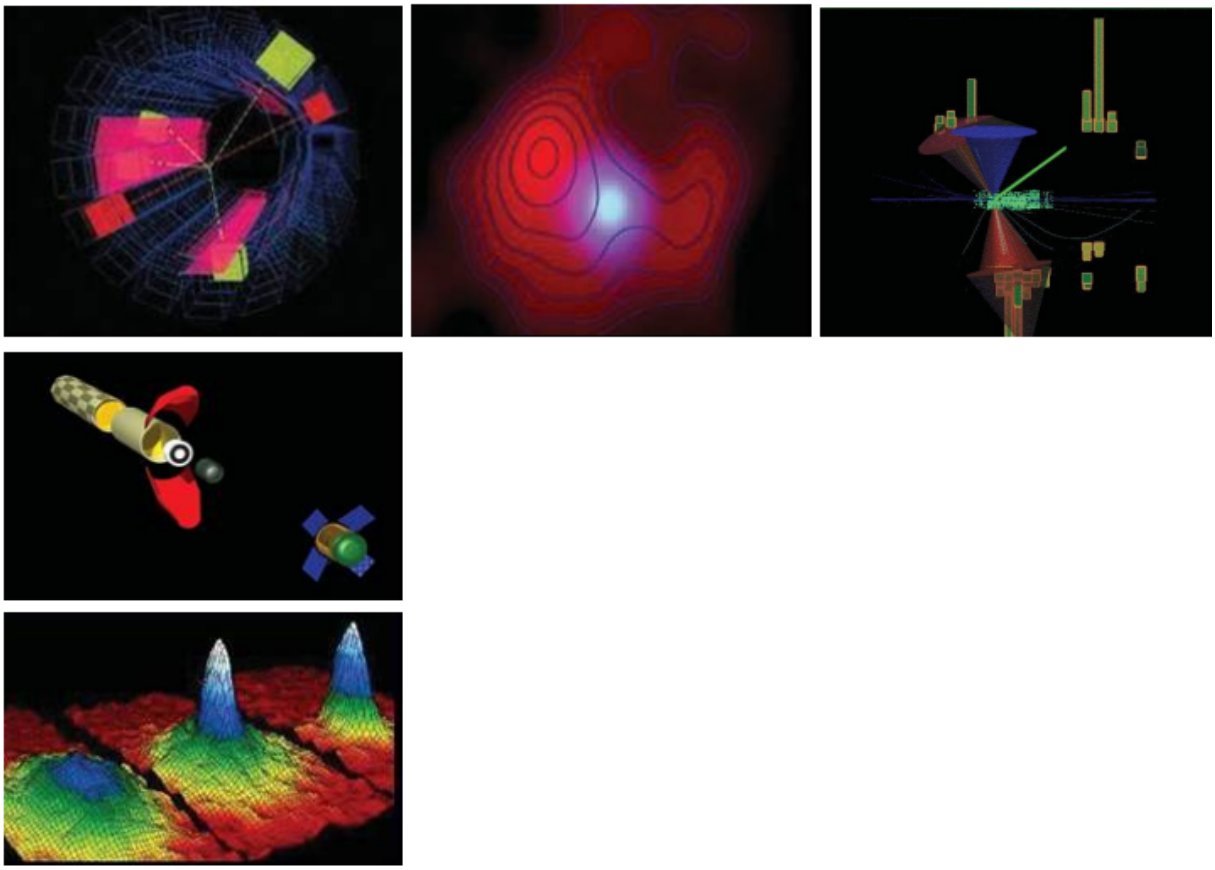
Physics and Astronomy



Undergraduate Handbook

Fall - Winter 2025 - 2026

science | YORK UNIVERSITÉ UNIVERSITY

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Dept. of Physics and Astronomy Directory

Welcome to Physics and Astronomy

Welcome to the Department of Physics and Astronomy at York University. We are honoured that you have chosen to entrust us with your university education. We are committed to teaching of the highest quality. You will find that this process is enriched by our vigorous research activity, which occurs in a dazzling array of fields.

I want your experience with us to be both stimulating and productive. This Handbook and our website (www.yorku.ca/science/physics) will help to guide your way. Those students interested in engineering should refer to the mini-calendar or webpage https://lassonde.yorku.ca/ for the School of Engineering.

Faculty members in the Department are engaged in a wide variety of research activities for which they are internationally renowned. Our astronomers are active at the world's major observing facilities, including those in Hawaii and Chile, and also make use of a wide variety of space telescopes, including the Hubble Space Telescope and the James Webb Space Telescope. Our high energy physics group is privileged to perform experiments at particle accelerators in Switzerland, Japan, and the United States, and is supported by a strong departmental theory group. Our atomic and laser physicists have been involved in atom trapping, detection of antimatter, and creating Canada's first Bose-Einstein condensate (a new form of matter).

Physics and Astronomy students have access to well-equipped laboratories throughout their undergraduate career. For example, a state-of-the-art laser physics laboratory serves students in third and fourth year. Starting in first year, astronomy students are given access to the telescopes of the Allan I. Carswell Observatory located in the Petrie Building that houses the Department.

As part of their university experience, our students also enjoy diverse opportunities for enrichment outside of the classroom. These include events sponsored by Norman Bethune College, the natural campus home to science students at York.

Please don't hesitate to contact me for information about specific departmental matters or to arrange for an appointment. I can be reached by email to chphas@yorku.ca.

Professor Tom Kirchner, Chair

Directory

Physics and Astronomy Office	Emergency/Security Numbers
128 Petrie Science and Engineering Building Hours: 10:00am – 5:00pm (closed 12:00–1:00pm or 1:00–2:00pm) Tel: (416) 736-5249 www.science.yorku.ca/physics **Tom Kirchner** Department Chair Email: chphas@yorku.ca **Ozzy Mermut** Undergraduate Program Director Email: phasupd@yorku.ca **Wayne Michael Gordon** Operations Manager Email: wgordon@yorku.ca **Cristal Del Biondo** Administrative Assistant to the Chair Assistant to the Director, Graduate Program Email: phasgpa@yorku.ca **Janaki DeCamillis** Undergraduate Program Assistant Email: phas@yorku.ca	Emergencies – on - campus (Ambulance, Fire, Police) 911 (if required) then Security ext. 33333 Security Control Centre Ext. 58000 Student Security Escort Service 416-736-5454

Front Cover Photo Credits

Top row, left: Antihydrogen is detected by its annihilation products. Photo by Athena Collaboration.

Top row, centre: A radio image made using a global array of radio telescopes, which shows a possible black hole or neutron star in the centre of supernova 1986J. Image by M. Bietenholz and N. Bartel.

Top row, right: The production of a Higgs boson, observed via its decay to two b quarks and accompanying W boson, in a simulated proton-antiproton collision event in the DZero detector. Image by DZero Collaboration.

Centre left: The space element and staging design of Northern Light, a Canadian mission to Mars, York University and Thoth Technology Inc. Photo by Thoth Technology Inc.

Lower left: Transition of a thermal atom cloud to Bose Einstein Condensate as the temperature is lowered below 100 nanokelvin. Photo by W. van Wijngaarden.

Note: All general information and course references in this handbook have been checked for accuracy, but there may be inconsistencies or errors. If you become aware of any, please bring these to the attention of the Department of Physics and Astronomy.

Important Notice

This Handbook is meant as a supplement to the Official York University Academic Calendar (available at https://calendars.students.yorku.ca/). It describes in detail the options for studying Physics and Astronomy at York University, and contains detailed course descriptions. All general information and course references have been verified for accuracy. However, there may be inconsistencies or errors. If you become aware of any, please bring these to the attention of the Department of Physics & Astronomy. The Department reserves the right to make changes to the information contained in the Handbook without prior notice.

Students are responsible for familiarizing themselves with the specific requirements of the degree they seek.

Not every course listed in the Handbook will necessarily be offered in any academic year. York University reserves the right to limit the number of students who enroll in any program or course. While reasonable efforts will be made to offer courses and classes as required within programs, admission to a program does not guarantee admission to any given class or course.

If there is inconsistency between the general academic regulations and policies published in the Handbook and such regulations and policies as established by resolution of a Faculty or of the University Senate, the version of such material as it is established by the Faculty or the University Senate will prevail.

Summary of Support Services

Office or Contact	Primary Service
Emergencies – on – campus (Ambulance, Fire, Police) call 911 first then call 416-736-5333 (or ext. 33333) Non-Urgent Security Matters 416-650-8000 (or ext. 58000) goSAFE Security Escort Service 416-736-5454 (or ext. 55454)	Emergency/Security
Bethune College 416-736-5164 ext. 33940 https://bethune.yorku.ca/	General advising; study skills; college activities; upcoming events
Bethune Writing Centre 205 Bethune College 416-736-5164 https://bethune.yorku.ca/writing/	Improving writing skills
Career Centre 202 McLaughlin College 416-736-5351 https://careers.yorku.ca/	Career counselling; Learning skills development workshops; Virtual resources
Centre for Student Community & Leadership Development (SC&LD) S172 Ross Building 416- 736-5144 https://www.yorku.ca/scld/	Enrich student life by promoting education, awareness and growth; celebrating diversity encouraging collaboration and developing citizenship.
Centre for Human Rights S327 Ross Building 416-736-5682 https://rights.info.yorku.ca/ rights@yorku.ca	Assists individuals and groups to address and resolve allegations of discrimination and harassment as defined by the Ontario Human Rights Code.
Student Counselling, Health, and Well-Being N110 Bennett Centre for Student Services 416-736-5297 https://counselling.students.yorku.ca/	Personal counselors, crisis counseling, group development workshops, learning skills training, support for learning disabilities and psychiatric disabilities.

Office or Contact	Primary Service
Office of the Ombudsperson 1050 York Research Tower https://ombuds.info.yorku.ca/ ombuds@yorku.ca	Provides an impartial and confidential service to assist current members of York University who have been unable to resolve their concerns about University authorities' application of York University policies, procedures and/or practices.
Office of the Registrar Bennett Centre for Student Services 416-872-YORK https://registrar.yorku.ca/	Enrolment procedures; Sessional dates and refund table; Petitions, permission to take a course at anotheru niversity, transcripts, and most forms
Sexual Assault Survivor's Support Line B449 Student Centre 416-736-2100 x 40345 https://sassl.info.yorku.ca	Provide unbiased and non-judgmental peer support and referrals to survivors of sexual violence; Educational Workshops
Student Accessibility Services N108 Ross Building, N204 Bennett Centre 416-736-5755 https://accessibility.students.yorku.ca/ sasinfo@yorku.ca	Information and support for academic accommodation; support to students with disabilities
Student Financial Services N201 Bennett Centre for Student Services 416-872-YORK https://sfs.yorku.ca/	Scholarships; financial problems; OSAP information
Well-Being https://www.yorku.ca/well-being/resources/students/	Counselling Services Community Mental Health Resources 2SLGBTQIA+ Supports Primary Care Access Food Security
YFS Health Plan 336 Student Centre 416-736-5324 https://www.yfs.ca/healthplan/ healthplan@yorku.ca	Health plan sponsored by York Federation of Students
York International https://yorkinternational.yorku.ca/	Supports and Information for international students

Timetables

PHYS Timetable

Fall	Winter	Fall/Winter	Summer	Not Offered

Fall - Winter 2025 - 2026				
Course	Title	Day	Time	Instructor
PHYS 1011 3.0 A F	**Physics 1** Tutorial	MWF F	12:30-13:30 9:30-10:30	C. Bergevin
PHYS 1012 3.0 M W	**Physics 2** Tutorial	MWF T	12:30-13:30 13:30-14:30	S. Jerzak
PHYS 1070 3.0 M W	**Fundamentals of Astronomy** Tutorial	TR W	10:00-11:30 14:30-15:30	R. Kannan
PHYS 1411 3.0 A F	**Physics Fundamentals 1** Tutorial	TR M	13:00-14:30 12:30-13:30	R. Lewis
PHYS 1412 3.0 M W	**Physics Fundamentals 2** Tutorial	TR M	13:00-14:30 10:30-11:30	P. Scholz
PHYS 1421 3.0 A F	**Physics with Life Science Applications 1** Tutorial	MWF T	12:30-13:30 13:30-14:30	S. Jerzak
PHYS 1421 3.0 A S1	**Physics with Life Science Applications 1** Tutorial	MWF W	13:30-15:30 16:30-17:30	TBA
PHYS 1422 3.0 M W	**Physics with Life Science Applications 2** Tutorial	MWF T	12:30-13:30 9:30-10:30	M. George
PHYS 1422 3.0 M S2	**Physics with Life Science Applications 2** Tutorial	MWF W	13:30-15:30 16:30-17:30	TBA
PHYS 1470 3.0 A F	**Highlights of Astronomy** Tutorial	TR W	16:00-17:30 14:30-15:30	P. Scholz
PHYS 1470 3.0 M W	**Highlights of Astronomy**			Not offered W26
PHYS 1510 3.0 A F	**Introduction to Physics** Tutorial	TR T	16:00-17:30 9:30-10:30	W. van Wijngaarden

Fall - Winter 2025 - 2026				
Course	Title	Day	Time	Instructor
PHYS 1510 3.0 M W	**Introduction to Physics** Tutorial			Not offered W26
PHYS 1510 3.0 A SU	**Introduction to Physics**			Not offered SU25
PHYS 1800 3.0 A F	**Engineering Mechanics** Tutorial	MWF F	11:30-12:30 10:30-11:30	C.E. Boukaré
PHYS 1800 3.0 B F	**Engineering Mechanics** Tutorial	MWF M	14:30-15:30 16:30-17:30	S. Jerzak
PHYS 1800 3.0 D F	**Engineering Mechanics** Block Format	Block	BLEN	M. George
PHYS 1800 3.0 M WL	**Engineering Mechanics** Tutorial	 F	 12:30-13:30	Not Offered FW25-26
PHYS 1800 3.0 M W	**Engineering Mechanics** Tutorial	MWF F	08:30-09:30 9:30-10:30	A. Rafiee
PHYS 1801 3.0 M W	**Electricity, Magnetism and Optics for Engineers** Tutorial	MWF T	8:30-9:30 10:30-11:30	B. Hashemi Pour
PHYS 1801 3.0 N W	**Electricity, Magnetism and Optics for Engineers** Tutorial	MWF T	11:30-12:30 11:30-12:30	B. Hashemi Pour
PHYS 1801 3.0 A SU	**Electricity, Magnetism and Optics for Engineers**			TBA
PHYS 2010 3.0 M W	**Classical Mechanics** Tutorial	MWF F	11:30-12:30 9:30-10:30	E. Hessels
PHYS 2020 3.0 A F	**Electricity & Magnetism** Tutorial	TR W	11:30-13:00 11:30-12:30	A. Kumarakrishnan
PHYS 2020 3.0 M W	**Electricity & Magnetism** Tutorial	TR W	11:30-13:00 13:30-14:30	A. Kumarakrishnan Reserved B.ENG.
PHYS 2020 3.0 B SU	**Electricity & Magnetism**		ONCA	S. Tulin
PHYS 2030 3.0 M W	**Computational Methods**	W	15:30-18:30	S. Tulin
PHYS 2040 3.0 A F	**Relativity & Modern Physics** Tutorial	MWF F	13:30-14:30 9:30-10:30	E. Hessels
PHYS 2060 3.0 M W	**Optics & Spectra** Tutorial	MW M	09:00-10:30 13:30-14:30	W. Taylor
PHYS 2070 3.0 A F	**Galaxies & the Universe**	TR	10:00-11:30	A. Rafiee
PHYS 2211 1.0 M W	**Experimental Electromagnetism** Lab	 MTWRF	 various	M. George

Fall - Winter 2025 - 2026				
Course	Title	Day	Time	Instructor
PHYS 2212 1.0	**Experimental Physics**			Not Offered FW25-26
PHYS 2213 3.0 A Y	**Experimental Physics with Data Analysis** Lab	F	12:30-13:30	B. Howard
PHYS 3010 3.0 A F	**Classical Mechanics**	TR	11:30-13:00	W. van Wijngaarden
PHYS 3020 3.0 A F	**Electromagnetics I**	MWF	11:30-12:30	W. Taylor
PHYS 3030 3.0 M W	**Statistical & Thermal Physics**	MWF	9:30-10:30	W. van Wijngaarden
PHYS 3040 6.0 A Y	**Modern Physics** Tutorial	MWF M	10:30-11:30 16:00-17:00	R. Lewis Tut(F): T. Kirchner
PHYS 3050 3.0 A F	**Electronics I** Take EECS 2200 3.0 instead			
PHYS 3070 3.0 A F	**Planets & Planetary Systems**	TR	13:00-14:30	C.E. Boukaré
PHYS 3080 3.0 A F	**Atmospheric Radiation & Thermodynamics**	MW	9:00-10:30	ESSE dept.
PHYS 3090 3.0 A F	**Methods in Theoretical Physics**	MWF	9:30-10:30	N. Blinov
PHYS 3130 3.0 M W	**Practical Data Science Methods in Physical Sciences**			Not offered W26
PHYS 3150 3.0 M W	**Electronics 2** Take EECS 2210 3.0 instead			Not offered W26
PHYS 3220 3.0 A W	**Experiments in Modern Physics** Labs	T MTWRF	10:00-11:00 flexible	B.Howards
PHYS 3250 3.0 A F	**Introduction to Space Communications**	MWF	12:30-13:30	P. Scholz
PHYS 3280 3.0 M W	**Physics of the Space Environment**	TR	11:30-13:00	TBA
PHYS 3330 3.0 M W	**Material for Space Applications** Tutorial	TR T	10:00-11:30 17:30-20:30	ESSE dept.
PHYS 3600 3.0 A Y	**EXPLORE** BLEN	TR	09:00-10:00	S. Tulin
PHYS 3900 3.0 A F	**Physics or Astronomy Internship Work Term**			

Fall - Winter 2025 - 2026				
Course	Title	Day	Time	Instructor
PHYS 3900 3.0 A W	**Physics or Astronomy Internship Work Term**			
PHYS 3900 3.0 M SU	**Physics or Astronomy Internship Work Term**			
PHYS 4010 3.0 A F	**Quantum Mechanics**	MWF	13:30-14:30	T. Kirchner
PHYS 4011 3.0 M W	**Atomic and Molecular Physics/Structure**			Not offered W26
PHYS 4020 3.0 M W	**Electromagnetics II**	MWF	12:30-13:30	N. Blinov
PHYS 4030 3.0 A F	**Advanced Computational Methods**			Not offered F25
PHYS 4040 3.0 M W	**Elementary Particle Physics**	MWF	10:30-11:30	N. Blinov
PHYS 4050 3.0 M W	**Solid State Physics**			Not offered W26
PHYS 4060 3.0 A F	**Time Series & Spectral Analysis** Tutorial	TR T	8:30-10:00 11:30-14:30	ESSE dept.
PHYS 4061 3.0 A F	**Experimental Techniques in Laser Physics** Tutorial Labs	R R	14:30-15:30 15:30-16:30	M. George
PHYS 4062 3.0 M W	**Atom Trapping** Tutorial Labs	F F TR	15:30-16:30 16:30-17:30 11:30-14:30	A. Kumarakrishnan
PHYS 4070 3.0 M W	**Stars & Nebulae**	MWF	14:30-15:30	A. Muzzin
PHYS 4110 3.0 M W	**Dynamics of Space Vehicles**	TF	10:00-11:30	ESSE dept.
PHYS 4120 3.0 A F	**Gas and Fluid Dynamics**			Not Offered F25
PHYS 4170 3.0 M W	**Cosmology**			Not offered W26
PHYS 4210 3.0 M W	**Advanced Experimental Physics I** Lab	M MTWRF	14:30-15:30 Flexible	M. George
PHYS 4211 3.0 M W	**Advanced Experimental Physics II** Lab	M MTWRF	14:30-15:30 Flexible	M. George
PHYS 4270 3.0 A Y	**Astronomical Techniques**	R	14:30-16:00	A. Rafiee (F) P. Hall(W)
PHYS 4310 3.0 A F	**Physics/Astronomy Project**			
PHYS 4310 3.0 M W	**Physics/Astronomy Project**			
PHYS 4310 3.0 A SU	**Physics/Astronomy Project**			

Fall - Winter 2025 - 2026				
Course	Title	Day	Time	Instructor
PHYS 4330 3.0 M W	**Radio Sci. & Tech. for Space Exploration**			Not Offered W/26
PHYS 4350 6.0 A Y	**Space Hardware** Lab Lab	MR M W	10:00-11:30 13:00-16:00 10:00-13:00	ESSE dept.

BPHS Timetable

Fall	Winter	Fall/Winter	Summer	Not Offered

Fall - Winter 2025 - 2026				
Course	Title	Day	Time	Instructor
BPHS 2090 3.0 A F	**Current Topics in Biophysics**	MW	9:00-10:30	O. Mermut
BPHS 3900 3.0 A F	**Biophysics Internship Work Term**			
BPHS 3900 3.0 M W	**Biophysics Internship Work Term**			
BPHS 4080 3.0 M F	**Cellular Electrodynamics**	MWF	14:30-15:30	C. Bergevin
BPHS 4310 3.0 A F	**Biophysics Research Project**			
BPHS 4310 3.0 M W	**Biophysics Research Project**			
BPHS 4310 3.0 A S	**Biophysics Research Project**			

Program Information

What is Physics and Astronomy?

Physics is the most fundamental science discipline. Physics can be thought of as providing the complete model of the natural world. Although the beauty of this model is valued, the model must be subject to experimental verification.

Physics is largely concerned with the investigation of systems where the number of variables is small. Areas concerned with extremely complex systems, like geophysics and atmospheric physics, have become disciplines in their own right. Astronomers focus upon the most complex systems of all, using knowledge about fundamental physics in their attempts to understand them. In turn, astronomical research often leads to new insights into physics, such as the exciting connections between cosmology and elementary particle physics.

The sub disciplines of physics can be identified by the typical length scales which they probe.

The largest distance scales are studied in astronomy and astrophysics. In fact, astronomy covers a wide range of distances: in planetary astronomy, the astronomical unit (distance between Sun and Earth - 10^{11} m) is important, the light-year (about 10^{16} m) represents the distance scale of Galactic astronomy, while the range of millions to billions of light-years (10^{22} m to 10^{25} m) is relevant for studies of the nearest galaxies and beyond, all the way to the universe as a whole.

Physics at distance scales of our everyday experience (e.g., meters) is the concern of classical physics, including classical and fluid mechanics, with modern developments in the area of nonlinear phenomena, such as chaos.

At the distance scale of nanometers (10^{-9} m) we are at the size of atoms. This region is dominated by the electric and magnetic forces of charged particles (electrons and protons), and falls into the realm of atomic, molecular, and optical physics. The term optical physics has been coined because of the important role played by lasers in probing atoms. molecules, and macromolecules called atomic clusters (for example, fullerenes or buckyballs – soccer-ball-shaped assemblies of 60 or more carbon atoms).

When very many atoms (10^{24}) are bound to form a solid or a crystal, simply as the net result of electrostatic forces, we observe new phenomena. Conduction in metals, non-conduction in crystals, semiconductor devices - these are technologically important processes governed by quantum physics and studied in condensed matter or solid-state physics. When dealing with large numbers of particles in the gaseous or fluid state, the field becomes classical and/or quantum statistical mechanics. A special case occurs at high temperatures when atoms ionize. This is the field of plasma physics.

At the femtometer or fermi scale (10^{-15} m) we are entering the realm of nuclear physics. Nuclear physics treats neutrons and protons as the fundamental building blocks of nuclei and explains why light nuclei fuse (the energy production mechanism of stars, such as our Sun), and why one gains energy from the fission of heavy nuclei (such as in nuclear power plants). It explains why

certain nuclei are stable, and why others are not, and why they decay radioactively by particle emission.

At the sub-fermi scale, we study the structure of protons, neutrons and other particles, and find that they are made of quarks. Particle physics (also called high-energy physics) is the most fundamental of the physics disciplines. Our present understanding is that quarks, electrons, and neutrinos are point-like objects that come in three families, and form the basis of most, but perhaps not all matter in the universe. Big particle accelerators can be used to create particles that normally do not occur in our every-day life, but which existed in the earliest stages of the universe after the Big Bang.

Why is Physics and Astronomy Useful?

Physics and astronomy are classical disciplines that are founded upon a powerful investigative technique known as the Scientific Method. Experiments are used to observe nature and explore phenomena. Theories are constructed to understand the phenomena. They lead to further probing by refined experiments. This methodology is being applied increasingly to disciplines that were less mathematical in the past, such as biology, and even economics. Studying physics or astronomy may be the best way to grasp this methodology.

The traditional view of a physicist is that of someone hovering over an apparatus on a bench, and the traditional view of an astronomer is that of someone looking through a telescope. This is not quite right, as most physicists and astronomers today are using computers to test their theories as well as to collect and analyze data from their experiments. Students make extensive use of computers and have excellent prospects of finding computer-related jobs. Physics and Astronomy students acquire sophisticated problem-solving skills, and at the same time obtain computer training, in reasonably small classes.

What Study Physics and Astronomy at York?

Over the past 15 years York University has hired excellent young researchers in experimental as and theoretical physics, as well as astronomy/astrophysics. These researchers have built their careers while training graduate students and have joined senior colleagues in establishing sound curricula in physics and astronomy, with strong experimental components. We ensure that our students not only learn the subject matter, but that they also learn how to think critically about it and to apply it to analyze and solve problems. In the process, Physics and Astronomy studies provide an excellent opportunity to:

Acquire substantial mathematical skills with emphasis on practical mathematics, as opposed to theorems and formal language. Acquire computing skills including programming, visualization of data, symbolic and numerical computation, and computer-interfacing of laboratory experiments.

Acquire technical writing skills, particularly in the writing of scientific laboratory reports requiring a detailed analysis of the physics, the experimental methodology, and the description of results.

Acquire breadth both within and outside of physics and astronomy. To satisfy the general education requirement, students may choose amongst many options from offerings outside of the Faculty of Science.

Program Learning Outcomes (PLO)

At the completion of a Physics and Astronomy B.Sc. Honours Degree, students should be able to:

PLO 1 Describe foundational concepts of physics and recognize problems to which knowledge of physics may be productively applied.

PLO 2 Explain the scientific method and apply it to problems in physics and/or astronomy.

PLO 3 Identify and evaluate mathematical, computational, or experimental principles and techniques useful in solving problems under study.

PLO 4 Apply critical thinking skills to solving specific complex problems and solve such problems by applying all applicable general physics principles, including recognizing special or limiting cases.

PLO 5 Apply mathematical principles and techniques (including approximations and order-of-magnitude calculations) to solve practical and theoretical problems in the physical sciences.

PLO 6 Apply computational skills (such as writing, generating, and adapting existing code, interfacing computers with experimental apparatus, breaking a complex problem into logical steps) to solve mathematical and physical problems, and to analyze and model data to formulate and test hypotheses.

PLO 7 Formulate experimental hypothesis and (when required), evaluate the setup of experiments, and use complex instrumentation to carry out experiments effectively and conclude on the validity of the hypothesis.

PLO 8 Interpret and record knowledge received, summarize the knowledge, and clearly communicate concepts to others. Identify, locate, and critically analyze information and literature.

PLO 9 Identify uncertainties in experimental measurements, propagate these uncertainties through calculations, include uncertainties in model fits to the data to understand the statistical significance of the experiment's results and limitations of the conclusions derived from these results.

PLO 10 Independently and collaboratively execute experiments effectively and safely while keeping accurate and clear records.

PLO 11 Organize and communicate ideas to a variety of audiences from different backgrounds using words, mathematical equations, tables, graphs, pictures, animations, diagrams, and other visualization tools.

Co-op Program

The Science Co-op Program allows students to gain professional, paid work experience related to their program of study. During work terms, you will have the opportunity to apply your classroom learning in a real work environment. The program provides flexibility, allowing students to choose how much work experience they would like to gain (minimum 8 months, maximum 20 months) throughout their degree. Full-time students who are enrolled in the Physics and Astronomy Program are eligible to apply. For more information on Co-op, please visit: https://www.yorku.ca/science/students/experiential-education/co-op-program/

Internships

The Department of Physics and Astronomy provides upper year students with the opportunity to participate in an internship related to their field of study. The internship course is for students who are opting for a shorter, 4 month work experience. Students benefit from departmental supervision and support but are responsible for securing their own internship prior to enrolling in the course. Students interested in multiple work terms should consider the Co-op program.

For more information on internships, please visit: https://www.yorku.ca/science/students/experiential-education/internship-program/

Careers

Students wanting to know where their studies might lead them should refer to our survey of alumni of our programs who have established their careers. They survey can be found on our website. Students interested in exploring the current job market should check our website www.yorku.ca/science/physics under Careers, where we update web links to over 100 companies that hire physicists, engineers and information technologists.

Students interested in physics/astronomy-related graduate careers should focus on the 4-year degree paths. Students interested in becoming teachers - A B.Sc. is a possible route to a career in science education. In Ontario, an Honours degree opens up the opportunity to teach Grades 11 and 12. Students who acquire a Bachelor degree are eligible to teach Grades 1 through 10. To teach intermediate (Grades 9 and 10) or senior (Grades 11 and 12) levels, students must acquire a total of 36 credits in a first teaching subject and 24 credits in a second. Information about which courses in physics or astronomy can be counted towards a physics teachable is available from the Faculty of Education.

Students interested in becoming science teachers should seriously consider the B.Ed. Consecutive Program. Students are eligible to enter the B.Ed. Consecutive Program following completion of their undergraduate degree. Students acquire a B.Ed. after two more years of study beyond their B.Sc. Interested student should contact the Faculty of Education for further information.

Remember, our Office is always here to help! If you'd like further advice, please contact our Office to arrange an appointment to discuss your situation further.

Overview of Degrees

B.Sc. Bachelor and B.Sc. Honours Paths

Overview

There are many options for education, including combining studies in Physics and/or Astronomy with studies in other disciplines. Within the Department of Physics and Astronomy itself, students may choose among a variety of study paths. These paths are distinguished on the basis of course requirements. They are:

Physics and Astronomy Program

Physics Stream

The most flexible path for students wishing to become grounded in fundamental physics and its applications.

Astronomy and Astrophysics Stream

A path of study which provides grounding in astronomy and astrophysics on top of training in fundamental physics and its applications.

Applied Physics Stream

A more programmed path of physics study emphasizing applications.

Biomedical Physics Program

This is a path of study which allows students to learn not only fundamentals of biology and physics, but also how to apply the laws and methods of physics to understand biological processes. Interested students should refer to the Biomedical Physics Handbook for complete details.

Space Science Program

A path of study which emphasizes training in fields relevant to the exploration of space beyond the immediate environment of Earth. This path of study is open to students in the Department of Physics and Astronomy and to students who begin as Space Science or Space Engineering majors in the Department of Earth and Space Science and Engineering.

Students should also be aware that the Department is integrally involved in the teaching of science to space engineers.

Degree Classifications

The classification of the degree received after following a particular path of study depends upon the number of credits taken, whether the path is followed in conjunction with studies in another discipline, and whether the path followed is a ”stream” or a ”program”. Students involved with the Department of Physics and Astronomy will be granted one of the following degrees upon satisfaction of corresponding academic requirements:

3-year (90 credits) B.Sc. in Physics and Astronomy (Physics Stream or Astronomy and Astrophysics Stream)

4-year (120 credits) Specialized Honours B.Sc. in Physics and Astronomy (Physics Stream, Applied Physics Stream, Astronomy and Astrophysics Stream, or Space Science Stream)

4-year (120 credits) Specialized Honours B.Sc. in Biomedical Physics.

4-year (120 credits) Honours B.Sc. in Physics and Astronomy (Physics Stream or Astronomy and Astrophysics Stream).

4-year (120 credits) Double-Major Honours B.Sc. in Physics and Astronomy (Physics Stream or Astronomy and Astrophysics Stream) and in another discipline from the Faculty of Science or other Faculties.

4-year (120 credits) Major-Minor Honours B.Sc. in Physics and Astronomy (Physics Stream or Astronomy and Astrophysics Stream) and in another discipline from the Faculty of Science or other Faculties.

Which Path should you Choose?

The path you choose is largely determined by personal preference and career ambitions. Career possibilities are described elsewhere in this handbook, and you are urged to explore the possibilities as early as possible. The department offers advising to all interested students, including high-school students who intend to apply at some point. Please make use of the contact information provided to schedule an appointment. The following remarks should serve as a guide.

By the second year of studies, you should seriously consider whether you intend to continue with a graduate career (in physics, astronomy, space science, engineering, or other related disciplines - or a professional school, such as medicine, dentistry, law or business), or whether the intent is to enter the job market upon graduation (possibly after further technical training). To be accepted to graduate studies, you need to obtain at minimum a B average over the last two years of study in an Honours-level program (some institutions require at least a B+ average).

Switching between options is possible, in many instances without penalty with respect to the time required to complete the degree. Note that it is more difficult to switch in the final year(s).

Computational Physics and Computational Astronomy have emerged as important branches of physics over the last two decades. They are related to Theoretical Physics as well as to Applied Mathematics and have produced many Ph.D. graduates who have moved on to revolutionize fields in chemistry, biology, financial mathematics, and others. At York, you have excellent opportunities

to tap into the expertise of researchers in numerical and symbolic computing. This area is as important for those students who wish to pursue graduate careers as it is for those who wish to apply their scientific skills in the workplace immediately after graduation.

Entrance Requirements

To be eligible to major in Physics and Astronomy at York starting in first year, it is necessary to have passed Grade 12 courses or their equivalents in English, Physics, and Mathematics. Specifically, applicants from high schools in Ontario must have passed the following:

ENG4U - 12U English (York University requirement) SPH4U - 12U Physics MHF4U - 12U Advanced Functions MCV4U - 12U Calculus and Vectors

SCH4U - 12U Chemistry is recommended, but not required for admissions. Those students lacking Grade 12U Chemistry will be required to take an equivalent course at York prior to enrolling in University-level chemistry courses.

Applicants admitted to York who lack any of the requirements cannot become majors until such time as the deficiencies are corrected. York University offers bridging courses (high school equivalents) to help such students meet the entry requirements of the program. Students who are missing any prerequisites should enroll in an equivalent 1500-level course, such as PHYS 1510 3.0 and/or CHEM 1500 4.0, before proceeding further.

Course Selection

Physics and Astronomy studies are quite straightforward as far as course selection is concerned. For three of the streams (Physics, Applied Physics, and Astronomy & Astrophysics), there is a common core for the first two years. Recommended timetables for each stream are detailed later in this handbook.

Students who fall behind in the sequence of MATH courses for Physics majors should strive to catch up during the summer term if at all possible. It is important to complete MATH 1013, MATH 1014, and MATH 1025 before starting second-year Physics courses, and all three of those MATH courses are offered during the summer.

Any student who is able to take courses during the summer should consider taking MATH 2015 in the summer after their first year, so that they can take MATH 2271 in the fall of their second year. Students following that schedule are a semester ahead of the normal MATH sequence for Physics majors, giving them greater familiarity with mathematical concepts used in second-year physics courses in both the fall and winter terms.

For advancement to graduate studies in Physics, the following courses are especially important:

PHYS 2030 3.0 Computational Methods
PHYS 3010 3.0 Classical Mechanics
PHYS 3020 3.0 Electromagnetics I
PHYS 3030 3.0 Statistical and Thermal Physics
PHYS 3090 3.0 Methods in Theoretical Physics

PHYS 4010 3.0 Quantum Mechanics
PHYS 4020 3.0 Electromagnetics II

For advancement to graduate studies in Astronomy & Astrophysics, the following courses are particularly important:

PHYS 2030 3.0 Computational Methods
PHYS 3020 3.0 Electromagnetics I
PHYS 3030 3.0 Statistical and Thermal Physics
PHYS 3090 3.0 Methods in Theoretical Physics
PHYS 4020 3.0 Electromagnetics II
PHYS 4070 3.0 Stars and Nebulae
PHYS 4170 3.0 Observational and Theoretical Cosmology

Degree Requirements

The following are current degree requirements. **Students may graduate by fulfilling the current degree requirements for their year of graduation OR by fulfilling the degree requirements in place when they first declared a major in the program.** For past requirements, please consult the undergraduate handbook or the online academic calendar for the appropriate year: https://calendars.students.yorku.ca/previous-undergraduate-calendars.

The Program Core

The Program core (27 credits) is defined to be: SC/PHYS 1011 3.00; SC/PHYS 1012 3.00; SC/PHYS 2010 3.00; SC/PHYS 2020 3.00; SC/PHYS 2040 3.00; SC/PHYS 2060 3.00; SC/PHYS 3030 3.00; SC/PHYS 3040 6.00. The Program core applies to all streams within the Bachelor, Honours, and Specialized Honours Programs.

Non-Science Requirement

The non-science requirement provides a broad perspective on current scholarship and the diversity of human experience. These courses are also expected to enhance students' critical skills in reading, writing and thinking, and contribute to their preparation for post-university life. All BSc degree candidates must complete a minimum of 12 credits from at least two different areas of study, including at least three credits from each area, subject to the restrictions noted by the Faculty.

Visit the Faculty's website for details, particularly with respect to eligible courses: https://calendars.students.yorku.ca/

Bachelor Program- Physics Stream

1. **The program core:**
   See 'Program core' subsection for further explanation.
2. **Additional required courses:**
   - CHEM 1000 3.00; CHEM 1001 3.00
   - LE/EECS 1541 3.00
   - SC/MATH 1013 3.00; SC/MATH 1014 3.00; SC/MATH 1025 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00;
   - SC/PHYS 2030 3.00; SC/PHYS 2213 3.00; SC/PHYS 3090 3.00; SC/PHYS 3220 3.00;
   - Three credits from: SC/PHYS 4061 3.00, SC/PHYS 4210 3.00, SC/PHYS 4211 3.00;
   - Three credits from: SC/PHYS 3010 3.00, SC/PHYS 3020 3.00
3. **Non-Science requirement: 12 credits**
   See 'Non-Science Requirement' subsection for further explanation.

4. **Upper level requirements:** a minimum of 18 credits at the 3000 level or above.
5. **Additional elective credits, as required for a total of 90 credits**

Bachelor Program- Astronomy & Astrophysics Stream

1. **The program core:**
   See 'Program core' subsection for further explanation.
2. **Additional required courses:**
   - CHEM 1000 3.00; CHEM 1001 3.00
   - LE/EECS 1541 3.00
   - SC/MATH 1013 3.00; SC/MATH 1014 3.00; SC/MATH 1025 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00;
   - SC/PHYS 1070 3.00; SC/PHYS 2030 3.00; SC/PHYS 2070 3.00; SC/PHYS 2213 3.00; SC/PHYS 3220 3.00; SC/PHYS 4270 3.00;
   - Three credits from: SC/PHYS 3010 3.00, SC/PHYS 3020 3.00, SC/PHYS 3090 3.00
3. **Non-Science requirement: 12 credits**
   See 'Non-Science Requirement' subsection for further explanation.
4. **Upper level requirements:** a minimum of 18 credits at the 3000 level or above.
5. **Additional elective credits, as required for a total of 90 credits**

Honours Program- Physics Stream or Astronomy Stream

1. **The program core:**
   See 'Program core' subsection for further explanation.
2. **Additional required courses:**
   - CHEM 1000 3.00; CHEM 1001 3.00
   - LE/EECS 1541 3.00
   - SC/MATH 1013 3.00; SC/MATH 1014 3.00; SC/MATH 1025 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00;
   - SC/PHYS 2030 3.00; SC/PHYS 2213 3.00; SC/PHYS 3220 3.00
   - Three credits from: SC/PHYS 3010 3.00, SC/PHYS 3020 3.00, SC/PHYS 3090 3.00
   - Physics stream only: SC/PHYS 4061 3.00
   - Astronomy Stream only: SC/PHYS 1070 3.00; SC/PHYS 2070 3.00; SC/PHYS 4270 3.00
   - Nine additional credits in PHYS courses at the 4000 level.
3. **Non-Science requirement: 12 credits**
   See 'Non-Science Requirement' subsection for further explanation.
4. **Upper level requirements:** At least 42 credits at the 3000 or higher level, including at least 12 major credits at the 4000 level.

5. **Additional elective credits, as required for a total of 120 credits**

Specialized Honours Program- Physics Stream

1. **The program core:**
   See 'Program core' subsection for further explanation.
2. **Additional required courses:**
   - CHEM 1000 3.00; CHEM 1001 3.00
   - LE/EECS 1541 3.00
   - SC/MATH 1013 3.00; SC/MATH 1014 3.00; SC/MATH 1025 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00;
   - SC/PHYS 2030 3.00; SC/PHYS 2213 3.00; SC/PHYS 3010 3.00; SC/PHYS 3020 3.00
   - SC/PHYS 3090 3.00; SC/PHYS 3220 3.00; SC/PHYS 4010 3.00
   - SC/PHYS 4020 3.00, SC/PHYS 4061 3.00
   - Six credits from: SC/PHYS 4011 3.00, SC/PHYS 4040 3.00, SC/PHYS 4050 3.00
   - Six credits from: SC/PHYS 4062 3.00, SC/PHYS 4210 3.00, SC/PHYS 4211 3.00
   - Three additional credits in PHYS courses at the 3000 level or higher.
3. **Non-Science requirement: 12 credits**
   See 'Non-Science Requirement' subsection for further explanation.
4. **Upper level requirements:** At least 42 credits at the 3000 or higher level, including at least 12 major credits at the 4000 level.
5. **Additional elective credits, as required for a total of 120 credits**

Specialized Honours Program- Astronomy & Astrophysics Stream

1. **The program core:**
   See 'Program core' subsection for further explanation.
2. **Additional required courses:**
   - CHEM 1000 3.00; CHEM 1001 3.00
   - LE/EECS 1541 3.00
   - SC/MATH 1013 3.00; SC/MATH 1014 3.00; SC/MATH 1025 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00;
   - SC/PHYS 1070 3.00; SC/PHYS 2030 3.00; SC/PHYS 2070 3.00; SC/PHYS 2213 3.00;
   - SC/PHYS 3010 3.00; SC/PHYS 3020 3.00; SC/PHYS 3070 3.00;
   - SC/PHYS 3090 3.00; SC/PHYS 3220 3.00; SC/PHYS 4010 3.00; SC/PHYS 4020 3.00
   - SC/PHYS 4061 3.00; SC/PHYS 4070 3.00; SC/PHYS 4170 3.00; SC/PHYS 4270 3.00
   - Three credits from: SC/PHYS 4011 3.00, SC/PHYS 4040 3.00, SC/PHYS 4050 3.00, SC/PHYS 4120 3.00

- Three credits from SC/PHYS 3280 3.00, SC/PHYS 4060 3.00, SC/PHYS 4110 3.00, SC/PHYS 4330 3.00, LE/ESSE 4630 3.00
- Three additional credits in PHYS, ESSE, or MATH courses at the 3000 level or higher.

3. **Non-Science requirement: 12 credits**
   See 'Non-Science Requirement' subsection for further explanation.
4. **Upper level requirements:** At least 42 credits at the 3000 or higher level, including at least 12 major credits at the 4000 level.
5. **Additional elective credits, as required for a total of 120 credits**

Specialized Honours Program- Applied Physics Stream

1. **The program core:**
   See 'Program core' subsection for further explanation.
2. **Additional required courses:**
   - CHEM 1000 3.00; CHEM 1001 3.00
   - LE/EECS 1541 3.00
   - SC/MATH 1013 3.00; SC/MATH 1014 3.00; SC/MATH 1025 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00;
   - SC/PHYS 2030 3.00; SC/PHYS 2213 3.00; SC/PHYS 3010 3.00; SC/PHYS 3020 3.00
   - SC/PHYS 3050 3.00; SC/PHYS 3090 3.00; SC/PHYS 3150 3.00
   - SC/PHYS 3220 3.00, SC/PHYS 4010 3.00; SC/PHYS 4020 3.00; SC/PHYS 4050 3.00
   - SC/PHYS 4061 3.00
   - Six credits from SC/PHYS 4062 3.00, SC/PHYS 4210 3.00, SC/PHYS 4211 3.00
   - Nine credits from: SC/MATH 3241 3.00 [1], SC/PHYS 3250 3.00, SC/PHYS 3280 3.00, SC/PHYS 4120 3.00, SC/PHYS 4250 3.00, SC/PHYS 4310 3.00
3. **Non-Science requirement: 12 credits**
   See 'Non-Science Requirement' subsection for further explanation.
4. **Upper level requirements:** At least 42 credits at the 3000 or higher level, including at least 12 major credits at the 4000 level.
5. **Additional elective credits, as required for a total of 120 credits**

[1] MATH 3241 will not count towards major credit total

Specialized Honours Program- Space Science Stream

1. **The Space Science program core:**
   LE/ESSE 1010 3.00*; LE/ESSE 1011 3.00; SC/MATH 1025 3.00; SC/PHYS 1070 3.00; LE/EECS 2501 1.00; LE/ESSE 2030 3.00; LE/ESSE 2470 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00; SC/PHYS 2010 3.00; SC/PHYS 2020 3.00; SC/PHYS 2030 3.00; SC/PHYS 2040 3.00; SC/PHYS 2060 3.00; SC/PHYS 2213 3.0
   *OR LE/ESSE 1012 3.00 Note: the first-year engineering core would be an acceptable substitute for the first year courses.
2. **Additional required courses:**
   - CHEM 1000 3.00; CHEM 1001 3.00
   - LE/EECS 1541 3.00
   - SC/MATH 1013 3.00; SC/MATH 1014 3.00
   - SC/PHYS 1010 6.00; SC/PHYS 3020 3.00; SC/PHYS 3040 6.00; SC/PHYS 3050 3.00
   - SC/PHYS 3070 3.00, SC/PHYS 3150 3.00; SC/PHYS 3250 3.00; SC/PHYS 3280 3.00
   - Three credits from: SC/PHYS 3010 3.00, SC/PHYS 3030 3.00, SC/PHYS 3080 3.00, SC/PHYS 3090 3.00, SC/PHYS 3220 3.00
   - SC/PHYS 4110 3.00; SC/PHYS 4330 3.00; SC/PHYS 4350 3.00
   - at least Eight credits from: LE/ESSE 3670 3.00, LE/ESSE 4360 3.00, LE/ESSE 4361 3.00, SC/PHYS 4010 3.00, SC/PHYS 4020 3.00, SC/PHYS 4040 3.00, SC/PHYS 4050 3.00, SC/PHYS 4070 3.00, SC/PHYS 4120 3.00, SC/PHYS 4270 3.00, SC/PHYS 4310 3.00, SC/PHYS 4410 3.00.
3. **Non-Science requirement: 12 credits**
   See 'Non-Science Requirement' subsection for further explanation.
4. **Upper level requirements:** At least 42 credits at the 3000 or higher level, including at least 12 major credits at the 4000 level.
5. **Additional elective credits, as required for a total of 120 credits**

Degree Combinations

Honours B.Sc. Double Major and Major/Minor Programs

Students can combine Physics or Astronomy with most other programs in the Faculty of Science (FSc) or the Faculty of Liberal Arts and Professional Studies (LA&PS). The set of courses required for Physics or Astronomy as part of a double-major program are well-defined, and identical for each such program. Particularly popular combinations are with Computer Science, Chemistry, or Applied Mathematics.

Honours Program- Physics Stream Double Major or Major/Minor

The Physics-stream requirements shown in Honours Program- Physics Stream or Astronomy Stream.

Honours Program- Astronomy Stream Double Major or Major/Minor

The Astronomy-stream requirements shown in Honours Program- Physics Stream or Astronomy Stream.

Some Possible Honours B.Sc. Double Major Combinations

Physics and Astronomy Major (Physics Stream or Astronomy Stream) and:
Biology
Chemistry
Computer Science
Earth and Atmospheric Science
Applied Mathematics
Mathematics
Science and Technology Studies
Statistics

Some Possible Honours B.Sc. Major/Minor Combinations

Physics and Astronomy Major (Physics Stream or Astronomy Stream) and:

Faculty of Science: Biology, Chemistry, Computer Science, Earth and Atmospheric Science, Applied Mathematics, Mathematics, Mathematics for Commerce, Mathematics for Education, Science and Technology Studies, Statistics, Geography

Faculty of Health: Health Science, Health Studies, Kinesiology, Psychology

Faculty of Liberal Arts and Professional Studies: Various - consult Department for further information.

School of Media, Performance, and Design: Various - consult Department for further information.

Faculty of Environmental and Urban Change: Environmental Studies

Physics and Astronomy Minor Requirements

One can also combine a Minor in Physics or Astronomy with a Major from another discipline in FSc in a BSc (Hons.) program or within BA (Hons.), BES (Hons.) or BFA (Hons.) programs offered by other Faculties. The minimum requirements are listed together with cognate requirements:

Physics Minor Requirements

The Program Core as defined above (27 credits including six credits at the 3000 level).
SC/PHYS 2213 3.00; SC/PHYS 3220 3.00;
three credits from SC/PHYS 3010 3.00, SC/PHYS 3020 3.00, SC/PHYS 3090 3.00
for an overall total of 36 credits from PHYS courses.
In addition: SC/MATH 1013 3.0; SC/MATH 1014 3.0; SC/MATH 1025 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0

Astronomy Minor Requirements

The Program Core as defined above (27 credits including six credits at the 3000 level).
SC/PHYS 1070 3.00; SC/PHYS 2070 3.00; SC/PHYS 2213 3.00;
three credits from SC/PHYS 3070 3.00 or SC/PHYS 4270 3.00;
for an overall total of at least 39 credits from PHYS courses.
In addition: SC/MATH 1013 3.0; SC/MATH 1014 3.0; SC/MATH 1025 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0

Recommended Schedule

90 Credits B.Sc. Bachelor - Physics Stream

Required Courses and Suggested Rate of Progress

	Fall	**Winter**
Year 1	PHYS 1011 3.0 *Physics 1* CHEM 1000 3.0 *Chemical Structure* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra* Non-Science Requirement 3.0	PHYS 1012 3.0 *Physics 2* EECS 1541 3.0 *Introduction to Computing* CHEM 1001 3.0 *Chemical Dynamics* MATH 1014 3.0 *Applied Calculus II* Non-Science Requirement 3.0
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* MATH 2015 3.0 *Applied Multivariate & Vector Calculus*	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations*
	PHYS 2213 3.0 *Experimental Physics with Data Analysis* Non-Science Requirement 3.0 Additional Elective Credits 3.0	
Year 3	PHYS 3090 3.0 *Methods in Theo. Physics* PHYS 4061 3.0 *Exp. Tech. in Laser Physics*	PHYS 3030 3.0 *Statistical & Thermal Physics* PHYS 3220 3.0 *Exp. in Modern Physics*
	3.0 CREDITS FROM: PHYS 3010 3.0 *Classical Mechanics* PHYS 3020 3.0 *Electromagnetics I*	
	PHYS 3040 6.0 *Modern Physics* Non-Science Requirement 3.0 Additional Elective Credits 6.0	

90 Credits B.Sc. Bachelor - Astronomy and Astrophysics Stream

Required Courses and Suggested Rate of Progress

	Fall	Winter
Year 1	PHYS 1011 3.0 *Physics 1* PHYS 1070 3.0 *Fundamentals of Astronomy* CHEM 1000 3.0 *Chemical Structure* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra*	PHYS 1012 3.0 *Physics 2* EECS 1541 3.0 *Introduction to Computing* CHEM 1001 3.0 *Chemical Dynamics* MATH 1014 3.0 *Applied Calculus II* Non-Science Requirement 3.0
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* PHYS 2070 3.0 *Galaxies & the Universe* MATH 2015 3.0 *Applied Multivariate & Vector Calculus*	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations*
	PHYS 2213 3.0 *Experimental Physics with Data Analysis* Non-Science Requirement 3.0	
Year 3		PHYS 3030 3.0 *Statistical & Thermal Physics* PHYS 3220 3.0 *Exp. in Modern Physics*
	3.0 CREDITS FROM: PHYS 3010 3.0 *Classical Mechanics* PHYS 3020 3.0 *Electromagnetics I* PHYS 3090 3.0 *Methods in Theo. Physics*	
	PHYS 3040 6.0 *Modern Physics* PHYS 4270 3.0 ~~Astronomical Techniques~~ (FW 25/26)[1] Non-Science Requirement 6.0	

[1] Students requiring this course to graduate can take ESSE 4230 3.0 *Remote Sensing of the Atmosphere* with permission of the UPD.

120 Credits B.Sc. Honours - Physics Stream

Required Courses and Suggested Rate of Progress

	Fall	**Winter**
Year 1	PHYS 1011 3.0 *Physics 1* CHEM 1000 3.0 *Chemical Structure* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra* Non-Science Requirement 3.0	PHYS 1012 3.0 *Physics 2* EECS 1541 3.0 *Introduction to Computing* CHEM 1001 3.0 *Chemical Dynamics* MATH 1014 3.0 *Applied Calculus II* Non-Science Requirement 3.0
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* MATH 2015 3.0 *Applied Multivariate & Vector Calculus* Non-Science Requirement 3.0	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations* Non-Science Requirement 3.0
	PHYS 2213 3.0 *Experimental Physics with Data Analysis*	
Year 3		PHYS 3030 3.0 *Statistical & Thermal Physics* PHYS 3220 3.0 *Exp. in Modern Physics*
	3.0 CREDITS FROM: PHYS 3010 3.0 *Classical Mechanics* PHYS 3020 3.0 *Electromagnetics I* PHYS 3090 3.0 *Methods in Theo. Physics*	
	PHYS 3040 6.0 *Modern Physics* 9.0 Additional Elective Credits	
Year 4	PHYS 4061 3.0 *Exp. Tech. in Laser Phyiscs*	
	9.0 PHYS 4000-Level credits such as: PHYS 4010 3.0 *Quantum Mechanics* PHYS 4030 3.0 *Adv. Comput. Methods* PHYS 4011 3.0 Atomic & Mol. Physics PHYS 4020 3.0 Electromagnetics II PHYS 4040 3.0 Elementary Particle Physics PHYS 4050 3.0 Solid State Physics PHYS 4062 3.0 Atom Trapping PHYS 4210 3.0 Adv. Experimental Physics I	
	15.0 3000- or 4000- Level Credits 3.0 Additional Elective Credits	

120 Credits B.Sc. Honours - Astronomy and Astrophysics Stream

Required Courses and Suggested Rate of Progress

	Fall	Winter
Year 1	PHYS 1011 3.0 *Physics 1* PHYS 1070 3.0 *Fundamentals of Astronomy* CHEM 1000 3.0 *Chemical Structure* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra*	PHYS 1012 3.0 *Physics 2* EECS 1541 3.0 *Introduction to Computing* CHEM 1001 3.0 *Chemical Dynamics* MATH 1014 3.0 *Applied Calculus II* Non-Science Requirement 3.0
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* PHYS 2070 3.0 *Galaxies & the Universe* MATH 2015 3.0 *Applied Multivariate & Vector Calculus*	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations*
	PHYS 2213 3.0 *Experimental Physics with Data Analysis* Non-Science Requirement 3.0	
Year 3		PHYS 3030 3.0 *Statistical & Thermal Physics* PHYS 3220 3.0 *Exp. in Modern Physics*
	3.0 CREDITS FROM: PHYS 3010 3.0 *Classical Mechanics* PHYS 3020 3.0 *Electromagnetics I* PHYS 3090 3.0 *Methods in Theo. Physics*	
	PHYS 3040 6.0 *Modern Physics* PHYS 4270 3.0 ~~Astronomical Techniques~~ (FW 25/26)[1] 3.0 Non-Science Requirement 3.0 PHYS, ESSE, MATH at the 3000 or 4000 level (consider PHYS 3070 3.0) 6.0 Additional Elective Credits	
Year 4	9.0 credits of PHYS 4000 level, strongly recommend PHYS 4070 3.0 and PHYS 4170 3.0 3.0 Non-Science Requirement 6.0 Additional Elective Credits	

[1] Students requiring this course to graduate can take ESSE 4230 3.0 *Remote Sensing of the Atmosphere* with permission of the UPD.

120 Credits B.Sc. Specialized Honours - Physics Stream

Required Courses and Suggested Rate of Progress

	Fall	Winter
Year 1	PHYS 1011 3.0 *Physics 1* CHEM 1000 3.0 *Chemical Structure* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra* Non-Science Requirement 3.0	PHYS 1012 3.0 *Physics 2* EECS 1541 3.0 *Introduction to Computing* CHEM 1001 3.0 *Chemical Dynamics* MATH 1014 3.0 *Applied Calculus II* Non-Science Requirement 3.0
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* MATH 2015 3.0 *Applied Multivariate & Vector Calculus* Non-Science Requirement 3.0	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations* Non-Science Requirement 3.0
	PHYS 2213 3.0 *Experimental Physics with Data Analysis*	
Year 3	PHYS 3010 3.0 *Classical Mechanics* PHYS 3020 3.0 *Electromagnetics I* PHYS 3090 3.0 *Methods in Theo. Physics* Additional Elective Credits 3.0	PHYS 3030 3.0 *Statistical & Thermal Physics* PHYS 4020 3.0 *Electromagnetics II* PHYS 3220 3.0 *Exp. in Modern Physics* Additional Elective Credits 3.0
	PHYS 3040 6.0 *Modern Physics*	
Year 4	PHYS 4010 3.0 *Quantum Mechanics* PHYS 4061 3.0 *Exp. Tech. in Laser Physics*	PHYS 4062 3.0 Atom Trapping PHYS 4310 3.0 Physics Project PHYS 4040 3.0 Elementary Part. Phys.
	3.0 PHYS 4000-Level Credits (for PHYS 4011 / PHYS 4050) 3.0 3000- or 4000-Level Credits 12.0 Additional Elective Credits	

120 Credits B.Sc. Specialized Honours - Applied Physics Stream

Required Courses and Suggested Rate of Progress

	Fall	Winter
Year 1	PHYS 1011 3.0 *Physics 1* CHEM 1000 3.0 *Chemical Structure* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra* Non-Science Requirement 3.0	PHYS 1012 3.0 *Physics 2* EECS 1541 3.0 *Introduction to Computing* CHEM 1001 3.0 *Chemical Dynamics* MATH 1014 3.0 *Applied Calculus II* Non-Science Requirement 3.0
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* MATH 2015 3.0 *Applied Multivariate & Vector Calculus* Non-Science Requirement 3.0	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations* Non-Science Requirement 3.0
	PHYS 2213 3.0 *Experimental Physics with Data Analysis*	
Year 3	PHYS 3010 3.0 *Classical Mechanics* PHYS 3020 3.0 *Electromagnetics I* PHYS 3050 3.0 *Replace with EECS 2200* PHYS 3090 3.0 *Methods in Theo. Physics*	PHYS 3150 3.0 *Replace with EECS 2210* PHYS 4020 3.0 *Electromagnetics II* PHYS 3220 3.0 *Exp. in Modern Physics* 3.0 Additional Elective credits
	PHYS 3040 6.0 *Modern Physics*	
Year 4	PHYS 4010 3.0 *Quantum Mechanics* PHYS 4050 3.0 *Replace with PHYS 4XXX* PHYS 4061 3.0 *Exp. Tech. in Laser Physics*	PHYS 3030 3.0 *Stat. and Thermal Physics* PHYS 4062 3.0 *Atom Trapping*
	9.0 CREDITS FROM: PHYS 3250 3.0 *Intro. to Space Comm.* — PHYS 3280 3.0 *Phys. of the Space Env.* PHYS 4120 3.0 *Gas & Fluid Dynamics* MATH 3241 3.0 *Numerical Methods I* PHYS 4310 3.0 *Physics or Astronomy Project*	
	6.0 3000- or 4000- Level Credits	

120 Credits B.Sc. Specialized Honours - Astronomy and Astrophysics Stream

Required Courses and Suggested Rate of Progress

	Fall	**Winter**
Year 1	PHYS 1011 3.0 *Physics 1* PHYS 1070 3.0 *Fundamentals of Astronomy* CHEM 1000 3.0 *Chemical Structure* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra*	PHYS 1012 3.0 *Physics 2* EECS 1541 3.0 *Introduction to Computing* CHEM 1001 3.0 *Chemical Dynamics* MATH 1014 3.0 *Applied Calculus II* Non-Science Requirement 3.0
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* PHYS 2070 3.0 *Galaxies & the Universe* MATH 2015 3.0 *Applied Multivariate & Vector Calculus*	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations*
	PHYS 2213 3.0 *Experimental Physics with Data Analysis* Non-Science Requirement 3.0	
Year 3	PHYS 3010 3.0 *Classical Mechanics* PHYS 3020 3.0 *Electromagnetics I* PHYS 3090 3.0 *Methods in Theo. Physics*	PHYS 3030 3.0 *Statistical & Thermal Physics* PHYS 4020 3.0 *Electromagnetics II* PHYS 3220 3.0 *Exp. in Modern Physics*
	PICK EITHER GROUP OF TWO COURSES: PHYS 4070 3.0 ~~Stars and Nebulae~~ (FW 25/26) PHYS 4270 3.0 ~~Astronomical Techniques~~ (FW 25/26)[1] OR: PHYS 4170 3.0 *Cosmology* (FW 24/25, not FW25/26) 3.0 Additional Elective Credits	

<table>
<tr><th></th><th>Fall</th><th>Winter</th></tr>
<tr><td rowspan="5">Year 4</td><td>PHYS 3070 3.0 Planets & Planetary Sys.
PHYS 4010 3.0 Quantum Mechanics
PHYS 4061 3.0 Exp. Tech. in Laser Physics</td><td></td></tr>
<tr><td colspan="2">PICK EITHER GROUP OF TWO COURSES:
PHYS 4070 3.0 ~~Stars and Nebulae~~ (FW 25/26)
PHYS 4270 3.0 ~~Astronomical Techniques~~ (FW 25/26)[1]
OR:
PHYS 4170 3.0 Cosmology (FW 24/25, not FW25/26)
3.0 Additional Elective Credits</td></tr>
<tr><td colspan="2">3.0 CREDITS FROM:
PHYS 4120 3.0 Gas & Fluid Dynamics
PHYS 4011 3.0 Atomic & Mol. Phys.
PHYS 4040 3.0 Elementary Particle Phys.
PHYS 4050 3.0 Solid State Phys.</td></tr>
<tr><td colspan="2">3.0 CREDITS FROM:
PHYS 4060 3.0 Time Series & Spec. Anlys.
PHYS 3280 3.0 Phys. of the Space Env.
PHYS 4110 3.0 Dyn. of Space Vehicles
PHYS 4330 3.0 Radio Sci. and Techniques for Space Exploration
ESSE 4630 3.0 Image Proc. for Remote Sensing & Photogrammetry</td></tr>
<tr><td colspan="2">3.0 Credits at the 3000- or 4000- level</td></tr>
<tr><td colspan="2">6.0 Non-Science Requirement</td></tr>
</table>

[1] Students requiring this course to graduate can take ESSE 4230 3.0 *Remote Sensing of the Atmosphere* with permission of the UPD.

120 Credits B.Sc. Specialized Honours - Space Science: Physics & Astronomy Stream

Required Courses and Suggested Rate of Progress

	Fall	**Winter**
Year 1	PHYS 1011 3.0 *Physics 1* ESSE 1011 3.0 *Intro. to Atmos. Science* MATH 1013 3.0 *Applied Calculus I* MATH 1025 3.0 *Applied Linear Algebra* 3.0 CREDITS FROM: CHEM 1000 3.0 *Chemical Structure* CHEM 1001 3.0 *Chemical Dynamics*	PHYS 1012 3.0 *Physics 2* ESSE 1012 3.0 *The Earth Environment* MATH 1014 3.0 *Applied Calculus II* EECS 1541 3.0 *Introduction to Computing* PHYS 1070 3.0 *Fundamentals of Astronomy*
Year 2	PHYS 2020 3.0 *Electricity & Magnetism* PHYS 2040 3.0 *Relativity & Modern Physics* MATH 2015 3.0 *Applied Multivariate & Vector Calculus* ESSE 2030 3.0 *Geophysics & Space Science* EECS 2501 1.0 Fortran & Scien. Computing	PHYS 2010 3.0 *Classical Mechanics* PHYS 2030 3.0 *Computational Methods* PHYS 2060 3.0 *Optics and Spectra* MATH 2271 3.0 *Differential Equations* ESSE 2470 3.0 Intro. to Continuum Mechanics
	PHYS 2213 3.0 *Experimental Physics with Data Analysis*	
Year 3	PHYS 3020 3.0 *Electromagnetics I* PHYS 3050 3.0 *Electronics I* PHYS 3070 3.0 *Planets & Planetary Sys.* PHYS 3250 3.0 *Intro. to Space Comm.*	PHYS 3150 3.0 *Electronics II* 3.0 CREDITS FROM PHYS 3280 3.0 *Phys. of the Space Env.* PHYS 4330 3.0 *Radio Science & Technqiues for Space Exploration*
	PHYS 3040 6.0 *Modern Physics*	
	3.0 CREDITS FROM: PHYS 3010 3.0 *Classical Mechanics* PHYS 3030 3.0 *Stat. & Thermal Phys.* PHYS 3080 3.0 *Atmos. Radiation & Thermo.* PHYS 3220 3.0 *Exp. in Modern Phys.* PHYS 3090 3.0 *Methods in Theo. Phys.*	
	3.0 Non-Science Credits	

	Fall	Winter
Year 4		PHYS 4110 3.0 *Dynamics of Space Vehicles* 3.0 CREDITS FROM: PHYS 3280 3.0 *Phys. of the Space Env.* PHYS 4330 3.0 *Radio Science & Techniques for Space Exploration*
	PHYS 4350 6.0 *Space Hardware*	
	AT LEAST 8.0 CREDITS FROM: PHYS 4010 3.0 *Quantum Mechanics* PHYS 4120 3.0 *Gas & Fluid Dynamics* ESSE 3670 3.0 *Global Nav. & Sat. Sys.* ESSE 4360 3.0 *Payload Design*	PHYS 4020 3.0 Electromagnetics II PHYS 4040 3.0 *Elem. Particle Phys.* PHYS 4050 3.0 *Solid State Phys.* PHYS 4070 3.0 *Stars & Nebulae* PHYS 4410 3.0 *Space Geodynamics* PHYS 4361 3.0 *Space Mission Design* PHYS 4270 3.0 *Astronomical Techniques* PHYS 4310 3.0 *Physics or Astronomy Project*
	9.0 Non-Science Credits	

Example 5-year Schedules

You may choose to take a course load of less than 30 credits per year and complete a 120-credit degree in five years instead of four (or a 90-credit degree in four years instead of three). Below we present five-year degree schedules. Each has an average of 12 credits per term, and no summer enrollment is required. If you are considering a course load of less than 30 credits a year, talk to the Physics Office to make sure it's right for you.

Sp. Hons. Physics	Sp. Hons. Applied Physics	Sp. Hons. Astronomy (cycle 1)	Sp. Hons. Astronomy (cycle 2)
Year One	**Year One**	**Year One**	**Year One**
PHYS 1011 F	PHYS 1011 F	PHYS 1011 F	PHYS 1011 F
PHYS 1012 W	PHYS 1012 W	PHYS 1012 W	PHYS 1012 W
MATH 1013 F	MATH 1013 F	MATH 1013 F	MATH 1013 F
MATH 1014 W	MATH 1014 W	MATH 1014 W	MATH 1014 W
MATH 1025 F	MATH 1025 F	MATH 1025 F	MATH 1025 F
EECS 1541 W	EECS 1541 W	EECS 1541 W	EECS 1541 W
CHEM 1000 F	CHEM 1000 F	CHEM 1000 F	CHEM 1000 F
Non-Science Elective W	Non-Science Elective W	PHYS 1070 W	PHYS 1070 W
Year Two	**Year Two**	**Year Two**	**Year Two**
PHYS 2020 F	PHYS 2020 F	PHYS 2020 F	PHYS 2020 F
PHYS 2213 Y	PHYS 2213 Y	PHYS 2213 Y	PHYS 2213 Y
MATH 2015 F	MATH 2015 F	MATH 2015 F	MATH 2015 F
MATH 2271 W	MATH 2271 W	MATH 2271 W	MATH 2271 W
PHYS 2010 W	PHYS 2010 W	PHYS 2010 W	PHYS 2010 W
PHYS 2060 W	PHYS 2060 W	PHYS 2060 W	PHYS 2060 W
PHYS 2040 F	PHYS 2040 F	PHYS 2040 F	PHYS 2040 F
Non-Science Elective F or W	Non-Science Elective F or W	Non-Science Elective F or W or PHYS 2070 F	Non-Science Elective F or W or PHYS 2070 F
Year Three	**Year Three**	**Year Three**	**Year Three**
PHYS 3020 F	PHYS 3020 F	PHYS 3020 F	PHYS 3020 F
PHYS 3040 Y	PHYS 3040 Y	PHYS 3040 Y	PHYS 3040 Y
PHYS 3090 F	PHYS 3090 F	PHYS 3090 F	PHYS 3090 F
PHYS 2030 W	PHYS 2030 W	PHYS 2030 W	PHYS 2030 W
PHYS 4020 W	PHYS 4020 W	PHYS 4020 W	PHYS 4020 W
Non-Science Elective W or CHEM 1001 W	PHYS 3220 F	Non-Science Elective W, or PHYS 4170 W	Non-Science Elective W
	CHEM 1001 W	Non-Science Elective F, or PHYS 2070 F	PHYS 2070 F or PHYS 3070 F
Year Four	**Year Four**	**Year Four**	**Year Four**
PHYS 3030 W	PHYS 3030 W	PHYS 3030 W	PHYS 3030 W
PHYS 3220 F	PHYS 3050 F	PHYS 3220 F	PHYS 3220 F
PHYS 4010 F	PHYS 4010 F	PHYS 4010 F	PHYS 4010 F
PHYS 3010 F	PHYS 3010 F	PHYS 3010 F	PHYS 3010 F
PHYS 4210 W	PHYS 4210 W	PHYS 4070 W	PHYS 4170 W
PHYS 4011/40/50W	PHYS 4050 W	PHYS 3070 F	PHYS 4270 Y
Non-Science Elective	Non-Science Elective	CHEM 1001 F	CHEM 1001 W
Additional Elective	PHYS 3150 W	Non-Science Elective	Non-Science Elective
Year Five	**Year Five**	**Year Five**	**Year Five**
PHYS 4061 F	PHYS 4061 F	PHYS 4061 F	PHYS 4061 F
PHYS 4211/4062 W	PHYS 4211/4062W	PHYS 4270 Y	PHYS 4070 W

PHYS 4011/40/50 W	Non-Science Elective	PHYS 4170 W or Non-Science Elective W	PHYS3070 F or Non-Science Elective F
PHYS 3xxx/4xxx F	PHYS 3xxx/4xxx F	Science Electives	Science Electives
Additional Electives	Additional Electives	Non-Science Electives	Non-Science Electives

Interested in Theoretical Physics?

Below is an example of how to tailor the Honours Physics degree program to give yourself a solid background suitable for applying to graduate school in Theoretical Physics. Note that graduate programs typically require a B average or better in 3000- and 4000-level courses.

First and Second Year:
Same as Specialized Honours Physics, including PHYS 2030 3.0 W - Computational Physics.

Third Year:
PHYS 3020 3.0 F - Electromagnetics I
PHYS 3040 6.0 FW - Modern Physics
PHYS 3090 3.0 F - Mathematical Methods
PHYS 3220 3.0 F - Modern Physics Experiments
PHYS 3030 3.0 F - Thermal and Statistical Physics
PHYS 4020 3.0 W - Electromagnetics II
+ 9 elective credits, including 3 or 6 credits of PHYS or MATH courses from the list below

Fourth Year:
PHYS 4010 3.0 F - Quantum Mechanics (has 3040 prerequisite)
PHYS 4040 3.0 W - Particle Physics (has 4010 prerequisite)
PHYS 4061 3.0 F - Experimental Techniques in Laser Physics
+ 21 elective credits, including 15 credits of PHYS or MATH courses from the list below:

Suggested PHYS Elective Courses to choose from:
PHYS 3010 3.0 W - Classical Mechanics
PHYS 3080 3.0 F - Atmospheric Radiation & Thermodynamics (could take in 3rd year)
PHYS 3280 3.0 W - Physics of the Space Environment (Plasma physics; could take in 3rd year)
PHYS 4011 3.0 W - Atomic & Molecular Physics (has 4010 prerequisite)
PHYS 4050 3.0 W - Solid State Physics (has 3030 and 4010 prerequisite)
PHYS 4070 3.0 W - Stars & Nebulae (3030 prereq, 3040 coreq; offered alternate years)
PHYS 4120 3.0 F - Gas and Fluid Dynamics (could take in 3rd year)
PHYS 4170 3.0 W - Cosmology (3090 prerequisite; offered alternate years)
PHYS 4310 3.0 FWS - Research Project (ask faculty members if they have a suitable project in theoretical or computational physics or astrophysics)

Suggested MATH Elective Courses to choose from:
MATH 2001 3.0 F (TR16:00) - Real Analysis I (permission prerequisite)
MATH 2022 3.0 W (TR14:30) - Linear Algebra II (MATH 1025+permission prerequisite)
MATH 2030 3.0 FW (MWF8:30) - Elementary Probability (MATH 1014 prerequisite)
MATH 3001 3.0 W (TR17:30) - Real Analysis II (MATH 2001 prerequisite)
MATH 3010 3.0 F (MWF10:30) - Vector Integral Calculus (MATH 2015+permission prereq.)
MATH 3241 3.0 F (TR9:30/13:00) - Numerical Methods I (MATH 1014+1025+EECS 1541 prereq.)
MATH 3242 3.0 W (MWF9:30/10:30) - Numerical Methods II (MATH 3241 prerequisite)
MATH 3271 3.0 F (MWF14:30) - Partial Differential Equations (MATH 2015 + 2271 prereqs)
MATH 3410 3.0 W (TR13:00) - Complex Variables (MATH 2015 prerequisite)
MATH 4271 3.0 F (TR11:30) - Applied Dynamical Systems (MATH 1025, 2271 prerequisites)

Workload

Physics & Astronomy offers a three year (90 credit) or four year (120 credit) undergraduate degree.

A normal workload constitutes 5 full courses (30 credits) per year. A single credit is normally equated with one hour of classroom teaching per week over 12 weeks, or 3 laboratory hours per week for 12 weeks. A full course counts as 6 credits and is typically three lecture hours per week for 24 weeks. Lectures are scheduled typically as 1-hour (50 minute) classes on Mondays, Wednesdays, and Fridays, or as 1.5-hour (80 minute) classes on Tuesdays and Thursdays. Traditionally, Departments offer few courses over the summer. Those courses offered tend to cater to students in their early years of study.

There has been some change in recent years as to the meaning of full-time attendance at a University. The regrettable increases in tuition fees have resulted in students engaging in part-time work while studying. For Physics & Astronomy students, this represents a daunting task given how demanding the program offerings are. Students who are forced into this situation should be prepared to extend their studies over an additional year and should consult with members of the Department who act as advisors in order to structure their course load appropriately (to satisfy prerequisites and corequisites for courses.)

See elsewhere in this handbook for example five-year degree schedules.

Useful Information

Grading System

To help understand the grading system and calculation of averages, grades and grade-point equivalencies are listed below. The percentage equivalencies used within the Faculty of Science and Engineering are also listed.

Letter Grade	Grade-Point Value	Grade-Point Average Range	Percentage Range
A+	9	8.5+	90 - 100
A	8	7.5 – 8.4	80 - 89
B+	7	6.5 – 7.4	75 – 79
B	6	5.5 – 6.4	70 – 74
C+	5	4.5 – 5.4	65 – 69
C	4	3.5 – 4.4	60 – 64
D+	3	2.5 – 3.4	55 – 59
D	2	1.5 – 2.4	50 – 54
E	1	0.1 – 1.4	40 – 49
F	0	0	0 - 39

Repeating a course: Check the Registrar's Office website for information: http://calendars.registrar.yorku.ca/

Standards

To remain in any Honours or Specialized Honours Program, students must achieve a minimum credit-weighted grade point average each year. This average increases according to credits completed as outlined below:

Honours Progression – Overall GPA Requirements

Fewer than 24 credits	4.0
Fewer than 54 credits	4.25
Fewer than 84 credits	4.8
At least 84 credits	5.0

To graduate in an Honours program requires successful completion of all Faculty requirements and departmental required courses, and a minimum cumulative credit-weighted grade point average of 5.0 (C+) over all courses completed.

Opportunities for Research

There are a variety of opportunities for undergraduate students in Physics, Astronomy, or Biomedical Physics to gain direct experience in research.

NSERC: Natural Sciences & Engineering Research Council of Canada

Annually, NSERC offers University Student Research Awards to foster involvement of superior undergraduates in scientific research. First, Faculty develop research projects for which they would like student assistance. Students who apply for a Student Research Award identify those projects of particular interest to them. After receiving an award, a student will have the opportunity to work for the duration of the summer term (May through August) on one of the selected projects. Students are paid a salary which is a combination of the award and funding from the supervisor. Information about Student Research Awards becomes available in each Department in January each year.

Work Study Program

York University manages a program which offers a subsidy to help faculty pay for research assistance. It is called the Work Study Program. For example, this program assists astronomy students who are interested in becoming involved in research activities undertaken with the York Observatories. There is no formal procedure for identifying research opportunities. Some projects are advertised online, but there may be many that are not. Students who would like to get involved in research are encouraged to talk to faculty with overlapping interests about possible opportunities for work. Many professors have projects for which they need assistance and, if an appropriate student can be found, will take the necessary steps to apply for funding through York's Work Study Program. Applications for Fall/Winter are due in July, and for Summer in March. For further information on the Work Study program, visit https://sfs.yorku.ca/work-study-programs.

Research at York (RAY) Program

The Research at York (RAY) Program was created to enhance both the research culture of the University and the Undergraduate student academic experience. Through the RAY Program, eligible Undergraduate students have the opportunity to participate in research projects with Faculty members and/or fellow student while receiving compensation at a competitive rate. Visit https://sfs.yorku.ca/work-study-programs for further information.

Talk to your Professors

Many faculty are undertaking research that could benefit from student involvement, but often don't advertise this fact. As is the case for the Work Study program, a simple expression of interest in research may actually lead to an opportunity for participation. Talk to your professors and see what they have to say. Some professors may be limited financially, but others may have the capacity to pay you. Volunteering might also be fruitful, although professors do have limits to the amount of time they can spend supervising.

Professional Certification

The Canadian Association of Physicists (CAP) has instituted a professional certification process (P.Phys.) that is intended to help to raise the perceived status of a physics degree (versus an engineering degree). Full details about certification are available at www.cap.ca. At present, the CAP has close to 300 certified members who use the title P.Phys. To get a P.Phys., you have to:

- be of good character meet the education standards established by the CAP (meaning you need an Honours B.Sc. in a physics or closely related discipline (graduate studies count)
- have 3 years of physics-related work experience after graduation
- be a CAP member
- be 18 or older
- pass the Professional Practice Examination (PPE)

Annually, the Department of Physics and Astronomy offers third and fourth-year undergraduate students an opportunity to write the Professional Practice Examination. A sample is on-line at www.cap.ca. Except for CAP membership, you don't have to satisfy the other requirements for certification to write the exam. The PPE does not test technical knowledge but, rather, focuses on ability to communicate as well as to understand, and show an appreciation for, ethical issues. Exams are conveyed to the CAP's Certification Committee, which will keep results on file. In this way, you will be able to apply for certification as soon as you meet the experience criteria.

Undergraduate Laboratory Information

It is extremely important and required that all students who take part in science laboratories become safety conscious. Specific safety instructions and rules will appear in individual lab manuals. As certain special precautions may be necessary for particular experiments, it is essential that students pay special attention to lab lectures so that they can observe the instructions given by their demonstrator and/or laboratory supervisor/course director.

Clubs and Associations

Please see the following websites to learn about our clubs:
Biomedical Physics Club: https://www.facebook.com/profile.php?id=100057607472574
Astronomy Club: https://astroatyork.wixsite.com/acyu
Biological Society: https://www.facebook.com/yorkubio/timeline
Physics Society: https://physics-society.info.yorku.ca/
Pre-Medical Society: https://www.facebook.com/premedicalassociationatyork

Exchange Opportunities

York University has established exchange agreements with many universities around the world. Through such agreements, students gain opportunities to add an international component to their York degree. To participate, students apply during their second year to spend one or two terms of their third year at one of York's partner universities. Exchange opportunities exist in Asia, Australia, Europe, and South America. Especially, students should consider looking into the Baden-Württemberg Program, which allows students to study at the famous University of Heidelberg in Germany. Other partners which have programs which overlap ours include:

- Dublin City University (Ireland)
- Flinders University (Australia)
- University of Western Sydney (Australia)
- Monash University (Australia)
- Keele University (England)
- University of London – Royal Holloway (England)
- University of York (England)
- Helsinki University of Technology (Finland)
- University of Helsinki (Finland)
- Copenhagen University (Denmark)
- Stockholm University (Sweden)
- Swansea University (Wales)
- Uppsala University (Sweden)

The list is continually growing, so students are encouraged to contact York International at (416) 736-5177 or: https://yorkinternational.yorku.ca/ for the latest options, as well as information session dates and application forms.

Awards

Various awards are administered by the Department of Physics and Astronomy. Recipients are rewarded financially and with a record on their transcript

The Embleton Award

Awarded to one female student in the Lassonde School of Engineering and 1 female student in Physics, Biomedical Physics, Astronomy, and/or Chemistry (excluding Biochemistry) who has completed 84 credits towards an Honours BSc or BASc and has earned a GPA of 6.0 (B) or better on the most recently earned 30 credits. To be eligible, applicants must be Canadian citizens, permanent residents or protected persons or have Protected Person status, be Ontario residents and demonstrate financial need.

The Denise Hobbins Prize

Awarded to the student who obtains the highest average mark in the first-year physics courses PHYS 1011 3.0 and PHYS 1012 3.0 when taken in the same academic year. The prize commemorates Denise Hobbins, who was a physics undergraduate at York and went to Cornell University for her PhD studies in Physics. She was killed in a hit-and-run car accident shortly before defending her thesis. The prize has been set up by her family and friends.

The W.J. Megaw Prize in Experimental Physics

Awarded for outstanding achievement in PHYS 3220 3.0 to commemorate the late Jim Megaw, who was Chairman of the Department of Physics and Astronomy for ten years.

The Emeritus Professors' Award

Awarded to a student (Canadian citizen or permanent resident and Ontario resident) entering the final year of study for an Honours degree with the department, who has achieved an excellent academic record over their entire university career while maintaining a course load of at least 24 credits/year and who has demonstrated financial need.

The Charlene Anne Heisler Prize

Awarded to commemorate a former postdoctoral researcher in the Department. She was about to start her PhD in astronomy when she was diagnosed with cystic fibrosis that was likely to prove fatal in a few years. Nevertheless, her enthusiasm for astronomy enabled her to complete her PhD and eight years of postdoctoral research. The prize is awarded to a student who has earned at least a B+ average in two or more science astronomy courses and who has demonstrated a commitment to the communication of science while at York University.

The Herschel Prize

Awarded for outstanding achievement in PHYS 1070 3.0 Astronomy to recognize Sir William Herschel, his sister Caroline, and his son John, each of whom has made their own outstanding contributions to astronomy.

The R.M. Hobson Prize

Awarded for outstanding achievement in PHYS 2010 3.0, PHYS 2020 3.0, PHYS 2040 3.0, and PHYS 2060 3.0 to commemorate the late Robert Hobson who was Chairman of the Department of Physics for ten years. The prize has been set up by family and friends.

The Gold Medal of The Royal Astronomical Society of Canada, Toronto Centre

Will be awarded, when warranted, to the top graduating Astronomy major with a cumulative GPA greater than or equal to 7.5 who has satisfied the requirements of a 120-credit Honours B.Sc. program in the Department of Physics and Astronomy.

The Julie Kim Memorial Award

Created by Justin Kim, who graduated from York University in 2017, in loving memory of his mother. The recipient will be a student majoring in Physics or Astronomy who has a minimum grade point average of 6.0 and who demonstrates financial need and a commitment to their peers and community.

The Iristel Undergraduate Scholarship

Awarded to two recipients enrolled in their 3rd or 4th year of an Honours or Specialized Honours program in the Department of Physics and Astronomy who have demonstrated academic excellence and proficiency in lab work related to physics. Applicants must submit a one-page statement outlining their interest in pursuing a career in experimental physics or bio photonics. Each recipient will receive a $5000 scholarship and will be granted the opportunity to interview for an internship with Iristel, Inc.

Allan D. & Josie A. Stauffer Scholarship in Theoretical Physics

Awarded to a student pursuing a 120-credit degree program in Physics and Astronomy and/or in Applied Mathematics, and achieving highest combined average in a single school year for the following two courses: PHYS 3090 Methods in Theoretical Physics and PHYS 3040 Modern Physics (or equivalent if these courses are revised). Should multiple students achieve the same grade then the Scholarship will be granted to those who have the highest third year GPA first, then granted to those who have the highest cumulative GPA. The late Professor Emeritus Allan D. Stauffer conducted research in the Faculty of Science for many years focusing on atomic and molecular processes, electron and positron scattering, and plasma physics. He collaborated with graduate students and international co-workers, and maintained close contact with various experimental groups and often published joint papers with these groups where theory and experiment were directly compared. He was the former President of the Association of Retired Faculty & Librarians of YU. Mrs. Josie A. Stauffer has a BSc degree in Computer Science and a MSc degree in Physics from the Faculty of Science at York University. She is also a former employee of York University.

More information about York University, Student Financial Services Awards and Bursaries can be found at this website: https://sfs.yorku.ca/scholarships/award-search.

Support

Computing and Passport York

York offers a wide array of computing resources and services for students. The website https://uit.yorku.ca/ provides a guide to finding and using services that are available to all York students. Additional services and resources are also frequently provided within specific faculties or programs passport York is York's primary method of online authentication. You must sign up for your Passport York username and password so that you can log into York's online services for students. Passport York determines which services you are able to access. If you are a new student and have not signed up for Passport York, the first time you go to an application that requires the Passport York login, click on any button that says "New Student Sign Up!". The next screen will ask you to login with your student number and date of birth. Follow the steps as they are listed. You will be asked to give yourself a Passport York username and password. Don't forget your password.

Bethune Writing Centre

The Bethune Writing Centre offers free one-on-one or small group instruction in academic writing to students affiliated with Bethune College and to undergraduate students in the Faculty of Science, the Faculty of Environmental and Urban Change, and the Lassonde School of Engineering. The Bethune Writing Centre can help with the following (and much more):

- Writing a thesis statement
- How to construct an argument for a critical essay or report
- Planning and organizing the structure of an essay or scientific report
- Drafts and proofreading
- Active reading skills
- Effective note-taking and reviewing of notes, using Cornell note-taking style or mind mapping
- Effective exam revision strategies

Appointments must be made in advance. To book an appointment: Call the Bethune Academic Secretary, (416) 736-2100 ext. 22035, or drop by the Bethune College Master's Office (207 Bethune, closed 1-2 pm). Web address: http://bethune.yorku.ca/writing/.

Student Ombuds Service (SOS)

The Student Ombuds Services (SOS) is an academic student organization in Bethune College that provides peer advising services for York students. It plays a crucial role in the transitional process of students of any year. The SOS particularly caters to the special needs of first year students coming out of high school, who need guidance in getting to know the University from an academic point of view. Furthermore, the SOS holds seminars and presentations for the student body to give them insight and information about the careers they are thinking about. These information sessions prepare students for what they are going to face and what they need to work on. The SOS office is a great resource center in itself, housing information on many careers that students may choose after their Undergraduate degree. It allows for an easy going environment with peer facilitators so students may drop in with any questions or concerns. Information on prerequisites and the admission process is readily available for various professions. In addition, referrals to campus services and people such as tutors for courses are readily available. The SOS Office is located in 208 Bethune College. Office hours are Monday-Thursday from 9:30 am – 4:30 pm. The SOS Office can also be reached by calling 416-736-5164 or by e-mailing or at: https://bethune.yorku.ca/sos/.

Course Descriptions

Physics and Astronomy

PHYS 1011 3.0 - Physics I

Topics include linear, rotational and oscillatory motion; Newtonian mechanics; work and energy; gravitation; waves and sound. Differential calculus and vector algebra are used. This course covers topics in greater depth than SC/PHYS 1411 3.00 or SC/PHYS 1421 3.00. It should be taken by all those likely to enroll in 2000-level physics courses, and is a prequel to SC/PHYS1012 3.0.

Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 3.00; MHF4U Advanced Functions and MCV4U Calculus and Vectors, or 12U Advanced Functions and Introductory Calculus, or OAC Algebra and OAC Calculus, or SC/MATH 1505 6.00, or SC/MATH 1520 3.00.

Recommended Corequisites: SC/MATH 1013 3.00, or equivalent

Course Credit Exclusions: SC/PHYS 1010 6.00; SC/PHYS 1411 3.00, SC/PHYS 1420 6.00; SC/PHYS 1421 3.00; SC/PHYS 1800 3.00; SC/ISCI 1310 6.00; SC/ISCI 1301 3.00.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Three laboratory hours in alternate weeks.

PHYS 1012 3.0 - Physics 2

A sequel to PHYS1011 3.0. Topics include electrostatics; magnetostatics; electric current, DC circuits, and induction; electromagnetic waves, optics. Differential and integral calculus and vector algebra are used. This course covers fewer topics than SC/PHYS 1411 3.00 or SC/PHYS 1421 3.00, but covers them in greater depth. It should be taken by all those likely to enrol in 2000-level physics courses.

Prerequisites: SC/PHYS 1011 3.00, or a minimum grade of C in either SC/PHYS 1411 3.00 or SC/PHYS 1421 3.00; SC/MATH 1013 3.00 or equivalent.

Corequisites: SC/MATH 1014 3.00, or SC/MATH 1505 6.00, or equivalents.

Course Credit Exclusions: SC/PHYS 1410 6.00; SC/PHYS 1420 6.00; SC/PHYS 1412 3.00; SC/PHYS 1422 3.00; SC/PHYS 1801 3.00; SC/ISCI 1310 6.00; SC/ISCI 1302 3.00.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Three laboratory hours in alternate weeks.

PHYS 1070 3.0 - Fundamentals of Astronomy

An introduction to the foundations of astronomy and astrophysics. The course covers basic measurement concepts and techniques, and gives an overview of the properties and workings of planets and stars.

Content: Introduction: space and time, celestial sphere, positions and motions of celestial bodies, seasons. The Earth and Moon: motions, geometry, tides, eclipses, structure. Observational Methods: telescopes, CCDs, photometry, spectroscopy. The Solar System: overview: planetary motions, Kepler's Laws, rocky planets, gas giants, extra-solar planets. Small Bodies and the Origin of the Solar System: asteroids, comets, meteors, formation of solar system. Matter and Radiation: structure of the atom, nature of radiation, relation between matter and radiation. The Sun: basic properties, structure, energy source, activity, relevance to Earth. The Stars: motions and distances, the spectral sequence, temperature and luminosity, the Hertzsprung-Russell diagram, star clusters

Reference: R. Freedman, Universe, latest edition (WH Freeman), with supplementary materials provided.

Prerequisites: 12U Physics or OAC Physics or SC/PHYS

1510 3.0.

Prerequisites or Corequisites: : SC/MATH 1013 3.0 or SC/MATH 1505 6.0 or equivalent.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Some day sessions at the Observatory

PHYS 1411 3.0 - Physics Fundamentals 1

A calculus-based survey of physics. Topics include kinematics, dynamics, momentum and energy for linear and rotational motion; elementary kinetic theory and thermodynamics.

This course is recommended for students unlikely to take 2000-level Physics courses, and is a prequel to PHYS 1412 3.0.

Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 3.00; MHF4U Advanced Functions and MCV4U Calculus and Vectors, or 12U Advanced Functions and Introductory Calculus, or OAC Algebra and OAC Calculus, or SC/MATH 1505 6.00, or SC/MATH 1520 3.00.

Course Credit Exclusions: SC/PHYS 1010 6.00; SC/PHYS 1011 3.00, SC/PHYS 1420 6.00; SC/PHYS 1421 3.00; SC/PHYS 1800 3.00; SC/ISCI 1310 6.00; SC/ISCI 1301 3.00.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Three laboratory hours in alternate weeks.

PHYS 1412 3.0 - Physics Fundamentals 2

A calculus-based survey of physics and sequel to PHYS 1411 3.0. Topics include static and current electricity; waves and physical and geometrical optics; elements of modern physics. This course is recommended for students unlikely to take 2000-level Physics courses.

Prerequisites: SC/PHYS 1411 3.00 or SC/PHYS1421 3.00 or SC/PHYS1011 3.00 or SC/PHYS 1800 3.00.

Corequisites: SC/MATH 1014 3.00, or SC/MATH 1505 6.00, or equivalents.

Course Credit Exclusions: SC/PHYS 1010 6.00, SC/PHYS 1410 6.00, SC/PHYS 1420 6.00; SC/PHYS 1012 3.00, SC/PHYS 1422 3.00; SC/PHYS 1801 3.00; SC/ISCI 1310 6.00; SC/ISCI 1302 3.00

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Three laboratory hours in alternate weeks.

PHYS 1421 3.0 - Physics with Life Science Applications 1

Fundamental physics concepts are emphasized through applications to the life sciences. Topics include linear and rotational motion; Newtonian mechanics; work and energy; fluid statics and dynamics. Differential calculus and vector algebra are used.

This course is recommended for students unlikely to enroll in 2000-level physics courses, and is a prequel to SC/PHYS1422 3.00.

Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 3.00; MHF4U Advanced Functions and MCV4U Calculus and Vectors, or 12U Advanced Functions and Introductory Calculus, or OAC Algebra and OAC Calculus, or SC/MATH 1505 6.00, or SC/MATH 1520 3.00.

Course Credit Exclusions: SC/PHYS 1010 6.00 SC/PHYS 1011 3.00; SC/PHYS 1410 6.00; SC/PHYS 1411 3.00; SC/PHYS 1800 3.00; SC/ISCI 1310 6.0; SC/ISCI 1301 3.00.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Three laboratory hours in alternate weeks.

PHYS 1422 3.0 - Physics with Life Science Applications 2

A sequel to PHYS1421 3.0 in which fundamental concepts are emphasized through applications to the life sciences.

Topics include electrostatics; DC circuits; magnetic fields; induction; oscillation and waves, electromagnetic waves; optics.

Differential calculus and vector algebra are used. This course is recommended for students unlikely to enrol in 2000-level physics courses.

Prerequisites: SC/PHYS 1421 3.00 or SC/PHYS1411 3.00 or SC/PHYS1011 3.00 or SC/PHYS 1800 3.00.

Course Credit Exclusions: SC/PHYS 1010 6.00, SC/PHYS1410 6.00, SC/PHYS 1420 6.00; SC/PHYS 1012 3.00, SC/PHYS 1412 3.00; SC/PHYS 1801 3.00; SC/ISCI 1310 6.00; SC/ISCI 1302 3.00.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Three laboratory hours in alternate weeks.

PHYS 1470 3.0 - Highlights of Astronomy

This introductory course on modern astronomy for science students surveys the nature, formation, and evolution of planets, stars, galaxies, and the universe by highlighting selected topics of wide interest and importance.

Content:

1. Understanding astronomy
   - Discovering the night sky
   - Gravitation and the motion of planets
   - Light and telescopes
   - Atomic physics and spectra

2. The Solar System - Formation of the solar system
   - The terrestrial planets
   - The outer planets
   - Vagabonds of the solar system
   - Our sun
   - Planets outside our solar system

3. The Stars - Characterizing stars
   - The lives of stars
   - The deaths of stars
   - Neutron stars, gamma-ray bursts & black holes

4. The Universe - Our milky way galaxy
   - Galaxies and dark matter in the universe
   - Quasars, active galactic nuclei, relativistic jets and supermassive black holes
   - Cosmology, the big bang and the fate of the Universe
   - Search for extraterrestrial life

Reference: N. Comins, W. Kaufmann III, Discovering the Universe, latest edition, Freeman Publications.

Prerequisites or Corequisites: SC/MATH 1013 3.0 or SC/MATH 1505 6.0 or equivalent.

Note: This course is not open to any student who has passed or is taking SC/PHYS 1070 3.0.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week.

PHYS 1510 3.0 - Introduction to Physics

An introductory course for students lacking adequate preparation for SC/PHYS 1011 3.00, SC/PHYS 1411 3.00, or SC/PHYS 1421 3.00. Topics include dynamics (forces and motion, including oscillatory motion), energy and momentum, gravitational, electric and magnetic fields, the wave nature of light, and geometric optics. No calculus is used, but vectors are used extensively.

Content:

1. Linear motion
2. Laws of motion
3. Rotational motion
4. Oscillatory motion
5. Energy, work and momentum
6. Properties of matter
7. Temperature and heat
8. Geometrical optics
9. Electricity and magnetism
10. Structure of atoms and nuclear energy

Reference: R. Serway, J. Faughn and C. Vuille, College Physics, 11th Edition. Nelson Education; 2018.

Prerequisites: Ontario Grade 11 Functions and Relations (new curriculum) or Ontario Grade 12 Advanced Mathematics (old curriculum).

Note: May not be taken by any student who has taken or is currently taking another University course in physics.

One term. Four credits.
Three lecture hours per week. One tutorial hour per week. Includes one lab hour per week.

PHYS 1800 3.0 - Engineering Mechanics

A survey of physics in which fundamental concepts in statics and dynamics are emphasized on engineering applications. This is a calculus-based course intended primarily for engineering students. It includes tutorial and laboratory components.

Content:

1. Force vectors, statics of particles
2. Motion in one, two and three dimensions
3. Newton's laws of motion and their application; free-body force diagrams
4. Work, energy, and power
5. Linear momentum and collisions
6. Torque vectors, equilibrium of rigid bodies in two- and three-dimensions
7. Rotational motion, moment of inertia and angular dimensions
8. Gravitation
9. Oscillatory motion
10. Waves

Reference: R. Hawkes. et al. Physics for Scientists and Engineers. Nelson; 2013.

Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 3.00. MHF4U Advanced Functions and MCV4U Calculus and Vectors, or 12U Advanced Functions and Introductory Calculus, or OAC Algebra and OAC Calculus

Corequisite: SC/MATH 1013 3.0 or SC/MATH 1300 3.0 or SC/MATH 1505 6.0.

Course Credit Exclusion: SC/PHYS 1011 3.00, SC/PHYS 1411 6.00, SC/PHYS 1421 3.00

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Two lab hours per week.

PHYS 1801 3.0 - Electricity, Magnetism, and Optics for Engineers

Survey of physics in which fundamental concepts in electricity, magnetism and optics are emphasized through engineering applications. This is a calculusbased course intended primarily for engineering students. It includes tutorial and laboratory components.

Content:

1. Electric force and field
2. Electric potential difference and energy
3. Capacitance and dielectrics
4. DC circuits
5. Magnetic fields and materials
6. Induction and inductance
7. AC circuits and Impedance
8. Overview of semiconductors
9. Electromagnetic waves
10. Geometrical optics
11. Physical optics

Reference: R. Hawkes. et al. Physics for Scientists and Engineers. Nelson; 2013.

Prerequisites: SC/PHYS 1800 3.00, SC/MATH 1013 3.00

Corequisite: SC/MATH 1014 3.0 or SC/MATH 1310 3.0 or SC/MATH 1505 6.0.

Course Credit Exclusion: SC/PHYS 1012 3.00, SC/PHYS 1412 3.00, SC/PHYS 1422 3.00.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week. Two lab hours per week.

PHYS 1901 3.0 - Physics Laboratory 1

This course is equivalent to the laboratory component for first-year physics courses PHYS 1011, PHYS 1411, and PHYS 1421. Students who were unable to successfully complete those laboratory activities in parallel with the lecture course may complete them at a later date by enrolling in this course.

PHYS 1902 3.0 - Physics Laboratory 2

This course is equivalent to the laboratory component for first-year physics courses PHYS 1012, PHYS 1412, and PHYS 1422. Students who were unable to successfully complete those laboratory activities in parallel with the lecture course may complete them at a later date by enrolling in this course.

PHYS 2010 3.0 - Classical Mechanics

Newtonian mechanics of mass points and rigid bodies. Accelerated reference frames and rotational motion, centrifugal and Coriolis forces. Central force motion in celestial mechanics. Euler's equations: precession and nutation in the gyroscope.

Content:

1. One dimensional motion of a particle
2. The harmonic oscillator, forced oscillations
3. Motion in two and three dimensions
4. Non-inertial reference frames and dynamics
5. Central forces: applications to celestial mechanics
6. Systems of particles – Centre of mass and angular momentum
7. Moment of inertia and rigid-body rotation

Reference: G. Fowles, G. Cassiday, Analytical Mechanics. Thomson Publications; 2004

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0; SC/MATH 1014 3.0 or equivalent; SC/MATH 1025 3.0 or equivalent; SC/MATH 2015 3.0 or equivalent.

Corequisite: SC/MATH 2271 3.0

One term. Three credits.
Three lecture hours per week. One tutorial hour per week.

PHYS 2020 3.0 - Electricity and Magnetism

This course introduces the fundamentals of classical electromagnetism, with an emphasis on theoretical and mathematical foundations. Topics in vector calculus, which is necessary to provide a full appreciation of this subject, are introduced where needed.

Content:

1. Electrostatics: Coulomb's law, Gauss's law, electric fields and potentials, continuous charge distributions, work and conservative vs non-conservative forces, Poisson's and Laplace's equations.
2. Conductors and electric currents: principles of conducting systems, capacitors, time-dependent circuits, current densities and the continuity equation
3. Magnetism: magnetic fields, Lorentz force law, Ampere's law, and Biot-Savart law
4. Electromagnetic induction: Faraday's law and inductance.
5. Maxwell's equations: displacement current, electromagnetic waves, and the speed of light.
6. Special relativity: Unification of electric and magnetic phenomena due to Einstein.

Reference: (2020 A) Purcell & Morin, 3rd ed., Cambridge University Press. (2020 E) Halliday Resnick, Crane vol. 2.

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0.

Corequisite: SC/MATH 2015 3.0

One term. Three credits.
Three lecture hours per week. One tutorial hour per week.

PHYS 2030 3.0 - Computational Methods for Physicists and Engineers

Programming strategies and techniques using a language such as Python are developed as a tool for numerical analysis, modeling, and computations in physics, astronomy, and engineering.

Content: This course provides programming strategies and techniques using a language such as Python are developed as a tool for numerical analysis, modeling, and computations in physics, astronomy, and engineering.

Reference: Numerical Methods For Physics, Revised Second Edition, Alejandro L. Garcia, ISBN: 978-1- 514136-68-3

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0; either LE/EECS 1011 3.00 or LE/EECS 1541 3.00; SC/MATH 1014 3.00 or equivalent; SC/MATH 2015 3.00 or equivalent.

Corequisite: SC/MATH 2271 3.00 or equivalent

Prior to Fall 2016 Prerequisites: SC/PHYS 1010 6.00 or a minimum grade of C in SC/PHYS 1410 6.00 or SC/PHYS 1420 6.00; One of LE/EECS 1020 3.00, LE/EECS 1540 3.00; SC/MATH 1014 3.00 or equivalent.

Prior to Fall 2016 Corequisite: SC/MATH 2015 3.00 or equivalent

One term. Three credits.
Three lecture hours per week. One tutorial hour per week.

PHYS 2040 3.0 - Relativity and Modern Physics

An introduction to the theories of relativity and quantum mechanics. Relativistic concepts of space, time and energy are presented. The quantum nature of radiation and matter is introduced.

This course is the beginning of a sequence of courses in modern physics, including SC/PHYS 3040 6.0, SC/PHYS 4010 3.0, SC/PHYS 4011 3.0 and SC/PHYS 4040 3.0.

Content:

1. Einstein's postulates, time dilation, and space contraction
2. Relativistic kinematics
3. Relativistic dynamics
4. Quantization of matter and radiation
5. The Bohr atom
6. Matter waves and the Uncertainty Principle

Reference: S. Thornton, A. Rex, Modern Physics for Scientists and Engineers, 3rd ed. Nelson Publications: 2005. R. Resnick and D. Halliday, Basic Concepts in Relativity and Early Quantum Theory (Macmillan, 1992) T. Moore, Six Ideas That Shaped Physics, 2nd ed. (McGraw-Hill, 2003).

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0.

Corequisite: SC/MATH 2015 3.0

One term. Three credits.
Three lecture hours per week. One tutorial hour per week.

PHYS 2060 3.0 - Optics and Spectra

An introductory course in optics covering the following topics: wave nature of light, reflection, refraction, spherical mirrors and lenses, interference, diffraction, polarization, introduction to lasers.

Content:

1. Electromagnetic waves
2. Propagation of light, Doppler effect
3. Geometrical optics, index of refraction
4. Interference and diffraction
5. Polarization
6. Gratings and interferometers
7. Physics of lasers
8. Atomic spectra
9. Laser cooling

Reference: D. Halliday, R. Resnick, J. Walker. Physics: Extended Version, 8th ed. John Wiley and Sons Publications; 2007. E. Hecht, Optics, Addison Wesley Publications; 1979, F. Pedrotti, L. Pedrotti, Introduction to Optics, 2nd ed. Prentice-Hall; 1993.

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0; MATH 1014 3.0 or equivalent; SC/MATH 1025 3.0 or equivalent.

One term. Three credits.
Three lecture hours per week. One tutorial hour per week.

PHYS 2070 3.0 - Galaxies and the Universe

An introduction to the structure, evolution and origin of galaxies, aggregates of galaxies, and the universe as a whole. Relevant details of stellar evolution are encompassed. Topics such as supernovae, pulsars, black holes, quasars, density waves, the cosmic web, cosmic expansion and dark constituents of the universe are included.

Content:

1. Stellar properties relevant to studies of galaxies: H-R diagram; star clusters; mass and luminosity; age; evolution; variables; supernovae; black holes; standard candles.
2. Introduction to galaxies and their organization: Milky Way; how galaxies were discovered; what galaxies are; stellar populations; organization, including Large-Scale Structure in the Universe.
3. Properties of galaxies: morphology; clustering; nature versus nurture; changes with redshift; distances; stars, gas, and dust; nuclear activity; internal motions and implications for mass; dark matter.
4. Evolution of galaxies: chemistry; spiral structure.
5. Cosmology: Olbers' Paradox; the Redshift; Hubble's Law; Hubble's Constant; the Cosmic Microwave Background; the Cosmological Principle; the Scale Factor; the Density Parameter; geometry; dark matter; dark energy; the Big Bang; formation and evolution of structure.

Reference: R. Freedman, Universe, latest edition (WH Freeman), with supplementary materials provided (including lab manual).

Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 4.0; SC/PHYS 1070 3.0, or SC/PHYS 1470 3.00 and permission of the instructor.

One term. Three credits.
Three lecture hours per week. One project requiring at least two evening sessions at the observatory.

PHYS 2211 1.0 - Experimental Electromagnetism

An introductory laboratory course for second-year students. The course consists of 10 experiments covering basic concepts of electromagnetism.

Content: Practice with laboratory equipment such as oscilloscopes, function generators, and prototyping circuit boards. Practice with computer programming to control experiments, technical writing, visualization of data in graphs and histograms, and working in groups.

Typically ten experiments are performed. Reviewing the laboratory manual and other background material and completing a prelab quiz in advance of each 3-hour lab is required. Laboratory journals are submitted at the end of each lab.

Reference: Online laboratory manual.

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0.

Corequisite: SC/PHYS 2020 3.0

Course Credit Exclusion: SC/PHYS 2213 3.0.

Course material pertaining to SC/PHYS 2211 1.0 is covered in SC/PHYS 2020 3.0. All Physics & Astronomy majors/minors must register in SC/PHYS 2213 3.0 (effective September 2005). Students whose programs require 2 credits of 2000-level experimental physics take both SC/PHYS 2211 1.0 and SC/PHYS 2212 1.0.

One term. One credit.

PHYS 2212 1.0 - Experimental Physics

An introductory laboratory course based on lasers and modern optics. Includes different experiments than those completed in SC/PHYS 2211 1.0.

Content: Practice with laboratory equipment such as lasers, lenses, and CCD sensors. Practice with data analysis, including propagation of uncertainties, statistical distributions, technical writing and visualization of data in graphs and histograms.

Seven experiments are performed. Reviewing the laboratory manual and other background material in advance of each 3-hour lab is required. Laboratory journals are submitted at the end of each lab and more detailed reports summarizing the experiment and the data analysis are prepared and submitted later. Laser safety training and successful completion of a quiz are mandatory. Laser safety glasses must be worn in the lab when indicated.

Reference: Online laboratory manual and J. Taylor, An Introduction to Error Analysis, University Science Books, 1997

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0; SC/PHYS 2211 1.0.

Corequisite: SC/PHYS 2060 3.0 strongly recommended.

Course Credit Exclusion: SC/PHYS 2213 3.0.

Course material pertaining to SC/PHYS 2212 1.0 is covered in SC/PHYS 2060 3.0. All Physics & Astronomy majors/minors must register in SC/PHYS 2213 3.0 (effective September 2005.) Students whose programs require 2 credits of 2000-level experimental physics take both SC/PHYS 2211 1.0 and SC/PHYS 2212 1.0

One term. One credit.

PHYS 2213 3.0 - Experimental Physics with Data Analysis

Experiments in Electricity and Magnetism and in Modern Optics. Basic methods for analyzing experimental data and understanding statistical and systematic errors.

Content: Practice with laboratory equipment, such as oscilloscopes, function generators, lasers, lenses, and CCD sensors. Practice with data analysis, including propagation of uncertainties, statistical distributions, technical writing and visualization of data in graphs and histograms. Career planning.

One lecture hour per week with assigned homework. Seven experiments are performed each term for a total of fourteen 3-hour labs. Reviewing the laboratory manual and other background material in advance of each lab is required. Laboratory journals are submitted at the end of each lab and more detailed reports summarizing the experiment and the data analysis are prepared and submitted later. Laser safety training and successful completion of a quiz are mandatory. Laser safety glasses must be worn in the lab when indicated.

Reference: Online laboratory manual and J. Taylor, An Introduction to Error Analysis, University Science Books, 1997

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0.

Corequisite: SC/PHYS 2020 3.0; SC/PHYS 2060 3.0 strongly recommended.

Course Credit Exclusion: : SC/PHYS 2211 1.0 and SC/PHYS 2212 1.0.

Course material pertaining to SC/PHYS 2212 1.0 is covered in SC/PHYS 2060 3.0. All Physics & Astronomy majors/minors must register in SC/PHYS 2213 3.0 (effective September 2005.) Students whose programs require 2 credits of 2000-level experimental physics take both SC/PHYS 2211 1.0 and SC/PHYS 2212 1.0

Two terms. Three credits.

PHYS 3010 3.0 - Classical Mechanics

Intermediate classical mechanics, including dynamics of particles and systems of particles. Lagrange's equations and Hamilton's equations.

Content:

1. Calculus of variations
2. Lagrangian and Hamiltonian dynamics
3. Central force problem and collisions
4. Dynamics of rigid bodies
5. Coupled oscillations and normal modes
6. Introduction to nonlinear oscillations and chaos

Reference: S. Thornton, J. Marion, Classical Dynamics of Particles and Systems, Thomson Publications; 2003.

Prerequisites: SC/PHYS 2010 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0.

One term. Three credits.
Three lecture hours per week.

PHYS 3020 3.0 - Electromagnetics I

Electrostatic and magnetostatic fields, derived from charge and current distributions studied in vacuum and in material media.

Content:

1. Vector calculus in Cartesian, cylindrical and spherical polar coordinates
2. Electrostatic fields and electrostatic potentials from discrete and continuous charge distributions *in vacuo*
3. Work and energy in electrostatics
4. Laplace's equation, solutions to Laplace's equation by separation of variables in Cartesian and spherical geometry
5. Multipole expansions of electrostatic fields
6. Electrostatic fields in dielectric material, bound charge, polarization and displacement fields, linear media
7. Magnetostatic fields from distributed currents *in vacuo*
8. The Lorentz force law, the Biot Savart law, the mag-

netic vector potential
9. Multipole expansions of the magnetic vector potential
10. Magnetic fields in matter, bound currents, magnetization, the “auxiliary field”, linear media

Reference: D.J. Griffiths, Introduction to Electrodynamics, 3rd ed. Prentice Hall; 1999.

Prerequisites: SC/PHYS 2020 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0.

Prior to Fall 2009 Prerequisites: SC/PHYS 2020 3.0; AS/SC/MATH 2015 3.0; AS/SC/MATH 2271 3.0.

One term. Three credits.
Three lecture hours per week.

PHYS 3030 3.0 - Statistical and Thermal Physics

Statistical mechanics of systems of large numbers of elements. Probability, ensembles, fluctuations. Applications: spin magnetism, electrons in metals, radiation, specific heats of solids. Transport theory.

Content:

1. Review of classical thermodynamics: three laws, specific heats, adiabatic processes, heat engines
2. Quantum states of weakly interacting particles
3. Pauli exclusion principle
4. Entropy and probability, Boltzmann’s relation, two-level systems, Boltzmann distribution
5. Distribution of quantum states, subsystems and reservoirs, partition function, free energies, entropy of a two-level system, systems of harmonic oscillators, classical perfect gas, diatomic molecules
6. Equipartition theorem, kinetic theory of gases, transport properties
7. Planck radiation law, Bose and Fermi gases

Reference: Concepts in Thermal Physics, Stephen J. Blundell and Katherine M. Blundell, second edition, Oxford University Press, 2010

Prerequisites: SC/PHYS 2020 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0.

Prior to Fall 2009 Prerequisites: SC/PHYS 2020 3.0; AS/SC/MATH 2015 3.0; AS/SC/MATH 2271 3.0.

One term. Three credits.
Three lecture hours per week.

PHYS 3040 6.0 - Modern Physics

Survey of the basis of contemporary physics: introduction to elementary wave mechanics, and the quantum theory of atoms, molecules, solids, nuclei, elementary wave mechanics and elementary particles.

Content:

1. Phenomenological basis of quantization; Planck’s hypothesis; matter waves; particle-wave duality; probabilistic interpretation; uncertainty principle.
2. Schrodinger equation; stationary & nonstationary states; expectation values; 1-D box; finite square well; eigenfunctions and eigenvalues; harmonic oscillator; barrier penetration; 3-D box; operators & commutation relations
3. Central forces; separation of variables; quantization of angular momentum; intrinsic spin; addition of angular momenta; hydrogen atom; dipole transitions; many-electron atoms; Pauli exclusion principle.
4. Selected topics and applications from the following: molecular, condensed matter, and nuclear physics

Reference: R. Scherrer, Quantum Mechanics: An Accessible Introduction. Addison-Wesley Publications; 2006.

Prerequisites: SC/PHYS 2010 3.0; SC/PHYS 2020 3.0; SC/PHYS 2060 3.0; SC/MATH 1025 3.0, SC/MATH 2015 3.0; SC/ MATH 2271 3.0.

Corequisite: SC/PHYS 3090 3.0 recommended

Prior to Fall 2009 Prerequisites: SC/PHYS 2010 3.0; SC/PHYS 2020 3.0; SC/PHYS 2060 3.0; AK/AS/SC/MATH 1025 3.0; AK/AS/SC/MATH 2015 3.0; AS/SC/MATH 2271 3.0.

Two terms. Six credits.
Three lecture hours per week. One tutorial hour per week.

PHYS 3050 3.0 - Electronics I

Introduction to physical electronics including DC and AC circuit theory and network analysis; bandpass filters; introduction to the p-n junction and semiconductor devices: diodes, DC power supplies, transistors, analysis and design of basic amplifiers, operational amplifiers. With laboratory exercises.

Content:

1. Electronic instruments and measurements
2. DC and AC circuit analysis
3. Filters
4. The p-n junction and diodes
5. Diode applications
6. Transistors
7. Switches and amplifiers

Reference: M. Plonus, Electronics and Communications for Scientists and Engineers. Harcourt Academic Press; 2001. J. Edminister, Schaum's Outline of Theory and Problems of Electric Circuits. McGraw-Hill; 2003. A. Sedra, K. Smith, Micro-electronic Circuits, 5th ed. Oxford University Press; 2004. J. Cathey, Schaum's Outline of Theory and Problems of Electronic Devices and Circuits. McGraw-Hill; 2002. S. Nasar, 3000 Solved Problems in Electrical Circuits. McGraw-Hill; 1998.

Prerequisites: SC/PHYS 1010 6.0; SC/PHYS 2020 3.0 and SC/PHYS 2211 1.0.

Course Credit Exclusion: LE/SC/ENG 2200 3.0.

Prior to Summer 2013 Prerequisites: SC/PHYS 1010 6.0; SC/PHYS 2020 3.0 and SC/PHYS 2211 1.0.

One term. Three credits.
Two lecture hours per week. Three laboratory hours per week.

PHYS 3070 3.0 - Planets and Planetary Systems

Survey of planetary astrophysics. Topics include: the formation and evolution of planetary systems; the search for and discovery of extra-solar planets; current knowledge of the atmospheres, interiors and surfaces of planets, satellites and minor bodies within the Solar System.

Content:

1. Definition of a planet
2. Planetary formation and the origin of the Solar System
3. Solar System dynamics
4. Chemical evolution of Solar System
5. Planetary surfaces, interiors and atmospheres
6. Planetary satellite evolution
7. Planetary ring systems
8. Cratering history of Solar System
9. Extrasolar planets: including detection methods (spectroscopic, photometric); general properties; current results from literature
10. Evolution of a habitable planet; rare earth hypothesis

Reference: Custom Course Pack - CSPI Publishing. Additional material will be drawn from the research literature

Prerequisites: SC/PHYS 1010 6.0, or a minimum grade of C in SC/PHYS 1410 6.00 or SC/PHYS 1420 6.00.

Prerequisites or Corequisite: AS/SC/MATH 2015 3.0; AK/AS/SC/MATH 2271 3.0

Prior to Fall 2009 Prerequisites: SC/PHYS 1010 6.0 or a minimum grade of C in SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0; SC/PHYS 1070 3.0,

One term. Three credits.
Three lecture hours per week.

PHYS 3080 3.0 - Atmospheric Radiation and Thermodynamics

Applications of basic thermodynamic principles to dry and moist atmospheric situations. Solar (short wave) and terrestrial (long wave) radiation with respect to absorption and scattering processes involving atmospheric atoms, molecules, aerosol particles and clouds.

Reference: G. Petty, A First Course in Atmospheric Radiation, 2nd ed. Sundog Publishing; 2006. G. Petty, A First Course in Atmospheric Thermodynamics, Sundog Publishing; 2008.

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 3090 3.0 - Methods in Theoretical Physics

Methods of classical and modern theoretical physics are introduced to solve problems such as heat diffusion, wave propagation, modes of vibrating strings and membranes, electromagnetic potentials from charge distributions, Schrödinger waves and eigenvalues, and the angular distribution of cosmic radiation. The array of mathematical methods and techniques covered in this course are essential for theoretical physics. The themes of vector spaces, initial value problems, and the wonders of the complex plane are woven throughout the course.

Content:

1. Complex analysis
2. Fourier series
3. Fourier and Laplace transforms
4. Green's functions
5. Coupled systems and eigenvalue problems
6. Group theory

Reference: Mathematical Methods for Physicists, Arfken, Weber, & Harris, Academic Press, 2012

Prerequisites: SC/PHYS 2020 3.0

Corequisite: SC/PHYS 3040 6.0

One term. Three credits.
Three lecture hours per week.

PHYS 3130 3.0 - Practical Data Science Methods in Physical Sciences

This course provides practical modern research methods including a wide range of skills encompassing statistics, research methodologies and data science investigations. This course allows students to conduct their own research project, conduct a literature review, use, and understand physics and astronomy data science methods, access cloud computing tools, and employ Python code to illustrate their research methods. Real physics and astronomy data sets are required (students may choose from provided sets or select a new one with instructor approval) for all student projects. Through the research project, students employ critical thinking to solve a problem on real-world data. Students enhance their written communication as well as knowledge of the data science environment by presenting their project at the end of the course. The tool-centric nature of this course will see students introduced to many modern scientific workhorses like the API (Application Program Interface) call, pipelines, databases, SQL, TopCat and more. This course provides not only an invaluable toolkit to students, but also a roadmap on how to use these tools and techniques in science research. Students may find this course a helpful precursor to research and 4000 level courses like PHYS 4030, 4270, 4310 and more.

Prerequisites: SC/PHYS 2213 3.0, SC/PHYS 2030 3.0, or by permission of the instructor.

One term. Three credits.

PHYS 3150 3.0 - Electronics II

The concept of feedback and its use in circuits employing operational amplifiers; analysis/design of such circuits, including amplifiers, filters, oscillators, pulse generators; digital concepts and logic circuits with applications to data manipulation (computers) and storage. Laboratory exercises and project.

Content:

1. Feedback principles
2. Characteristics of operational amplifiers
3. Operational amplifier circuits
4. Basic digital concepts
5. Basic digital logic circuits
6. Analogue/digital conversion
7. Microcomputer fundamentals

Reference: M. Plonus, Electronics and Communications for Scientists and Engineers. Harcourt Academic Press; 2001. A. Sedra, K. Smith, Micro-electronic Circuits, 5th ed. Oxford University Press; 2004. J. Edminister, Schaum's Outline of Theory and Problems of Electric Circuits. McGraw-Hill; 2003. J. Cathey, Schaum's Outline of Theory and Problems of Electronic Devices and Circuits. McGraw-Hill; 2002. S. Nasar, 3000 Solved Problems in Electrical Circuits. McGraw-Hill; 1998.

Prerequisites: SC/PHYS 1010 6.0; and SC/PHYS 3050 3.0 recommended.

Course Credit Exclusion: LE/SC/ENG 2210 3.00

One term. Three credits.
Two lecture hours per week. Three laboratory hours per week.

PHYS 3220 3.0 - Experiments in Modern Physics

A selection of experiments in fluid mechanics, electromagnetism, optics, and atomic, nuclear, and particle physics. Analysis of the data and detailed writeups are required. One lecture hour which is devoted to techniques of data analysis and three laboratory hours per week.

Reference: J. Taylor, An Introduction to Error Analysis. University Science Books; 1997

Prerequisites:: SC/PHYS 2020 3.0; SC/PHYS 2060 3.0; SC/PHYS 2213 3.0.

Corequisite: SC/PHYS 3040 6.0

Course Credit Exclusion: SC/PHYS 3210 6.0

One term. Three credits.
One lecture hour per week. 4 experiments are performed through the semester. These labs each normally take 3 to 6 hours of laboratory time in addition to reviewing the laboratory manual and other background material in advance of the lab.

PHYS 3250 3.0 - Introduction to Space Communications

The course covers all aspects of communications between spacecraft and ground stations. Topics include orbital aspects of satellite communications, communications components of satellites and interplanetary spacecraft, ground stations, transmission, reception, link equation, modulation, multiplexing techniques and access to a satellite

Content:

1. History and overview of present status
2. Orbital aspects of satellite communications
3. Spacecraft
4. Earth station
5. Communications link
6. Modulation and multiplexing techniques
7. Multiple access to a satellite

Reference: D. Roddy, Satellite Communications, 4th ed. McGraw-Hill; 2006.

Prerequisites: SC/PHYS 2020 3.0.

One term. Three credits.
Three lecture hours per week.

PHYS 3280 3.0 - Physics of the Space Environment

An introduction to the physical processes of the upper atmosphere, the ionosphere, the magnetosphere and the heliosphere, and the interactions that occur with space vehicles that traverse these regions of space.

Content:

1. Atmospheric structure and composition particularly at spacecraft altitudes in the ionosphere, thermosphere and exosphere
2. Essentials of solar physics
3. Solar electromagnetic radiation
4. Solar wind and its interactions with the terrestrial atmosphere
5. Terrestrial magnetism
6. Solar-terrestrial phenomena
7. Magnetosphere

Reference: T.F. Tascione, Introduction to the Space Environment, 2nd ed. Krieger; 1994

Prerequisites: SC/PHYS 2020 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0.

One term. Three credits.
Three lecture hours per week.

PHYS 3320 3.0 - Microsystem Technology

The course covers the principles and implementations of miniaturised sensors and actuators in a range of physical domains, such as optical, magnetic, thermal, and mechanical systems. Examples include electronic cameras, micro-electro-mechanical systems, thermal microsystems, and display technologies.

Content:

1. Introduction: Introduction to microsystems; general principles of transduction; definitions
2. Fabrication & Micromachining Technology: Overview of CMOS technology relevant to microsystems, materials properties, micromachining technology
3. Mechanical Microsystems: Overview of mechanics and mechanical properties of materials; mechanisms of mechanical transconduction; mechanical sensors (e.g. accelerometer, gyroscope, pressure sensor); mechanical actuators (e.g. electrostatic micromotors, micromirrors)
4. Optical Microsystems: Optical detection; optical sensors (CCD, CMOS, non-silicon); optical actuators – displays (LCD, field emission, LED, organic)
5. Terrestrial magnetism
6. Radiation Detection: Interaction of radiation (e.g. X-ray, ionizing radiation) with matter; radiation sensors (large area, space applications)
7. Thermal Microsystems: Review of heat transfer mechanisms; transduction principles; thermal sensors (junction bases sensors, thermomechanical and –resistive sensors); thermal imaging (IR image sensors); thermal actuators (e.g. Peltier cooler)
8. Magnetic Microsystems: Magnetic sensors (magnetoresistive, magnetostrictive, Hall effect); magnetic actuators (e.g. RF passive components, read/write heads)
9. Chemical and Fluidic Microsystems: Chemical sensors (e-nose); fluidic sensors (flow sensors)

Reference: No required text. G. Kovacs, Micromachined Transducers Handbook. McGraw-Hill Publications; 1998.

Prerequisites: SC/PHYS 2020 3.0; SC/PHYS 2211 1.0; SC/PHYS 2060 3.0 recommended; SC/PHYS 2212 1.0 recommended.

Corequisite: SC/PHYS 3050 3.0 recommended.

One term. Three credits.
Three lecture hours per week.

PHYS 3330 3.0 - Materials for Space Applications

This course covers the behaviour of materials relevant to the engineering of spacecraft. Material responses to thermal, mechanical, vacuum, electrical and ionizing radiation stresses are discussed. Engineering analysis tools and environmental models are also covered.

Degree Credit Exclusion: LE/ENG 3330 3.0

Reference: A.C. Tribble, The Space Environment Implications for Spacecraft Design, Revised and Expanded edition (Princeton University Press, 2003).

Prerequisites: SC/CHEM 1100 4.0, SC/PHYS 2020 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 3600 3.0 - Experiential Learning Opportunity through Research and Exchange (EXPLORE)

Students engage and collaborate in cutting-edge scientific research as part of an international team of faculty mentors and student peers from other universities in Canada and in other countries. Students read scientific literature, learn the process of scientific research, make oral and written presentations, and participate in research team activities using virtual workspaces and remote collaboration tools. Research themes are decided in advance by faculty mentors and may include topics in theoretical and/or computational physics, astrophysics, or biophysics; or data analysis related to experimental physics or biophysics, observational astronomy or cosmology, or numerical simulations of physical systems.

Enrollment by instructor permission only.

Normally students would have completed SC/PHYS 2020 3.0 and SC/PHYS 2030 3.0.

PHYS 3900 0.0 - Physics or Astronomy Internship Work Term

This experiential education course reflects the work term component of the Technology Internship Program (TIP). Qualified Honours students gain relevant work experience as an integrated complement to their academic studies, reflected in the requirements of a learning agreement and work term report. Students are required to register in this course for each four month work term, with the maximum number of work term courses being four (i.e. 16 months.) Students in this course receive assistance from the Career Centre prior to and during their internship, and are also assigned a Faculty Supervisor/Committee.

Prerequisites: Enrollment is by permission only. Criteria for permission include: 1. That students have successfully completed at least nine PHYS credits at the 3000 level or higher, and have a GPA of at least 5.00 in PHYS courses overall; 2. That students are enrolled full-time in the Honours program prior to beginning their internship and have attended the mandatory preparatory sessions as outlined by the Career Centre; 3. That students have not been absent for more than two consecutive years as a full-time student from their Honours degree studies; 4. That upon enrolling in this course students have a minimum of 9 credits remaining toward their Honours degree and needs to return as a full-time student for at least one academic term to complete their degree after completion of their final work term. Note: This is a pass/fail course, which does not count for degree credit. Registration in SC/PHYS 3900 0.00 provides a record on the transcript for each work term.

PHYS 4010 3.0 - Quantum Mechanics

Physical concepts and mathematical foundations of quantum mechanics. Emphasis on approximation methods, treatment of angular momentum, spin and their couplings. Introduction to relativistic quantum mechanics and scattering theory.

Content:

1. Postulates of quantum mechanics
2. Operators
3. Expectation values
4. Uncertainty
5. Time-evolution operators
6. Particle in a box
7. Bohr correspondence principle
8. Dirac notation
9. Hilbert space: linearity, inner product, norm, completeness
10. Hermitian operators: reality of eigenvalues, orthogonality of eigenfunctions
11. Mathematical aside: Fourier transforms
12. Momentum representation
13. Commutators
14. General uncertainty relations
15. Time development: wavefunctions, expectation values, Ehrenfest theorem
16. Wave packets: gaussian wave packet
17. Conservation laws: energy, momentum, angular momentum, parity
18. Translation operator, rotation operator, parity operator
19. Harmonic oscillator – creation, annihilation operators
20. Tunneling: transmission resonances
21. WKB approximation: connection formulae, Airy functions
22. Angular momentum: commutation relations, J+ and J-
23. Spherical harmonics
24. Hydrogen atom
25. Variational method
26. Matrix mechanic
27. Spin
28. Addition of angular momenta
29. Perturbation theory: time-independent, degenerate, time-dependent
30. Relativistic quantum mechanics: Dirac equation, Klein-Gordon equation

Reference: R. Liboff, Introductory Quantum Mechanics, 4th ed. Addison Wesley; 2002. C. Cohen-Tannoudji, Quantum Mechanics (2 vol. set.) Wiley; 1992. J. Sakurai, Modern Quantum Mechanics, 2nd ed. Addison Wesley; 2010.

Prerequisites: SC/PHYS 3040 6.0

Prerequisite or Corequisite: SC/PHYS 3020 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 4011 3.0 - Atomic and Molecular Physics

Application of quantum mechanics to atomic and molecular structure. One-electron systems, many electron atoms, Hartree-Fock approximation, fine structure, hyperfine structure, atom-laser interactions.

Integrated with GS/PHYS 5050 3.0.

Content:

1. Two-particle systems: centre-of-mass and internal motion
2. Spin of the electron; addition of angular momenta; spin-orbit interaction
3. Time-independent perturbation theory, nondegenerate and degenerate, with applications to atomic physics
4. Variational methods, with applications to atomic physics
5. Identical particles: Permutation operators; symmmetrization postulate; exchange terms; Pauli exclusion principle
6. Atomic structure: (simple) screened nucleus model; Hartree self-consistent field model
7. Fine structure of atomic spectra: relativistic kinetic energy; L S interaction; Darwin term
8. Hyperfine structure of atomic spectra: nuclear volume effect; nuclear quadrupole moment; nuclear magnetic moment
9. Molecular bonding: ionic, van der Waals; Heitler-London theory of covalent bonding
10. Molecular spectra: Born-Oppenheimer approximation; translational, electronic vibrational and rotational motion; band spectra
11. Quantum theory of the electromagnetic field: creation and annihilation operators; field operators; number states
12. Atom-photon interaction: multipole hamiltonian
13. Time-dependent perturbation theory: transitions
14. First-order radiation processes: absorption, stimulated and spontaneous emission; Einstein A and B

coefficients; applications to the laser and cooling of atoms

15. Higher-order radiation processes: two-photon absorption, emission (stimulated and spontaneous), and scattering (ordinary and stimulated; Rayleigh and Raman)
16. Interaction of a 2-level atom with a single intense field mode

Reference: R. Liboff, Introductory Quantum Mechanics, 4th ed. Addison-Wesley Publications; 2002.Addison Wesley; 1998. C. Cohen-Tannoudji, Quantum Mechanics, Vol 2. John Wiley and Sons; 1992.

Prerequisites: SC/PHYS 4010 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 4020 3.0 - Electromagnetics II

Time–dependent electric and magnetic fields, Maxwell's differential equations in linear, isotropic, homogeneous conductors and dielectrics; the radiation and transmission of electromagnetic energy; relativistic transformations; scalar diffraction theory.

Content:

1. Electromagnetic induction; Maxwell's equations; boundary conditions
2. Conservation laws for energy and linear and angular momentum in electrodynamics; Poynting's theorem; Maxwell stress tensor
3. Electromagnetic wave propagation in vacuum; in linear dielectrics; in conductors
4. Absorption and dispersion in conductors and in dielectrics
5. Electromagnetic wave transmission in wave guides; co-axial transmission lines
6. Potentials and fields; gauge transformations; retarded potentials; Lienard-Wiechert potentials
7. Electromagnetic radiation; electric dipole radiation; magnetic dipole radiation; radiation from an arbitrary source; radiation reaction
8. Special relativity; relativistic mechanics; Minkowski space-time; four vectors and four tensors in space-time; relativistic electrodynamics; Maxwell's equations in covariant form.

Reference: D.J. Griffiths, Introduction to Electrodynamics, 3rd ed. Prentice Hall; 1999

Prerequisites: SC/PHYS 2040 3.0; SC/PHYS 3020 3.0.

One term. Three credits.
Three lecture hours per week.

PHYS 4030 3.0 - Advanced Computational Method

Computational approaches are developed to introduce, demonstrate, and reinforce advanced core conceptual topics in physics. Topics include advanced data analysis and computational modeling techniques (e.g., signal processing, Monte Carlo simulations, numerical integration of ordinary and partial differential equations, etc.) as well as visualization strategies. Basic tenets and elements of "Data Science" and machine learning (e.g., Deep Learning) are introduced so that students gain exposure to, and an appreciation of, how large-scale computation is rapidly evolving and affecting a broad range of scientific methodologies.

Prerequisites: PHYS 2030 3.0 or equivalent. MATH 2271 3.0 or equivalent. 6 credits from PHYS/BPHS 3*** (PHYS 3090 in particular is encouraged)

One term. Three credits.
Three lecture hours per week.

PHYS 4040 3.0 - Elementary Particle Physics

The properties of the fundamental particles (quarks and leptons), and the forces between them are studied. Topics include the interactions of particles with matter, symmetry principles and experimental techniques. Integrated with GS/PHYS 5040 3.0

Content:

1. Nuclear phenomenology: properties of nuclei, masses and sizes of nuclei, stability and instability of nuclei; some nuclear models
2. Nuclear radiation: alpha decay and barrier penetration, beta decay and intro to weak interactions , gamma decay
3. Energy deposition in media: energy loss of charged particles, interaction of photons, particle detectors and accelerators
4. Conservation laws and Invariance principles: electric charge, baryon number, particles and antiparticles, isospin, P.C.T. conservation and CP violation
5. Standard Model: quarks and leptons, quark content of mesons and baryons, symmetries and symmetry breaking, colour force, deep inelastic scattering; structure functions
6. Beyond the standard model (time permitting)

Reference: Griffiths, D. Introduction to Elementary Particles, 2nd ed., Wiley-VCH; 2008. C. Coughlan, J. Dodd, The Ideas of Particle Physics. Cambridge University Press; 1991. A. Das, T. Ferbel, Introduction to Nuclear and Particle Physics. John Wiley and Sons; 1993. B. Martin, G. Shaw, Particle Physics. John Wiley and Sons; 2006. D. Perkins, Introduction to High Energy Physics. Cambridge University Press; 2000. W. Williams, Nuclear and Particle Physics. Oxford University Press; 1991.

Prerequisites: SC/PHYS 2040 3.0; SC/PHYS 4010 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 4050 3.0 - Solid State Physics

The structural, mechanical, thermal, electrical and magnetic properties of crystalline solids are studied.

Integrated with GS/PHYS 5100 3.0.

Content:

1. Molecular forces and interatomic bonding
2. Crystal structure, diffraction and the reciprocal lattice
3. Elastic constants and elastic waves: continuum approach
4. Phonon and lattice vibrations: monatomic and diatomic lattices; local phonon modes; thermal properties of insulators; lattice specific heat, thermal conductivity; thermal expansion
5. Free electron theory of metals: Fermi surface; Fermi–Dirac distribution function; specific heat of metals
6. electrical conductivity; thermal conductivity, band theory of solids: Kronig–Penny model; effective mass; conductors, insulators, semi–metals, and semi–conductors; holes; magnetic properties
7. Superconductivity: BCS theory (Introduction only)

Reference: C. Kittel, Introduction to Solid State Physics, 8th ed. John Wiley and Sons; 2005 Ashcroft and Mermin, Solid State Physics Modeling: Introduction to Solid State Physics. Harcourt College Publishers; 1976. J. Blakemore, Solid State Physics, 2nd ed. Saunders; 1974. M. Ali Omar, Elementary Solid State Physics. Addison Wesley; 1975.

Prerequisites: SC/PHYS 3030 3.0; SC/PHYS 4010 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 4060 3.0 - Time Series and Spectral Analysis

Treatment of discrete sampled data involving correlation, convolution, spectral density estimation, frequency domain filtering, and Fast Fourier Transforms. Same as: LE/ESSE 4020 3.0 Integrated with: GS/ESS 5020 3.0

Content:

1. Discrete, Equispaced Time Series: Power and energy signals, wavelets; convolution and the z– transform; expected value, autocorrelation and cross correlation; impulse, white noise and World decomposition; time reversal; properties of wavelets; linear, optimum filtering; deconvolution, shaping and spiking filters
2. Fourier Methods: Finite Fourier transform; Fourier transform effects of sampling and record length; digital frequency filtering; the power spectrum; fast Fourier transform.

Reference: E. Kanasewich, Time Sequence Analysis in Geophysics. University of Alberta Press; 1981, A. Enders, Multichannel Time Series Analysis with Digital Computer Programs. Holden–Day; 1978, A. Enders, S. Treital, Geophysical Signal Analysis. Prentice Hall Inc.; 1980

Prerequisites: LE/EECS 1540 3.0 or LE/EECS 1541 3.0 or equivalent programming experience; SC/MATH 2015 3.0; SC/MATH 2271 3.0

Course Credit Exclusion: LE/CSE 3451 4.0; LE/CSE 3451 3.0; SC/MATH 4130B 3.0; SC/MATH 4930C 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 4061 3.0 - Experimental Techniques in Laser Physics

Involves a selection of experiments in laser physics, with emphasis on techniques necessary for trapping neutral atoms with lasers.

Integrated with: GS/PHYS 5061 3.0

Content:

Reference: K.F. Renk, Basics of Laser Physics for Students of Science and Engineering, Springer, 2012. (free e-resource at York Library). Lab manual, provided through eClass.

Prerequisites: SC/PHYS 2211 1.0 and SC/PHYS 2212 1.0, or SC/PHYS 2213 3.0; SC/PHYS 2020 3.0; SC/PHYS 2060 3.0

Corequisites: SC/PHYS 3040 6.0

One term. Three credits.
One lecture hours per week. One tutorial hour per week. Three lab hours per week.

PHYS 4062 3.0 - Atom Trapping

Involves trapping atoms with lasers and investigating the properties of laser-cooled atoms. The course includes a set of lectures that cover theoretical concepts including basic properties of two-level atoms, radiation pressure, the laser cooling force, magnetic trapping, and the dipole force.

Integrated with: GS/PHYS 5062 3.0

Content:

Reference: No Textbook Required - Lab Manual only. W. Demtroder, Laser Spectroscopy (Springer); P. W. Milonni and J. H. Eberly, Lasers (Wiley); H. J. Metcalf and P. van der Straten, Laser Cooling and Trapping (Springer); B. H. Bransden, C. J. Joachain, Physics of Atoms and Molecules (Longman)

Prerequisites: SC/PHYS 4061 3.0

One term. Three credits.
One lecture hours per week. One tutorial hour per week. Sixteen three-hour lab sessions spread over eight weeks.

PHYS 4070 3.0 - Stars and Nebulae

The astrophysics of radiating matter in the universe. The course covers radiation processes, radiative transfer, interstellar matter, stellar atmospheres and stellar interiors.

Integrated with: GS/PHYS 5090 3.0

Content:

1. Interactions of matter with radiation
2. Emission lines and absorption lines
3. Overview of interstellar matter
4. Theory and observation of gaseous nebulae
5. Theory and observation of stellar atmospheres
6. Stellar interiors and stellar evolution

Reference: E. Bohm-Vitense, Introduction to Stellar Astrophysics, Volumes 2 and 3, Cambridge University Press; 1992, D. Osterbrock and G. Ferland, Astrophysics of Gaseous Nebulae and Active Galactic Nuclei, 2nd ed. University Science Books; 2005 D. Gray, Observation and Analysis of Stellar Photospheres. Cambridge University Press; 1992 J. Irwin, Astrophysics: Decoding the Cosmos. Wiley Interscience; 2007 G. Rybicki, A. Lightman, Radiative Processes in Astrophysics. Wiley Interscience; 1979 T. Swihart, Radiation Transfer and Stellar Atmospheres. Pachart Publishing House; 1981

Prerequisites: SC/PHYS 1070 3.0; SC/PHYS 3030 3.0; SC/PHYS 3040 6.0

Prerequisite or Corequisite: SC/PHYS 3040 6.0

One term. Three credits.
Three lecture hours per week.

Normally offered in alternate years

PHYS 4110 3.0 - Dynamics of Space Vehicles

This course presents a coherent and unified framework for mathematical modeling and analysis of space vehicles. The course can be divided into two main parts: orbit dynamics and attitude dynamics and control. The topics covered by this course include twobody problem, coordinate transformation, orbital elements, perturbation theory, orbital maneuvers, relative motion and rendezvous, interplanetary trajectories, rocket dynamics, and attitude dynamics and control. Spacecraft dynamics and control problems of practical interests are treated from a dynamical systems point of view. This course will focus on a comprehensive treatment of spacecraft dynamics and control problems and their practical solutions.

Content:

1. Overview and Introduction
2. Particle dynamics/dynamics of point mass
3. Rocket vehicle dynamics
4. Two body problem
5. Orbital elements
6. Coordinate transformations
7. Orbital perturbation theory
8. Orbital maneuvers
9. Relative motion and rendezvous
10. Interplanetary trajectories, Launch windows
11. Rigid-body dynamics
12. Satellite attitude dynamics
13. Attitude control system
14. Introduction to stability analysis
15. Possible additional topics: Reentry dynamics, N-body problem, Orbit determination

Reference: W. Wiesel, Space Flight Dynamics, 2nd ed. McGraw-Hill; 1997.

Prerequisites: SC/PHYS 2010 3.0 or LE/ESSE 2470 3.0; SC MATH 2015 3.0; SC/MATH 2271 3.0.

One term. Three credits.
Three lecture hours per week.

PHYS 4120 3.0 - Gas and Fluid Dynamics

Fundamental laws; conservation of mass, momentum and energy, vortex motion; incompressible, compressible and viscous flows, turbulent flow, surface waves.

Content:

1. Introduction: basis of continuum model, pressure isotropy, compressibility, viscosity
2. Mass, momentum, and energy conservation equations
3. Hydrostatics
4. Velocity potential, vortex motion, stream function
5. Potential flows of incompressible fluid in two and three dimensions
6. Viscous incompressible flows: Navier–Stokes equation, solutions for pipe and channel flows, laminar and turbulent boundary layers
7. Nonviscous compressible flows: shock waves, expansion flows

Reference:J. Katz, Introductory Fluid Mechanics, Cambridge University Press; 2010

Prerequisites: SC/PHYS 2010 3.0 or LE/ESSE 2470 3.0; SC/ MATH 2015 3.0; SC/MATH 2271 3.0.

Prerequisites Prior to Summer 2013: SC/PHYS 2010 3.00 or SC/EATS 2470 3.00; AS/SC/MATH 2015 3.00; AS/SC/MATH 2271 3.00

One term. Three credits.
Three lecture hours per week.

PHYS 4170 3.0 - Observational and Theoretical Cosmology

A survey of observational and theoretical foundations of modern cosmology. Observational constraints on the history and current state of the universe are examined. Theoretical foundations of modern cosmology are introduced and employed to interpret observations. In the process, ideas about the early evolution of the universe, including the introduction of cosmic inflation and the development of large-scale structure, are elucidated.

Integrated with: GS/PHYS 5590 3.0

Content:

1. Redshifts, expansion of the universe, and the Hubble Constant
2. The Big Bang
3. The Cosmic Microwave Background radiation
4. The approach to models: The Cosmological Principle, the Robertson-Walker metric, and the Friedmann equations
5. Cosmological models
6. Density parameters
7. Horizons
8. Observational constraints on cosmological parameters
9. Dark Matter
10. The Cosmological Constant and Dark Energy
11. The age of the Universe
12. Measures of distance and time and their relation to redshift
13. The thermal history of the Universe
14. Big Bang nucleosynthesis
15. Inflation
16. Matter/antimatter Asymmetry
17. LambdaCDM cosmology and the development of structure
18. The Multiverse
19. Before the Beginning

Reference: B. Ryden, Introduction to Cosmology, Addison-Wesley; 2002.

Prerequisites: SC/PHYS 3090 3.00.

One term. Three credits.
Three lecture hours per week.

PHYS 4210 3.0 - Advanced Experimental Physics I

Selected advanced experiments in physics related to topics in solid state physics, atomic spectroscopy, microwaves, low-noise measurements, superconductivity, and nuclear and particle physics.

Reference: A.C. Melissinos, Experiments in Modern Physics (Academic Press, 1975). D.W. Preston and E.R. Dietz, The Art of Experimental Physics (John Wiley and Sons, 1991).

Prerequisites: SC/PHYS 3220 3.00; registration in a Bachelor or Honours Program in physics and astronomy or in biophysics

Corequisite: SC/PHYS 3040 6.00

One term. Three credits.
Open laboratory hours

PHYS 4211 3.0 - Advanced Experimental Physics II

Selected advanced experiments in physics related to topics in solid state physics, atomic spectroscopy, microwaves, low-noise measurements, superconductivity, and nuclear and particle physics.

Reference: A.C. Melissinos, Experiments in Modern Physics (Academic Press, 1975). D.W. Preston and E.R. Dietz, The Art of Experimental Physics (John Wiley and Sons, 1991).

Prerequisites: SC/PHYS 3220 3.00; registration in a Bachelor or Honours Program in physics and astronomy or in biophysics

Corequisite: SC/PHYS 3040 6.00

One term. Three credits.
Open laboratory hours

PHYS 4270 3.0 - Astronomical Techniques

An introduction to modern astronomical instrumentation, observational methods, data analysis, and numerical methods. In addition to weekly lectures, the course provides students with hands–on experience with both observational and theoretical techniques of modern astronomy.

Integrated with: GS/PHYS 5390 3.0

Content:

1. Radiation and telescopes
2. Detectors, especially CCDs and NIR arrays
3. Photometry
4. Spectroscopy
5. Astrometry
6. Statistics

Reference: Kitchin, Astrophysical Techniques, 7th edition. Wall & Jenkins, Practical Statistics for Astronomers. Birney, Gonzalez, & Oesper, Observational Astronomy, 2nd edition. Chromey, To Measure the Sky, 2nd edition.

Prerequisites: SC/PHYS 1070 3.0; SC/PHYS 2070 3.0; AS/SC/MATH 2271 3.0.

Prerequisite or Corequisite: SC/PHYS 3220 3.0.

Includes several laboratory exercises.
Normally offered in alternate years.
Students who miss PHYS 4270 3.0 due to the timing of Departmental course offerings may substitute ESSE 4230 3.0 Remote Sensing of the Atmosphere, with the express permission of the Undergraduate Program Director of the Department of Physics and Astronomy.

PHYS 4310 3.0 - Physics or Astronomy Project

A faculty-supervised research endeavor, either experimental of theoretical, in physics or astronomy. Before enrolling, the student and faculty member must agree upon the project scope, background reading, milestones including student-faculty meeting schedule, and deliverables including final written report.

Note: Open to students in the final year of the Physics, Applied Physics or Astronomy streams of an Honours Physics and Astronomy program.

One term. Three credits.

PHYS 4330 3.0 - Radio Science and Techniques for Space Exploration

The theory and application of modern radio science and radio techniques in space exploration and space navigation. Topics include signal processing, radio astronomy fundamentals, Deep Space Network instrumentation, antenna theory, arrays, Very Long Baseline Interferometry, spacecraft navigation, radar systems, range, range rate and the radar equation.

Integrated with: GS/PHYS 6190 3.0

Content:

1. Signal Processing Fundamentals
   (a) Continuous and discrete signals
   (b) Fourier series (FS)
   (c) Fourier transform (FT)
   (d) Properties of the FT
   (e) The 2-dim FT
   (f) Linear systems, convolution and filtering
   (g) Energy, power and their spectral densities
2. Radio Astronomy Fundamentals
   (a) Introduction
   (b) Power, spectral power, brightness and flux density
   (c) Antenna temperature and noise
   (d) Minimum detectable antenna temperature and flux density
3. Radio Observatory and DSN Instrumentation Fundamentals
   (a) Antennas, Antenna arrays and VLBI
   (b) Time and frequency standards
   (c) Multibeam antenna systems
4. VLBI and DSN Applications to Spacecraft Navigation (Radiometric tracking techniques for deep-space navigation)
   (a) Introduction
   (b) Earth-based tracking and navigation overview
   (c) Range and Doppler tracking observables
   (d) Future directions in radiometric tracking
5. Introduction to Radar Systems (Radar fundamentals)
   (a) Introduction
   (b) Range
   (c) Doppler frequency or range rate
   (d) The Radar Equation
   (e) CW radar (FM)

Reference: B. Mahafza, Introduction to Radar Analysis. CRC Press; 1998, J. Kraus, Radio Astronomy, 2nd ed. Cygnus-Quasar, C. Thornton, J. Borders, Radiometric Tracking Techniques for Deep Space Navigation. JPL Publication; 00-11. (Web Document)

Prerequisites: SC/PHYS 3250 3.0

One term. Three credits.
Three lecture hours per week.

PHYS 4350 6.0 - Space Hardware

Explores the theoretical, practical and experimental techniques needed to acquire and manipulate typical signals used in spacecraft system operations or integration and testing.
Same as: LE/ESSE 4350 6.0

Content: The course is divided into 4 sections (2 sections each semester). The first semester covers analog and digital signals and associated test equipment. The second semester covers RF signals and the final section of the course is a software development project where students develop code to calculate antenna pointing angles necessary to track a spacecraft in orbit. Lectures are used to review and reinforce concepts learned in the hands-on lab sessions. Students also write the Basic and Advanced Industry Canada exams to become certified amateur radio operators during the course.

Reference: Course Kit

Prerequisites: SC/PHYS 3150 3.0; SC/PHYS 3250

3.0

Prerequisites prior to Fall 2013: LE/CSE 2031 3.0 or LE/CSE 1541 3.0

Three laboratory hours and two lecture hours per week.

PHYS 4410 3.0 - Space Geodynamics

The dynamical behaviour of the Earth from space measurements. Included are the external gravity field of the Earth, orbital dynamics of artificial satellites, satellite geoid, internal figure of the Earth, rotation of the Earth and its measurement by space techniques.

Content:

1. Introduction
2. Mathematical Foundation
3. Block Diagrams and Signal-Flow Graphs
4. Modeling of Physical Systems
5. State Variable Analysis
6. Stability of Linear Control Systems
7. Time-Domain Analysis of Control Systems
8. Root-Locus Technique
9. Frequency-Domain Analysis
10. Design of Control Systems

Reference: G. Franklin, J. Powell, A. Emami-Naeini, Feedback Control of Dynamics Systems, 5th ed. Prentice Hall; 2006

Prerequisites or Corequisites: LE/ESSE 3020 3.0; SC/MATH 3241 3.0 or LE/CSE 3121 3.0; SC/MATH 3271 3.0

Offered irregularly

Bethune College

SC/BC 3030 3.0 - Technical and Professional Writing

This writing-intensive course is for upper-year science students and others in related fields. Students develop confidence and competence in professional and technical writing. Focus is on communication of complex information in a clear, sensible style.

Prerequisites: At least six non-science general education credits.

Corequisites: Concurrent enrolment in at least one 3000- or 4000-level Science course (or course which is cross-listed with a Science course), or permission of the instructor.

One term. Three credits.
Three lecture hours per week.

Biophysics

BPHS 2090 3.0 - Current Topics in Biophysics

An introduction to biophysics highlighting major themes in pure and applied biophysical research. Included is coverage of fundamental concepts in fluid mechanics. The course will present biology and physics students with an overview of the role of physics in biological research

Prerequisites: SC/PHYS 1011 3.0 and SC/PHYS 1012 3.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1411 3.0 and SC/PHYS 1412 3.0 or SC/PHYS 1421 3.0 and SC/PHYS 1422 3.0; SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0, or SC/BIOL 1410 6.0.

Cross-listed: SC/BIOL 2090 3.00

One term. Three credits.
Three lecture hours per week.

BPHS 3900 0.0 - Biophysics Internship Work Term

This experiential education course reflects the work term component of the Technology Internship Program (TIP.) Qualified Honours students gain relevant work experience as an integrated complement to their academic studies, reflected in the requirements of a learning agreement and work term report. Students are required to register in this course for each for month work term, with the maximum number of work term courses being four (i.e. 16 months.) Students in this course receive assistance from the Career Centre prior to and during their internship, and are also assigned a Faculty Supervisor/Committee.

Prerequisites: : Enrollment is by permission only. Criteria for permission include:

1. That students have successfully completed at least 9 BPHS or PHYS credits at the 3000 level or higher, including SC/BPHS 3090, and have a GPA of at least 5.0 in BPHS, BIOL, and PHYS courses overall.
2. That students are enrolled full-time in the Honours program prior to beginning their internship and have attended the mandatory preparatory sessions as outlined by the Career Centre.
3. That students have not been absent for more than two consecutive years as a fulltime student from their Honours degree studies.
4. That upon enrolling in this course students have a minimum of 9 credits remaining toward their Honours degree and need to return as a full-time student for at least one academic term to complete their degree after completion of their final work term.

Note: This course is a Pass/Fail course, which does not count for degree credit. Registration in SC/BPHS 3900 0.0 provides a record on the transcript for each work term

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BPHS 4080 3.0 - Cellular Electrodynamics

This course will focus on physics relevant to cellular dynamics and transport. Basic principles will include: electrodynamics (e.g., charge transport across cells, Nernst potentials), diffusion, osmosis, and wave propagation. Salient biological topics will be approached in a rigorous mathematical fashion and include those such as: cellular homeostasis, the Hodgkin-Huxley model for action potentials, molecular biology of ion channels, and molecular motors (e.g., motion in low Reynolds-number regimes).

The objective of the course is to help students to integrate the knowledge gained in second and third year biology and physics courses and to use methods of physics to study biological processes.

Integrated with: GS/PHYS 5802 3.0

Prerequisites: : SC/BPHS 2090 3.0; SC/PHYS 2020 3.0 or equivalent; SC/PHYS 2060 3.0 or equivalent.

One term. Three credits.

BPHS 4090 3.0 - Biophysical Techniques

This course will focus on applications of atomic, nuclear, and quantum physics in biology and medicine. Topics will include interactions between radiation and matter (including spectroscopy), principles of imaging and radiation therapy in medicine, and micro/nano-fluidics. An array of modern experimental techniques will also be covered, including those such as: optical tweezers, atomic force microscopy (AFM), x-ray crystallography, and nuclear magnetic resonance (NMR, MRI). Relevant signal processing strategies such as spectral analysis (e.g., Fourier transforms) and image analysis (e.g., convolutions, tomography) will be covered in detail.

A regular one-hour tutorial will serve to provide background training and hands-on support for student lab work.

Integrated with: GS/PHYS 5800 3.0

Reference: R. Hobbie, B. Roth, Intermediate Physics for Medicine and Biology, 4th ed. Springer Publications; 2009.

Prerequisites: SC/BPHS 2090 3.00 or permission of the instructor; SC/PHYS 2020 3.00; SC/PHYS 2060 3.00.

Corequisite: SC/PHYS 3040 6.00.

One term. Three credits.

BPHS 4310 3.0 - Biophysics Research Project

A faculty-supervised research endeavour in experimental or theoretical biophysics. The student and faculty member must agree upon (and the Biophysics Program Director must approve) the project scope, background reading, milestones including student-faculty meeting schedule, and deliverables including final written report.

Six hours per week. One term. Three credits.

Chemistry

CHEM 1000 3.0 - Chemical Structure

Introduction to chemistry with emphasis on physical and electronic structure of matter, including gases, liquids and solids. Topics include behaviour of gases; thermochemistry; atomic structure and periodic table; chemical bonding and architecture; structure of liquids and solids; frontiers of chemistry.

Prerequisites: OAC chemistry, 12U chemistry or SC/CHEM 1500 4.00 or equivalent.

Course Credit Exclusions: Course credit exclusions: SC/CHEM 1100 3.00, SC/ISCI 1201 3.00, SC/ISCI 1210 6.00.

One term. Three credits.
Two and one-half lecture hours per week, one tutorial hour per week, six three-hour laboratory sessions.

CHEM 1001 3.0 - Chemical Dynamics

This course complements SC/CHEM 1000 3.0 - with emphasis on chemical change and equilibrium. Topics include chemical kinetics; chemical equilibrium; entropy and free energy as driving forces for chemical change; electrochemistry; frontiers in chemistry.

Prerequisites: OAC chemistry, 12U chemistry or SC/CHEM 1500 4.00 or equivalent.

Course Credit Exclusions: SC/ISCI 1202 3.00, SC/ISCI 1210 6.00.

One term. Three credits.
Two and one-half lecture hours per week, one tutorial hour per week, six three-hour laboratory sessions.

CHEM 2020 3.0 - Introductory Organic Chemistry I

An introduction to organic chemistry: nomenclature, bonding, structure, resonance, reactivity, thermodynamics, kinetics, preparation and reactions of alkanes, alkenes, alkynes, alkyl halides and alcohols, with mechanisms.

Prerequisites: SC/CHEM 1000 3.0, SC/CHEM 1001 3.0.

Course Credit Exclusions: SC/CHEM 2020 6.0.

One term. Three credits.
Three lecture hours and one tutorial hour per week. One three-hour laboratory session every two weeks.

CHEM 2021 3.0 - Introductory Organic Chemistry II

A continuation of SC/CHEM 2020 3.0: structure determination (IR, MS, NMR), aromaticity, electrophilic aromatic substitution, preparation and reactions of ethers, epoxides, carbonyl compounds, amines, carboxylic acids and derivatives, with mechanisms.

Prerequisites: SC/CHEM 2020 3.0.

Course Credit Exclusions: SC/CHEM 2020 6.0.

One term. Three credits.
Three lecture hours and one tutorial hour per week. One three-hour laboratory session every two weeks.

CHEM 4092 3.0 - X-Ray Crystallography

Principles, practical details and computational methods of X-ray crystallographic structure determination. Students carry out an original structure determination from raw reflection data.

Prerequisites: : SC/CHEM 2011 3.00 and SC/CHEM 3051 3.00.

The Department of Chemistry is willing to give Biophysics Majors permission to enter the course without having the required prerequisites.

One term. Three credits.

CHEM 4093 3.0 - Biomaterials Chemistry

This course serves as an introduction to materials used for biomedical applications for students with background in chemistry, physics and biology. Emphasis is on biological and biomimetic surfaces, interactions at the biomaterial/tissue interfaces, and mechanisms involved with biologically driven materials self-assembly.

Content The course covers a range of natural and synthetic biomaterials, general aspects of their structure, properties, behavior in contact with biological systems and selected applications. It highlights latest advancements in biomaterials research and technology including approaches to surface modification for enhanced biocompatibility of materials, development of materials with controlled properties for drug delivery and biologically inspired materials that mimic natural systems and processes as well as design of sophisticated three-dimensional architectures for tissue engineering.

1. Review of major classes of biomaterials.
2. Bulk properties of biomaterials.
3. Surface properties of biomaterials, interactions with biological systems and biocompatibility. Methods of surface characterization.
4. Surface modification strategies for enhanced biocompatibility.
5. Principles of molecular self-assembly. Biomimetic materials.
6. Immunoisolation strategies and drug delivery.
7. Approaches to tissue engineering.

Prerequisites: SC/CHEM 3051 3.0 or SC/CHEM 3090 3.0.

One term. Three credits.
Three lecture hours per week.

Earth and Space Science and Engineering

ESSE 1010 3.0 - The Dynamic Earth and Space Geodesy

An overview of modern geophysics: origin of the Earth, impact cratering, internal structure and rheology, earthquakes, plate tectonics, geomagnetism. Space geodetic positioning techniques such as VLBI, SLR and GPS are introduced as means of detecting and monitoring tectonic movements.

Prerequisites: 12U Calculus and Vectors or 12U Advanced Functions and Introductory Calculus (pre 2007 version) or equivalent, or SC/MATH 1515 3.0; 12U Physics or SC/PHYS 1510 4.0.

Course Credit Exclusions: LE/ESSE 1010 6.0, SC/NATS

1750 6.0.

One term. Three credits.

ESSE 1011 3.0 - Introduction to Atmospheric Science

The origin, composition and vertical structure of the Earth's atmosphere and those of other planets. The present global atmospheric circulation. Weather systems, measurements and weather maps; atmospheric chemistry; the ozone layer and atmospheric pollution.

Prerequisites: 12U Calculus and Vectors or 12U Advanced Functions and Introductory Calculus (pre 2007 version) or equivalent; SC/MATH 1515 3.00; 12U Physics or SC/PHYS 1510 4.00.

Course Credit Exclusion: LE/EATS 1010 6.00 (prior to Fall 2014), SC/EATS 1010 6.00 (prior Summer 2013), SC/NATS 1750 6.00. Previously offered as: LE/EATS 1011 3.00.

One term. Three credits.
Three lecture hours per week, five three-hour laboratory sessions.

ESSE 1012 3.0 - The Earth and Environment

Provides essential topics in Earth environment (Earth and oceanic science, atmospheric science, and geology) and explores the role played by global and local scale processes in shaping our planet. Concepts are described; the latest technology discussed, and links between engineering disciplines are provided. The course lectures are complemented by hands-on laboratory and field experience.

Prerequisites: 12U calculus and vectors or 12U advanced functions, or SC/MATH 1515 3.00; 12U physics or SC/PHYS 1510 4.00.

Corequisites: LE/ENG 1101 4.00; LE/ENG 1102 4.00; SC/PHYS 1800 3.00, SC/PHYS 1801 3.00.

One term. Three credits.

ESSE 2030 3.0 - Planetary Geophysics

This course analyzes the nature and usefulness of numerous geophysical tools for terrestrial and planetary exploration and in geologic observations. Tools include radar sounding and synthetic aperture radar, seismic waves, earthquake fault plane solutions, geochronology, gravity, paleomagnetism, rock magnetism, and thermal physics for Earth, the moon, and the terrestrial planets.

Prerequisites: SC/PHYS 1012 3.00; or SC/PHYS 1010 6.00; or any of the following acceptable substitutes: SC/PHYS 1801 3.00; or SC/ISCI 1310 6.00; or SC/ISCI 1302 3.00; or any of the following with a minimum grade of C in each course: SC/PHYS 1410 6.00; SC/PHYS 1420 6.00; SC/PHYS 1412 3.00; SC/PHYS 1422 3.00.

One term. Three credits.

ESSE 2470 3.0 - Introduction to Continuum Mechanics

Introductory tensor algebra and calculus. Stress and strain analysis. Symmetry of stress tensor, equilibrium conditions. Lagrangian and Eulerian descriptions of strain. Physical interpretation of stress, strain and strain rate tensors. Conservation laws in continua. Consistency and compatibility considerations. Constitutive relations.

Prerequisites: LE/EECS 1011 3.00 or LE/EECS1541 3.00; SC/MATH 1025 3.00; SC/MATH 2015 3.00; SC/PHYS 1012 3.00; or SC/PHYS 1010 6.00; or SC/PHYS1801 3.00; or any of the following acceptable substitutes: SC/ISCI 1310 6.00; or SC/ISCI 1302 3.00; or any of the following with a minimum grade of C in each course: SC/PHYS 1410 6.00; SC/PHYS 1420 6.00; SC/PHYS 1412 3.00; SC/PHYS 1422 3.00.

One term. Three credits.
Two lecture hours and a tutorial or problems laboratory session.

ESSE 3670 3.0 - Global Navigation Satellite Systems

Satellite-based positioning, navigation and timing. Spatial and temporal reference systems. Orbital mechanics. GNSS signal structure, hardware, observables, and error sources. GNSS point positioning, relative positioning, and augmentation techniques. GNSS / inertial integration. GNSS evolution and applications.

Prerequisites: LE/ESSE 3610 3.00; LE/ESSE 3620 3.00 or LE/ESSE 2640 3.00

Course Credit Exclusion: LE/ESSE 4610 3.00.

ESSE 4360 3.0 - Payload Design

This course provides students with a comprehensive and accurate approach for the specification and detailed design of different spacecraft payloads, including optical payload, microwave payload, communications payload, and planetary exploration payload. Reliability analysis and its application will also be covered for space systems. Payload design projects will be assigned to students during the course. Three lecture hours per week.

Prerequisites: LE/ENG 2001 3.00, LE/ESSE 3280 3.00

ESSE 4361 3.0 - Space Mission Design

This course covers the basic aspects of space mission design from a ”blank sheet”. It includes mission design structure using systems engineering approaches to the design problem. Mission design starts with a set of mission objectives and aims to develop a viable solution for meeting these objectives given a set of technical cost and programmatic constraints. This course brings together systems engineering, mission types, objectives, technical readiness, risk mitigation, mission subsystems, and cost estimation.

Prerequisites: LE/ESSE 4360 3.00 or permission of the Instructor.

ESSE 4610 3.0 - Global Positioning Systems

Positioning by space vehicles. Coordinate systems and transformations. GPS, GLONASS, GALILEO, Satellite Laser Ranging, Very Long Baseline Interferometry. Positioning of moving vehicles and platforms: marine, land, airborne and space vehicles. GPS/INS integration. Real time kinematic applications.

Prerequisites: LE/ESSE 3020 3.00; LE/ESSE 3610 4.00 or LE/ENG 3110 4.00; LE/ESSE 3620 4.00 or LE/ENG 3120 4.00; or permission of the course director. PRIOR TO FALL 2014: Prerequisites: LE/EATS 3020 3.00; LE/EATS 3610 4.00 or LE/ENG 3110 4.00; LE/EATS 3620 4.00 or LE/ENG 3120 4.00; or permission of the Instructor. PRIOR TO SUMMER 2013: Prerequisites: SC/EATS 3020 3.00; SC/EATS 3610 4.00 or SC/ENG 3110 4.00; SC/EATS 3620 4.00 or SC/ENG 3120 4.00; or permission of the Instructor.

One Term. Three Credits.
Three lecture hours weekly and three hours of laboratory exercises every other week.

ESSE 4630 3.0 - Image Processing for Remote Sensing

Digital imaging from remote platforms. Image processing and analysis, including radiometric and geometric corrections and geometric enhancements, multispectral classification, digital photogrammetry fundamentals, workstations, photogrammetric processing.

Prerequisites: Prerequisites: LE/ESSE 3650 3.00; LE/ESSE 4220 3.00. PRIOR TO FALL 2014: Prerequisites: LE/EATS 3650 4.00 or LE/ENG 3150 4.00; LE/EATS 4220 3.00. PRIOR TO SUMMER 2013: Prerequisites: SC/EATS 3650 4.00 or SC/ENG 3150 4.00; SC/EATS 4220 3.00.

One Term. Three Credits.
Two lecture hours and three hours of laboratory exercises per week.

Electrical Engineering & Computer Science

EECS 1541 3.0 - Introduction to Computing for the Physical Sciences

An introduction to scientific computing using an integrated computing and visualization platform. Elements of procedural programming such as: control structures, data types, program modules. Visualization in two and three dimensions. Applications to numerical computation and simulations relevant to the physical sciences.

Prerequisites: SC/MATH 1013 3.00 or equivalent; Corequisites:

Corequisites: SC/PHYS 1010 6.00 or SC/PHYS 1410 6.00 or SC/PHYS 1420 6.00; and SC/MATH 1021 3.00 or SC/MATH 1025 3.00.

Course Credit Exclusions: LE/SC/CSE 1560 3.0, LE/SC/CSE 1570 3.0. PRIOR TO FALL 2014: course credit exclusions: LE/CSE 1560 3.00, LE/SE 1570 3.00. PRIOR TO SUMMER 2013: course credit exclusions: SC/CSE 1560 3.00, SC/CSE 1570 3.00.

One term. Three credits.
Twice weekly meetings, each consisting of one lecture hour followed by a one and a half hour laboratory session.

Mathematics and Statistics

MATH 1013 3.0 - Applied Calculus I

Introduction to the theory and applications of both differential and integral calculus. Limits. Derivatives of algebraic and trigonometric functions. Riemann sums, definite integrals and the Fundamental Theorem of Calculus. Logarithms and exponentials, Extreme value problems, Related rates, Areas and Volumes.

Prerequisites: SC/MATH 1515 3.0 or SC/MATH 1520 3.0, or a high school calculus course.

Course Credit Exclusions: SC/MATH 1000 3.0, SC/MATH 1300 3.0, SC/MATH 1505 6.0, SC/MATH 1513 6.0, SC/MATH 1530 3.0, SC/MATH 1550 6.0, GL/MATH/MODR 1930 3.0, AP/ECON 1530 3.0.

One term. Three credits.
Three lecture hours per week.

MATH 1014 3.0 - Applied Calculus II

Calculus in Polar Coordinates. Techniques of Integration. Indeterminate Forms. Improper Integrals. Sequences, infinite series and power series. Approximations. Introduction to ordinary differential equations.

Prerequisites: One of SC/MATH 1000 3.0, SC/MATH 1013 3.0, SC/MATH 1300 3.0, or SC/MATH 1513 6.0; for non-science students only, six credits from SC/MATH 1530 3.0 and SC/MATH 1540 3.0, SC/MATH 1550 6.0, AP/ECON 1530 3.0 and AP/ECON 1540 3.0.

Course Credit Exclusions: SC/MATH 1010 3.0, SC/MATH 1310 3.0, SC/MATH 1505 6.0, GL/MATH/MODR 1940 3.0.

One term. Three credits.
Three lecture hours per week.

MATH 1025 3.0 - Applied Linear Algebra

Topics include spherical and cylindrical coordinates in Euclidean 3-space, general matrix algebra, determinants, vector space concepts for Euclidean n-space (e.g. linear dependence and independence, basis, dimension, linear transformations etc.), an introduction to eigenvalues and eigenvectors.

Prerequisites: One 12U or OAC mathematics course or equivalent.

Course Credit Exclusions: SC/MATH 1021 3.0, SC/MATH 2021 3.0, SC/MATH 2221 3.0, GL/MATH/MODR 2650 3.0.

One term. Three credits.
Two and one-half lecture hours per week. One Tutorial hour per week. Six three hour laboratory sessions.

MATH 2015 3.0 - Applied Multivariate & Vector Calculus

Topics covered include partial derivatives; grad, div, curl and Laplacian operators; line and surface integrals; theorems of Gauss and Stokes; double and triple integrals in various coordinate systems; extrema and Taylor series for multivariate functions.

Prerequisites: One of SC/MATH 1010 3.0, SC/MATH 1014 3.0, SC/MATH 1310 3.0; or SC/MATH 1505 6.0 plus permission of the course coordinator.

Course Credit Exclusions: SC/MATH 2010 3.0, SC/MATH 2310 3.0, GL/MATH/MODR 2670 3.0, GL/MATH 3200 3.0.

One term. Three credits.
Three lecture hours per week.

MATH 2271 3.0 - Differential Equations for Scientists and Engineers

Introduction to ordinary and partial differential equations, including their classification, boundary conditions, and methods of solution. Equations, methods, and solutions relevant to science and engineering are emphasized, and exploration is encouraged with the aid of software.

Prerequisites: One of SC/MATH 2010 3.0, SC/MATH 2015 3.0, SC/MATH 2310 3.0 or equivalent; one of SC/MATH 1025 3.0, SC/MATH 2022 3.0, SC/MATH 2222 3.0 or equivalent.

Course Credit Exclusions: SC/MATH 2270 3.0, GL/MATH 3400 3.0.

One term. Three credits.
Three lecture hours per week.

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* since Oct 1, 2024
** as of Jan 1, 2026

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*	Sabbatical July 2025 - June 2026
**	Sabbatical January 2025 - December 2025
***	Sabbatical January 2026 - December 2026

Research Fields

AA	Astronomy & Astrophysics
AMO	Atomic, Molecular & Optical Physics
B	Biological Physics
CCM	Chemical & Condensed Matter Physics
HEP	High Energy & Particle Physics
PP	Planetary & Exoplanetary Physics