BACHELOR OF ARTS IN PHYSICS

Undergraduate Programs in Physics and Astronomy

High school preparation for undergraduate programs in physics, astronomy, and astrophysics should include four years of math at least through pre-calculus and one year each of chemistry, physics, and computer programming. Students are strongly encouraged to periodically meet with a major advisor to review course selection and degree progress.

The B.A. degrees are ideal for students who want a strong background in physical science but desire more flexibility to blend their curriculum with "liberal arts" and other interests. Students with B.A. degrees often pursue careers in teaching, science communication & journalism, science outreach (at science museums, planetaria & public observatories), medical, dental, and other health fields, or business sub-fields in which a rigorous scientific background is beneficial. The B.S. degrees require more in-depth technical training, advanced laboratory experiences, and specialized elective topics. Students with B.S. degrees often pursue science and engineering careers in colleges & universities, industrial research & development labs, or government labs & agencies, or pursue advanced graduate degrees in physics, astronomy, planetary science, or engineering. The B.S. Physics, Concentration in Physics for Teaching allows for a very versatile curriculum that can be combined with Mathematics, Chemistry, or Earth & Climate Sciences to provide breadth across the physical sciences ideal for future K-12 teachers.

All degrees in physics and astronomy have the same lower-division physics and math requirements. First-year students and sophomores focus on completing calculus (MATH 226, 227, 228) and the introductory physics sequence (PHYS 220/222, 230/232, 240/242). Physics and math tracks are very hierarchical in that students must master one course before they can take the next course and many courses must be taken in a prescribed order. Which math course a student initially takes depends on what their math preparation was prior to enrolling at SF State. Students who have completed algebra and geometry and almost no or very little trigonometry benefit from taking an extended two-semester pre-calculus sequence MATH 197 (Prelude to Calculus I) and MATH 198 (Prelude to Calculus II). Students who have completed intermediate algebra and some trigonometry can usually start with the one-semester version of pre-calculus MATH 199 (Pre-calculus). Students who have previously done well (grade of B or better) in a solid pre-calculus course that included a significant amount of trigonometry can dive right into the first course in the calculus sequence, MATH 226 (Calculus I). The Department of Mathematics is responsible for the university policy on Advanced Placement (A.P.) credit for calculus. Scores of 4 or 5 on the A.P. Calculus AB exam (or the AB subpart of the BC exam) earn students 4 units of credit for MATH 226: Calculus I and can move on to MATH 227: Calculus II. Credit for MATH 227: Calculus II is much more restrictive; students must earn an overall score of 5 on the A.P. Calculus BC exam along with a 5 on the AB subpart, and they must meet with a math advisor to get final approval before they will earn 4 units of credit for MATH 227.

After students complete the three-semester calculus sequence through MATH 228, they move on to linear algebra and differential equations. Students have a choice of MATH 245 (Elementary Differential Equations and Linear Algebra), or a more in-depth, advanced two-semester sequence of MATH 325 (Linear Algebra) and MATH 376 (Ordinary Differential Equations). Note that MATH 325 will count for 3 units toward major electives. Students who intend to complete a math minor must take the two-semester sequence. The Math Department will allow either PHYS 430 or PHYS 460 to count toward the Minor in Mathematics – that means Physics majors will only need ONE more math class to complete the Minor in Mathematics! Recommended courses include: MATH 380: Complex Analysis, MATH 400: Numerical Analysis, MATH 440: Probability & Statistics I, MATH 450: Topology, MATH 451: Differential Geometry, and MATH 477: Partial Differential Equations.

Students are advised to start the physics sequence immediately after completing MATH 226. The first physics course in the sequence is PHYS 220 (General Physics with Calculus I) and the corresponding 1-unit lab PHYS 222. Most students will then take PHYS 230/232, followed by PHYS 240/242. However, PHYS 240/242 can be taken simultaneously or even before PHYS 230/232. This is especially relevant for students who may choose to take summer courses because PHYS 230/232 are offered in the summer session, but PHYS 240/242 is not (at least not at SF State, but perhaps at some community colleges). Note that PHYS 230/232 and PHYS 240/242 both require previous completion of MATH 227 with a grade of C or better (or A.P. Calculus BC with a score of 5). Students who earn a score of 4 or 5 on the A.P. Physics C: Mechanics exam are credited with 4 units for PHYS 220/222. Students who earn a score of 4 or 5 on the A.P. Physics C: Electricity & Magnetism exam are credited with 4 units for PHYS 230/232. Note that the A.P. Physics 1 & 2 (algebra/trig-based courses) do not earn any credit toward Physics/Astronomy degrees at SF State.

The B.S. Physics and the B.S. Physics concentration in Astrophysics both require CSC 309: Computer Programming, but students on the B.A. track are also strongly encouraged to take it. Students should complete this course within their first two years because upper-division physics and astronomy courses may require computer programming on some assignments. Currently, CSC 309 teaches Python programming.

The B.A. Physics with a concentration in Astronomy requires ASTR 115: Introduction to Astronomy. There is an optional 1-unit lab ASTR 116: Astronomy Laboratory. ASTR 115 gives a broad, descriptive survey of all of astronomy with very little math or physics. This course should be taken in the first two years. While ASTR 115 is not required for the B.S. Physics with a concentration in Astrophysics, B.S. students benefit from the overview of astronomy (however, the units do not count toward the B.S. degree). ASTR 300: Stars, Planets, and the Milky Way is the first astronomy course that uses significant math and physics. B.A. and B.S. students should take this course in the spring semester immediately following completion of (or concurrent enrollment in) PHYS 230 & 240 (usually in the spring of sophomore year). This is not a course that is typically offered at many community colleges, and so most transfer students will take in junior spring. ASTR 301: Observational Astronomy Laboratory is usually taken in the fall semester of junior year. Students with sufficient preparation may take it earlier with the permission of the instructor.

- While required major core courses should be taken for letter grades, a maximum of 6 units of upper-division courses taken CR/NC may be counted toward physics and astronomy degrees.
- All prerequisites for upper-division courses must be completed with a grade of C- or better. See course descriptions for prerequisite requirements.

Program Learning Outcomes

Graduates with physics, astronomy, and astrophysics degrees will be able to:

1.) Describe universal physical principles in classical mechanics, electricity & magnetism, special & general relativity, thermodynamics & statistical mechanics, quantum mechanics, astronomy & astrophysics, and relate fundamental conservation principles (conservation of energy, conservation of linear momentum, conservation of angular momentum) to underlying symmetries of nature.

2.) Analyze real-world physical systems on Earth and throughout the Universe, develop simplified models of such systems, translate physical principles into the language of mathematics, and then apply the appropriate mathematical tools (vector calculus, linear algebra, differential equations, variational techniques, probability & statistics, numerical & computational methods) to determine a system's spatiotemporal evolution with an awareness of the limitations of any solutions due to the approximations of the physical models and/or mathematical/computational techniques.

3.) Demonstrate proficiency with basic laboratory skills and experimental techniques with electronics, lasers & optical devices, sensors, detectors, microscopes, and telescopes, always with appropriate safety practices (especially with respect to lasers, chemicals, radioactive materials).

4.) Articulate and apply the "scientific method," the empirical, iterative method of acquiring new knowledge through developing models to explain observations of the natural world, formulating testable hypotheses, designing and executing experimental, computational, and theoretical investigations to test predictions, analyzing data with appropriate statistics and attention to uncertainties, ascertaining consistency with existing theories, and sharing results with the broader scientific community for confirmation and validation.

5.) Demonstrate writing, speaking, and visual data presentation skills to effectively communicate science at the appropriate level of sophistication for the relevant target audience (e.g., instructors, students, scientists, public-at-large, policy-makers).

6.) Develop the social and communication skills to effectively participate in diverse scientific teams, including those that are multidisciplinary and/or interdisciplinary, and appreciate that the pursuit of science is a human endeavor and that progress is best made when the full spectrum of humanity is encouraged to participate and share their perspectives, passions, and skills.

7.) Engage local, state, national & global communities to address current and emerging scientific and technological challenges in equitable and environmentally sustainable ways.

Physics (B.A.) — 52 units

Lower/Upper-Division Prerequisites (27 units)

Code	Title	Units
MATH 226	Calculus I	4
MATH 227	Calculus II	4
MATH 228	Calculus III	4
Select One:		3
MATH 245	Elementary Differential Equations and Linear Algebra	
MATH 376	Ordinary Differential Equations I	
PHYS 220 & PHYS 222	General Physics with Calculus I and General Physics with Calculus I Laboratory	4
PHYS 230 & PHYS 232	General Physics with Calculus II and General Physics with Calculus II Laboratory	4
PHYS 240 & PHYS 242	General Physics with Calculus III and General Physics with Calculus III Laboratory	4

Upper-Division Requirements (25 units)

Code	Title	Units
PHYS 320	Modern Physics I	3
PHYS 321	Modern Physics Laboratory	2
PHYS 330	Analytical Mechanics I	3
PHYS 360	Electricity and Magnetism I	3
PHYS 370	Thermodynamics and Statistical Mechanics	3
PHYS 385	Introduction to Theoretical Physics I	3
PHYS 491GW	Advanced Laboratory Techniques I - GWAR	3
PHYS 695	Culminating Experience in Physics	1
Upper-division electives on advisement (PHYS 460 or PHYS 325 recommended)		4

Note: A minimum of 30 upper-division units must be completed for the degree (including upper-division units required for the major, general education, electives, etc.). A student can complete this major yet not attain the necessary number of upper-division units required for graduation. In this case, additional upper-division courses will be needed to reach the required total.

Requirement	Course Level	Units	Area Designation
Oral Communication	LD	3	A1
Written English Communication	LD	3	A2
Critical Thinking	LD	3	A3
Physical Science	LD	3	B1
Life Science	LD	3	B2
Lab Science	LD	1	B3
Mathematics/ Quantitative Reasoning	LD	3	B4
Arts	LD	3	C1
Humanities	LD	3	C2
Arts or Humanities	LD	3	C1 or C2
Social Sciences	LD	3	D1
Social Sciences: US History	LD	3	D2
Lifelong Learning and Self-Development (LLD)	LD	3	E
Ethnic Studies	LD	3	F
Physical and/or Life Science	UD	3	UD-B
Arts and/or Humanities	UD	3	UD-C
Social Sciences	UD	3	UD-D

SF State Studies			
Courses certified as meeting the SF State Studies requirements may be upper or lower division in General Education (GE), a major or minor, or an elective.			
American Ethnic and Racial Minorities	LD or UD	3	AERM
Environmental Sustainability	LD or UD	3	ES
Global Perspectives	LD or UD	3	GP
Social Justice	LD or UD	3	SJ

Note: LD = Lower-Division; UD = Upper-Division.

First-Time Student Roadmap (4 Year)

a. The roadmaps presented in this Bulletin are intended as suggested plans of study and do not replace meeting with an advisor. For a more personalized roadmap, please use the Degree Planner (https://registrar.sfsu.edu/degreeplanner/) tool found in your Student Center.
b. In order to choose your English Composition A2 course and your QR/Math B4 course, please complete the online advising activities at writingadvising.sfsu.edu (https://writingadvising.sfsu.edu) and mathadvising.sfsu.edu. Questions? Contact Gator Smart Start (https://gatorsmartstart.sfsu.edu).

First-Time Student Roadmap (http://bulletin.sfsu.edu/colleges/science-engineering/physics-astronomy/ba-physics/roadmap-i-ii-eng/)

Transfer Student Roadmap (2 Year)

For students with an AS-T in **Physics**.
PHYS ADT Roadmap (http://bulletin.sfsu.edu/colleges/science-engineering/physics-astronomy/ba-physics/adt-roadmap/)

This degree program is an approved pathway ("similar" major) for students earning the ADT in Physics

California legislation SB 1440 (2009) mandated the creation of the Associate Degree for Transfer (ADT) to be awarded by the California Community Colleges. Two types of ADTs are awarded: Associate in Arts for Transfer (AA-T) and Associate in Science for Transfer (AS-T).

Note: no specific degree is required for admission as an upper-division student. However, the ADT includes specific guarantees related to admission and graduation and is designed to clarify the transfer process and strengthen lower-division preparation for the major.

An ADT totals 60 units and in most cases includes completion of all lower-division General Education requirements and at least 18 units in a specific major. (The Biology, Chemistry, and Environmental Science AS-T degrees defer 3 units in lower-division GE area C and 3 units in lower-division GE area D until after transfer.) Students pursuing an ADT are guaranteed admission to the CSU if minimum eligibility requirements are met, though not necessarily to the CSU campus of primary choice.

Upon verification that the ADT has been awarded prior to matriculation at SF State, students are guaranteed B.A. or B.S. completion in 60 units if pursuing a "similar" major after transfer. Determinations about "similar" majors at SF State are made by faculty in the discipline.

Degree completion in 60 units cannot be guaranteed when a student simultaneously pursues an additional major, a minor, certificate, or credential.

A sample advising roadmap for students who have earned an ADT and continue in a "similar" major at SF State is available on the Roadmaps tab on the degree requirements page for the major. The roadmap displays:

- How many lower-division units required for the major have been completed upon entry based on the award of a specific ADT;
- Which lower-division requirements are considered complete upon entry based on the award of a specific ADT;
- How to complete the remaining 60 units for the degree in four semesters.

Students who have earned an ADT should seek advising in the major department during the first semester of attendance.

General Advising Information for Transfer Students

a. Before transfer, complete as many lower-division requirements or electives for this major as possible.
b. The following courses are not required for admission but are required for graduation. Students are strongly encouraged to complete these units before transfer; doing so will provide more flexibility in course selection after transfer.
    - a course in U.S. History
    - a course in U.S. & California Government

For information about satisfying the requirements described in (1) and (2) above at a California Community College (CCC), please visit http://www.assist.org (http://assist.org). Check any geographically accessible CCCs; sometimes options include more than one college. Use ASSIST to determine:

- Which courses at a CCC satisfy any lower-division major requirements for this major;
- Which courses at a CCC satisfy CSU GE, US History, and US & CA Government requirements.

Remedial courses are not transferable and do not apply to the minimum 60 semester units/90 quarter units required for admission.

Additional units for courses that are repeated do not apply to the minimum 60 units required for upper-division transfer (for example, if a course was not passed on the first attempt or was taken to earn a better grade).

Before leaving the last California Community College of attendance, obtain a summary of completion of lower-division General Education units (IGETC or CSU GE Breadth). This is often referred to as a GE certification worksheet. SF State does not require delivery of this certification to Admissions, but students should retain this document for verifying degree progress after transfer.

Credit for Advanced Placement, International Baccalaureate, or College-Level Examination Program courses: AP/IB/CLEP credit is not automatically transferred from the previous institution. Units are transferred only when an official score report is delivered to SF State. Credit is based on the academic year during which exams were taken.

Refer to the University Bulletin in effect during the year of AP/IB/CLEP examination(s) for details regarding the award of credit for AP/IB/CLEP.

Students pursuing majors in science, technology, engineering, and mathematics (STEM) disciplines often defer 6-9 units of lower-division General Education in Areas C and D until after transfer to focus on preparation courses for the major. This advice does not apply to students pursuing associate degree completion before transfer.

Transferring From Institutions Other Than CCCs or CSUs

Review SF State's lower-division General Education requirements. Note that, as described below, the four basic skills courses required for admission meet A1, A2, A3, and B4 in the SF State GE pattern. Courses that fulfill the remaining areas of SF State's lower-division GE pattern are available at most two-year and four-year colleges and universities.

Of the four required basic skills courses, a course in critical thinking (A3) may not be widely offered outside the CCC and CSU systems. Students should attempt to identify and take an appropriate course no later than the term of application to the CSU. To review more information about the A3 requirement, please visit bulletin.sfsu.edu/undergraduate-education/general-education/lower-division/#AAEL.

Waiting until after transfer to take a single course at SF State that meets both US and CA/local government requirements may be an appropriate option, particularly if transferring from outside of California.