

PHYSICS (PHYS)

Updated March 18, 2013

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, Associate Professor: D. Vincent, J. Martin, M. Martin, C. Bidinosti; Assistant Professors: Esmat Elhami, Andrew Frey, Blair Jamieson; Instructors: I. Burley, D.G. 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.

Course Offerings

PHYS-1301(6) Introduction to Physics does not involve Calculus and is offered for pre-medical, pre-dental, and arts students.

PHYS-1501(6) Modern Technology meets the Science Requirement and is aimed at liberal arts students who seek a qualitative approach to the understanding of current technology.

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 I 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.

Physics Computing Practicum

Every upper-level Physics course (second year and up) will contain a Physics Computing component as part of its normal workload. The purpose of this program is to provide students with problem-solving skills using high level software packages and computer programming languages. All Physics graduates will thereby acquire technical expertise that should prove invaluable in today's world of ever-increasing computerization.

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

Graduation GPA Requirement:	120 credit hours 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.
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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.
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REQUIREMENTS FOR A 3-YEAR BSc IN PHYSICS**MAJOR REQUIREMENT**

Single Major:	Minimum 36 credit hours/Maximum 48 credit hours.
Double Major:	33 or 36 credit hours in each Major subject or program, as specified.

Required courses:

MATH-1101(6)	Introduction to Calculus OR the equivalent MATH-1103 (3) Introduction to Calculus I AND MATH-1104 (3) Introduction to Calculus II
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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

A minimum of 3 credit hours from the following:

PHYS-2102(3)	Scientific Computing I
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 a 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)

Single Major: Minimum 66 credit hours in Applied Computer Science, Mathematics, and Physics, as per required course list.

Required Courses (36 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 I
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

Plus 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 at least 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)	Nuclear Physics
PHYS-4501(6)	Introduction to General Relativity
PHYS-4901(3)	Advanced Physics Laboratory

Plus at least 18 credit hours selected 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 THE 3 YEAR BSc (RADIATION HEALTH AND SAFETY)

MAJOR REQUIREMENT: Minimum of 60 Credit Hours as per the courses listed below.

Required:

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 I
PHYS-2201(6)	Electricity and Magnetism
PHYS-2302(6)	Foundations of Physics II
PHYS-2510(3)	Radiation Biology (CancerCare course)
PHYS-2540(3)	Radiation Protection and Health Physics (CancerCare course)
PHYS-3901(3)	Intermediate Physics Laboratory

Plus at least 15 credit hours selected 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 (CancerCare course)
CCMB-2530(3)	Industrial, Therapy, and Imaging Apparatus (CancerCare course)
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 (U of M course)
STAT-2001(3)	Elementary Biological Statistics II

Note: The "CCMB" department code indicates the course is taught through CancerCare Manitoba.

REQUIREMENTS FOR A 4-YEAR BSc IN PHYSICS

MAJOR REQUIREMENT

Single Major:	Minimum 54 credit hours/ Maximum 78 credit hours.
Double Major:	Minimum 54 credit hours in Physics and specified number of credit hours in the other Major.

Required courses:

MATH-1101(6)	Introduction to Calculus
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

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 96 credit hours in Chemistry, Mathematics and Physics as per Required Courses list.

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 at least 3 credit hours selected 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 12 credit hours selected from the following:

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 12 credit hours selected from the following:

PHYS-2102(3)	Scientific Computing I
PHYS-2103(3)	Computational Physics
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
MATH-2801(6)	Fundamentals of Computing
MATH-2105(3)	Intermediate Calculus I
MATH-2106(3)	Intermediate Calculus II
MATH-2103(3)	Differential Equations II
MATH-2203(3)	Linear Algebra

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

MAJOR REQUIREMENT

Single Major: Minimum 96 credit hours in Applied Computer Science, Mathematics and Physics as per Required Courses list.

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
PHYS-1101(6)	Foundations of Physics I
PHYS-2102(3)	Scientific Computing I
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

Plus 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

PHYS-2105(3) Mathematical Physics I and
PHYS-2106(3) Mathematical Physics II

Plus at least 12 credit hours selected 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) Honor's thesis
PHYS-4302(3) Condensed Matter Physics
PHYS-4303(3) Nuclear Physics
PHYS-4501(6) Introduction to General Relativity
PHYS-4901(3) Advanced Physics Laboratory

Plus at least 27 credit hours selected from

MATH-3701(3) Numerical Methods
PHYS-2804(3) Introduction to Digital Systems

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

REQUIREMENTS FOR THE 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 72 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.

Required courses:

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 1

MATH 2106(3) **Intermediate Calculus 2**

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 18 credit hours from:

PHYS-2102(3) Scientific Computing I

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 THE HONOURS BSc (CHEMICAL PHYSICS STREAM)

HONOURS REQUIREMENT

Single Honours: Minimum 96 credit hours in Chemistry, Mathematics and Physics as per Required Courses list.

Required courses:

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 at least 3 credit hours selected from:

CHEM-2201(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 6 credit hours selected from the following:

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 12 credit hours selected from the following:

PHYS-2102(3)	Scientific Computing I
PHYS-2103(3)	Computational Physics
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
MATH-2801(6)	Fundamentals of Computing
MATH-2105(3)	Intermediate Calculus 1
MATH-2106(3)	Intermediate Calculus 2
MATH-2103(3)	Differential Equations II
MATH-2203(3)	Linear Algebra

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

REQUIREMENTS FOR THE HONOURS BSc (MATHEMATICAL PHYSICS STREAM)

HONOURS REQUIREMENT

Single Honours: Minimum 66 credit hours in Physics and 30 credit hours in Mathematics.

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 1
MATH-2106(3)	Intermediate Calculus 2
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 at least 6 credit hours selected from:

MATH-1401(3)	Discrete Mathematics
MATH-3101(6)	Advanced Calculus and Analysis
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
MATH-4604(3)	Introduction to Differential Geometry

Plus at least 15 credit hours selected 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 THE HONOURS BSc (MEDICAL PHYSICS)

HONOURS REQUIREMENT: Minimum of 84 Credit Hours as per the courses listed below.

Required courses:

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 I
PHYS-2105(3)	Mathematical Physics I
PHYS-2106(3)	Mathematical Physics II
PHYS-2102(3)	Scientific Computing I
PHYS-2302(6)	Foundations of Physics II
PHYS-3103(3)	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 at least 15 credit hours from:

PHYS-2502(3)	Radiation and the Environment
PHYS 2503(3)	Medical Imaging
PHYS-2103(3)	Computational Physics
PHYS-3104(3)	Mechanics II
PHYS 3220(3)	Medical Physics and Physiological Measurement (given through the University of Manitoba)
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

COURSE LISTINGS

PHYS-1005(6)	Concepts in Science	PHYS-2540(3)	Radiation Protection & Health Physics
PHYS-1101(6)	Foundations of Physics I	PHYS-2705(6)	Cosmology: Science Fact to Science Fiction
PHYS-1301(6)	Introduction to Physics	PHYS-2812(3)	The Physics of Music
PHYS-1701(6)	Astronomy	PHYS-3103(3)	Special Topics in Physics
PHYS-2102(3)	Scientific Computing	PHYS-3202(3)	Classical Mechanics I
PHYS-2103(3)	Computational Physics	PHYS-3203(3)	Classical Mechanics II
PHYS-2105(3)	Mathematical Physics I	PHYS-3301(6)	Quantum Mechanics I
PHYS-2106(3)	Mathematical Physics II	PHYS-3402(3)	Thermal Physics I
PHYS-2110(3)	Statics	PHYS-3403(3)	Thermal Physics II
PHYS-2201(6)	Electricity and Magnetism	PHYS-3901(3)	Intermediate Physics Laboratory
PHYS-2302(6)	Foundations of Physics II	PHYS-4001(6)	Honours Thesis
PHYS-2502(3)	Radiation and the Environment	PHYS-4201(6)	Electromagnetic Theory
PHYS-2503(3)	Medical Imaging	PHYS-4302(3)	Condensed Matter Physics
PHYS-2510(3)	Radiation Biology	PHYS-4303(3)	Subatomic Physics
PHYS-2520(3)	Physics of Radiation Therapy	PHYS-4501(6)	Introduction to General Relativity
PHYS-2530(3)	Industrial, Therapy & Imaging Apparatus	PHYS-4601(6)	Quantum Mechanics II
		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 (Le6) 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.

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 Mathematics 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.

PHYS-2102(3) SCIENTIFIC COMPUTING I (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: Have 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), MATH-1101(6) OR the equivalent MATH-1103(3) AND MATH-1104 (3)

PREREQUISITE: PHYS-2105(3), or permission of the department

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).

COREQUISITE: The Mathematical Physics Courses PHYS-2105(3) and PHYS-2106(3) to be taken concurrently .

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)

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 source. 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 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 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 us 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 2540 (or permission of instructor)

PHYS-2520(3) PHYSICS OF RADIATION THERAPY 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

COREQUISITE: CCMB 2503, PHYS 2530

PHYS-2530(3) INDUSTRIAL, THERAPY & IMAGING APPARATUS 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 is provided in a lab setting.

PREREQUISITES: PHYS 1301, BIOL 1112

COREQUISITES: CCMB 2503, PHYS 2540

PHYS-2540(3) RADIATION PROTECTION & HEALTH PHYSICS 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 2504, PHYS 2530, PHYS 2540)

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. It encompasses a description of astronomical phenomena on the very largest scales and a description of quantum physics on the very smallest scales. The most recent discoveries in physics will be discussed and applied to cosmological models that vary from the well-supported to the speculative. Modern aspects of 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 extraterrestrial lifeforms fit into the overall scheme of things. Throughout, reference will be made to how certain aspects of these topics have been incorporated (correctly and incorrectly) into science-fiction books, television shows, and movies. Although the subjects discussed will be conceptually sophisticated, the presentation will require minimal mathematical knowledge. This course fulfils the Science Requirement.

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 first-year standing 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 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: The Mathematical Physics Courses 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 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: The Mathematical Physics Courses 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).

RECOMMENDED: Mathematics MATH-2102(3)

STRONGLY RECOMMENDED: The Mathematical Physics Courses PHYS-2105(3) and PHYS-2106(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.

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); Mathematics MATH-2101(6).

STRONGLY RECOMMENDED: The Mathematical Physics Courses 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: The Mathematical Physics Courses 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-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: The Mathematical Physics Courses 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: The Mathematical Physics Courses 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.