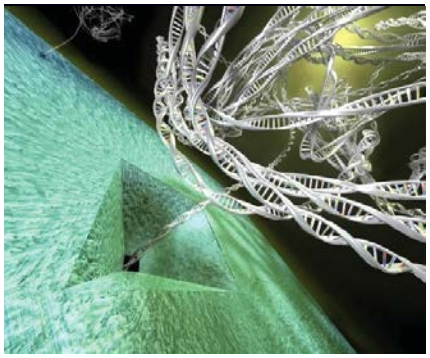
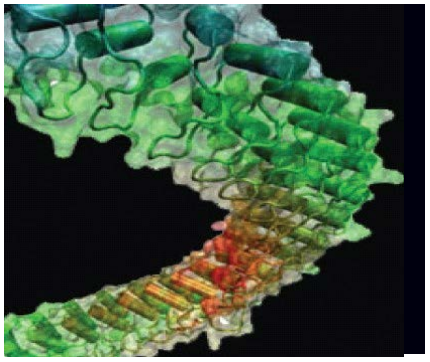
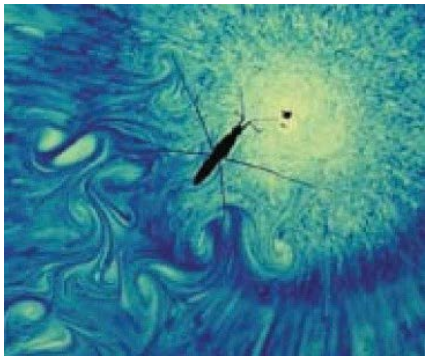
BIOPHYSICS




UNDERGRADUATE HANDBOOK 2018 - 2019

www.biophysics.yorku.ca

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Front Cover Photo Credits

Top row, left: DNA translocating through a solid-state nanopore. Image by Biophysics Group at the Kavli Institute of NanoScience, Delft University of Technology

Top row, centre: A real-time enhanced vein image is projected onto a subject's wrist in an effort to help in finding a vein for making injections. Photo by Herbert Zeman

Top row, right: Ankyrin, a molecule located in hair cell bundles in the inner ear, behaves like a soft spring, facilitating the conversion of mechanical energy into electrical signals when hairs are deflected by sound. Image by Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign

Centre left: A dye on the surface of water reveals a trail of vortices behind a water strider, yielding insights into how the insect propels itself. Image by David L. Hu, Brian Chan, and John W. M. Bush

Lower left: Autofluorescence of a common deer tick feasting on the ear of a golden hamster, as viewed by laser scanning confocal microscopy. Photo by Marna E. Ericson.

Biophysics Office

128 Petrie Science and Engineering Building
Hours: 10:00am – 5:00pm
(closed 12:00pm – 1:00pm)
Tel: (416) 736-5249

M. McCall, Undergraduate Program Director
Email: chphas@yorku.ca
(416) 736-2100 x 33773

J. DeCamillis, Undergraduate Program Secretary
Email: phas@yorku.ca
(416) 736-5249

Biology Departmental Office

108 Farquharson Science Building
Hours: 9:00am - 3:30pm
(closed 12:00pm – 1:00pm)
(416) 736-5311

Websites

www.biophysics.yorku.ca
www.physics.yorku.ca
www.science.yorku.ca/biology

WELCOME TO BIOPHYSICS

Welcome to the Biophysics Program at York University. We are honoured that you have chosen to entrust us with your university education.

The Biophysics Program was constructed by the Department of Physics and Astronomy in collaboration with the Department of Biology. It is administered by the Department of Physics and Astronomy. The Program is different from any in Biology or Physics and Astronomy by virtue of its unique core requirements. Not only are there foundational courses in biology, chemistry, and physics, but enrichment comes through specialized courses in biology and physics considered to be particularly valuable to a biophysics education, and unification comes through courses dedicated to biophysics.

I want your experience with us to be both stimulating and productive. This Handbook and our website **(http://www.biophysics.yorku.ca)** will help to guide your way. In case you need it, detailed information about offerings in biology is available at the website of the Biology Department, **http://science.yorku.ca/biology/**. The offerings of the Physics and Astronomy Department are described comprehensively at **www.physics.yorku.ca**. We are committed to teaching of the highest quality. You will find that this process is enriched by our vigourous research activity, which occurs in a dazzling array of fields.

Biophysics 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 year, and a dedicated biophysics laboratory supports studies in fourth year. As part of their university experience, our students also enjoy diverse opportunities for enrichment outside of the classroom. Besides the Biophysics Club, Biological Society, Pre-Med Society, Physics Society, and Astronomy Club, 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 program affairs or to arrange for an appointment. I can be reached by phone at 416-736-5249 or by email at **chphas@yorku.ca**.

Professor Marshall McCall, Director of Biophysics

IMPORTANT NOTICE

This Handbook is meant as a supplement to the Official York University Calendar (available at York Calendars). It describes in detail the options for studying Biophysics at York University, and contains detailed course descriptions. All general information and course references have been checked for accuracy, but there may remain a few 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 any 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) ext. 33333 (Not 911) Security Control Centre Ext. 58000 Student Security Escort Service 416-736-5454	Emergency/Security
Bethune College Academic Advisor 416-736-2100 ext. 33940 bcadvisr@yorku.ca	General advising; study skills; college activities; upcoming events
Bethune Writing Centre 205 Bethune College 416-736-5164 http://bethune.yorku.ca/writing/	Improving writing skills
Career Centre 202 McLaughlin College 416-736-5351 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 http://scld.yorku.ca/	Enrich student life by promoting education, awareness and growth; celebrating diversity, encouraging collaboration and developing citizenship.
Counselling & Disability Services N110 Bennett Centre for Student Services 416-736-5297 http://pcs.info.yorku.ca/	Personal counselors, crisis counseling, group development workshops, learning skills training, and support for learning disabilities and psychiatric disabilities.
Faculty and Staff	Advice on courses and careers
Centre for Human Rights S327 Ross Building 416-736-5682 www.yorku.ca/rights rights@yorku.ca	Assists individuals and groups to address and resolve allegations of discrimination and harassment as defined by the Ontario Human Rights Code (Code).
Office of the Ombudsperson 1050 York Research Tower ombudsperson 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 or Contact	Primary Service
Office of the Registrar Bennett Centre for Student Services 416-872-YORK www.registrar	Enrolment procedures; Sessional dates and refund table Petitions, permission to take a course at another university, transcripts, and most forms
Sexual Assault Survivor's Support Line B449 Student Centre 416-736-2100 x 40345 http://www.yorku.ca/sassl/main/	Provide unbiased and non-judgmental peer support and referrals to survivors of sexual violence; Educational workshops
Student Financial Services N201 Bennett Centre for Student Services 416-872-YORK http://sfs.yorku.ca	Scholarships, financial problems, OSAP information
YFS Health Plan 336 Student Centre 416-736-5324 www.yfs.ca healthplan@yorku.ca	Health plan sponsored by York Federation of Students

TIMETABLE

FALL/WINTER 2018 – 2019

Course	Title	Day	Time	Instructor
BPHS 2090 3.0 A F	**Current Topics in Biophysics**	TR	11:30-13:00	S. Jerzak
BPHS 3900 0.0 A F	**Biophysics Internship Work Term**			
BPHS 3900 0.0 M W	**Biophysics Internship Work Term**			
BPHS 4090 3.0 M W	**Biophysical Techniques**	MWF	13:30-14:30	O. Mermut
BPHS 4310 3.0 A F	**Biophysics Research Project**			
BPHS 4310 3.0 M W	**Biophysics Research Project**			
PHYS 1010 6.0 A Y	**Physics**	MWF	12:30-13:30	R. Lewis
	Tutorial	R	13:30-14:30	
	Lab	M	14:30-17:30	
	Lab	T	18:30-21:30	
	Lab	W	14:30-17:30	
	Lab	R	14:30-17:30	
	Lab	F	14:30-17:30	
	Lab	R	9:30-12:30	
PHYS 1070 3.0 A W	**Fundamentals of Astronomy**	TR	11:30-13:00	M. De Robertis
	Tutorial	W	14:30-15:30	
	Tutorial	T	9:30-10:30	
PHYS 1800 3.0 A F	**Engineering Mechanics**	MWF	12:30-13:30	M. George
	Tutorial	M	14:30-15:30	
PHYS 1801 3.0 A W	**Electricity, Magnetism & Optics for Engineers**	MWF	12:30-13:30	S. Jerzak
	Tutorial	F	10:30-11:30	
PHYS 2010 3.0 M W	**Classical Mechanics**	WF	8:30-10:00	J. Zylberberg
	Tutorial	W	3:30-14:30	

Course	Title	Day	Time	Instructor
PHYS 2020 3.0 A F	**Electricity & Magnetism**	MWF	12:30-13:30	S. Tulin
	Tutorial	W	11:30-12:30	
PHYS 2020 3.0 E F	**Electricity & Magnetism**	WF	11:30-13:00	A. Kumarakrishnan
	Tutorial	W	9:30-10:30	
PHYS 2030 3.0 M W	**Computational Methods**	MWF	11:30-12:30	P. Hall
	Lab	M	14:30-15:30	
	Lab	W	15:30-16:30	
PHYS 2040 3.0 A F	**Relativity & Modern Physics**	MWF	13:30-14:30	M. Horbatsch
	Tutorial	M	14:30-15:30	
PHYS 2060 3.0 M W	**Optics & Spectra**	TR	10:00-11:30	W. van Wijngaarden
	Tutorial	M	13:30-14:30	
PHYS 2070 3.0 A F	**Galaxies & the Universe**	TR	10:00-11:30	M. McCall
PHYS 2211 1.0 M W	**Experimental Electromagnetism**	M	9:30-12:30	W. Taylor
	Lab	or M	13:30-16:30	
	Lab	or T or W	14:30-17:30	
	Lab	or W	11:30-14:30	
PHYS 2212 1.0 M W	**Experimental Physics**	W	14:30-17:30	W. Taylor
	Lab	T	14:30-17:30	
	Lab	R	11:30-14:30	
	Lab	R	14:30-17:30	
PHYS 2213 3.0 A Y	**Experimental Physics with Data Analysis**	W	14:30-15:30	W. Taylor
	Lab	T, R	14:30-17:30	
	Lab	R	11:30-14:30	
PHYS 3010 3.0 M W	**Classical Mechanics**	MWF	9:30-10:30	W. van Wijngaarden
PHYS 3020 3.0 A F	**Electromagnetics I**	MWF	11:30-12:30	E. Hessels
PHYS 3030 3.0 A F	**Statistical & Thermal Physics**	TR	10:00-11:30	R. Lewis

Course	Title	Day	Time	Instructor
PHYS 3040 6.0 A Y	**Modern Physics**	MWF	10:30-11:30	M. Horbatsch
	Tutorial	T	15:30-16:30	
PHYS 3050 3.0 A F	**Electronics I**	TR	11:30-13:00	G. Grau
	Lab	T	16:00-19:00	
	Lab	or R	15:30-18:30	
	Lab	or M	19:00-21:00	
PHYS 3070 3.0 A F	**Planets & Planetary Systems**	TR	13:00-14:30	J. Moores
PHYS 3080 3.0 A F	**Atmospheric Radiation & Thermodynamics**	MWF	9:30-10:30	J. Whiteway
PHYS 3090 3.0 A F	**Methods in Theoretical Physics**	MWF	9:30-10:30	S. Tulin
PHYS 3150 3.0 M W	**Electronics II**	TR	11:30-13:00	H. Kassiri
	Lab	T or R	15:30-18:30	
PHYS 3220 3.0 A F	**Experiments in Modern Physics**	T	14:30-15:30	C. Storry
	Lab	MTW RF	10:00-16:00	
	Lab		(3 hours, open)	
PHYS 3250 3.0 A F	**Introduction to Space Communications**	MWF	12:30-13:30	N. Bartel
PHYS 3280 3.0 M W	**Physics of the Space Environment**	MWF	13:30-14:30	N. Bartel
PHYS 3320 3.0 M W	**Microsystems Technology**	TR	16:00-17:30	TBA
PHYS 3330 3.0 M W	**Materials for Space Applications**	TR	10:00-11:30	H. Chesser
	Tutorial	R	13:00-14:00	
PHYS 3900 0.0 A F	**Physics or Astronomy Internship Work Term**			
PHYS 3900 0.0 M W	**Physics or Astronomy Internship Work Term**			
PHYS 4010 3.0 A F	**Quantum Mechanics**	MW	10:00-11:30	L. Sagunski

Course	Title	Day	Time	Instructor
PHYS 4011 3.0 M W	**Atomic and Molecular Physics**	MWF	13:30-14:30	T. Kirchner
PHYS 4060 3.0 A F	**Time Series & Spectral Analysis**	TR	8:30-10:00	P. Taylor
PHYS 4061 3.0 A F	**Experimental Techniques in Laser Physics**	F	14:30-15:30	A. Kumarakrishnan
	Tutorial	F	15:30-16:30	
	Lab	MT	14:30-17:30	
	Lab	WR	14:30-17:30	
PHYS 4062 3.0 M W	**Atom Trapping**	R	14:30-15:30	A. Kumarakrishnan
	Tutorial	R	15:30-16:30	
	Lab	WF	14:30-17:30	
PHYS 4110 3.0 M W	**Dynamics of Space Vehicles**	M	16:00-19:00	J. Shan
PHYS 4120 3.0 A F	**Gas and Fluid Dynamics**	TR	11:30-13:00	M. Haslam
PHYS 4170 3.0 M W	**Cosmology**	TR	13:00-14:30	A. Muzzin
PHYS 4210 3.0 M W	**Advanced Experimental Physics I**	M	14:30-15:30	C. Storry
	Lab	MTW RF	10:00-16:00	
PHYS 4211 3.0 M W	**Advanced Experimental Physics II**	M	14:30-15:30	C. Storry
	Lab	MTW RF	10:00-16:00	
	Lab		(6 hours, open)	
PHYS 4310 3.0 A F	**Physics or Astronomy Project**			
PHYS 4310 3.0 M W	**Physics or Astronomy Project**			
PHYS 4350 6.0 A Y	**Space Hardware**	MF	10:00-11:30	H. Chesser
	Lab	M	14:30-17:30	
	Lab	W	10:00-13:00	

Building Codes

ACW	Accolade West
BC	Norman Bethune College
BRG	Bergeron Centre for Engineering Excellence
CB	Chemistry Building
CC	Calumet College
CLH	Curtis Lecture Halls
FC	Founders College
LAS	Lassonde Building
PSE	Petrie Science & Engineering
R	Ross Building
SC	Stong College
DB (formerly TEL)	Dahdaleh Building (Formerly Technology and Enhanced Learning Building)

INTRODUCTION

What is Biophysics?

Biophysics is an interdisciplinary frontier of science in which the principles and techniques of physics are applied to study living things and how they work. To a great extent, biophysics became established as a bonafide field of science after the discovery of X-rays in 1895, which heralded the beginnings of nuclear medicine.

One of the major breakthroughs in biophysics came from work on radar, that evolved from much earlier developments in pure and applied physics. The electrical circuits that were developed were used to show that the flow of sodium and potassium across cell membranes triggers neurons to fire. More recently, biophysicists have brought expertise in laser physics to map cells in three dimensions, reveal bacteria in drinking water, and even cure bad breath.

Biophysicists are also involved in applying their knowledge of fundamental physics to develop and implement new techniques for analyzing organisms. Some of the most noteworthy are EM (Electron Microscopy), CAT (Computer-Aided Tomography), MRI (Magnetic Resonance Imaging), NMR (Nuclear Magnetic Resonance spectroscopy), PET (Positron Emission Tomography) and X-ray crystallography. Biophysicists may even facilitate the application of biological knowledge to problems in physics. For example, the DNA of salmon has been found to improve the performance of light emitting diodes, and studies of the shells of beetles are leading to whiter whites and micro-mirrors.

Why is Biophysics Useful?

Interest in biophysics is exploding as a result of a realization that biological phenomena cannot be understood fully without physical insight. Students undertaking studies in biophysics can have the satisfaction of becoming players in a real frontier of modern science with a vast potential for breakthroughs. What makes biophysics especially exciting is the diversity of applications.

At a macroscopic level, biophysicists are exploring how organisms develop and how they see, hear, taste, feel, and think. Also, they are examining activities such as movement, breathing, muscle contractions, and the operation of bones. Research along these avenues can have significant technological spinoffs, such as the development of better robots. At a microscopic level, biophysicists are studying how cells move and divide, how they harness and process energy, and how they react to external stimuli. Particularly interesting subjects include how a muscle cell converts the chemical energy of ATP into movement, how DNA can exactly replicate itself during cell division, and whether the shapes of nucleotides define a “second genetic code”. Spinoffs include the development of nanotechnology founded upon the unique mechanical and electrical properties of DNA. To facilitate their explorations, biophysicists are at the cutting edge of research aimed at developing new or improved techniques of imaging, diagnosis, and analysis.

Why Study Biophysics at York?

York University is one of only a few institutions which offer a comprehensive four-year undergraduate degree program in biophysics. The program is special because it is strong in both physics and biology, focused by courses dedicated to biophysics, and sufficiently broad in scope to expose students to knowledge and techniques applicable not only to humans but to all of the kingdoms of life.

Students acquire a theoretical and practical understanding of biology, physics and biophysics through both lecture-based and lab-based courses. Practical skills in mathematics and computing are developed by promoting applications to physical and biophysical problems. Powers of lateral thinking are enhanced through the mixing of physics and biology courses and the unification of material through biophysics courses. In the end, students learn to recognize biological problems that could benefit from physical insights as well as physical principles which might productively confront biological challenges. Most important, students gain the ability to think critically and to analyze and solve complex problems, talents that are in high demand in both the private and public sectors.

CAREERS

Because of the breadth of their training, biophysicists have a wide range of career options. Students are urged to visit the York University Biophysics website **www.biophysics.yorku.ca** for details. Areas in which a biophysics background can be useful include the environment, medicine, computing, fashion, aerospace, neuroscience, pharmaceuticals, energy, imaging, forensics, health, nanotechnology, robotics, agriculture, vision, and teaching. Job opportunities exist in both the private and public sectors. For example, l'Oreal has a biophysics unit working on skin and hair, and there is demand for biophysicists in many large and small biomedical companies as well as in public institutions such as hospitals. Biophysicists can contribute to the environmental sector because so many of the problems faced by life on Earth today have a physical root.

Many biophysics students may want to go on to more advanced programs of study before embarking on a career. For students whose ambition is to lead research, York's B.Sc. program is a logical starting point for graduate studies leading to a doctoral degree in biophysics. By carefully selecting options, the program can also be a lead-in to graduate studies in physics or biology. Biophysics is a highly regarded path towards a career in medicine. It is also a possible path to a career in optometry or dentistry. The degree provides outstanding preparation for careers in radiation therapy and other applied health sciences, such as offered by the Michener Institute.

Remember, we are here to help! If you require further advice, please feel free to contact our Office to arrange an appointment to discuss your situation further.

ENTRANCE REQUIREMENTS

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

ENG4U - 12U English (York University requirement)

SPH4U - 12U Physics

SBI4U - 12U Biology

MHF4U - 12U Advanced Functions

MCV4U - 12U Calculus and Vectors

SCH4U - 12U Chemistry is recommended, but not required for admission. Those students lacking 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 these requirements cannot become Biophysics 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 BIOL 1500 3.0, CHEM 1500 4.0, MATH 1510 6.0, MATH 1520 3.0 and/or PHYS 1510 4.0 before proceeding further.

DEGREE REQUIREMENTS

The Biophysics Program is an interdisciplinary 120-credit Specialized Honours degree program that leads to a B.Sc. (Spec. Hon.) in Biophysics. The focus of the program is to train students to recognize where and how to apply the laws and methods of physics to confront and understand biological problems.

1) The program core:

SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0 (or SC/BIOL 1010 6.0); SC/BIOL 2020 3.0; SC/BIOL 2021 3.0; SC/BIOL 2040 3.0; SC/BIOL 2070 3.0; SC/BPHS 2090 3.0; SC/BPHS 4080 3.0; SC/BPHS 4090 3.0; SC/CHEM 1000 3.0; SC/CHEM 1001 3.0; SC/MATH 1025 3.0; SC/MATH 2015 3.0; SC/MATH 2271 3.0; SC/PHYS 1010 6.00 or SC/PHYS 1410 6.00 or SC/PHYS 1420 6.00 with a grade of C or higher; SC/PHYS 1010 6.0; SC/PHYS 2010 3.0; SC/PHYS 2020 3.0; SC/PHYS 2030 3.0; SC/PHYS 2060 3.0; SC/PHYS 2213 3.0; SC/PHYS 3030 3.0; SC/PHYS 3040 6.0; SC/PHYS 4061 3.0.

2) Non-Science requirement: 12 credits

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 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:

www.science.yorku.ca/calendar/General-Education

3) Additional required courses:
SC/MATH 1013 3.0 and SC/MATH 1014 3.0; LE/EECS 1541 3.0

and

At least 9 credits from:
SC/PHYS 2040 3.0, SC/PHYS 3010 3.0, SC/PHYS 3020 3.0, SC/PHYS 3050 3.0, SC/PHYS 3090 3.0, SC/PHYS 3150 3.0, SC/PHYS 3220 3.0, SC/PHYS 3320 3.0, SC/PHYS 4010 3.0, SC/PHYS 4011 3.0, SC/PHYS 4020 3.0, SC/PHYS 4040 3.0, SC/PHYS 4050 3.0, SC/PHYS 4120 3.0;

and

At least 15 credits from:

SC/BIOL 2030 4.0, SC/BIOL 3010 3.0, SC/BIOL 3051 3.0, SC/BIOL 3060 4.0, SC/BIOL 3110 3.0, SC/BIOL 3120 3.0, SC/BIOL 3130 3.0, SC/BIOL 3150 4.0, SC/BIOL 3155 3.0, SC/BIOL 4030 3.0, SC/BIOL 4061 3.0, SC/BIOL 4141 3.0, SC/BIOL 4150 3.0, SC/BIOL 4151 3.0, SC/BIOL 4160 3.0, SC/BIOL 4380 3.0, BPHS 4310 3.0, SC/CHEM 2020 3.0, SC/CHEM 2021 3.0, SC/CHEM 4092 3.0, SC/CHEM 4093 3.0, HH/KINE 2031 3.0, HH/KINE 3012 3.0, HH/KINE 4455 3.0, HH/KINE 4470 3.0.

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 an overall total of at least 120 credits

Year 1 of 4

Course		Term	Prerequisites	Corequisites
BIOL 1000 3.0	Biology I: Cells, Molecular Biology and Genetics	F	12U Biology or BIOL 1500 3.0; 12U Chemistry or CHEM 1500 4.0	
BIOL 1001 3.0	Biology II: Evolution, Ecology, Biodiversity and Conservation Biology	W	BIOL 1000 3.0	
PHYS 1010 6.0	Physics	Y	12U Physics or PHYS 1510 4.0	MATH 1013 3.0 and MATH 1014 3.0, or MATH 1505 6.0
MATH 1013 3.0	Applied Calculus I	F	12U Calculus or MATH 1520 3.0	
MATH 1014 3.0	Applied Calculus II	W	MATH 1013 3.0 or MATH 1300 3.0	
MATH 1025 3.0	Applied Linear Algebra	F or W	12U Mathematics	
EECS 1541 3.0	Introduction to Computing for the Physical Sciences	W	MATH 1013 3.0	PHYS 1010 6.0 or PHYS 1410 6.0 or PHYS 1420 6.0; MATH 1021 3.0 or MATH 1025 3.0
6.0 non-science credits	Faculty of Science website			

Total = 30 credits

Year 2 of 4

Course		Term	Prerequisites	Corequisites
BPHS 2090 3.0	Current Topics in Biophysics	F	PHYS 1010 6.0 or both PHYS 1800 3.0 and PHYS 1801 3.0 or both ISCI 1301 3.0 and ISCI 1302 3.0 or one of PHYS 1410 6.0 or PHYS 1420 6.0; BIOL 1000 3.0 and BIOL 1001 3.0 or both ISCI 1101 3.0 and ISCI 1102 3.0	
BIOL 2040 3.0	Genetics	F or W	BIOL 1000 3.0 and BIOL 1001 3.0	
CHEM 1000 3.0	Chemical Structure	F	12U Chemistry or CHEM 1500 4.0	
CHEM 1001 3.0	Chemical Dynamics	W	12U Chemistry or CHEM 1500 4.0	
PHYS 2010 3.0	Classical Mechanics	W	PHYS 1010 6.0 or both PHYS 1800 3.0 and PHYS 1801 3.0 or both ISCI 1301 3.0 and ISCI 1302 3.0 or a minimum grade of C in one of PHYS 1410 6.0 or PHYS 1420 6.0; MATH 1014 3.0 and MATH 1025 3.0 and MATH 2015 3.0	MATH 2271 3.0
PHYS 2020 3.0	Electricity and Magnetism	F	PHYS 1010 6.0 or both PHYS 1800 3.0 and PHYS 1801 3.0 or both ISCI 1301 3.0 and ISCI 1302 3.0 or a minimum grade of C in one of PHYS 1410 6.0 or PHYS 1420 6.0	MATH 2015 3.0
PHYS 2060 3.0	Optics and Spectra	W	PHYS 1010 6.0 or both PHYS 1800 3.0 and PHYS 1801 3.0 or both ISCI 1301 3.0 and ISCI 1302 3.0 or a minimum grade of C in one of PHYS 1410 6.0 or PHYS 1420 6.0; MATH 1014 3.0 and MATH 1025 3.0	
PHYS 2213 3.0	Experimental Physics with Data Analysis	Y	PHYS 1010 6.0 or a minimum grade of C in one of PHYS 1410 6.0 or PHYS 1420 6.0	PHYS 2020 3.0 and PHYS 2060 3.0 recommended
MATH 2015 3.0	Applied Multivariate and Vector Calculus	F	MATH 1014 3.0 or MATH 1310 3.0	

MATH 2271 3.0	Differential Equations for Scientists and Engineers	W	MATH 2015 3.0 and MATH 1025 3.0	

Total = 30 credits

Year 3 of 4

Course		Term	Prerequisite	Corequisites
BPHS 4080 3.0[1]	Cellular Electrodynamics	W	BPHS 2090 3.0 or permission of instructor; PHYS 2020 3.0 and PHYS 2060 3.0	
or				
BPHS 4090 3.0[1]	Biophysical Techniques	W	BPHS 2090 3.0 or permission of instructor; PHYS 2020 3.0 and PHYS 2060 3.0	PHYS 3040 6.0
BIOL 2020 3.0	Biochemistry	F	BIOL 1000 3.0 and BIOL 1001 3.0; CHEM 1000 3.0 and CHEM 1001 3.0	
BIOL 2021 3.0	Cell Biology	W	BIOL 2020 3.0	
BIOL 2070 3.0	Research Methods in Cell and Molecular Biology	F or W	BIOL 1000 3.0 and BIOL 1001 3.0; CHEM 1000 3.0 and CHEM 1001 3.0	
PHYS 2030 3.0	Computational Methods for Physicists and Engineers	W	PHYS 1010 6.0 or both PHYS 1800 3.0 and PHYS 1801 3.0 or a minimum grade of C in one of PHYS 1410 6.0 or PHYS 1420 6.0; EECS 1541 3.0; MATH 1014 3.0 and MATH 2015 3.0	MATH 2271 3.0
PHYS 3030 3.0	Statistical and Thermal Physics	F	PHYS 2020 3.0 and MATH 2015 3.0 and MATH 2271 3.0	
PHYS 3040 6.0	Modern Physics	Y	PHYS 2010 3.0 and PHYS 2020 3.0 and PHYS 2060 3.0; MATH 1025 3.0 and MATH 2015 3.0 and MATH 2271 3.0	PHYS 3090 3.0 recommended
6 additional credits	See list below			

[1] Offered in alternate years

Total = 30 credits

Year 4 of 4

Course		Term	Prerequisite	Corequisites
PHYS 4061 3.0	Experimental Techniques in Laser Physics	F	PHYS 2213 3.0 and PHYS 2020 3.0 and PHYS 2060 3.0	PHYS 3040 6.0
BPHS 4090 3.0[1] OR BPHS 4080 3.0[1]	Biophysical Techniques	W	BPHS 2090 3.0 or permission from instructor; PHYS 2020 3.0 and PHYS 2060 3.0	PHYS 3040 6.0
	Cellular Electrodynamics	W	BPHS 2090 3.0 or permission of instructor; PHYS 2020 3.0 and PHYS 2060 3.0	
6.0 non-science credits	consult Faculty of Science website			
18 additional credits	See list below			

[1]Offered in alternate years

Total = 30 credits

Physics Options for 3rd and 4th year

At least 9 credits

Course		Term	Prerequisites	Corequisites
PHYS 2040 3.0	Relativity and Modern Physics	F	PHYS 1010 6.0 or both PHYS 1800 3.0 and PHYS 1801 3.0 or both ISCI 1301 3.0 and ISCI 1302 3.0 or a minimum grade of C in one of PHYS 1410 6.0 or PHYS 1420 6.0.	
PHYS 3010 3.0	Classical Mechanics	F	SC/PHYS 2010 3.00; SC/MATH 2015 3.00; SC/MATH 2271 3.00.	
PHYS 3020 3.0	Electromagnetics I	F	PHYS 2020 3.0 and MATH 2015 3.0 and MATH 2271 3.0	
PHYS 3050 3.0	Electronics I	F	PHYS 1010 6.0 and PHYS 2020 3.0 and PHYS 2213 3.0	
PHYS 3090 3.0	Methods in Theoretical Physics	F	PHYS 2020 3.0	PHYS 3040 6.0
PHYS 3150 3.0	Electronics II	W	PHYS 1010 6.0; PHYS 3050 3.0 recommended	
PHYS 3220 3.0	Experiments in Modern Physics	F	PHYS 2020 3.0 and PHYS 2060 3.0 and PHYS 2213 3.0	PHYS 3040 6.0
PHYS 3320 3.0	Microsystems Technology	W	PHYS 2020 3.0 and PHYS 2213 3.0; PHYS 2060 3.0 recommended	PHYS 3050 3.0 recommended
PHYS 4010 3.0	Quantum Mechanics	F	PHYS 3040 6.0	PHYS 3020 3.0
PHYS 4011 3.0	Atomic and Molecular Physics	W	PHYS 4010 3.0	
PHYS 4020 3.0	Electromagnetics II	W	PHYS 2040 3.0 and PHYS 3020 3.0	
PHYS 4040 3.0	Elementary Particle Physics	W	PHYS 2040 3.0 and PHYS 4010 3.0	
PHYS 4050 3.0	Solid State Physics	W	PHYS 3030 3.0 and PHYS 4010 3.0	
PHYS 4120 3.0	Gas and Fluid Dynamics	F	PHYS 2010 3.0 or EATS 2470 3.0 and both MATH 2015 3.0 and MATH 2271 3.0	

Life Science options for 3rd and 4th year

At least 15 credits

Course		Term	Prerequisites	Corequisites
BIOL 2030 4.0	Animals	F or W	BIOL 1000 3.0 and BIOL 1001 3.0	
BIOL 3010 3.0	Advanced Biochemistry	W	BIOL 2020 3.0 and CHEM 2021 3.0	
BIOL 3051 3.0	Macromolecules of Biochemical Interest	F	BIOL 2020 3.0 and CHEM 2021 3.0	
BIOL 3060 4.0	Animal Physiology I	F	BIOL 2020 3.0 and BIOL 2021 3.0 and BIOL 2030 4.0	
BIOL 3110 3.0	Molecular Biology I: Nucleic Acid Metabolism	F	BIOL 2020 3.0 and BIOL 2021 3.0 and BIOL 2040 3.0 and BIOL 2070 3.0	
BIOL 3120 3.0	Immunobiology	F or W	BIOL 2020 3.0 and BIOL 2021 3.0 and BIOL 2040 3.0 and BIOL 2070 3.0	
BIOL 3130 3.0	Molecular Biology II: Regulation of Gene Expression	W	BIOL 3110 3.0	
BIOL 3150 4.0	Microbiology	F or W	BIOL 2020 3.0 and BIOL 2021 3.0 and BIOL 2040 3.0 and BIOL 2070 3.0	
BIOL 3155 3.0	Virology	W	BIOL 2020 3.0 and BIOL 2021 3.0	
BIOL 4030 3.0	Proteomics	W	BIOL 3130 3.0	
BIOL 4061 3.0	Cell and Molecular Biology of Development	W	BIOL 2020 3.0 and BIOL 2021 3.0 and BIOL 2040 3.0 and BIOL 2070 3.0	
BIOL 4141 3.0	Current Topics and Methods in Cell Biology	F	BIOL 3130 3.0	
BIOL 4150 3.0	Cellular Regulation	F	BIOL 2020 3.0 and BIOL 2021 3.0 and BIOL 2070 3.0	BIOL 3010 3.0 and BIOL 3110 3.0 strongly recommended
BIOL 4151 3.0	Membrane Transport	F	BIOL 2020 3.0 and BIOL 2021 3.0	BIOL 3010 3.0 and BIOL 3110 3.0 strongly recommended

Course		Term	Prerequisites	Corequisites
BIOL 4160 3.0	Photosynthesis	not offered	BIOL 2021 3.0 and BIOL 2070 3.0	
BIOL 4380 3.0	Systems Neuroscience	W	BIOL 3060 4.0	
BPHS 4310 3.0	Biophysics Research Project	F or W or S	Permission of Program Director	
CHEM 2020 3.0	Introductory Organic Chemistry I	F or W	CHEM 1000 3.0 and CHEM 1001 3.0	
CHEM 2021 3.0	Introductory Organic Chemistry II	W	CHEM 2020 3.0	
CHEM 4092 3.0*	X-Ray Crystallography	F	CHEM 2011 3.0 and BIOL 3051 3.0	
CHEM 4093 3.0	Biomaterials Chemistry	W	BIOL 3051 3.0 or CHEM 3090 3.0	
KINE 2031 3.0	Human Anatomy	F	None	
KINE 3012 3.0	Human Physiology II	W	KINE 2011 3.0	
KINE 4455 3.0**	Movement Analysis Laboratory	W	KINE 3020 3.0 and KINE 3030 3.0	
KINE 4470 3.0**	Muscle and Joint Biomechanics	not offered	KINE 3030 3.0	

The Department of Chemistry is willing to give Biophysics Majors permission to enter CHEM 4092 3.0 without having the required prerequisites.

The School of Kinesiology is willing to give Biophysics Majors permission to enter the course without having taken the prerequisites.

ADVICE ABOUT OPTIONS AND ELECTIVES

Considerations Regarding Biology Courses

The Department of Biology strictly enforces pre-requisites and co-requisites for its courses. Students who register for a BIOL course without having taken any pre-requisite or co-requisite will ultimately be de-registered, possibly without warning.

Two of the most important biology courses in the Biophysics Program are BIOL 2020 3.0 (Biochemistry) and BIOL 2021 3.0 (Cell Biology), because they are pre-requisites for a large number of 3000- and 4000-level BIOL options. However, the Recommended Schedule for Completion in Four Years delays these two courses until 3rd year. This is because the pre-requisites CHEM 1000 3.0 and CHEM 1001 3.0 are delayed until 2nd year to enable Biophysics majors to avoid having to take three laboratory courses per semester in 1st year. An unfortunate consequence is that the range of life science options accessible to students in 3rd year is narrowed. To alleviate this problem without exceeding a normal credit load in any semester, students should consider one of the following:

Take CHEM 1000 and 1001 in 1st year instead of 6 non-science credits. This would free up space to take BIOL 2020 and 2021 in 2nd year, albeit with the penalty of having to do three lab courses per semester in 1st year. The 6 non-science credits could be made up any time after 2nd year.

Take CHEM 1000 and 1001 in the summer following 1st year. This would free up space to take BIOL 2020 and 2021 in 2nd year.

Take BIOL 2020 and 2021 in the summer following 2nd year.

Another important biology course in the Biophysics Program is BIOL 2070 3.0 (Research Methods in Cell and Molecular Biology), which is also a pre-requisite for some 3000- and 4000-level BIOL options. However, the Recommended Schedule for Completion in Four Years delays this course until 3rd year. Students who manage to take CHEM 1000 and 1001 before 2nd year ought to consider taking BIOL 2070 in 2nd year instead of 3rd year. To free up space to do so, PHYS 2010 3.0

(Classical Mechanics) could be delayed until 3rd year. Although PHYS 2010 is listed as a pre-requisite for PHYS 3040 6.0 (Modern Physics), it is feasible to wait to take PHYS 2010 until the winter semester of 3rd year if you are willing to do a bit of independent reading about the harmonic oscillator.

Considerations about Non-Science Courses

In meeting the non-science requirement, students must take care to select courses that are deemed “non-science” by the Faculty of Science. What may seem to be a non-science course may not be eligible. For example, Psychology 1000 is not eligible because it is too close to science, and introductory language courses are not eligible because of the risk that students who are already fluent will take them. To check what are eligible non-science courses, go to **www.science.yorku.ca/calendar/General-Education**

Considerations for Specializations within biophysics

Majors interested in **Applied Biophysics** should consider enrolling in the following elective courses:
PHYS 3020 3.0, PHYS 3050 3.0, PHYS 3150 3.0, PHYS 3220 3.0, PHYS 3320 3.0, PHYS 4040 3.0, PHYS 4050 3.0, PHYS 4120 3.0, BIOL 3060 4.0, BIOL 3120 3.0, BIOL 4030 3.0, BIOL 4141 3.0, BIOL 4151 3.0, BIOL 4160 4.0, CHEM 4093 3.0, KINE 2031 3.0, KINE 4455 3.0, KINE 4470 3.0.

Majors interested in **Structural Biology** should consider enrolling in the following elective courses:
PHYS 3020 3.0, PHYS 3090 3.0, PHYS 3220 3.0, PHYS 4010 3.0, PHYS 4011 3.0, BIOL 3010 3.0, BIOL 3051 3.0, BIOL 3110 3.0, BIOL 3130 3.0, BIOL 4030 3.0, CHEM 2020 3.0, CHEM 2021 3.0, CHEM 4092 3.0, CHEM 4093 3.0.

Considerations for Professional Schools

Majors contemplating a career in **Medicine** should take Organic Chemistry (CHEM 2020 3.0 and/or CHEM 2021 3.0) as options, as many Medical Schools require this material for admission (but not Ontario Medical Schools.)

Majors contemplating a career in **Optometry** (via the University of Waterloo) should take courses in English and Ethics as part of their general education credits, and should add courses in Psychology and Physiology.

Majors contemplating a career in **Applied Health Sciences** (e.g., via the Michener Institute) should take Human Anatomy (KINE 2031 3.0) and should add a course in Physiology.

Considerations for Graduate Studies

Many students who graduate from the Biophysics Program wish to continue on to graduate (M.Sc. or Ph.D.) or professional studies. The Program as structured provides excellent preparation for graduate degrees in Biophysics or Medical Physics as well as for professional degrees in Medicine or Applied Health Sciences. By carefully selecting options and adding a few courses as recommended below, students will also be well-prepared for graduate studies in Biology or Physics.

For advancement to graduate studies in Cell/Molecular Biology, the following courses are particularly important:

BIOL 3100 2.0 Current Topics in Biological Research

BIOL 3110 3.0** Molecular Biology I: Nuclei Acid Metabolism

BIOL 3130 3.0** Molecular Biology II: Regulation of Gene Expression

BIOL 3140 3.0 Advanced Biochemistry and Molecular Genetics Laboratory

Students should consult with the Department of Biology if they are considering specializing in other areas of biology at the graduate level.

For advancement to graduate studies in Physics (or Biological Physics in a Physics Program), the following courses are particularly important:

PHYS 3030 3.0* Statistical and Thermal Physics

PHYS 3090 3.0** Methods in Theoretical Physics

PHYS 4010 3.0** Quantum Mechanics

PHYS 3020 3.0** Electromagnetics I

PHYS 4020 3.0** Electromagnetics II

* Required course of Biophysics Program

** Specified option of Biophysics Program

WORKLOAD

The Biophysics Program is a 4-year path of study which leads to a B.Sc. (Honours) in Biophysics. A normal workload constitutes 5 full courses (30 credits) per year. A single credit is equated with one hour of classroom teaching per week over 13 weeks, or 3 laboratory hours per week for 13 weeks. A full course counts as 6 credits, and is typically three lecture hours per week for 26 weeks and may include a laboratory. The term “4-year” degree refers to a 120-credit program. 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 Biophysics 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.)

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

Repeated Courses: Check the Registrar's Office website for information: **http://calendars.registrar.yorku.ca/**

STANDARDS

To remain in the Biophysics 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 Academic Standards – Overall GPA Requirements

Fewer than 24 credits	4.0	Fewer than 84 credits	4.8
Fewer than 54 credits	4.25	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.

INTERNSHIPS

Students in the Biophysics Program have an opportunity to engage in workplace internships for up to four semesters (16 months) following their third year of study. In combination with advice from the Program, the Career Centre of York University coordinates internships through its Technology Internship Program (TIP), providing students with training and support in seeking internship positions and also overseeing their administration. Employers are motivated to hire students in the internship program because involvement in experiential education entitles them to tax benefits. Each work term completed successfully is noted officially by an entry on the student's transcript. Eligible students must be enrolled full-time in the Honours program prior to beginning their internship, have successfully completed at least 9 BPHS or PHYS credits at the 3000 level or higher, including SC/BPHS 3090 3.0, have an overall cumulative grade point average of at least 5.0 in BPHS, BIOL, and PHYS courses overall, must have at least 9 credits remaining to graduate, and have not been absent for more than two consecutive years as a full-time student from their Honours degree studies. Students interested in participating in the internship program should identify themselves to the Biophysics Program and to TIP at least one semester before the semester in which they would like to begin working. For more information, visit: **http://internships.yorku.ca/**.

OPPORTUNITIES FOR RESEARCH

There are a variety of opportunities for undergraduate students in the Biophysics Program to gain direct experience in research.

Natural Sciences and Engineering Research Council of Canada (NSERC)

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 available Work Study positions, visit **http://careers.yorku.ca/**.

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 **http://sfs.yorku.ca/employment/ray/** 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.

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** is awarded to one or two female students of Physics, Biophysics, Engineering Physics, Astronomy, and/or Chemistry (excluding Biochemistry) who have completed 84 credits towards an Honours BSc or BASc and have 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 is given for outstanding achievement in PHYS 1010 6.0 Physics to commemorate 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 is given 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** is given 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** is awarded to a student with at least a B+ average in two or more (science) astronomy courses, and has shown an interest in communicating science while at York University.

More information about the prizes and past winners can be found under the Undergraduate link on our website **http://www.physics.yorku.ca/index.php/undergraduate/awards** or the university website **http://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 **computing.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.

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:

Biophysics Club: **http://yorkuphysics.wix.com/biophysicsclub**

Astronomy Club: **http://astroatyork.wix.com/acyu**

Biological Society: **https://www.facebook.com/yorkubio/timeline**

Physics Society: **http://physicssocietyyu.wix.com/home**

Pre-Medical Society: **https://www.facebook.com/premedicalassociationatyork**

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, to undergraduate students in the Faculty of Science and Engineering, and to undergraduate students in the Faculty of Environmental Studies 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 **http://bethune.yorku.ca/advising/ or http://bethune.yorku.ca/sos/.**

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-Wurttemburg 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 **http://yorkinternational.yorku.ca/** for the latest options, as well as information session dates and application forms.

COURSE DESCRIPTIONS

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.

Reference: No Reference

Prerequisites: SC/PHYS 1010 6.0 or SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0; SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0, or SC/BIOL 1410 6.0.

One term. Three credits.

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 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 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.

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.

Reference: TBA

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 three-hour laboratory is an integral part of the course. Students will undertake several experiments covering topics such as the following: diffusion of bio-molecules (including electro-diffusion across membranes), action potentials, absorption of radiation and fluorescence of bio-molecules, NMR spectroscopy, X-ray crystallography to determine protein structure, and bioacoustics. The objective of the course is to help students to integrate the knowledge gained in third and fourth year biology and physics courses and to use methods and techniques of physics to study biological processes. The course is designed to be a capstone to the Biophysics Program.

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 3090 3.0; SC/PHYS 3040 6.0.

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.

BIOLOGY

BIOL 1000 3.0 - BIOLOGY I - CELLS, MOLECULAR BIOLOGY AND GENETICS

An introduction to major unifying concepts and fundamental principles of biology, including evolution and cell theory. Topics include cells, biological energetics, metabolism, cell division and genetics. The laboratory and lecture components must be passed independently to pass the course.

Reference: Course kit

Prerequisites: OAC Biology or 12U Biology or SC/BIOL 1500 3.0; OAC Chemistry or 12U Chemistry or SC/CHEM 1500 4.0.

Course Credit Exclusions: SC/BIOL 1010 6.0; SC/BIOL 1410 6.0.
One term. Three credits.
Three lecture hours per week; three laboratory hours in alternate weeks.

BIOL 1001 3.0 - BIOLOGY II: EVOLUTION, ECOLOGY, BIODIVERSITY AND CONSERVATION BIOLOGY

A continuation of Biology I, exploring major unifying concepts and fundamental principles of biology, building on earlier concepts. Topics include mechanisms of evolution, ecology, a survey of biodiversity and conservation biology. The laboratory and lecture components must be passed independently to pass the course.

Prerequisite: SC/BIOL 1000 3.0

Course credit exclusions: SC/BIOL 1010 6.0; SC/BIOL 1410 6.0.
Three lecture hours per week; three laboratory hours in alternate weeks.
One term. Three credits.

BIOL 2020 3.0 - BIOCHEMISTRY

A study of the cell biology and biochemistry of biomolecules. Topics include intermediary metabolism related to bioenergetics, including the biology of mitochondria and chloroplasts, protein structure and function, nucleic acid replication, gene expression, chromosome organization and recombinant DNA technology.

Reference: TBA

Prerequisites: Both SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0 or SC/BIOL 1010 6.0; both SC/CHEM 1000 3.0 and C/CHEM 1001 3.0, or SC/CHEM 1000 6.0.

Course Credit Exclusion: SC/BIOL 2020 3.0, SC/BCHM 2020 4.0, SC/CHEM 2050 4.0.

One term. Three credits.

Three lecture hours, three laboratory hours.

BIOL 2021 3.0 - CELL BIOLOGY

A study of cell biology and aspects of related biochemistry. Topics include membranes, the endomembrane system, the cytoskeleton, cellular motility, the extracellular matrix, intercellular communication and intracellular regulation.

Prerequisites: One of the following: One of the following: (1) SC/BIOL 2020 3.0, (2) SC/BCHM 2020 3.0, or (3) SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0 and SC/CHEM 2050 4.0.

Course credit exclusions: SC/BIOL 2021 3.0, SC/BCHM 2021 4.0.

Course Credit Exclusion: SC/BIOL 2021 3.0, SC/BCHM 2021 4.0.

Reference: TBA

One term. Three credits.

Three lecture hours, three laboratory hours.

BIOL 2030 4.0 - ANIMALS

A study of the diversity of animals, their structure, physiology and evolution.

Prerequisites: SC/BIOL 1010 6.0 or SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0.

Degree Credit Exclusion: SC/BIOL 2030 4.0, SC/BIOL 2031 3.0, SC/BIOL 2031 3.0.

One term. Four credits.

Three lecture hours, one tutorial hour.

BIOL 2040 3.0 – GENETICS

A study of the organization and behaviour of genes and chromosomes and their roles in cells, organisms, populations and evolution.

Reference: TBA

Prerequisites: Both SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0 or SC/BIOL 1010 6.0.
Degree Credit Exclusion: SC/BIOL 2040 3.0

One term. Four credits.
Three lecture hours, one tutorial hour.

BIOL 2070 3.0 - RESEARCH METHODS IN CELL AND MOLECULAR BIOLOGY

This course focuses on laboratory techniques in the life sciences. Practical research skills are developed through experiential learning using current biochemistry, cell and molecular biology techniques. Research skills include scientific writing, data analysis/interpretation, experimental design and hypothesis testing.

Reference: TBA

Prerequisites: SC/BIOL 1010 6.0, or SC/BIOL 1000 3.0 and SC/BIOL 1001 3.0; SC/CHEM 1000 3.0 and SC/CHEM 1001 3.0.

One term. Three credits.

One lecture hour, six laboratory/practical hours per week.

BIOL 3010 3.0 - ADVANCED BIOCHEMISTRY

A detailed discussion of enzyme structure and function. The chemistry and metabolism of biological molecules. Metabolic regulation at the level of enzyme activity. Knowledge of general concepts of metabolism and of basic aspects of enzyme structure and function is assumed.

Reference: TBA

2004* available in any recent, university level biochemistry texts.

Prerequisites: SC/BIOL 2020 3.0 or SC/BCHM 2020 4.0 or SC/CHEM 2050 4.0; SC/CHEM 2020 3.0.

One term. Three credits.

Three lecture hours.

* This text is recommended, but not strictly required. Most of the material will be

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BIOL 3051 3.0 - MACROMOLECULES OF BIOCHEMICAL INTEREST

A discussion of the structures and functions of naturally occurring macromolecules, including nucleic acids, proteins, polysaccharides and related macromolecular conjugates

Prerequisites: SC/CHEM 2020 6.0 and either SC/CHEM 2050 4.0 or SC/BCHM 2020 4.0 or SC/BIOL 2020 3.0.

Reference: TBA

One term. Three credits.

Three lecture hours.

BIOL 3060 4.0 - ANIMAL PHYSIOLOGY I

Fundamental concepts in sensory, neural and behavioural physiology. The biochemical mechanisms whereby nerve cells detect and transmit information and the processes whereby information is integrated in the nervous system and gives rise to the outputs of behaviour.

Reference: TBA.

Prerequisites: SC/BIOL 2030 4.0, SC/BIOL 2020 3.0, SC/BIOL 2021 4.0.

One term. Four credits.

Three lecture hours, three laboratory hours.

BIOL 3110 3.0 - MOLECULAR BIOLOGY I: NUCLEIC ACID METABOLISM

Discussion of the metabolism of DNA and RNA, including the physical-chemical properties of nucleic acids; DNA-protein interactions; chromosome structure; nucleic acid replication, repair and recombination; recombinant DNA technology.

Reference: TBA

Prerequisites: One of the following: (1) SC/BIOL 2020 3.0 or SC/BCHM 2020 4.0; SC/BIOL 2021 4.0 or SC/BCHM 2021 4.0; SC/BIOL 2040 4.0; (2) if the three credit course is taken in either one or more of SC/BIOL 2020 3.0, SC/BIOL 2021 3.0, SC/BIOL 2040, then SC/BIOL 2070 3.0 is required.

One term. Three credits.

Three lecture hours.

BIOL 3120 3.0 - IMMUNOBIOLOGY

The biology and chemistry of the immune response. Structure and function of antibodies; antibody diversity; anatomy and development of the immune system; cellular interactions; immunological responses in disease. Production and use of monoclonal and polyclonal antibodies.

Reference: TBA

Prerequisites: SC/BIOL 2020 3.0; SC/BIOL 2021 4.0; SC/BIOL 2040 4.0.

One term. Three credits.

Three lecture hours

BIOL 3130 3.0 - MOLECULAR BIOLOGY II: REGULATION OF GENE EXPRESSION

Gene structure and function. Mechanisms of gene expression in prokaryotes and eukaryotes. Storage and retrieval of genetic information; transcription, translation and their control.

Reference: TBA

Prerequisites: SC/BIOL 3110 3.0 or SC/BCHM 3110 3.0.

One term. Three credits.

Three lecture hours.

BIOL 3150 4.0 - MICROBIOLOGY

Fundamentals of microbiology; microbial organisms; microbe-host interactions; microbial genetics and evolution; microorganisms and human disease; environmental and applied microbiology.

Reference: TBA

Prerequisites: One of the following: (1) SC/BIOL 2020 3.0 or SC/BCHM 2020 3.0; SC/BIOL 2021 3.0 or SC/BCHM 2021 3.0; SC/BIOL 2040 3.0; (2) if the 3 credit course is taken in either one or more of SC/BIOL 2020 3.0, SC/BIOL 2021 3.0, SC/BIOL 2040 3.0, then SC/BIOL 2070 3.0 is required.

Course Credit Exclusion: SC/BIOL 3150 3.0.

One term. Four credits.

Three lecture hours, three laboratory hours.

BIOL 3155 3.0 - VIROLOGY

An in-depth examination of cellular, molecular and structural aspects of virology. Molecular processes and concepts are emphasized using examples from current research literature. Virus-host interactions are investigated in various systems.

Reference: TBA

Prerequisites: SC/BIOL 2020 3.0; SC/BIOL 2021 4.0.

One term. Three credits.

Three lecture hours per week.

BIOL 4030 3.0 - PROTEOMICS

Contemporary proteomic methodologies and applications. Specific topics: high-throughput methods, protein identification, protein complexes, structural proteomics, sub-cellular proteomics and molecular modeling.

Reference: TBA

Prerequisites: SC/BCHM 3110 3.0 or SC/BIOL 3110 3.0.

BIOL 4061 3.0 - CELL & MOLECULAR BIOLOGY OF DEVELOPMENT

This course presents a genetic and molecular biological approach to the field of developmental biology. Topics range from unicellular systems, both prokaryotic and eukaryotic, to more complex, multicellular systems.

Reference: TBA

Prerequisites: SC/BIOL 2020 3.0; SC/BIOL 2021 4.0; SC/BIOL 2040 4.0.
One term. Three credits.

Three lecture hours.

BIOL 4141 3.0 - CURRENT TOPICS AND METHODS IN CELL BIOLOGY

Selected topics in cell biology, such as membrane dynamics, cell cycle control, apoptosis, signal transduction and cellular rhythmicity. Presentation and critical discussion of recent research papers, emphasizing current methods and experimental design.

Reference: TBA

Prerequisites: SC/BIOL 3130 3.0.

Course credit exclusion: SC/BIOL 4140 3.0 from Fall/Winter 2002-2003 only.

One term. Three credits.

Three lecture hours.

BIOL 4150 3.0 - CELLULAR REGULATION

A detailed examination of molecular, cellular and physiological processes associated with the action of peptide hormones, neuro-transmitters and growth factors. Emphasis is on cell receptors and signal transduction mechanisms involving cyclic nucleotides and calcium.

Reference: TBA

Prerequisites: SC/BIOL 2020 3.0; SC/BIOL 2021 4.0; SC/BIOL 3010 3.0 and SC/BIOL 3110 3.0 strongly recommended as prerequisites or corequisites.

One term. Three credits.

BIOL 4151 3.0 - MEMBRANE TRANSPORT

The fundamental properties of solute transport are presented by discussing active ion pumps, passive transporters and ion channels of bacteria, plants and animals. The role of transport in regulating the intracellular environment in animals and plants is emphasized.

Reference: Course Kit

Prerequisites: SC/BIOL 2020 3.0; SC/BIOL 2021 4.0; SC/BIOL 3010 3.0 and SC/BIOL 3110 3.0 strongly recommended as prerequisites or corequisites.

One term. Three Credits.

Three lecture hours.

BIOL 4160 3.0 – PHOTOSYNTHESIS

A study of the process of photosynthesis at the biochemical, organelle and whole-organism levels, including structure of the photosynthetic apparatus, primary light-harvesting processes, electron transport; photophosphorylation, mechanism of carbon dioxide fixation in higher plants and algae, photorespiration.

Reference: TBA

Prerequisites: One of the following: (1) SC/BIOL 2021 4.0 or SC/BCHM 2021 4.0; (2) SC/BIOL 2021 3.0 or SC/BCHM 2021 3.0; SC/BIOL 2070 3.0.

One term. Three credits

Two lecture hours, three laboratory hours.

BIOL 4380 3.0 - SYSTEMS NEUROSCIENCE

This course investigates the neural basis of visual and auditory perception, echolocation, smell, short- and long-term memory, and motor control. Emphasis is on understanding how neural interactions analyze sensory information and control complex behaviour.

Reference: TBA

Prerequisites: SC/BIOL 3060 4.0.

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.

Reference: TBA

Prerequisites: OAC chemistry, 12U chemistry or SC/CHEM 1500 4.0 or equivalent.

Course Credit Exclusion: SC/CHEM 1000 6.0, SC/CHEM 1010 6.0.

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.

Reference: TBA

Prerequisites: OAC chemistry, 12U chemistry or SC/CHEM 1500 4.0 or equivalent.

Course Credit Exclusion: SC/CHEM 1000 6.0, SC/CHEM 1010 6.0.

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.

Reference: TBA

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

Course Credit Exclusion: 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.

Reference: TBA

Prerequisites: SC/CHEM 2020 3.0.

Course Credit Exclusion:
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.

Reference: TBA

Prerequisites: SC/CHEM 3030 3.0 or SC/CHEM 3030 4.0.
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.

Reference: TBA

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

One term. Three credits.

Three lecture hours.

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.

Reference: TBA

Prerequisites: SC/MATH 1013 3.0 or equivalent.

Corequisites: SC/PHYS 1010 6.0 or SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0; and SC/MATH 1021 3.0 or SC/MATH 1025 3.0.

Course Credit Exclusions: LE/SC/CSE 1560 3.0, LE/SC/CSE 1570 3.0.

One Term. Three credits.

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

MATHEMATICS & 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.

Reference: TBA

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

Course Credit Exclusion: 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.

Prior to Fall 2009

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

Course credit exclusions: AS/SC/MATH 1000 3.0, AK/AS/SC/MATH 1300 3.0, AS/SC/MATH 1505 6.0, AS/SC/MATH 1513 6.0, AS/MATH 1530 3.0, AK/AS/MATH 1550 6.0, GL/MATH/MODR 1930 3.0, AS/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.

Reference: TBA

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 Exclusion: SC/MATH 1010 3.0, SC/MATH 1310 3.0,

SC/MATH 1505 6.0, GL/MATH/MODR 1940 3.0.

Prior to Fall 2009

Prerequisites: One of AS/SC/MATH 1000 3.0, AS/SC/MATH 1013 3.0, AK/AS/SC/MATH 1300 3.0, or AS/SC/MATH 1513 6.0; for non-science students only, six credits from AS/MATH 1530 3.0 and AS/MATH 1540 3.0, AK/AS/MATH 1550 6.0, AS/ECON 1530 3.0 and AS/ECON 1540 3.0. **Course credit exclusions:** AS/SC/MATH 1010 3.0, AK/AS/SC/MATH 1310 3.0, AS/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.

Reference: TBA

Prerequisites: One 12U or OAC mathematics course or equivalent.
Course Credit Exclusion: SC/MATH 1021 3.0, SC/MATH 2021 3.0, SC/MATH 2221 3.0, GL/MATH/MODR 2650 3.0.

Prior to Fall 2009

Course credit exclusions: AK/AS/SC/MATH 1021 3.0, AS/SC/MATH 2021 3.0, AK/AS/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.
Reference: TBA

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 Exclusion: SC/MATH 2010 3.0, SC/MATH 2310 3.0, GL/MATH/MODR 2670 3.0, GL/MATH 3200 3.0.

Prior to Fall 2009

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

Course credit exclusions: AS/SC/MATH 2010 3.0, AK/AS/SC/MATH 2310 3.0, GL/MATH/MODR 2670 3.0, GL/MATH 3200 3.0
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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.

Reference: TBA

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 Exclusion: SC/MATH 2270 3.0, GL/MATH 3400 3.0.
Prior to Fall 2009

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

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

One term. Three credits.

Three lecture hours per week.

KINESIOLOGY

KINE 2031 3.0 - HUMAN ANATOMY

An overview of the organization and structure of the human body. Each of the following systems is examined with respect to cell morphology, cell and tissue arrangement and inter-systems organization: skeletal, muscular, nervous, circulatory, lymphatic, respiratory, urinary, reproductive and endocrine.

Reference: TBA

Course Credit Exclusions:
AS/SC/KINE 3070 3.0.

Prior to Fall/Winter 1997-1998
AS/SC/PHED 2070 3.0

Prior to Fall/Winter 1996-1997

SC/PHED 2070 4.0

Prior to Fall/Winter 1996-1997
AS/PHED 3070 3.0

Prior to Fall/Winter 1996-1997
SC/PHED 3070 4.0

Prior to Fall/Winter 1996-1997
SC/NATS 1650 6.0

One term. Three credits.

Three lecture hours per week, two laboratory hours in alternate weeks.

KINE 3012 3.0 - HUMAN PHYSIOLOGY II

The principles of homeostasis and physiological regulation are studied in relation to the cardiorespiratory, renal, locomotor, reproductive and digestive systems. Laboratory work is an essential part of the course.

Reference: TBA

Prerequisite: AS/HH/SC/KINE 2011 3.0 or AS/HH/SC/KINE 3011 3.0. Introductory biology or life science is highly recommended.

Course credit exclusions:
AS/SC/KINE 3070 3.0 (prior to Fall/Winter 1997-1998), AS/SC/PHED 2070 3.0 (prior to Fall/Winter 1996-1997), SC/PHED 2070 4.0 (prior to Fall/Winter 1996-1997), AS/SC/PHED 3010 3.0 (prior to Fall/Winter 1996-1997), SC/PHED 3010 4.0 (prior to Fall/Winter 1996-1997), AS/PHED 3070 3.0 (prior to Fall/Winter 1996-1997), SC/PHED 3070 4.0 (prior to Fall/Winter 1996-1997).

One term

Three lecture hours per week, two laboratory hours in alternate weeks.

Course Credit Exclusions:
AS/SC/KINE 3070 3.0.

KINE 4455 3.0 - MOVEMENT ANALYSIS LABORATORY

This course focuses on the theory and practice of methods for analyzing the mechanics and control of movement. Methods include collection and analysis of biological signals such as electromyography and evoked potentials, as well as techniques for both kinematic and kinetic analysis of movement.

Reference: TBA

Prerequisite: AS/HH/SC/KINE 3020 3.0, AS/HH/SC/KINE 3030 3.0.

Course Credit Exclusions: None
Two lecture hours and two lab hours per week. One term.

KINE 4470 3.0 - MUSCLE AND JOINT BIOMECHANICS

Quantitative biomechanical principles are used to evaluate the production of human motion at the joint and muscle level. Factors affecting total joint moment of force are studied including muscle mechanics, muscle architecture, moment arm and electrophysiology.

Reference: TBA

Prerequisite: AS/HH/SC/KINE 3030 3.0

Course Credit Exclusions: Prior to Fall/Winter 2003-2004 AS/SC/KINE 3470 3.0

One term

Two lecture hours and two laboratory hours per week.

PHYS 1010 6.0 - PHYSICS

Topics include linear, rotational and oscillatory motion; Newtonian mechanics; gravitation; electrostatics; magnetostatics; electric current and induction; heat; geometrical and physical optics and sound. Differential and integral calculus and vector algebra are used. This course covers fewer topics than SC/PHYS 1410 6.0, but covers them in greater depth. It should be taken by all those likely to enrol in 2000-level physics courses. Includes three hour laboratory component normally in alternating weeks.

Content:

1. Motion in one, two and three dimensions
2. Newton's laws
3. Work, energy, power
4. Momentum
5. Torque and rotational motion
6. Angular momentum
7. Oscillations
8. Gravitation
9. Thermodynamics
10. Static electricity
11. Capacitance
12. DC circuits
13. Magnetic fields
14. Electromagnetic induction
15. Waves and sound
16. Electromagnetic waves
17. Physical and geometrical optics

In addition, some concepts of modern physics are introduced interspersed throughout.

Reference: TBA

Prerequisites: OAC Physics or 12U Physics or SC/PHYS 1510 4.0.

Corequisites: SC/MATH 1013 3.0 and SC/MATH 1014 3.0, or SC/MATH 1505 6.0, or equivalents.

Course Credit Exclusion: SC/PHYS 1410 6.0 and SC/PHYS 1420 6.0.

Two terms. Six credits

Three lecture hours per week in both terms; three laboratory hours in alternate weeks in both terms; one tutorial hour each week in both terms.

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 Central forces: applications to celestial mechanics
5. Systems of particles – Centre of mass and angular momentum
6. Moment of inertia and rigid-body rotation

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

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/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

Prior to Fall 2010

Prerequisites: SC/PHYS 1010 6.0, or a minimum grade of C in SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0; AS/SC/MATH 1014 3.0 or equivalent; AS/SC/MATH 1025 3.0 or equivalent;

Corequisite: SC/MATH 2015 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.

Topics to be covered:

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: Purcell & Morin, 3rd ed., Cambridge University Press.

Prerequisites: SC/PHYS 1010 6.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0or SC/ISCI 1301 3.0 and SC/ISCI 1302 3.0 or a minimum grade of C in SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0.

Corequisite: SC/MATH 2015 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.
Corequisite: AS/SC/MATH 2015 3.00.

One term. Three credits.

Three lectures hours per week. One tutorial hour per week

PHYS 2030 3.0 - COMPUTATIONAL METHODS FOR PHYSICISTS AND ENGINEERS

The symbolic and numeric computing environments provided by Maple and MATLAB are used to solve problems in Mechanics and Electromagnetism.

Content:
This course provides a practical introduction to symbolic and numeric computing methodologies for solving real problems in science and engineering. Examples and exercises including radioactive decay, oscillatory motion and chaos, orbit and trajectory analysis, quantum mechanics and vibrations and waves of musical instruments are developed from the course text and implemented in the MATLAB programming environment. MATLAB's Simulink and Maple toolboxes are utilized for time-dependent numerical simulation and symbolic manipulation respectively.

1. Introduction to MATLAB, Simulink and Maple
2. Solving symbolic problems in Calculus
3. Numerical simulation: modeling time-dependent problems
4. Monte-Carlo simulation: integral solutions by numerical search
5. Bayesian probability: estimating probability density functions and modeling uncertainty
6. Function optimization, solution searches, guesswork and practical estimation theory

Reference: J. N. Kutz, Data-driven Modeling & Scientific Computation, Oxford University Press: 2013.

Prerequisites: SC/PHYS 1010 6.0, or SC/PHYS 1800 3.0 and SC/PHYS 1801 3.0, or a minimum grade of C in SC/PHYS 1410 6.0 or SC/PHYS

1420 6.0; either LE/EECS 1011 3.0 or LE/EECS 1541 3.0; SC/MATH 1014 3.0 or equivalent; SC/MATH 2015 3.0 or equivalent.

Corequisite: SC/MATH 2271 3.0 or equivalent.

Prior to Fall 2016
Prerequisites: SC/PHYS 1010 6.0 or a minimum grade of C in SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0; One of LE/EECS 1020 3.0, LE/EECS 1540 3.0; SC/MATH 1014 3.0 or equivalent.

Corequisite: SC/MATH 2015 3.0 or equivalent.

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.

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.

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

One term. Three credits.

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

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.

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.

References: E. Hecht, Optics, Addison Wesley Publications; 1979
F. Pedrotti, L. Pedrotti, Introduction to Optics, 2nd ed. Prentice-Hall; 1993.

Prerequisites: SC/PHYS 1010 6.0 or a minimum grade of C in SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0; MATH 1014 3.0 or equivalent; SC/MATH
1025 3.0 or equivalent.

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/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 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:

<u>Experiments:</u>

1. Classical Hall Effect
2. Coulomb's Law
3. Motion of electrons in electric and magnetic fields
4. Simple DC circuits
5. The Biot Savart Law
6. Earth's magnetic field
7. Force on a current carrying wire placed in a magnetic field
8. Faraday's Law
9. RC and RL circuits
10. Electrical resonance
11. Photoelectric effect

12. Fourier analysis
13. Lenses
14. Diffraction of light
15. Michelson Interferometer
16. Microwaves
17. Fabry-Perot Interferometer
18. Polarization of light
19. Acousto-optic effect
20. Spatial profile of a laser beam

Lectures:

1. Precision and accuracy, estimating uncertainties, reporting discrepancies, significant figures
2. General formulae for error propagation
3. Characteristics of a histogram of data – mean, standard deviation and standard deviation of the mean
4. Estimation of random and systematic errors
5. Properties of the Gaussian distribution
6. Addition of errors in quadrature
7. Weighted averages and criterion for rejection of data
8. Least squares fitting – straight line and other functions
9. Statistics of spontaneous decays (e.g. radioactivity)
10. Chi-Squared tests for discrete and continuous variables

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

Prerequisite: SC/PHYS 1010 6.0, or a minimum grade of C in SC/PHYS 1410 6.0 or SC/PHYS 1420 6.0.
Corequisite: SC/PHYS 2020 3.0; SC/PHYS 2060 3.0 recommended.

Degree credit exclusion: SC/PHYS 2211 1.0 and SC/PHYS 2212 1.0.

Two terms. Three credits.

Three laboratory hours per week, one lecture hour every two weeks.

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 magnetic 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 moleculesEquipartition theorem, kinetic theory of gases, transport properties

6. 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 & non-stationary 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.

Corequisite: SC/PHYS 3090 3.0 recommended.
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.

References: 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.

Course credit exclusion: SC/ENG 2200 3.0.
One term.
Two lecture hours, three laboratory hours.

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.

Content:

1. Coordinate systems appropriate for physical symmetries
2. Basic fluid flow: vectors, divergence, gradient, and curl
3. Fluid flow using complex variables
4. Dynamics, forces, and specific differential equations
5. Vibrating strings, quantum waves, and Fourier series
6. Vibrating membranes, heat flow, and Bessel functions
7. Fourier transforms and power spectra, such as for time-varying phenomena
8. Laplace transforms and physical modelling, such as for electric circuits and control analyses

Reference: TBA

Prerequisite: SC/PHYS 2020 3.0

Corequisite: SC/PHYS 3040 6.0
One term. Three credits.

Three lecture hours per week.

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.

References: 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.

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

Course Credit Exclusion: LE/SC/ENG 2210 3.0

Prior to Summer 2013

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

Course credit exclusion: SC/ENG 2210 3.0

One term. Three credits.

Two lecture hours, three laboratory hours.

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 write-ups 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.

Prerequisite: 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 3320 3.0 - MICROSYSTEMS 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. Radiation Detection: Interaction of radiation (e.g. X-ray, ionizing radiation) with matter; radiation sensors (large area, space applications)
6. Thermal Microsystems: Review of heat transfer mechanisms; transduction principles; thermal sensors (junction bases sensors, thermo-mechanical and –resistive sensors); thermal imaging (IR image sensors); thermal actuators (e.g. Peltier cooler)
7. Magnetic Microsystems: Magnetic sensors (magnetoresistive, magnetostrictive, Hall effect); magnetic actuators (e.g. RF passive components, read/write heads)
8. Chemical and Fluidic Microsystems: Chemical sensors (e-nose); fluidic sensors (flow sensors)

Reference: No Reference

Reference: 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 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 mechanics
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.

Prerequisite: SC/PHYS 3040 6.0

Prerequisites or Corequisites:

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.

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, non-degenerate 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, Quantum Mechanics. Addison Wesley; 1998. C. Cohen-Tannoudji, Quantum Mechanics, Vol 2. John Wiley and Sons; 1992.

Reference: R. Liboff, Introductory Quantum Mechanics, 4th ed. Addison-Wesley Publications; 2002.
Prerequisite: 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 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.

References: 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; electrical conductivity; thermal conductivity, band theory of solids: Kronig–Penny model;

effective mass; conductors, insulators, semi–metals, and semi–conductors; holes; magnetic properties

6. Superconductivity: BCS theory (Introduction only)

Reference: C. Kittel, Introduction to Solid State Physics, 8th ed. John Wiley and Sons; 2005.

References: 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 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

Reference: Course Kit

Recommended Texts:

Atomic Physics

1) B. H. Bransden, C. J. Joachain, Physics of Atoms and Molecules (Longman).

2) A. Corney, Atomic and Laser Spectroscopy (Oxford).

Lasers
1) A. E. Seigman, Lasers (University Science Books).
2) O. Svelto, Principles of Lasers (Plenum).
3) D. C. O'Shea, W. R. Callen, W. T. Thodes, Introduction to Lasers and Their Applications (Adison-Wesley).
4) R. S. Quimby, Photonics and Lasers (Wiley).

5) C. C. Davis, Lasers and Electro-Optics (Cambridge).

Optics
1) E. Hecht, Optics (Addison Wesley).
2) Pedrotti and Pedrotti, Introduction to Optics (Prentice Hall).
3) G. R. Fowles, Introduction to Modern Optics (Dover).
4) M. Mansuripur, Classical Optics (Cambridge).

Error Analysis
1) J. R. Taylor, An Introduction to Error Analysis (University Science Books).

General Interest

1) D. W. Preston and E. R. Dietz, The Art of Experimental Physics (Wiley).

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, SC/MATH.

Corequisites: SC/PHYS 3040 6.0
One term. Three credits
Includes two three hour laboratory sessions 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:

2) Introduction: basis of continuum model, pressure isotropy, compressibility, viscosity
3) Mass, momentum, and energy conservation equations
4) Hydrostatics
5) Velocity potential, vortex motion, stream function
6) Potential flows of incompressible fluid in two and three dimensions
7) Viscous incompressible flows: Navier–Stokes equation, solutions for pipe and channel flows, laminar and turbulent boundary layers
8) 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.

Prior to Summer 2013:

Prerequisites: SC/PHYS 2010 3.0 or SC/EATS 2470 3.0; AS/SC/MATH 2015 3.0; AS/SC/MATH 2271 3.0.

Prior to Fall 2009:

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

One term. Three credits

Three lecture hours per week

DEPARTMENT OF PHYSICS AND ASTRONOMY DIRECTORY

128 Petrie Science and Engineering Building (PSE)
4700 Keele Street, Toronto, ON M3J 1P3
Tel: 416-736-5249
www. biophysics.yorku.ca
www.physics.yorku.ca
Follow us as @YorkUPhysics on Twitter: https://twitter.com/YorkUPhysics

Departmental Chair	M. McCall	125 PSE	chphas@yorku.ca
Biophysics Undergraduate Program Director	M. McCall	125 PSE	chphas@yorku.ca
PHAS Undergraduate Program Director	M. Horbatsch	229 PSE	phasupd@yorku.ca
Graduate Program Director	T. Kirchner	228 PSE	phasgpd@yorku.ca
Administrative Assistant	C. Del Biondo	125 PSE	delbiond@yorku.ca
Undergraduate Program Assistant	J. DeCamillis	128 PSE	phas@yorku.ca

Faculty **☎ York University** **Telephone No: (416) 736-2100**

Name	Office	Ext ☎	Research Field	Email
Bartel, N.	331 PSE	55424	AA, PP	bartel@yorku.ca
Bergevin, C*	240 PSE	60356	BP	cberge@yorku.ca
Bhadra, S.	235 PSE	22470	HEP	bhadra@yorku.ca
Delaney, P.**	329 PSE	77763	AA	pdelaney@yorku.ca
De Robertis, M.	326 PSE	77761	AA	mmdr@yorku.ca
Hall, P.	337 PSE	77752	AA	phall@yorku.ca
Hessels, E.	201 PSE	33040	AMO	hessels@yorku.ca
Horbatsch, M.	229 PSE	77747	AMO, HEP	marko@yorku.ca
Jerzak, S.	223 PSE	44102	CCM	jerzak@yorku.ca
Johnson, M. *	322 PSE	33747	AA, HEP	matthewj@yorku.ca
Kirchner, T.	228 PSE	33695	AMO	tomk@yorku.ca
Koniuk, R.	219 PSE	66480	HEP	koniuk@yorku.ca
Kumarakrishnan, A.	252 PSE	77755	AMO	akumar@yorku.ca
Lewis, R.	223 PSE	22759	HEP	randy.lewis@yorku.ca
McCall, M.	334 PSE	33773	AA	mccall@yorku.ca
Menary, S.*	237 PSE	22982	HEP	menary@yorku.ca
Mermut, O.	244 PSE	33452	BP	omermut@yorku.ca
Muzzin, A	338 PSE	33175	AA	muzzin@yorku.ca
Quine, B.	256 PSE	33483	PP	bquine@yorku.ca
Storry, C.	253 PSE	77756	AMO	codys@yorku.ca
Taylor, W.	239 PSE	77758	HEP	taylorw@yorku.ca
Tulin, S.	217 PSE	33504	HEP	stunlin@yorku.ca
van Wijngaarden, W.	247 PSE	77750	AMO	wlaser@yorku.ca

*Sabbatical July 2018- June 2019
** Sabbatical January 2019 – June 2019

Research Fields

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