TTU Department of Physics and Astronomy

Undergraduate Handbook – 2021-2022 Catalog

This handbook is designed to serve as a guide for the physics major. Only students who enter the College of Arts & Sciences in Fall 2021 or later will be under the guidelines of this booklet.

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Texas Tech University
Department of Physics and Astronomy
Undergraduate Programs

Professors: Akchurin, Duncan, Grave de Peralta, Huang, Lee, Maccarone, Owen, and Romano; Associate Professors: Corsi, Gibson, Sanati, Thacker, and Volobouev; Assistant Professors: Chatzakis, DeGottardi, Kim, Kupfer, Whitbeck; Research Professors: Kunori, Lodhi; Lecturers: Antoniou, Damgov, Tsai; Instructors: Farooq, West; Retired and Emeriti: Borst, Estreicher, Glab, Lamp, Myles, Wigmans.

The Bachelor of Science degree can be taken in any of three areas of concentration, to be described below. These concentrations allow a student to tailor their studies towards their particular career goals. A physics major should declare a concentration when they file a degree plan upon completing 30 hours of coursework.

Majors in this department are required to maintain a minimum grade point average of 2.5 in physics courses and required mathematics adjunct courses and receive a C- or better in each of these courses. Students also have a variety of university and College of Arts & Sciences requirements that must be met. The minimum number of hours to attain a bachelor’s degree in physics in each of the various concentrations is 120. Credit for any transferred physics hours will be handled on an individual basis with the department’s undergraduate advisor and the Transfer Evaluation Office. Students transferring into physics from another department or college must have and maintain an institutional grade point average of 2.5 or better to enter and remain in the program.

Students are strongly encouraged to devote time to undergraduate research. Research areas in the department include astrophysics, biophysics, condensed matter physics (including nanotechnology), physics education, and particle physics.

The physics B.S. curricula are designed around the assumption that physics students will minor in mathematics. However, a variety of other minors that complement study in physics can be selected. Choice of a minor other than mathematics may require that a student complete more than 120 hours for their degree.

**B.S. in Physics, Professional Concentration**

The professional concentration provides a traditional curriculum for students majoring in physics and is intended to prepare them for graduate study or employment in the private or government sector as a physicist. A typical sequence of courses begins with PHYS 1408, 2401, 2302, 3301/3201, and 2305 for a total of 19 hours at the introductory level. PHYS 1408 and 2401 have special sections for physics majors, and majors are expected to take these sections. These are usually followed by the intermediate and advanced sequences, PHYS 3304, 3305, 3306, 3401, 4302, 4304, 4307, 4308 and 4306 (Capstone Project). Two 3-hour physics elective courses are also required. Students desiring to pursue advanced degrees are recommended to take advanced topic courses. Students are strongly encouraged to devote time to undergraduate research and sign up for PHYS 3000 to earn credit hours for their research. Three hours of PHYS 3000 can count as a PHYS elective.
**B.S. in Physics, Astrophysics Concentration**

The astrophysics concentration is a variation of the professional concentration and is intended for students who have a particular interest in astronomy and astrophysics. In addition to preparing students for possible employment paths associated with the professional concentration, the astrophysics concentration will prepare students to pursue graduate study in astronomy or astrophysics. This concentration has physics course requirements very similar to the professional concentration, but it also includes 20 hours of ASTR courses in addition to either PHYS 4312 or PHYS 4350. The Capstone Project (PHYS 4306) is not required for the astrophysics concentration, but it is strongly recommended. Majors in this concentration are strongly encouraged to minor in mathematics. Choice of a different minor may result in a student needing to take more than 120 hours to complete their degree. Students are strongly encouraged to devote time to undergraduate research.

**B.S. in Physics, Applied Physics Concentration**

The applied physics concentration is a variation of the professional concentration for students who wish to pursue more applied work, such as graduate study or employment in engineering or other technical fields. It requires the same physics coursework as the professional option (with only one PHYS elective and no requirement to take PHYS 4308) with an additional 12 required hours in an applied specialty or specialties. Applied electives must be approved by the physics undergraduate advisor. Again, majors in this concentration are strongly encouraged to minor in mathematics (note that applied physics courses cannot double-count towards an Applied Physics BS and a minor). Choice of a different minor may result in a student needing to take more than 120 hours to complete their degree. Students are strongly encouraged to devote time to undergraduate research.

**Required Mathematics Courses for Physics Majors:**

The required mathematics courses for physics majors in all three concentrations are MATH 1451, 1452, 2450, PHYS 4325, and 4326 (Math Methods for Physicists I and II). MATH 2360 (Linear Algebra) is strongly recommended and required for a MATH minor. MATH 3354 and 4354 or 3350 and 3351 may be substituted for the physics math methods courses with the consent of the undergraduate advisor. Please note that the mathematics sequence under PHYS will count towards a math minor. Students planning to pursue an advanced degree in physics should consult the physics undergraduate advisor about appropriate additional courses.

**Minors for Physics Majors:**

A broad variety of minor subjects may be chosen by a student majoring in physics. These include but are not limited to mathematics, biochemistry, physical chemistry, geophysics, computer science, business, and electrical engineering. A frequent minor choice for physics majors is mathematics, the requirements for which are automatically satisfied by the sequence of MATH courses required for the physics major plus MATH 2360 Linear Algebra. Students contemplating minors outside of the College of Arts & Sciences should seek the advice of the physics undergraduate advisor before beginning that minor.
Minor in Physics

A minor in physics requires 19 semester hours, of which at least 6 must be at the 3000 level or higher and must be approved by the undergraduate advisor. The minor sequence is PHYS 1408, 2401, and 3301/3201 plus 6 hours of approved 3000/4000 level courses. It should be noted that the first three courses have Calculus I, II, and III as prerequisites. Students must receive a grade of C- or better in all courses applied toward a minor. The astronomy courses ASTR 1400 and 1401 may not be used to satisfy requirements for the physics major or minor (with the exception of 1400 or 1401 for astrophysics majors). The astrophysics courses ASTR 3300, 4301, 4302, and 4305 may be applied to the physics minor.

Minor in Astronomy

A minor in astronomy by students majoring in subjects other than physics requires at least 22 semester hours of physics and astronomy courses, at least 9 of which must be at the 3000 or higher level and which must be approved by the undergraduate advisor. The recommended sequence is PHYS 1408, PHYS 2401, PHYS 3301/3201 with additional credits selected from among ASTR 2401, ASTR 3300, ASTR 4301, ASTR 4302, ASTR 4305, PHYS 4350, and undergraduate research in astronomy (PHYS 3000). It should be noted that the first three courses have Calculus I, II, and III as prerequisites. Under some circumstances, courses in engineering, geosciences or mathematics with significant astronomy content may be taken in place of the courses listed here.

Society of Physics Students (SPS)

Students are strongly encouraged to participate in the Society of Physics Students, which sponsors several academic and social activities. SPS is headquartered in Room 004 of the Science building, and its members organize community outreach activities and plan many fun and/or educational events and trips.
Physics Major
Degree Requirements

General Education Requirements – College of Arts & Sciences

English (9 hours) ENGL 1301 ENGL 1302 ENGL 23--

Oral Communication (3 hours)

Mathematics (6 hours) MATH 1451 MATH 1452

Life and Physical Sciences (8 hours) PHYS 1408 PHYS 2401

United States History (6 hours) HIST 2300 HIST 2301 -OR- HIST 2310

Political Science (6 hours) POLS 1301 POLS 2306

Social and Behavioral Sciences (3 hours)

Language, Philosophy, and Culture (3 hours)

Creative Arts (3 hours)

Multicultural (3 hours)

Personal Fitness and Wellness (1 hour)

Foreign Language: Freshman proficiency plus 3 hours at the sophomore level or higher in the same language. (Students who wish to take Spanish should take the Spanish Placement Exam.)

40 Credits Required at the Junior/Senior Level

120 Credits Required Total

This menu of courses is required by Texas Tech University for any student seeking a B.S. degree in the College of Arts & Sciences. The basic pattern is defined by the state and SACS. Courses for the various categories can be found under “Academic Requirements” in the 2021-2022 Catalog or at https://www.depts.ttu.edu/artsandsciences/students/undergraduate/gen_degree_req.php.

Communication Literacy Requirement: Regardless of concentration, a physics major must take at least 3 courses with the Communication Literacy (CL) attribute within the major. Communication Literacy (CL) courses (marked with an asterisk below) will be aimed towards providing and assessing student abilities in both oral and written communication of scientific information in the specific ways that are common to professional physicists and astrophysicists, both in traditional and non-traditional positions.
Physics Major, Professional Concentration

Required Physics Courses (47 hours)

- PHYS 1408 Principles I - Mechanics
- PHYS 2401 Principles II - E&M
- PHYS 2302 Principles III
- PHYS 2305 Computation for the Physical Sciences (Communication Literacy)*
- PHYS 3301 Principles IV - Introduction to Quantum Physics
- PHYS 3201 Modern Physics Lab and Data Analysis (must be taken with 3301)
- PHYS 3304 Intermediate Experimental Physics (Communication Literacy)*
- PHYS 3305 Electricity & Magnetism I
- PHYS 3306 Electricity & Magnetism II
- PHYS 3401 Optics (Communication Literacy)*
- PHYS 4302 Statistical & Thermal
- PHYS 4304 Mechanics
- PHYS 4307 Quantum Mechanics I
- PHYS 4308 Quantum Mechanics II
- PHYS 4306 Capstone Project (Communication Literacy)*

Physics Electives (choose 6 or more hours)

- PHYS 3000 Undergraduate Research
- PHYS 4000 Independent Study
- PHYS 4301 Computational
- PHYS 4309 Solid State
- PHYS 4312 Nuclear and Particle
- PHYS 4350 Relativity
- ASTR 3300 Special Topics in Astrophysics
- ASTR 4301 Astrophysics I
- ASTR 4302 Astrophysics II
- ASTR 4305 Radiative Processes

Required Mathematics Courses (18 hours)

- MATH 1451 Calculus I
- MATH 1452 Calculus II
- MATH 2450 Calculus III
- PHYS 4325 Math Methods for Physicists I (counts towards MATH minor)
- PHYS 4326 Math Methods for Physicists II (counts towards MATH minor)

Students are strongly encouraged to take MATH 2360 (Linear Algebra) to complete a MATH minor.
Physics Major, Astrophysics Concentration

**Required Physics Courses (40 or 41 hours)**

PHYS 1408 Principles I - Mechanics  
PHYS 2401 Principles II - E&M  
PHYS 2302 Principles III  
PHYS 2305 Computation for the Physical Sciences (Communication Literacy)*  
PHYS 3301 Principles IV - Introduction to Quantum Physics  
PHYS 3201 Modern Physics Lab and Data Analysis (must be taken with 3301)  
PHYS 3304 Intermediate Experimental Physics (Communication Literacy)*  
PHYS 3305 Electricity & Magnetism I  
PHYS 3401 Optics* - **OR**- PHYS 3306 E&M II (Optics is a Communication Literacy course)  
PHYS 4302 Statistical & Thermal  
PHYS 4304 Mechanics  
PHYS 4307 Quantum Mechanics I  
PHYS 4312 Nuclear and Particle Physics - **OR**- PHYS 4350 Relativity

Astrophysics students are strongly encouraged to take PHYS 4306 Capstone Project

**Required Astronomy Courses (20 hours)**

ASTR 1401 Stellar Astronomy  
ASTR 2401 Observational Astronomy  
ASTR 3300 Special Topics in Astrophysics  
ASTR 4301 Astrophysics I  
ASTR 4302 Astrophysics II  
ASTR 4305 Radiative Processes

**Required Mathematics Courses (18 hours)**

MATH 1451 Calculus I  
MATH 1452 Calculus II  
MATH 2450 Calculus III  
PHYS 4325 Math Methods for Physicists I (counts towards MATH minor)  
PHYS 4326 Math Methods for Physicists II (counts towards MATH minor)

Students are strongly encouraged to take MATH 2360 (Linear Algebra) to complete a MATH minor.
Physics Major, Applied Physics Concentration

Required Physics Courses (44 hours)

- PHYS 1408 Principles I - Mechanics
- PHYS 2401 Principles II - E&M
- PHYS 2302 Principles III
- PHYS 2305 Computation for the Physical Sciences (Communication Literacy)*
- PHYS 3301 Principles IV - Introduction to Quantum Physics
- PHYS 3201 Modern Physics Lab and Data Analysis (must be taken with 3301)
- PHYS 3304 Intermediate Experimental Physics (Communication Literacy)*
- PHYS 3305 Electricity & Magnetism I
- PHYS 3306 Electricity & Magnetism II
- PHYS 3401 Optics (Communication Literacy)*
- PHYS 4302 Statistical & Thermal
- PHYS 4304 Mechanics
- PHYS 4307 Quantum Mechanics I
- PHYS 4306 Capstone Project (Communication Literacy)*

Physics Electives (choose 3 or more hours)

- PHYS 3000 Undergraduate Research
- PHYS 4000 Independent Study
- PHYS 4301 Computational
- PHYS 4308 Quantum Mechanics II
- PHYS 4309 Solid State
- PHYS 4312 Nuclear and Particle
- PHYS 4350 Relativity
- ASTR 3300 Special Topics in Astrophysics
- ASTR 4301 Astrophysics I
- ASTR 4302 Astrophysics II
- ASTR 4305 Radiative Processes

Applied Physics or Engineering Electives (choose 12 or more hours)

- Pre-approved ECE courses: ECE 3302, 3303, 3306, 3311, 3312, 4314, 4341, 4344, 4354, 4381
- Pre-approved Geophysics courses: GPH 3300, 3310, 4300, 4321, 4323
- Pre-approved Wind Energy courses: WE 3300, 3301, 4321, 4322
- Pre-approved ATMO courses: ATMO 3301, 3310, 3316, 4300, 4312, GIST 3300, GEOL 3322

Required Mathematics Courses (18 hours)

- MATH 1451 Calculus I
- MATH 1452 Calculus II
- MATH 2450 Calculus III
- PHYS 4325 Math Methods for Physicists I (counts towards MATH minor)
- PHYS 4326 Math Methods for Physicists II (counts towards MATH minor)

Students are strongly encouraged to take MATH 2360 (Linear Algebra) to complete a MATH minor.
Course Planning for a Calculus-Ready Physics Major

The following is an example of how the four years of a calculus-ready Texas Tech physics major might be structured. Courses outside the Physics & Astronomy department and electives for the professional and applied physics concentrations have been omitted. This table is just an example—always confer with the academic advisor before registering for classes.

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<td>MATH 1451 Calculus I</td>
<td>PHYS 1408 Physics I</td>
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<tr>
<td>PHYS 2401 Physics II</td>
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<td>^MATH 2360 Linear Algebra</td>
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<td>MATH 2450 Calculus III</td>
<td>PHYS 3201 Modern Lab &amp; Data Analysis</td>
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<td>PHYS 3301 Physics IV</td>
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<td>**PHYS 3306 E&amp;M II</td>
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<td>PHYS 4307 Quantum Mechanics I</td>
<td>PHYS 3304 Intermediate Lab</td>
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<td>PHYS 4302 Statistical &amp; Thermal Physics</td>
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<td>**PHYS 4306 Capstone Project</td>
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<td>***PHYS 4308 Quantum Mechanics II</td>
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<td>*PHYS 4312 Nuclear &amp; Particle –OR– PHYS 4350 Relativity</td>
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^ Required for the mathematics minor
*Required for the astrophysics concentration
**Required for the professional and applied physics concentrations
***Required for the professional concentration
Scheduling of Physics Course Offerings

The courses PHYS 1408 and 2401 are offered every long semester and in the summer. The ASTR courses 1400 and 1401 and the PHYS courses 2302, 3301 + 3201, 3304 are offered every long semester. PHYS 3000, 4000, and 4306 may be taken during any semester or summer session with instructor permission. Other courses are offered as shown in the listing below and depending on instructor availability.

Courses Offered in AY 2021-2022

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<th>FALL 2021</th>
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<tr>
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<td>3306 E&amp;M II</td>
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<td>4000-040 Intro to Quantum Computing</td>
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Courses Tentatively Planned for Future Semesters

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<td>3305 E&amp;M I</td>
<td>3304 Intermediate Physics Laboratory</td>
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<th>ODD FALLS</th>
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Physics Course Descriptions

PHYS 1401. Physics for Nonscience Majors (4:3:2). 4 Credit Hours. Covers the basic laws and vocabulary of science using a minimum of mathematics. Partially fulfills core Life and Physical Sciences requirement.

PHYS 1403. General Physics I (4:3:3). 4 Credit Hours. Prerequisite: MATH 1320, MATH 1550, MATH 1420, MATH 1451, or MATH 1321. Non-calculus introductory physics covering mechanics, heat, and sound, thus providing background for study in science-related areas. Partially fulfills core Life and Physical Sciences requirement.

PHYS 1404. General Physics II (4:3:3). 4 Credit Hours. Prerequisite: PHYS 1403. Non-calculus introductory physics covering electricity, magnetism, light, and modern physics, thus providing background for study in science-related areas. Partially fulfills core Life and Physical Sciences requirement.

PHYS 1406. Physics of Sound and Music (4:3:2). 4 Credit Hours. Sound and music, including waves, harmonics, musical instruments, voice, hearing, room acoustics, elementary music theory, classroom demonstrations, music performances, high school mathematics. Laboratory. Satisfies natural science requirement in Arts and Sciences. Partially fulfills core Life and Physical Sciences requirement.

PHYS 1408. Principles of Physics I (4:3:2). 4 Credit Hours. Prerequisite: MATH 1451. Calculus-based introductory physics covering mechanics, kinematics, energy, momentum, and thermodynamics. (Honors section offered) Partially fulfills core Life and Physical Sciences requirement.

PHYS 2302. Principles of Physics III: Intermediate Classical Mechanics (3:3:0). 3 Credit Hours. Prerequisites: C or better in PHYS 1408 (PHYS 2401 recommended) and MATH 1452. Special and general relativity, thermodynamics, and statistical dynamics.

PHYS 2305. Computation for the Physical Sciences (3:3:0). 3 Credit Hours. Prerequisites: PHYS 1408 and PHYS 2401. Introduces computational tools to solve science problems. Emphasizes interplay between technology application and practical learning. (Communication Literacy).

PHYS 2401. Principles of Physics II (4:3:2). 4 Credit Hours. Prerequisites: PHYS 1408 and MATH 1452. Calculus-based introductory physics covering electric and magnetic fields, electromagnetic waves, and optics. (Honors section offered) Partially fulfills core Life and Physical Sciences requirement.

PHYS 3000. Undergraduate Research (V1-6). 1 to 6 Credit Hours. Prerequisite: Permission of the instructor. Individual and/or group research projects in basic or applied physics, under the guidance of a faculty member.

PHYS 3101. Legacy Modern Physics Lab (1:0:3). 1 Credit Hour. Corequisite PHYS 3301. Laboratory experiments designed to illustrate the basis of quantum physics. (For students with catalogs 2016-17 and earlier).
PHYS 3201. Modern Physics Lab and Data Analysis (2:1:3). 2 Credit Hours. Corequisite PHYS 3301. Laboratory experiments and accompanying lectures designed to illustrate the basis of quantum physics and proper techniques for data acquisition, analysis, and determination of uncertainties. (For students with catalogs 2017-18 and later).

PHYS 3301. Principles of Physics IV: Introduction to Quantum Physics (3:3:0). 3 Credit Hours. Prerequisite: PHYS 1408 and MATH 2450. Corequisites: PHYS 3201 or PHYS 3101. Failure of classical physics in the microscopic realm, development and fundamentals of quantum theory, applications to atoms, molecules, solids, nuclei, and particles.

PHYS 3304. Intermediate Physics Laboratory (3:0:6). 3 Credit Hours. Prerequisite: C or better in PHYS 3301 and PHYS 2305. Laboratory course on advanced physical principles. Experiments in atomic, molecular, solid state, and nuclear, and particle physics as well as relativity, electricity and magnetism including data acquisition and analyses. (Communication Literacy).

PHYS 3305. Electricity and Magnetism I (3:3:0). 3 Credit Hours. Prerequisite: PHYS 2401 and MATH 4325 or equivalent. Electrostatics, dielectric materials, Maxwell’s equations, currents, and magnetostatics.

PHYS 3306. Electricity and Magnetism II (3:3:0). 3 Credit Hours. Prerequisite: PHYS 3305 and MATH 4326 or equivalent. Magnetic properties of materials, electrodynamics, electromagnetic waves, waveguides and resonators, interaction with matter, AC circuits, radiation.

PHYS 3400. Fundamentals of Physics (4:3:3). 4 Credit Hours. Prerequisites: Education majors only; preference given to EC or HDFS; instructor approval. Teaches the fundamentals of physics and strategies for teaching these fundamentals. Not open to engineering, science, or mathematics majors.

PHYS 3401. Optics (4:2:4). 4 Credit Hours. Prerequisites: PHYS 3301. Covers geometrical and physical optics, waves, reflection, scattering, polarization, interference, diffraction, modern optics, and optical instrumentation. (Communication Literacy).

PHYS 4000. Independent Study (V1-4). 1 to 4 Credit Hours. Prerequisite: Approval of advisor. Study of advanced topics of current interest under direct supervision of a faculty member.


PHYS 4302. Statistical and Thermal Physics (3:3:0). 3 Credit Hours. Prerequisites: PHYS 3301 and PHYS 4325 or equivalent. Introduction to statistical methods in physics. Formulation of thermodynamics and statistical mechanics from a unified viewpoint with applications from classical and quantum physics.

PHYS 4304. Mechanics (3:3:0). 3 Credit Hours. Prerequisite: PHYS 1408 and PHYS 4325 or equivalent. Dynamics of particles and extended bodies, both rigid and fluid, using Newtonian mechanics and the Euler-Lagrange equations from Hamilton’s principle. Nonlinear systems and chaos with numerical modeling. Applications of the Navier Stokes equation.
PHYS 4306. Capstone Project (3). 3 Credit Hours. Prerequisite: Senior standing in physics major. Research in a current topic in physics and astronomy with a faculty mentor culminating in an oral presentation and a written report. (Communication Literacy).

PHYS 4307. Quantum Mechanics I (3:3:0). 3 Credit Hours. Prerequisite: C or better in PHYS 3301 and PHYS 4325 or equivalent. Introduction to fundamental concepts in quantum mechanics: probability, normalization, operators, solutions to Schrodinger equation for various potentials. Discussion of quantum mechanics in 3D, generalized uncertainty principle, angular momentum and hydrogen atom.

PHYS 4308. Quantum Mechanics II (3:3:0). 3 Credit Hours. Prerequisite: PHYS 4307. Review of quantum mechanics, time-independent and dependent perturbation theory, variational principle, WKB approximation, the adiabatic approximation and scattering.

PHYS 4309. Solid State Physics (3:3:0). 3 Credit Hours. Prerequisites: PHYS 3305 and knowledge of elementary quantum mechanics. The structural, thermal, electric, and magnetic properties of crystalline solids. Free electron theory of metals. Concept of energy bands and elementary semiconductor physics.

PHYS 4312. Nuclear and Particle Physics (3:3:0). 3 Credit Hours. Prerequisite: PHYS 4307. Deals with modern nuclear physics covering such topics as nuclear structure models, radioactivity, nuclear reactions, elementary particles, nuclear conservation, forces, and symmetry.

PHYS 4325. Mathematical Methods in Physical Sciences I (3:3:0) 3 Credit Hours. Prerequisite: C or better in MATH 2450. Vectors and coordinate systems, vector and scalar fields, ordinary differential equations, boundary-value problems and partial differential equations. (MATH 4325)

PHYS 4326. Mathematical Methods in Physical Sciences II (3:3:0) 3 Credit Hours. Prerequisite: C or better in PHYS 4325. Continuation of PHYS 4325. Calculus of variations, an introduction to complex analysis special functions, integral transforms. (MATH 4326)

PHYS 4350. Relativity (3:3:0) 3 Credit Hours. Prerequisites: C or better in PHYS 3305 and PHYS 4304 (may be taken concurrently). Introduction to spacetime, differential geometry, special and general relativity; with applications to black holes, cosmology, and gravitational waves.
Astronomy Course Descriptions

**ASTR 1400. Solar System Astronomy (4:3:2).** 4 Credit Hours. Covers the sun, planets, moons, asteroids, comets, gravitation, and formation. (Honors section offered.) Partially fulfills core Life and Physical Sciences requirement.

**ASTR 1401. Stellar Astronomy (4:3:2).** 4 Credit Hours. Covers stars, star formation, galaxies, and cosmology models. (Honors section offered.) Partially fulfills core Life and Physical Sciences requirement.

**ASTR 2401. Observational Astronomy (4:3:2).** 4 Credit Hours. Prerequisite: ASTR 1400 or 1401 or consent of instructor. Designed for anyone interested in learning the use of an optical telescope, both visually and for imaging.

**ASTR 3300. Special Topics in Astrophysics (3:3:0).** 3 Credit Hours. Prerequisites: C- or better in ASTR 2401, PHYS 2302, PHYS 3301, and PHYS 4325 or equivalent. Topics in radio astronomy, X-ray astronomy, gravitational wave astronomy, compact objects, accretion, stellar explosions and others. May be repeated in different areas.

**ASTR 4301. Astrophysics I (3:3:0).** 3 Credit Hours. Prerequisite: PHYS 3301. Introduction to the tools of astronomy, stellar properties, stellar structure, and stellar evolution.

**ASTR 4302. Astrophysics II (3:3:0).** 3 Credit Hours. Prerequisite: PHYS 3301. Structure, formation and evolution of galaxies; cosmology.

**ASTR 4305. Radiative Processes in Astrophysics (3:3:0).** 3 Credit Hours. Prerequisites: C or better in PHYS 3305 and PHYS 4307. A survey of the physical processes related to the production and propagation of radiation in astrophysical phenomena, including thermal and non-thermal radiation, and atomic transitions.
Faculty Members


