, discrete and continuous random variables, special distributions, mathematical expectation, conditional probability and independence, multivariate distributions, Laws of Large Numbers, and the Central Limit Theorem.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Differential and Integral Calculus, Set Theory
COREQUISITE	Calculus III (Multivariate Calculus)

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
define basic terms in probability																					✓
perform and compute probabilities from experiments																	✓	✓			
define and give examples of mutually exclusive events and independent events																					✓
define a random variable and explain its usefulness in computing probabilities of events																					✓
enumerate the properties of a cumulative distribution function and probability distribution function																					✓
derive the probability distribution function from the cumulative distribution function																			✓		

and vice versa																					
name some commonly used special discrete and continuous distributions and their properties																					✓
give examples of experiments yielding special distributions																					
compute probabilities, means, and variances of special probability distributions							✓														
derive the distribution of a function of random variables using different techniques							✓										✓		✓		
explain the notion of a random vector																					✓
explain and give the properties of a joint cumulative distribution function and joint probability distribution																					✓
derive conditional distributions and marginal distributions																	✓		✓		
explain and show independence of random variables																	✓		✓		✓
compute mathematical and conditional expectations involving functions of a random vector							✓										✓				
construct sampling distributions and compute their means and variances							✓										✓				
explain the law of large numbers and the Central Limit Theorem																			✓		✓
discuss the importance of the Central Limit Theorem																					✓

C. Course Outline

Week	Topics
1-2	Probability • Sample spaces and events • Methods of assigning probabilities • Axiomatic approach to probability • Calculating probabilities • Conditional probability and independence • Bayes' rule
3-5	Random Variables, Distribution Functions and Expectation • Random variables • Distribution functions- definition and properties • Discrete and continuous random variables • Mathematical Expectation

6-8	Some Special Distributions • Discrete probability distributions-uniform, Bernoulli/binomial, Poisson, hypergeometric, and negative binomial/geometric distributions • Continuous probability distributions: uniform, normal/standard normal, gamma/exponential, Beta, Weibull, Cauchy
9-10	Functions Of Random Variables • Mathematical formulation • Distribution of a function of random variables-CGF technique, MGF technique, method of transformations • Expectation of functions of random variables
11-12	Joint and Marginal Distributions • The notion of a random vector • Joint distribution functions • Marginal distributions • Mathematical expectations
13-14	Conditional Distribution and Stochastic Independence • Conditional distributions • Stochastic independence • Mathematical expectation
15-16 4 hours	Sampling and Sampling Distributions
16-17 4 hours	Laws of Large Numbers and the Central Limit Theorem

D. Suggested Teaching Strategies

- Lecture, discussion, exercises (seatwork, boardwork, assignments, recitation, group work)

E. Suggested Assessment / Evaluation

- Class participation (recitation/ boardwork), Assignment, problem sets, quizzes, final exam

F. Learning Resources

A. References

- Hogg, Craig and Mckean. Introduction to Mathematical Statistics
- Larsen and Marx. Introduction to Mathematical Statistics and Its Applications
- Mood, Graybill and Boes. Introduction to the Theory of Statistics
- Ross. A First Course in Probability

A. Course Details

COURSE NAME	**Real Analysis**
COURSE DESCRIPTION	This course provides an introduction to measure and integration theory. It develops the theory of Lebesgue measure and integration over the real numbers. The course covers topics like the real number system, measurable functions, measurable sets, convergence theorems, integrals of simple and nonnegative measurable functions, and Lebesgue integral.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Advanced Calculus I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
demonstrate understanding of inner and outer measure by providing examples.									✓							✓	✓			✓	
determine when a set or function is measurable.									✓							✓	✓		✓	✓	
compare Riemann and Lebesgue integration.									✓							✓	✓			✓	
compute and solve Lebesgue integrals									✓							✓	✓			✓	
be familiar with the proof and applications of Fatou's Lemma and other convergence theorems.									✓							✓	✓		✓	✓	

C. Course Outline

Week	Topics
1	Introduction • Comparison between Lebesgue and Riemann integral • Countable and uncountable sets • The extended real number system • Infinite limits of sequences
2	Measurable functions Integral • Measurable sets • Measurable functions
3	Measures • Lebesgue measure • Measure spaces

4	Integrals • Simple functions and their integrals • The integral of a non-negative extended real-valued measurable function • The monotone convergence theorem • Fatou's lemma and properties of integrals
5	Integrable functions • Integrable real-valued functions • The positivity and linearity of the integral • The Lebesgue dominated convergence theorem
6	Modes of convergence • Relations between convergence in mean • Uniform convergence • Almost everywhere convergence • Convergence in measure • Almost uniform convergence • *Egoroff's Theorem* • *Vitali Convergence Theorem*
7	*The Lebesgue spaces Lp* • *Normed linear spaces* • *The Lp spaces* • *Holder's inequality* • *The completeness theorem* • *The Riesz's representation theorem for Lp*

Note: *Italicized items are optional topics.*

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Bartle. Elements of Integration and Lebesque Measure
- Chae and Soo Bong . Lebesgue Integration
- Royden. Real Analysis

STATISTICAL THEORY

A. Course Details

COURSE NAME	**Statistical Theory**
COURSE DESCRIPTION	This course is an introduction to statistics and data analysis. It covers the following: reasons for doing Statistics, collection, summarization and presentation of data, basic concepts in probability, point and interval estimation, and hypothesis testing.
NUMBER OF UNITS	3 units (Lec/Lab)
PREREQUISITE	Fundamental Concepts of Mathematics, Calculus III

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
demonstrate knowledge of the basic terms, concepts and procedures in statistics;						✓															
use appropriate methods of data collection and presentation;						✓	✓		✓								✓	✓			✓
summarize data using different numerical measures						✓	✓		✓		✓				✓		✓	✓			✓
demonstrate knowledge of the basic terms, concepts and procedures in statistics;						✓															
use appropriate methods of data collection and presentation;						✓	✓		✓								✓	✓			✓
apply rules of probability in handling probability sampling distributions;						✓	✓		✓								✓	✓			✓
make inferences about the mean and proportion of one and two populations using sample information through estimation and hypothesis testing;						✓	✓		✓		✓				✓		✓	✓			✓
investigate the linear relationship between two variables by measuring the strength of association and obtaining a regression equation to describe the						✓	✓		✓		✓					✓	✓	✓			✓

relationship																					
analyze data resulting from the conduct of experiments						✓	✓		✓		✓					✓	✓	✓			✓
guard against misuses of statistics						✓										✓	✓				✓

C. Course Outline

Week	Topics
1 (2 hours)	Introduction • Description and history of statistical science • Population and sample
2	Collection and Presentation of Data • Methods of data collection • Probability and non-probability sampling • Tabular and graphical presentations: frequency distribution, stem-and-left display, cross tabulation, histogram
3	Measures of Central Tendency and Location • Arithmetic mean, median and mode • Percentiles
4	Measures of Dispersion and Skewness • Measures of absolute dispersion • Measures of relative dispersion • Measure of skewness • The boxplot
5	Probability • Random experiments, sample spaces, events • Properties of probability
6-7 (5 hours)	Probability Distributions • Concept of a random variable • Discrete and continuous probability distributions • Expected values • The normal distribution • Other common distributions
8	Sampling Distributions
9-10	Estimation • Basic concepts of estimation • Estimating the mean • Estimating the difference of two means *(optional)* • Estimating proportions • Estimating the difference of two proportions *(optional)* • Sample size determination
11-13 (8 hours)	Tests of Hypothesis • Basic concepts of statistical hypothesis testing • Testing a hypothesis on the population mean • Testing a hypothesis on the population proportion • Testing the difference of two means • Testing the difference of two proportions • Test of independence
13-15 (8 hours)	Regression and Correlation • The correlation coefficient

	• Testing a hypothesis on the correlation coefficient • Simple linear regression
16	Analysis of Variance

D. Suggested Teaching Strategies

- Lecture, discussion, exercises, computer laboratory sessions, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, final exam, individual/group reports, problem sets

F. Learning Resources

A. References

- Hayter, A. (2002). Probability and Statistics for Engineers and Scientists (2nd edition). CA: Duxbury.
- Levine, Berenson & Stephan (2002). Statistics for Managers Using Microsoft Excel (3rd edition). Upper Saddle River, NJ: Prentice Hall
- Mann, P. (2010). Introductory Statistics (7th edition). Hoboken, NJ: Wiley.
- Mendenhall, Beaver & Beaver (2009). Introduction to Probability and Statistics (13th edition). Belmont, CA: Thomson/Brooke/Cole.
- Walpole, Myers, Myers & Ye (2005). Probability and Statistics for Engineers and Scientists (7th edition). Singapore: Pearson Education (Asia).

THEORY OF INTEREST

A. Course Details

COURSE NAME	**Theory of Interest**
COURSE DESCRIPTION	This course covers measures of interest, present and future values, equations of value, annuity certains, general annuity certains, yield rates, extinction of debts, and bonds and securities.
NUMBER OF UNITS	3 units (Lec/Lab)
PREREQUISITE	Calculus III

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME																				
At the end of this course, the students should be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
apply appropriate formulas, concepts and procedures to solve various investment problems.							✓	✓	✓								✓				
distinguish different types of interest rates and how to use these in finding the present value or future value of an investment. Moreover, learn how to compare these rates to make sound judgment as to which rate gives the best return.							✓		✓		✓						✓	✓			
recognize different types of annuities and learn how to find its value at the start, at the end and on any date within or outside its term.							✓		✓		✓						✓	✓			
learn to track the growth/diminution of an investment/a loan.							✓	✓	✓		✓						✓	✓			
determine the value/price, as well as the yield rate of different types of financial instruments like stocks and bonds at different dates during its term.							✓	✓	✓		✓						✓	✓			

C. Course Outline

Time Allotment	Topics
6 hours	Measures of Interest • Accumulation and amount functions • Simple and compound interest • Effective rate of interest • Present and future values • Nominal rates of interest and discount • Force of interest
4 hours	Equations of Value • Present and future values • Current value equation • Unknown time and unknown interest rate
6 hours	Annuity Certain • Annuity immediate • Annuity Due

6 hours	General Annuities • Annuities payable less frequently than interest is convertible • Annuities payable more frequently than interest is convertible • Continuous annuities • Basic varying identities • More general varying identities
8 hours	Yield Rates • Discounted cash flow analysis • Definition of yield rates • Uniqueness of the yield rate • Reinvestment rates • Interest measurement of a fund • Dollar-weighted rate of interest for a single period • Time-weighted rates of interest • Portfolio methods • Investment year methods
6 hours	Extinction of debts • Loan extinction • Computation of the outstanding balance • Amortization method • Sinking fund method
10 hours	Bonds and Securities • Basic financial securities • Bonds and stocks • Price of a bond (FRANK formula) • Other formulas for the bond • Premium and discount • Valuation between coupon payment dates • Yield rates and the Bond Salesman's Formula • Callable bonds • Serial bonds and stocks

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Skills check (boardwork, quizzes, long exam), individual/group report, individual/group project, final exam

F. Learning Resources

A. References

- William Hart. Mathematics of Investment
- Stephen Kellison. The Theory of Interest
- Shao and Shao. Mathematics for Management and Finance

TOPOLOGY

A. Course Details

COURSE NAME	**Topology**
COURSE DESCRIPTION	This course is an introduction to topology. It includes topics fundamental to modern analysis and geometry like topological spaces and continuous functions, connectedness, compactness, countability axioms, and separation axioms.
NUMBER OF UNITS	3 units (Lec)
PREREQUISITE	Advanced Calculus I

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	**PROGRAM OUTCOME**																				
At the end of this course, the students should be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**
Determine whether a collection of subsets of a set determines a topology.									✓							✓	✓			✓	
Prove that certain subsets of Euclidean space are topologically equivalent.									✓							✓	✓		✓	✓	
Understand notion of connectedness and be familiar with some standard applications									✓							✓	✓		✓	✓	
Use the definitions of the subspace, product, and quotient topologies to prove their properties and be familiar with standard examples.									✓							✓	✓		✓	✓	
Recognize when a topological space is compact and be familiar with basic properties of compact spaces.									✓							✓	✓		✓	✓	
Develop the concept of metric spaces.									✓							✓	✓		✓	✓	
Recognize when a topological space is connected and be familiar with basic properties of connected sets.									✓							✓	✓		✓	✓	
Demonstrate understanding of countability and separation axioms and illustrate their uses.									✓							✓	✓		✓	✓	

C. Course Outline

Week	Topics
1	Review of Fundamental Concepts of Set Theory and Logic
2	Topological Spaces and Continuous Functions • Topological spaces • Basis for a topology • Continuous functions and homeomorphisms • Construction of subspace, product, quotient, and sum topologies • Closed sets and limit points • The metric topology and the metrization problem
3	Connectedness and Compactness • Connected spaces • Connected sets in the real line • Compact spaces • Tychonoff's Theorem • Compact sets in the real line • Limit point compactness
4	Countability and Separation Axioms • The countability axioms • The separation of axioms and characterization of various spaces • *The Urysohn Lemma: Tietze Extension Theorem* • *The Urysohn Metrization Theorem*

Note: *Italicized items are optional topics.*

D. Suggested Teaching Strategies

- Lectures, exercises, discussion, individual inquiry

E. Suggested Assessment / Evaluation

- Quizzes, problem sets, long exams, midterm exam, final exam

F. Learning Resources

A. References

- Munkres. Topology: A First Course
- Simmons. Topology and Modern Analysis
- Engelking and Sieklucki. Introduction to Topology
- Jänich. Topology
- Kahn. Topology, An Introduction to the Point-Set and Algebraic Areas
- Dixmier. General Topology

ABSTRACT ALGEBRA I — **Sample Final Examination**

Directions: Answer the following as indicated and in the given order. In each case, show your complete solution.

I. Answer each item. For true or false items, explain why or give a counterexample if your answer if F. (3 pts each for items 1 to 6)

1. True or False: The element (4,2) of $\mathbb{Z}_{12} \times \mathbb{Z}_8$ has order 12.
2. True or False: The order of the coset $14 + \langle 8 \rangle$ in the factor group $\mathbb{Z}_{24}/\langle 8 \rangle$ is 3.
3. True or False: $12\mathbb{Z}$ is a maximal ideal of $3\mathbb{Z}$.
4. True or False: There is a homomorphism of the symmetric group S_3 into $\mathbb{Z}_6$.
5. Let G and H be groups. What is the kernel of the homomorphism $\varphi : G \times H \to G$ given by the map $(g, h) \mapsto g$.
6. Define: *ideal of a ring* and *prime ideal* and give examples of each.
7. Give an example of a relation on $\mathbb{Z}$ that is not symmetric. (2 pts)

II. Do all. Explain all work. (10 pts each)

1. Let $g = (1\ 4)$, $h = (2\ 1\ 5)$ and $f = (3\ 4\ )$ be permutations in S_5.
   (a) Write ghf as a single permutation.
   (b) Is ghf odd or even?
   (c) What is the inverse of gf?
   (d) What is the order of hf?
2. (a) State Lagrange's Theorem.
   (b) Give one of its corollaries.
   (c) Give a proof of either Lagrange Theorem or the corollary you stated in (b).
3. (a) Solve for x in the equation $x^3 + 2x^2 - 3x = 0$ in the ring $(\mathbb{Z}_{11}, +, \cdot)$.
   (b) Find the group of units $(U(\mathbb{Z}_{18}), \cdot)$ in the ring $\mathbb{Z}_{18}$ under addition and multiplication modulo 10.
   (c) What group is $(U(\mathbb{Z}_{18}), \cdot)$isomorphic to?
4. Let $G = \mathbb{Z}_4 \times \mathbb{Z}_4$, under component-wise addition modulo 4. Let $H = \langle (1, 2) \rangle$.
   (a) List down the elements of H and G/H.
   (b) Is $(2, 1) + H = (1, 3) + H$? Why or why not?
   (c) To which known group is G/H isomorphic and why?
5. Let $\phi : G \to G'$ be a homomorphism, where G and G' are finite groups.
   (a) Show that the kernel of ϕ is a subgroup of G.
   (b) Show that $|\phi(G)|$ divides both $|G'|$ and $|G|$.
6. Let G be a group with identity e for which $x^2 = e$ for all x in G.
   (a) Show that G is abelian.
   (b) Show that for any elements $a, b, c, d \in G$, if $ab = cd$ then $ac = bd$.
7. (a) Let $\phi : \mathbb{Z}_8 \to \mathbb{Z}_{24}$ be the homomorphism satisfying $\phi(7) = 4$. Find the kernel of ϕ, and the images of all the elements of $\mathbb{Z}_8$.
   (b) State the 1st Isomorphism Theorem for Groups.

End of Exam (Total: 100 points)