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
- 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:
   - 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
     (with an average grade of B- or higher)

2. 2.5 credits in:
   - 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:
   - 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

4. 1.0 credit from:
   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
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)

7. 1.0 credit from:
   - 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

8. 3.5 credits in:
   - 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:
   - MATH 3800 [0.5] Mathematical Modeling and Computational Methods

10. 1.0 credits from:
    - 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

12. 0.5 credit in:
    - 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

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)

1. 1.0 credit from:
<table>
<thead>
<tr>
<th>Objective</th>
<th>Courses</th>
</tr>
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<tbody>
<tr>
<td>2. 2.0 credits in:</td>
<td>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</td>
</tr>
<tr>
<td>3. 1.0 credit in:</td>
<td>ELEC 2501 [0.5] Circuits and Signals, ELEC 2507 [0.5] Electronics I</td>
</tr>
<tr>
<td>4. 4.5 credits in:</td>
<td>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 Mechanics 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</td>
</tr>
<tr>
<td>5. 1.0 credit from:</td>
<td>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]</td>
</tr>
<tr>
<td>6. 1.0 credit in:</td>
<td>PHYS 4807 is recommended for 0.5 credit</td>
</tr>
<tr>
<td>7. 0.5 credit in:</td>
<td>PHYS, COMP, ELEC, MATH and/or STAT</td>
</tr>
<tr>
<td>B. Credits Not Included In the Major CGPA (9.0 credits)</td>
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</tr>
<tr>
<td>8. 1.0 credit from:</td>
<td>BIOL 1103 [0.5] Foundations of Biology I, &amp; BIOL 1104 [0.5] Foundations of Biology II, CHEM 1001 [0.5] General Chemistry I, &amp; CHEM 1002 [0.5] General Chemistry II, CHEM 1005 [0.5] Elementary Chemistry I, &amp; CHEM 1006 [0.5] Elementary Chemistry II, ERTH 1006 [0.5] Exploring Planet Earth, &amp; ERTH 1009 [0.5] The Earth System Through Time</td>
</tr>
<tr>
<td>9. 3.0 credits in:</td>
<td>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</td>
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<tr>
<td>3. 1.0 credit from:</td>
<td>MATH 2004 [0.5] Multivariable Calculus for Engineering or Physics, MATH 3705 [0.5] Mathematical Methods I, STAT 3502 [0.5] Probability and Statistics, Math 3705 [0.5] Mathematical Methods I, STAT 3502 [0.5] Probability and Statistics, Math 3705 [0.5] Mathematical Methods I, STAT 3502 [0.5] Probability and Statistics</td>
</tr>
<tr>
<td>10. 0.5 credit in:</td>
<td>MATH 3800 [0.5] Mathematical Modeling and Computational Methods</td>
</tr>
<tr>
<td>11. 1.0 credit from:</td>
<td>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, &amp; ECOR 2606 [0.5] Numerical Methods</td>
</tr>
<tr>
<td>12. 0.5 credit at the 2000-level or higher in COMP, MATH, or PHYS</td>
<td>0.5</td>
</tr>
<tr>
<td>13. 0.5 credit from:</td>
<td>NSCI 1000 [0.5] Seminar in Science</td>
</tr>
<tr>
<td>14. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design</td>
<td>1.5</td>
</tr>
<tr>
<td>15. 1.0 credit in free electives</td>
<td>1.0</td>
</tr>
<tr>
<td>Total Credits</td>
<td>20.0</td>
</tr>
</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] Foundations of Physics I, PHYS 1002 [0.5] Foundations of Physics II (recommended) |
| 2. 2.0 credits in: | PHYS 2001 [0.5] Advanced Dynamics, PHYS 2002 [0.5] Modern Physics II |
| 4. 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 Mechanics 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: | 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: | PHYS 4807 is recommended for 0.5 credit |
| 7. 0.5 credit in: | PHYS, COMP, ELEC, MATH and/or STAT |
| B. Credits Not Included In the Major CGPA (9.0 credits) | 1.0 |
| 8. 1.0 credit from: | 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 |
| 9. 3.0 credits in: | MATH 2004 [0.5] Multivariable Calculus for Engineering or Physics, MATH 3705 [0.5] Mathematical Methods I, STAT 3502 [0.5] Probability and Statistics, Math 3705 [0.5] Mathematical Methods I, STAT 3502 [0.5] Probability and Statistics, Math 3705 [0.5] Mathematical Methods I, STAT 3502 [0.5] Probability and Statistics |
| 10. 0.5 credit in: | MATH 3800 [0.5] Mathematical Modeling and Computational Methods |
| 11. 1.0 credit from: | 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 |
| 12. 0.5 credit at the 2000-level or higher in COMP, MATH, or PHYS | 0.5 |
| 13. 0.5 credit from: | NSCI 1000 [0.5] Seminar in Science |
| 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 |
B.Sc. Major (20.0 credits)

1. 1.0 credit from:

   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:

   a. MATH 1004 [0.5] Calculus for Engineering or Physics
   b. MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
   c. MATH 1104 [0.5] Linear Algebra for Engineering or Science
   d. MATH 2004 [0.5] Multivariable Calculus for Engineering or Physics
   e. MATH 2107 [0.5] Linear Algebra II
   f. MATH 3705 [0.5] Mathematical Methods I
   g. STAT 3502 [0.5] Probability and Statistics

8. 3.5 credits in:

   a. MATH 1004 [0.5] Calculus for Engineering or Physics
   b. MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
   c. MATH 1104 [0.5] Linear Algebra for Engineering or Science
   d. MATH 2004 [0.5] Multivariable Calculus for Engineering or Physics
   e. MATH 2107 [0.5] Linear Algebra II
   f. MATH 3705 [0.5] Mathematical Methods I
   g. STAT 3502 [0.5] Probability and Statistics

9. 0.5 credit in:

   a. MATH 3800 [0.5] Mathematical Modeling and Computational Methods

10. 1.0 credit from:

    a. COMP 1005 [0.5] Introduction to Computer Science I
    b. COMP 1006 [0.5] Introduction to Computer Science II
    or
    c. ECOR 1606 [0.5] Problem Solving and Computers
    d. 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:

    a. 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:

    a. PHYS 1001 [0.5] Foundations of Physics I
    b. PHYS 1002 [0.5] Foundations of Physics II (recommended)
    c. PHYS 1003 [0.5] Introductory Mechanics and Thermodynamics
    d. PHYS 1004 [0.5] Introductory Electromagnetism and Wave Motion

2. 2.0 credits in:

    a. PHYS 2202 [0.5] Wave Motion and Optics
    b. PHYS 2305 [0.5] Electricity and Magnetism
    c. PHYS 2401 [0.5] Thermal Physics
    d. 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:

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

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:

    a. BIOL 1103 [0.5] Foundations of Biology I
    b. BIOL 1104 [0.5] Foundations of Biology II
    c. CHEM 1001 [0.5] General Chemistry I
    d. CHEM 1002 [0.5] General Chemistry II
    e. CHEM 1005 [0.5] Elementary Chemistry I
    f. CHEM 1006 [0.5] Elementary Chemistry II
    g. ERTH 1006 [0.5] Exploring Planet Earth
    h. ERTH 1009 [0.5] The Earth System Through Time

9. 3.0 credits in:

    a. MATH 1004 [0.5] Calculus for Engineering or Physics
    b. MATH 1005 [0.5] Differential Equations and Infinite Series for Engineering or Physics
    c. MATH 1104 [0.5] Linear Algebra for Engineering or Science
    d. MATH 2004 [0.5] Multivariable Calculus for Engineering or Physics
    e. MATH 2107 [0.5] Linear Algebra II
    f. MATH 3705 [0.5] Mathematical Methods I
    g. STAT 3502 [0.5] Probability and Statistics

10. 0.5 credit from:

    a. COMP 1005 [0.5] Introduction to Computer Science I
    b. 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:

    a. 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:**
   - 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] (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. **1.0 credit in:**
   - ELEC 2501 [0.5] Circuits and Signals
   - ELEC 2507 [0.5] Electronics I

4. **0.5 credit from:**
   - ELEC 2606 [0.5] Numerical Methods
   - MATH 3800 [0.5] Mathematical Modeling and Computational Methods

5. **4.0 credits in:**
   - 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:**
   - 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:**
   - 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:**

9. **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]

### B. Credits Not Included in the Major CGPA (9.0 credits)

10. **3.0 credits in:**
   - BIOI 1103 [0.5] Foundations of Biology I & BIOI 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

11. **0.5 credit from:**
   - COMP 1006 [0.5] Introduction to Computer Science I & ECOR 1606 [0.5] Problem Solving and Computers

12. **4.0 credits in:**
   - (COMP 1006 and COMP 2401) or (SYSC 2006 and SYSC 2004)
   - a. 1.5 credits in approved courses outside the faculties of Science and Engineering and Design
   - b. 1.5 credit in free electives
   - c. 1.5 credit in free electives

13. **0.5 credit from:**
   - NSCI 1000 [0.5] Seminar in Science

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.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tr>
<td>MATH 2000</td>
<td>Multivariable Calculus and Fundamentals of Analysis</td>
<td>1.0</td>
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<tr>
<td>MATH 2100</td>
<td>Algebra</td>
<td>1.0</td>
</tr>
<tr>
<td>MATH 2454</td>
<td>Ordinary Differential Equations (Honours)</td>
<td>0.5</td>
</tr>
<tr>
<td>STAT 2655</td>
<td>Introduction to Probability with Applications (Honours)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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

1. **7.5 credits in:**
   - MATH 1052 [0.5] Calculus and Introductory Analysis I
   - MATH 1152 [0.5] Introductory Algebra I
   - MATH 1800 [0.5] Introduction to Mathematical Reasoning

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
</tr>
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<tbody>
<tr>
<td>MATH 1052</td>
<td>Calculus and Introductory Analysis I</td>
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</tr>
<tr>
<td>MATH 1152</td>
<td>Introductory Algebra I</td>
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<td>MATH 1800</td>
<td>Introduction to Mathematical Reasoning</td>
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### B. Credits Not Included in the Major CGPA (4.5 credits)

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Description</th>
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<tbody>
<tr>
<td>MATH 2000 [1.0]</td>
<td>Multivariable Calculus and Fundamentals of Analysis</td>
<td>1.0</td>
</tr>
<tr>
<td>MATH 2052 [0.5]</td>
<td>Calculus and Introductory Analysis II</td>
<td>0.5</td>
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<tr>
<td>MATH 2100 [1.0]</td>
<td>Algebra</td>
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<td>MATH 2152 [0.5]</td>
<td>Introductory Algebra II</td>
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<tr>
<td>MATH 2454 [0.5]</td>
<td>Ordinary Differential Equations (Honours)</td>
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<td>MATH 3001 [0.5]</td>
<td>Real Analysis I (Honours)</td>
<td>0.5</td>
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<tr>
<td>MATH 3008 [0.5]</td>
<td>Ordinary Differential Equations (Honours)</td>
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<td>MATH 3057 [0.5]</td>
<td>Functions of a Complex Variable (Honours)</td>
<td>0.5</td>
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<tr>
<td>MATH 3705 [0.5]</td>
<td>Mathematical Methods I</td>
<td>0.5</td>
</tr>
<tr>
<td>STAT 2655 [0.5]</td>
<td>Introduction to Probability with Applications (Honours)</td>
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<tr>
<td>MATH 3002 [0.5]</td>
<td>Real Analysis II (Honours)</td>
</tr>
<tr>
<td>MATH 3003 [0.5]</td>
<td>Advanced Differential Calculus (Honours)</td>
</tr>
<tr>
<td>MATH 3106 [0.5]</td>
<td>Introduction to Group Theory (Honours)</td>
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<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>
</tbody>
</table>

| 3. 1.0 credit in 4000-level or higher MATH, STAT | 1.0 |
| 4. 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) |

<table>
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<th>5. 2.0 credits in:</th>
<th>2.0</th>
</tr>
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<tbody>
<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>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. 3.0 credits in:</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 3308 [0.5]</td>
<td>Electromagnetism</td>
</tr>
<tr>
<td>PHYS 3701 [0.5]</td>
<td>Elements of Quantum Mechanics</td>
</tr>
<tr>
<td>PHYS 3802 [0.5]</td>
<td>Advanced Dynamics</td>
</tr>
<tr>
<td>PHYS 4409 [0.5]</td>
<td>Thermodynamics and Statistical Physics</td>
</tr>
<tr>
<td>PHYS 4707 [0.5]</td>
<td>Introduction to Quantum Mechanics I</td>
</tr>
<tr>
<td>PHYS 4708 [0.5]</td>
<td>Introduction to Quantum Mechanics II</td>
</tr>
</tbody>
</table>

| 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)

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 1103 [0.5]</td>
<td>Foundations of Biology I</td>
<td>1.0</td>
</tr>
<tr>
<td>&amp; BIOL 1104 [0.5]</td>
<td>Foundations of Biology II</td>
<td></td>
</tr>
<tr>
<td>CHEM 1001 [0.5]</td>
<td>General Chemistry I</td>
<td>1.0</td>
</tr>
<tr>
<td>&amp; CHEM 1002 [0.5]</td>
<td>General Chemistry II</td>
<td></td>
</tr>
<tr>
<td>CHEM 1005 [0.5]</td>
<td>Elementary Chemistry I</td>
<td>1.0</td>
</tr>
<tr>
<td>&amp; CHEM 1006 [0.5]</td>
<td>Elementary Chemistry II</td>
<td></td>
</tr>
<tr>
<td>ERTH 1006 [0.5]</td>
<td>Exploring Planet Earth</td>
<td>1.0</td>
</tr>
<tr>
<td>&amp; ERTH 1009 [0.5]</td>
<td>The Earth System Through Time</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. 1.0 credit from:</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 4707 [0.5]</td>
<td>Introduction to Quantum Mechanics I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10. 0.5 credit in:</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 1005 [0.5]</td>
<td>Introduction to Computer Science I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>11. 0.5 credit from:</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSCI 1000 [0.5]</td>
<td>Seminar in Science</td>
</tr>
</tbody>
</table>

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

- Total Credits: 21.5

#### Biology and Physics

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

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

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 1001 [0.5]</td>
<td>Foundations of Physics I</td>
<td>1.0</td>
</tr>
<tr>
<td>&amp; PHYS 1002 [0.5]</td>
<td>Foundations of Physics II (recommended)</td>
<td></td>
</tr>
<tr>
<td>PHYS 1003 [0.5]</td>
<td>Introductory Mechanics and Thermodynamics</td>
<td>1.0</td>
</tr>
<tr>
<td>&amp; PHYS 1004 [0.5]</td>
<td>Introductory Electromagnetism and Wave Motion</td>
<td></td>
</tr>
<tr>
<td>PHYS 1007 [0.5]</td>
<td>Elementary University Physics I</td>
<td>1.0</td>
</tr>
<tr>
<td>&amp; PHYS 1008 [0.5]</td>
<td>Elementary University Physics II (with an average grade of B- or higher)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. 3.5 credits in:</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<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 3007 [0.5]</td>
<td>Third Year Physics Laboratory: Selected Experiments and Seminars</td>
</tr>
<tr>
<td>PHYS 3207 [0.5]</td>
<td>Topics in Biophysics</td>
</tr>
<tr>
<td>PHYS 3701 [0.5]</td>
<td>Elements of Quantum Mechanics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. 1.0 credit from:</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 3308 [0.5]</td>
<td>Electromagnetism</td>
</tr>
<tr>
<td>PHYS 3606 [0.5]</td>
<td>Modern Physics II</td>
</tr>
<tr>
<td>PHYS 3802 [0.5]</td>
<td>Advanced Dynamics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. 1.0 credit from:</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 3308 [0.5]</td>
<td>Electromagnetism</td>
</tr>
<tr>
<td>PHYS 3606 [0.5]</td>
<td>Modern Physics II</td>
</tr>
<tr>
<td>PHYS 3802 [0.5]</td>
<td>Advanced Dynamics</td>
</tr>
<tr>
<td>PHYS 3807 [0.5]</td>
<td>Mathematical Physics</td>
</tr>
<tr>
<td>PHYS 4203 [0.5]</td>
<td>Physical Applications of Fourier Analysis</td>
</tr>
<tr>
<td>PHYS 4409 [0.5]</td>
<td>Thermodynamics and Statistical Physics</td>
</tr>
<tr>
<td>PHYS 4707 [0.5]</td>
<td>Introduction to Quantum Mechanics I</td>
</tr>
</tbody>
</table>

2021-2022 Carleton University Undergraduate Calendar 5
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 (recommended)
   - PHYS 1003 [0.5] Introductory Mechanics and
   - PHYS 1004 [0.5] Thermodynamics
   - PHYS 1005 [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. 3.0 credits in:
   - 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:
   - 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

4. 0.5 credit in PHYS at the 4000 level
   - PHYS 4908 [0.5] Fourth-Year Project

5. 5.0 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 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:
   - 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
   - CHEM 4908 [1.0] Research Project and Seminar

8. 1.0 credit from:
   - CHEM 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:
   - MATH 1004 [0.5] Calculus for Engineering or Physics
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.

**Requirements**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 1001</td>
<td>Foundations of Physics I</td>
</tr>
<tr>
<td>PHYS 1003</td>
<td>Introductory Mechanics and Thermodynamics</td>
</tr>
<tr>
<td>PHYS 1007</td>
<td>Elementary University Physics I (with a grade of B- or higher)</td>
</tr>
<tr>
<td>PHYS 1002</td>
<td>Foundations of Physics II</td>
</tr>
<tr>
<td>PHYS 1004</td>
<td>Introductory Electromagnetism and Wave Motion</td>
</tr>
<tr>
<td>PHYS 1008</td>
<td>Elementary University Physics II (with a grade of B- or higher)</td>
</tr>
</tbody>
</table>

**Total Credits** 20.0

**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 (with a grade of B- or higher)

**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 (with a grade of B- or higher)

**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

**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**

**Academic Performance Evaluation for 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:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1007</td>
<td>Elementary Calculus I</td>
</tr>
<tr>
<td>MATH 1004</td>
<td>Calculus for Engineering or Physics</td>
</tr>
<tr>
<td>MATH 1107</td>
<td>Linear Algebra I</td>
</tr>
<tr>
<td>MATH 1104</td>
<td>Linear Algebra II</td>
</tr>
<tr>
<td>MATH 2007</td>
<td>Elementary Calculus II</td>
</tr>
<tr>
<td>MATH 2107</td>
<td>Linear Algebra II</td>
</tr>
</tbody>
</table>

**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 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 (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 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 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

<table>
<thead>
<tr>
<th>Biochemistry</th>
<th>Biology</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOC 2200 [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>Chemistry</th>
<th>Earth Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 1001 [0.5]</td>
<td>ERTH 1006 [0.5] Exploring Planet Earth</td>
</tr>
<tr>
<td>CHEM 1002 [0.5]</td>
<td>ERTH 1009 [0.5] The Earth System Through Time</td>
</tr>
<tr>
<td>CHEM 1005 [0.5]</td>
<td>ERTH 2102 [0.5] Mineralogy to Petrology</td>
</tr>
<tr>
<td>CHEM 1006 [0.5]</td>
<td>ERTH 2404 [0.5] Engineering Geoscience</td>
</tr>
<tr>
<td>CHEM 2103 [0.5]</td>
<td>ERTH 2802 [0.5] Field Geology I</td>
</tr>
<tr>
<td>CHEM 2203 [0.5]</td>
<td>ERTH 3111 [0.5] Vertebrate Evolution: Mammals, Reptiles, and Birds</td>
</tr>
<tr>
<td>CHEM 2204 [0.5]</td>
<td>ERTH 3112 [0.5] Vertebrate Evolution: Fish and Amphibians</td>
</tr>
<tr>
<td>CHEM 2302 [0.5]</td>
<td>ERTH 3204 [0.5] Mineral Deposits</td>
</tr>
<tr>
<td>CHEM 2303 [0.5]</td>
<td>ERTH 3205 [0.5] Physical Hydrogeology</td>
</tr>
<tr>
<td>CHEM 2800 [0.5]</td>
<td>ERTH 3806 [0.5] Structural Geology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food Sciences</th>
<th>Geography</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOOD 3001 [0.5]</td>
<td>GEG 1010 [0.5] Global Environmental Systems</td>
</tr>
<tr>
<td>FOOD 3002 [0.5]</td>
<td>GEG 3108 [0.5] Soil Properties</td>
</tr>
<tr>
<td>FOOD 3005 [0.5]</td>
<td>Neur 3206 [0.5] Sensory and Motor Neuroscience</td>
</tr>
<tr>
<td></td>
<td>Neur 3207 [0.5] Systems Neuroscience</td>
</tr>
<tr>
<td></td>
<td>Neur 4600 [0.5] Advanced Lab in Neuroanatomy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Neuroscience</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEUR 3206 [0.5]</td>
<td>PHYS 1001 [0.5] Foundations of Physics I</td>
</tr>
<tr>
<td>NEUR 3207 [0.5]</td>
<td>PHYS 1002 [0.5] Foundations of Physics II</td>
</tr>
<tr>
<td>NEUR 4600 [0.5]</td>
<td>PHYS 1003 [0.5] Introductory Mechanics and Thermodynamics</td>
</tr>
<tr>
<td></td>
<td>PHYS 1004 [0.5] Introductory Electromagnetism and Wave Motion</td>
</tr>
<tr>
<td></td>
<td>PHYS 1007 [0.5] Elementary University Physics I</td>
</tr>
<tr>
<td></td>
<td>PHYS 1008 [0.5] Elementary University Physics II</td>
</tr>
<tr>
<td></td>
<td>PHYS 2202 [0.5] Wave Motion and Optics</td>
</tr>
<tr>
<td></td>
<td>PHYS 2604 [0.5] Modern Physics I</td>
</tr>
</tbody>
</table>
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)
- CHEM (Chemistry)
- COMP (Computer Science) A maximum of two half-credits at the 2000-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**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 4810</td>
<td>Education Research in Biology</td>
</tr>
<tr>
<td>CHEM 1003</td>
<td>The Chemistry of Food, Health and Drugs</td>
</tr>
<tr>
<td>CHEM 1004</td>
<td>Drugs and the Human Body</td>
</tr>
<tr>
<td>CHEM 1007</td>
<td>Chemistry of Art and Artifacts</td>
</tr>
<tr>
<td>ERTH 1010</td>
<td>Our Dynamic Planet Earth</td>
</tr>
<tr>
<td>ERTH 1011</td>
<td>Evolution of the Earth</td>
</tr>
<tr>
<td>ERTH 2415</td>
<td>Natural Disasters</td>
</tr>
<tr>
<td>ISCI 1001</td>
<td>Introduction to the Environment</td>
</tr>
<tr>
<td>ISCI 2000</td>
<td>Natural Laws</td>
</tr>
<tr>
<td>ISCI 2002</td>
<td>Human Impacts on the Environment</td>
</tr>
<tr>
<td>MATH 0107</td>
<td>Algebra and Geometry</td>
</tr>
<tr>
<td>PHYS 1901</td>
<td>Planetary Astronomy</td>
</tr>
<tr>
<td>PHYS 1902</td>
<td>From our Star to the Cosmos</td>
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<tr>
<td>PHYS 1905</td>
<td>Physics Behind Everyday Life</td>
</tr>
<tr>
<td>PHYS 2903</td>
<td>Physics Towards the Future</td>
</tr>
</tbody>
</table>

**Prohibited Courses**

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

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 1001</td>
<td>Introduction to Computational Thinking for Arts and Social Science Students</td>
</tr>
<tr>
<td>MATH 0005</td>
<td>Precalculus: Functions and Graphs</td>
</tr>
<tr>
<td>MATH 0006</td>
<td>Precalculus: Trigonometric Functions and Complex Numbers</td>
</tr>
<tr>
<td>MATH 1009</td>
<td>Mathematics for Business</td>
</tr>
<tr>
<td>MATH 1119</td>
<td>Linear Algebra: with Applications to Business</td>
</tr>
<tr>
<td>MATH 1401</td>
<td>Elementary Mathematics for Economics I</td>
</tr>
<tr>
<td>MATH 1402</td>
<td>Elementary Mathematics for Economics II</td>
</tr>
</tbody>
</table>

**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 is admitted to co-op from high school, their grades will be reviewed two terms to one year prior to their first work term to ensure they continue to meet the academic requirements after their 1st or 2nd year of study. The time at which evaluation takes place depends on the program of study. Students will automatically be notified via their Carleton email account if they are permitted to continue.

Students not admitted to Carleton University with the co-op option on their degree can apply for admission via the co-operative education program website. To view application deadlines, visit carleton.ca/co-op.

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.

**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 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 has applied

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:

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<tbody>
<tr>
<td>Term</td>
<td>Pattern</td>
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<td>Fall</td>
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<td>Winter</td>
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<td>S</td>
<td>Winter</td>
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<tr>
<td>Summer</td>
<td>*OW</td>
<td>Summer</td>
<td>*W</td>
<td>Summer</td>
</tr>
</tbody>
</table>

Legend
S: Study
W: Work
O: Optional
* indicates recommended work study pattern
** student finds own employer for this work-term.

Admissions Information

Admission Requirements are for the 2021-22 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.)

Admission Requirements

B.Math 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 3.0 - Academic Regulations for Degree Students) for their year level. Advanced standing will be granted only for those subjects assessed as being appropriate for the program and the stream selected.

B.Math 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 3.0 - Academic Regulations for Degree Students) 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 2021-22 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. (Major)
- B.Sc.

**Admission Requirements**

**B. Sc. 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 Biochemistry, Bioinformatics, Biotechnology, Chemistry, Combined Honours in Biology and Physics, Chemistry and Physics, Computational Biochemistry, Food Science, Nanoscience, Neuroscience, 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 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 3.50 or higher and an overall CGPA of 3.50 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, 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.

**B.Sc. 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 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. Equivalent courses may be substituted between the old and new Ontario mathematics curriculum.

**Advanced Standing**
For entry to a B.Sc. or B.Sc. Major program after the completion of 5.0 included credits, a student must have a major and core CGPA of 3.50 or higher and an overall CGPA of 3.50 or higher. A student beginning the final 5.0 credits towards a B.Sc. or B.Sc. Major degree must present a major and core CGPA of 4.00 or higher and an overall CGPA of 4.00 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.

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 1046) (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 (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 (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. 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, 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

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**

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 3608 [0.5 credit]
Modern Applied Physics
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 two 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 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
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
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