

Minor Program Adjustment

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|---|---|
| Faculty: Science | Date: December 2016 |
| Program: Bachelor of Science in Physics | |
| Undergraduate: <input checked="" type="checkbox"/> | Graduate: <input type="checkbox"/> |

Minor Program Adjustments include: New required courses, Deletion of required courses, Other changes to degree requirements or program learning outcomes, New academic requirements or changes to existing requirements.

Motion to CPRC: That CPRC approve course sequencing changes, as well as addition and deletion of course and elective options, in the Physics program.

Proposal Brief

Summary of the proposed change

We propose a variety of changes to the Physics program, including some rearrangement of courses, deletion of two required courses, addition of more elective choice, some general clean-up, and corresponding changes to our specializations in Astrophysics and Energy and Environmental Physics.

1. Move PHY 2060U Modern Physics to 1st year Winter
2. Move PHY 2050U Thermodynamics to Fall
3. Move STAT 2010U Statistics and Probability for Physical Scientists to Winter
4. Move PHY 3080U Electricity and Magnetism II to Fall 4th year
5. Delete PHY 3060U Fluid Dynamics as a required course
6. Move PHY 3010U Statistical Mechanics to Winter
7. Move PHY 3040U Mathematical Physics to Fall
8. Add Senior Physics Elective to third year fall term
9. Add Senior Physics Elective to third year winter term
10. Add Senior Physics Elective to fourth year fall term
11. Delete PHY 4030U Topics in Contemporary Physics as a Required Course
12. Minor changes to Astrophysics specialization:
 - a. Move PHY 2900U Astronomy I to Fall second year

- b. Delete PHY 4910U Techniques in Modern Astrophysics and PHY 4920U Cosmology as required courses in favour of specifying “Senior Astrophysics Electives,” which will include both courses as options.
 - c. Add PHY 3030U Electronics as a required course.
 - d. Add PHY 4010U Condensed Matter as a required course.
 - e. Follow the above changes for the comprehensive program with regard to rearrangement of courses. This gives the Astrophysics specialization the same base map as the comprehensive. See the program maps below for more information.
13. Changes to the Energy and Environmental Physics specialization:
- a. Add PHY 2040U Mechanics II as a required course rather than recommended.
 - b. Add PHY 4020U Quantum Mechanics II as a required course in fourth year fall.
 - c. Add PHY 4010U Condensed Matter as a required course in fourth year winter.
 - d. Follow the above changes for the comprehensive program with regard to rearrangement of courses. The gives the Energy and Environmental specialization the same base map as the comprehensive. See the program maps below for more information.

Description of the ways in which the proposed change will enhance the program and/or opportunities for students

These changes will make our overall program more balanced with respect to student workload, help with retention issues, and form a base to make future improvements.

In thoroughly reviewing our Physics curriculum, we’ve identified the following issues:

- Retention from year 1 to year 2 is low; we suspect part of the issue is students switching to Engineering after first year. We also see some retention problems between second and third year.
- Workload for students overall is unbalanced:
 - Fall of second year has no electives, and furthermore has three non-physics courses; we feel this impacts retention, student workload, and student interest.
 - A disproportionately high workload in the third year, particularly the fall term.
- Lack of senior physics electives. This was highlighted as a top issue in our recent Undergraduate Program Review.
- Difficulty in fitting a Minor into the program, limiting student choice.
- Low enrollment and lack of resources in our Energy and Environmental Physics specialization.

Of the six courses taught specific to this specialization, full time faculty members only teach one.

- Lack of a unified idea of what constitutes a core set of physics courses means students in our specializations don’t take some physics courses.

In addressing these issues, we propose the aforementioned rearrangement of courses, deletion of courses not considered “core” physics courses from the list of required courses, and moving to more Senior Physics Electives that would alternate every two years and be open to students in their third and fourth years.

One of the benefits of the proposed changes is more flexibility for students wishing to take a Minor. In particular, students would now be able to fit a proposed Data Science Minor into their program map. Other minors (e.g., Chemistry, Biology) would likewise be easier for students to take.

Specifically, the above changes will address the following:

1. Move PHY 2060U Modern Physics to 1st year Winter (Retention): Gets to interesting physics early on; with only first year physics students in the course, they can get to know each other quickly and support each other right away. Both of these points should help with retention from 1st to 2nd year. The lab component in a first year course, however, becomes too much of a workload, while tutorials would be highly beneficial. We therefore propose weekly tutorials rather than labs, maintaining the same credit-hours and TA costs (course change template attached).
2. Move PHY 2050U Thermodynamics to Fall (Balance workload): This foundational physics subject is new and exciting for second year students (unlike, e.g., Mechanics or E&M, which are covered in first year), and, with its lab component, is furthermore an excellent opportunity to begin teaching physics students proper lab tools and techniques. It should be taught right away in second year to help with balancing physics and math course loads as well as improving retention beyond first year.
3. Move STAT 2010U Statistics and Probability for Physical Scientists to Winter (Balance workload): This change is purely for a better balance of physics courses and math/CS courses. We currently have, in the fall term, CSCI 2000U, MATH 2015U, and STAT 2010U, while in the winter term, only MATH 2060U. STAT 2010U isn't required for anything until third year.
4. Move PHY 3080U Electricity and Magnetism II to Fall 4th year (Balance workload): Electrodynamics is a pillar of undergraduate physics, but can be very challenging mathematically and conceptually. Moving it out of Fall 3rd year allows that year to be better balanced for student workload (currently has four physics courses) and allows it to be taught at a higher, more appropriate level.
5. Delete PHY 3060U Fluid Dynamics as a required course (More senior physics electives): Fluid dynamics is a rich, exciting course, but also one that is not offered at most institutions; we would not consider it a necessary course for a B.Sc. in Physics. Furthermore, it is of sufficient advanced level that both third and fourth year students could take it. This makes it an obvious choice to offer in alternate years as a Senior Physics Elective.
6. Move PHY 3010U Statistical Mechanics to Winter (Balance workload): Statistical mechanics requires concepts from quantum mechanics; it should be offered after that course.
7. Move PHY 3040U Mathematical Physics to Fall (Balance workload): Students would benefit from having this course taught earlier; this change also allows for more advanced Senior Physics Electives in Winter 3rd and 4th years.
8. – 10. Add Senior Physics Elective to third year fall term, third year winter term, and fourth year fall term (More senior physics electives).
11. Delete PHY 4030U Topics in Contemporary Physics as a Required Course (More senior physics electives): PHY 4030U is a topics-based course with content that changes from year-to-year. It would therefore not be considered a necessary course for a B.Sc. in Physics. It would make a good candidate for a Senior Physics Elective, offered every second year.
12. Minor changes to Astrophysics specialization: Gives the specialization the same base map as the comprehensive.
13. Changes to the Energy and Environmental Physics specialization: Gives the specialization the same base map as the comprehensive.

Process of consultation with other units if the change(s) involves students, staff, and/or faculty from other programs or courses

Two of the proposed changes are related to the Math group:

- a. STAT 2010U is only offered in the fall; after consultation with the Math group, the simplest solution would be to cross-list STAT 2800U Statistics and Probability for Engineers and STAT 2010U. This solution would be helpful to students, who might benefit from a more applied course.
- b. PHY 3040U Mathematical Physics is a required course for the Applied and Industrial

Mathematics program in the winter term. After consultation with the Math group, they agree to make the corresponding switch to the fall in their program map.

Analysis of financial and enrolment implications

It is important to note that the above changes to the physics program are cost-positive; even though we are offering more senior physics electives than in the past, they will be open to both third and fourth years and will be alternating. That means, in a given year, four senior physics electives only count as two courses. Furthermore, removing courses we no longer have expertise in to teach lowers the total number of required courses we must offer on a yearly basis.

The changes proposed above will result in a positive financial result due to the overall reduced number of course sections the Physics group will be required to teach. Over the last few years, the group has taught 39 sections (not including thesis courses; this is for academic years 2014/2015 and 2015/2016). With the proposed program maps, that number would drop to 35. This is mainly due to alternating Senior Physics Electives. We will also no longer be teaching PHY 1810U Physics for Health Sciences, which is included in the reduction but outside the scope of these changes (see later, Minor Curricular Changes).

We propose that the laboratory component of PHY 2060U become weekly tutorials, using the same number of contact and TA hours. There are no financial implications for this as it is cost neutral, and there are no other changes to labs or tutorial components.

We furthermore anticipate only positive effects on enrollment. Our Senior Physics Elective will be taken by both third and fourth year students and will therefore see an approximate doubling of enrollment. Courses like PHY 2040U Mechanics II, PHY 3030U Electronics, and PHY 4010U Condensed Matter will see an enrollment increase as they will now be required courses for all physics students, including those in Astrophysics and Energy and Environmental Physics.

Proposed Implementation Date

Fall 2017

Transition Plan

We have a detailed transition plan in which the above changes are brought in sequentially:

- New students entering in Fall 2017 would follow the proposed maps above. Current students would follow their current map.
- In 2017/2018 we would offer the new first year curriculum, including moving PHY 2060U to first year.
- In 2018/2019 we would offer the new second year curriculum, including move STAT 2010 to winter and removing PHY 2060U from fall.
- In 2019/2020 we would offer the new third year curriculum, including removing PHY 3080U from fall of third year and rearranging PHY 3040U and PHY 3010U.
- In 2020/2021 we would offer of the new fourth year curriculum, including adding PHY 3080U to Fall of fourth year.

After 2021 the new program map would be fully in place.

Calendar Copy and/or Program Maps (highlight revisions to existing curriculum)

Please find below relevant sections of the Calendar copy with revisions noted (Calendar copy based on web Calendar, 2016-2017). Note: there is no impact to the and Management program 5th year, therefore, that portion is not included below.

APPROVAL DATES

| | |
|--------------------------------|---------------|
| Curriculum Committee approval | November 2016 |
| Faculty Council approval | December 2016 |
| CPRC Approval | |
| Submission to Academic Council | |

Physics

Year 1

Semester 1 (15 credit hours)

- CHEM 1010U – Chemistry I
- CSCI 1040U – Introduction to Programming for Scientists
- One of:
 - BIOL 1011U – Introductory Cell and Molecular Biology ⁺ or
 - BIOL 1010U – Biology I: Molecular and Cellular Systems
- One of:
 - MATH 1000U – Introductory Calculus ⁺⁺ or
 - MATH 1010U – Calculus I ⁺⁺
- One of:
 - PHY 1010U – Physics I ⁺⁺ or
 - PHY 1030U – Introductory Physics ⁺⁺

Semester 2 (15 credit hours)

- **Elective****
- MATH 1020U – Calculus II
- MATH 2050U – Linear Algebra
- PHY 1020U – Physics II
- One of:
 - BIOL 1021U – Introduction to Organismal Biology and Ecology ⁺ or
 - BIOL 1020U – Biology II: Diversity of Life and Principles of Ecology or
- CHEM 1020U – Chemistry II

Regular program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III

Physics

Year 1

Semester 1 (15 credit hours)

- CHEM 1010U – Chemistry I
- CSCI 1040U – Introduction to Programming for Scientists
- One of:
 - BIOL 1011U – Introductory Cell and Molecular Biology ⁺ or
 - BIOL 1010U – Biology I: Molecular and Cellular Systems
- One of:
 - MATH 1000U – Introductory Calculus ⁺⁺ or
 - MATH 1010U – Calculus I ⁺⁺
- One of:
 - PHY 1010U – Physics I ⁺⁺ or
 - PHY 1030U – Introductory Physics ⁺⁺

Semester 2 (15 credit hours)

- MATH 1020U – Calculus II
- MATH 2050U – Linear Algebra
- PHY 1020U – Physics II
- **PHY 2060U – Modern Physics**
- One of:
 - BIOL 1021U – Introduction to Organismal Biology and Ecology ⁺ or
 - BIOL 1020U – Biology II: Diversity of Life and Principles of Ecology or
- CHEM 1020U – Chemistry II

Regular program

Year 2

Semester 1 (15 credit hours)

- **Elective****
- CSCI 2000U – Scientific Data Analysis

- PHY 2030U – Mechanics I
- PHY 2060U – Modern Physics
- STAT 2010U – Statistics and Probability for Physical Science

Semester 2 (15 credit hours)

- Elective**
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- PHY 2050U – Thermodynamics and Heat Transfer

Year 3

Semester 1 (15 credit hours)

- Elective**
- PHY 3010U – Statistical Mechanics
- PHY 3020U – Quantum Mechanics I
- PHY 3050U – Waves and Optics
- PHY 3080U – Electricity and Magnetism II

Semester 2 (15 credit hours)

- Two electives**
- PHY 3030U – Electronics
- PHY 3040U – Mathematical Physics
- PHY 3060U – Fluid Dynamics

Year 4

Semester 1 (15 credit hours)

- Senior Physics elective**
- Two electives**
- PHY 4020U – Quantum Mechanics II
- One of:
- PHY 4410U – Physics Thesis Project I *** or
- Senior Science elective***

Semester 2 (15 credit hours)

- Two electives**
- PHY 4010U – Condensed Matter

- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2050U – Thermodynamics and Heat Transfer

Semester 2 (15 credit hours)

- Elective**
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- STAT 2010U – Statistics and Probability for Physical Science

Year 3

Semester 1 (15 credit hours)

- Senior Physics Elective**
- Elective**
- PHY 3020U – Quantum Mechanics I
- PHY 3040U – Mathematical Physics
- PHY 3050U – Waves and Optics

Semester 2 (15 credit hours)

- Senior Physics Elective**
- Two electives**
- PHY 3010U – Statistical Mechanics
- PHY 3030U – Electronics

Year 4

Semester 1 (15 credit hours)

- Senior Physics elective**
- Elective**
- PHY 3080U – Electricity and Magnetism II
- PHY 4020U – Quantum Mechanics II
- One of:
- PHY 4410U – Physics Thesis Project I *** or
- Senior Science elective***

Semester 2 (15 credit hours)

- Senior Physics Elective**

- PHY 4030U – Topics in Contemporary Physics
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Co-operative Education program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2060U – Modern Physics
- STAT 2010U – Statistics and Probability for Physical Science

Semester 2 (15 credit hours)

- Elective**
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- PHY 2050U – Thermodynamics and Heat Transfer

Semester 3

- SCCO 1000W – Science Co-op Work Term I *

Year 3

Semester 1 (15 credit hours)

- Elective**
- PHY 3010U – Statistical Mechanics
- PHY 3020U – Quantum Mechanics I
- PHY 3050U – Waves and Optics
- PHY 3080U – Electricity and Magnetism II

Semester 2

- SCCO 2000W – Science Co-op Work Term II *

Semester 3

- SCCO 3000W – Science Co-op Work Term III *

- Two electives**
- PHY 4010U – Condensed Matter
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Co-operative Education program

Year 2

Semester 1 (15 credit hours)

- Elective**
- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2050U – Thermodynamics and Heat Transfer

Semester 2 (15 credit hours)

- Elective**
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II

STAT 2010U – Statistics and Probability for Physical Science

Semester 3

- SCCO 1000W – Science Co-op Work Term I *

Year 3

Semester 1 (15 credit hours)

- Senior Physics Elective**
- Elective**
- PHY 3020U – Quantum Mechanics I
- PHY 3040U – Mathematical Physics
- PHY 3050U – Waves and Optics

Semester 2

- SCCO 2000W – Science Co-op Work Term II *

Semester 3

Year 4

Semester 1

- SCCO 4000W – Science Co-op Work Term IV *

Semester 2 (15 credit hours)

- Two electives**
- PHY 3030U – Electronics
- PHY 3040U – Mathematical Physics
- PHY 3060U – Fluid Dynamics

Semester 3

- SCCO 5000W – Science Co-op Work Term V *

Year 5

Semester 1 (15 credit hours)

- Senior Physics elective**
- Two electives**
- PHY 4020U – Quantum Mechanics II
- One of:
- PHY 4410U – Physics Thesis Project I *** or
- Senior Science elective***

Semester 2 (15 credit hours)

- Two electives**
- PHY 4010U – Condensed Matter
- PHY 4030U – Topics in Contemporary Physics
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Astrophysics Specialization

Year 1

Semester 1 (15 credit hours)

- SCCO 3000W – Science Co-op Work Term III *

Year 4

Semester 1

- SCCO 4000W – Science Co-op Work Term IV *

Semester 2 (15 credit hours)

- Senior Physics Elective**
- Two electives**
- PHY 3010U – Statistical Mechanics
- PHY 3030U – Electronics

Semester 3

- SCCO 5000W – Science Co-op Work Term V *

Year 5

Semester 1 (15 credit hours)

- Senior Physics elective**
- Elective**
- PHY 3080U – Electricity and Magnetism II
- PHY 4020U – Quantum Mechanics II
- One of:
- PHY 4410U – Physics Thesis Project I *** or
- Senior Science elective***

Semester 2 (15 credit hours)

- Senior Physics Elective**
- Two electives**
- PHY 4010U – Condensed Matter
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Astrophysics Specialization

Year 1

Semester 1 (15 credit hours)

- CHEM 1010U – Chemistry I
- CSCI 1040U – Introduction to Programming for Scientists
- One of:
- BIOL 1011U – Introductory Cell and Molecular Biology ⁺ or
- BIOL 1010U – Biology I: Molecular and Cellular Systems
- One of:
- MATH 1000U – Introductory Calculus ⁺⁺ or
- MATH 1010U – Calculus I ⁺⁺
- One of:
- PHY 1010U – Physics I ⁺⁺ or
- PHY 1030U – Introductory Physics ⁺⁺

Semester 2 (15 credit hours)

- MATH 1020U – Calculus II
- MATH 2050U – Linear Algebra
- PHY 1020U – Physics II
- **PHY 2900U – Astronomy I**
- One of:
- BIOL 1021U – Introduction to Organismal Biology and Ecology ⁺ or
- BIOL 1020U – Biology II: Diversity of Life and Principles of Ecology or
- CHEM 1020U – Chemistry II

Regular program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- **PHY 2060U – Modern Physics**
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- **STAT 2010U – Statistics and Probability for Physical Science**

Semester 2 (15 credit hours)

- CHEM 1010U – Chemistry I
- CSCI 1040U – Introduction to Programming for Scientists
- One of:
- BIOL 1011U – Introductory Cell and Molecular Biology ⁺ or
- BIOL 1010U – Biology I: Molecular and Cellular Systems
- One of:
- MATH 1000U – Introductory Calculus ⁺⁺ or
- MATH 1010U – Calculus I ⁺⁺
- One of:
- PHY 1010U – Physics I ⁺⁺ or
- PHY 1030U – Introductory Physics ⁺⁺

Semester 2 (15 credit hours)

- MATH 1020U – Calculus II
- MATH 2050U – Linear Algebra
- PHY 1020U – Physics II
- **PHY 2060U – Modern Physics**
- One of:
- BIOL 1021U – Introduction to Organismal Biology and Ecology ⁺ or
- BIOL 1020U – Biology II: Diversity of Life and Principles of Ecology or
- CHEM 1020U – Chemistry II

Regular program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- **PHY 2050U – Thermodynamics and Heat Transfer**
- **PHY 9900U – Astronomy I**

Semester 2 (15 credit hours)

- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- PHY 2050U – Thermodynamics and Heat Transfer
- PHY 3900U – Astronomy II

Year 3

Semester 1 (15 credit hours)

- Elective**
- PHY 3010U – Statistical Mechanics I
- PHY 3020U – Quantum Mechanics I
- PHY 3050U – Waves and Optics
- PHY 3080U – Electricity and Magnetism II

Semester 2 (15 credit hours)

- Two electives** (recommend MATH 2072U)
- PHY 3040U – Mathematical Physics
- PHY 3060U – Fluid Dynamics
- One of:
 - PHY 4910U – Techniques of Modern Astrophysics or
 - PHY 4920U – Cosmology

Year 4

Semester 1 (15 credit hours)

- Senior Physics elective**
- Two electives**
- PHY 4020U – Quantum Mechanics II
- One of:
 - PHY 4410U – Physics Thesis Project I *** or
 - Senior Science elective***

Semester 2 (15 credit hours)

- Senior Physics elective**
- Two electives** (recommend CSCI 3010U)
- One of:
 - PHY 4910U – Techniques of Modern Astrophysics or

- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- PHY 3900U – Astronomy II
- STAT 2010U – Statistics and Probability for Physical Science

Year 3

Semester 1 (15 credit hours)

- Two Electives**
- PHY 3020U – Quantum Mechanics I
- PHY 3040U – Mathematical Physics
- PHY 3050U – Waves and Optics

Semester 2 (15 credit hours)

- Senior Physics Elective **
- Senior Astrophysics Elective**
- Elective**
 - PHY 3010U – Statistical Mechanics
 - PHY 3030U – Electronics

Year 4

Semester 1 (15 credit hours)

- Two electives**
- PHY 3080U – Electricity and Magnetism II
- PHY 4020U – Quantum Mechanics II
- One of:
 - PHY 4410U – Physics Thesis Project I *** or
 - Senior Science elective***

Semester 2 (15 credit hours)

- Elective**
- Senior Physics elective**
- Senior Astrophysics Elective**
- PHY 4010U – Condensed Matter
- One of:
 - PHY 4420U – Physics Thesis Project II *** or

- PHY 4920U – Cosmology
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Co-operative Education program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- PHY 2060U – Modern Physics
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- STAT 2010U – Statistics and Probability for Physical Science

Semester 2 (15 credit hours)

- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- PHY 2050U – Thermodynamics and Heat Transfer
- PHY 3900U – Astronomy II

Semester 3

- SCCO 1000W – Science Co-op Work Term I *

Year 3

Semester 1 (15 credit hours)

- Elective**
- PHY 3010U – Statistical Mechanics I
- PHY 3020U – Quantum Mechanics I
- PHY 3050U – Waves and Optics
- PHY 3080U – Electricity and Magnetism II

Semester 2

- SCCO 2000W – Science Co-op Work Term II *

Semester 3

- SCCO 3000W – Science Co-op Work Term III *

- Senior Science elective***

Co-operative Education program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2050U – Thermodynamics and Heat Transfer
- PHY 9900U – Astronomy I

Semester 2 (15 credit hours)

- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- PHY 3900U – Astronomy II
- STAT 2010U – Statistics and Probability for Physical Science

Semester 3

- SCCO 1000W – Science Co-op Work Term I *

Year 3

Semester 1 (15 credit hours)

- Two Electives**
- PHY 3020U – Quantum Mechanics I
- PHY 3040U – Mathematical Physics
- PHY 3050U – Waves and Optics

Semester 2

- SCCO 2000W – Science Co-op Work Term II *

Semester 3

- SCCO 3000W – Science Co-op Work Term III *

Year 4

Semester 1

- SCCO 4000W – Science Co-op Work Term IV *

Year 4

Semester 1

- SCCO 4000W – Science Co-op Work Term IV *

Semester 2 (15 credit hours)

- Two electives** (recommend MATH 2072U)
- PHY 3040U – Mathematical Physics
- PHY 3060U – Fluid Dynamics
- One of:
 - PHY 4910U – Techniques of Modern Astrophysics or
 - PHY 4920U – Cosmology

Semester 3

- SCCO 5000W – Science Co-op Work Term V

Year 5

Semester 1 (15 credit hours)

- Senior Physics elective**
- Two electives**
- PHY 4020U – Quantum Mechanics II
- One of:
 - PHY 4410U – Physics Thesis Project I *** or
 - Senior Science elective***

Semester 2 (15 credit hours)

- Senior Physics elective**
- Two electives** (recommend CSCI 3010U)
- One of:
 - PHY 4910U – Techniques of Modern Astrophysics or
 - PHY 4920U – Cosmology
- One of:
 - PHY 4420U – Physics Thesis Project II *** or
 - Senior Science elective***

Energy and Environmental Physics Specialization

Semester 2 (15 credit hours)

- Senior Physics Elective **
- Senior Astrophysics Elective**
- Elective**
- PHY 3010U – Statistical Mechanics
- PHY 3030U – Electronics

Year 5

Semester 1 (15 credit hours)

- Two electives**
- PHY 3080U – Electricity and Magnetism II
- PHY 4020U – Quantum Mechanics II
- One of:
 - PHY 4410U – Physics Thesis Project I *** or
 - Senior Science elective***

Semester 2 (15 credit hours)

- Elective**
- Senior Physics elective**
- Senior Astrophysics Elective**
- PHY 4010U – Condensed Matter
- One of:
 - PHY 4420U – Physics Thesis Project II *** or
 - Senior Science elective***

Energy and Environmental Physics Specialization

Year 1

Semester 1 (15 credit hours)

- CHEM 1010U – Chemistry I
- CSCI 1040U – Introduction to Programming for Scientists
- One of:
 - BIOL 1011U – Introductory Cell and Molecular Biology ⁺ or
 - BIOL 1010U – Biology I: Molecular and Cellular Systems
- One of:
 - MATH 1000U – Introductory Calculus ^{**} or
 - MATH 1010U – Calculus I ^{**}
- One of:
 - PHY 1010U – Physics I ^{**} or
 - PHY 1030U – Introductory Physics ^{**}

Semester 2 (15 credit hours)

- CHEM 1020U – Chemistry II
- MATH 1020U – Calculus II
- MATH 2050U – Linear Algebra
- PHY 1020U – Physics II
- One of:
 - BIOL 1021U – Introduction to Organismal Biology and Ecology ⁺ or
 - BIOL 1020U – Biology II: Diversity of Life and Principles of Ecology

Regular program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2060U – Modern Physics
- STAT 2010U – Statistics and Probability for Physical Science

Semester 2 (15 credit hours)

Year 1

Semester 1 (15 credit hours)

- CHEM 1010U – Chemistry I
- CSCI 1040U – Introduction to Programming for Scientists
- One of:
 - BIOL 1011U – Introductory Cell and Molecular Biology ⁺ or
 - BIOL 1010U – Biology I: Molecular and Cellular Systems
- One of:
 - MATH 1000U – Introductory Calculus ^{**} or
 - MATH 1010U – Calculus I ^{**}
- One of:
 - PHY 1010U – Physics I ^{**} or
 - PHY 1030U – Introductory Physics ^{**}

Semester 2 (15 credit hours)

- MATH 1020U – Calculus II
- MATH 2050U – Linear Algebra
- PHY 1020U – Physics II
- PHY 2060U – Modern Physics
- One of:
 - BIOL 1021U – Introduction to Organismal Biology and Ecology ⁺ or
 - BIOL 1020U – Biology II: Diversity of Life and Principles of Ecology
- Or
- CHEM 1020U – Chemistry II

Regular program

Year 2

Semester 1 (15 credit hours)

- Elective**
- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2050U – Thermodynamics and Heat Transfer

- Elective** (recommend PHY 2040U)
- ENV5 2010U – Introductory Environment Science
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2050U – Thermodynamics and Heat Transfer

Year 3

Semester 1 (15 credit hours)

- PHY 3010U – Statistical Mechanics I
- PHY 3020U – Quantum Mechanics I
- PHY 3050U – Waves and Optics
- PHY 3080U – Electricity and Magnetism II
- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics

Semester 2 (15 credit hours)

- ENV5 3110U – Economics and Politics of the Environment
- PHY 3030U – Electronics
- PHY 3040U – Mathematical Physics
- PHY 3060U – Fluid Dynamics
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells

Year 4

Semester 1 (15 credit hours)

- Senior Physics elective**
- Two electives**
- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics
- One of:
- PHY 4410U – Physics Thesis Project I *** or
- Senior Science elective***

Semester 2 (15 credit hours)

- ENV5 2010U – Introductory Environment Science
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- STAT 2010U – Statistics and Probability for Physical Science

Year 3

Semester 1 (15 credit hours)

- Elective**
- PHY 3020U – Quantum Mechanics I
- PHY 3040U – Mathematical Physics
- PHY 3050U – Waves and Optics
- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics

Semester 2 (15 credit hours)

- Elective**
- ENV5 3110U – Economics and Politics of the Environment
- PHY 3010U – Statistical Mechanics
- PHY 3030U – Electronics
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells

Year 4

Semester 1 (15 credit hours)

- Elective**
- PHY 3080U – Electricity and Magnetism II
- PHY 4020U – Quantum Mechanics II
- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics
- One of:
- PHY 4410U – Physics Thesis Project I *** or

Semester 2 (15 credit hours)

- Senior Physics elective**
- Two electives**
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Co-operative Education program

Year 2

Semester 1 (15 credit hours)

- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2060U – Modern Physics
- STAT 2010U – Statistics and Probability for Physical Science

Semester 2 (15 credit hours)

- Elective** (recommend PHY 2040U)
- ENV5 2010U – Introductory Environment Science
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2050U – Thermodynamics and Heat Transfer

Semester 3

- SCCO 1000W – Science Co-op Work Term I *

Year 3

Semester 1 (15 credit hours)

- PHY 3010U – Statistical Mechanics I
- PHY 3020U – Quantum Mechanics I
- PHY 3050U – Waves and Optics
- PHY 3080U – Electricity and Magnetism II

- Senior Science elective***

Semester 2 (15 credit hours)

- Two electives**
- PHY 4010U – Condensed Matter
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Co-operative Education program

Year 2

Semester 1 (15 credit hours)

- Elective**
- CSCI 2000U – Scientific Data Analysis
- MATH 2015U – Calculus III
- PHY 2030U – Mechanics I
- PHY 2050U – Thermodynamics and Heat Transfer

Semester 2 (15 credit hours)

- ENV5 2010U – Introductory Environment Science
- MATH 2060U – Differential Equations
- PHY 2010U – Electricity and Magnetism I
- PHY 2040U – Mechanics II
- STAT 2010U – Statistics and Probability for Physical Science

Semester 3

- SCCO 1000W – Science Co-op Work Term I *

Year 3

Semester 1 (15 credit hours)

- Elective**
- PHY 3020U – Quantum Mechanics I
- PHY 3040U – Mathematical Physics

- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics

Semester 2

- SCCO 2000W – Science Co-op Work Term II *

Semester 3

- SCCO 3000W – Science Co-op Work Term III *

Year 4

Semester 1

- SCCO 4000W – Science Co-op Work Term IV *

Semester 2 (15 credit hours)

- ENV5 3110U – Economics and Politics of the Environment
- PHY 3030U – Electronics
- PHY 3040U – Mathematical Physics
- PHY 3060U – Fluid Dynamics
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells

Semester 3

- SCCO 5000W – Science Co-op Work Term V *

Year 5

Semester 1 (15 credit hours)

- Senior Physics elective**
- Two electives**
- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics
- One of:
- PHY 4410U – Physics Thesis Project I *** or
- Senior Science elective***

Semester 2 (15 credit hours)

- Senior Physics elective**

- PHY 3050U – Waves and Optics
- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics

Semester 2

- SCCO 2000W – Science Co-op Work Term II *

Semester 3

- SCCO 3000W – Science Co-op Work Term III *

Year 4

Semester 1

- SCCO 4000W – Science Co-op Work Term IV *

Semester 2 (15 credit hours)

- Elective**
- ENV5 3110U – Economics and Politics of the Environment
- PHY 3010U – Statistical Mechanics
- PHY 3030U – Electronics
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells

Semester 3

- SCCO 5000W – Science Co-op Work Term V *

Year 5

Semester 1 (15 credit hours)

- Elective**
- PHY 3080U – Electricity and Magnetism II
- PHY 4020U – Quantum Mechanics II
- One of (offered in alternating years):
- ENV5 3020U – Introductory Energy Science or
- PHY 4040U – Solar Energy and Photovoltaics
- One of:
- PHY 4410U – Physics Thesis Project I *** or
- Senior Science elective***

- Two electives**
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

Semester 2 (15 credit hours)

- Two electives**
- PHY 4010U – Condensed Matter
- One of (offered in alternating years):
- PHY 4050U – Emerging Energy Systems or
- PHY 4080U – Hydrogen-Based Energy Systems and Fuel Cells
- One of:
- PHY 4420U – Physics Thesis Project II *** or
- Senior Science elective***

COURSE CHANGE TEMPLATE

For new courses see New Course Template

| | |
|---|---|
| Faculty: Science | |
| Course number: PHY 2060U | Current course title: Modern Physics |
| <input checked="" type="checkbox"/> X Core <input type="checkbox"/> Elective | |

COURSE CHANGES (check all that apply)

| | | | |
|--|---------------------------------|---|--|
| | Course title | | Credit weighting |
| | Course description | | Contact hours |
| | Course number | X | Prerequisites |
| | Course design | X | Co-requisites |
| | Learning outcomes | | Cross-listings |
| | Mode of delivery | | Credit restrictions |
| | Teaching and assessment methods | | Credit exclusions |
| | Delete course | X | Other (please specify): Lab/Tutorial Hours |

REASON FOR CHANGE AND WAYS IN WHICH IT MAINTAINS/ENHANCES COURSE OBJECTIVES

There are currently 3 laboratory hours (biweekly) for this course. In delivering it to first years, however (who already have a laboratory component in PHY 1020U, taken concurrently with this course), it would be more beneficial to offer those hours as tutorials (weekly). This would allow for further instruction and practice in the needed mathematical skills as well the high-level physics concepts covered in this course.

In addition, the prerequisites of the course will be changes to co-requisites to allow first year students to take this course. Having PHY 1020U and MATH 1020U as co-requisites will ensure that students are covering the needed mathematics and physics background along with the content in this course.

CHANGE TO CALENDAR ENTRY

| Current | Proposed |
|---|---|
| <p>PHY 2060U – Modern Physics An overview of early 20th century physics with a focus on atomic and nuclear physics. Topics include quantum physics, including blackbody radiation, the photoelectric effect, wave-particle duality, the wave function and Schrödinger equation, and the uncertainty principle; atomic physics, including the hydrogen atom, multielectron atoms, and the Pauli exclusions principle; and nuclear physics, including binding, radioactivity, and nuclear reactions.</p> <p>Formerly: Nuclear Physics and Relativity Credit hours: 3</p> | <p>PHY 2060U – Modern Physics An overview of early 20th century physics with a focus on atomic and nuclear physics. Topics include quantum physics, including blackbody radiation, the photoelectric effect, wave-particle duality, the wave function and Schrödinger equation, and the uncertainty principle; atomic physics, including the hydrogen atom, multielectron atoms, and the Pauli exclusions principle; and nuclear physics, including binding, radioactivity, and nuclear reactions.</p> <p>Formerly: Nuclear Physics and Relativity Credit hours: 3</p> |

| | |
|---|---|
| Lecture hours: 3 Laboratory hours: 3 (biweekly) Prerequisite(s): PHY 1020U, MATH 1020U Credit restriction(s): CHEM 2010U | Lecture hours: 3 Tutorial hours: 3 (weekly) Co-requisite(s): PHY 1020U, MATH 1020U Credit restriction(s): CHEM 2010U |
|---|---|

CONSULTATION AND FINANCIAL IMPLICATIONS, WHERE APPROPRIATE

There are no financial implications; TA hours are the same in moving to tutorials.

APPROVAL DATES

| | |
|--------------------------------|---------------|
| Curriculum Committee approval | November 2016 |
| Faculty Council approval | December 2016 |
| Date of Submission to CPRC/GSC | January 2017 |