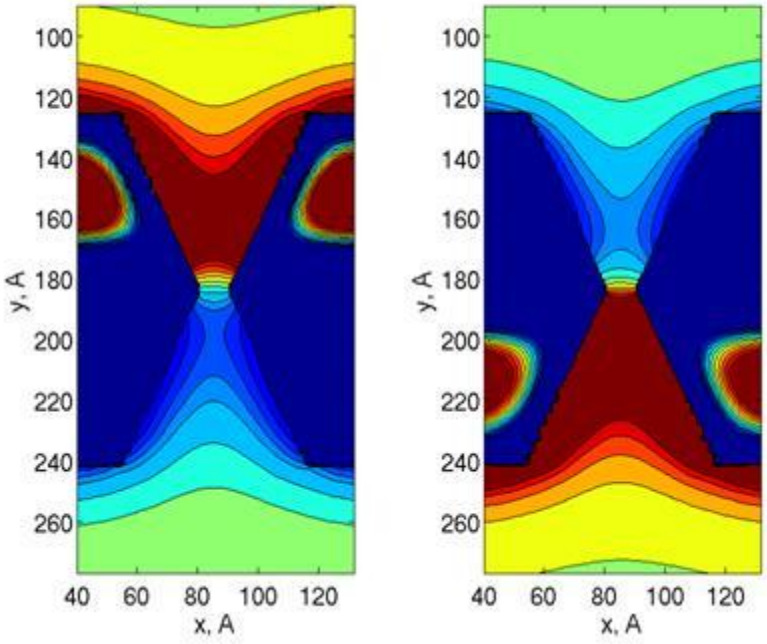
Clarkson UNIVERSITY defy convention™

Physics at Clarkson



Charge distribution in a double-layered n-p semiconductor membrane with a nanopore, immersed in an electrolyte: (Left) Negative and (Right) positive charges in the solid-state materials and the electrolyte.
Photo Courtesy of Professor Maria Gracheva

Undergraduate Handbook

PHYSICS AT CLARKSON

THE PHYSICS PROFESSION

Why study Physics?

The world is full of experiences that cry out for explanation. Think, for example, of the colors of the rainbow and soap bubbles, the vapor trails of high flying aircraft, the fact that liquid water abruptly changes into solid ice at a certain temperature, the production of lightning and the thunder that follows it in a storm, the beautiful hexagonal symmetry of small snowflakes; all this, and a limitless list of other phenomena, fall within the province of Physics. The essence of Science in general is the observation and exploration of the world with a view to identifying some underlying order in what we find. Physics is that part of science, which deals primarily with the inanimate world, and is concerned with identifying its fundamental and unifying principles. Physics is also fun and exciting.

What can you do with a degree in Physics from Clarkson?

Obviously, you can become a physicist. But that's not all. Because of the flexibility in our curriculum, your opportunities are more extensive. With your degree in Physics, you can go directly into business, industrial, or governmental employment, as a design, research, quality control, or development scientist or engineer.[1] You may also go into the teaching profession. If you want to continue your higher education, you can enter graduate school not only in Physics, but also in Mathematics, Chemistry, Engineering, Business Administration or you can continue in a professional program such as Medicine, Dentistry, Physical Therapy, or Law.

PHYSICS PROGRAMS AND OPTIONS AVAILABLE

Structure of the Physics program at Clarkson

The University requires 120 credit hours (about 40 courses) for graduation. Many of these are electives, permitting design of individual concentrations to match your needs and interests. Four options of concentration are offered: (1) Physics (the core option), (2) Engineering Physics, (3) Biological Physics (which covers all the academic requirements for Pre-Med) and (4) Materials Science. In each case, Physics (or equivalent) courses make up 35 credit hours. For students transferring into the Department of Physics, suitable Engineering and Science courses are accepted as equivalent to required Physics courses. Similar arrangements are made for students double majoring with Physics. The four Physics programs are outlined later in this section. Check out the Physics Department's web site for information on these programs:
http://www.clarkson.edu/physics/

A faculty member of the Physics Department will be assigned to you as your academic advisor. The advisor will help with your academic needs for the duration of your

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[1] Recent employment data for physics graduates can be found on the American Institute of Physics Web Site: *http://www.aip.org/statistics/trends/emptrends*

studies at Clarkson. Starting from selection of courses, to applying for graduate schools or jobs, you can consult your advisor at any time regarding your career plans. In your first year at Clarkson, you will be enrolled in a Freshman Seminar course. This is a one-hour meeting every week where you are introduced to all the members, activities, research projects, and facilities of the department.

Major emphasis in the Physics curriculum is placed on undergraduate research. All faculty members are actively engaged in research in support of the Physics graduate program (offering M.S. and Ph.D. degrees). Early in their undergraduate careers, students are encouraged to participate in research. Usually students identify research projects in their areas of concentration and continue to work on the project until graduation (following essentially the pattern of graduate work). Frequently their research leads to publication in internationally recognized scientific journals.

► Physics - The Core Option

This is our broadest and most flexible option. This also is the most suitable option for pursuing a *Double Major* program within four years. It is suited for both those who want an intensive and focused Physics program and those who wish to diversify in areas not covered by our other concentrations. Those pursuing the Physics core program will typically be heading for graduate school in Physics or for careers as Science teachers. Other students may want to exploit the flexibility and large number of electives in this program to follow other interests or to develop double majors. A sample curriculum is provided later in this booklet.

► Concentration Options

Engineering Physics

The Engineering Physics option affords excellent training for careers at the forefront of technology, where basic knowledge of science complements engineering expertise to develop unique devices and systems. This option is also ideal for those unsure of which science or engineering areas they wish to enter. A detailed list of courses will be developed between the student and their advisor. Electives are spread among Physics, Mathematics, and Engineering courses tailored to the individual's special interests and career objectives. For a sample curriculum, see the last section of this booklet.

Biological Physics (including Pre-Med)

The Biological Physics option offers Physics majors an early focus in their curriculum. To solve outstanding problems of biotechnology, a synthesis of several disciplines is needed. Consequently, Biological Physics has become one of the most rapidly growing areas of physical sciences. In addition to basic courses in Physics, students will be offered a solid foundation in Biology, including laboratory experience. Biological Physics is also an area of research in the department. This program covers all the academic requirements needed to enter a medical school. A detailed list of courses will be developed between the student and their advisor. For a sample curriculum, see the last section of this booklet.

Materials Science

The Materials Science option is designed for students interested in the study of materials with technological applications. Building on a firm foundation in Physics and Mathematics, students concentrate electives in materials-specific areas such as metallic materials, ceramics, polymeric materials, and electronic materials. A detailed list of courses will be developed between the student and their advisor. Electives are drawn from the Departments of Chemistry, Chemical Engineering, Electrical Engineering, and Mechanical Engineering. Materials Science students benefit from the resources and expertise available through Clarkson's Center for Advanced Materials Processing—New York State Center for Advanced Technology. Consult with your advisor to learn more about the Materials Science Concentration in Physics.

► Physics Team Design Program

The Physics Team Design Program is centered around an advanced laboratory experience where students are taught mathematical modeling skills and analytical thinking as it applies to some special projects. For a physicist, mathematical modeling is the name of the game! These projects are group-oriented projects that cover such topics as modeling the motion of a toy car (on a long and adjustable track) and modeling the motion of an electric train (powered by a charged capacitor). Although the subject matter covers the physics of toys, the actual projects are quite challenging and structured to be competitive! Teams of four students typically work for a period of 10-12 weeks before entering into the *Challenge Sessions*, a series of competitive challenges and obstacles that must be carefully examined to insure success. The *Challenge Sessions* provide a grand finale to the semester long project with a fun but competitive atmosphere.

► Three-Year Accelerated Degree Program

The three-year program is available to students who enter Clarkson University with excellent preparation from high school. The challenging pace of this program will require harder work and special dedication. Students will have the opportunity to complete their degree in a shortened time span, realizing savings in educational costs, and enter the job market a year earlier.
Students are expected to earn 108 credits by taking on average six courses per semester. The remaining 12 credits would be drawn from a combination of advanced placement (AP) credits from high school and coursework taken during summer sessions. The student must sign up to enter in this program.

► Minor in Physics

For those majoring in other fields, having an interest in Physics, and wishing this to be recognized on their transcript, the ***Physics minor*** program is an option. The 24-credit course of study for this option is described in the last section of this booklet. A minimum 2.0 average must be maintained in these courses and none can be designated pass/no entry.
The minor should be initiated by the beginning of the Junior year to allow time to complete the necessary coursework.

► Student-Faculty Interactions

The student-to-faculty ratio in our undergraduate physics program typically stays around 5:1. This promotes an informal, relaxed atmosphere for learning. The small class size allows each student to get close attention from the instructor. You can approach any of the professors, not just your academic advisor, for advice. This way, often through informal conversations, you can learn about each professor's research subject. It often happens that you can get involved in this research in a meaningful way and our faculty is always on the lookout for aspects of their research in which undergraduates can contribute. Several of our students have benefited from the program "Research Experiences for Undergraduates" (REU) funded by the National Science Foundation.

► Choosing Your Post-Graduation Career

The Clarkson Career Development Center helps you find prospective employers and arranges for on-campus interviews with them. More importantly, throughout your four years at Clarkson, Physics faculty members can be called on to help you design your future professional career.

It is likely that by the end of your junior year at Clarkson (after being exposed to significant amounts of course material and research work) you will develop a taste for a certain type of career. Our professors can help you examine the "real-world situation" of the profession you like. They can guide you in choosing the graduate schools (if you decide on graduate studies) suitable for you and your interests. They can also help you prepare for the GRE (Graduate Record Examination: it is similar to the SAT but it is on the material you learn in college and it applies to your admission to a graduate program). The GRE is offered internationally. Therefore, even if you do not choose to attend a graduate school, your GRE score may serve as an indicator of your academic standing on an international scale. Our Physics Department will provide you with sample GRE tests from the past and information on the various Physics graduate programs in the country.

► Double Major Opportunities

The core Physics curriculum is flexible and allows for multidisciplinary studies. Free and concentration electives sum up to 28 credits. This allows Physics majors to double major in other fields. Recent popular choices have included Computer Science, Mathematics, as well as Computer, Electrical and Mechanical Engineering. For illustration, a sample curriculum is included in the last section of this booklet, for a double major in Physics and Computer Science.

PHYSICS EXPERIENCE

► Extracurricular Activities

You probably already know about the various fun activities and sports events at Clarkson (see the Clarkson web site**:** *http://www.clarkson.edu*). In addition to these, the Physics Department offers a number of extracurricular activities. The Clarkson Physics Club is run entirely by students. It sponsors student projects and oversees operation of the Clarkson Observatory. This is a motorized, revolving dome on the outskirts of Potsdam, housing several telescopes for doing serious astrophotography. During the club meetings (where you often get pizza and soda) a professor may discuss a timely development in science or you may get to watch a science documentary movie. Recently the Physics Club has expanded its horizon by publishing its own Journal (and of course, there is a club T-shirt). Participation in the Clarkson Chapter of Sigma Pi Sigma (the national Physics honor society) is also quite popular among the students. Apart from all these, the annual Physics picnic is always a lot of fun. To see what the Physics Club is doing now, check out *http://people.clarkson.edu/clubs/phyclub/officerList.php*.

► Awards

Some of the prizes and awards applicable to all Clarkson students are listed in the University Catalog. In addition, the Physics Department offers three annual awards: (1) Freshman Award, to the freshman student majoring in Physics who demonstrates the greatest proficiency in Physics. (2) Senior Award, to the senior Physics student showing the most promise for a successful professional career. (3) S. Arajs Award for outstanding performance in freshman Physics laboratories.

► Employment in the Department

Physics seniors and juniors have opportunities to work as graders, teaching helpers, proctors, and lab instructors. Cooperative programs and similar, typically semester-long, employment options, including those at National Laboratories, are available to students with an excellent academic record. Sometimes you may find summer employment within the Physics department. Usually the job involves assisting a faculty member in research, and your task may well be a continuation of your own research project.

► What is so special About Physics at Clarkson?

Facilities: The instructional and research facilities of the Clarkson Physics Department offer you the advances in modern technologies. Here you can learn about the technologies by using them and not just by reading about them. You can gain hands-on experience in large scale computing, photovoltaic devices, biosensors, optical and electronic signal processing, computer interfacing, data acquisition and processing, scanning probe microscopy and surface spectroscopy. The technical skills you gain by using these facilities can significantly boost your position in a competitive job market in Science and Engineering.

In addition to the technical facilities, the department offers a colloquium every week. Well-known scientists present results of their most recent discoveries. By attending these seminars, you gain a broad perspective about today's world of science. Recent colloquium topics have covered a variety of most modern advances in Biological Physics, Atomic Force Microscopy, Photovoltaic Devices, Lithium Ion Battery Technologies, Information Processing with Biomolecules, Quantum Computing, Percolation Models, Statistical Physics, and Physics Education. A more complete list of our colloquia and seminars is available at: *http://www.clarkson.edu/physics/seminars.html*

Research Experience: Many of the technical facilities described above are tied in with the department's graduate research program. You can get direct access to our departmental research facilities as early as your sophomore year. Colleges without a graduate Physics program are often unable to offer such facilities. On the other hand, the large number of graduate students, postdoctoral researchers and technicians dominates graduate research at many other universities. In comparison with such places, Clarkson undergraduates play a much larger role in the overall life of the department. The balanced ratio of graduate/undergraduate students allows for research participation by the undergraduates. This also promotes a close student-faculty relationship and the undergraduates get to work side by side with their graduate colleagues, under the direct supervision of the faculty members. Such a strong research program for undergraduates is one of the most attractive features of our Physics Department.

Now, you may ask, *what is so great about doing research as an undergraduate?* The answer is that the most interesting (and often the most highly paid) jobs are those where no one gives you the answers, no one tells you do step A, then step B, etc. You are on your own and are expected to do your own thinking. That is what research is all about and Physics research is a great way to get started.

However, even if you don't count the intellectual stimulation of doing research, for a variety of jobs your experience makes you a better candidate than someone without a research background. The technical communication and computational skills you acquire through research are obviously important for your post-graduation career. In addition, there is more to it:

- By participating in research, you can attend regional and national conferences. There you can take a closer look at the current activities in the areas of your interest; you will know who is doing what and who is interested in hiring people like you.
- With the recommendation of your faculty supervisor, you may get a chance to spend a semester at one of the prestigious National Laboratories. There you can make more contacts with prospective employers. Moreover, the experience you gain in such a laboratory can become an impressive feature of your resume. In the recent past, our Physics majors have worked at Brookhaven National Laboratory, at Argonne National Laboratory, and at Los Alamos National Laboratory.

- By working with the graduate students on a regular basis, you get a first-hand view of life in a graduate school and the general format of graduate research. This experience can help you decide whether you should look for a graduate school or for a job after college.

Placement Record: Traditionally, Clarkson Physics graduates have been extremely successful in competitive employment as well as in top ranking graduate schools. For instance, in the recent past, they have been employed by AT&T, IBM, General Electric, General Dynamics, Hewlett Packard, Texas Instruments, Intel, Analog Devices, Eastman Kodak, US Air Force, Lawrence Livermore Laboratory, and Naval Research Laboratory. Some of our recent graduates have gone to graduate schools at Cornell University, Stanford University, University of Illinois, University of Chicago, University of Rochester, Georgia Tech, Rice University, Carnegie-Mellon University and Rensselaer Polytechnic Institute. More details on placement information can be obtained from the University Alumni Office, or by visiting *http://www.clarkson.edu/career/employment.html.*

The University: Founded in 1896, Clarkson is a small, independent university, long recognized for its strong reputation in technical and scientific programs. Clarkson is distinguished by three major characteristics: the excellence of the faculty, the professional orientation of the curricula, and the friendliness of the people. All the Physics faculty hold Ph.D. 's and many of the faculty have won national and international honors and recognition for their research and scholarship.

Location: Potsdam, New York, is an attractive village of 10,000 residents located along the banks of the Raquette River on a rolling plain between the Adirondack forest and mountain preserve (10 mi. south) .The St. Lawrence River and Great Lakes Navigational Seaway System of Locks (25 mi. north) is another tourist attraction. Visit *http://www.greatlakes-seaway.com*. For the outdoor enthusiast, opportunities for fishing, hiking, climbing, boating, golfing, camping, swimming, tennis and skiing throughout the area are endless. Clarkson students have taken advantage of their neighboring majestic natural environment of the Adirondack Park just a few miles from campus. The high peaks, valleys, rivers, lakes, woods, and wetlands are always awaiting the outdoor enthusiast.

There are two liberal arts colleges close by: Potsdam College of the State University of New York, and St. Lawrence University in nearby Canton. For those who occasionally wish to avail themselves of the activities of a large city, Potsdam is 100 miles from Montreal, Quebec; 90 miles from Ottawa, Ontario; 130 miles from Syracuse, New York; and 80 miles from Lake Placid, New York.

The Department of Physics offers accredited M.S. and Ph.D. programs. The master's program has a non-thesis option. Diverse faculty research interests present students with a variety of research possibilities funded both by federal agencies, such as the National Science Foundation, and private sources. The low student-to-faculty ratio has made it possible to maintain an intimate and friendly atmosphere and a strong tradition of undergraduate and graduate research participation.

In recent years the Physics Department has played a major role in the developments of the Center for Quantum Device Technology and the Nanoengineering and Biotechnology Laboratories Center (NABLAB). The Physics Department continues to be closely associated with Clarkson Institute for Statistical Physics. Several faculty members of the department are closely involved with materials research that represents key focus areas of the Center for Advanced Materials Processing (CAMP). Physics Education represents another strong and active research component of our department.

Campus computing facilities include a network of several mainframe computers and numerous workstations and PCs. The *Office of Information Technology* (OIT) provides a campus-wide, high-speed LAN interconnecting Clarkson with computing power and databases around the world.[2]

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PRIMARY THEORETICAL RESEARCH AREAS

- Reaction kinetics
- Surface adsorption
- Dynamics of noise-driven systems
- Nonlinear optics
- Condensed and soft matter physics
- Transport properties
- Effects of disorder
- Statistical mechanics
- Phase transitions
- Scaling and finite size effects
- Surface and interface physics
- Quantum computation

PRIMARY EXPERIMENTAL RESEARCH AREAS

- Biological physics
- Biological sensors
- Characterization of nanomaterials
- Surface & interface physics
- Electrochemical impedance spectroscopy
- Atomic force microscopy
- Physics education
- Linear & nonlinear optics
- Nanomaterials for energy storage conversion devices
- Photovoltaic devices

[2] OIT Web Site: http://www.clarkson.edu/oit

► The Program

Thirty credits are required for the M.S. degree, and 90 credits beyond the B.S. are required for the Ph.D. It typically takes a student at least one year to complete the M.S. degree requirements and an additional three to four years to complete requirements for the Ph.D. Graduate study in Physics at Clarkson comprises both thesis research and coursework. Each graduate student is required to do experimental and/or theoretical thesis research, in close collaboration with a faculty member. A written thesis must be completed and defended orally in front of a faculty committee. For the M.S. degree, students may elect a non-thesis option.[3]

M.S. Degree Program: Students entering with a B.S. degree are required to complete at least 30 hours of course and seminar-work. Typically, this would consist of graduate courses taken during the academic year, along with seminars, and credits of thesis work. The latter can be taken in the summer to bring the credit total to the required 30 within one year.

Ph.D. Degree Program: A minimum of 90 credit hours are required for the Ph.D. This corresponds to a minimum of three academic years of full-time study, of which two must be in residence at Clarkson. The M.S. degree may be accepted in lieu of a maximum of 30 credit hours. At Clarkson, a student entering with a B.S. usually completes the non-thesis option M.S. degree as part of the Ph.D. program unless the M.S. has been received from another institution.

► Financial Assistance

Teaching Assistantships provide a stipend plus a full tuition scholarship. Duties include; teaching of laboratory and recitation sections, office hours and help sessions, and grading of reports, exams, and homework. Research Assistantships provide a stipend. The Research carried out by the Assistant is used towards thesis requirements. Research Assistants also receive full tuition scholarships.

► Application for Admission

Applicants must have received a bachelor's degree and achieved an above average academic record. All applicants are required to take the general Graduate Record Examination (GRE). Advanced (subject) GRE is also recommended, but not required. International applicants should submit a TOEFL score; a minimum of 550 is required. All accepted international students for whom English is a second language would be asked to take an English placement exam to determine whether they should complete remedial requirements. For applications and other information, or to schedule a visit to campus, please refer to the contact information on the last page of this booklet.

Specific requirements for MS and PhD in Physics can be found at *http://www.clarkson.edu/*

PHYSICS FACULTY AND THEIR RESEARCH FIELDS

Daniel ben-Avraham (Ph.D., Bar-Ilan, 1985). Network systems, phase transitions, polymer science, transport in disordered media, reaction kinetics.

Erik Bollt (Ph.D., University of Colorado at Boulder, 1995). Dynamical Systems, chaos theory, complex networks.

Ming-Cheng Cheng (Ph.D., Polytechnic University, Brooklyn, 1990). Modeling and simulation of microelectronics and solid-state devices.

Benjamin Dorfman (Ph.D., Moscow Inst. of Electronic Controlling Machines and Institute of Fine Chemistry). Solid State Physics.

M. Lawrence Glasser (Ph.D., Carnegie-Mellon, 1962). Solid state physics, statistical mechanics, mathematical physics. *Faculty Emeriti*

Maria Gracheva (Ph.D., Moscow State Engineering Physics Institute Technical University, 1998). Biophysics, solid state physics, nanotechnology.

Dmitriy Melnikov (Ph.D., Lehigh University, 2001). Solid state physics, nanoelectronics, spintronics.

Vladimir Privman (Ph.D., Technion, 1982). Phase transitions, scaling theory, finite size effects, surface and interfacial phenomena, polymer physics, colloids, quantum computing.

Michael Ramsdell (Ph.D., Clarkson University, 2004). Physics Education, Laboratory Curriculum Development and Design.

Dipankar Roy (Ph.D., Rensselaer Polytechnic, 1986). Surface engineered materials, linear and nonlinear optics, surface characterization, photovoltaic materials, advanced lithium ion batteries.

Lawrence Schulman (Ph.D., Princeton, 1967). Path integration, statistical physics, phase transitions, astrophysics, quantum theory.

Igor Sokolov (Ph.D., St. Petersburg, Russia, 1991). Experimental /Theoretical scanning probe microscopy, nanomaterials, quantum physics, cosmology, and theory of gravity.

David Wick (Ph.D., Clarkson, 1996). Physics of fluids, turbulence, nonlinear systems, physics education.

GENERAL REQUIREMENTS FOR THE BACHELOR'S DEGREE

1. At least 120 credit hours
2. At least a 2.000 cumulative average
3. At least a 2.000 cumulative average in the major field of study for the Class of 2004 or later
4. Meet the requirements of the *Clarkson Common Experience*
5. Meet the requirements for a degree program as determined by the offering department or school
6. A student entering as a first semester freshman must be in residence for at least four semesters, including the final undergraduate semester
7. If entering with advanced standing, a student must complete at least half the remaining upper-level undergraduate work in residence at Clarkson. The program must include a minimum of two semesters (30 credit hours) including the final undergraduate semester

ESL REQUIREMENT

Students for whom English is a second language must take an English language placement examination upon entering Clarkson. Based on the outcome of this examination, a student may be required to complete one or more ESL course(s) prior to enrolling in the Clarkson Seminar or any course assigned one or two communications.

SPECIFIC CATEGORIES WITHIN CLARKSON COMMON EXPERIENCE (CCE) REQUIREMENTS

I. FY 100 First-Year Seminar
(1 Credit): Offered in the fall semester, required only for first-year students.

II. UNIV 190 The Clarkson Seminar
(3 Credits) Offered each semester

III. Knowledge Areas (KA) and University Courses

The following 6 areas must be covered with 5 courses (15 credits; these will include at least 4 single KA courses and at least 1 UNIV course):

1. Cultures and Societies (CSO)
2. Contemporary and Global Issues (CGI)
3. Imaginative Arts (IA)
4. Science, Technology, and Society (STS)
5. Economics and Organizations (EC)
6. Individual and Group Behavior (IG)

All students must take at least one University Course after the first year. University Courses cover two KA areas, and in the Course Booklet are designated as UNIV/KA-1/KA-2 (for example, UNIV/CGI/STS, etc.)

IV. Mathematics, Science and Technology Courses

- 18 credits of Mathematics, including MA 131, MA 132, MA 231, MA 232, plus 3 credits of Probability/Statistics from: MA 381, STAT 381, STAT 383, MA 381, etc.
- "Science" course requirements do not separately apply to Physics majors
- 3 credits of Technology Elective. Typical TECH courses taken by Physics Majors: ES 260, CS 141, ES 300, PY 456, etc.

V. Communications

- At least 6 Communication Points (C-1/C-2 courses combined) are required
- At least 2 communication points (two C-1 or 1 C-2) must be earned in Physics through courses at the 300- or 400-level (PH 327, PH 445-446)

VI. Physics Professional *Requirement*

- This involves taking a series of courses that incorporate professionalism, ethics, and diversity in its undergraduate curriculum.
- These courses are taken throughout the four years of the physics undergraduate program with courses ranging from 100- to 400-levels. Unlike the other Common Experience requirements, the courses taken under this specific category can be used to satisfy other requirements.
- PH 121, PH 232, PH 327, PH 331 [these represent part of the Core Curriculum]
- 3 Credits from the list: PH 445, PH 446, PH 470-477 [these are the Physics Professional Electives]

VII. Physics Professional Experience

This requirement focuses on project-based professional experience such as co-op, internship, directed research, or community project clearly related to the student's professional goals. To meet this requirement, a Physics Major student will take one course (at least 1 credit) from one of the following three categories:

- Senior Thesis -- PH445, Senior Thesis I; PH446, Senior Thesis II
- Directed Research -- PH478, Directed Research in Experimental Physics; PH479, Directed Research in Theoretical Physics
- Internship/Co-Op – PH480, Internship/Co-Op in Physics

VIII. Physics Professional Elective, Information Technology and Biology

These are requirements set forth by the Physics Department

- Physics Professional Elective (see Category IV under CCE): This course is just part of the CCE Professional Requirement
- Typical Info Tech classes (only 1 required) taken by Physics Majors include: CS 110, IS 110, CS 141, CS 142, etc.
- Typical Biology classes (only 1 required) taken by Physics Majors include: BY 110 (without the lab BY 112), BY 222 (C-1), BY 280, etc.

Here are some useful notes about the CCE:

- More details about CCE can be found at:
  http://www.clarkson.edu/common_experience/
- A same course cannot be used to simultaneously satisfy more than one CCE requirement
- Common Experience Courses are listed on SAS web site:
  http://www.clarkson.edu/sas/classes_schedules/commonexperiencecourses.html
- Currently available Communication Points courses in Physics: PH 232 (C-1), PH 327 (C-2), PH 445 (C-2) and PH 446 (C-2)
- Both *Professional Requirement* and *Professional Experience* are included in the CCE, and represent separate categories as described above. Professional Requirement is a sequence of courses spread out over four years (most of which already are included in the Core Curriculum) including at least 3 credits of Physics Professional Elective (research/directed study class). Professional Experience requires at least 1 credit from PH 445/446, PH 478/479 or PH 480

Double majors may be able to use a single Professional Experience (obtained through one of the two majors) to cover the requirements for both majors. *Details should be discussed with the student's academic advisor.*

PHYSICS UNDERGRADUATE CURRICULUM

Required Courses*	**Credit Hours**
First Year Seminar	1
Clarkson Seminar	3
Physics[1] (or equivalent)	35
Mathematics	18
Chemistry	8
Biology Elective	3
Communication Elective (C2)	3
Knowledge Area and University Course Electives	15
Concentration Electives[2]	9
Information Technology Elective	3
Technology Elective	3
Free Electives (including one C1 course[3])	19
TOTAL	**120**

* Some non-credit courses in physical education, aerospace studies and/or military science might be required for graduation.

[1] Including the core courses, PH 131, PH 132, PH 221, PH 231, PH 232, PH 325, PH 327, PH 380 and at least 1 credit Professional Experience selected from the variable credit courses PH 445, 446, PH 470-471, and PH 474-477.

[2] All these must be in one area outside Physics; an area need not be a department.

[3] At least one of the free electives should be a [C1] or [C2] designated Communication Intensive Course unless a [C1] course is already included in the Biology or Concentration electives.

PHYSICS CURRICULUM (CORE OPTION)

Course Title	*Cr. Hrs.*	*Course Title*	*Cr. Hrs.*
Fall 1		***Spring 1***	
PH 131 Physics I	4	PH 132 Physics II	4
First Year Seminar	1	MA 132 Calculus II	3
MA 131 Calculus I	3	CM 132 Chemistry II	4
CM 131 Chemistry I	4	Knowledge Area Elective	3
Clarkson Seminar	3	PH 121 Phy Freshman Seminar	1
	15		**15**
Fall 2		***Spring 2***	
PH 231 Modern Physics	3	PH 221 Theoretical Mechanics	3
PH 232 Modern Phys Lab	1	MA 231 Calculus III	3
MA 232 Differential Eq	3	Free elective (C1 or C2)	3
Biology Elective	3	Knowledge Area/Univ. Elec.	3
Knowledge Area/Univ. Elec.	3	Communication Elective (C2)	3
Information Tech. Elec.	3		
	16		**15**
Fall 3		***Spring 3***	
PH 325 Thermal Physics	3	PH 331 Quantum Physics I	3
PH 380 Eletromag Th I	3	Free elective	3
MA 381 Probability	3	MA 331 Fourier Ser & BVP.	3
Concentration Elective	3	PH 327 Exper. Phys I	3
Knowledge Area/Univ. Elec.	3	Free elective (Recom. PH 381)	3
	15		**15**
Fall 4		***Spring 4***	
PH Elective (Recom. PH432)	3	Concentration Elective	3
PH 435 Senior Seminar	1	Technology Elective	3
KA/Univ. Elective	3	Free elective	3
Concentration Elective	3	Free elective	3
PH Professional Elective	3	Free elective	3
Free elective	1		
	14		**15**

Physics Minor Curriculum

PH 131 Physics I	(4 cr)
PH 132 Physics II	(4 cr)
PH 231 Fundamentals of Modern Physics	(3 cr)
PH 221 Theoretical Mechanics I	(3 cr)
PH 331 Quantum Physics I	(3 cr)
Any two three-credit Physics courses at the 300-400 level These may include:	(6 cr)
PH 371 (CM 371) Physical Chemistry I	(3 cr)
PH 372 (CM 372) Physical Chemistry II	(3 cr)
One of the following one-credit courses:	
PH 121 Physics Freshman Seminar	(1 cr)
PH 232 Modern Physics Laboratory	(1 cr)
PH 435 Physics Senior Seminar	(1 cr)
PH 470 Directed Study Experimental	(1 cr)
PH 474 Directed Study Theoretical	(1 cr)

PHYSICS BACHELOR'S DEGREE
COURSE-CHECKLIST

Fr. Year Seminar (1 credit) (For 1st yr students)
Clarkson Seminar (3 credits) (For 1st yr students)

Physics or equivalent (35)

PH 121 (1)
PH 131 (4)
PH 132 (4)
PH 221 (3)
PH 231 (3)
PH 232 (1) [C1]
PH 327 (3) [C2]
PH 331 (3)
PH 380 (3)
PH 435 (1)
PH 325 (3)

PH Prof Exp (1)
[PH 445/446/478/479/480]

PH Prof. Elec. (3)
[PH 445/446, PH 470-477]

PH Elective (3) [PH 381 recommended]
PH Elective (3) [PH 432 recommended]
PH Elective (3)

Mathematics (18 credits)

MA 131 (3)
MA 132 (3)
MA 231 (3)
MA 232 (3)

MA/STAT Probability/Statistics (3)

MA Elective (3)
[MA331 recommended]

PHYSICS BACHELOR'S DEGREE
COURSE-CHECKLIST (Continued)

Chemistry and Biology: 11 credits)
CM 131(4)
CM 132 (4)
BY Elective (3)

Info Tech Elective (3 credits)
University Course (2 KAs combined in 1 course: 3 credits)
Knowledge areas (12 credits)
Communication Elective (3 credits)
Technology Elective (3 credits)
Concentration Elective (9 credits)
Free Electives (19 credits)

Requirement for undergraduate students taking graduate classes

- To enroll in a 500-level course, the student's cumulative quality point average must be 3.0 or higher. To enroll in a 600-level course, the student's cumulative quality point average must be 3.5 or higher. Approval must be obtained using a form from SAS. For more information, see: **http://www.clarkson.edu/studentaffairs/regulations/ii.html**

Procedure for receiving PH 480 credit through External Internship/Co-Op Plan

1. In consultation with your academic advisor/supervisor you will fill out "Attachment 2" of the "Internship/Co-Op Plan" form. This form can be obtained from the Physics Dept. Office.
2. Find out who will be your field supervisor at your Internship site. He/she also needs to sign Attachment 2 before you start your internship.
3. Return the completed Attachment 2 to the Physics Department (before you start your internship) with a brief narrative attached, that will describe your specific learning objectives and responsibilities during the internship/co-op period (if you need help with writing this, see your advisor or department chair for assistance). The narrative should also estimate the number of hours to be worked and provide a brief description of the products that will be used by the academic supervisor for evaluation. Typically, this "product" is a report of your work performed during your internship, to be submitted by you with Attachment 4 (see below).
4. Sign-up for PH 480 (Sec No of your academic supervisor). This is a pass/fail (1) credit course only used for internship/co-op.*
5. Within two weeks of the conclusion of your internship, your field supervisor will fill out Attachment 3, and return it to your academic advisor/supervisor.
6. After you complete your internship, you will fill out Attachment 4 and return it to the Physics Dept along with a report of your work.

*If the internship is for a summer, normally you will sign up for PH 480 during the fall semester, after you return from internship to prepare your report.

SAMPLE PHYSICS CURRICULUM
ENGINEERING PHYSICS OPTION

Course Title	*Cr. Hrs.*	*Course Title*	*Cr. Hrs.*
Fall 1		***Spring 1***	
PH 131 Physics I	4	PH 132 Physics II	4
Freshman Year Seminar	1	MA 132 Calculus II	3
MA 131 Calculus I	3	CM 132 Chemistry II	4
CM 131 Chemistry 1	4	Knowledge Area Elective	3
Clarkson Seminar	3	PH 121 Phy Fr. Seminar	1
	15		**15**
Fall 2		***Spring 2***	
PH 231 Modern Physics	3	PH 221 Theoretical Mechanics	3
PH 232 Modern Phys Lab (C1)	1	MA 231 Calculus III	3
MA 232 Differential Eq	3	ES 250 Electrical Science	3
ES 220 Statics	3	Knowledge Area/UC Elec.	3
Knowledge Area/UC Elec.	3	Communication Elective (C2)	3
ES 260 Mater Sci. Eng.	3		
	16		**15**
Fall 3		***Spring 3***	
PH 325 Thermal Physics	3	PH 331 Quantum Physics I	3
PH 380 Eletromag Th I	3	ME 212 Intro. Eng. Design	3
EE 341 Microelectronics	3	MA 331 Fourier Ser & BVP.	3
Information Tech. Elec.	3	PH 327 Exper. Phys I (C2)	3
Knowledge Area/UC Elec. (C1)	3	ES 330 Fluid Mechanics	3
	15		**15**
Fall 4		***Spring 4***	
PH Elective (Recom. PH323)	3	ES Elective	3
PH 435 Senior Seminar	1	Technology Elective	3
Knowledge Area/UC Elective	3	Free Elec (Recom. PH 341)	3
MA Elec (Prob & Stat)	3	ES Elective	3
Free Elective (Recom. PH 310)	1	PH Professional Elective	3
Biology Elective	3		
	14		**15**

PROFESSIONAL ELECTIVES FOR ENGINEERING PHYSICS OPTION

CH 302	**HEAT TRANSFER**	**[ES 330]**[1]
CH 410	**CHEMICAL ENGINEERING LABORATORY**	**[ES 330]**
CE 212	**INTRODUCTION TO ENGINEERING DESIGN**	**[ES 100, PH 131]**
CE 452	**ADVANCED MECHANICS OF MATERIALS**	**[ES 222]**
EE 211	**ELECTRICAL ENGINEERING LABORATORY I**	**[EE 221, EE 264]**
EE 221	**LINEAR CIRCUITS**	**[ES 250]**
EE 311	**ELECTRICAL ENGINEERING LABORATORY II**	**[EE 221, EE 264]**
EE 447	**VLSI DESIGN**	**[EE 341]**
ES 222	**STRENGTH OF MATERIALS**	**[ES 220]**
ES 223	**RIGID BODY DYNAMICS**	**[ES 220, MA 232]**
ES 357	**MICROELECTRONIC CIRCUIT FABRICATION**	
ES 360	**MATERIALS SCIENCE II**	**[ES 260]**
ES 405	**DESIGN OF EXPTS.&ANALYSIS OF DATA**	
ME 326	**INTERMEDIATE FLUID MECHANICS**	**[ES 330, ES 340]**
ME 411	**INTRODUCTION TO HEAT TRANSFER**	**[ES 330, ES 340]**
ME 431	**GAS DYNAMICS**	**[ES 330, ES 340]**
ME 455	**MECHANICAL VIBRATIONS**	**[ES 223]**
PH 341	**SOLID STATE PHYSICS I**	**[PH 231]**
PH 381	**ELECTROMAGNETIC THEORY II**	**[PH 380]**
PH 442	**SOLID STATE PHYSICS II**	**[PH 341]**
PH 447	**NUCLEAR PHYSICS**	**[PH 331]**

[1] **[…] DENOTES PRIMARY PREREQUISITES FOR LISTED COURSES, WHERE APPLICABLE**

MATERIALS SCIENCE OPTION

Course Title	*Cr. Hrs.*	*Course Title*	*Cr. Hrs.*
Fall 1		***Spring 1***	
PH 131 Physics I	4	PH 132 Physics II	4
Freshman Year Seminar	1	MA 132 Calculus II	3
MA 131 Calculus I	3	CM 132 Chemistry II	4
CM 131 Chemistry I	4	Knowledge Area Elective	3
Clarkson Seminar	3	PH 121 Phy Freshman Seminar	1
	15		**15**
Fall 2		***Spring 2***	
PH 231 Modern Physics	3	PH 221 Theoretical Mechanics	3
PH 232 Modern Phys Lab (C1)	1	MA 231 Calculus III	3
MA 232 Differential Eq	3	ES222 Strenght of Mater	3
ES 260 Mater Sci & Eng I	3	Knowledge Area/UC Elec	3
Knowledge Area/UC Elec	3	Communication Elec (C2)	3
Information Technology Elec	3		
	16		**15**
Fall 3		***Spring 3***	
PH 325 Thermal Physics	3	PH 331 Quantum Physics I	3
PH 380 Eletromag Th I	3	MA 331 Fourier Ser & BVP	3
PH 341 Solid State Physics I	3	PH 327 Exper. Phys. I (CS2).	3
CM 371 Phys Chemistry I	3	ES 330 Fluid Mechanics	3
ES 365 Polymer Materials	3	Knowledge Area/UC Elec	3
	15		**15**
Fall 4		***Spring 4***	
Math Electrive	3	TC Elective	3
PH 435 Senior Seminar	1	Knowledge Area/UC Elective	3
CM 430 Colloids & Interf	3	Professional Electives[1]	6
Professional Elective [1]	3	PH Elective	2
Free Elective [2]	5		
	15		**14**

[1] Professional Electives must be chosen from an approved list of courses
[2] Including 3 credits of Biology

PROFESSIONAL ELECTIVES FOR MATERIALS SCIENCE OPTION

CH 250	**CHEMICAL PROCESS CALCULATIONS**	**[CM 132][1]**
CH 302	**HEAT TRANSFER**	**[ES 330]**
CH 484	**POLYMER ENGINEERING**	**[ES 330]**
CE 452	**ADVANCED MECHANICS OF MATERIALS**	**[ES 222]**
EE 341	**MICROELECTRONICS**	**[ES 250]**
EE 447	**VLSI DESIGN**	**[EE 341]**
ES 220	**STATICS**	**[MA 131, PH 131]**
ES 250	**ELECTRICAL SCIENCE**	
ES 357	**MICROELECTRONIC CIRCUIT FABRICATION**	**[ES 260]**
ES 360	**MATERIALS SCIENCE & ENG. II**	**[ES 260]**
ES 361	**FINE PARTICLE TECHNOLOGY**	**[CM 132]**
ES 464	**ELECTROCHEMICAL AND CORROSION ENG.**	**[CM 132]**
ME 326	**INTERMEDIATE FLUID MECHANICS**	**[ES 330, ES 340]**
ME 452	**ADVANCED STRENGHT OF MATERIALS**	**[ES 222]**
ME 457	**COMPOSITE MECHANICS AND DESIGN**	**[ES 222, ES 260]**
CM 372	**PHYSICAL CHEMISTRY II**	**[CM 371]**
PH 323	**OPTICS**	**[PH 132]**
PH 381	**ELECTROMAGNETIC THEORY II**	**[PH 380]**
PH 442	**SOLID STATE PHYSICS II**	**[PH 341]**
PH 447	**NUCLEAR PHYSICS**	**[PH 331]**

[1] **[…] DENOTES PRIMARY PREREQUISITES FOR LISTED COURSES, WHERE APPLICABLE**

SAMPLE PHYSICS CURRICULUM
CONCENTRATION OPTION IN BIOLOGICAL PHYSICS

Course Title	*Cr. Hrs.*	*Course Title*	*Cr. Hrs.*
Fall 1		***Spring 1***	
PH 131 Physics I	4	PH 132 Physics II	4
Freshman Year Seminar	1	MA 132 Calculus II	3
MA 131 Calculus I	3	CM 132 Chemistry II	4
CM 131 Chemistry 1	4	Knowledge Area Elective	3
Clarkson Seminar	3	PH 121 Phy Freshman Seminar	1
	15		**15**
Fall 2		***Spring 2***	
PH 231 Modern Physics	3	PH 221 Theoretical Mechanics	3
PH 232 Modern PhysLab (C1)	1	MA 231 Calculus III	3
MA 232 Differential Eq	3	BY 214 Genetics	3
BY 160 Cell & Mol Biology	3	Knowledge Area/UC Elec.	3
BY 162 Cell & Mol Bio Lab	2	Communication Elective (C2)	3
Knowledge area/UC elective	3		
	15		**15**
Fall 3		***Spring 3***	
PH 325 Thermal Physics	3	PH 331 Quantum Physics I	3
PH 380 Eletromag Th I	3	BY Elective	3
BY Elective	3	MA 331 Fourier Ser & BVP.	3
Information Technology Elec.	3	PH 327 Exper. Phys I (C2)	3
Knowledge Area/UC Elec. (C1)	3	BY 320 Microbiology	3
		BY 322 Microbiology Lab	1
	15		**16**
Fall 4		***Spring 4***	
Technology Elective	3	CM 242 Organic Chem II	3
PH 435 Senior Seminar	1	PH 426 Biophysics	3
Knowledge Area/UC Elective	3	CM 244 Org. Chem. Lab I	3
MA Elective (Prob & Stat)	3	BY 416 Occup Toxicology	3
Free Elective (Recom. PH 310)	1	PH Professional Elective	3
CM 241 Organic Chem I	3		
	14		**15**

NOTE: At least one CS course is expected to satisfy the technology elective requirement.

SAMPLE CURRICULUM FOR PHYSICS MAJORS WHO DOUBLE MAJOR IN COMPUTER SCIENCE

Course Title	*Cr. Hrs.*	*Course Title*	*Cr. Hrs.*
Fall 1		***Spring 1***	
PH 131 Physics I	4	PH 132 Physics II	4
Freshman Year Seminar	1	MA 132 Calculus II	3
MA 131 Calculus I	3	CS 142 Intro to Comp Sci II	4
CS 141 Intro to Comp Sci I	4	Knowledge Area Elective	3
Clarkson Seminar	3	PH 121 Phy Fresh. Seminar	1
		Communication Elective	3
	15		**18**
Fall 2		***Spring 2***	
PH 231 Modern Physics	3	PH 221 Theoretical Mechanic	3
PH 232 Modern Phys Lab (C1)	1	MA 231 Calculus III	3
MA 232 Differential Eq	3	CS 241 Comp Organization	3
MA 211 Foundations	3	CM 132 General Chemistry II	4
CM 131 General Chemistry I	4	CS 344 Algor & Data Struct	3
CS 242 Adv Prog Java	3		
	17		**16**
Fall 3		***Spring 3***	
PH 325 Thermal Physics	3	PH 331 Quantum Physics I	3
PH 380 Eletromag Th I	3	CS 444 Operating Systems	3
CS 341 Prog. Language	3	PH 327 Exper. Phys. I (CS2).	3
CS 345 Automata Theory	3	MA 383 Appl. Stat. I	3
Knowledge Area/UC Elec. (C1)	3	Knowledge Area/UC Elective	3
CS 350 Software Des & Dev	3	CS Elective	3
	18		**18**
Fall 4		***Spring 4***	
MA 339 Appl Linear Algebra	3	CS Elective	3
PH 435 Senior Seminar	1	Knowledge Area/UC Elective	3
PH Elective (Recom. PH 432)	3	CS Elective	3
CS Elective	3	PH Professional Elective	3
Biology Elective	3	Knowledge Area/UC Elective	3
CS Elective	3		
	16		**15**

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Physics Undergraduate Program: **http://www.clarkson.edu/physics/undergrad/**
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Physics Faculty Web Pages: **http://www.clarkson.edu/physics/faculty.html**
Center for Quantum Device Technology Web Page: **http://www.clarkson.edu/cqdt/**