PROPOSAL 14-01

BS PROGRAM IN BIOINFORMATICS

The Senate approves the program as described below.

A. Executive Summary
This proposal is a formal request that Michigan Technological University offer a Bachelor of Science degree in Bioinformatics. Bioinformatics is the emerging field of biological sciences, which couples the fundamental biochemistry of organisms with computational analysis, thus providing a vast new insight into biological processes and organisms. This degree program will draw from and add a new strength to the existing programs in Biological Sciences and Computer Science. Bioinformatics is globally recognized as the growth area for the foreseeable future. There is tremendous need for qualified graduates in this field, and there are very few programs currently available that offer a Bachelor of Science degree in Bioinformatics. Establishment of this program at Michigan Tech will solidify the position of Michigan Tech as a university of choice for Bachelor of Science degree in Bioinformatics.

B. Need for the Proposed Program
The current revolutions in molecular biology, biotechnology and information technology are changing the world as we enter the 21st century. Advances in molecular genetics, protein science coupled with computer science, artificial intelligence, robotics and other technologies, have made significant inroads into the understanding of biological macromolecules. Large scale sequencing of genetic material from a variety of organisms is a part of the scientific landscape. While the sequence databases were compiled one gene at a time by individual research laboratories in the past; numerous genome sequencing projects in the recent years have produced the entire sequences of viruses, bacteria, and increasingly complex eukaryotic organisms including plants. The complete human genome, with its genetic code comprising of more than three billion base pairs of information, will soon be available.

The enormous amount of information contained in the sequence databases and their smaller structural counterparts represent a priceless resource for the future. Some of the applications that can be made available from this information include identification of genes responsible for various pathological conditions and genetic disorders, agriculturally and nutritionally important genes, genes with applications in pharmaceutical industry, the study of structural and functional relationships, the identification of targets for drug discovery, and work on molecular evolution and genetic relationships. The recent breakthroughs in computer science have made the storage, organization, analysis and utilization of these very large data collections a reality. All these emerging areas of science require a large number of qualified individuals. Many institutions have recently begun graduate programs relating to Bioinformatics. The students entering these programs come with diverse backgrounds and do not have a solid foundation in the requisite core program containing both biological and computer science oriented courses. Thus, there is a need for a dedicated undergraduate curriculum that is designed to provide a strong foundation in bioinformatics that would allow students to directly take up jobs after graduation or to be better suited to pursue more demanding bioinformatics graduate research. There is a great demand for students who have a Bioinformatics expertise both at undergraduate level and also students who are more experienced in specialized Bioinformatics graduate research. Most of these positions require graduates with a BS level education in Bioinformatics. Informal discussions with various members of several corporations indicate the need for hundreds of bioinformatics educated graduates to fill anticipated jobs over the next several years. However, many will be filled by students who have either MS or PhD degrees because there are no qualified students available with BS in Bioinformatics. At the present, there is only one other institution offering a dedicated program with a BS in Bioinformatics, RPI in NY. Two other programs, one from Penn State and another from UC Santa Cruz are still being developed.

C. Relevance to University Strategic Plan
The Bioinformatics initiative directly supports the strategic plan Goal 1 "Strategic objective 1.3 - Focus on programs with national recognition and in areas of critical needs". The BS program in bioinformatics will fill a critical need for students educated in this emerging area of biological sciences. The demand for graduates with these skills is observed in the job placement advertisements (e.g., Science) and from corporate inquiries and their anticipated hiring (e.g., Dow Agro).

The BS Bioinformatics will supply students for both corporate positions and graduate schools. Bioinformatics graduates will be sought after and improve MTU's national recognition and fill a critical need. The BS program will support growth in Graduate programs by providing well-educated students, and the faculty supporting the BS program will necessarily maintain active graduate research programs. We anticipate an enrollment of about 150 students in this program. This provides a class size of 35-40. Industry should be able to provide the appropriate number of coop positions based on our current information. This program will also broaden MTU's base of corporate contact and support.

D. Related Programs
There is only a handful of institutions across the nation that have initiated the process of offering BS in Bioinformatics (RPI, UC Santa Cruz). Within the state of Michigan, there are no Bioinformatics programs offered at BS level. The establishment and accreditation of Bioinformatics BS program at Michigan Tech will raise our level of competitiveness within the state and at national level. The addition of a new program within the state of Michigan is also justified by the statewide and a nation wide demand for Bioinformatics graduates. The current offerings in the BS programs in the Department of Biological sciences and Computer science provide a basis and also support for the proposed BS in Bioinformatics. Faculty in these departments also recognize the need for - and enthusiastically support - the initiation of this new degree program.

E. Program Administration
Administration of the proposed bachelor's degree program will be within the Department of Biological Sciences through the designated Coordinator of Bioinformatics.

The curriculum committee will be composed of representatives from the departments participating in this program (Biological Sciences, Chemistry, Computer Science, School of Forestry and Wood Products, Mathematical Sciences and Physics). The Chair of Biological Sciences in consultation with the Coordinator of Bioinformatics, and the Bioinformatics curriculum committee will be responsible for curriculum implementation and other administrative duties associated with the program. Furthermore, an industrial advisory board will provide external guidance for the program.

F. Faculty Resources and Institutional Impact
For academic year 2001-2002 the Departments of Biological Sciences, Computer Science, Mathematical Sciences and the School of Forestry and Wood Products will contribute one-time personnel and financial resources to initiate the coordination of program, cooperative agreement statements, and course offerings. With the demonstrated success of the program enrollment, the University will support at least two new faculty lines. The first position should be ideally in Microbial Genomics in Biological Sciences which will strengthen and enhance the current faculty expertise in genomics/Proteomics/Biomolecular modeling. The second faculty position should be a shared position within participating departments supporting the Bioinformatics initiative. (Biological Sciences, Chemistry, Computer Science, School of Forestry and Wood Products, Mathematical Sciences, Physics).

The Washington Advisory Group has explicitly identified the Bioinformatics area as an important program within the University Strategic Plan. Based on the current strengths in the Biological Sciences and Computer Science and, also because the Bioinformatics program represents an intersection of the existing curricula between these two departments, the addition of new faculty will provide the necessary critical mass sufficient to maintain the new program. The Bioinformatics

program success will increase the need for new course offerings. At least four new courses in Biological Sciences and one to two new courses need to be added in Computer Sciences. Three of these courses are already proposed and awaiting University approval BL2300 Molecular Biology for Bioinformatics, BL3300 Genomics, BL4500 Critical Discussions in Bioinformatics. As with all academic programs on campus the number of faculty in the areas of Bioinformatics should be linked to the overall growth, success, and needs of the program and its supporting departments.

The library holdings in this area are fairly broad due to existing research priorities of faculty in various departments. We anticipate the need to add two journal subscriptions to complete the holdings.

G. Facilities and Equipment

The Department of Biological Sciences in conjunction with the Department of Geological Engineering and Sciences and Remote Sensing Institute currently operates general purpose computing facilities that occupy approximately 3000 square feet on the 7th floor of Dow Building. These facilities include 60 Sun Ultra 10 and Ultra 60 Workstations, 6 multi processor Sun Ultra CPU servers and nearly 1 Terabyte of disk storage. High-resolution black and white and color laser and large format printing are provided. These facilities could handle another 150 students and maintain a 10 students per workstation ratio. These facilities with appropriate software can meet the Bioinformatics needs for 150 students. No new hardware is necessary. We also are working to harness the power of all the machines in the college in a distributed computing effort. New software from Sun has just made this possible and this can be made available for the Bioinformatics students. MTU is also entering into a partnership with Sun for computing in higher education. In addition to the existing hardware many software packages for DNA and protein analysis (BLAST, PHRED, FRAP, COGS, PROSITE, PFAM) are available from NIH and other places free for academic institutions. We do need specialized software packages for student training in DNA and Protein analysis, Molecular Modeling and Database development. These packages can be obtained for a one-time cost of about $15,000. Most of the teaching laboratories that deal with the core program for Bioinformatics are in place. However, for the specialized courses in genomics, proteomics, etc. we will need some additional equipment support for the teaching labs as well as service contracts on equipment currently in use, but not for instruction. This will be a more efficient way to maximize the utilization of equipment, without having to buy very expensive equipment solely for the use of teaching labs. We estimate $100,000 will be needed to update the teaching labs for teaching the specialized courses for the BS in Bioinformatics program. We plan to submit a grant proposal to NSF-ILI program to obtain the equipment. However, this requires a one to one match from Michigan Tech. In addition, we plan on seeking support from private organizations and foundations to obtain funds or equipment to develop the teaching labs.

We also anticipate that these additions and improvements to core facilities would facilitate the development of graduate level programs in Bioinformatics and biotechnology at Michigan Tech in the near future as well as allow us to compete more effectively for grant monies.

The Department of Computer Science currently has 80 workstations for student use in approximately 3000 square feet of floor space in Fisher Hall. Based on current usage, these facilities cannot support significant increase in use. Solutions to this problem include increasing the lab space and workstations in the Computer Science lab area, or providing access for Bioinformatic students from Computer Science through the Biological Sciences computing facilities. The computational support for Bioinformatics with emphasis in either concentration (Biological Sciences or Computer Science) can thus be handled through the Biological Sciences/Geological Sciences computational system with the addition of appropriate software.

H. Schedule

The proposed Bioinformatics program is proposed to begin Fall semester 2001. At that time, we anticipate having freshman, sophomores and possibly a few juniors in the program. A few degrees may be awarded in 2003, but the first significant graduating class will likely occur in 2004.

I. Curriculum Structure

The proposed curriculum was designed by a curriculum steering committee consisting of faculty from both the Department of Biological Sciences and the Department of Computer Science. The curriculum meets the general education and program-specific requirements that are set by Michigan Technological University. The primary focus for this program is to provide a right balance both in Biological Sciences and Informatics to make the graduates "desirable" for both entry-level positions in industry as well as for graduate programs. Since this is an interdisciplinary field, every student will be provided broad training in both fields through a core. At the same time the program allows an option to students at the junior and senior years to obtain a more in-depth and focused training in the cell-molecular biology area or informatics area. A preliminary plan for the curriculum is described in this proposal. However, the curriculum will be refined as the need arises and also as new faculty join the program.

A summative overview of the curriculum as proposed represented below with course listings under Degree Requirements (p10). The Degree Requirements encompass the essential components of the major disciplines. Within the General Education requirements students will be advised to enroll in HU3120 Technical & Scientific Communication.

Core Credits	
Biological Sciences	22
Chemistry	9
Computer Science	26
Mathematics	14
General Education	28
Concentration credits	17
Free Electives	12
Total BS Bioinformatics	128

The Concentration Area Menu is designed to allow student selection within their particular interest area of Bioinformatics. Students will be advised to develop a depth of knowledge within specific areas as their interest and coop opportunities dictate. The menu is broad to accommodate students with a variety of skills and interests entering bioinformatics from different fields.

Various options within this degree will emerge as the program develops. Among the options anticipated are: Statistical Genomics, Biomolecular Modeling, Computational Chemistry, and Molecular Dynamics. These options will allow students to focus within the "Concentration Area Menu." The concentration area menu course listing is purposely broad in anticipation of option development.

CO-OP Program in Bioinformatics

An important and mandatory part of the proposed BS in Bioinformatics program is the Co-op component. Co-op arrangements with various biotech, pharmaceutical and bioinformatics industries are being made to provide students with real life experience in this field. This approach will give students the training and preparation needed to compete effectively for the future job markets. In addition, the Bioinformatics program will also allow students to opt for graduate school or medical school.

We have already made contact with several biotech and Bioinformatics companies and obtained a tentative commitment from some of them to provide co-op experiences. We anticipate several dozen coop positions to be established from among these and other companies. In addition, we will also establish an Advisory Board consisting of members from Industry, Academia and Federal Agencies to guide and advise us as well as provide input about funding sources. The following is the list of companies and potential advisory board members. The names in bold indicate corporations and individuals from whom we have a positive support commitment.

Co-op program contacts have been made:

Dow-Agro

Corning Life Sciences

Celera Genomics

Biodiscovery Corp.

Millenium Biotech Corp.

Incyte Corp.

Advisory board members - in progress

Dr. Temple Smith - Boston University

Dr. Ron Phillips - Univ. of Minnesota

Dr. Jonathan Pevsner - Johns Hopkins

Dr. Leland Ellis - USDA National BI Program Leader

Dr. Sam Reddy - Director Ag Genomics Dow Agro

Dr. Anis Khimani - Product Manager Microarray Division Corning Life Sci.

Dr. Ricki Ryan - Celera genomics

J. BS in Bioinformatics Degree Program and Detailed Curriculum Structure

Bioinformatics approaches incorporate expertise from the biological sciences, physical and chemical sciences, computer science, and mathematics. Michigan Tech's bioinformatics undergraduate curriculum will include training in biochemistry and molecular biology, mathematics, chemistry, and physics. At the core of the program are courses in the theory and practice of bioinformatics, dealing with topics such as database design and search algorithms, sequence alignment, sequence analysis, and molecular modeling. The core also includes a co-op program for students to obtain real world experience in an industry setting.

The curriculum is flexible, allowing for dual majors with several other disciplines, including computer science, chemistry, mathematics and physics. Petition of courses as equivalent will be considered as the program and courses develop. Advanced courses are available through the biological sciences and the computer science programs, and chemistry and physics programs including a strong set of advanced laboratory courses. The choice of electives allows one to tailor the program to the needs of those students who intend to function primarily as molecular biologists with a computational background, or those who intend to be fully trained computer scientists with a knowledge of biological sciences. Students will be advised to select courses which provide a depth of knowledge within their interest areas of bioinformatics. This will provide a concentrated area of expertise. Extensive opportunities will be available to pursue undergraduate research in faculty laboratories through undergraduate research and honors research.

The program is structured to provide a comprehensive training for students to pursue careers or graduate studies in Bioinformatics or related fields. The program provides flexibility for students to pursue a BS in Bioinformatics or dual majors with Biological Sciences or Chemistry or Math or Computer science. The BS in Bioinformatics program will have 4 major theme areas of education: Biological, Molecular Sciences and Genomics; Mathematics and Statistics; Computer Science and Computational Biology; Chemistry. We anticipate the development of degree options from the concentration area menu such as Statistical Genomics, Biomolecular Modeling, Computational Chemistry, and Molecular Dynamics.

The co-op program is an important and mandatory part of the BS in bioinformatics to provide experience to students.

Year 1: BL1020 (4) General Biology II or

BL1040 Principles of Biology for non-majors

CH1110 (4) Univ. Chem I

CH1111 (1) Univ. Chem Lab

CH1120 (4) Univ. Chem II

MA1160 (4) Calculus with Technology I

MA2160 (4) Calculus with Technology II

CS1121 (3) Intro. Comp. Sci. I

CS1122 (3) Intro. Comp. Sci. II

General Ed requirements: (7)

Year 2: BL2100 (3) Principles of Biochemistry

BL2300 (3) Mol. Biol. for Bioinformatics. (Pre Req or Co-Req BL1020 or BL1040, and CH1120, and BL2100)

CS2321 (3) Foundations I

CS2322 (3) Foundations II

CS3421 (4) Computer Architecture

CONCENTRATION AREA MENU SELECTIONS:

BL2200 (3) Genetics

CH2410 (3) Organic Chemistry I

CH2420 (3) Organic Chemistry II

CH3500 (2) Phy. Chem for Life Sci.

FW2080 (3) Intro to Plant Biotechnology

MA3160 (3) Multivariable Calc. With Technology

MA3210 (3) Intro. to Combinatorics

PH2100 (3) College Physics I

PH2200(3) College Physics II

General Ed requirements: (6)

Year 3: BL3300 (4) Genomics

MA2720 (4) Statistical Methods

MA3720 (3) Probability

CS4321 (3) Introduction to Algorithms

CS4411 (4) Introduction to Operating Systems

CS4421 (3) Database Systems

CONCENTRATION AREA MENU SELECTIONS:

BL3210 (4) General Microbiology

BL4010 (3) Biochemistry I

BL4430 (3) Biol. Simulation techniques

BL4820 (3) Biochemical Techniques

CH3510 (3) Physical Chemistry I

CH3520 (3) Physical Chemistry II

MA4208 (3) Optimization and Graph Algorithms

MA4209 (3) Combinatorics and Graph theory

MA4720 (3) Design and Analysis of Experiments

General Ed requirements: (6)

Year 4: BL4030 (3) Mol. Biology

BL 4500 (2)(Capstone course) Critical Discussions in Bioinformatics

BL4840 (3) Mol. Techniques (pre req. 2300 or 2200, co. req 4030)

CONCENTRATION AREA MENU SELECTIONS:

FW4089 (3) Plant Bioinformatics

CH4710 (3) Chemical Principles in Biology

CH5560 (3) Computational modeling

CSE5200(3) Computational genomics

MA4760 (3) Mathematical Statistics I

MA4770 (3) Mathematical Statistics II

General Ed requirements: (9)

BS in Bioinformatics

Major Requirements

BL 1040 Principles of Biology **4 credits**

Basic principles through which biological systems operate. Topics include cell biology, structure, and function, energy production, genetics, physiology, diversity, evolution and ecology.

(or)

BL1020 General Biology II **4 credits**

Discussion of the major principles by which life is organized. Topics include scientific methods, biological chemistry, cell structure and organization, multicellular organization, diversity of organisms, energetics and photosynthesis, cellular reproduction genetics, gene structure and expression, and recombinant DNA.

BL2100 Principles of Biochemistry **3 credits**

Introductory overview to biochemistry. Topics include the biochemistry of amino acids, proteins, coenzymes, carbohydrates, nucleotides, nucleic acids, lipids and water, as well as bioenergetics and photosynthesis.

New Course

BL2300 Molecular Biology for Bioinformatics **3 credits**

Introduction to Cell and Molecular biology, proteins, genes, gene structures, expression and regulation. Topics covering various molecular tools and applications in medicine, agriculture and biotechnology.

New Course

BL3300 Introduction to Genomics **4 credits**

Introduction to Genome structure organization and analysis. Topics covered include various aspects of organization and structure of genomes, rationale for genome mapping, assembling of physical maps, strategies and techniques for genome sequencing and analysis. Expression profiling by microarray/genechip, proteomics, etc.

BL4030 Molecular Biology **3 credits**

Molecular biology of gene structure, expression and regulation. Also topics covering various molecular techniques and applications of these techniques and biotechnology.

New Course

BL4500 Discussions in Bioinformatics **2 credits**

Critical discussions on current topics in bioinformatics. Oral written presentations requiring synthesis of information from various sources including primary literature.

BL4840 Molecular Biology Techniques **3 credits**

Laboratory techniques in molecular biology, including methods of recombinant DNA technology for identification, cloning, and characterization of genes.

CH1110 University Chemistry I **4 credits**

An introduction to the experimental and theoretical foundations of chemistry, including electronic structure of atoms and molecules, intermolecular forces, states of matter, chemical reactions, gas laws, thermochemistry, and chemical kinetics. Not recommended for students in programs requiring only one semester of first-year chemistry.

CH1111 University Chemistry Lab 1 **1 credit**

Laboratory to accompany CH1110.

CH1120 University Chemistry II **4 credits**

A continuation of CH1110, this course introduces more complex concepts in chemistry including kinetics, chemical equilibria, acid-base equilibria, thermodynamics, electrochemistry, and chemical analysis. Additional topics may include chemistry of the metals and non-metals, biochemical systems and nuclear chemistry. Includes laboratory component that emphasizes lecture concepts.

CS1121 Intro to Computer Science I **3 credits**

Starting point of the computer science program. A high-level, object-oriented programming language is introduced as a problem-solving tool. Topics include design, coding, documentation, debugging and testing of program. Programming assignments are given in both a closed lab setting and as homework.

CS1122 Intro to Computer Science II **3 credits**

Continuation of CS1121. Topics include object-oriented design, defining and using classes, complexity-based algorithm choices, data abstraction, simple data structures, pointers, recursion, and software development concepts. Homework programming assignments are given.

CS2321 Foundations I **3 credits**

This course presents a unifying foundation of important topics in computer science including topics in discrete structures (propositional calculus, boolean algebra, sets, relations, functions, recurrence relations, combinatorics, and mathematical induction): additional data structures (ADT's, trees, tables): and, programming projects designed to apply these concepts.

CS2322 Foundations II **3 credits**

A continuation of CS2321. A unifying presentation of important computer science topics in discrete structures (predicate calculus, graphs, recursion, inductive proofs): additional data structures (graphs, queues, lists): formal languages regular expressions and grammars, abstract machines (finite state machines, Turing machines and others) and, programming projects designed to apply these concepts. It also covers system design.

CS3421 Computer Architecture **4 credits**

Introduction to the logical structure of computers, including the fundamentals of logic design, information storage and manipulation, control, input/output, and assembly language programming. Topics include a review of current hardware technology, combinational and sequential logic, arithmetic, datapaths, hard-wired control, interrupts, caches, virtual memory, and an introduction to pipelining.

CS4321 Introduction to Algorithms **3 credits**

Techniques for design and analysis of computer algorithms. Topics include asymptotic notation, methods for solving recurrences, divide-and-conquer algorithms, dynamic programming, greedy algorithms, graph algorithms, NP-completeness.

CS4411 Intro to Operating Systems **4 credits**

This course presents topics on program representation and execution: operating systems, process and threads, process scheduling, memory management, file systems, network programming and security and privacy.

CS4421 Database Systems **3 credits**

Topics include goals of database management: data definition, data models, data normalization, data retrieval and manipulation, security, integrity, and privacy measures, file, data, and storage organization, object-database systems, and parallel and distributed databases. Surveys a number of general database systems and examines in detail at least one database system.

MA1160 Calculus with Technology I **4 credits**

An introduction to single-variable calculus, which includes a computer laboratory. Topics include trigonometric, exponential, and logarithmic function, differentiation and its uses, and basic integration. This course integrates symbolic tools, graphical concepts, data and numerical calculations.

MA2160 Calculus with Technology II **4 credits**

Continued study of calculus, which includes a computer laboratory. Topics include integration and its uses, function approximation, vectors, and elementary modeling with differential equations.

MA2720 Statistical Methods **4 credits**

Introduction to the design and analysis of statistical studies. Topics covered include methods of data collection, descriptive and graphical methods, probability, statistical inference on means, regression and correlation, and single variable ANOVA. Not open to mathematics majors or students with credit in MA3710.

MA3720 Probability **3 credits**

Introduction to probabilistic methods. Topics include probability laws, distribution theory and limit theorems; elementary statistics, parameter estimation, reliability, introduction to random processes and their properties.

UN3002 Cooperative Laboratory **2 credits**

Offered by each participating college or school - the free elective option of cooperative education. Requires 2.20 GPA or better, registration with the Office of Cooperative Education, acceptability by a recognized employer. In addition, transfer students must have completed at least one full-time semester on the MTU campus.

Concentration Requirements

Select 21 credits from courses listed below:

BL2200 Genetics **3 credits**

A study of classical and molecular genetics. Topics include one- and two-locus genetics, recombination, gene structure, regulation and function, quantitative and population genetics, and genetic engineering. Both prokaryotes and eukaryotes are covered.

BL3210 General Microbiology **4 credits**

Introduction to the general principles and techniques involved in the study of microorganisms, including bacteria, fungi, and viruses. Topics to be covered include cell structure and function, growth, metabolism, biodiversity, and interactions.

BL4010 Biochemistry I **3 credits**

Structure, chemical properties, and function of important biomolecules, such as proteins, carbohydrates and lipids. Enzyme chemistry (structure, catalysis, kinetics, and inhibition) is introduced.

BL4430 Biological Simulation Techniques **3 credits**

Introduction to the use of mathematical techniques for simulation of biological phenomena, including programming techniques for computers.

BL4820 Biochem Techniques I **3 credits**

Laboratory techniques fundamental to studies in the area of biochemistry including cell growth and disruption, membrane isolation and purification using sucrose density gradients, phospholipid extraction and analysis and determination of fatty acid compositions using gas chromatographic analysis.

CH2410 Organic Chemistry I **3 credits**

A study of the chemistry of carbon compounds. Review of hybrid orbitals, covalent bonding, and resonance. Introduction to nomenclature, stereochemistry, infrared and nuclear magnetic resonance spectroscopy, functional group chemistry based on reaction mechanisms, and multi-step synthesis.

CH2420 Organic Chemistry II **3 credits**

Covers more functional group chemistry based on reaction mechanisms; more involved multi-step synthesis; introduction to carbohydrates, amino acids, proteins, nucleic acids; and topics of specialized interest.

CH3500 Physical Chemistry for Env. and Life Sciences **2 credits**

Equilibrium thermodynamics, chemical kinetics, transport properties, gas laws, and phase equilibria with an emphasis on solution behavior and applications to molecules important in the environmental and life sciences.

CH3510 Physical Chemistry I **3 credits**

Ideal and non-ideal gas laws, the kinetic theory of gases, equations of state, liquid-vapor equilibrium, the laws of thermodynamics, solid-liquid-vapor equilibria, the chemical potential, chemical equilibrium, electrochemistry, the phase rule, and phase diagrams.

CH3520 Physical Chemistry II **3 credits**

Covers chemical kinetics, solid-state chemistry, surface chemistry, atomic and molecular spectroscopy and structure, chemical applications of group theory, valence, the periodic table, elements of quantum mechanics, and statistical thermodynamics.

CH4710 Chemical Principles in Biology **3 credits**

Studies biochemistry with emphasis on understanding the interconnections between biology and chemistry and the underlying chemical logic of biomolecules and metabolic pathways.

CH5560 Computational Chemistry **3 credits**

The theory and method of modern computational techniques applied to the study of molecular properties and reactivity. These will be developed with a combination of lecture material and computer projects using modern software packages. Classical mechanical as well as quantum mechanical approaches will be covered.

CSE5200 Computational Genomics **3 credits**

Topics include introduction to molecular biology, DNA sequence assembly, fast database searching, sequence alignment, and gene recognition.

FW2080 Intro to Plant Biotechnology **3 credits**

Introduction to basic concepts and practical applications of plant biotechnology with an emphasis on forest and wood products industry-related applications. Use of biotechnological approaches to resolve problems related to wood quality, biomass production, and environmental stresses of forest trees. Successful cases, potential applications and problems will be discussed.

FW4089 Tools in Bioinformatics **3 credits**

Computer applications in molecular biology. Hands-on experience with using popular computer programs for DNA, RNA and protein sequence analysis, Database management, Data editing, assembly, and organization. Multiple sequence comparisons, Protein Structural analysis, Evolutionary relationships of genes. Use of Internet for data retrieval, comparison and analysis.

MA3160 Multivariable Calc with Tech **4 credits**

Introduction to calculus in two and three dimensions, which includes a computer laboratory. Topics include functions of several variables, partial derivatives, the gradient, multiple integrals, introduction to vector-valued functions and vector calculus,

divergence, curl, and the integration theorems of Green, Stokes, and Gauss. Completion of MA2330 or MA2320 recommended.

MA3210 Intro. to Combinatorics 3 credits

Topics include set theory, mathematical induction, integers, functions and relations, counting methods, recurrence relations, generating functions, permutations, combinations, principle of inclusion and exclusion, graphs (including planar graphs). Further possible topics are graph coloring, trees and cutsets, combinatorial designs, Boolean algebra.

MA4208 Optimization and Graph Algorithms 3 credits

An introduction to linear and integer programming and related graph problems. Topics include simplex algorithm, duality, branch-and-bound and branch-and-cut, shortest paths, spanning trees, matchings, network flow, graph coloring, and perfect graphs.

MA4209 Combinatorics and Graph Theory 3 credits

An introductory course in combinatorics and graph theory. Topics include designs, enumeration, extremal set theory, finite geometry, graph coloring, inclusion-exclusion, network algorithms, permutations, and trees.

MA4720 Design and Analysis of Experiments 3 credits

Covers construction and analysis of completely randomized, randomized block, incomplete block, Latin squares, factorial, fractional factorial, nested and split-plot designs. Also examines fixed, random and mixed effects models and multiple comparisons and contrasts. The SAS statistical package is an integral part of the course.

MA4760 Mathematical Statistics I 3 credits

Covers probability set functions and distributions, multivariate distributions, special distributions, distributions of functions of random variables, and limiting distributions.

MA4770 Mathematical Statistics II 3 credits

Point estimation, confidence intervals, sufficient statistics, Bayesian estimation, the Rao-Cramer inequality, hypothesis testing, including optimal te

PH2100 University Physics I - Mechanics 3 credits

A calculus-based introduction to classical mechanics. Topics include kinematics, Newton's laws, work and energy, the universal law of gravitation, systems of particles, rotational motion, oscillations, and transverse waves.

PH2200 University Physics II - Electricity & Magnetism 3 credits

A calculus-based introduction to electromagnetism. Topics include Coulomb's law, electric fields, Gauss's law, electric potential, capacitance, circuits, magnetic forces and fields, Ampere's law, induction, Maxwell's equations, electromagnetic waves and geometrical optics.

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