Physics

This section presents the requirements for programs in:

- Physics (Astrophysics Stream) B.Sc. Honours
- Physics (Experimental Stream) B.Sc. Honours
- Physics (Theory Stream) B.Sc. Honours
- Physics B.Sc. Major
- Physics B.Sc.
- Applied Physics B.Sc. Honours
- Mathematics and Physics B.Sc. Double Honours
- Biology and Physics B.Sc. Combined Honours
- Chemistry and Physics B.Sc. Combined Honours
- Minor in Physics

The Department of Physics also offers the program: Engineering Physics - B.Eng. Consult the Engineering program section for details about this program.

Program Requirements

Course Categories for Physics

The program descriptions below make use of the following course categories, which are defined in the B.Sc. Regulations section.

- Approved Courses Outside the Faculties of Science and Engineering and Design
- Free Elective

Physics (Astrophysics Stream) B.Sc. Honours (20.0 credits)

A. Credits Included in the Major CGPA (10.5 credits)		
1. 1.0 credit from:		1.0
PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 2.5 credits in:		2.5
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2203 [0.5]	Astronomy	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 2604 [0.5]	Modern Physics I	
3. 5.0 credits in:		5.0
PHYS 3009 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars with Observational Astronomy	
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 3807 [0.5]	Mathematical Physics I	
PHYS 4201 [0.5]	Astrophysics	
PHYS 4202 [0.5]	Cosmology	
PHYS 4409 [0.5]	Thermodynamics and Statistical Physics	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
4. 1.0 credit from:		1.0
a. PHYS 4907 plus 0.5 credit 4000-level PHYS		
b. PHYS 4908 plus 0.5 credit 4000-level PHYS		
c. PHYS 4909 [1.0]		
5. 0.5 credit in PHYS at the 4000-level or above		0.5
6. 0.5 credit in PHYS, COMP, MATH and/or STAT at the 3000-level or above		0.5
B. Credits Not Included In the Major CGPA (9.5 credits)		
7. 1.0 credit from:		1.0
BIOL 1103 [0.5] & BIOL 1104 [0.5]	Foundations of Biology I Foundations of Biology II	
CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
CHEM 1005 [0.5] & CHEM 1006 [0.5]	Elementary Chemistry I Elementary Chemistry II	
ERTH 1006 [0.5] & ERTH 1009 [0.5]	Exploring Planet Earth The Earth System Through Time	
8. 3.5 credits in:		3.5
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
MATH 2107 [0.5]	Linear Algebra II	
MATH 3705 [0.5]	Mathematical Methods I	
STAT 3502 [0.5]	Probability and Statistics	
9. 0.5 credit in:		0.5
MATH 3800 [0.5]	Mathematical Modeling and Computational Methods	
10. 1.0 credits from:		1.0
COMP 1005 [0.5] & COMP 1006 [0.5]	Introduction to Computer Science I Introduction to Computer Science II	
or		
ECOR 1606 [0.5] & ECOR 2606 [0.5]	Problem Solving and Computers Numerical Methods	
11. 0.5 credit at the 2000-level or higher in COMP, MATH, or PHYS		0.5
12. 0.5 credit in:		0.5
NSCI 1000 [0.5]	Seminar in Science (or approved courses outside the faculties of Science and Engineering and Design)	
Approved courses outside the faculties of Science and Engineering and Design		
13. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design		1.5
14. 1.0 credit in free electives		1.0
Total Credits		**20.0**

Physics (Experimental Stream) B.Sc. Honours (20.0 credits)

A. Credits Included in the Major CGPA (11.0 credits)		
1. 1.0 credit from:		1.0

PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 2.0 credits in:		2.0
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 2604 [0.5]	Modern Physics I	
3. 1.0 credit in:		1.0
ELEC 2501 [0.5]	Circuits and Signals	
ELEC 2507 [0.5]	Electronics I	
4. 4.5 credits in:		4.5
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 3807 [0.5]	Mathematical Physics I	
PHYS 4409 [0.5]	Thermodynamics and Statistical Physics	
PHYS 4008 [0.5]	Fourth-Year Physics Laboratory: Selected Experiments and Workshop	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
5. 1.0 credit from:		1.0
a. PHYS 4907 [0.5] plus 0.5 credit 4000-level PHYS		
b. PHYS 4908 [0.5] plus 0.5 credit 4000-level PHYS		
c. PHYS 4909 [1.0]		
6. 1.0 credit in 4000-level or above PHYS (PHYS 4807 is recommended for 0.5 credit)		1.0
7. 0.5 credit in 3000-level or above PHYS, COMP, ELEC, MATH and/or STAT		0.5
B. Credits Not Included In the Major CGPA (9.0 credits)		
8. 1.0 credit from:		1.0
BIOL 1103 [0.5] & BIOL 1104 [0.5]	Foundations of Biology I Foundations of Biology II	
CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
CHEM 1005 [0.5] & CHEM 1006 [0.5]	Elementary Chemistry I Elementary Chemistry II	
ERTH 1006 [0.5] & ERTH 1009 [0.5]	Exploring Planet Earth The Earth System Through Time	
9. 3.0 credits in:		3.0
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
MATH 3705 [0.5]	Mathematical Methods I	
STAT 3502 [0.5]	Probability and Statistics	
10. 0.5 credit in:		0.5
MATH 3800 [0.5]	Mathematical Modeling and Computational Methods	
11. 1.0 credit from:		1.0
COMP 1005 [0.5] & COMP 1006 [0.5]	Introduction to Computer Science I Introduction to Computer Science II	
or		
ECOR 1606 [0.5] & ECOR 2606 [0.5]	Problem Solving and Computers Numerical Methods	
12. 0.5 credit at the 2000-level or higher in COMP, MATH, or PHYS		**0.5**
13. 0.5 credit from:		0.5
NSCI 1000 [0.5]	Seminar in Science	
Approved courses outside the faculties of Science and Engineering and Design		
14. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design		1.5
15. 1.0 credit in free electives		1.0
Total Credits		**20.0**

Physics (Theory Stream)
B.Sc. Honours (20.0 credits)

A. Credits Included in the Major CGPA (10.5 credits)		
1. 1.0 credit from:		1.0
PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 2.0 credits in:		2.0
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 2604 [0.5]	Modern Physics I	
3. 4.5 credits in:		4.5
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 3807 [0.5]	Mathematical Physics I	
PHYS 4409 [0.5]	Thermodynamics and Statistical Physics	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
PHYS 4708 [0.5]	Introduction to Quantum Mechanics II	
4. 1.0 credit from:		1.0

a. PHYS 4907 plus 0.5 credit 4000-level PHYS		
b. PHYS 4908 plus 0.5 credit 4000-level PHYS		
c. PHYS 4909 [1.0]		
5. 1.0 credit in PHYS at the 4000-level or above		1.0
6. 1.0 credit in PHYS, COMP, MATH and/or STAT at the 3000-level or above		1.0
B. Credits Not Included In the Major CGPA (9.5 credits)		
7. 1.0 credit from:		1.0
BIOL 1103 [0.5] & BIOL 1104 [0.5]	Foundations of Biology I Foundations of Biology II	
CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
CHEM 1005 [0.5] & CHEM 1006 [0.5]	Elementary Chemistry I Elementary Chemistry II	
ERTH 1006 [0.5] & ERTH 1009 [0.5]	Exploring Planet Earth The Earth System Through Time	
8. 3.5 credits in:		3.5
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
MATH 2107 [0.5]	Linear Algebra II	
MATH 3705 [0.5]	Mathematical Methods I	
STAT 3502 [0.5]	Probability and Statistics	
9. 0.5 credit in:		0.5
MATH 3800 [0.5]	Mathematical Modeling and Computational Methods	
10. 1.0 credit from:		1.0
COMP 1005 [0.5] & COMP 1006 [0.5]	Introduction to Computer Science I Introduction to Computer Science II	
or		
ECOR 1606 [0.5] & ECOR 2606 [0.5]	Problem Solving and Computers Numerical Methods	
11. 0.5 credit at the 2000-level or higher in COMP, MATH, or PHYS		**0.5**
12. 0.5 credit in:		0.5
NSCI 1000 [0.5]	Seminar in Science	
or approved courses outside the faculties of Science and Engineering and Design		
13. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design		1.5
14. 1.0 credit in free electives		1.0
Total Credits		**20.0**

Physics
B.Sc. Major (20.0 credits)

A. Credits Included in the Major CGPA (9.0 credits)		
1. 1.0 credit from:		1.0
PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 2.0 credits in:		2.0
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 2604 [0.5]	Modern Physics I	
3. 1.0 credit in approved computer science, engineering, mathematics or statistics electives at the 2000-level or higher which may include 0.5 credit 1000-level computer science		1.0
4. 2.0 credits in:		2.0
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5] or PHYS 3608 [0.5]	Modern Physics II Modern Applied Physics	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
5. 1.0 credit in PHYS at the 4000-level		1.0
6. 1.5 credit in PHYS at the 3000-level or above		1.5
7. 0.5 credit in ELEC and/or science faculty electives (excluding TSES) at the 3000-level or above		0.5
B. Credits Not Included In the Major CGPA (11.0 credits)		
8. 1.0 credit from:		1.0
BIOL 1103 [0.5] & BIOL 1104 [0.5]	Foundations of Biology I Foundations of Biology II	
CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
CHEM 1005 [0.5] & CHEM 1006 [0.5]	Elementary Chemistry I Elementary Chemistry II	
ERTH 1006 [0.5] & ERTH 1009 [0.5]	Exploring Planet Earth The Earth System Through Time	
9. 3.0 credits in:		3.0
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
MATH 3705 [0.5]	Mathematical Methods I	
STAT 2507 [0.5] or STAT 3502 [0.5]	Introduction to Statistical Modeling I Probability and Statistics	
10. 0.5 credit from:		0.5
COMP 1005 [0.5]	Introduction to Computer Science I	
ECOR 1606 [0.5]	Problem Solving and Computers	
11. 3.5 credits in Advanced Science Faculty Electives and/or approved courses outside the Faculties of Science and Engineering selected in consultation with the Department to complement the study of physics; these credits may be used with an additional 0.5 credit to complete the requirements of a minor designation		3.5
12. 0.5 credit from:		0.5
NSCI 1000 [0.5]	Seminar in Science	
Approved courses outside the faculties of Science and Engineering and Design		

13. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design	1.5
14. 1.0 credit in free electives	1.0
Total Credits	**20.0**

Physics
B.Sc. (15.0 credits)

A. Credits Included in the Major CGPA (6.0 credits)		
1. 1.0 credit from:		1.0
PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 3.5 credits in:		3.5
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 2604 [0.5]	Modern Physics I	
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3802 [0.5]	Advanced Dynamics	
3. 0.5 credit from:		0.5
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3606 [0.5]	Modern Physics II	
or PHYS 3608 [0	Modern Applied Physics	
4. 1.0 credit in PHYS at the 3000-level or above		1.0
B. Credits Not Included in the Major CGPA (9.0 credits)		
5. 2.5 credits in:		2.5
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
MATH 3705 [0.5]	Mathematical Methods I	
6. 1.0 credit from:		1.0
BIOL 1103 [0.5] & BIOL 1104 [0.5]	Foundations of Biology I Foundations of Biology II	
CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
CHEM 1005 [0.5] & CHEM 1006 [0.5]	Elementary Chemistry I Elementary Chemistry II	
ERTH 1006 [0.5] & ERTH 1009 [0.5]	Exploring Planet Earth The Earth System Through Time	
7. 1.0 credit in Science Continuation Courses (not PHYS)		1.0
8. 1.5 credit in Science Faculty Electives and/or Science Continuation Courses		1.5
9. 2.0 credits in NSCI 1000 or approved courses outside the faculties of Science and Engineering and Design		2.0
10. 1.0 credit in free electives		1.0
Total Credits		**15.0**

Applied Physics
B.Sc. Honours (20.0 credits)

A. Credits Included in the Major CGPA (11.0 credits)		
1. 1.0 credit from:		1.0
PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 2.0 credits in:		2.0
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 2604 [0.5]	Modern Physics I	
3. 1.0 credit in:		1.0
ELEC 2501 [0.5]	Circuits and Signals	
ELEC 2507 [0.5]	Electronics I	
4. 0.5 credit from:		0.5
ECOR 2606 [0.5]	Numerical Methods	
MATH 3800 [0.5]	Mathematical Modeling and Computational Methods	
5. 4.0 credits in:		4.0
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3608 [0.5]	Modern Applied Physics	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 3807 [0.5]	Mathematical Physics I	
PHYS 4008 [0.5]	Fourth-Year Physics Laboratory: Selected Experiments and Workshop	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
6. 1.0 credit from:		1.0
PHYS 3207 [0.5]	Topics in Biophysics	
PHYS 4203 [0.5]	Physical Applications of Fourier Analysis	
PHYS 4208 [0.5]	Modern Optics	
PHYS 4608 [0.5]	Nuclear Physics	
PHYS 4807 [0.5]	Statistical Data Analysis Techniques for Physics	
7. 0.5 credit from:		0.5
ELEC 3509 [0.5]	Electronics II	
ELEC 3908 [0.5]	Physical Electronics	
COMP at the 3000-level		
PHYS at the 4000-level		
8. 1.0 credit from:		1.0
a. PHYS 4907 plus 0.5 credit 4000-level PHYS		
b. PHYS 4908 plus 0.5 credit 4000-level PHYS		

c. PHYS 4909 [1.0]		
B. Credits Not Included in the Major CGPA (9.0 credits)		
9. 1.0 credit from:		1.0
BIOL 1103 [0.5] & BIOL 1104 [0.5]	Foundations of Biology I Foundations of Biology II	
CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
CHEM 1005 [0.5] & CHEM 1006 [0.5]	Elementary Chemistry I Elementary Chemistry II	
ERTH 1006 [0.5] & ERTH 1009 [0.5]	Exploring Planet Earth The Earth System Through Time	
10. 3.0 credits in:		3.0
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
STAT 3502 [0.5]	Probability and Statistics	
MATH 3705 [0.5]	Mathematical Methods I	
11. 0.5 credit from:		0.5
COMP 1005 [0.5]	Introduction to Computer Science I	
ECOR 1606 [0.5]	Problem Solving and Computers	
12. 4.0 credits in:		4.0
a. (COMP 1006 and COMP 2401) or (SYSC 2006 and SYSC 2004)		
b. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design		
c. 1.5 credit in free electives		
13. 0.5 credit from:		0.5
NSCI 1000 [0.5]	Seminar in Science	
Approved courses outside the faculties of Science and Engineering and Design		
Total Credits		**20.0**

Mathematics and Physics
B.Sc. Double Honours (21.5 credits)

Note that the following courses have minimum grade requirements in their prerequisites. Refer to the section Course Prerequisites under the Mathematics and Statistics programs sections of the calendar.

MATH 2000 [1.0]	Multivariable Calculus and Fundamentals of Analysis
MATH 2100 [1.0]	Algebra
MATH 2454 [0.5]	Ordinary Differential Equations (Honours)
STAT 2655 [0.5]	Introduction to Probability with Applications (Honours)

A. Credits Included in the Major CGPA (17.0 credits)		
1. 7.5 credits in:		7.5
MATH 1052 [0.5]	Calculus and Introductory Analysis I	
MATH 1152 [0.5]	Introductory Algebra I	
MATH 1800 [0.5]	Introduction to Mathematical Reasoning	
MATH 2000 [1.0]	Multivariable Calculus and Fundamentals of Analysis	
MATH 2052 [0.5]	Calculus and Introductory Analysis II	
MATH 2100 [1.0]	Algebra	
MATH 2152 [0.5]	Introductory Algebra II	
MATH 2454 [0.5]	Ordinary Differential Equations (Honours)	
MATH 3001 [0.5]	Real Analysis I (Honours)	
MATH 3008 [0.5]	Ordinary Differential Equations (Honours)	
MATH 3057 [0.5]	Functions of a Complex Variable (Honours)	
MATH 3705 [0.5]	Mathematical Methods I	
STAT 2655 [0.5]	Introduction to Probability with Applications (Honours)	
2. 0.5 credit from:		0.5
MATH 3002 [0.5]	Real Analysis II (Honours)	
MATH 3003 [0.5]	Advanced Differential Calculus (Honours)	
MATH 3106 [0.5]	Introduction to Group Theory (Honours)	
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3606 [0.5]	Modern Physics II	
3. 1.0 credit in 4000-level or higher MATH, STAT		1.0
4. 1.0 credit from:		1.0
PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
5. 2.0 credits in:		2.0
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 2604 [0.5]	Modern Physics I	
6. 3.0 credits in:		3.0
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 4409 [0.5]	Thermodynamics and Statistical Physics	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
PHYS 4708 [0.5]	Introduction to Quantum Mechanics II	
7. 1.0 credit in PHYS at the 4000-level		1.0
8. 1.0 credit from:		1.0
a. MATH 4905 or PHYS 4907 or PHYS 4908 plus 0.5 credit 4000-level MATH or PHYS		
b. PHYS 4909 [1.0]		
B. Credits Not Included in the Major CGPA (4.5 credits)		
9. 1.0 credit from:		1.0
BIOL 1103 [0.5] & BIOL 1104 [0.5]	Foundations of Biology I Foundations of Biology II	

CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
CHEM 1005 [0.5] & CHEM 1006 [0.5]	Elementary Chemistry I Elementary Chemistry II	
ERTH 1006 [0.5] & ERTH 1009 [0.5]	Exploring Planet Earth The Earth System Through Time	
10. 0.5 credit in:		0.5
COMP 1005 [0.5]	Introduction to Computer Science I	
11. 0.5 credit from:		0.5
NSCI 1000 [0.5]	Seminar in Science	
Approved courses outside the faculties of Science and Engineering and Design		
12. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design		1.5
13. 1.0 credit in free electives		1.0
Total Credits		**21.5**

Biology and Physics
B.Sc. Combined Honours (20.0 credits)

A. Credits Included in the Major CGPA (12.5 credits)

1. 1.0 credit from:		1.0
PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 3.5 credits in:		3.5
PHYS 2604 [0.5]	Modern Physics I	
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3207 [0.5]	Topics in Biophysics	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
3. 1.0 credit from:		1.0
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3802 [0.5]	Advanced Dynamics	
4. 1.0 credit from:		1.0
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 3807 [0.5]	Mathematical Physics I	
PHYS 4203 [0.5]	Physical Applications of Fourier Analysis	
PHYS 4409 [0.5]	Thermodynamics and Statistical Physics	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
5. 4.0 credits from:		4.0
BIOL 1103 [0.5]	Foundations of Biology I	
BIOL 1104 [0.5]	Foundations of Biology II	
BIOL 2200 [0.5]	Cellular Biochemistry	
BIOL 2104 [0.5]	Introductory Genetics	
BIOL 2001 [0.5]	Animals: Form and Function	
BIOL 2002 [0.5]	Plants: Form and Function	
BIOL 3201 [0.5]	Cell Biology	
BIOL 3104 [0.5]	Molecular Genetics	
BIOL 3305 [0.5]	Human and Comparative Physiology	
6. 1.0 credit from:		1.0
BIOL 3501 [0.5]	Biomechanics	
BIOL 4106 [0.5]	Advances in Molecular Biology	
BIOL 4109 [0.5]	Laboratory Techniques in Molecular Genetics	
BIOL 4201 [0.5]	Advanced Cell Culture and Tissue Engineering	
BIOL 4202 [0.5]	Mutagenesis and DNA Repair	
BIOL 4301 [0.5]	Current Topics in Biotechnology	
BIOL 4306 [0.5]	Animal Neurophysiology	
BIOL 4309 [0.5]	Studies in Human Performance	
BIOL 4319 [0.5]	Studies in Exercise Physiology	
7. 1.0 credit from:		1.0
BIOL 4905 [1.0]	Honours Workshop	
BIOL 4907 [1.0]	Honours Essay and Research Proposal	
BIOL 4908 [1.0]	Honours Research Thesis	
PHYS 4909 [1.0]	Fourth-Year Project	
PHYS 4907 plus 0.5 credit 4000-level PHYS		
PHYS 4908 plus 0.5 credit 4000-level PHYS		

B. Credits Not Included in the Major CGPA (7.5 credits)

8. 1.0 credit in:		1.0
CHEM 1001 [0.5] & CHEM 1002 [0.5]	General Chemistry I General Chemistry II	
9. 1.5 credits in:		1.5
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
10. 2.0 credits in:		2.0
STAT 2507 [0.5]	Introduction to Statistical Modeling I	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
MATH 3705 [0.5]	Mathematical Methods I	
MATH 3800 [0.5]	Mathematical Modeling and Computational Methods	
11. 0.5 credit in:		0.5
COMP 1005 [0.5]	Introduction to Computer Science I	
12. 2.0 credits in approved courses outside the faculties of Science and Engineering and Design (may include NSCI 1000)		2.0
13. 0.5 credit in free electives		0.5
Total Credits		**20.0**

Chemistry and Physics
B.Sc. Combined Honours (20.0 credits)

A. Credits Included in the Major CGPA (13.0 credits)

1. 1.0 credit from:		1.0

PHYS 1001 [0.5] & PHYS 1002 [0.5]	Foundations of Physics I Foundations of Physics II (recommended)	
PHYS 1003 [0.5] & PHYS 1004 [0.5]	Introductory Mechanics and Thermodynamics Introductory Electromagnetism and Wave Motion	
PHYS 1007 [0.5] & PHYS 1008 [0.5]	Elementary University Physics I Elementary University Physics II (with an average grade of B- or higher)	
2. 3.0 credits in:		3.0
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2604 [0.5]	Modern Physics I	
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
PHYS 3807 [0.5]	Mathematical Physics I	
3. 1.5 credits from:		1.5
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 4707 [0.5]	Introduction to Quantum Mechanics I	
4. 0.5 credit in PHYS at the 4000 level		0.5
5. 5.0 credits in:		5.0
CHEM 1001 [0.5]	General Chemistry I	
CHEM 1002 [0.5]	General Chemistry II	
CHEM 2103 [0.5]	Physical Chemistry I	
CHEM 2203 [0.5]	Organic Chemistry I	
CHEM 2204 [0.5]	Organic Chemistry II	
CHEM 2501 [0.5]	Introduction to Inorganic and Bioinorganic Chemistry	
CHEM 3100 [0.5]	Physical Chemistry II	
CHEM 3102 [0.5]	Methods of Computational Chemistry	
CHEM 3503 [0.5]	Inorganic Chemistry I	
CHEM 4102 [0.5]	Advanced Topics in Physical Chemistry II	
6. 0.5 credit from:		0.5
CHEM 3106 [0.5]	Computational Chemistry Methods Laboratory	
CHEM 3107 [0.5]	Experimental Methods in Nanoscience	
7. 0.5 credit in CHEM at the 4000 level		0.5
8. 1.0 credit from:		1.0
CHEM 4908 [1.0]	Research Project and Seminar	
PHYS 4909 [1.0]	Fourth-Year Project	
PHYS 4907 plus 0.5 credit in PHYS at the 4000 level		
PHYS 4908 plus 0.5 credit in PHYS at the 4000 level		
B. Credits Not Included in the Major CGPA (7.0 credits)		
9. 3.0 credits in:		3.0
MATH 1004 [0.5]	Calculus for Engineering or Physics	
MATH 1005 [0.5]	Differential Equations and Infinite Series for Engineering or Physics	
MATH 1104 [0.5]	Linear Algebra for Engineering or Science	
MATH 2004 [0.5]	Multivariable Calculus for Engineering or Physics	
STAT 3502 [0.5]	Probability and Statistics	
MATH 3705 [0.5]	Mathematical Methods I	
10. 0.5 credit from:		0.5
COMP 1005 [0.5]	Introduction to Computer Science I	
ECOR 1606 [0.5]	Problem Solving and Computers	
11. 0.5 credit from:		0.5
MATH 3800 [0.5]	Mathematical Modeling and Computational Methods	
ECOR 2606 [0.5]	Numerical Methods	
12. 0.5 credit from:		0.5
NSCI 1000 [0.5]	Seminar in Science	
Approved courses outside the faculties of Science and Engineering and Design		
13. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design (may include NSCI 1000, if not used above)		1.5
14. 1.0 credit in free electives.		1.0
Total Credits		**20.0**

Minor in Physics (4.0 credits)

The Minor in Physics is available to students registered in degree programs other than those offered by the Department of Physics. Careful attention must be paid to prerequisites.

Students are required to present a Minor CGPA of 4.00 or higher at graduation in order to be awarded a Minor in Physics.

Requirements

1. 0.5 credit from:		0.5
PHYS 1001 [0.5]	Foundations of Physics I	
PHYS 1003 [0.5]	Introductory Mechanics and Thermodynamics	
PHYS 1007 [0.5]	Elementary University Physics I (with a grade of B- or higher)	
2. 0.5 credit from:		0.5
PHYS 1002 [0.5]	Foundations of Physics II	
PHYS 1004 [0.5]	Introductory Electromagnetism and Wave Motion	
PHYS 1008 [0.5]	Elementary University Physics II (with a grade of B- or higher)	
3. 1.0 credit in:		1.0
PHYS 2604 [0.5]	Modern Physics I	
PHYS 3701 [0.5]	Elements of Quantum Mechanics	
4. 2.0 credits from:		2.0
PHYS 2202 [0.5]	Wave Motion and Optics	
PHYS 2305 [0.5]	Electricity and Magnetism	
PHYS 2401 [0.5]	Thermal Physics	
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars	
PHYS 3207 [0.5]	Topics in Biophysics	
PHYS 3308 [0.5]	Electromagnetism	
PHYS 3606 [0.5]	Modern Physics II	
PHYS 3802 [0.5]	Advanced Dynamics	
PHYS 3807 [0.5]	Mathematical Physics I	

PHYS at the 4000-level	
Total Credits	**4.0**

B.Sc. Regulations

The regulations presented in this section apply to all Bachelor of Science programs. In addition to the requirements presented here, students must satisfy the University regulations common to all undergraduate students including the process of Academic Continuation Evaluation (see the *Academic Regulations of the University* section of this Calendar).

Breadth Requirement for the B.Sc.

Students in a Bachelor of Science program must present the following credits at graduation:

1. 2.0 credits in Science Continuation courses not in the major discipline; **students completing a double major are considered to have completed this requirement providing they have 2.0 credits in Science Continuation courses in each of the two majors;**
2. 2.0 credits in courses outside of the faculties of Science and Engineering and Design (may include NSCI 1000)

In most cases, the requirements for individual B.Sc. programs, as stated in this Calendar, contain these requirements, explicitly or implicitly.

Students admitted to B.Sc. programs by transfer from another institution must present at graduation (whether taken at Carleton or elsewhere):

1. 2.0 credits in courses outside of the faculties of Science and Engineering and Design (may include NSCI 1000) if the student received fewer than 10.0 transfer credits; or,
2. 1.0 credit in courses outside of the faculties of Science and Engineering and Design (may include NSCI 1000) if the student received 10.0 or more transfer credits.

Declared and Undeclared Students

Degree students are considered "Undeclared" if they have been admitted to a degree, but have not yet selected and been accepted into a program within that degree. The status "Undeclared" is available only in the B.A. and B.Sc. degrees. Undeclared students must apply to enter a program upon or before completing 3.5 credits.

Change of Program within the B.Sc. Degree

To transfer to a program within the B.Sc. degree, applicants must normally be *Eligible to Continue* (EC) in the new program, by meeting the CGPA thresholds described in Section 3.1.9 of the *Academic Regulations of the University.*

Applications to declare or change programs within the B.Sc. degree must be made online through Carleton Central by completing a Change of Program Elements (COPE) application form within the published deadlines. Acceptance into a program, or into a program element or option, is subject to any enrolment limitations, and/or specific program, program element or option requirements as published in the relevant Calendar entry.

Minors, Concentrations, and Specializations

Students may add a Minor, Concentration, or Specialization by completing a Change of Program Elements (COPE) application form online through Carleton Central. Acceptance into a Minor, Concentration, or Specialization normally requires that the student be *Eligible to Continue* (EC) and is meeting the minimum CGPAs described in Section 3.1.9 of the *Academic Regulations of the University*, as well as being subject to any specific requirements of the intended Minor, Concentration, or Specialization as published in the relevant Calendar entry.

Experimental Science Requirement

Students in a B.Sc. degree program must present at graduation at least two full credits of Experimental Science chosen from two different departments or institutes from the list below:

Approved Experimental Science Courses

Biochemistry	
BIOC 2200 [0.5]	Cellular Biochemistry
BIOC 4001 [0.5]	Methods in Biochemistry
BIOC 4201 [0.5]	Advanced Cell Culture and Tissue Engineering
Biology	
BIOL 1103 [0.5]	Foundations of Biology I
BIOL 1104 [0.5]	Foundations of Biology II
BIOL 2001 [0.5]	Animals: Form and Function
BIOL 2002 [0.5]	Plants: Form and Function
BIOL 2104 [0.5]	Introductory Genetics
BIOL 2200 [0.5]	Cellular Biochemistry
BIOL 2600 [0.5]	Ecology
Chemistry	
CHEM 1001 [0.5]	General Chemistry I
CHEM 1002 [0.5]	General Chemistry II
CHEM 1005 [0.5]	Elementary Chemistry I
CHEM 1006 [0.5]	Elementary Chemistry II
CHEM 2103 [0.5]	Physical Chemistry I
CHEM 2203 [0.5]	Organic Chemistry I
CHEM 2204 [0.5]	Organic Chemistry II
CHEM 2302 [0.5]	Analytical Chemistry I
CHEM 2303 [0.5]	Analytical Chemistry II
CHEM 2800 [0.5]	Foundations for Environmental Chemistry
Earth Sciences	
ERTH 1006 [0.5]	Exploring Planet Earth
ERTH 1009 [0.5]	The Earth System Through Time
ERTH 2102 [0.5]	Mineralogy to Petrology
ERTH 2404 [0.5]	Engineering Geoscience
ERTH 2802 [0.5]	Field Geology I
ERTH 3111 [0.5]	Vertebrate Evolution: Mammals, Reptiles, and Birds
ERTH 3112 [0.5]	Vertebrate Evolution: Fish and Amphibians
ERTH 3204 [0.5]	Mineral Deposits
ERTH 3205 [0.5]	Physical Hydrogeology
ERTH 3806 [0.5]	Structural Geology
Food Sciences	

FOOD 3001 [0.5]	Food Chemistry
FOOD 3002 [0.5]	Food Analysis
FOOD 3005 [0.5]	Food Microbiology
Geography	
GEOG 1010 [0.5]	Global Environmental Systems
GEOG 3108 [0.5]	Soil Properties
Neuroscience	
NEUR 3206 [0.5]	Sensory and Motor Neuroscience
NEUR 3207 [0.5]	Systems Neuroscience
NEUR 4600 [0.5]	Advanced Lab in Neuroanatomy
Physics	
PHYS 1001 [0.5]	Foundations of Physics I
PHYS 1002 [0.5]	Foundations of Physics II
PHYS 1003 [0.5]	Introductory Mechanics and Thermodynamics
PHYS 1004 [0.5]	Introductory Electromagnetism and Wave Motion
PHYS 1007 [0.5]	Elementary University Physics I
PHYS 1008 [0.5]	Elementary University Physics II
PHYS 2202 [0.5]	Wave Motion and Optics
PHYS 2604 [0.5]	Modern Physics I
PHYS 3007 [0.5]	Third Year Physics Laboratory: Selected Experiments and Seminars
PHYS 3606 [0.5]	Modern Physics II
PHYS 3608 [0.5]	Modern Applied Physics

Course Categories for B.Sc. Programs

Science Geography Courses

GEOG 1010 [0.5]	Global Environmental Systems
GEOG 2006 [0.5]	Introduction to Quantitative Research
GEOG 2013 [0.5]	Weather and Water
GEOG 2014 [0.5]	The Earth's Surface
GEOG 3003 [0.5]	Quantitative Geography
GEOG 3010 [0.5]	Field Methods in Physical Geography
GEOG 3102 [0.5]	Geomorphology
GEOG 3103 [0.5]	Watershed Hydrology
GEOG 3104 [0.5]	Principles of Biogeography
GEOG 3105 [0.5]	Climate and Atmospheric Change
GEOG 3106 [0.5]	Aquatic Science and Management
GEOG 3108 [0.5]	Soil Properties
GEOG 4000 [0.5]	Field Studies
GEOG 4005 [0.5]	Directed Studies in Geography
GEOG 4013 [0.5]	Cold Region Hydrology
GEOG 4017 [0.5]	Global Biogeochemical Cycles
GEOG 4101 [0.5]	Two Million Years of Environmental Change
GEOG 4103 [0.5]	Water Resources Engineering
GEOG 4104 [0.5]	Microclimatology
GEOG 4108 [0.5]	Permafrost

Science Psychology Courses

PSYC 2001 [0.5]	Introduction to Research Methods in Psychology
PSYC 2002 [0.5]	Introduction to Statistics in Psychology
PSYC 2700 [0.5]	Introduction to Cognitive Psychology
PSYC 3000 [1.0]	Design and Analysis in Psychological Research
PSYC 3506 [0.5]	Cognitive Development
PSYC 3700 [1.0]	Cognition (Honours Seminar)
PSYC 3702 [0.5]	Perception
PSYC 2307 [0.5]	Human Neuropsychology I
PSYC 3307 [0.5]	Human Neuropsychology II

Science Continuation Courses

A course at the 2000 level or above may be used as a Science Continuation credit in a B.Sc. program if it is not in the student's major discipline, and is chosen from the following:

- BIOC (Biochemistry)
- BIOL (Biology) Biochemistry students may use BIOL 2005 only as a free elective.
- CHEM (Chemistry)
- COMP (Computer Science) A maximum of two half-credits at the 1000-level in COMP, excluding COMP 1001 may be used as Science Continuation credits.
- ERTH (Earth Sciences), except ERTH 2415 which may be used only as a free elective for any B.Sc. program. Students in Earth Sciences programs may use ERTH 2401, ERTH 2402, and ERTH 2403 only as free electives.
- Engineering. Students wishing to register in Engineering courses must obtain the permission of the Faculty of Engineering and Design.
- ENSC (Environmental Science)
- FOOD (Food Science and Nutrition)
- GEOM (Geomatics)
- HLTH (Health Sciences)
- ISAP (Interdisciplinary Science Practice)
- MATH (Mathematics)
- NEUR (Neuroscience)
- PHYS (Physics), except PHYS 2903
- Science Geography Courses (see list above)
- Science Psychology Courses (see list above)
- STAT (Statistics)
- TSES (Technology, Society, Environment) except TSES 2305. Biology students may use these courses only as free electives. Integrated Science and Environmental Science students may include these courses in their programs but may not count them as part of the Science Sequence.

Science Faculty Electives

Science Faculty Electives are courses at the 1000-4000 level chosen from:

- BIOC (Biochemistry)
- BIOL (Biology) Biology & Biochemistry students may use BIOL 1010 and BIOL 2005 only as free electives
- CHEM (Chemistry) except CHEM 1003, CHEM 1004 and CHEM 1007
- COMP (Computer Science) except COMP 1001
- ERTH (Earth Sciences) except ERTH 1010, ERTH 1011 and ERTH 2415. Earth Sciences students may use ERTH 2401, ERTH 2402, and ERTH 2403 only as free electives.

Engineering
ENSC 2001
FOOD (Food Science and Nutrition)
GEOM (Geomatics)
HLTH (Health Science)
ISAP (Interdisciplinary Science Practice)
MATH (Mathematics)
NEUR (Neuroscience)
PHYS (Physics) except PHYS 1901, PHYS 1902, PHYS 1905, PHYS 2903
Science Geography (see list above)
Science Psychology (see list above)
STAT (Statistics)
TSES (Technology, Society, Environment) Biology students may use these courses only as free electives.

Advanced Science Faculty Electives

Advanced Science Faculty Electives are courses at the 2000-4000 level chosen from the Science Faculty Electives list above.

Approved Courses Outside the Faculties of Science and Engineering and Design (may include NSCI 1000)

All courses offered by the Faculty of Arts and Social Sciences, the Faculty of Public Affairs, and the Sprott School of Business are approved as Arts or Social Sciences courses EXCEPT FOR: All Science Geography courses (see list above), all Geomatics (GEOM) courses, all Science Psychology courses (see list above). NSCI 1000 may be used as an Approved Course Outside the Faculties of Science and Engineering and Design.

Free Electives

Any course is allowable as a Free Elective providing it is not prohibited (see below). Students are expected to comply with prerequisite requirements and enrolment restrictions for all courses as published in this Calendar.

Courses Allowable Only as Free Electives in any B.Sc. Program

BIOL 4810 [0.5]	Education Research in Undergraduate Science
CHEM 1003 [0.5]	The Chemistry of Food, Health and Drugs
CHEM 1004 [0.5]	Drugs and the Human Body
CHEM 1007 [0.5]	Chemistry of Art and Artifacts
ERTH 1010 [0.5]	Our Dynamic Planet Earth
ERTH 1011 [0.5]	Evolution of the Earth
ERTH 2415 [0.5]	Natural Disasters
ISCI 1001 [0.5]	Introduction to the Environment
ISCI 2000 [0.5]	Natural Laws
ISCI 2002 [0.5]	Human Impacts on the Environment
MATH 0107 [0.5]	Algebra and Geometry
PHYS 1901 [0.5]	Planetary Astronomy
PHYS 1902 [0.5]	From our Star to the Cosmos
PHYS 1905 [0.5]	Physics Behind Everyday Life
PHYS 2903 [0.5]	Physics Towards the Future

Prohibited Courses

The following courses are not acceptable for credit in any B.Sc. program:

COMP 1001 [0.5]	Introduction to Computational Thinking for Arts and Social Science Students
MATH 0005 [0.5]	Precalculus: Functions and Graphs
MATH 0006 [0.5]	Precalculus: Trigonometric Functions and Complex Numbers
MATH 1009 [0.5]	Mathematics for Business
MATH 1119 [0.5]	Linear Algebra: with Applications to Business
MATH 1401 [0.5]	Elementary Mathematics for Economics I
MATH 1402 [0.5]	Elementary Mathematics for Economics II

Co-operative Education

For more information about how to apply for the Co-op program and how the Co-op program works please visit the Co-op website.

All students participating in the Co-op program are governed by the Undergraduate Co-operative Education Policy.

Undergraduate Co-operative Education Policy

Admission Requirements

Students can apply to Co-op in one of two ways: directly from high school, or after beginning a degree program at Carleton.

If a student applies to a degree program with a Co-op option from high school, their university grades will be reviewed two terms to one year prior to their first work term to ensure they meet the academic requirements after their first or second year of study. The time at which the evaluation takes place depends on the program of study. Students will automatically receive an admission decision via their Carleton email account.

Students who did not request Co-op at the time they applied to Carleton can request Co-op after they begin their university studies. To view application instructions and deadlines, please visit carleton.ca/co-op.

To be admitted to Co-op, a student must successfully complete 5.0 or more credits that count towards their degree, meet the minimum CGPA requirement(s) for the student's Co-op option, and fulfil any specified course prerequisites. To see the unique admission and continuation requirements for each Co-op option, please refer to the specific degree programs listed in the Undergraduate Calendar.

Participation Requirements

COOP 1000

Once a student has been given admission or continuation confirmation to the co-op option s/he must complete and pass COOP 1000 (a mandatory online 0.0 credit course). Students will have access to this course a minimum of two terms prior to their first work term and will be notified when to register.

Communication with the Co-op Office

Students must maintain contact with the co-op office during their job search and while on a work term. All

email communication will be conducted via the students' Carleton email account.

Employment

Although every effort is made to ensure a sufficient number of job postings for all students enrolled in the co-op option of their degree program, no guarantee of employment can be made. Carleton's co-op program operates a competitive job search process and is dependent upon current market conditions. Academic performance, skills, motivation, maturity, attitude and potential will determine whether a student is offered a job. It is the student's responsibility to actively conduct a job search in addition to participation in the job search process operated by the co-op office. Once a student accepts a co-op job offer (verbally or written), his/her job search will end and access to co-op jobs will be removed for that term. Students that do not successfully obtain a co-op work term are expected to continue with their academic studies. The summer term is the exception to this rule. Students should also note that hiring priority is given to Canadian citizens for co-op positions in the Federal Government of Canada.

Registering in Co-op Courses

Students will be registered in a Co-op Work Term course while at work. The number of Co-op Work Term courses that a student is registered in is dependent upon the number of four-month work terms that a student accepts.

While on a co-op work term students may take a maximum of 0.5 credit throughout each four-month co-op work term. Courses must be scheduled outside of regular working hours.

Students must be registered as full-time before they begin their co-op job search. All co-op work terms must be completed before the beginning of the final academic term. Students may not finish their degree on a co-op work term.

Work Term Assessment and Evaluation

To obtain a Satisfactory grade for the co-op work term students must have:

1. A satisfactory work term evaluation by the co-op employer;
2. A satisfactory grade on the work term report.

Students must submit a work term report at the completion of each four-month work term. Reports are due on the 16th of April, August, and December and students are notified of due dates through their Carleton email account.

Workplace performance will be assessed by the workplace supervisor. Should a student receive an unsatisfactory rating from their co-op employer, an investigation by the co-op program manager will be undertaken. An unsatisfactory employer evaluation does not preclude a student from achieving an overall satisfactory rating for the work term.

Graduation with the Co-op Designation

In order to graduate with the co-op designation, students must satisfy all requirements for their degree program in addition to the requirements according to each co-op program (i.e. successful completion of three or four work terms).

Note: Participation in the co-op option will add up to one additional year for a student to complete their degree program.

Voluntary Withdrawal from the Co-op Option

Students may withdraw from the co-op option of their degree program during a study term ONLY. Students at work may not withdraw from the work term or the co-op option until s/he has completed the requirements of the work term.

Students are eligible to continue in their regular academic program provided that they meet the academic standards required for continuation.

Involuntary or Required Withdrawal from the Co-op Option

Students may be required to withdraw from the co-op option of their degree program for one or any of the following reasons:

1. Failure to achieve a grade of SAT in COOP 1000
2. Failure to pay all co-op related fees
3. Failure to actively participate in the job search process
4. Failure to attend all interviews for positions to which the student has applied
5. Declining more than one job offer during the job search process
6. Continuing a job search after accepting a co-op position
7. Dismissal from a work term by the co-op employer
8. Leaving a work term without approval by the Co-op manager
9. Receipt of an unsatisfactory work term evaluation
10. Submission of an unsatisfactory work term report

Standing and Appeals

The Co-op and Career Services office administers the regulations and procedures that are applicable to all co-op program options. All instances of a student's failure during a work term or other issues directly related to their participation in the co-op option will be reported to the academic department.

Any decision made by the Co-op and Career Services office can be appealed via the normal appeal process within the University.

International Students

All International Students are required to possess a Co-op Work Permit issued by Immigration, Refugees and Citizenship Canada before they can begin working. It is illegal to work in Canada without the proper authorization. Students will be provided with a letter of support to accompany their application. Students must submit their application for their permit before being permitted to view and apply for jobs on the Co-op Services database. Confirmation of a position will not be approved until a student can confirm they have received their permit. Students are advised to discuss the application process

and requirements with the International Student Services Office.

B.Sc. Honours Physics, Applied Physics: Co-op Admission and Continuation Requirements

- Maintain full-time status in each study term;
- Be eligible to work in Canada (for off-campus work)
- Have successfully completed COOP 1000 [0.0]

In addition to the following:

1. Registered as a full-time student in the B.Sc. Honours Physics or Applied Physics program;
2. Successfully completed 5.0 or more credits;
3. Obtained an Overall CGPA of at least 6.50 and a Major CGPA of at least 8.00. These CGPAs must be maintained throughout the duration of the degree.

B.Sc. Honours Physics and Applied Physics students must successfully complete three (3) work terms to obtain the Co-op Designation.

Co-op Work Term Course: PHYS 3999
Work/Study Pattern:

Year 1		Year 2		Year 3		Year 4		Year 5	
Term	**Pattern**	**Term**	**Pattern**	**Term**	**Pattern**	**Term**	**Pattern**	**Term**	**Pattern**
Fall	S	Fall	S	Fall	S	Fall	W	Fall	S
Winter	S	Winter	S	Winter	S	Winter	W	Winter	S
Summer		Summer	W	Summer	W	Summer	W		

Legend
S: Study
W: Work

Admissions Information

Admission Requirements are for the 2023-24 year only, and are based on the Ontario High School System. Holding the minimum admission requirements only establishes eligibility for consideration. The cut-off averages for admission may be considerably higher than the minimum. See also the **General Admission and Procedures** section of this Calendar. An overall average of at least 70% is normally required to be considered for admission. Some programs may also require specific course prerequisites and prerequisite averages and/or supplementary admission portfolios. Higher averages are required for admission to programs for which the demand for places by qualified applicants exceeds the number of places available. The overall average required for admission is determined each year on a program by program basis. Consult admissions.carleton.ca for further details.

Note: Courses listed as *recommended* are not mandatory for admission. Students who do not follow the recommendations will not be disadvantaged in the admission process.

Admissions Information

Admission requirements are based on the Ontario High School System. Prospective students can view the admission requirements through the Admissions website at admissions.carleton.ca. The overall average required for admission is determined each year on a program-by-program basis. Holding the minimum admission requirements only establishes eligibility for consideration; higher averages are required for admission to programs for which the demand for places by qualified applicants exceeds the number of places available. All programs have limited enrolment and admission is not guaranteed. Some programs may also require specific course prerequisites and prerequisite averages and/or supplementary admission portfolios. Consult admissions.carleton.ca for further details.

Note: If a course is listed as *recommended*, it is not mandatory for admission. Students who do not follow the recommendations will not be disadvantaged in the admission process.

Degree

- Bachelor of Mathematics (B. Math.) (Honours)
- Bachelor of Mathematics (B.Math.)

Admission Requirements

B.Math Honours

First Year

The Ontario Secondary School Diploma (OSSD) or equivalent including a minimum of six 4U or M courses. The six 4U or M courses must include Advanced Functions, and Calculus and Vectors.

The overall admission cut-off average and/or the prerequisite course average may be considerably higher than the stated minimum requirements for admission to the combined B.Math./M.Sc. in Mathematics or Statistics.

Advanced Standing

Applications for admission beyond first year will be assessed on their merits. Applicants must normally be Eligible to Continue in their year level, in addition to meeting the CGPA thresholds described in Section 3.1.9 of the Academic Regulations of the University. Advanced standing will be granted only for those subjects assessed as being appropriate for the program and the stream selected.

B.Math

First Year

The Ontario Secondary School Diploma (OSSD) or equivalent including a minimum of six 4U or M courses. The six 4U or M courses must include Advanced Functions, and Calculus and Vectors.

Advanced Standing

Applications for admission beyond first year will be assessed on their merits. Applicants must normally be *Eligible to Continue* (EC) in their year level. Advanced standing will be granted only for those subjects assessed as being appropriate for the program and the stream selected.

Co-op Option

Direct Admission to the First Year of the Co-op Option
Applicants must:

1. meet the required overall admission cut-off average and prerequisite course average. These averages may be higher than the stated minimum requirements;
2. be registered as a full-time student in the Bachelor of Mathematics Honours program;
3. be eligible to work in Canada (for off-campus work placements).

Meeting the above requirements only establishes eligibility for admission to the program. The prevailing job market (and thus the availability of co-op placement) may limit enrolment in the co-op option.

Note: continuation requirements for students previously admitted to the co-op option and admission requirements for the co-op option after beginning the program are described in the Co-operative Education Regulations section of this Calendar.

Admissions Information

Admission Requirements are for the 2023-24 year only, and are based on the Ontario High School System. Holding the minimum admission requirements only establishes eligibility for consideration. The cut-off averages for admission may be considerably higher than the minimum. See also the **General Admission and Procedures** section of this Calendar. An overall average of at least 70% is normally required to be considered for admission. Some programs may also require specific course prerequisites and prerequisite averages and/or supplementary admission portfolios. Higher averages are required for admission to programs for which the demand for places by qualified applicants exceeds the number of places available. The overall average required for admission is determined each year on a program by program basis. Consult admissions.carleton.ca for further details.

Note: Courses listed as *recommended* are not mandatory for admission. Students who do not follow the recommendations will not be disadvantaged in the admission process.

Admissions Information

Admission requirements are based on the Ontario High School System. Prospective students can view the admission requirements through the Admissions website at admissions.carleton.ca. The overall average required for admission is determined each year on a program-by-program basis. Holding the minimum admission requirements only establishes eligibility for consideration; higher averages are required for admission to programs for which the demand for places by qualified applicants exceeds the number of places available. All programs have limited enrolment and admission is not guaranteed. Some programs may also require specific course prerequisites and prerequisite averages and/or supplementary admission portfolios. Consult admissions.carleton.ca for further details.

Note: If a course is listed as *recommended*, it is not mandatory for admission. Students who do not follow the recommendations will not be disadvantaged in the admission process.

Degrees

- B.Sc. (Honours)
- B.Sc. (Major)
- B.Sc.

Admission Requirements

B. Sc. Honours

First Year

The Ontario Secondary School Diploma (OSSD) or equivalent including a minimum of six 4U or M courses. For most programs including Biochemistry, Bioinformatics, Biotechnology, Chemistry, Combined Honours in Biology and Physics, Chemistry and Physics, Computational Biochemistry, Food Science, Nanoscience, Neuroscience and Biology, Neuroscience and Mental Health, and Psychology, the six 4U or M courses must include Advanced Functions, and two of Biology, Chemistry, Earth and Space Sciences, or Physics. (Calculus and Vectors is strongly recommended).

Specific Honours Admission Requirements
For the Honours programs in Earth Sciences, Environmental Science, Geomatics, Interdisciplinary Science and Practice, and Physical Geography, Calculus and Vectors may be substituted for Advanced Functions.

For the Honours programs in Physics and Applied Physics, and for double Honours in Mathematics and Physics, Calculus and Vectors is required in addition to Advanced Functions and one of 4U Physics, Chemistry, Biology, or Earth and Space Sciences. For all programs in Physics, 4U Physics is strongly recommended.

For Honours in Psychology, a 4U course in English is recommended.

For Honours in Environmental Science, a 4U course in Biology and Chemistry is recommended.

Advanced Standing

Applications for admission beyond first year will be assessed on their merits. Applicants must normally be *Eligible to Continue* in their year level, in addition to meeting the CGPA thresholds described in Section 3.1.9 of the Academic Regulations of the University. Advanced standing will be granted only for those subjects deemed appropriate for the program and stream selected.

B.Sc. Major and B.Sc.

First Year

The Ontario Secondary School Diploma (OSSD) or equivalent including a minimum of six 4U or M courses. The six 4U or M courses must include Advanced Functions and two of Calculus and Vectors, Biology, Chemistry, Earth and Space Science, or Physics (Calculus and Vectors is strongly recommended). For the B.Sc. Major in Physics, 4U Physics is strongly recommended.

Advanced Standing

Applications for admission beyond first year will be assessed on their merits. Applicants must normally

be *Eligible to Continue* (EC) in their year level. Advanced standing will be granted only for those subjects deemed appropriate for the program and stream selected.

Co-op Option

Direct Admission to the First Year of the Co-op Option
Applicants must:

1. meet the required overall admission cut-off average and prerequisite course average. These averages may be higher than the stated minimum requirements;
2. be registered as a full-time student in the Bachelor of Science Honours program;
3. be eligible to work in Canada (for off-campus work placements).

Note that meeting the above requirements only establishes eligibility for admission to the program. The prevailing job market may limit enrolment in the co-op option.

Note: continuation requirements for students previously admitted to the co-op option and admission requirements for the co-op option after beginning the program are described in the Co-operative Education Regulations section of this Calendar.

Physics (PHYS) Courses

PHYS 1001 [0.5 credit]
Foundations of Physics I
This calculus-based course on classical mechanics covers kinematics, dynamics, gravitation, and oscillatory motion. This is a specialist course for students intending to take further courses in physics.
Includes: Experiential Learning Activity
Precludes additional credit for BIT 1002, BIT 1203, PHYS 1003, PHYS 1007.
Prerequisite(s): Grade 12 Mathematics: Advanced Functions and Grade 12 Mathematics: Calculus and Vectors or equivalent, plus one of MATH 1004 or MATH 1002 or MATH 1052 (the MATH course may be taken concurrently); or permission of the Physics Department. Grade 12 Physics is strongly recommended.
Lectures three hours a week, laboratory or tutorial three hours a week.

PHYS 1002 [0.5 credit]
Foundations of Physics II
An introduction to electricity, magnetism, electromagnetic fields, and wave motion. This is a specialist course for students intending to take further courses in physics.
Includes: Experiential Learning Activity
Precludes additional credit for BIT 1003 (no longer offered), BIT 1007, BIT 1204, PHYS 1004, PHYS 1008.
Prerequisite(s): PHYS 1001, or PHYS 1003, or PHYS 1007 with a grade of B-; MATH 1004 or MATH 1002 (may be taken concurrently) or MATH 2052 (may be taken concurrently); or permission of the Department.
Lectures three hours a week, laboratory or tutorial three hours a week.

PHYS 1003 [0.5 credit]
Introductory Mechanics and Thermodynamics
Mechanics, gravitation, oscillations, and thermodynamics. The application of calculus to solve problems in these areas of physics is introduced. This course is intended for students in the physical sciences and engineering.
Includes: Experiential Learning Activity
Precludes additional credit for BIT 1002, BIT 1203, PHYS 1001, PHYS 1007.
Prerequisite(s): Grade 12 Physics or equivalent, plus Grade 12 Mathematics: Advanced Functions or equivalent, plus one of MATH 1004 or MATH 1002 or MATH 1052 (the MATH course may be taken concurrently). Note that Grade 12 Mathematics: Calculus and Vectors is strongly recommended.
Lectures three hours a week, laboratory or tutorial three hours a week.

PHYS 1004 [0.5 credit]
Introductory Electromagnetism and Wave Motion
This calculus-based course introduces potential energy, work, electricity, magnetism, oscillations and waves.
Includes: Experiential Learning Activity
Precludes additional credit for BIT 1003 (no longer offered), BIT 1007, BIT 1204, PHYS 1002, PHYS 1008.
Prerequisite(s): MATH 1004, ECOR 1101 or ECOR 1053 or (ECOR 1045 and ECOR 1048) (the ECOR courses may be taken concurrently) or PHYS 1001 or PHYS 1003 or PHYS 1007 (a grade of at least B- is required for PHYS 1007), or permission of the Department.
Lectures three hours a week, laboratory or tutorial three hours a week.

PHYS 1007 [0.5 credit]
Elementary University Physics I
Mechanics, properties of matter, thermodynamics. Applications chosen in part from the life sciences. For students who lack the prerequisites for PHYS 1001 or PHYS 1003, or who do not intend to take upper-year courses in physics.
Includes: Experiential Learning Activity
Precludes additional credit for BIT 1002, BIT 1203, PHYS 1001, PHYS 1003.
Prerequisite(s): (i) Grade 12 Mathematics: Advanced Functions or equivalent, or MATH 0107 (may be taken concurrently); or (ii) Grade 12 Mathematics: Calculus and Vectors or equivalent, or MATH 1007 (may be taken concurrently; or (iii) permission of the Physics Department.
Lectures three hours a week, laboratory or tutorial three hours per week.

PHYS 1008 [0.5 credit]
Elementary University Physics II
Electricity and magnetism, DC and AC circuits, wave motion and light. Elements of modern physics. Applications chosen in part from the life sciences.
Includes: Experiential Learning Activity
Precludes additional credit for BIT 1003 (no longer offered), BIT 1007, BIT 1204, PHYS 1002, PHYS 1004.
Prerequisite(s): PHYS 1001 or PHYS 1003 or PHYS 1007.
Lectures three hours a week, laboratory or tutorial three hours per week.

PHYS 1901 [0.5 credit]
Planetary Astronomy
Description of the known stellar, galactic and extra-galactic systems together with the instruments used to study them. Modern ideas concerning the structure, origin and evolution of our own planet. Formation of the Moon - Earth system. Study of the planets in our solar system.
Precludes additional credit for PHYS 2203.
Lectures two and one-half hours a week.

PHYS 1902 [0.5 credit]
From our Star to the Cosmos
Starting with the Sun, the course studies its composition and source of power, then compares our Sun with the other stars in the galaxy and beyond. Modern ideas concerning the structure, origin and evolution of the universe, pulsars and supernovae are examined.
Precludes additional credit for PHYS 2203.
Lectures two and one-half hours a week.

PHYS 1905 [0.5 credit]
Physics Behind Everyday Life
Examination of the physics behind everyday life. Topics may include transportation, sports, weather and climate, electricity, and sustainable energy. No science background is required. Faculty of Science students may only take this course as a free elective.
Includes: Experiential Learning Activity
Online Course.

PHYS 2004 [0.5 credit]
Modern Physics for Engineers
Introduction to aspects of modern physics relevant to engineering. Thermal radiation. Concepts of relativistic kinematics. Wave-particle duality. Elements of quantum mechanics. Optical and x-ray spectra, lasers. Nuclear physics and applications. Condensed matter physics.
Precludes additional credit for PHYS 2604.
Prerequisite(s): PHYS 1002 or PHYS 1004 or PHYS 1008 with a grade of B- or better, plus MATH 1004 and MATH 1104 or equivalent. Restricted to B.Eng. students not in the Engineering Physics program. Students in programs other than B.Eng. must obtain permission of the Department.
Lectures three hours a week.

PHYS 2101 [0.5 credit]
Mechanics and Properties of Matter
Equations of motion for a single particle. Harmonic oscillation. Noninertial reference frames. Orbits in a central force field. Motion of systems of particles and of rigid bodies. Introduction to special relativity. Laboratory experiments in classical mechanics and properties of matter.
Includes: Experiential Learning Activity
Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004, alternatively PHYS 1007 and PHYS 1008 with an overall average of B- or better; MATH 1004 and MATH 1104, or MATH 1002 and MATH 1102.
Lectures three hours a week, laboratory three hours a week, tutorials (optional) once a week.

PHYS 2202 [0.5 credit]
Wave Motion and Optics
Geometrical optics. Types of waves, vibrating string and the classical wave equation. General solutions for traveling waves. Superposition and interference, coherence, wave packets, waves in 2 and 3 dimensions. Propagation of electromagnetic waves. Light and physical optics, oscillator model for dispersion, diffraction, polarization, and refraction.
Includes: Experiential Learning Activity
Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004 (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B- is presented); plus MATH 1104 or MATH 1102 or MATH 2152, and MATH 2004 or MATH 2000 (MATH 2000 may be taken concurrently).
Lectures three hours a week, laboratory three hours a week.

PHYS 2203 [0.5 credit]
Astronomy
The observational basis of astronomy. The history of astronomy, properties of light, solar system observations and stellar astronomy.
Precludes additional credit for PHYS 1901 and PHYS 1902.
Prerequisite(s): PHYS 1002 or PHYS 1004 or permission of the department. PHYS 1008 with a grade of B- or better may also be used if MATH 1004 or MATH 1007 or MATH 1002 or MATH 2052 have been successfully completed.
Lectures three hours a week.

PHYS 2305 [0.5 credit]
Electricity and Magnetism
Electrostatic field and potential, Gauss' law. Properties of conductors. Magnetic effects from currents. Motion of charges in electric and magnetic fields. Energy in electric and magnetic fields. Electromagnetic induction. Maxwell's equations in vacuum using vector differential and integral calculus.
Prerequisite(s): PHYS 1001, PHYS 1002, or PHYS 1003 and PHYS 1004, alternatively PHYS 1007 and PHYS 1008 with an overall grade of B- or higher; MATH 2004 or MATH 2000 (MATH 2000 may be taken concurrently).
Lectures three hours a week.

PHYS 2306 [0.5 credit]
Physics of Electrical and Electronic Measurements I
D.C. and A.C. circuit theory. Resonant circuits. Basic measuring devices, the oscilloscope; impedances, bandwidth, noise; vacuum tubes, transistors, useful approximations for circuit design; feedback, amplifiers, oscillators; operational circuits; digital circuits. Lectures emphasize the physical basis of instrument design. Laboratory emphasizes modern digital instrumentation.
Includes: Experiential Learning Activity
Prerequisite(s): PHYS 1001, PHYS 1002 or PHYS 1003 and PHYS 1004, alternatively PHYS 1007 and PHYS 1008 with an overall grade of B- or better.
Lectures three hours a week, laboratory three hours a week.

PHYS 2401 [0.5 credit]
Thermal Physics
Introduction to thermodynamics and statistical mechanics. Temperature and thermodynamic equilibrium. Work, internal energy and heat; first law. Kinetic theory of gases. Basic probability theory. Microscopic states and entropy. Absolute temperature, reversibility and the second law of thermodynamics. Thermodynamic processes and applications.
Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004, (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B-) ; plus MATH 1004 and MATH 1104 or MATH 1002 (no longer offered) and MATH 1102 (no longer offered), or MATH 2052 and MATH 2152.
Lectures three hours a week.

PHYS 2604 [0.5 credit]
Modern Physics I
The course is designed to provide a logical transition from classical to modern physics. Special relativity. Rutherford scattering, atomic models. Thermal radiation. Photoelectric effect, Compton scattering. Bohr theory of the hydrogen atom. Atomic energy states, optical spectra, lasers. X-rays. Radioactivity. Quantum Mechanics.
Includes: Experiential Learning Activity
Precludes additional credit for PHYS 2004.
Prerequisite(s): PHYS 1001 and PHYS 1002, or PHYS 1003 and PHYS 1004 (PHYS 1007 and PHYS 1008 are also acceptable provided a minimum average grade of B- is presented); plus MATH 1004 and MATH 1104, or MATH 1002 (no longer offered) and MATH 1102 (no longer offered) or MATH 2052 and MATH 2152.
Lectures three hours a week, laboratory three hours a week.

PHYS 2903 [0.5 credit]
Physics Towards the Future
From classical phenomena to aspects of modern physics and recent advances. Topics may include light and colour, music and sound, cell phones, the galaxy and beyond. No science background is required. Faculty of Science students may only take this course as a free elective.
Includes: Experiential Learning Activity
Prerequisite(s): second-year standing.
Online course.

PHYS 3007 [0.5 credit]
Third Year Physics Laboratory: Selected Experiments and Seminars
Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. An exercise on literature searches and student seminars on experimental and numerical methods are included.
Includes: Experiential Learning Activity
Precludes additional credit for PHYS 3008, PHYS 3009.
Prerequisite(s): PHYS 2202 and PHYS 2604, or permission of the Department.
Six hours a week.

PHYS 3008 [0.5 credit]
Third Year Physics Laboratory: Selected Experiments and Workshop
Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. Instruction on instrumentation building techniques will be given.
Includes: Experiential Learning Activity
Precludes additional credit for PHYS 3007, PHYS 3009.
Prerequisite(s): PHYS 2202 and PHYS 2604, or permission of the department.
Six hours a week.

PHYS 3009 [0.5 credit]
Third Year Physics Laboratory: Selected Experiments and Seminars with Observational Astronomy
Students complete a small number of experiments selected from astronomy, astrophysics, modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. At least one astronomy/astrophysics related experiment is required. An exercise on literature searches and student seminars on experimental and numerical methods are included.
Includes: Experiential Learning Activity
Precludes additional credit for PHYS 3007, PHYS 3008.
Prerequisite(s): PHYS 2202, PHYS 2604 and PHYS 2203 or permission of the Department.
Six hours a week.

PHYS 3207 [0.5 credit]
Topics in Biophysics
Introduction to biophysics. Random motion of molecules and diffusion; viscosity and the circulatory system; laws of thermodynamics and physical forces responsible for chemical reactions, molecular self-assembly and recognition; enzyme kinetics and molecular machines; nerve impulse and its propagation.
Prerequisite(s): PHYS 2604 or permission of the Department.
Lectures three hours a week, tutorial or seminar one hour a week.

PHYS 3308 [0.5 credit]
Electromagnetism
Electrostatics feld and magnetostatics in the presence of matter. Solving Laplace's and Poisson's equations. Multipole expansions. Vector potential. Faraday's laws of induction; Maxwell's equations in matter. Waves in vacuum and dielectric media, guided waves.
Precludes additional credit for ELEC 3909.
Prerequisite(s): PHYS 2202, PHYS 2604, PHYS 2305, MATH 2004 or MATH 2008, and MATH 3705, or permission of the Department.
Lectures three hours a week.

PHYS 3402 [0.5 credit]
Heat and Thermodynamics
Zeroth, First, Second and Third Laws of Thermodynamics; enthalpy, Helmholtz and Gibbs functions and the Maxwell relations; phase transitions; thermodynamics of magnetism; cryogenics cooling by Joule-Thompson effect, adiabatic expansion of a gas, adiabatic demagnetization, helium dilution refrigeration; black body radiation; negative temperatures.
Prerequisite(s): PHYS 2101 and PHYS 2305, MATH 2007, MATH 2008, MATH 2107 and MATH 2401 or permission of the Department.
Lectures three hours a week.

PHYS 3606 [0.5 credit]
Modern Physics II
Elements of condensed matter physics, semiconductors, superconductivity. Elements of nuclear physics, fission, fusion, power generation. Introduction to particle physics. Ionizing radiation: production, interactions, detection. Medical physics: radiation biophysics, cancer therapy, imaging.
Includes: Experiential Learning Activity
Also listed as PHYS 3608.
Prerequisite(s): PHYS 2604 and PHYS 3701, or permission of the Department.
Lectures three hours a week, laboratory two hours a week.

PHYS 3608 [0.5 credit]
Modern Applied Physics
Elements of condensed matter physics, semiconductors, superconductivity. Modern optics. Elements of nuclear physics, fission, fusion, power generation. Ionizing radiation: production, interactions, detection. Medical physics: radiation biophysics, cancer therapy, imaging.
Includes: Experiential Learning Activity
Also listed as PHYS 3606.
Prerequisite(s): PHYS 2604 and PHYS 3701, or permission of the Department.
Lectures three hours a week, laboratory three hours a week.

PHYS 3701 [0.5 credit]
Elements of Quantum Mechanics
Analysis of interference experiments with waves and particles; fundamental concepts of quantum mechanics, Schrödinger equation; angular momentum, atomic beams; hydrogen atom; atomic and molecular spectroscopy; Pauli principle; simple applications in the physics of elementary particles.
Prerequisite(s): PHYS 2604, MATH 2000 [1.0] (may be taken concurrently), or MATH 2004 or MATH 2008, and MATH 3705 (may be taken concurrently), or permission of the Department.
Lectures three hours a week.

PHYS 3801 [0.5 credit]
Classical Mechanics
Introduction to Lagrangian and Hamiltonian mechanics: Poisson brackets, tensors and dyadics; rigid body rotations: introductory fluid mechanics coupled systems and normal coordinates; relativistic dynamics.
Prerequisite(s): PHYS 2101, PHYS 2202, PHYS 2305, MATH 2007, MATH 2008, MATH 2107, MATH 2401 or permission of the Department.
Lectures three hours a week.

PHYS 3802 [0.5 credit]
Advanced Dynamics
Equations of motion for a single particle. Oscillatory Motion. Lagrangian and Hamiltonian formulations of mechanics. Central force motion. Motion of systems of particles and of rigid bodies.
Prerequisite(s): PHYS 2202, PHYS 2604, and MATH 2004, or permission of the Department.
Lectures three hours a week.

PHYS 3807 [0.5 credit]
Mathematical Physics I
Boundary Value problems involving curvilinear coordinates; spherical harmonics, Bessel functions, Green's functions. Functions of a complex variable: analytic functions, contour integration, residue calculus.
Precludes additional credit for MATH 3007 or MATH 3057.
Prerequisite(s): PHYS 2202, MATH 2004, MATH 3705 or permission of the Department.
Lectures three hours a week, tutorial one hour a week.

PHYS 3808 [0.5 credit]
Mathematical Physics II
Solution of second-order total differential equations by Frobenius' method. Sturm-Liouville theory. Special functions: Legendre, Bessel. Hermite, Laguerre and associated functions. Partial differential equations: method of separation of variables, eigenfunctions and eigenvalues and eigenfunction expansions. Green's function techniques for solving inhomogeneous partial differential equations.
Precludes additional credit for MATH 3004, MATH 3008, MATH 3705, and PHYS 3806.
Prerequisite(s): PHYS 3807 or MATH 3007 or permission of the Department.
Lectures three hours a week.

PHYS 3999 [0.0 credit]
Co-operative Work Term Report
Provides practical experience for students enrolled in the Co-operative option. Students must receive satisfactory evaluations from their work term employer. Written and oral reports will be required. Graded as Sat or Uns.
Includes: Experiential Learning Activity
Prerequisite(s): registration in the Physics Co-operative education option and permission of the Department.

PHYS 4007 [0.5 credit]
Fourth-Year Physics Laboratory: Selected Experiments and Seminars
Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. An exercise on literature searches and student seminars on experimental and numerical methods are included.
Includes: Experiential Learning Activity
Prerequisite(s): PHYS 3606 (or PHYS 3608) and registration in the Engineering Physics program.
Laboratory, six hours a week.

PHYS 4008 [0.5 credit]
Fourth-Year Physics Laboratory: Selected Experiments and Workshop
Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. Instruction on instrumentation building techniques will be given.
Includes: Experiential Learning Activity
Prerequisite(s): PHYS 3007.
Six hours a week.

PHYS 4201 [0.5 credit]
Astrophysics
Stellar evolution, including stellar modeling, main sequence stars, red giants and the end states of stars such as neutron stars and black holes. Galactic structure and dynamics. Neutrino astrophysics.
Prerequisite(s): PHYS 3701, PHYS 3606 or PHYS 3608, and PHYS 2401 or PHYS 4409, or permission of the Department. (PHYS 3606 or PHYS 3608 and PHYS 4409 may be taken concurrently).
Also offered at the graduate level, with different requirements, as PHYS 5401, for which additional credit is precluded.
Lectures three hours a week.

PHYS 4202 [0.5 credit]
Cosmology
Observational evidence for the Big Bang. Cosmological space-time, expansion dynamics and contents of the universe. Physical processes in the expanding universe, inflation, nucleosynthesis, the cosmic microwave background, dark matter, and dark energy.
Prerequisite(s): PHYS 3701, PHYS 3606 or PHYS 3608, and PHYS 2401 or PHYS 4409, or permission of the Department. (PHYS 3606 or PHYS 3608 and PHYS 4409 may be taken concurrently).
Also offered at the graduate level, with different requirements, as PHYS 5402, for which additional credit is precluded.
Lectures three hours per week.

PHYS 4203 [0.5 credit]
Physical Applications of Fourier Analysis
Fourier transform, convolution. Sampling theorem. Applications to imaging: descriptors of spatial resolution, filtering. Correlation, noise power. Discrete Fourier transform, FFT. Filtering of noisy signals. Image reconstruction in computed tomography and magnetic resonance. Laplace transform. Integral transforms, application to boundary value problems.
Prerequisite(s): MATH 3705, or permission of the Department.
Also offered at the graduate level, with different requirements, as PHYS 5313, for which additional credit is precluded.
Lectures three hours a week.

PHYS 4208 [0.5 credit]
Modern Optics
Electromagnetic wave propagation; reflection, refraction; Gaussian beams, guided waves. Laser theory: stimulated emission, cavity optics, modes, gain and bandwidth; atomic and molecular lasers. Mode locking, Q switching. Diffraction theory, coherence, Fourier optics, holography, laser applications. Optical communication systems, nonlinear effects: devices, fibre sensors, integrated optics.
Prerequisite(s): PHYS 2202, PHYS 3606 (or PHYS 3608), and PHYS 3308 or permission of the Department.
Also offered at the graduate level, with different requirements, as PHYS 5318, for which additional credit is precluded.
Lectures three hours a week.

PHYS 4307 [0.5 credit]
Electromagnetic Radiation
Electromagnetic wave propagation in a vacuum, dielectrics, conductors, and ionized gases, reflection, refraction, polarization at the plane boundary between two media; waveguide and transmission line propagation; dipole and quadrupole radiation fields; antenna systems. Electromagnetic mass, radiation pressure. Tensor notation, transformation of the electromagnetic fields.
Prerequisite(s): PHYS 3308, PHYS 3801, PHYS 3807 and PHYS 3808 (except for Mathematics and Physics Double Honours students), or permission of the Department.
Lectures three hours a week.

PHYS 4407 [0.5 credit]
Statistical Physics
Equilibrium statistical mechanics and its relation to thermodynamics. Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics are derived, and applied in appropriate physical situations. Fluctuations. Kinetics and transport processes, including the Boltzmann transport equation and some of its applications.
Prerequisite(s): PHYS 3402, PHYS 2602 or PHYS 3601, PHYS 3701 or PHYS 3602, PHYS 4707 (may be taken concurrently); or permission of the Department.
Lectures three hours a week.

PHYS 4409 [0.5 credit]
Thermodynamics and Statistical Physics
The three Laws of Thermodynamics, enthalpy, Helmholtz and Gibbs functions. Equilibrium statistical mechanics and its relation to thermodynamics. Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics.
Precludes additional credit for PHYS 3402 and PHYS 4407.
Prerequisite(s): PHYS 3701 (may be taken concurrently), MATH 2004 and MATH 3705, or permission of the Department.

PHYS 4508 [0.5 credit]
Solid State Physics
An introduction to solid state physics. Topics include crystal structure, phonons and lattice vibrations, conductors, semiconductors, insulators and superconductivity.
Prerequisite(s): PHYS 3606 or PHYS 3608, and PHYS 3701, or permission of the Department.
Lectures three hours a week.

PHYS 4602 [0.5 credit]
Physics of Elementary Particles
Standard Model. Properties of leptons, quarks, hadrons. Fundamental interactions: photon, gluons, W/Z bosons. Higgs boson. Conservation laws, invariance principles, quantum numbers. Decay rates and scattering cross-sections. Quantum electrodynamics and chromodynamics. Resonances. Weak interactions, CKM matrix, parity and CP violation. Neutrino masses and oscillations. Future directions.
Prerequisite(s): PHYS 4707 or permission of the Department.
Also offered at the graduate level, with different requirements, as PHYS 5602, for which additional credit is precluded.
Lectures three hours a week.

PHYS 4608 [0.5 credit]
Nuclear Physics
Ground state properties of nuclei. Nuclear models, binding energy, properties of excited nuclei. Alpha, beta and gamma decay. Passage of radiation through matter, detectors. Nuclear reactions, cross sections, fission, fusion. Elements of neutron physics.
Prerequisite(s): PHYS 3606 or PHYS 3608 or permission of the Department.
Lectures three hours a week.

PHYS 4707 [0.5 credit]
Introduction to Quantum Mechanics I
The basic interpretative postulates of quantum mechanics; applications of wave mechanics and operator methods to various quantum mechanical systems; quantum mechanical treatment of angular momentum.
Prerequisite(s): PHYS 3701 and PHYS 3807 or equivalent, or permission of the Department.
Lectures three hours a week.

PHYS 4708 [0.5 credit]
Introduction to Quantum Mechanics II
Scattering theory and application; bound state problems; approximation methods.
Prerequisite(s): PHYS 4707 or permission of the Department.
Lectures three hours a week.

PHYS 4804 [0.5 credit]
Introduction to General Relativity
Special relativity using tensor analysis. Curved spacetime with physics applications which may include the solar system, stars, black holes and gravitational waves. Introduction to differential geometry and Einstein's field equations.
Prerequisite(s): PHYS 3308, PHYS 3802 and PHYS 3807 or equivalent, or permission of the Department.
Also offered at the graduate level, with different requirements, as PHYS 5804, for which additional credit is precluded.
Lectures three hours a week.

PHYS 4807 [0.5 credit]
Statistical Data Analysis Techniques for Physics
Computational methods used in analysis of experimental data. Introduction to probability and random variables. Monte Carlo methods for simulation of random processes. Statistical methods for parameter estimation and hypothesis tests. Confidence intervals. Multivariate data classification. Unfolding methods. Examples primarily from particle and medical physics.
Prerequisite(s): third year standing in a physics program and an ability to program in Python, Java, C or C++, and permission of the Department.
Also offered at the graduate level, with different requirements, as PHYS 5002, for which additional credit is precluded.
Lectures three hours a week.

PHYS 4901 [0.5 credit]
Special Topics in Physics
Each year, at the direction of the Department, a course on a special topic may be offered.
Prerequisite(s): permission of the Department.

PHYS 4907 [0.5 credit]
Fourth-Year Project
Advanced projects of an experimental or theoretical nature with an orientation towards research. A written mid-term progress report is required and also a written and oral report at the conclusion of the project.
Includes: Experiential Learning Activity
Prerequisite(s): fourth-year standing in an Honours Physics program or equivalent, and permission of the Department.
Project. Fall term only.

PHYS 4908 [0.5 credit]
Fourth-Year Project
Advanced projects of an experimental or theoretical nature with an orientation towards research. A written mid-term progress report is required and also a written and oral report at the conclusion of the project.
Includes: Experiential Learning Activity
Prerequisite(s): fourth-year standing in an Honours Physics program or equivalent, and permission of the Department.
Project. Winter term only.

PHYS 4909 [1.0 credit]
Fourth-Year Project
Advanced projects of an experimental or theoretical nature with an orientation towards research. A written mid-term progress report is required and also a written and oral report at the conclusion of the project.
Includes: Experiential Learning Activity
Prerequisite(s): fourth-year standing in an Honours Physics program or equivalent, and permission of the Department.
Project