PHYSICS (PHYS)

Note: The department/program code PHYS replaces the former code 38. Students cannot hold credit in PHYS-xxxx and the former 38.xxxx having the same course number (e.g., PHYS-1301(6) and 38.1301(6)).

Chair: D. Vincent; Professors: G. Kunstatter, J. Martin; Associate Professors: D. Vincent, M. Martin, C. Bidinosti; Assistant Professors: E. Elhami, A. Frey, B. Jamieson; Instructors: I. Burley, D. Campbell, V. Milosevic-Zdjelar.

DEGREES/PROGRAMS OFFERED

3-Year BSc
3-Year BSc (Computational Physics Stream)
3-Year BSc (Radiation Health and Safety Stream)
4-Year BSc
4-Year BSc (Chemical Physics Stream)
4-Year BSc (Computational Physics Stream)
4-Year BSc (Radiation Therapy) – New Program - See Radiation Therapy section of Calendar.
Honours BSc
Honours BSc (Chemical Physics Stream)
Honours BSc (Mathematical Physics Stream)
Honours BSc (Medical Physics Stream)

INTRODUCTION

   Physics is the study of nature at its most fundamental level. Its purpose is to formulate theories that accurately account for the behaviour of observed phenomena at all levels, from the microscopic world of the atom, to the vast reaches of the universe as a whole. In the process of trying to understand nature, physics often makes surprising discoveries that revolutionize the world. Such discoveries include lasers, the electronic processes underlying today's compact, high-speed computers, and the nuclear processes behind medical imaging systems such as MRI's. Even the World Wide Web was developed by particle physicists as a graphics-based communications system to enable them to share information.

   A degree in Physics can lead to careers in teaching at the school or university level and research in universities, government labs, and high-tech industry. Physicists acquire skills that are also useful in a wide variety of other fields, such as engineering, health sciences, and finance. Specialized streams in chemical, mathematical, and computational physics are available for those wanting to pursue studies in one of these cross-disciplinary fields. Students pursuing any 3-year or 4-year BSc in Physics also have the opportunity to take a Business Stream (see the "Science with a Business Stream" section of this Course Calendar)**.**

   Those students interested in Engineering may wish to consider the dual degree option offered in conjunction with the University of Minnesota. Under this program a student completes a 3 year BSc Degree at the University of Winnipeg and then can obtain an Engineering degree after two years at the Institute of Technology at the University of Minnesota. Further details are available in the calendar, on the University of Winnipeg's web site, or from the Department of Physics office.

GENERAL INFORMATION

Prerequisites
Note that prerequisites may be waived in some circumstances; please consult the Department Chair.

Notes on Specific Courses and their Applicability
PHYS-1301(6) Introduction to Physics does not involve Calculus and is offered for pre-medical, pre-dental, and arts students.
PHYS-1701(6) Astronomy, **PHYS-2705(6)** Cosmology, and **PHYS-2812(3)** The Physics of Music meet the Science Requirement and are intended for liberal arts students who desire a non-mathematical approach to the understanding of science.
PHYS-2102(3) and PHYS-2103(3) - Scientific Computing and Computational Physics - provide an introduction to the use of computers in science, and should be useful to anyone interested in gaining practical experience with a variety of programming languages.

GENERAL 3-YEAR BSc DEGREE REQUIREMENTS

ADMISSION REQUIREMENT   Students must consult with a Department advisor in planning their course of study.

GRADUATION REQUIREMENT   90 credit hours

RESIDENCE REQUIREMENT
Degree: Minimum 30 credit hours.
Major: Minimum 18 credit hours.

GENERAL DEGREE REQUIREMENT
Humanities: Minimum 12 credit hours in Humanities.
Writing: Minimum 3 credit hours of Academic Writing.
Maximum Introductory Courses: Students may use a maximum of 42 credit hours at the 1000 level. Of these, a maximum of 6 credit hours may be below the 1000 level.
Distribution: Minimum three (3) credit hours from each of five (5) different subjects.

MAJOR REQUIREMENT
Single Major: Minimum 33 credit hours/Maximum 48 credit hours in Major subject.
Double major: 33 credit hours in Physics and the specified number of credit hours in the other Department/ program.

GENERAL 4-YEAR BSc DEGREE REQUIREMENTS

ADMISSION REQUIREMENT   Students must consult with a Department advisor in planning their studies.

GRADUATION REQUIREMENT   120 credit hours; that is, 90 credit hours meeting the requirements for the 3-Year BSc plus 30 additional credit hours.

RESIDENCE REQUIREMENT
Degree: Minimum 60 credit hours.
Major: Minimum 30 credit hours.

GENERAL DEGREE REQUIREMENT
Humanities: Minimum 12 credit hours.
Writing: Minimum 3 credit hours of Academic Writing.
Maximum Introductory Courses: Students may use a maximum of 42 credit hours at the 1000 level. Of these, a maximum of 6 credit hours may be below the 1000 level.
Distribution: Minimum three (3) credit hours from each of five (5) different subjects.

GENERAL HONOURS BSc DEGREE REQUIREMENTS

ADMISSION REQUIREMENT   Students must have completed 30 credit hours.
Students must consult and have the approval of the Department Chair or the Chair's designate when planning their studies.

GRADUATION REQUIREMENT   120 credit hours
Graduation GPA Requirement: To graduate with a BSc (Honours), students must have a minimum GPA of 3.0 on all major (Physics) courses which will be calculated on all course attempts in the major, and a minimum GPA of 2.75 on all non-major courses which will be calculated as for the general degree.

RESIDENCE REQUIREMENT
Degree: Minimum 60 credit hours.
Major: Minimum 30 credit hours, including minimum 18 credit hours at upper level (3000/4000) of which a minimum of 12 credit hours are at the 4000 level.

GENERAL DEGREE REQUIREMENT
Humanities: 12 credit hours
Writing: Minimum 3 credit hours of Academic Writing.
Maximum Introductory Courses: Students may use a maximum of 42 credit hours at the 1000 level. Of these, a maximum of 6 credit hours may be below the 1000 level.
Distribution: Minimum three (3) credit hours from each of five (5) different subjects.

HONOURS REQUIREMENT
Single Honours: Minimum 60 credit hours in the Major subject.
Minimum 30 credit hours in upper-level (3000 and 4000) Honours subject courses of which a minimum of 12 credit hours must be at the 4000 level.

REQUIREMENTS FOR A 3-YEAR BSc IN PHYSICS

MAJOR REQUIREMENT

Single Major: Minimum of 42 credit hours as per the courses listed below.

Required Courses (39 credit hours):

MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
PHYS-1101(6)	Foundations of Physics I (Minimum 2.0 GPA, C)
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2201(6)	Electricity & Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory

Plus a minimum of 3 credit hours from:

PHYS-2102(3)	Scientific Computing
PHYS-2103(3)	Computational Physics
PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-4201(6)	Electromagnetic Theory
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4501(6)	Introduction to General Relativity
PHYS-4601(6)	Quantum Mechanics II

Recommended:	Students are advised to include courses in the areas of Calculus and Differential Equations as part of their degree program. Students are advised to consult with the Department Chair before entering Year 2 of their studies.
Combined Major:	Minimum of 48 credit hours from two (2) different majors with not less than 18 credit hour from each major subject.
Prescribed courses:	Required courses depend on the second major area and will be determined in consultation with the department.

REQUIREMENTS FOR A 3-YEAR BSc (COMPUTATIONAL PHYSICS STREAM)

MAJOR REQUIREMENT

Single Major: Minimum of 66 credit hours as per the courses listed below.

Required Courses (42 credit hours):

MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
PHYS-1101(6)	Foundations of Physics I
PHYS-2102(3)	Scientific Computing
PHYS-2103(3)	Computational Physics
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2201(6)	Electricity and Magnetism
PHYS-2302(6)	Foundations of Physics II
With either	
ACS-1903(3)	Programming Fundamentals I and
ACS-1904(3)	Programming Fundamentals II
OR	
ACS-1905(3)	Programming Fundamentals and
ACS-2947(3)	Data Structures and Algorithms

Plus a minimum of 6 credit hours from:

PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4501(6)	Introduction to General Relativity
PHYS-4901(3)	Advanced Physics Laboratory

Plus a minimum of 18 credit hours from:

MATH-3701(3)	Numerical Methods

Any courses from the Applied Computer Science 4-year B. Sc. Group I or Group II electives

REQUIREMENTS FOR A 3-YEAR BSc (RADIATION HEALTH AND SAFETY)

MAJOR REQUIREMENT:
    Single Major: Minimum of 60 credit hours as per the courses listed below.

Required Courses (45 credit hours):

MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
BIOL-1112(6)	Human Anatomy and Physiology
STAT-1501(3)	Elementary Biological Statistics I
PHYS-1101(6)	Foundations of Physics I
PHYS-2102(3)	Scientific Computing
PHYS-2201(6)	Electricity and Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-2510(3)*	Radiation Biology
PHYS-2540(3)*	Radiation Protection and Health Physics
PHYS-3901(3)	Intermediate Physics Laboratory

Plus a minimum of 15 credit hours from:

PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2103(3)	Computational Physics
PHYS-2502(3)	Radiation and the Environment
PHYS-2503(3)	Medical Imaging
PHYS-2520(3)*	Physics of Radiation Therapy
PHYS-2530(3)*	Industrial, Therapy, and Imaging Apparatus
PHYS-3301(6)	Quantum Mechanics I
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-3220(3)**	Medical Physics and Physiological Measurement
STAT-2001(3)	Elementary Biological Statistics II

*These courses are taught through CancerCare Manitoba (CCMB).
**This course is taught through the University of Manitoba.

REQUIREMENTS FOR A 4-YEAR BSc IN PHYSICS

MAJOR REQUIREMENT
    Single Major: Minimum of 60 credit hours as per the courses listed below.

Required Courses (48 credit hours):

MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
PHYS-1101(6)	Foundations of Physics I (Minimum 2.0 GPA, C)
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2201(6)	Electricity & Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4601(6)	Quantum Mechanics II
PHYS-4901(3)	Advanced Physics Laboratory

Plus a minimum of 12 credit hours from:

PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-4201(6)	Electromagnetic Theory
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4501(6)	Introduction to General Relativity

Students must complete a special registration form available from the Department Chair before registering for the 66th credit hour.

Combined Major:	Minimum of 60 credit hours from two (2) different majors with not less than 24 credit hours from each major subject.
Prescribed courses:	Required courses depend on the second major area and will be determined in consultation with the department.

REQUIREMENTS FOR A 4-YEAR BSc (CHEMICAL PHYSICS STREAM)

MAJOR REQUIREMENT
Single Major: Minimum of 96 credit hours as per the courses listed below.

Required Courses (69 credit hours):
CHEM-1111(3)	Introduction to the Chemical Properties of Matter
CHEM-1112(3)	Basic Principles of Chemical Reactivity
CHEM-2102(3)	Thermodynamics and Kinetics
CHEM-2103(3)	Atoms, Molecules and Spectroscopy
CHEM-2401(3)	Inorganic Chemistry I
CHEM-3101(3)	Physical Chemistry of Condensed Phases
CHEM-3102(3)	Quantum Chemistry and Spectroscopy
CHEM-4101(3)	Molecular Structure, Spectroscopy and Reactivity
MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
MATH-1201(3)	Linear Algebra I
MATH-2102(3)	Differential Equations I
PHYS-1101(6)	Foundations of Physics I
PHYS-2201(6)	Electricity and Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4601(6)	Quantum Mechanics II

Plus a minimum of 3 credit hours from:
CHEM-2202(3)	Organic Chemistry I
CHEM-2203(3)	Organic Chemistry II
CHEM-2302(3)	Quantitative Chemical Analysis
CHEM-3401(3)	Inorganic Chemistry II: Coordination and Organometallic Chemistry

Plus a minimum of 12 credit hours from:
PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4001(6)	Honours Thesis

Plus a minimum of 12 credit hours from:
PHYS-2102(3)	Scientific Computing
PHYS-2103(3)	Computational Physics
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
MATH-2105(3)	Intermediate Calculus I
MATH-2106(3)	Intermediate Calculus II
MATH-2103(3)	Differential Equations II
MATH-2203(3)	Linear Algebra II

REQUIREMENTS FOR A 4-YEAR BSc (COMPUTATIONAL PHYSICS STREAM)

MAJOR REQUIREMENT
Single Major: Minimum of 96 credit hours as per the courses listed below.

Required Courses (57 credit hours):
MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
PHYS-1101(6)	Foundations of Physics I
PHYS-2102(3)	Scientific Computing
PHYS-2103(3)	Computational Physics
PHYS-2201(6)	Electricity and Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4601(6)	Quantum Mechanics II
PHYS-2105(3)	Mathematical Physics I and
PHYS-2106(3)	Mathematical Physics II
With either	
ACS-1903(3)	Programming Fundamentals I and
ACS-1904(3)	Programming Fundamentals II
OR	
ACS-1905(3)	Programming Fundamentals and
ACS-2947(3)	Data Structures and Algorithms

Plus a minimum of 12 credit hours from:
PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-4001(6)	Honours Thesis
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4501(6)	Introduction to General Relativity
PHYS-4901(3)	Advanced Physics Laboratory

Plus a minimum of 27 credit hours from:
MATH-3701(3)	Numerical Methods

Any courses from the Applied Computer Science 4 year B. Sc. Group I or Group II electives

REQUIREMENTS FOR A 4-YEAR BSc (RADIATION THERAPY)

Radiation Therapy is a new program. Please see the "Radiation Therapy" section of the Course Calendar.

REQUIREMENTS FOR AN HONOURS BSc IN PHYSICS

HONOURS REQUIREMENT
Single Honours: Minimum of 96 credit hours as per the courses listed below.

Required Courses (66 credit hours):
MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
MATH-2105(3)	Intermediate Calculus I
MATH 2106(3)	Intermediate Calculus II
PHYS-1101(6)	Foundations of Physics I
PHYS-2201(6)	Electricity & Magnetism
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2302(6)	Foundations of Physics II
PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4001(6)	Honours Thesis
PHYS-4601(6)	Quantum Mechanics II
PHYS-4901(3)	Advanced Physics Laboratory

Plus a minimum of 18 credit hours from:
PHYS-2102(3)	Scientific Computing
PHYS-2103(3)	Computational Physics
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-4201(6)	Electromagnetic Theory
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4501(6)	Introduction to General Relativity

In addition to the above, students must select a further 6 credit hours in Mathematics and 6 credit hours from Biology and/or Chemistry excluding **BIOL-1102(6)** Biology and Human Concerns and **CHEM-2801(6)** Chemistry and Society.
If necessary, alternate Mathematics or Physics courses can be substituted with written permission from the Department of Physics.

REQUIREMENTS FOR AN HONOURS BSc (CHEMICAL PHYSICS STREAM)

HONOURS REQUIREMENT
Single Honours: Minimum of 96 credit hours as per the courses listed below.

Required Courses (75 credit hours):
CHEM-1111(3)	Introduction to the Chemical Properties of Matter
CHEM-1112(3)	Basic Principles of Chemical Reactivity
CHEM-2102(3)	Thermodynamics and Kinetics
CHEM-2103(3)	Atoms, Molecules and Spectroscopy
CHEM-2401(3)	Inorganic Chemistry I

CHEM-3101(3)	Physical Chemistry of Condensed Phases
CHEM-3102(3)	Quantum Chemistry and Spectroscopy
CHEM-4101(3)	Molecular Structure, Spectroscopy and Reactivity
MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
MATH-1201(3)	Linear Algebra I
MATH-2102(3)	Differential Equations I
PHYS-1101(6)	Foundations of Physics I
PHYS-2201(6)	Electricity and Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4001(6)	Honours Thesis
PHYS-4601(6)	Quantum Mechanics II

Plus a minimum of 3 credit hours from:

CHEM-2202(3)	Organic Chemistry I
CHEM-2203(3)	Organic Chemistry II
CHEM-2302(3)	Quantitative Chemical Analysis
CHEM-3401(3)	Inorganic Chemistry II: Coordination and Organometallic Chemistry

Plus a minimum of 6 credit hours from:

PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics

Plus a minimum of 12 credit hours from:

PHYS-2102(3)	Scientific Computing
PHYS-2103(3)	Computational Physics
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
MATH-2105(3)	Intermediate Calculus I
MATH-2106(3)	Intermediate Calculus II
MATH-2103(3)	Differential Equations II
MATH-2203(3)	Linear Algebra II

If necessary, alternate Mathematics or Physics courses can be substituted with written permission from the Department of Physics.

REQUIREMENTS FOR AN HONOURS BSc (MATHEMATICAL PHYSICS STREAM)

HONOURS REQUIREMENT

Single Honours: Minimum of 96 credit hours as per the courses listed below.

Required Courses (75 credit hours):

MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
MATH-1201(3)	Linear Algebra I
MATH-2105(3)	Intermediate Calculus I
MATH-2106(3)	Intermediate Calculus II
MATH-2102(3)	Differential Equations I
MATH-2103(3)	Differential Equation II
MATH-2203(3)	Linear Algebra II
PHYS-1101(6)	Foundations of Physics I
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2201(6)	Electricity and Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4001(6)	Honours Thesis
PHYS-4201(6)	Electromagnetic Theory
PHYS-4601(6)	Quantum Mechanics II

Plus a minimum of 6 credit hours from:

MATH-3101(6)	Advanced Calculus and Analysis
MATH-3103(3)	Methods in Advanced Calculus
MATH-3202(3)	Group Theory
MATH-3402(3)	Combinatorics
MATH-3701(3)	Numerical Methods
MATH-4101(3)	Complex Analysis
MATH-4403(3)	Set Theory
MATH-4601(3)	Introduction to Topology and Analysis

Plus a minimum of 15 credit hours from:

PHYS-3202(3)	Classical Mechanics I
PHYS-3203(3)	Classical Mechanics II
PHYS-3103(3)	Special Topics in Physics
PHYS-3402(3)	Thermal Physics I
PHYS-3403(3)	Thermal Physics II
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4501(6)	Introduction to General Relativity
PHYS-4901(3)	Advanced Physics Laboratory

If necessary, alternate Mathematics or Physics courses can be substituted with written permission from the Department of Physics.

REQUIREMENTS FOR AN HONOURS BSc (MEDICAL PHYSICS STREAM)

HONOURS REQUIREMENT
 Single Honours: Minimum of 84 credit hours as per the courses listed below.

Required Courses (69 credit hours):

BIOL-1112(6)	Human Anatomy and Physiology
STAT-1501(3)	Elementary Biological Statistics I
MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
PHYS-1101(6)	Foundations of Physics I
PHYS-2201(6)	Electricity & Magnetism
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2102(3)	Scientific Computing
PHYS-2302(6)	Foundations of Physics II
PHYS-3202(3)	Classical Mechanics I
PHYS-3301(6)	Quantum Mechanics I
PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-4001(6)	Honours Thesis
PHYS-4601(6)	Quantum Mechanics II
PHYS-4901(3)	Advanced Physics Laboratory

Plus a minimum of 15 credit hours from:

PHYS-2502(3)	Radiation and the Environment
PHYS 2503(3)	Medical Imaging
PHYS-2103(3)	Computational Physics
PHYS-3203(3)	Classical Mechanics II
PHYS 3220(3)*	Medical Physics and Physiological Measurement
PHYS-4302(3)	Condensed Matter Physics
PHYS-4303(3)	Subatomic Physics
PHYS-4501(6)	Introduction to General Relativity
PHYS-4201(6)	Electromagnetic Theory
STAT-2001(3)	Elementary Biological Statistics II

Strongly recommended electives:

BIOL-1115(3)	Cells and Cellular Processes
BIOL-3202(3)	Histology

*This course is taught through the University of Manitoba.

COURSE LISTINGS

PHYS-1005(6)	Concepts in Science	PHYS-2705(6)	Cosmology: Science Fact to Science Fiction
PHYS-1101(6)	Foundations of Physics I		
PHYS-1301(6)	Introduction to Physics	PHYS-2803(3)	Fundamentals of Digital Electronics
PHYS-1701(6)	Astronomy	PHYS-2812(3)	The Physics of Music
PHYS-2102(3)	Scientific Computing	PHYS-3103(3)	Special Topics in Physics
PHYS-2103(3)	Computational Physics	PHYS-3202(3)	Classical Mechanics I
PHYS-2105(3)	Mathematical Physics I	PHYS-3203(3)	Classical Mechanics II
PHYS-2106(3)	Mathematical Physics II	PHYS-3301(6)	Quantum Mechanics I
PHYS-2110(3)	Statics	PHYS-3402(3)	Thermal Physics I
PHYS-2201(6)	Electricity and Magnetism	PHYS-3403(3)	Thermal Physics II
PHYS-2302(6)	Foundations of Physics II	PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-2502(3)	Radiation and the Environment	PHYS-4001(6)	Honours Thesis
PHYS-2503(3)	Medical Imaging	PHYS-4201(6)	Electromagnetic Theory
PHYS-2510(3)	Radiation Biology	PHYS-4302(3)	Condensed Matter Physics
PHYS-2520(3)	Physics of Radiation Therapy	PHYS-4303(3)	Subatomic Physics
PHYS-2530(3)	Industrial, Therapy & Imaging Apparatus	PHYS-4501(3)	Introduction to General Relativity
		PHYS-4601(6)	Quantum Mechanics II
PHYS-2540(3)	Radiation Protection & Health Physics	PHYS-4901(3)	Advanced Physics Laboratory

COURSE DESCRIPTIONS

As some senior courses are offered only in alternate years, students are advised to consult WebAdvisor or the Timetable.

PHYS-1005(6) CONCEPTS IN SCIENCE (Le3) This course explores science at a qualitative level from this interdisciplinary viewpoint, with an aim to foster scientific literacy and develop critical thinking skills that are so crucial in today's society. Topics are drawn from biology, chemistry, geography, and physics, and range from the large - the universe, the earth, and ecosystems – to the small – cells, molecules, and atoms. Emphasis is placed on the unifying concepts running through such diversity, with activities and demonstrations forming an integral component. The course fulfills the Science requirement.
PREREQUISITE: None
CROSS-LISTED: BIOL-1005(6) and MULT-1005(6)

PHYS-1101(6) FOUNDATIONS OF PHYSICS I (Le3, La3) This calculus-based course provides students with a working knowledge of the basic concepts underlying modern physics. Topics covered include the following: Introduction to Newtonian mechanics with special emphasis on the principles of conservation (i.e., energy and momentum); applications of Newtonian mechanics, including the simple harmonic oscillator and harmonic waves on a string; gravity theory, including planetary/satellite motion, escape velocity, gravity as curved spacetime and black holes; postulates of special relativity and their consequences; geometric optics applied to mirrors, lenses, and optical instruments; electromagnetic phenomena, including interference and diffraction; quantum behaviour, wave-particle duality, the uncertainty principle, atomic physics with applications to the laser. This course is intended primarily for Physics majors but is also useful preparation for entrance exams for professional programs.
PREREQUISITES: Physics 40S and Pre-Calculus Mathematics 40S, or Applied Mathematics 40S
COREQUISITE: MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)

PHYS-1301(6) INTRODUCTION TO PHYSICS (Le3, La3) This is a non-calculus course intended for pre-medical, pre-dental, and arts students. Topics include the following: mechanics, electric and magnetic fields, electric circuits, light, optics, Bohr theory, radioactivity, and nuclear reactions.

PREREQUISITES: Pre-Calculus Mathematics 40S, or Applied Mathematics 40S
Note: In order for a student with credit in course PHYS-1301(6) to proceed to further courses in Physics he/she must have (a) permission of the Department and (b) standing in MATH-1101(6), OR the equivalent MATH-1103(3) AND MATH-1104 (3), OR MATH-1102(3)

PHYS-1701(6) ASTRONOMY (Le3) This course is a science elective intended for the liberal arts student. There is no formal laboratory, but there will be periodic observations and demonstrations. The topics include the following: stellar astronomy and stellar evolution, the solar system and its evolution, galaxies, and theories of the universe. There will also be an introductory treatment of the composition of matter, the nature of light, the principles of optics, and the operation of telescopes and auxiliary instruments. This course fulfils the Science Requirement.
PREREQUISITE: None

PHYS-2102(3) SCIENTIFIC COMPUTING (Le3) Many problems arising in science are too difficult to solve analytically, and thus require some form of computer-based analysis. Using the language of C/C++, this course introduces the most common programming constructs used in scientific computing. The critical importance of data structures to represent information is emphasized, which naturally leads to an object-oriented approach to problem-solving. The use of external libraries, such as those for numerical analysis, to solve more advanced problems are explored, with attention paid to checks that can be made on the reliability of the results.
PREREQUISITE: None. However, experience with elementary computer programming languages is strongly recommended.
CROSS-LISTED: ACS-2102(3)

PHYS-2103(3) COMPUTATIONAL PHYSICS (Le3) This course introduces methods to construct and analyze models of various complex systems. The visual insight gained into the behaviour of such models through the use of graphic techniques will play a significant role. An emphasis is placed on the universal computational features found in large classes of physical models, such as chaotic behaviour, fractal nature, and the existence of phase transitions of different types. The use of models to simulate complicated temporal and spatial

interactions is also explored. Physics-related examples may be drawn from both the life and physical sciences. Although no mathematics prerequisite is required, comfort with basic algebra is assumed.
PREREQUISITE: None
STRONGLY RECOMMENDED: Some knowledge in Introductory Calculus

PHYS-2105(3) MATHEMATICAL PHYSICS I (Le3) This course provides a study of mathematical techniques commonly used in Physics. Topics covered include vector calculus, coordinate systems, complex variables, distributions, and introductory matrix algebra. The companion course Mathematical Physics II continues this study with further areas of interest. The MAPLE symbolic algebra computer program is introduced and then used throughout the course.
RESTRICTIONS: Students who have obtained credit in the former PHYS-2104(6) may not receive credit for this course.
PREREQUISITE: PHYS-1101(6), MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)

PHYS-2106(3) MATHEMATICAL PHYSICS II (Le3) This course, which is a companion course to Mathematical Physics I, is a study of mathematical techniques commonly used in Physics. Topics covered include diagonalization of complex matrices, Fourier analysis, ordinary and partial differential equations, and special functions. The MAPLE symbolic algebra computer program is used throughout the course.
RESTRICTIONS: Students who have obtained credit in the former PHYS-2104(6) may not receive credit for this course.
PREREQUISITE: PHYS-1101(6), PHYS-2105(3) or permission of the department, MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)

PHYS-2110(3) STATICS (Le3) This course provides an introduction to systems in static equilibrium. Topics covered include statics of particles, equivalent systems of forces, equilibrium of rigid bodies, centroids and centers of gravity, and analysis of complicated structures.
PREREQUISITE: PHYS-1101(6), MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)

PHYS-2201(6) ELECTRICITY AND MAGNETISM (Le3, La3) Electrostatics, DC circuits, magnetic effects of a current, electromagnetic induction, properties of dielectric and magnetic materials, elements of AC circuit theory.
PREREQUISITE: PHYS-1101(6), MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)
COREQUISITE: PHYS-2105(3) and PHYS-2106(3)

PHYS-2302(6) FOUNDATIONS OF PHYSICS II (Le3, La3) This course contains a series of topics in physics which together with Foundations of Physics I, provide students with a broad understanding of physics. Topics include the following: rotation of rigid bodies, angular momentum, fluid mechanics, thermodynamics, special relativity, quantum mechanics, atomic physics, solid state physics, and nuclear physics.
PREREQUISITE: PHYS-1101(6), MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)
STRONGLY RECOMMENDED: PHYS-2105(3) and PHYS-2106(3) to be taken concurrently

PHYS-2502(3) RADIATION AND THE ENVIRONMENT (Le3, La3) This course provides an overview of radiation in the environment and its effects on materials and living systems. Topics will include x-rays, ultraviolet, visible, infrared, microwave and radio-frequency emissions, acoustical and ultrasonic radiation, and alpha, beta and gamma radiation from radioactive sources. Emphasis will be placed on the applications of radiation in the real world, including health and environmental issues.
PREREQUISITE: Any core laboratory course in Biology, Chemistry, or Physics.

PHYS-2503(3) MEDICAL IMAGING (Le3) This course is an introduction to medical techniques, such as ultrasound, x-rays, CT scans, MRIs, and PET scans. The basics of how each technique works as well as what causes contrast in the images will be explored, both qualitatively and quantitatively, using simple algebra and trigonometry. The suitability of each technique for imaging specific medical problems will be discussed.
PREREQUISITE: Any core laboratory course in Biology, Chemistry, or Physics.

PHYS-2510(3) RADIATION BIOLOGY (Run through CancerCare Manitoba) This course deals with the fundamentals of radiation biology and focuses on the effects of radiation at a cellular and molecular level. The theory of radiation biology is examined at the cellular level and applied to the clinical impact on patients. Radiation biology gives insight into ways to exploit cellular differences in healthy cells so as to increase the likelihood of tumor eradication. The theory of how radiation interacts with cells and tissues, what impact radiation has on organisms and the radiation patient, and how to best achieve our treatment goals are all examined in this lecture based course.
PREREQUISITE: PHYS-2520(3), or permission of instructor

PHYS-2520(3) PHYSICS OF RADIATION THERAPY (Run through CancerCare Manitoba) This series of lectures is designed to provide the student radiation therapist with a fundamental understanding of the physical nature of both photons and electrons and specifically the manner in which they interact with an absorbing/scattering medium. The concepts presented in this series will enhance the student's ability to make decisions regarding clinical radiation therapy treatments.
PREREQUISITE: PHYS-1301(6)
COREQUISITE: CCMB-2903(3) or permission of instructor, PHYS-2530(3)

PHYS-2530(3) INDUSTRIAL, THERAPY & IMAGING APPARATUS (Run through CancerCare Manitoba) This course introduces the student to the principles of operation of radiation therapy simulation and treatment equipment. It focuses on design of equipment, physical processes involved in equipment operation and radiological imaging processes. Practical reinforcements of principles are provided in a lab setting.
PREREQUISITE: PHYS-1301(6), BIOL-1112(6)
COREQUISITE: CCMB-2903(3) or permission of instructor, PHYS-2520(3)

PHYS-2540(3) RADIATION PROTECTION & HEALTH PHYSICS (Run through CancerCare Manitoba) This course builds on Industrial, Therapy & Imaging Apparatus, including the fundamental concepts used to minimize risk when working with sources of ionizing radiation, with emphasis on the application of these concepts to radiation therapy. Topics covered include: types and sources of radiation, radiation quantities and units, biological effects and potential risk, basic principles of protection, regulation and dose limits, methods of dose monitoring, and application in radiation therapy.
PREREQUISITE: CCMB-2904(3) or permission of instructor, PHYS-2530(3)

PHYS-2705(6) COSMOLOGY: SCIENCE FACT TO SCIENCE FICTION (Le3) This course gives an introduction to the scientific study of the universe as a whole. Modern aspects of cosmological physics, not usually encountered in elementary

physics courses, will be covered. These topics include the following: the standard scenario for early universe evolution; the triumph of big bang cosmology; the hierarchical nature of galaxy formation and clustering; the speed-of-light constraint on space travel and communication; the paradoxical nature of quantum physics; the existence of antimatter; the success of the Special Theory of Relativity; the description of gravity using Einstein's General Theory of Relativity; the characteristics of neutron stars, black holes, wormholes, cosmic strings and other astrophysical oddities; and the logic of spacetime topology of higher dimensions, of parallel universes, and of time travel. Finally, the course will consider how human beings and extra-terrestrial life forms fit into the overall scheme of things. Although the subjects discussed will be conceptually sophisticated, the presentation will require minimal mathematical knowledge. This course fulfils the Science Requirement.
PREREQUISITE: None

PHYS-2803(3) FUNDAMENTALS OF DIGITAL ELECTRONICS (Le3, La3) Basic circuit theory, digital logic, integrated circuits, microcontroller fundamentals, sensors, and applications.
PREREQUISITES: Students must have completed 18 credit hours in order to enrol in this course.
STRONGLY RECOMMENDED: Prior experience with elementary computer programming.

PHYS-2812(3) THE PHYSICS OF MUSIC (Le3) This course is an introduction to the physical underpinnings of the production, propagation and perception of the sounds that we interpret as music. After an overview of the fundamentals of both physics and music, we explore the nature and propagation of sound waves, the meaning of pure tones, and the question of how pure tones combine to form the harmonious complex waveforms produced by various musical instruments. Other topics include the workings of the human ear, and basic elements of concert hall acoustics. Finally, by studying elements of "fractal music", we examine some issues surrounding the question of what "is" music, compared to, say, a random collection of sounds.
PREREQUISITE: Students must have completed 30 credit hours in order to enrol in this course.

PHYS-3103(3) SPECIAL TOPICS IN PHYSICS (SV3) This course examines a topic in physics chosen to meet student needs. The topic will vary from year to year. Please consult the Physics Department for the current topic.
PREREQUISITE: Permission of the department.

PHYS-3202(3) CLASSICAL MECHANICS I (Le3) This course is a three dimensional vector treatment of Newtonian particle dynamics with an emphasis on conservation principles. Topics will include advanced problems in dynamics, including friction, rotation of rigid bodies and moments of inertia, and damped and forced oscillations.
PREREQUISITES: PHYS-1101(6), MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)
STRONGLY RECOMMENDED: PHYS-2105(3) and PHYS-2106(3)
RESTRICTIONS: Students who have obtained credit in PHYS-3102(6) may not receive credit in this course.

PHYS-3203(3) CLASSICAL MECHANICS II (Le3) This course is a continuation of the treatment of classical mechanics contained in PHYS-3202(3). Topics will include rotation of rigid bodies, central force fields, especially gravity, and Kepler's laws, small vibrations, and normal modes. As well, the Lagrange and Hamiltonian formalisms will be introduced, including that involving constraints.

PREREQUISITES: PHYS-1101(6), PHYS-3202(3)
STRONGLY RECOMMENDED: PHYS-2105(3) and PHYS-2106(3)
RESTRICTIONS: Students who have obtained credit in PHYS-3102(6) may not receive credit in this course.

PHYS-3301(6) QUANTUM MECHANICS I (Le3) This course covers the following topics: special relativity, statistical distributions, wave properties of matter, quantum operators, probabilistic interpretation of wave-functions, and applications of the Schrodinger equation, including the treatment of the harmonic oscillator.
PREREQUISITE: PHYS-2302(6), PHYS-2105(3), PHYS-2106(3)
RECOMMENDED: MATH-2102(3)

PHYS-3402(3) THERMAL PHYSICS I (Le3) This course introduces the standard concepts of classical thermodynamics. It also prepares the student for a quantum statistical approach to what fundamentally underlies these laws of thermodynamics. Topics include the absolute temperature scale, heat, work internal energy, entropy, Carnot engines, as well as the three laws of thermodynamics. Elementary concepts in probability and statistics and the Boltzmann Hypothesis are also discussed.
PREREQUISITE: None
COREQUISITE: PHYS-3301(6)

PHYS-3403(3) THERMAL PHYSICS II (Le3) This course develops the standard methodology of statistical mechanics which strives to derive all of the classical results of thermodynamics through quantum statistical analysis. Topics included are the microcanonical ensemble, the canonical ensemble, Boltzmann's Distribution, as well as the quantum mechanical description of heat and work. Other more advanced topics in statistical mechanics are discussed depending on time.
PREREQUISITE: PHYS-3402(3)
COREQUISITE: PHYS-3301(6)

PHYS-3901(3) INTERMEDIATE PHYSICS LABORATORY (La3 both terms) This course introduces students to instrumentation in the areas of atomic and nuclear physics. Students will set up and conduct several experiments as well as formulate and present reports on their work.
PREREQUISITE: PHYS-2302(6)
RESTRICTIONS: Students who have obtained credit in PHYS-3301(6) prior to September 2001 are **not** permitted to take this course.

PHYS-4001(6) HONOURS THESIS (P) This course is normally taken in the final year of the honours program. Students will undertake a research program in experimental or theoretical physics under the supervision of a faculty member. An essential component of the course is the oral and written presentation of the results. Students must consult with the Department Chair and the prospective supervisor before enrolling.
PREREQUISITE: Permission of the Department.

PHYS-4201(6) ELECTROMAGNETIC THEORY (Le3) This course will develop Maxwell's equations and apply them to problems of conductors, dielectrics, and magnetic materials.
PREREQUISITES: PHYS-2201(6), MATH-2105(3), and MATH-2106(3)
STRONGLY RECOMMENDED: PHYS-2105(3) and PHYS-2106(3)

PHYS-4302(3) CONDENSED MATTER PHYSICS (Le3) This course deals with the physics resulting from assembling a very large number of atoms to form a macroscopic piece of a solid. The main topics are: ordering of atoms to form crystal structures, and how the crystal structures vibrate; electronic characteristics of solid insulators, semiconductors and metals; magnetic properties of solids; and how defects significantly modify the physical characteristics of solids.

COREQUISITE: PHYS-3301(6)
PREREQUISITES: PHYS-2105(3) and PHYS-2106(3)
RESTRICTIONS: Students who have obtained credit in the former PHYS-4301(6) may not receive credit for this course.
CROSS-LISTED: CHEM-3104(3)

PHYS-4303(3) SUBATOMIC PHYSICS (Le3) In this course students are introduced to the very small world of the nucleus. First nuclear properties are reviewed, and then various models for forces between nucleons are presented. Radioactive decay/nuclear reactions and detectors are considered. Various applications of nuclear physics are discussed in the areas of power plants, condensed matter physics, and medical physics. Particle physics is considered to the extent that time permits.
COREQUISITE: PHYS-3301(6)
PREREQUISITES: PHYS-2105(3) and PHYS-2106(3)
RESTRICTIONS: Students who have obtained credit in the former PHYS-4301(6) may not receive credit for this course.

PHYS-4501(6) INTRODUCTION TO GENERAL RELATIVITY (Le3) This course will introduce the student to the modern theory of gravitation called General Relativity. The course begins with a thorough treatment of the role of Special Relativity in mechanics and electromagnetism using four-vectors and spacetime diagrams. A short introduction to tensor analysis will then be given. Following this, the Einstein equations will be formulated and the standard solutions will be analyzed. Using these solutions the experimental tests of General Relativity will be investigated as well as astrophysical and cosmological predictions.
PREREQUISITES: MATH-2105(3) and MATH-2106(3)
RESTRICTIONS: Students who have obtained credit in the former PHYS-3401(3) and PHYS-4501(3) are not permitted to take this course.
Note: In general, the student will be expected to have, or be willing to acquire, a high degree of mathematical literacy. Students should consult with the instructor.

PHYS-4601(6) QUANTUM MECHANICS II (Le3) This is an advanced course that describes the underlying structure of quantum mechanics and its applications. Topics include general formalism, spin and angular momentum, approximation methods, and scattering theory. Various interpretations of the formalism are also discussed with emphasis on conceptual issues. The basic theory is applied to several physical problems including the fine structure of the hydrogen atom and stimulated emission in lasers.
PREREQUISITE: PHYS-3301(6)
STRONGLY RECOMMENDED: PHYS-2105(3) and PHYS-2106(3)

PHYS-4901(3) ADVANCED PHYSICS LABORATORY (La3 both terms**)** This laboratory course familiarizes students with advanced laboratory techniques and introduces research methodologies.   A selection of experiments will be chosen from the areas of electromagnetism, atomic and nuclear physics, solid state physics, theoretical physics, quantum mechanics and classic experiments in physics.
PREREQUISITES: PHYS-2201(6) and PHYS-3901(3)
COREQUISITES: PHYS-4601(6)
RESTRICTIONS: Students who have obtained credit in any of PHYS-3401, PHYS-4201, PHYS-4301 and/or PHYS-4601 prior to September 2002 must consult with the chair of the department before enrolling in this course.