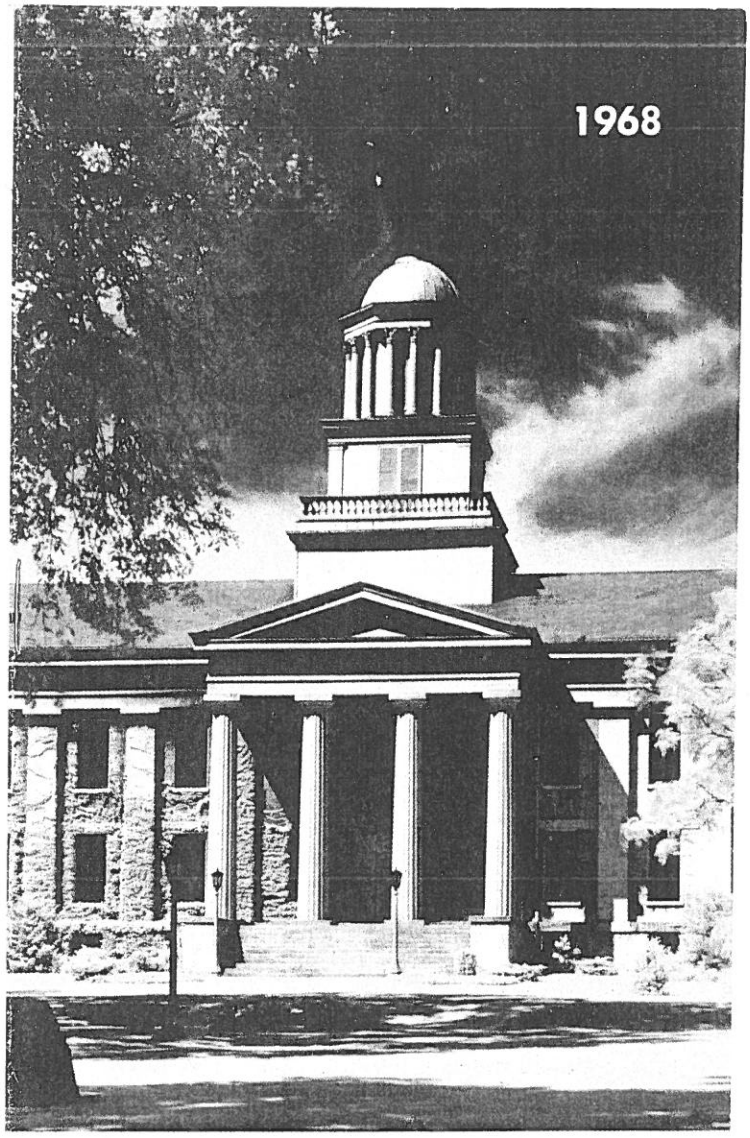

Physics and Astronomy

THE UNIVERSITY OF IOWA
Iowa City

CALENDAR

SUMMER SESSION	1968
Orientation for new undergraduate students	June 10, Monday
Registration for summer session, 8 a.m.	June 11, Tuesday
Opening of classes, 7 a.m.	June 12, Wednesday
University Holiday, offices closed	July 4, Thursday
Close of session, 5 p.m.	August 7, Wednesday
University Commencement, 7:30 p.m.	August 7, Wednesday
Opening of Independent Study Unit for Law and Graduate students	August 8, Thursday
University Holiday, offices closed	September 2, Monday
Close of Independent Study Unit	September 4, Wednesday

FIRST SEMESTER	1968-69
Beginning of Registration, 1 p.m.	September 18, Wednesday
Opening of classes, 7:30 a.m.	September 23, Monday
University Induction Ceremony, 8:45 a.m.	September 23, Monday
Homecoming, classes suspended, except for classes meeting on Saturdays only	October 12, Saturday
Beginning of Thanksgiving recess, 10 p.m.	November 26, Tuesday
University Holiday, offices closed	November 28, Thursday
Resumption of classes, 7:30 a.m.	December 2, Monday
Beginning of Holiday recess, 12:20 p.m.	December 21, Saturday
University Holiday, offices closed (12 noon)	December 24, Tuesday
University Holiday, offices closed	December 25, Wednesday
University Holiday, offices closed (12 noon)	December 31, Tuesday
University Holiday, offices closed	January 1, Wednesday
Resumption of classes, 7:30 a.m.	January 6, Monday
Close of First Semester classes	January 22, Wednesday
Beginning of Examination Week, 7:30 a.m.	January 24, Friday
Close of Examination Week	January 31, Friday
University Commencement, 10 a.m.	February 1, Saturday

SECOND SEMESTER	1968-69
Beginning of Registration, 8 a.m.	February 3, Monday
Opening of classes, 7:30 a.m.	February 5, Wednesday
Foundation Day	February 25, Tuesday
Beginning of Easter recess, 10 p.m.	April 1, Tuesday
Resumption of classes, 7:30 a.m.	April 9, Wednesday
Beginning of Examination Week, 7:30 a.m.	May 26, Monday
University Holiday, offices closed	May 30, Friday
Close of Second Semester classes	June 4, Wednesday
University Commencement, 9:30 a.m.	June 6, Friday

FIRST SEMESTER	1969-70
Beginning of Registration, 1 p.m.	September 10, Wednesday
Opening of classes, 7:30 a.m.	September 15, Monday
University Induction Ceremony, 8:45 a.m.	September 15, Monday
Homecoming, classes suspended, except for classes meeting on Saturdays only	October 25, Saturday
Beginning of Thanksgiving recess, 10 p.m.	November 25, Tuesday
University Holiday, offices closed	November 27, Thursday
Resumption of classes, 7:30 a.m.	December 1, Monday
Beginning of Holiday recess, 12:20 p.m.	December 20, Saturday
University Holiday, offices closed	December 25, Thursday
University Holiday, offices closed	December 26, Friday
University Holiday, offices closed	January 1, Thursday
Resumption of classes, 7:30 a.m.	January 5, Monday
Close of First Semester classes	January 14, Wednesday
Beginning of Examination Week, 7:30 a.m.	January 16, Friday
Close of Examination Week	January 23, Friday
University Commencement, 10 a.m.	January 24, Saturday

PHYSICS

AND ASTRONOMY

PHYSICS AND ASTRONOMY

Head of Department, James A. Van Allen
Office, 203 Physics Research Center

Associate Head of Department and
Undergraduate Adviser, Edward B. Nelson
Office, 211 Physics Research Center

The Department of Physics and Astronomy aims to provide opportunity for comprehensive study of all basic aspects of these subjects and for individual scholarly work at an advanced level.

Career Opportunities

Persons possessing a mastery of physics and astronomy are in great demand as teachers in universities and colleges and as research workers in government and industrial laboratories. Those with a good working knowledge of these subjects at the B.A. level find many opportunities in high school teaching and in a variety of administrative and technical pursuits.

Undergraduate Major in Physics

The following courses or their equivalents are required for the Bachelor of Arts degree with a major in physics:

29:17, 18, 19	Introductory Physics I, II, III (each)	5 s.h.
29:118	Kinetic Theory and Thermodynamics	3 s.h.
29:129, 130	Electricity and Magnetism	6 s.h.
29:132	Intermediate Laboratory	6 s.h.
29:191	Atomic Physics	3 s.h.
22M:19	Topics in Applied Mathematics	3 s.h.
22M:103, 104	Elementary Theoretical Mechanics	6 s.h.
22M:105	Advanced Calculus	3 s.h.

Undergraduate majors who plan to pursue graduate study in physics are advised to

(1) take 29:171, 172 Methods of Theoretical Physics,
(2) acquire reading facility in either Russian or German, and
(3) go beyond the minimum requirements listed above to the greatest feasible extent.

Honors in Physics or Astronomy

Selected junior and senior majors take 6 to 8 semester hours of Honors Seminar, 29:99, as part of their program for the degree Bachelor of Arts with Honors in Physics or Astronomy.

For the general requirements of the College of Liberal Arts, see *College of Liberal Arts.*

Undergraduate Major in Astronomy

The following courses or their equivalents are required for the Bachelor of Arts degree with a major in astronomy:

29:61, 62	General Astronomy	8 s.h.
29:17, 18, 19	Introductory Physics I, II, III	(each) 5 s.h.
29:120	Introductory Astrophysics I	3 s.h.
22M:103, 104	Elementary Theoretical Mechanics	6 s.h.
29:129, 130	Electricity and Magnetism	6 s.h.
29:132	Intermediate Laboratory	2 s.h.
29:137	Astronomical Laboratory	1 s.h.
22M:19	Topics in Applied Mathematics	3 s.h.

Undergraduate majors who plan to pursue graduate study in astronomy are advised to

(1) take 29:118 Kinetic Theory and Thermodynamics, 29:171, 172 Methods of Theoretical Physics, 29:191 Atomic Physics

(2) acquire reading facility in either Russian or German, and

(3) go beyond the minimum requirements listed above to the greatest feasible extent.

Graduate Program

Two advanced degrees are offered in physics, the Master of Science (with or without thesis) and the Doctor of Philosophy; and one in astronomy, the Master of Science (with or without thesis). A student who wishes to pursue a program in astronomy beyond the M.S. level may qualify for a Doctor of Philosophy degree in Physics with specialization and a dissertation in astronomy or astrophysics. An interdepartmental program leading to the M.S. and Ph.D. degrees in chemical physics is also available.

Each entering graduate student is assigned to a faculty adviser who will assist him in preparing a plan of study and in guiding his progress. A graduate student becomes a candidate for an advanced degree in physics or astronomy only after he has passed a general examination in all principal areas of the subject at the level of advanced undergraduate work. The examination is ordinarily given in February of each year and must be taken by all first-year graduate students. Ordinarily, a candidate for an advanced degree should begin research in his chosen specialty during his second year of residency. His thesis or essay adviser then becomes his general adviser and the chairman of his final examination committee.

For the general requirements for admission to the Graduate College and for advanced degrees, see *Graduate College.*

Master of Science Degree in Physics

The M.S. degree is offered with thesis or without thesis. Either degree may be an intermediate step toward a Ph.D. degree, or it may be a terminal degree. The final examination in either case is an oral one by a faculty committee appointed by the Dean of the Graduate College.

The program for the M.S. degree with thesis requires at

least 24 semester hours of graduate course work and a thesis based on an original experimental or theoretical investigation by the candidate.

The program for the M.S. degree without thesis comprises a somewhat broader program of courses (total of 38 semester hours of graduate work), an independent study of the literature on a chosen topic, and the preparation of a critical essay on that topic (for which a maximum of 4 semester hours of credit is allowed). Up to one-third of the graduate program may be in related scientific fields other than physics and mathematics, e.g., chemistry, astronomy, engineering, etc.

The candidate for either of the M.S. degrees must have completed satisfactorily at least the following courses or their equivalents as an undergraduate or a graduate:

22M:101	Differential Equations	3 s.h.
29:117	Optics	4 s.h.
29:118	Kinetic Theory and Thermodynamics	3 s.h.
22M:103, 104	Elementary Theoretical Mechanics	6 s.h.
22M:105	Advanced Calculus	3 s.h.
29:129, 130	Electricity and Magnetism	8 s.h.
29:133	Advanced Laboratory	4 s.h.
29:191	Atomic Physics	3 s.h.
29:192	Nuclear Physics	3 s.h.
29:193	Introductory Solid State Physics	3 s.h.

His plan of study should provide for as much advanced work as his aptitude and previous preparation permit. If he expects to continue toward a Ph.D. degree, he should take 29:171 and 172 during his first year of residency. Study of scientific Russian or German is recommended, but is not required of M.S. candidates.

Master of Science Degree in Astronomy

The M.S. degree is offered with thesis or without thesis. The general nature of the program of study for either degree is similar to that for the corresponding M.S. degree in physics (q.v.).

Specific departmental requirements for the M.S. degree in astronomy are:

The substantial equivalent of the undergraduate major program in astronomy listed in earlier paragraphs, and as many of the following courses as it is feasible to complete:

22M:115	Numerical Methods in Mathematics	3 s.h.
22M:116	Numerical Solution of Differential Equations	3 s.h.
29:117	Optics	3 s.h.
29:119	Stellar Dynamics and Galactic Structure	3 s.h.
29:121	Introduction to Astrophysics II	3 s.h.
29:131	Radio Astronomy	2 s.h.
29:171, 172	Methods of Theoretical Physics	6 s.h.
29:191	Atomic Physics	3 s.h.
29:192	Nuclear Physics	3 s.h.
29:194	Plasma Physics	3 s.h.
29:232, 233	Theoretical Astrophysics I, II	6 s.h.
29:234	Stellar Structure and Stellar Evolution	2 s.h.

An individual plan of study must be worked out by each candidate early in his graduate study.

Doctor of Philosophy Degree in Physics

The program of study for the Ph.D. degree with major in physics includes:

Thorough course work in both classical and modern theoretical physics for all candidates, whether their specialized research is to be in an experimental or a theoretical area.
Comprehensive examinations.
Participation in advanced seminars.
Successful conduct of a major original research in experimental physics, theoretical physics, or astrophysics; and the preparation and defense of a written dissertation based on this work.

Emphasis is laid on the capabilities developed and the knowledge gained rather than on the particular courses taken, credits acquired, or other aspects of the means to the end. Although no specific courses are required, the following are recommended as preparation for the comprehensive examinations:

29:191, 192, 193	Atomic, Nuclear and Solid State Physics
29:205	Classical Mechanics
29:212	Statistical Mechanics
29:213, 214	Classical Electrodynamics
29:245, 246	Quantum Mechanics I, II

Advanced mathematics such as theory of functions of a complex variable and vector and tensor analysis are used freely in these courses. An introduction to these fields is given in Methods of Theoretical Physics 29:171, 172. The selection of less advanced courses will depend on the adequacy of the student's preparation for graduate work; his choice of more advanced and specialized courses will depend on the direction in which his interests develop.

Before a candidate is admitted to the comprehensive examinations, he must acquire and demonstrate to the appropriate foreign language department a reading competence in any two of the following three foreign languages: German, Russian and French.

A candidate for the Ph.D. degree will not be recommended for the degree until he has written his dissertation in proper form for formal publication and has submitted it, with the approval of his research adviser, for publication to a standard scientific journal of wide distribution.

Research

The department has an excellent library and a number of well-equipped laboratories. An IBM 360/65 digital computer and the associated facilities of the University Computer Center are available for research by students and staff of the department. The central machine shop is fully equipped and staffed with skilled instrument makers and machinists, and there are several electronics and machine shops for the use of advanced students and the research staff.

Experimental research is conducted in the fields of nuclear structure physics, cosmic rays, atmospheric and space physics, astrophysics, chemical physics, and solid state physics.

Theoretical research is devoted to atomic and nuclear theory, quantum field theory, statistical mechanics, plasma physics, theory of solids, theory of elementary particles, solar-terrestrial physics, and astrophysics.

Persons qualified for graduate study are invited to apply for fellowships and assistantships. Inquiries should be directed to the departmental office.

STAFF

Professors: Richard R. Carlson, Fritz Coester, Edward B. Nelson, Edwin Norbeck, James A. Van Allen.

Visiting Professor: J. H. Piddington.

Professors Emeriti: John A. Eldridge*, E. P. T. Tyndall*, Charles A. Wylie* (Astronomy).

*Not in residence 1967-68.

Associate Professors: Raymon T. Carpenter, Louis A. Frank, Georg Knorr, David C. Montgomery, Peter D. Noerdlinger, William R. Savage, Margaret A. Waggoner.

Assistant Professors: Donald A. Gurnett, Noah Hershkowitz, William H. Klink, Stamatios M. Krimigis, Edward R. McCliment, John S. Neff (Astronomy), George P. Payne, John W. Schweitzer.

Instructor: Donald C. Enemark.

Research Associates: Theodore A. Fritz, S. Peter Gary, George P. Haskell, Glenn Joyce, Robert A. Mendelson, C. Rao, Stanley D. Shawhan.

Graduate Assistants: Ingvar S. Akersten, T. K. Bisht, T. B. Burns, Gerald A. Clapp, William G. Delinger, George P. Durkee, John W. Edie, Herbert R. Flindt, John W. Gerty, David R. Gilbert, John P. Holden, Richard H. Kitchen, K. Logan Kuiper, Andrew Lacis, Charles F. Lebeda, Philip M. McClean, Kenneth A. Murphy, Robert R. Shaw, Jerry L. Underfer, James H. Williams, William R. Wing.

Graduate College Research Assistants: Francis B. Huck, William D. Teeters, Paul F. Tumelty.

Graduate Research Assistants: Kent L. Ackerson, Bruce D. Aldrich, Charles P. Catalano, Jose M. Cuevas, Larry L. Gadeken, Sister Jean Gibson, M. Wayne Greene, Rollin C. Harding, F. Duane Ingram, Clarence G. Jacobs, David J. Johnson, David M. Klumpar, Michael D. O'Connor, John E. Poling, Bruce A. Randall, Lory R. Rice, Franklin D. Snyder, David J. Spyr, Medville J. Throop, Chin-Ming Tsai, Charles D. Wende, Harlan W. Wyborny, David M. Yeager, Richard Yeh, Alexander K. Yui.

U.S. Steel Foundation Fellow: John D. Craven.

National Science Foundation Fellow: Russell E. Warren.

National Aeronautics and Space Administration Graduate Trainees: Roger R. Anderson, A. Lee Burns, Mavis George Cauffman, Jerry F. Drake, William G. Innanen, Michael J. Lavan, Stephen R. Mosier, Melvin N. Oliven, John M. Rankin, Paul Rodriguez, Granville J. Smith, William W. Taylor, Michael A. Vlachos, Donald R. Zrudsky.

National Defense Education Act Fellows: David P. Cauffman, Donald D. Cobb, Duane H. Faulkner, Lloyd E. Johnson, John A. Tanis.

Rockefeller Foundation Scholar: Celso R. Roque.

International Institute of Education Fellow: P. A. Sengupta.

Physics

Prerequisites are specified as a guide and may be waived with the consent of the instructor.

Primarily for Undergraduates

29:1 College Physics — *4 s.h.*

Open to freshmen. For premedical, predental, and pharmacy students, and others interested in elementary physics. Descriptive lectures, laboratory and problem work in mechanics, heat and sound. Prerequisite or corequisite, Mathematics 22M:4. Both semesters and summer session. Instructors: Noerdlinger, Nelson.

29:2 College Physics — *4 s.h.*

Continuation of 29:1, which is prerequisite. Electricity, magnetism, and light. Both semesters and summer session. Instructors: Nelson, Noerdlinger.

29:7 General Physics *4 s.h.*

For engineering students. Three lectures and one three-hour laboratory-recitation each week on mechanics, heat and sound. Prerequisite or corequisite, Mathematics 22M:6. Both semesters. Instructors: Carlson, Norbeck.

29:8 General Physics *4 s.h.*

Continuation of 29:7, which is prerequisite. Electricity, magnetism, and light. Both semesters. Instructors: Krimigis, Carlson.

29:9 Introduction to Modern Physics *3 or 4 s.h.*

Electronic, atomic, and nuclear phenomena from an experimental and interpretative point of view. Three lectures and one laboratory each week. Prerequisites, 29:1, 2 or 29:7, 8, and Mathematics 22M:7. Instructor: Payne.

29:17 Introductory Physics I* *5 s.h.*

Classical and modern physics for physics majors, honors students and others by permission of the instructor. Four lecture-discussion sections and one laboratory per week. Corequisite, Mathematics, 22M:6. Instructor: Krimigis.

29:18 Introductory Physics II* *5 s.h.*

A continuation of 29:17, which is prerequisite. Corequisite, Mathematics 22M:7. Instructor: Savage.

29:19 Introductory Physics III* *5 s.h.*

A continuation of 29:18, which is prerequisite. Instructor: Savage.

29:93 Reading in Physics *cr.arr.*

Consult head of department before registering. Staff.

29:99 Honors Seminar* *cr.arr.*

For junior and senior honors candidates majoring in physics or astronomy. Guidance in conducting original scholarly investigations. Instructor: Savage.

For Undergraduates and Graduates

(These courses presuppose a working knowledge of differential and integral calculus, and completion of 29:17, 18, 19 or equivalents.)

29:103 Reading in Physics *cr.arr.*

Consult head of department before registering. Staff.

29:117 Optics *3 s.h.*

Geometrical and physical optics. Lectures on the properties of lenses and simple optical instruments; phenomena of propagation of electromagnetic waves, interference, diffraction and polarization. Three lectures each week. Instructor: Norbeck.

29:118 Kinetic Theory and Thermodynamics *3 s.h.*

The kinetic theory of matter. Macroscopic description of thermal phenomena. The fundamental laws of thermodynamics and their application. Instructor: Klink.

29:127 Electricity and Electrical Measurements *3 s.h.*

Electrical circuits, measurements, and electronics. Introduction to electromagnetic fields. Two lectures and one laboratory each week. Prerequisite, 29:2 or 29:8 and 22M:6. Staff.

29:128 Electronics *3 s.h.*

Characteristics of vacuum tubes and transistors. Design and study of analog and digital circuits. Two lectures and one laboratory each week. Prerequisite, 29:127 or equivalent. Instructor: Enemark.

29:129 Electricity and Magnetism *3 s.h.*

Fundamental principles including the phenomenological foundations of Maxwell's equations and their application. Three lectures each week. Instructor: Frank.

29:130 Electricity and Magnetism *3 s.h.*

Continuation of 29:129, which is prerequisite. Instructor: Frank.

29:132 Intermediate Laboratory *2 s.h.*

Laboratory work in electricity and magnetism and electronics, atomic, nuclear and solid state physics, optics, and spectroscopy. One laboratory period each week. May be repeated. Staff.

29:133 Advanced Laboratory *2 s.h.*

Laboratory work in optical and X-ray spectroscopy, solid state, nuclear physics, and cosmic rays. One laboratory period each week. May be repeated. Instructor: Hershkowitz.

29:171 Methods of Theoretical Physics *3 s.h.*

Linear algebra, integration methods, complex variables, transforms, special functions. Prerequisite, Mathematics 22M:105. Instructor: Payne.

29:172 Methods of Theoretical Physics *3 s.h.*

Continuation of 29:171. Partial differential equations, Green's functions, numerical methods. Instructor: Payne.

29:191 Atomic Physics *3 s.h.*

Introductory quantum theory and wave mechanics, atomic and molecular spectra, atomic structure. Prerequisite, 29:9 or 29:19. Instructor: Waggoner.

29:192 Nuclear Physics *3 s.h.*

Nuclear masses, radioactivity, alpha, beta, and gamma ray spectra, nuclear energy levels and nuclear structure, nuclear reactions, the neutron, fission and fusion reactions, passage of radiations through matter, mesons and elementary particles, experimental techniques. Instructor: Waggoner.

29:193 Introductory Solid State Physics *3 s.h.*

Phenomenological and theoretical properties of solids; classification of solids and crystal structures, electronic and vibrational processes in materials; thermal, optical, magnetic, and dielectric properties of solids. Instructor: Hershkowitz.

29:194 Plasma Physics *3 s.h.*

Introduction to physics of ionized gases including: orbit theory, guiding center motion, adiabatic invariants; description of plasmas by fluid variables and distribution functions; linearized wave motions and instabilities; magnetohydrodynamics and MHD shock waves. Prerequisites, 29:130 and some knowledge of vector analysis. Instructor: Gurnett.

*Honors Course.

29:195 Plasma Physics *3 s.h.*

Continuation of 29:194. Topics covered include linear and non-linear solutions of the Vlasov equation, test charge problems, and the Fokker Planck equation. Instructor: Gurnett.

Primarily for Graduates

29:205 Classical Mechanics *3 s.h.*

Dynamics of mass points. Lagrange's and Hamilton's equations. Canonical transformations and Hamilton-Jacobi theory. Prerequisite, Mathematics 22M:103. Instructor: Schweitzer.

29:211 Mechanics of Continua *3 s.h.*

Hydrostatics, dynamics of ideal fluids, both incompressible and compressible; viscous flow; the classical theory of elasticity. Prerequisites, Mathematics 22M:103, 104, and 29:171, 172, or the equivalent. Instructor: Montgomery.

29:212 Statistical Mechanics I *3 s.h.*

The problem of Boltzmann. The H-theorem, general principles of classical statistical mechanics. Specific heat theory, nonideal gases. Stochastic processes. Einstein-Bose and Fermi-Dirac statistics and applications. Prerequisites, 29:118, Mathematics 22M:103, 104, and 29:171, 172, or the equivalent. Instructor: Knorr.

29:213 Classical Electrodynamics *3 s.h.*

Advanced electro-magnetostatics, boundary value problems, Green's functions, Maxwell's equations, radiation theory, physical optics, multipole expansion of radiation field. Prerequisites, 29:129, 130, 171, 172, or equivalent. Instructor: Klink.

29:214 Classical Electrodynamics *3 s.h.*

Special relativity, motion of charges in fields, theories of radiation reaction, special topics. Prerequisite, 29:213. Instructor: Klink.

29:220 Individual Critical Study *cr.arr.*

An essay is to be written on a topic chosen in consultation with a member of the faculty. For candidates for the M.S. degree without thesis in physics or astronomy. Staff.

29:245 Quantum Mechanics I *3 s.h.*

Nonrelativistic quantum mechanics; Schrödinger wave mechanics, Hilbert space methods, perturbation theory, scattering, spin and angular momentum, identical particles, selected applications; introduction to relativistic theory. Prerequisites, 29:191, 171, 172. Instructor: McCliment.

29:246 Quantum Mechanics II *3 s.h.*

Continuation of 29:245. Instructor: McCliment.

29:249 Advanced Nuclear Physics *3 s.h.*

The phenomena of nuclear physics and their interpretation. Static properties of nuclei, nuclear moments, shell model, collective model, γ transitions, β decay, nuclear reaction mechanisms and other topics. Prerequisites, 29:191, 192 and 245. May be repeated. Instructor: Carpenter.

29:250 Advanced Nuclear Physics *3 s.h.*

Continuation of 29:249. Instructor: Carpenter.

29:262 Seminar: Solid State Physics *cr.arr.*

Discussion of current research. Instructor: Savage.

29:265 Seminar: Theoretical Physics *cr.arr.*

Discussion of current research. Staff.

29:266 Seminar: Space Physics *cr.arr.*

Discussion of current research. Instructor: Van Allen.

29:267 Seminar: Nuclear Physics *cr.arr.*

Discussion of current research. Instructor: Carlson.

29:269 Special Topics in Nuclear Physics *cr.arr.*

Advanced lectures on one or more of the following topics: nuclear models and their relations, theory of nuclear reactions, weak interactions, heavy ion reactions. Prerequisites, 29:249, 250. May be repeated. Instructor: Carlson.

29:271 Theoretical Solid State Physics *3 s.h.*

Central principles of the quantum theory of solids. Lattice dynamics, electronic properties, many-body effects, superconductivity, magnetism, and other topics. Emphasis on the viewpoint of elementary excitations. Prerequisites, 29:193, 245, 246. Instructor: Schweitzer.

29:272 Theoretical Solid State Physics *3 s.h.*

Continuation of 29:271. May be repeated. Instructor: Hershkowitz.

29:273 Relativity *3 s.h.*

Relativistic formulation of mechanics and electrodynamics; Einstein's theory of gravitation. Staff.

29:274 Statistical Mechanics II *3 s.h.*

Advanced topics in statistical mechanics. Content may vary from year to year; e.g., foundations of kinetic theory and non-equilibrium statistical mechanics, or quantum statistical mechanics. Instructor: Schweitzer.

29:276 Special Topics in Quantum Mechanics *3 s.h.*

Contemporary topics in quantum theory. Field theory, dispersion relations, group theoretic analysis of fundamental particle classification schemes, Regge poles, many-body problems. The topics discussed will vary from year to year as circumstances demand. Prerequisites, 29:245, 246. May be repeated. Staff.

29:278 Solar-Terrestrial Physics *2 s.h.*

Phenomena in the solar atmosphere, corpuscular and electromagnetic radiation in interplantary space, the geomagnetic field and interplanetary magnetic fields, magnetic storms, aurorae and the geomagnetically trapped radiation. May be repeated. Instructors: Frank, Van Allen.

29:281 Research in Physics *cr.arr.*

Prerequisite, consent of head of department. Staff.

29:290 Physics and Chemistry of the Upper Atmosphere *2 s.h.*

Physics of neutral and ionized gases. Absorption of solar radiation in relation to the ionosphere, the ozone layer, and chemical processes in the ionosphere. Electric currents associated with daily magnetic variations and magnetic storms. May be repeated. Staff.

29:294 Advanced Plasma Physics I *3 s.h.*

Statistical mechanics of plasmas; Liouville equation;

BBGKY hierarchy; Fokker-Planck equation and relaxation processes; Balescu-Lenard equation; Vlasov's equation and linearized wave motion; shocks, nonlinear plasma motions, and instabilities; fluctuations and radiation processes; magnetohydrodynamics; recent papers. Prerequisites, 29:212, 213 or consent of instructor. Instructor: Knorr.

29:295 Advanced Plasma Physics II *3 s.h.*

Continuation of 29:294. May be repeated. Instructor: Montgomery.

Astronomy

Primarily for Undergraduates

29:61 General Astronomy *4 s.h.*

Open to freshmen. Descriptive lectures and laboratory work in elementary astronomy. Study of the solar system and astronomical techniques. One laboratory per week for observation with the telescope and problem work. Prerequisite, at least one year each of high school algebra and geometry. Instructor: Neff.

29:62 General Astronomy *4 s.h.*

Continuation of 29:61. Stellar astronomy. Motions and physics of the stars; systems of stars; interstellar matter; galaxies. Prerequisite, same as 29:61. Instructor: Neff.

29:94 Reading in Astronomy *cr.arr.*

Consult head of department before registering. Staff.

29:99 Honors Seminar *cr.arr.*

See Physics.

For Undergraduates and Graduates

29:104 Reading in Astronomy *cr.arr.*

Consult head of department before registering. Staff.

29:105 General Astronomy *4 s.h.*

Accelerated course offered only in the summer. Prerequisite, same as 29:61. Staff.

29:119 Stellar Dynamics and Galactic Structure *3 s.h.*

Fundamentals of astrometry and stellar spectroscopy. Properties of visual, spectroscopic, and eclipsing binary stars. Stellar kinematics and dynamics. Distance indicators, their application to the investigation of the structure of the galaxy and extragalactic systems. Prerequisites, 29:18 and 22M:7 or equivalent. Offered alternate years starting 1968. Instructor: Neff.

29:120 Stellar and Galactic Astrophysics *3 s.h.*

Basic problems and methods of astrophysics. Radiation and spectra of the sun, stars, nebulae, and interstellar matter. Prerequisites, 29:19 and 22M:7 or equivalent. Instructor: Neff.

29:121 Solar System Astrophysics *3 s.h.*

Astronomical coordinates, celestial dynamics, the two and N body problems, planetary properties, planetary atmospheres. The sun and interplanetary space. Prerequisites, 29:19 and 22M:7 or equivalent. Alternate years starting 1967-68. Instructor: Neff.

29:131 Radio Astronomy *2 s.h.*

Current developments in radio astronomy; radio-frequency radiations from the sun, stars, planets, and interstellar matter. Observational techniques. Prerequisite, 29:120 or consent of instructor. Alternate years starting 1967-68. Instructor: Shawhan.

29:137 Astronomical Laboratory *1 s.h.*

Advanced laboratory work and observing with the 24-inch telescope. Techniques of astronomical photography, photometry, and spectroscopy. Laboratory work in data reduction, instrument calibration, and numerical computation. Prerequisites, 29:120 and consent of instructor. May be repeated. Alternate years starting 1968-69. Instructor: Neff.

29:220 Individual Critical Study *cr.arr.*

See Physics.

29:232 Theoretical Astrophysics I *3 s.h.*

Theory of stellar photospheres and the continuous spectra of stars. Formation of absorption lines in the spectra stars. Prerequisite, consent of instructor. Alternate years starting 1968-69. Staff.

29:233 Theoretical Astrophysics II *3 s.h.*

Interstellar matter, nebulae, novae, and galactic radiation. Continuation of 29:232, which is a prerequisite. Alternate years starting 1968-69. Staff.

29:234 Stellar Structure and Stellar Evolution *2 s.h.*

Structure of stellar interiors. Nuclear-genesis and chemical synthesis in stars, and the evolution of stars. Prerequisite, consent of instructor. Alternate years starting 1967-68. Instructor: Neff.

29:263 Seminar: Astrophysics *cr.arr.*

Discussion of current research. Staff.

29:282 Research in Astronomy *cr.arr.*

Prerequisite, consent of head of department. Staff.