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)

<table>
<thead>
<tr>
<th>1. 1.0 credit from:</th>
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<tbody>
<tr>
<td>PHYS 1001 [0.5]</td>
<td>Foundations of Physics I</td>
</tr>
<tr>
<td>PHYS 1002 [0.5]</td>
<td>Foundations of Physics II</td>
</tr>
<tr>
<td>PHYS 1003 [0.5] &amp; PHYS 1004 [0.5]</td>
<td>Introductory Mechanics and Thermodynamics</td>
</tr>
<tr>
<td>PHYS 1007 [0.5] &amp; PHYS 1008 [0.5]</td>
<td>Elementary University Physics I and II (with an average grade of B- or higher)</td>
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2. 2.5 credits in:

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>PHYS 2202 [0.5]</td>
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<tr>
<td>PHYS 2203 [0.5]</td>
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<tr>
<td>PHYS 2305 [0.5]</td>
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<tr>
<td>PHYS 2401 [0.5]</td>
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<td>PHYS 2604 [0.5]</td>
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3. 5.0 credits in:

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<tr>
<td>PHYS 3308 [0.5]</td>
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<td>PHYS 3606 [0.5]</td>
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<td>PHYS 3701 [0.5]</td>
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<td>PHYS 3802 [0.5]</td>
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<td>PHYS 3807 [0.5]</td>
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<tr>
<td>PHYS 4201 [0.5]</td>
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<tr>
<td>PHYS 4202 [0.5]</td>
</tr>
<tr>
<td>PHYS 4409 [0.5]</td>
</tr>
<tr>
<td>PHYS 4707 [0.5]</td>
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4. 1.0 credit from:

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</tr>
<tr>
<td>b. PHYS 4908 plus 0.5 credit 4000-level PHYS</td>
</tr>
<tr>
<td>c. PHYS 4909 [1.0]</td>
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5. 0.5 credit in PHYS at the 4000-level or above |

6. 0.5 credit in PHYS, COMP, MATH and/or STAT at the 3000-level or above |

B. Credits Not Included In the Major CGPA (9.5 credits)

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<td>CHEM 1001 [0.5]</td>
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<td>&amp; CHEM 1002 [0.5]</td>
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<tr>
<td>CHEM 1005 [0.5] &amp; CHEM 1006 [0.5]</td>
</tr>
<tr>
<td>ERTH 1006 [0.5]</td>
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<tr>
<td>&amp; ERTH 1009 [0.5]</td>
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8. 3.5 credits in:

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</tr>
<tr>
<td>MATH 2004 [0.5]</td>
</tr>
<tr>
<td>MATH 2107 [0.5]</td>
</tr>
<tr>
<td>MATH 3705 [0.5]</td>
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<td>STAT 3502 [0.5]</td>
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9. 0.5 credit in:

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10. 1.0 credits from:

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<td>&amp; COMP 1006 [0.5]</td>
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<tr>
<td>or</td>
</tr>
<tr>
<td>ECOR 1606 [0.5]</td>
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<tr>
<td>&amp; ECOR 2606 [0.5]</td>
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11. 0.5 credit at the 2000-level or higher in COMP, MATH, or PHYS |

12. 0.5 credit in:

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<tbody>
<tr>
<td>NSCI 1000 [0.5]</td>
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</table>

13. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design |

14. 1.0 credit in free electives |

Total Credits 20.0

Physics (Experimental Stream)

B.Sc. Honours (20.0 credits)

A. Credits Included in the Major CGPA (11.0 credits)

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<tr>
<td>PHYS 1007 [0.5] &amp; PHYS 1008 [0.5]</td>
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2. 2.0 credits in:

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<tr>
<td>Course Code</td>
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<tr>
<td>PHYS 4409</td>
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<td>PHYS 4008</td>
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<td>PHYS 4707</td>
</tr>
<tr>
<td>BIOL 1103</td>
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<tr>
<td>CHEM 1001</td>
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<tr>
<td>ECOR 1606</td>
</tr>
<tr>
<td>ECOR 2606</td>
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</tbody>
</table>

**Physics (Theory Stream)**

**B.Sc. Honours (20.0 credits)**

**A. Credits Included in the Major CGPA (10.5 credits)**

1. **1.0 credit from:**
   - PHYS 1001 [0.5] & PHYS 1002 [0.5] Foundations of Physics I & II (recommended)
   - PHYS 1003 [0.5] & PHYS 1004 [0.5] Introductory Mechanics and Thermodynamics
   - PHYS 1007 [0.5] & PHYS 1008 [0.5] Elementary University Physics I & II (with an average grade of B- or higher)

2. **2.0 credits in:**
   - 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:**
   - 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:**
   - PHYS 4907 plus 0.5 credit 4000-level PHYS
   - PHYS 4908 plus 0.5 credit 4000-level PHYS
   - PHYS 4909 [1.0]

5. **1.0 credit in PHYS at the 4000-level or above**

6. **1.0 credit in PHYS, COMP, MATH and/or STAT at the 3000-level or above**

**B. Credits Not Included In the Major CGPA (9.0 credits)**

7. **1.0 credit from:**
   - BIOL 1103 [0.5] Foundations of Biology I
   - CHEM 1001 [0.5] General Chemistry I
   - CHEM 1002 [0.5] General Chemistry II
   - CHEM 1005 [0.5] Elementary Chemistry II
   - CHEM 1006 [0.5] Elementary Chemistry I
   - CHEM 1007 [0.5] Elementary Chemistry II
   - ELEC 1501 [0.5] Introductory Electrical Science I
   - ELEC 1502 [0.5] Introductory Electrical Science II
   - MATH 2001 [0.5] Linear Algebra for Engineering and Physics
   - MATH 2002 [0.5] Multivariable Calculus for Engineering or Physics
   - MATH 3705 [0.5] Mathematical Methods I
   - MATH 4707 [0.5] Introduction to Quantum Mechanics I
   - MATH 4708 [0.5] Introduction to Quantum Mechanics II
   - NSCI 1000 [0.5] Seminar in Science

Total Credits: 20.0
ERTH 1006 [0.5] Exploring Planet Earth
& ERTH 1009 [0.5] 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] Introduction to Computer Science I
& COMP 1006 [0.5] Introduction to Computer Science II
or
ECOR 1606 [0.5] Problem Solving and Computers
& ECOR 2606 [0.5] 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] Foundations of Physics I
& PHYS 1002 [0.5] Foundations of Physics II (recommended)

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 (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] Modern Physics II
or PHYS 3608 [0.5] 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] Foundations of Biology I
& BIOL 1104 [0.5] Foundations of Biology II

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

ERTH 1006 [0.5] Exploring Planet Earth
& ERTH 1009 [0.5] 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] Introduction to Statistical Modeling I
or STAT 3502 [0.5] 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 3.5
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

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

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] Foundations of Physics I
& PHYS 1002 [0.5] Foundations of Physics II (recommended)

PHYS 1003 [0.5] Introductory Mechanics and Thermodynamics
& PHYS 1004 [0.5] Introductory Electromagnetism and Wave Motion

UNOFFICIAL 2018-2019 Carleton University Undergraduate Calendar
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>PHYS 1007 [0.5]</td>
<td>Elementary University Physics I</td>
</tr>
<tr>
<td>PHYS 1008 [0.5]</td>
<td>Elementary University Physics II (with an average grade of B- or higher)</td>
</tr>
<tr>
<td>PHYS 2202 [0.5]</td>
<td>Wave Motion and Optics</td>
</tr>
<tr>
<td>PHYS 2305 [0.5]</td>
<td>Electricity and Magnetism</td>
</tr>
<tr>
<td>PHYS 2401 [0.5]</td>
<td>Thermal Physics</td>
</tr>
<tr>
<td>PHYS 2604 [0.5]</td>
<td>Modern Physics I</td>
</tr>
<tr>
<td>PHYS 2202 [0.5]</td>
<td>Wave Motion and Optics</td>
</tr>
<tr>
<td>PHYS 2305 [0.5]</td>
<td>Electricity and Magnetism</td>
</tr>
<tr>
<td>PHYS 2401 [0.5]</td>
<td>Thermal Physics</td>
</tr>
<tr>
<td>PHYS 2604 [0.5]</td>
<td>Modern Physics I</td>
</tr>
<tr>
<td>PHYS 3007 [0.5]</td>
<td>Third Year Physics Laboratory: Selected Experiments and Seminars</td>
</tr>
<tr>
<td>PHYS 3308 [0.5]</td>
<td>Electromagnetism</td>
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<tr>
<td>PHYS 3608 [0.5]</td>
<td>Modern Applied Physics</td>
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<tr>
<td>PHYS 3701 [0.5]</td>
<td>Elements of Quantum Mechanics</td>
</tr>
<tr>
<td>PHYS 3801 [0.5]</td>
<td>Advanced Dynamics</td>
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<td>PHYS 3801 [0.5]</td>
<td>Advanced Dynamics</td>
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<td>PHYS 3802 [0.5]</td>
<td>Advanced Dynamics</td>
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<td>PHYS 4008 [0.5]</td>
<td>Fourth-Year Physics Laboratory: Selected Experiments and Workshop</td>
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<td>PHYS 4707 [0.5]</td>
<td>Introduction to Quantum Mechanics I</td>
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<td>ELEC 2501 [0.5]</td>
<td>Circuits and Signals</td>
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<td>Electronics I</td>
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<td>ELEC 2507 [0.5]</td>
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<td>MATH 3800 [0.5]</td>
<td>Mathematical Modeling and Computational Methods</td>
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<td>MATH 1002 [1.0]</td>
<td>Calculus and Introductory Analysis I</td>
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<tr>
<td>MATH 1102 [1.0]</td>
<td>Algebra I</td>
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<td>MATH 1800 [0.5]</td>
<td>Introduction to Mathematical Reasoning</td>
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<tr>
<td>MATH 2001 [1.0]</td>
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<td>MATH 2100 [1.0]</td>
<td>Algebra II (Honours)</td>
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<td>MATH 2454 [0.5]</td>
<td>Ordinary Differential Equations (Honours)</td>
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<td>STAT 2655 [0.5]</td>
<td>Introduction to Probability with Applications (Honours)</td>
</tr>
<tr>
<td>STAT 3502 [0.5]</td>
<td>Probability and Statistics</td>
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<tr>
<td>MATH 3705 [0.5]</td>
<td>Mathematical Methods I</td>
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<tr>
<td>MATH 1004 [0.5]</td>
<td>Calculus for Engineering or Physics</td>
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<tr>
<td>MATH 1104 [0.5]</td>
<td>Linear Algebra for Engineering or Science</td>
</tr>
<tr>
<td>MATH 2004 [0.5]</td>
<td>Multivariable Calculus for Engineering or Physics</td>
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</table>

**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.

**A. Credits Included in the Major CGPA (17.0 credits)**

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<td>PHYS 4908 plus 0.5 credit 4000-level PHYS</td>
<td></td>
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<tr>
<td>PHYS 4909 [0.5]</td>
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**B. Credits Not Included in the Major CGPA (9.0 credits)**

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<td>Foundations of Biology I</td>
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<td>&amp; BIOL 1104 [0.5]</td>
<td>Foundations of Biology II</td>
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<td>CHEM 1001 [0.5]</td>
<td>General Chemistry I</td>
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<td>&amp; CHEM 1002 [0.5]</td>
<td>General Chemistry II</td>
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<td>CHEM 1005 [0.5]</td>
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<td>&amp; CHEM 1006 [0.5]</td>
<td>Elementary Chemistry II</td>
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<tr>
<td>ERTH 1006 [0.5]</td>
<td>Exploring Planet Earth</td>
</tr>
<tr>
<td>&amp; ERTH 1009 [0.5]</td>
<td>The Earth System Through Time</td>
</tr>
<tr>
<td>MATH 1004 [0.5]</td>
<td>Calculus for Engineering or Physics</td>
</tr>
</tbody>
</table>
### Introduction to Group Theory (Honours)

**PHYS 3106 [0.5]**
Third Year Physics Laboratory: Selected Experiments and Seminars

**PHYS 3606 [0.5]**
Modern Physics II

### 1.0 credit in 4000-level or higher MATH, STAT

**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

**PHYS 1007 [0.5]** & **PHYS 1008 [0.5]**
Elementary University Physics I & Elementary University Physics II (with an average grade of B- or higher)

### 2.0 credits in:

**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

### 3.0 credits in:

**PHYS 3007 [0.5]**
Third Year Physics Laboratory: Selected Experiments and Seminars

**PHYS 3207 [0.5]**
Topics in Biophysics

**PHYS 3606 [0.5]**
Modern Physics II

**PHYS 3701 [0.5]**
Elements of Quantum Mechanics

### 4.0 credits in:

**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

### Total Credits: 21.5
### B.Sc. Combined Honours (20.0 credits)

**Physics and Chemistry**

1. **2.0 credits in:**
   - COMP 1005 [0.5] Introduction to Computer Science I
   - MATH 1004 [0.5] Calculus for Engineering or Physics
   - MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
   - PHYS 1001 [0.5] Introductory Mechanics and Thermodynamics
   - PHYS 1002 [0.5] Elementary University Physics I
   - PHYS 1003 [0.5] Elementary University Physics I (recommended)
   - PHYS 1007 [0.5] Introductory Electromagnetism and Wave Motion
   - PHYS 1008 [0.5] Elementary University Physics II
   - PHYS 2202 [0.5] Wave Motion and Optics
   - PHYS 2305 [0.5] Electricity and Magnetism

2. **3.0 credits in:**
   - CHEM 1001 [0.5] General Chemistry I
   - CHEM 1002 [0.5] General Chemistry II (See Note, below)

3. **2.0 credits in:**
   - STAT 2507 [0.5] Introduction to Statistical Modeling I
   - MATH 2004 [0.5] Multivariable Calculus for Science

4. **0.5 credit in:**
   - COMP 1005 [0.5] Introduction to Computer Science I

5. **2.0 credits in:**
   - STAT 3502 [0.5] Introduction to Probability and Statistics
   - MATH 2004 [0.5] Multivariable Calculus for Science

6. **0.5 credit from:**
   - CHEM 2103 [0.5] Physical Chemistry I
   - CHEM 2203 [0.5] Organic Chemistry I

7. **0.5 credit from:**
   - 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

8. **0.5 credit from:**
   - CHEM 3106 [0.5] Computational Chemistry Methods Laboratory
   - CHEM 3107 [0.5] Experimental Methods in Nanoscience

9. **1.0 credit from:**
   - PHYS 2604 [0.5] Modern Physics I
   - PHYS 2907 [0.5] Elements of Quantum Mechanics
   - PHYS 3807 [0.5] Mathematical Physics I
   - PHYS 3907 [0.5] Elements of Quantum Mechanics

10. **0.5 credit in:**
    - 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

Note: For **Item 8** above, CHEM 1001 and CHEM 1002 are strongly recommended for this program. Students may substitute CHEM 1005 and CHEM 1006, respectively. Students choosing CHEM 1005 and CHEM 1006 will be required to obtain a grade of B- or higher in CHEM 1006 to take BIOL 2200 and more advanced courses in BIOL and CHEM. Students completing CHEM 1005 with a grade of B- or higher are encouraged to register for CHEM 1002.

### 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:**
   - 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 1007 [0.5] Elementary University Physics I
   - PHYS 1008 [0.5] Elementary University Physics II

2. **3.0 credits in:**
   - PHYS 2202 [0.5] Wave Motion and Optics
   - PHYS 2305 [0.5] Electricity and Magnetism

3. **0.5 credit from:**
   - CHEM 1001 [0.5] General Chemistry I
   - CHEM 1002 [0.5] General Chemistry II

4. **1.0 credit from:**
   - PHYS 2202 [0.5] Wave Motion and Optics
   - PHYS 2305 [0.5] Electricity and Magnetism

5. **0.5 credit from:**
   - PHYS 2604 [0.5] Modern Physics I
   - PHYS 2907 [0.5] Elements of Quantum Mechanics
   - PHYS 3807 [0.5] Mathematical Physics I
   - PHYS 3907 [0.5] Elements of Quantum Mechanics

6. **1.5 credits from:**
   - 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

7. **4.5 credits in:**
   - 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 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

8. **0.5 credit from:**
   - CHEM 2204 [0.5] Organic Chemistry II
   - CHEM 2206 [0.5] Organic Chemistry IV

9. **0.5 credit from:**
   - CHEM 3106 [0.5] Computational Chemistry Methods Laboratory

10. **3.0 credits in:**
    - PHYS 2604 [0.5] Modern Physics I
    - PHYS 2907 [0.5] Elements of Quantum Mechanics
    - PHYS 3807 [0.5] Mathematical Physics I
    - PHYS 3907 [0.5] Elements of Quantum Mechanics

11. **0.5 credit from:**
    - 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 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

12. **0.5 credit from:**
    - 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

13. **0.5 credit from:**
    - CHEM 3106 [0.5] Computational Chemistry Methods Laboratory

**B. Credits Not Included in the Major CGPA (7.0 credits)**

1. **1.0 credit in:**
   - 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 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

2. **0.5 credit in:**
   - CHEM 2204 [0.5] Organic Chemistry II
   - CHEM 2206 [0.5] Organic Chemistry IV

Note: For **Item 8** above, CHEM 1001 and CHEM 1002 are strongly recommended for this program. Students may substitute CHEM 1005 and CHEM 1006, respectively. Students choosing CHEM 1005 and CHEM 1006 will be required to obtain a grade of B- or higher in CHEM 1006 to take BIOL 2200 and more advanced courses in BIOL and CHEM. Students completing CHEM 1005 with a grade of B- or higher are encouraged to register for CHEM 1002.
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. NOTE: PHYS 1007 and PHYS 1008 are acceptable only if the average grade over these two courses is at least 7.0 (B-).

Requirements
1. 0.5 credit from:
   - PHYS 1001 [0.5] Foundations of Physics I
   - PHYS 1003 [0.5] Introductory Mechanics and Thermodynamics
   - PHYS 1007 [0.5] Elementary University Physics I (see note below)
2. 0.5 credit from:
   - 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 (see note below)
3. 1.0 credit in:
   - PHYS 2604 [0.5] Modern Physics I
   - PHYS 3701 [0.5] Elements of Quantum Mechanics
4. 2.0 credits from:
   - 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

Regulations
In addition to the program requirements described here and academic performance evaluation requirements listed below, students must satisfy the University regulations common to all undergraduate students (see the Academic Regulations section of this Calendar).

Students should consult with the School of Mathematics and Statistics when planning their program and selecting courses.

Academic Performance Evaluation
Bachelor of Mathematics
The standard procedures for Academic Performance Evaluation are followed with the following additions:

Good Standing at any Academic Performance Evaluation requires that the CGPA over the following courses be at least 7.00 for Honours programs and at least 5.00 for General programs:

- MATH 1007 [0.5] Elementary Calculus I
- MATH 1004 [0.5] Calculus for Engineering or Physics
- MATH 1107 [0.5] Linear Algebra I
- MATH 1104 [0.5] Linear Algebra for Engineering or Science
- MATH 2007 [0.5] Elementary Calculus II
- MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
- MATH 2107 [0.5] Linear Algebra II

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 Performance Evaluation (see the Academic Regulations of the University section of this Calendar).

Breadth Requirement for the B.Sc.
Students in Bachelor of Science Honours, Major, or General programs 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 (but 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 (but may include NSCI 1000) if, on transfer, the student received credit for fewer than 10.0 credits.
2. 1.0 credit in courses outside of the faculties of Science and Engineering and Design (but may include NSCI 1000) if, on transfer, the student received credit for 10.0 or more credits.

Declared and Undeclared Students
Students who are registered in a program within the degree are called Declared students. Most students designate a program of study when they first apply...
for admission and so begin their studies as Declared students. Students may also choose to begin their studies within the B.Sc. degree without being registered in a program. These students are referred to as Undeclared students. The recommended course pattern for Undeclared students is provided in the Undeclared entry of the Programs section of this Calendar. Undeclared students normally must apply to enter a program before beginning their second year of study. The Science Student Success Centre (SSSC) provides Undeclared students guidance to the appropriate support services in making this decision.

**Change of Program within the B.Sc. Degree**

Students may transfer to a program within the B.Sc. degree if upon entry to the new program they would be in good academic standing.

Other applications for change of program will be considered on their merits; students may be accepted in the new program in *Good Standing* or on *Academic Warning*.

Applications to declare or change their program 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, and/or specific requirements of the intended 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 requires that the student be in *Good Standing* and is subject to any specific requirements of the intended Minor, Concentration or Specialization as published in the relevant Calendar entry.

**Experimental Science Requirement**

Students in B.Sc. Honours, Major, or General degree programs 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**

<table>
<thead>
<tr>
<th>Biochemistry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOC 2200 [0.5]</td>
<td>Cellular Biochemistry</td>
</tr>
<tr>
<td>BIOC 4001 [0.5]</td>
<td>Methods in Biochemistry</td>
</tr>
<tr>
<td>BIOC 4201 [0.5]</td>
<td>Advanced Cell Culture and Tissue Engineering</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biology</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 1103 [0.5]</td>
<td>Foundations of Biology I</td>
</tr>
<tr>
<td>BIOL 1104 [0.5]</td>
<td>Foundations of Biology II</td>
</tr>
<tr>
<td>BIOL 2001 [0.5]</td>
<td>Animals: Form and Function</td>
</tr>
<tr>
<td>BIOL 2002 [0.5]</td>
<td>Plants: Form and Function</td>
</tr>
<tr>
<td>BIOL 2104 [0.5]</td>
<td>Introductory Genetics</td>
</tr>
<tr>
<td>BIOL 2200 [0.5]</td>
<td>Cellular Biochemistry</td>
</tr>
<tr>
<td>BIOL 2600 [0.5]</td>
<td>Ecology</td>
</tr>
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<table>
<thead>
<tr>
<th>Chemistry</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>CHEM 1001 [0.5]</td>
<td>General Chemistry I</td>
</tr>
<tr>
<td>CHEM 1002 [0.5]</td>
<td>General Chemistry II</td>
</tr>
<tr>
<td>CHEM 1005 [0.5]</td>
<td>Elementary Chemistry I</td>
</tr>
<tr>
<td>CHEM 1006 [0.5]</td>
<td>Elementary Chemistry II</td>
</tr>
<tr>
<td>CHEM 2103 [0.5]</td>
<td>Physical Chemistry I</td>
</tr>
<tr>
<td>CHEM 2203 [0.5]</td>
<td>Organic Chemistry I</td>
</tr>
<tr>
<td>CHEM 2204 [0.5]</td>
<td>Organic Chemistry II</td>
</tr>
<tr>
<td>CHEM 2206 [0.5]</td>
<td>Organic Chemistry IV</td>
</tr>
<tr>
<td>CHEM 2302 [0.5]</td>
<td>Analytical Chemistry I</td>
</tr>
<tr>
<td>CHEM 2303 [0.5]</td>
<td>Analytical Chemistry II</td>
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<tr>
<td>CHEM 2800 [0.5]</td>
<td>Foundations for Environmental Chemistry</td>
</tr>
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**Earth Sciences**

<table>
<thead>
<tr>
<th>ERTH 1006 [0.5]</th>
<th>Exploring Planet Earth</th>
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<tbody>
<tr>
<td>ERTH 1009 [0.5]</td>
<td>The Earth System Through Time</td>
</tr>
<tr>
<td>ERTH 2102 [0.5]</td>
<td>Mineralogy to Petrology</td>
</tr>
<tr>
<td>ERTH 2404 [0.5]</td>
<td>Engineering Geoscience</td>
</tr>
<tr>
<td>ERTH 2802 [0.5]</td>
<td>Field Geology I</td>
</tr>
<tr>
<td>ERTH 3111 [0.5]</td>
<td>Vertebrate Evolution II</td>
</tr>
<tr>
<td>ERTH 3112 [0.5]</td>
<td>Vertebrate Evolution I</td>
</tr>
<tr>
<td>ERTH 3204 [0.5]</td>
<td>Mineral Deposits</td>
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<tr>
<td>ERTH 3205 [0.5]</td>
<td>Physical Hydrogeology</td>
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<tr>
<td>ERTH 3806 [0.5]</td>
<td>Structural Geology</td>
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**Food Sciences**

<table>
<thead>
<tr>
<th>FOOD 3001 [0.5]</th>
<th>Food Chemistry</th>
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<tbody>
<tr>
<td>FOOD 3002 [0.5]</td>
<td>Food Analysis</td>
</tr>
<tr>
<td>FOOD 3005 [0.5]</td>
<td>Food Microbiology</td>
</tr>
</tbody>
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**Geography**

<table>
<thead>
<tr>
<th>GEOG 1010 [0.5]</th>
<th>Global Environmental Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOG 3108 [0.5]</td>
<td>Soil Properties</td>
</tr>
</tbody>
</table>

**Neuroscience**

<table>
<thead>
<tr>
<th>NEUR 3206 [0.5]</th>
<th>Sensory and Motor Neuroscience</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEUR 3207 [0.5]</td>
<td>Integrative Neuroscience</td>
</tr>
<tr>
<td>NEUR 4600 [0.5]</td>
<td>Advanced Lab in Neuroanatomy</td>
</tr>
</tbody>
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**Physics**

<table>
<thead>
<tr>
<th>PHYS 1001 [0.5]</th>
<th>Foundations of Physics I</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 1002 [0.5]</td>
<td>Foundations of Physics II</td>
</tr>
<tr>
<td>PHYS 1003 [0.5]</td>
<td>Introductory Mechanics and Thermodynamics</td>
</tr>
<tr>
<td>PHYS 1004 [0.5]</td>
<td>Introductory Electromagnetism and Wave Motion</td>
</tr>
<tr>
<td>PHYS 1007 [0.5]</td>
<td>Elementary University Physics I</td>
</tr>
<tr>
<td>PHYS 1008 [0.5]</td>
<td>Elementary University Physics II</td>
</tr>
<tr>
<td>PHYS 2202 [0.5]</td>
<td>Wave Motion and Optics</td>
</tr>
<tr>
<td>PHYS 2604 [0.5]</td>
<td>Modern Physics I</td>
</tr>
<tr>
<td>PHYS 3007 [0.5]</td>
<td>Third Year Physics Laboratory: Selected Experiments and Seminars</td>
</tr>
<tr>
<td>PHYS 3606 [0.5]</td>
<td>Modern Physics II</td>
</tr>
<tr>
<td>PHYS 3608 [0.5]</td>
<td>Modern Applied Physics</td>
</tr>
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**Course Categories for B.Sc. Programs**

**Science Geography Courses**

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

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>PSYC 2001</td>
<td>[0.5] Introduction to Research Methods in Psychology</td>
</tr>
<tr>
<td>PSYC 2002</td>
<td>[0.5] Introduction to Statistics in Psychology</td>
</tr>
<tr>
<td>PSYC 2700</td>
<td>[0.5] Introduction to Cognitive Psychology</td>
</tr>
<tr>
<td>PSYC 3000</td>
<td>[1.0] Design and Analysis in Psychological Research</td>
</tr>
<tr>
<td>PSYC 3506</td>
<td>[0.5] Cognitive Development</td>
</tr>
<tr>
<td>PSYC 3700</td>
<td>[1.0] Cognition (Honours Seminar)</td>
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<tr>
<td>PSYC 3702</td>
<td>[0.5] Perception</td>
</tr>
<tr>
<td>PSYC 2307</td>
<td>[0.5] Human Neuropsychology I</td>
</tr>
<tr>
<td>PSYC 3307</td>
<td>[0.5] Human Neuropsychology II</td>
</tr>
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</table>

Science Psychology Courses

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<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>PSYC 2001</td>
<td>[0.5] Introduction to Research Methods in Psychology</td>
</tr>
<tr>
<td>PSYC 2002</td>
<td>[0.5] Introduction to Statistics in Psychology</td>
</tr>
<tr>
<td>PSYC 2700</td>
<td>[0.5] Introduction to Cognitive Psychology</td>
</tr>
<tr>
<td>PSYC 3000</td>
<td>[1.0] Design and Analysis in Psychological Research</td>
</tr>
<tr>
<td>PSYC 3506</td>
<td>[0.5] Cognitive Development</td>
</tr>
<tr>
<td>PSYC 3700</td>
<td>[1.0] Cognition (Honours Seminar)</td>
</tr>
<tr>
<td>PSYC 3702</td>
<td>[0.5] Perception</td>
</tr>
<tr>
<td>PSYC 2307</td>
<td>[0.5] Human Neuropsychology I</td>
</tr>
<tr>
<td>PSYC 3307</td>
<td>[0.5] Human Neuropsychology II</td>
</tr>
</tbody>
</table>

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)
- 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)
- MATH (Mathematics)
- NEUR (Neuroscience)
- PHYS (Physics), except PHYS 2903

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

- 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.
Admission Requirements
Undergraduate Co-operative Education Policy

Admission to the co-op option is based on the completion of 5.0 or more credits at Carleton University, the CGPA requirement for the students' academic program as well as any course prerequisites. The articulated CGPA for each program is the normal standard for assessment. Please see the specific degree program sections for the unique admission and continuation requirements for each academic program.

English Language Proficiency
Students admitted to Carleton based on CAEL, IELTS or TOEFL assessments and who are required to take an ESL course must take and pass the Oral Proficiency in Communicative Settings (OPECs) Test. The test must be taken before being permitted to register in COOP 1000. Admission to the co-op program can be confirmed with a minimum score of 4+.

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 (2.0 credits). 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 Citizenship and Immigration 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 (2.0 credits);
- Be eligible to work in Canada (for off-campus work);
- Have successfully completed COOP 1000 [0.0]

In addition to the following:

1. Completion of 5.0 or more credits at Carleton University;
2. Registered as a full-time student in the Bachelor of Science Honours degree program;
3. Obtained and maintained a major CGPA of 8.0 or higher and an overall CGPA of 6.50 or higher

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:**

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**Legend**
- S: Study
Admissions Information

Admission Requirements are for the 2018-2019 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.

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

Admission Requirements

Honours Program

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 two prerequisite courses (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 individual merits. Applicants must normally be in Good Standing (see Undergraduate Calendar section 7.0 - Academic Regulations) for their year level. Advanced standing will be granted only for those subjects assessed as being appropriate for the program and the stream selected.

General Program

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 two prerequisite courses (Advanced Functions and Calculus and Vectors). Equivalent courses may be substituted between the old and new Ontario mathematics curriculum.

Advanced Standing
Applications for admission beyond first year will be assessed on their individual merits. Applicants must normally be in Good Standing (see Undergraduate Calendar section 7.0 - Academic Regulations) for 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 2018-2019 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.

Degrees
- B.Sc. (Honours)
- B.Sc. (General)
- B.Sc. (Major)
Admission Requirements

Honours Program

First Year
The Ontario Secondary School Diploma (OSSD) or equivalent including a minimum of six 4U or M courses. For most programs including Bioinformatics, Biology, Biochemistry, Biotechnology, Chemistry, combined Honours in Biology and Physics, Chemistry and Physics, Computational Biochemistry, Food Science and Nutrition, Neuroscience, Neuroscience and Mental Health, Nanoscience 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 Environmental Science, Geography, Geomatics and Earth Sciences, 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 the Combined Honours program in Chemistry and Computer Science, 4U Chemistry and Calculus and Vectors are 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
For entry to an Honours program after the completion of 5.0 included credits, a student must have a major CGPA of 5.50 or higher, an overall CGPA of 4.50 or higher and the recommendation of the Honours department or committee. A student beginning the final 10.0 credits towards an Honours degree must present a major CGPA of 6.00 or higher and an overall CGPA of 5.00 or higher and the recommendation of the Honours department or committee. A student beginning the final 5.0 credits towards an Honours degree must present a major CGPA of 6.50 or higher and an overall CGPA of 5.00 or higher, as calculated for graduation. Advanced standing will be granted for studies undertaken elsewhere when these are recognized as the equivalent of subjects offered at Carleton University.

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. 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 (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. Precludes additional credit for BIT 1003, 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 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. The laboratory is an essential and autonomous part of the course. 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 (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 electricity, magnetism, oscillations, waves and optics. The laboratory is an essential and autonomous part of the course. Precludes additional credit for BIT 1003, BIT 1204, PHYS 1002, PHYS 1008. Prerequisite(s): MATH 1004, ECOR 1101 (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. 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. Precludes additional credit for BIT 1003, 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. A 14-inch telescope is available for student use. Note: Science students may only take this course as a free elective. 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. A 14-inch telescope is available for student use. Note: Science students may only take this course as a free elective. Precludes additional credit for PHYS 2203. Lectures two and one-half hours a week.

PHYS 1905 [0.5 credit]  
How Things Work: Physics in Everyday Life  
Intended for students with little or no background in Science. Examination of the physics behind everyday objects to learn about the basis for our modern technological world. Topics may include cell phones, microwave ovens, sustainable energy, weather, dance, music, hockey, and skiing. Faculty of Science students may only take this course as a free elective. Lectures three hours a week.
PHYS 2004 [0.5 credit]
Modern Physics for Engineers
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
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.
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 and MATH 1102.
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 have been successfully completed.
Lectures three hours a week.

PHYS 2305 [0.5 credit]
Electricity and Magnetism
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.
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.
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
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 and MATH 1102.
Lectures three hours a week.

PHYS 2604 [0.5 credit]
Modern Physics I
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 and MATH 1102.
Lectures three hours a week, laboratory three hours a week.
PHYS 2903 [0.5 credit]
Physics and the Imagination
Physics has had a profound influence on music, philosophy, literature, film, and art. This is examined in a conceptual, non-technical, manner. A selection of topics will be studied. Note: Faculty of Science students may only take this course as a free elective.
Prerequisite(s): second-year standing.
Lectures and discussion groups three hours a week.

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.
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.
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.
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
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
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
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
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, or permission of the Department.
Lectures three hours a week, tutorial one hour a week.

PHYS 3808 [0.5 credit]
Mathematical Physics II
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.
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.
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.
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. 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).
Lectures three hours a week.

PHYS 4202 [0.5 credit]
Cosmology
Observational evidence for the Big Bang. Introduction to general relativity, 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).
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 and 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]
Particle Physics
Properties of leptons, quarks and hadrons. The fundamental interactions, conservation laws, invariance principles and quantum numbers. Resonances in hadron-hadron interactions. Three body phase space. Dalitz plots. Quark model of hadrons, mass formulae. Weak interactions, parity violation, decay of neutral kaons, CP violation, Cabibbo theory. 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. Stress energy tensors for matter and electromagnetism. Differential geometry and Einstein's field equations. Applications may include the solar system, black holes, gravitational waves, and cosmology.  
Prerequisite(s): PHYS 3802, PHYS 3308 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]  
Computational Physics  
Prerequisite(s): third year standing in a physics program and an ability to program in FORTRAN, 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.  
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.  
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.  
Prerequisite(s): fourth-year standing in an Honours Physics program or equivalent, and permission of the Department.  
Project

Summer session: some of the courses listed in this Calendar are offered during the summer. Hours and scheduling for summer session courses will differ significantly from those reported in the fall/winter Calendar. To determine the scheduling and hours for summer session classes, consult the class schedule at central.carleton.ca  
Not all courses listed are offered in a given year. For an up-to-date statement of course offerings for the current session and to determine the term of offering, consult the class schedule at central.carleton.ca