quantificational logic. Taught jointly with the Mathematics Department. Also listed as Mathematics 381.

383 **Metaphysics** (3). * S. A study of selected topics of metaphysics. Not offered 2002-03.

390 **Readings and Research**. F, I, and S. Prerequisite: Permission of chair. *Staff.*

395 **Philosophy Seminar** (4). * F. An advanced seminar on topics of current interest in philosophy, culminating in the preparation and presentation of a research paper. Prerequisite: Three courses in philosophy. *K. Corcoran.*

Graduate Courses

501 **The Educational Enterprise: A Philosophical Perspective** (3). S and SS. An examination of factors presently operative in the educational enterprise from the perspective of the history of Western philosophy. *G. Mellema.*

590 **Independent Study**. * F, I, and S. *Staff.*

Physical Education and Recreation

See the Department of Health, Physical Education, Recreation, Dance, and Sport for descriptions of course offerings.

Physics

*Professors S. Haan (chair), J. Jadrich, L. Molnar, **S. Steenwyk, D. Van Baak*
Associate Professors P. Harper, †M. Walhout
Assistant Professors D. Haarsma, L. Haarsma, G. Lenters

The Physics and Astronomy Department offers programs of concentration for students interested in careers or graduate studies in physics, astrophysics, or related disciplines, and for students interested in high school physics teaching. Students intending to major in physics are advised to enter college with four years of mathematics and to complete their 100- and 200-level courses in mathematics and physics during their first and second years. The Physical World core requirement may be met by Physics 110, 113, 133, 134, 212, 221, or 223. The entire science core requirement (both Physical World and Living World) may be met by the two-course sequence of Physics 133-134 or 133-235.

PHYSICS MAJOR:
at least 32 semester hours including:

Physics 133, 134, 235, and 306 (or higher level substitutes)
Two or more advanced theory courses from Physics 335-376 (excluding 347 and 359)
Two or more upper-level laboratory courses from Physics or Astronomy 380-386 (Engineering 204 is allowed as a substitute for Physics 381)
Departmentally approved electives to bring the total to at least 32 hours

Cognates

Computer Science 153-154, 155, or 185
Mathematics 161
Mathematics 162
Mathematics 232 or 261 (Mathematics 261 is recommended)
Mathematics 231 is also recommended

All physics majors who are juniors or seniors must enroll in Physics 195 or 196 each semester and are expected to attend Physics Department seminars.

The 32-hour major is intended primarily for students seeking a flexible program, e.g., who are also majoring in another discipline or earning an engineering degree but have an active interest in physics. The major satisfies the college's concentration requirement for graduation with a B.A. degree.

Students wanting a B.S. degree must complete a total of at least 58 semester hours of science and mathematics. Persons interested in a physics-related career who want to earn a B.S. degree based upon a physics major should complete the above minimum requirements plus at least one more upper-level theory course, Physics 395, and Mathematics 231. Students planning to pursue graduate study in physics should take all the upper-level theory courses (Physics 335, 336, 345, 346, 347, 365, 375, and 376), Mathematics 333, and Physics 395-396. A summer working as a full-time research assistant is also strongly encouraged.

Students interested in a career in astronomy or astrophysics should major in Physics, minor in Astronomy, and plan their programs with D. Haarsma or L. Molnar.

PHYSICS MINOR:

At least 20 semester hours of physics, including:

Physics 133
Physics 134
Physics 235
Physics 246
Physics 306 or the combination of Physics 196 and 335

SECONDARY EDUCATION MAJOR IN PHYSICS: 32 semester hours

At least 32 semester hours including:

Same as the standard physics major, with the following exceptions:
Physics 384 is required as one of the upper-level experimental modules
Physics 380 is recommended as the second module
There are additional cognates of Chemistry 103 and one of Astronomy 211, 212, or Geology 151

SECONDARY EDUCATION PHYSICS MINOR:

The secondary education physics minor is the same as the standard physics minor.

ELEMENTARY AND SECONDARY GENERAL SCIENCE STUDIES MAJOR

The elementary and secondary group science majors require at least 36 hours of natural science courses, which are selected in consultation with a science education advisor. The major includes at least four semester hours in each of biology, chemistry, physics and earth science; a pre-approved course that discusses the relationships among science, technology, and society; and course sequence(s) in particular science areas, which are chosen in consultation with the science education advisor. Cognate courses may also be required (e.g., Mathematics 110, 143, or 161). A more detailed description of this program can be found in the *Teacher Education Program Guidebook*. Science Education Advisors: Secondary: U. Zylstra, Biology Department; Elementary: S. Haan and J. Jadrich, Physics Department.

ELEMENTARY AND SECONDARY GENERAL SCIENCE STUDIES MINOR

The elementary and secondary group science majors require at least 24 hours of natural science courses, which are selected in consultation with a science education advisor. Both elementary and secondary minors require at least four semester hours in each of biology, chemistry, physics, and earth science. The secondary minor requires a sequence of approved courses in one particular science area and a pre-approved course that discusses the relationships among science, technology, and society. Cognate courses may also be required (e.g., Mathematics 110, 143, or 161). A more detailed description of this program can be found in the *Teacher Education Program Guidebook*. Science Education Advisors: Secondary: U. Zylstra, Biology Department; Elementary: S. Haan and J. Jadrich, Physics Department.

PHYSICS/COMPUTER SCIENCE GROUP MAJOR

Physics 133
Physics 235

Physics 280
Computer Science 185
Computer Science 186
Computer Science 280
One from Computer Science 230, Engineering 220, or an upper division computer-science elective
Physics or Computer Science electives (to provide a minimum of 24 semester hours in either physics or computer science)

Cognates
Mathematics 161
Mathematics 162
Mathematics 231 or 255
Mathematics 261 or 232

OPTICS MINOR
At least 21 hours, including:
Physics 133
Physics 235
Physics 246
Physics 345 or Engineering 302
Physics 346
Physics 386

Students pursuing a Physics Major and Optics Minor must follow college guidelines for overlap between a major and a minor; this is facilitated by the option in the Physics Major of substituting upper-level courses for introductory ones.

HONORS

The requirements for graduation with honors in physics are:

1. Minimum cumulative GPA of 3.3 and total of six honors courses (18 hours minimum) overall, including two honors courses outside the major;
2. At least three honors courses (of 3 or more semester hours each) in physics or astronomy; at least one of the three must be an advanced theory course from 335-379, excluding 347 and 359;
3. Cumulative GPA of at least 3.3 in physics, astronomy, and mathematics collectively;
4. Completion of an approved physics major, with at least 40 semester hours of physics or the secondary education physics major;
5. Regular participation in the departmental seminar program; and
6. Successful completion of a departmentally approved research project in physics or astronomy (typically through summer research) and Physics or Astronomy 395.

To obtain honors credit in any physics or astronomy course, a student can make a Contract with the course instructor regarding a special project. Alternatively, a student in a 100- or 200-level physics or astronomy course may earn honors in that course by concurrently taking the seminar course, Physics 195, and completing its requirements. A student must earn a grade of "B" or better in a course to receive honors designation for that course.

GROUP SCIENCE MAJOR

A group major in science and mathematics meets the needs of some students, particularly those in professional programs. The majors are not appropriate for students who anticipate attending graduate school in physics or who are in teacher education programs. Such group majors require twelve courses in the sciences and mathematics, ten of which must be from two departments with no fewer than four from either, with the remaining two courses chosen from a third department. The chairs of the three departments must approve each program of this type.

COURSES

Introductory Courses

110 **Physical Science** (4). F or S. This course focuses on scientific theories and models that provide practical understanding of everyday phenomena and modern technologies. Historical case studies, as well as hands-on laboratory activities, give insight into the methods of physical science and the process of discovery. The course also addresses the status of scientific knowledge in the context of religious belief and highlights certain ethical issues related to technological applications. It is intended primarily for non-science majors. Laboratory. Prerequisite: Mathematics 100 or high school equivalent. Not offered 2002-03.

112 **Physical and Earth Science for Elementary School Teachers** (4). * F and S. This course uses a hands-on approach in surveying topics in chemistry, earth science, and physics that are relevant for teaching in el-

ementary school. The course is designed to give prospective teachers background knowledge and experiences that will help them to teach inquiry-based science effectively. Topics covered include scientific models, climate and weather, convection, the particulate nature of matter, energy, electricity and magnetism, and the development of evidence in scientific investigations.

113 **Scientific Analysis for Elementary School Teachers** (4). F and S. This course integrates life, earth, and physical science, as well as the process of science, at a level that is appropriate for those planning to teach at the elementary level. Students gain the skills and content mastery necessary for engaging in inquiry-based science at the elementary level. Topics covered include the development of evidence in scientific investigations, the process of scientific analysis through framing, scientific questions and conducting experiments, and solving scientific problems. These scientific processes are analyzed and discussed in terms of their limits and their relevancy to a Christian perspective of the world and science. Prerequisites: Physics 112. Elementary education students pursuing a science minor or major should take Physics 212 instead of this course.

133 **Introductory Physics: Mechanics and Gravity** (4). F and S. An introduction to classical Newtonian mechanics applied to linear and rotational motion; a study of energy and momentum and their associated conservation laws; introductions to oscillations and to gravitation. Attention is given throughout to the assumptions and methodologies of the physical sciences. Laboratory. Prerequisite: Concurrent registration in Mathematics 162 or permission of the instructor.

134 **Matter, Space, and Energy** (4). S. Theories of the fundamental character of matter, interactions, and space, including historical perspectives. Observational astronomy, Greek science, and the five essences. The Copernican revolution and the Newtonian synthesis. Gravity and force at a distance. The atomic model of matter, including the states of matter. Introductory thermodynamics and the arrow of time. Blackbody radiation and energy quantization. Electromagnetic and nuclear forces. Radioactivity, nuclear processes, and the weak force. $E=mc^2$. Quarks, gluons, and the Standard Model. Relativity and Spacetime. Modern Cosmology. Perspectives on the character of scientific inquiry, models, and humans' quest for understanding. Laboratory. Prerequisite: Mathematics 132, 161, or permission of the instructor.

195 **Physics and Astronomy Student Seminar** (0). F and S. A seminar course featuring student and faculty presentations on topics relating to new developments in physics, to science, technology, and society issues, and to ethical issues related to physics. Junior and senior physics majors must attend each semester; freshmen and sophomores intending to major are encouraged to attend. By meeting stated requirements in this non-credit course, students can receive an honors designation in another concurrent 100- or 200-level physics or astronomy course.

196 **Physics and Astronomy Student Seminar** (1). F and S. A seminar course featuring student and faculty presentations on topics relating to new developments in physics, to science, technology, and society issues, and to ethical issues related to physics. Both reading and laboratory topics are available for study and discussion. Students may not register for Physics 195 and 196 concurrently. This course may be repeated up to two times, for a total 3 semester hours credit.

212 **Inquiry-Based Physics** (4). * F. This course provides a hands-on study of important concepts in physics. The course is designed specifically to meet the needs of teacher-education students who wish to be elementary- or middle-school science specialists, but is open to other students who satisfy the prerequisites. Topics covered include mechanics (energy, force, friction, work, torque, momentum, and simple machines), pressure, waves, sound, light, resonance, electricity, magnetism, and radioactivity. Reflections on the nature of physical science and the physical world are included; connections to everyday experience and to technology are discussed. Prerequisite: Physics 112 or high-school physics.

221 **General Physics** (4). F. This course is designed for those who do not intend to do further work in physics. Topics covered in the two-semester sequence (Physics 221-222) include Newtonian mechanics, fluids, waves,

thermodynamics, electricity, magnetism, light, optics, atomic physics, and nuclear radiation. Attention is given throughout to quantitative analysis, empirical methods, experimental uncertainties, perspectives on the assumptions and methodologies of the physical sciences, and the use of physics in the life sciences. Laboratory. Prerequisites: High-school algebra and trigonometry.

222 **General Physics** (4). S. A continuation of Physics 221, which is a prerequisite. Laboratory.

223 **Physics for the Health Sciences** (4). F. An introduction to those topics in physics that are applicable to a variety of health science fields, with special emphasis on understanding various physical aspects of the human body. Topics include basic laboratory techniques and instruments for physical measurements, data analysis, basic mechanics, fluids, heat, electrical circuits, sound, optics, radioactivity and x-rays, a discussion of the nature of physical science, and a Christian approach to science. Laboratory. Prerequisites: High school geometry and algebra. Not open to those who have taken or plan to take Physics 221.

235 **Introductory Physics: Electricity and Magnetism** (4). F. A study of electric and magnetic forces, fields, and energy, and of the integral form of Maxwell's equations, which describe these fields; electric circuits. Laboratory. Prerequisites: Physics 133 and concurrent registration in or completion of Mathematics 261.

246 **Waves, Optics, and Optical Technology** (4). S. Introduction to the basic properties of waves and light, with applications to optical technology. Development of wave and particle models for light. Interactions between light and matter. Reflection, refraction, interference, and diffraction. Devices and applications, including lasers and other light sources, detectors, lenses, thin films, gratings, interferometers, polarizers, phase retarders, fiber optics, nonlinear crystals, and electro-optical technologies. Laboratory. Prerequisites: Physics 235 or Physics 222 and Mathematics 162.

Advanced Theory Courses

306 **Introduction to Quantum Physics** (4). S. An introduction to non-classical phenomena and their explanation in quantum mechanics. Wave-particle duality of matter and light; the Heisenberg uncertainty principle; Schroedinger's wave mechanics; spin; quantum mechanical treatment of atoms; introduction to statistical mechanics; the quantum mechanical description of solids; introduction to nuclear physics; and quantum computing. Prerequisites: Physics 134 or 235 and at least concurrent enrollment in Mathematics 261 or 232. Mathematics 231 is recommended.

335 **Classical Mechanics** (3). * F, alternate years. The motion of particles and systems in Newtonian terms, covering the assumptions, goals, and methods of Newtonian mechanics, and describing some of its notable successes. Areas of coverage include systems of particles, conservation laws, harmonic motion, central-force motion, rotational motion, and motion in non-inertial reference frames. The status of Newtonian determinism and the question of predictability are also addressed. Prerequisites: Mathematics 261 or Mathematics 232 and at least concurrent enrollment in Physics 235. Not offered 2002-03.

336 **Classical Mechanics II** (3). * S, alternate years. Continuation of Physics 335. Coupled oscillators, moment of inertia tensors and extended bodies in rotation. Lagrangian mechanics, the principle of least action, and the Hamiltonian formulation of mechanics. Nonlinear systems and chaotic motion. Prerequisites: Physics 335 and Mathematics 231. Not offered 2002-03.

345 **Electromagnetism** (4). * F, even years. The basic equations of electromagnetism are developed and applied to simple charge and current distributions. Further applications are made to electromagnetic energy and electromagnetic properties of matter. Prerequisite: Physics 235.

346 **Advanced Optics** (3). * S, alternate years. The systematic application of Maxwell's Equations to electromagnetic radiation, including the interaction of light with matter, electromagnetic wave propogation, polarization, interference and diffraction. Includes a study of technologically significant systems such as waveguides, optical filters and fibers, laser cavities, and some electro-optical technologies. Prerequisites: Physics 246 and Physics 345 or Engineering 302.

347 **Relativistic Electrodynamics** (1). * S, alternate years. Special relativity is reformulated in terms of 4-vectors and this new understanding is used to explicitly articulate the relativistic nature of Maxwell's equations. An introductory understanding of special relativity is assumed. Prerequisites: Physics 134 and concurrent registration in Physics 346.

359 **Seminar in Secondary Teaching of Physics** (3). S. A course in perspectives on, principles of, and practices in the teaching of physics and the other natural sciences at the secondary level. Included are teaching strategies, curriculum studies, readings regarding new developments in science education, and considerations of educational uses of statistics and computers. This course should be taken concurrently with Education 346, and provides a forum for the discussion of concerns that develop during directed teaching. This course is part of the professional education program and may not be included in the major or minor in physics.

365 **Thermodynamics and Statistical Mechanics** (4). * S, even years. Equations of state, heat capacities, and the laws of thermodynamics. The thermodynamic potentials. Application to some simple systems and changes of phase. Kinetic theory. Statistical mechanics with emphasis on the canonical ensemble. Determination of entropy and the thermodynamic potentials with application to crystals and gases. Introduction to quantum statistical mechanics. Prerequisite: Physics 335. Not offered 2002-03.

375 **Quantum Mechanics** (3). * F, alternate years. The main emphasis is on wave mechanics and its application to atoms and molecules. One-electron atoms are discussed in detail. Additional topics discussed are electronic spin and atomic spectra and structure. Nuclei, the solid state, and fundamental particles are also considered. Prerequisite: Physics 226.

376 **Quantum Mechanics** (3). * S, alternate years. A continuation of Physics 375, which is a prerequisite.

390 **Independent Study in Physics**. F, I, and S. Independent readings and research in physics under the supervision of a member of the departmental staff. Prerequisite: Permission of the chair.

Laboratory Courses

380 **Great Experiments in Physics** (2). * F, alternate years. Students recreate several historic experiments that originally led to the development or confirmation of physical theories related to quantum mechanics, nuclear physics, wave-particle duality, relativity, and gravity. Prerequisite: Physics 306. Not offered 2002-03.

381 **Electronic Instrumentation** (2). F, alternate years. An introduction to electronic circuits and devices and to their use in scientific measurements. Topics include a review of DC and AC circuits, introductions to diode and transistor characteristics, operational amplifiers, digital logic, and the use of specialized instruments in laboratory measurements. Prerequisite: Physics 235 or permission of the instructor.

384 **Laboratory Investigations in Physics** (2). * S, alternate years. A laboratory-based course in which students choose and complete investigative projects under the supervision of the instructor. The projects are relatively open-minded, with students being responsible for learning background information regarding their topics and becoming familiar with relevant equipment, then designing and conducting open-ended investigations, interpreting their results, and presenting their conclusions. Prerequisite: Concurrent registration in Physics 306. Students may concurrently enroll in Physics 395 and use Physics 384 and 395 as a single package. Not offered 2002-03.

386 **Advanced Optics Laboratory** (2). * S, alternate years. This course builds upon the conceptual and laboratory skills developed in Physics 246 by giving students the opportunity to investigate optical phenomena and applications using advanced instrumentation. Each student selects from a list of several multi-week projects in the fields of laser technology, spectroscopy, interferometry, electro-optical devices, non-linear optics, and quantum optics. Prerequisite: Physics 246.

395 **Physics Research, Writing, and Presentation** (0-3). * F, I, and S. Completion of an approved experimental or theoretical research with presentation of results. The research may be done entirely as part of this course or through another avenue (e.g., summer research with a faculty member or Physics 384).

Normally, each student is required to submit a formal, written report and to present results in a department seminar and/or poster presentation. This course may be repeated twice. Prerequisites: A faculty sponsor and approval of the department.

Graduate Courses

590 **Independent Study**. F, I, and S.

Political Science

*Professors R. De Vries, *D. Koopman, *J. Penning, C. Smidt, W. Stevenson (chair)*
Assistant Professors S. Goi, M.C. Smith, A. Patterson

The department offers a variety of courses in the areas of American politics, international relations, comparative politics, and political theory. Students majoring in political science may follow either the regular major program or a program of concentration in international relations or public administration.

POLITICAL SCIENCE MAJOR: 33 semester hours

Political Science 101
Political Science 207
Political Science 240
Political Science 251
One from Political Science 102, 275, 276, 277, 278, or 279
Eighteen additional semester hours from the department, which may include one interim course

POLITICAL SCIENCE MAJOR: INTERNATIONAL RELATIONS CONCENTRATION (33 semester hours plus twelve approved cognate hours)

Political Science 101
Political Science 207
Political Science 240
Political Science 251
Five from Political Science 102, 275, 276, 277, 278, 279, 308, or 309
Six additional semester hours from the department, which may include one interim course
Twelve approved cognate semester hours

POLITICAL SCIENCE MAJOR: PUBLIC ADMINISTRATION CONCENTRATION (33 semester hours plus four approved cognate courses)

Political Science 101
Political Science 202
Political Science 207
Political Science 209
Political Science 212
Political Science 240
Political Science 251
One from Political Science 102, 275, 276, 277, 278, or 279
One from Political Science 208, 310, 314, 317, or 318
One internship in either State/Local Government or Washington, D.C. (minimum 6 hours)
One Political Science elective (if needed to fulfill 33 hr. major requirement)
Four approved cognate courses in Business/Economics (Recommended: Business 160, 203, 204, Economics 151, 221, 222, or 339)

POLITICAL SCIENCE MINOR: 21 semester hours

One from Political Science 101, 202, 209, 212, 310, 314, 317, or 318
One from Political Science 102, 207, 275, 276, 277, 278, 279, 308, or 309
One from Political Science 110, 240, 306, or 320
Twelve additional semester hours from the department, which may include one interim course