Main undergraduate courses for IIS

Grades	Semester	Course name	Credit	Course Description
Freshman	Fall	Introduction to Computer Science	3	Designed to appeal to a diverse audience, this course examines some of the fundamental ideas of the science of computing. Lectures and hands-on assignments cover a wide variety of topics such as hardware organization, the Internet, computer programming, limits of computing, and graphics. No prerequisite.
		Linear Algebra	4	Linear algebra finds wide applications in various fields, such as computer sciences, physics, mathematics and their interdisciplinary fields. This course introduces the basic concepts and techniques of linear algebra. It includes the study of matrices and their properties, linear transformations and vector spaces. Concrete topics include systems of linear equations, row reduction and Echelon form, vector equations, solution sets of a linear equation, linear independence, linear transformation, the matrix of linear transformation, matrix algebra, characterization of invertible matrices, determinants, subspaces, null spaces, column spaces, bases and dimension, rank, eigenvalues and eigenvectors, diagonalization, inner product, etc. By introducing the concepts through concrete examples, students will learn the basic concepts and methods of linear algebra, and their capacity to think from the linear algebra perspective will be systematically trained and enhanced.
		Introduction to Programming in C/C++	2	This course introduces the basic concepts in programming and object-

				oriented design. It is designed to be the first programming course for IIIS students. No prior programming experience is expected. We will start with the basic syntax of the C/C++ programming language and gradually extend to more advanced topics such as inheritance, polymorphism, modern C++ features, and program efficiency/performance. Lectures will include frequent live code demos. Students will first learn the concepts/techniques in lectures, and later master them through course projects. Upon successful completion of this course, students should be able to write effective, concise, and efficient C++ programs, and should feel confident taking any higher-level courses in the department.
	Spring	Mathematics for Computer Science and Artificial Intelligence	4	This course aims to introduce fundamental mathematical techniques to undergraduate students majoring in AI and CS, with applications in algorithm design and analyses. Modern computer science and artificial intelligence education requires students to master broad mathematical knowledge and be able to flexibly and innovatively solve technological challenges. Toward this goal, in this course we cover mathematical skills including algebra, geometry, probability theory, stochastic models, mathematical optimization, and information theory. These skills will be applied to problems and algorithm design in different topics, such as machine learning, big data, cryptography, distributed systems, algorithm design and optimization, etc. Finally, the course introduces students to more advanced topics, such as complexity, cryptography, reinforcement learning, etc.
		General Physics(1)(in English)	4	General physics course for students majoring in science and

				engineering with interest in physics. This course is Calculus-based. Students are required to actively participate during the lectures. This class will provide with an opportunity to acquire a good understanding of fundamental mechanics and thermodynamics and to learn how to apply the physics knowledge and beyond. The main contents are, mechanical parts, mainly including: displacement, velocity, acceleration, etc; Force, Newton's three laws of motion, force analysis, the center of mass frame of reference, inertia force; Momentum and angular momentum, rigid body motion; Special relativity is introduced, and so on. Thermal parts, mainly including: the temperature and the zeroth law of thermodynamics; Ideal gas state equation of constant pressure and constant volume, isothermal and adiabatic and other basic thermodynamic process; Molecular motion laws; The first law of thermodynamics. The second law of thermodynamics, the heat engine and refrigerator, Carnot cycle; Statistical physics are introduced.
		Abstract Algebra	4	Abstract algebra studies fundamental algebraic structures of groups, rings and fields, etc. It is the foundation of modern mathematics and has broad and vital applications across different disciplines including computer science, physics, and chemistry. In this course, the students will learn the basic theory of groups, rings and fields, including subgroups, groups' actions, Sylow theorems, homomorphisms and isomorphism, the fundamental homomorphism theorem, Cauchy's theorem, the fundamental theorem of finitely generated groups, polynomial rings, quotient rings, ideas, the Chinese remainder

				theorem, Euclidean domains; principal idea domains; unique factorization domains; field extension, algebraic extensions; splitting field, fundamental theorem of algebra, and Galois theory, etc. In addition, this course will also introduce the basics of lattices and Boolean algebras.
		Introduction to Computer Systems	4	This course covers selected elements from different system areas including computer organization, operating systems, and networking. The students will learn the concepts, tools, and design patterns, as well as practice developing real- world applications using the C programming language. The topics we will cover include C and assembly language, computer organization, memory management, virtual memory, process management, operating system kernels, file systems and I/O, networking and socket interfaces, multi-threading and concurrency. We will also cover useful software engineering and system development tools and processes.
		Introduction to Large Language Model Applications	2	This course is a freshmen seminar, aiming to equip students with basic knowledge of the unique research and development methodologies, application scenarios, and hands-on practices of large language models (LLMs). The topics covered in the course include the using LLM for in-context learning, end-to-end application development using LLMs, fine-tuning, data management for AI, and development tools and services for large language models. The course consists of lectures and a significant amount of programming labs. Under the guidance of teaching assistants, students will complete several independent mini-experiments and team up to design a real-world

				LLM-based application. In this course, students will: 1)Learn how to use LLM for in-context learning with modern open-source frameworks; 2)Understand the fine-tuning methods of large language models, the usage of distributed training systems, and metrics to evaluate the quality of LLMs; 3)Learn the end-to-end practical development methods of LLM applications by designing and developing a non-trivial LLM application project; 4)Know the latest application scenarios of large language models and cutting- edge research problems in LLM. 5)Improve their team collaboration skills and project presentation skills.
Sophomore	Fall	General Physics(2)(in English)	4	This course is a follow-up course of General Physics I and for undergraduate students with serious interests in physics and interdisciplinary sciences. The main focus of this course is to cover the most important topics in classical electrodynamics including electrostatics, magnetostatics, Maxwell's equations for electromagnetic fields. This course will emphasize both basic concepts and solving practical problems. After completing this course, students are expected to gain a good understanding of basic classical electrodynamics.
		Algorithm Design	4	This course gives an introduction to the basics of algorithm, common algorithm design techniques, and the analysis of running time (complexity). The main contents include: tools of algorithm analysis, divide and conquer algorithms, dynamic programming, greedy algorithms etc. algorithm design techniques, and NP complete, randomized algorithms, approximation algorithms and other advanced

				topics.
		Computer Architecture	4	This course introduces modern computer architecture, which focuses on the hardware/software interface and the internal structural organization of computer systems. It covers the major hardware components and key design techniques in computer architecture, including system performance and efficiency metrics, instructions and instruction set architectures, processor structures, and memory hierarchies. From an architectural perspective, the course focuses on the high-level functionalities and interaction of the system components, and abstracts away the low-level implementation details. It demonstrates how to optimize the performance and efficiency of the software through better understanding the architecture of the hardware. In addition, the course introduces several advanced topics such as virtualization, security, and specialization, as well as state-of-the-art research advances. The lab assignments involve the assembly-level code analysis and optimization, the processor pipeline simulation, the cache functional implementation, and more. Upon the completion of the course, students will understand the basic concepts and the main functionalities of the system components, as well as how they interact with each other. They will also learn the analysis methodology and the design principles for computer architecture, and be introduced to the tradeoffs between performance, efficiency, and cost in computer systems.
		Artificial Intelligence: Principles and Techniques	3	This course will introduce the basic ideas and techniques underlying the design of intelligent computer systems. Specific topics include

				search, constraint satisfaction, game playing, graphical models, machine learning, Markov decision processes, and reinforcement learning. The main goal of the course is to equip students with the tools to tackle new AI problems you might encounter in life and also to serve as the foundation for further study in any AI area you choose to pursue.
		Machine learning	4	Machine learning studies how computers learn from experiences. Combining ideas from theoretical computer science and statistics, researchers have developed many successful learning methods for computer vision, bioinformatics, natural language processing etc. This course mainly covers the framework of machine learning, classical methods for solving various machine learning problems, and also basic machine learning theory. It includes linear methods, support vector machine, basic optimization and generalization theory, basic neural networks, popular classification/regression methods, clustering methods, nearest neighbor search, useful algebra methods, etc. This course is a basic course for machine learning, but it is challenging.
		Electronics for Experimental Physics	3	The first 6 weeks of this course focus on the theories and principles of the electronic technologies used in quantum information experiments, which include: basic electronics, digital logic, key control technologies in experiments, PID locking technology, photoelectric detection, etc. The following 5 weeks will focus on the training of experimental techniques in lab, including: how to use the common equipment in lab, programming of FPGA, the implementation of PID controller, photoelectric detection. Besides, in last 8 weeks of the

				course, the students will be involved into different cutting-edge projects in CQI labs. The students will be divided into different groups and tackle the real-world tasks in the lab. These projects will demonstrate the frontier of the experimental quantum information science to the students.
		Advanced Applied Probability	3	Probability theory constitutes fundamental underpinnings across various domains of applied mathematics, including statistical science, machine learning, operations research, and mathematical finance. Starting from the basic definition of probability and measure, the content of this class includes basic probability inequality, characteristic functions, central limit theorem, weak law of larger number, Kolmogorov strong law of large number and martingale theory. We will discuss all of their proof details as well as basic probability knowledge necessary to derive the proof of these theorems. At the end of this class, we will also discuss a few topics related to recent progress in applied probability research.
		Introduction to optimization theory	3	As a basic part, this course first introduces the concept of linear programming with concrete examples, analyzes its geometrical properties, and elaborates the important duality theory. Then three important methods solving linear programming, the simplex method, the ellipsoid method, and interior point method, will be introduced, and examples that reveal their differences will be given. The next topics are sensitivity analysis and robust optimization that are involved in linear programming. As an application of the above knowledge, the problem of network flows will be analyzed carefully.

				To broaden the scope of considered optimization problems, we then turn to convex optimization, a larger class having linear programming as a special case. After studying its geometrical characters and duality theory, we introduce Newton’s method and gradient descent method that are often used to solve convex optimizations, which will be compared with interior point method introduced earlier. Lastly, an important case of convex optimization, semidefinite programming, will be highlighted, where a lot of examples raised in quantum computing will be analyzed.
	Spring	Quantum Computer Science	4	Quantum computer science is a course offered to undergraduate students with a solid preparation in linear algebra but no-prerequisite on quantum theory. The course will cover many topics at the forefront of the new field of quantum computer science, including, foundation of quantum mechanics with an emphasis on finite-dimensional quantum systems; Quantum entanglement theory including concept of bipartite and multipartite entanglement and its quantification, many-body entanglement and graph states, quantum teleportation and nonlocality measured by Bell’s inequality; Quantum computation model and quantum complexity; Quantum algorithms, including Shor’s factorization, quantum search, quantum phase estimation, quantum algorithm for linear systems of equations, and quantum machine learning. Implementation of quantum computation including trapped-ion and superconducting quantum computer. The purpose of this course is to bring the students to the exciting research frontiers of quantum computer science.

		Theory of Computation	4	This course gives an introduction to the basics of computation theory, including: Mathematical Logic, Finite Automata, Context-Free Grammars, Turing machine, undecidablity, and computational intractable topics (NP complete, PSPACE, BPP, interactive proof, fine-grained complexity, etc).
		Game Theory	4	Part One: Normal-form games Part Two: Extensive games Part Three: Bayesian games Part Four: Mechanism design
		Fundamentals of Cryptography	4	In this course we will introduce the basic concepts in modern cryptography. The contents include encryption, pseudorandomness, digital signature, interactive protocols, zero-knowledge proofs, multiparty computation, homomorphic encryption, and program obfuscation.
		Database Systems	4	This course is designed to introduce the fundamental concepts and implementations of modern database management systems. This is not a course that teaches you how to build database applications (e.g., schema design, SQL programming). It is designed as a systems course, with an emphasis on database internals. Topics include relational model and SQL, storage and indexing, query processing and optimization, transactions and concurrency control, distributed and cloud databases, as well as advanced research topics in the field. Students taking this course should have basic knowledge on computer systems. No prior database experience is assumed. The course consists of lectures, written assignments, and projects. Assignments

				and projects are designed to reinforce what the student learned in lectures and to provide hands- on experience in building a database system. Upon successful completion of this course, the student should feel confident taking a job as a database developer or conducting database-related research in graduate school.
		Computer Vision	3	This course introduce both of the basics and advances of computer vision. The content ranges from computer vision basics, such as image formation, image processing, to recent development of feature extraction, 3D vision, as well as recent breakthroughs such as deep learning, image recognition and object detection. We emphasize on the foundation of computer vision, but we also teach the most recent technology advancement. We hope the students can have a good understanding of the foundation of computer vision, and at the same time be enthusiastic about the cool stuff in computer vision.
		Deep Learning	3	Deep learning is one of the core techniques in modern AI. It is also the fundamental tool for handling massive data in the “Big Data” era. This course aims to provide a comprehensive overview of the basic ideas, methods and techniques of deep learning. Students will be also asked to use deep learning approaches to solve real-world problems in homework and final project. The course topics include supervised learning, generative models, sequence models, unsupervised learning, meta-learning, security and explainability.
		Experimental Quantum Information Processing	3	The first 4 weeks of this course focus on the theory and principle of quantum information experiments, which include: atomic physics for quantum information experiments, laser spectroscopy and

				applications, laser cooling and trapping, laser stabilization, etc. the following weeks will focus on three main quantum computing experiments, including ion trapping and cooling, the PDH laser locking with an optical cavity, quantum circuit design and measurement, focusing on RF simulation for superconducting cavity, CPW resonator pattern design, characterization of resonance frequency, quality factor and coupling strength. The students will be divided into three groups and tackle the real-world tasks in the lab. Each experiment will include the principle explanation, system design and construction, experimental data collection and analysis. These projects will bring the students to the frontier of the experimental quantum information science.
Junior	Fall	Operating Systems and Distributed Systems	4	The purpose of this course is to teach the principles and design of modern operating systems and distributed systems, as well as system programming. Topics we will cover include concepts of operating systems, networking and distributed systems, including multiple-programing systems (processes, inter- process communication, and synchronization), memory management (segmentation, paging), resource allocation and scheduling, file systems, networking (packet switching, file control, reliability), transaction and recovery, distributed systems protocols (timing, mutual exclusion, consensus), remote procedure calls, distributed storage, distributed computing systems, distributed system security and blockchain. Students are expected to complete set of major design and implementation projects.
		Quantum communication and cryptography	3	This course is offered to upper level undergraduate students, junior or

				senior students in the Yao Class, physics, EE, and computer science departments. The course will cover topics at the forefront of the new field of quantum communication and cryptography, including, for instance, foundation of quantum information, quantum entanglement, quantum cryptography, quantum communication, quantum random number generation, physical implementation of quantum communication and networks. The goal is to help the future researchers to find the interesting topics to work on.
		Natural Language Processing	3	This course will introduce important problems in the field of natural language processing such as language modeling, machine translation, and question answering, as well as core technologies to solve these problems including attention-based neural networks and language model pretraining. The course will cover basic algorithms, real-world applications, as well as open problems in academic research.
		Advanced Computer Graphics	3	This course is an elective course for undergraduate students at the Institute for Interdisciplinary Information Sciences, Tsinghua University. Its purpose is to introduce fundamental concepts, theories, methods, and systems of computer graphics. The main topics include geometric processing, 3D transformations, rasterization, shading, texturing, ray tracing, physical simulation, computer animation, color models, and the application of deep learning in computer graphics.
		Quantum Computation +X	4	This course discusses the real-life applications of quantum computers after the students systematically learn the basics of quantum computing. It starts from reviewing the quantum algorithms on a large-scale universal quantum computer and the current research

				status, and then move on to introduce the potential applications of a noisy intermediate-scale quantum (NISQ) device that can be achieved in the near term. Students will learn methods like quantum annealing, variational quantum optimization, variational quantum eigensolver and quantum machine learning, and learn how to execute these methods on a classical simulator or a cloud-based quantum computer. Students will further survey the interdisciplinary applications of a quantum computer in fields like chemistry, material science, medicine, energy industry, engineering, nuclear physics, finance, artificial intelligence, etc., and apply the methods they learn to design quantum algorithms to solve crucial problems in these fields.
		Intelligent Systems and Robotics	3	This course introduces both the theoretical foundations and advanced techniques in the fields of intelligent systems and robotics, from a unified algorithmic view of both the traditional robotic control perspective and the learning perspective. The contents range from robotic system modeling and problem formulation, planning and control, estimation and perception, to adaptive behaviors using both the indirect (model-based learning) methods and direct (model-free learning) methods. The course concludes with an introduction to industrial robotic arms, autonomous vehicles, and other areas.
		Embodied Artificial Intelligence	3	This course will discuss a working definition of intelligence and use it to delve into the questions of sensorimotor learning goals and building embodied intelligent agents. The course will first observe behavioral experiments of human’s sensorimotor stage and extrapolate the knowledge into the design of intelligent sensorimotor algorithms for

				robots. Specifically, we will cover the computational basis of sensorimotor as well as fundamental algorithmic approaches. This course provides hands on experience for constructing agents that learn to act from raw sensory observations.
		Introduction to Artificial Intelligence Chip：From Verilog to FPGA	3	This is a course focusing both on theoretical and experimental hardware fundamentals. The target is to implement small scale convolution operation in CNN on FPGA. After the course, students should be able to handle: How to divide control logics and computing logics. How to implement logics, timing, state-machine etc. Able to make testbenches. Able to map to FPGA, and debug on it. Know basics about back-end about ASIC chip design, like verification, layout etc. Able to implement a 3*3 convolution layer, and finish the local memory, global memory.
		Large Language Models from Scratch: Theory and Practice	3	In recent years, large language models (LLMs) have advanced rapidly, demonstrating remarkable capabilities in natural language processing, code generation, reasoning, and decision-making. This course focuses on LLMs, providing a comprehensive overview of the entire pipeline from pretraining to alignment. Key topics include model architecture design, scaling laws, training algorithms, and data curation, with an emphasis on the underlying theoretical foundations. Through lectures and course projects, students will gain a deep understanding of the core techniques in LLM training and the various factors that influence model performance. The course aims to improve students' abilities in theoretical analysis and hands-on practice, equipping them with the skills to independently stay abreast of the latest research advances and

				systematically analyze real-world LLM challenges. This course can serve as an advanced follow-up to deep learning, natural language processing, and machine learning courses.
		Advanced Atomic Physics	3	This undergraduate course is dedicated to explaining the knowledge of atomic physics from the perspective of quantum information applications. It also introduces the basic principles and applications of atomic systems and atomic- like systems in quantum information processing. It is suitable for students interested in pursuing graduate studies in the field of quantum information or AOM (atomic, molecular, and optical) physics. The course curriculum includes: foundations of quantum mechanics and introduction to atomic physics, hydrogen atom, helium atom, helium atom and alkalis, LS coupling and j-j coupling, hyperfine structure and isotope shift, the interaction of atoms with radiation, laser spectroscopy, laser cooling and trapping, and an overview of common quantum experimental systems.
		Economics and Computation	2	This is an undergraduate course that covers a variety of topics at the intersection of economics and computer science. Topics to be covered include: matching market, auction design, information elicitation and aggregation, blockchain mechanism design, financial market design, behavioral economics and AI. The aim of the course is two-fold: (1) to understand the game- theoretic issues behind systems involving computation, and (2) to learn how computer science can help with designing better decision and allocation mechanisms in the offline world. Some familiarity with game theory is helpful but not a formal

				prerequisite.
		Introduction to Computer Networks	3	This course aims at giving a comprehensive introduction to the fundamentals of computer networks and network performance analysis. The course contains two parts. The first part covers various networking topics including network principles, Ethernet, WiFi, routing, inter-networking, transport, WiMax and LTE, QoS, and physical layer knowledge. The second part presents mathematical techniques for modeling, analyzing and designing computer systems, including convex optimization, queueing theory, game theory and stochastic analysis. This course is intended for junior or senior undergraduate students in computer science or electrical engineering.
		Cryptography Protocols: Zero-Knowledge and MPC	3	Zero-knowledge and Secure Multiparty Computation are the most popular and interesting topics in Cryptography. In this course, we will start from the background and definition of these two notions and learn how the basic constructions work and why they are secure.
	Spring	Multi-modal Machine Learning	2	With the development of Internet, multimedia data have become increasingly accessible, such as images, audios, videos, texts, etc; the advances of artificial neural networks (e.g. large multi-modal model GPT4) have also made multimodal fusion a general trend in AI. This course covers applications including image/video processing and generation, audio/ speech processing and generation, natural language processing and generation. It introduces popular signal processing and machine learning techniques in the artifitial intelligence field, such as data representation, data compression, sequence models, data synthesis, multimodal fusion, etc. Through lectures and course

				projects, students learn about the features of different signals, and their common ground. This class can be a follow-up for computer vision and natural language processing classes.
		Embodied AI Safety	3	This course introduces the core challenges and recent advances in embodied intelligence safety, covering theoretical foundations, attack and defense methods, and safety assurance for intelligent robots. It begins with a review of the fundamentals of machine learning and deep learning, followed by an overview of common threats to deep learning systems, including adversarial attacks, data poisoning, and robustness issues. The course then explores key techniques for enhancing the safety of embodied robotic systems. In the section on embodied foundation models, topics include reward modeling, human preference alignment, fine-tuning attacks, and corresponding defense mechanisms. Further discussions address verifiable control for robots and the safety of multi-agent systems. Finally, the course presents methods for evaluating and certifying embodied intelligence systems, culminating in a final presentation where students will apply the knowledge gained to analyze risks and propose improved designs for real-world embodied intelligence systems.
Elective Course	Fall	Zero-code software development for beginners	2	Open to all undergraduates, this course pioneers a "zero-code" paradigm for building full-stack systems comprising 50,000 lines of code. Instead of teaching traditional syntax instruction, the curriculum focuses on systemic architectural thinking and human-AI collaboration methodologies, cultivating students' core competencies as "system architects." The course covers four core modules: First, it

				introduces functional programming and Monad structures, guiding students to describe data flows and side-effect isolation via logical chains to ensure the robustness of generated code. Second, it provides an in-depth analysis of layered software architectures, microservices, and API design, training students to decompose grand visions into independent, scalable service units. Third, it explores the evolution of design patterns in the AI era, leveraging natural language instructions to achieve high cohesion and low coupling. Finally, the course emphasizes hierarchical refinement protocols for model interaction, covering the entire workflow from top-level requirements to module specifications, alongside strategies for requirement iteration and intelligent debugging. Students will master the precise control of logic at every system layer, achieving a complete closed loop from conceptualization to industrial deployment, acquiring the capability to solve complex engineering challenges in the intelligent age.

Note : *You may not enroll in more than 16 credits per semester. Please select courses according to your grade level, and note that advanced courses require lower-level courses as prerequisites.*