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**COMP 102 Web Design and Multimedia Publishing (3 Credit Hours)**
This course introduces foundations of the world wide web technology, HTML, and multimedia publishing techniques. Topics include HTML syntax, CSS, XML, RSS, and various multimedia formats. Outcome: An understanding of the technologies behind web sites and the ability to use them effectively.

**COMP 104 Computer Animation (3 Credit Hours)**
The course introduces techniques for understanding and developing dynamic and interactive media by using sound, motion, images, and text. Relevant software knowledge areas are covered. Outcome: ability to publish created animated media projects to the web in a process that involves understanding human interface design.

**COMP 111 History of Computing (3 Credit Hours)**
The social and organizational history of humanity is intricately entangled with the history of technology in general and the technology of information in particular. Advances in this area have often been closely involved in social and political transformations. While the contemporary period is often referred to by such names as the Computing and Information Age, this is the culmination of a series of historical transformations that have been centuries in the making. This course will provide a venue for students to learn about history through the evolution of number systems and arithmetic, calculating and computing machines, and advanced communication technology via the internet.

**Course equivalencies: X - COMP 111 / HIST 279C**

**COMP 122 Introduction to Digital Music (3 Credit Hours)**
Computers and digital tools have been seeping into the world of music, this course aims to explore this newly formed territory. This course is intended for students who wish to learn more about electronic music, signal processing, and algorithmic music composition.

Knowledge Area: Quantitative Knowledge

Course equivalencies: X-COMP 122/MUSC 122

Outcomes:
Understanding of the physics of musical sound and digital audio, facility with hands-on applications of algorithmic music composition and musicology, and ability to design and render digital instruments

**COMP 125 Visual Information Processing (3 Credit Hours)**
This course, intended primarily for non-majors, provides an introduction to computer programming using a language well-suited to beginning programmers and practical applications, e.g., Visual Basic.Net. Outcome: Understanding of computer mechanisms for representing and analyzing numerical and logical information and the power of programmability; practical ability to implement useful computing tools. Restricted to Freshman or Sophomore standing OR majors other than COMP-BS AND CSEC-BS AND SWEN-BS.

Knowledge Area: Quantitative Knowledge

**COMP 141 Introduction to Computing Tools and Techniques (3 Credit Hours)**
This course introduces students to the Unix shell environment and essential tools for succeeding in computer science degrees. Students who complete this course will develop fluency in the Unix (Linux) environment, which is essential for solving problems in academic, research, and professional computing disciplines.

**COMP 150 Introduction to Computing (3 Credit Hours)**
The world overflows with electronic data. This course introduces programming in a simple, powerful language like Python, with selection, repetition, functions, graphical effects, and dynamic interaction with the Internet, plus connections to lower level computer organization and computer implications in the wider world. Outcome: Empowerment to manage and transform masses of data; understanding of technical, societal, and ethical issues involved. Restricted to Freshman or Sophomore standing OR majors other than COMP-BS AND CSEC-BS AND SWEN-BS.

Knowledge Area: Quantitative Knowledge

Course equivalencies: ACCOMP 150/COMP 150

**COMP 163 Discrete Structures (3 Credit Hours)**
Pre-requisites: MATH 117 or placement Outcome: The student will be prepared for the study of advanced ideas in computer science, from cryptography to databases to algorithms to computer architecture.

This course covers the mathematical foundations of computer science, including such topics as complexity of algorithms, modular arithmetic, induction and proof techniques, graph theory, combinatorics, Boolean algebra, logic circuits, and automata.

Interdisciplinary Option: Bioinformatics

Course equivalencies: COMP211/COMP163

**COMP 170 Introduction to Object-Oriented Programming (3 Credit Hours)**
Pre-requisites: MATH 118 or Placement or COMP 125 or COMP 141 or COMP 150 or COMP 180 or permission or SCPS student

This programming intensive course with its weekly lab component introduces basic concepts of object-oriented programming in a language such as Java. Prior experience with a procedural programming language is sufficient to obtain permission to enroll. Outcome: Ability to take a problem, break it into parts, specify algorithms, and express a solution in terms of variables, data types, input/output, repetition, choice, arrays, subprograms, classes, and objects; ability to judge a good program.

Interdisciplinary Option: Bioinformatics

Course equivalencies: COMP170/ISOM/INFS370

**COMP 171 Scripting Languages (1 Credit Hour)**
Scripting languages are rapid prototyping languages that are used extensively. This course covers the principles, syntax and semantics of widely used scripting languages. Outcome: Students will learn how a program can be put together quickly and efficiently to solve problems.

**COMP 180 Computing and Data Analysis for the Sciences (3 Credit Hours)**
Scientific computing emphasizes data analysis and visualization in a scientific context - analyzing data quickly for understanding by the individual, sharing automated workflows with collaborators, and preparing results for later publication. This course will emphasize rapid, interactive, and reproducible workflows for data scientific contribution. Students are required to have taken MATH 117: College Algebra as a prerequisite or to have been placed in MATH 118: Precalculus or higher. At the end of this course, students will be well versed in the use of a specific, interactive environment for data analysis (likely Python, R, or MATLAB as indicated in the course notes) for analyzing data and sharing results.

Interdisciplinary Option: Neuroscience
COMP 215 Object Oriented Programming with Mathematics (3 Credit Hours)

Pre-requisites: MATH 132 or MATH 162 or MATH 162A This is an introductory programming course for students interested in mathematics and scientific computing.

Students will program primarily in a general object-oriented language such as Python, with supplementary exercises in a computer algebra system. Examples will be drawn primarily from applications of calculus, elementary number theory, and cryptography. Outcome: Students will learn basic scripting and object-oriented programming, with the goal of being able to solve mathematical and scientific problems.

Course equivalencies: X-COMP215/MATH215

COMP 231 Data Structures & Algorithms for Informatics (3 Credit Hours)

This course introduces data structures and algorithms that are essential for data science and informatics. Here we will focus on identifying the right method for storing data and using the most efficient algorithm for analysis. A subset of data structures and algorithms fundamental to computer science will be covered. Prereq: (MATH/COMP 215 OR COMP 170) AND (COMP 141 OR AMTH-BS OR MATH-BS) Advisory: MATH/COMP 215 preferred. Outcome: Students will learn fundamental data structures and algorithms frequently used in informatics and data science. Students will be able to apply this knowledge for data analysis.

COMP 250 Introduction to Scientific and Technical Communication (3 Credit Hours)

This course trains students in writing clear, readable, and well-organized technical communications, including presentations, end-user documentation, internal project documentation, and scientific papers. Pre-requisites: A minimum grade of C- in COMP 125 or COMP 150 or COMP 170 or COMP/MATH 215.

Outcomes:
- students will learn to write clear technical documentation

COMP 251 Introduction to Database Systems (3 Credit Hours)

Pre-requisites: COMP 125 or COMP 150 or COMP 170 or COMP 180 or COMP/MATH 215 This course explores ways in which data collections are organized, stored, analyzed, and manipulated. Topics include relational databases, the SQL query language, and the basics of XML and web interfaces to data sets. Applications from a variety of domains illustrate the course's key concepts.

Course equivalencies: COMP 251 / COMP 368

Outcomes:
- Students will organize data in ways to emphasize relationships, write simple programs to process, visualize and graphically display data, mine data for patterns, and design web interfaces to data

COMP 264 Introduction to Computer Systems (3 Credit Hours)

Pre-requisites: COMP 141 and (COMP 170 or MATH/COMP 215) and (coreq or prereq of COMP 163 or MATH 201)

This course studies the hierarchy of abstractions and implementations that constitute a modern computer system, with a particular focus on issues of interest to programmers, typically including some systems programming instruction. COMP 163 coreq or prereq and COMP 170 prereq preferred. Outcome: Understanding of system issues that affect the performance, correctness, or utility of user-level programs.

COMP 266 Digital Electronics Lab (3 Credit Hours)

Combines and sequential logic devices, oscillators and timers, microprocessor components, CPU operation, computer architecture and digital/analog conversion. Outcome: Students will gain a working knowledge of digital electronics design and its application to computers, an understanding of CPU design and operation and the ability to document and report experimental results.

Course equivalencies: X-PHYS256/COMP266

COMP 271 Data Structures I (3 Credit Hours)

This course studies basic data structures including array lists, linked lists, stacks, queues, binary trees, and hash tables. Efficiency of data structure operations, study of recursion, applications of data structures, and simple analysis of algorithms are covered. Pre-requisite: COMP 141 and COMP 170 and (co-requisite or pre-requisite of COMP 163 (preferred) or MATH 201). For Bioinformatics majors, pre-requisite of COMP 141 and COMP 170. For SCPS students, pre-requisite of COMP 170.

Interdisciplinary Option: Bioinformatics

Outcomes:
- Students learn linear data structures and the performance of their operations, and they learn to solve simple computational problems by designing suitable algorithms and efficient data structures

COMP 272 Data Structures II (3 Credit Hours)

This course studies advanced abstract data types, such as sets, maps, and graphs, and their implementation using arrays and dynamically allocated nodes in an object-oriented language. The course also studies the performance of the data structures built-in operations and related algorithms such as sorting, searching, and traversing. Prereq COMP 271 and (COMP 163 or MATH 201) and (MATH 131 or MATH 161) Outcome: Students learn non-linear data structures and runtime performance of their operations, solve computational problems by choosing suitable data structures, and implement algorithms within the object-oriented paradigm.

COMP 301 Introduction to Computer Security (3 Credit Hours)

This is an introductory course on computer security covering a broad range of topics, including basic security goals, encryption, penetration testing, software exploitation, reverse engineering, packet sniffing, and secure coding. The course teaches both the principles and concepts of computer security as well as some of the tools and technologies. Prereq COMP 170 Students will learn to think like an adversary, find and exploit vulnerabilities in computer and network systems, understand cryptography and security goals, and learn about some of the commonly-used tools.

COMP 305 Database Administration (3 Credit Hours)

Pre-requisites: COMP 231 or COMP 251 or COMP 271 Business and scientific institutions increasingly use large commercial data base systems. This course teaches the theory and practice for the definition, security, backup, tuning, and recovery of these systems. Outcome: Students will be able to use theory and pragmatic approaches to define and implement realistic solutions for large database administration environments.

COMP 306 Data Mining (3 Credit Hours)

Pre-requisites: (COMP 231 or COMP 251 or COMP 271) and (STAT 103 or STAT 203 or ISCSM 241 or PSYC 304 or instructor permission) This course covers theory and practice of the analysis (mining) of extremely large datasets. With data growing at exponential rates knowledge gathering and exploration techniques are essential for gaining useful intelligence. Outcome: Students will be able to define and critically analyze data mining approaches for fields such as security, healthcare, science and marketing.
COMP 309 Numerical Methods (3 Credit Hours)
Pre-requisites: (COMP 170 or MATH/COMP 215), and [ (MATH 212, and MATH 264) or MATH 266] Students will obtain an understanding of how numerical methods can be used in a variety of areas of mathematics. This course offers an introduction to topics such as error analysis, interpolation and approximation, and the numerical solution of problems involving differentiation, integration, and ordinary and partial differential equations.
Course equivalencies: X-COMP309/MATH309

COMP 310 Operating Systems (3 Credit Hours)
Pre-requisites: COMP 264 and COMP 272. Outcome: Students will learn the different parts of an operating system at a functional level and how they interact with each other.
This course introduces principles of operating systems and how they are designed. Various important parts of operating systems such as memory addressing, file structures, processes, and threads are covered.

COMP 312 Open Source Software Practicum (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 271 or instructor permission. This course will cover the fundamentals of Free and Open Source software development.
Topics to be addressed include licensing, Linux, typical software development tools, applications, and techniques for managing remote servers. Outcome: Students will learn to implement projects involving Free and Open Source software and learn how to participate in open-source projects effectively.
This course satisfies the Engaged Learning requirement.

COMP 313 Object-Oriented Design (3 Credit Hours)
Object-orientation continues to be a dominant approach to software development. This intermediate programming-intensive course studies the use of classes and objects with an emphasis on collaboration among objects. Pre-requisites: COMP 272
Outcomes:
A thorough understanding of the principles of object-orientation: abstraction, delegation, inheritance, and polymorphism; exposure to basic design patterns; programming experience in mainstream object-oriented languages such as C++ and Java

COMP 314 Problem Solving Strategies I (1 Credit Hour)
Pre-requisites: COMP 271. This course allows students to sharpen problem-solving skills along with, or as part of, the ACM Programming Team.
Co-requisite or Groups generally work on old competition problems on alternate weekends, with short follow-ups during the next week. Outcome: Ability to work in small groups, quickly and accurately assessing and solving focused problems involving many sorts of programming knowledge.
Course equivalencies: COMP281/COMP314

COMP 315 Problem Solving Strategies II (2 Credit Hours)
Pre-requisites: Comp 314. This course allows students to sharpen problem-solving skills along with, or as part of, the ACM Programming Team.
Groups generally work on old competition problems on alternate weekends, with short follow-ups during the next week. Outcome: Ability to lead a small group, quickly and accurately assessing and solving focused problems involving many sorts of programming knowledge.

COMP 317 Social, Legal, and Ethical Issues in Computing (3 Credit Hours)
Pre-requisites: Any COMP course and Ethics Core Outcome: Understanding of laws and issues in areas such as privacy, encryption, freedom of speech, copyrights and patents, computer crime, and computer/software reliability and safety; understanding of philosophical perspectives such as utilitarianism versus deontological ethics and basics of the U.S. legal system.
This course covers social, legal, and ethical issues commonly arising in key areas related to computing technologies.
Interdisciplinary Option: Sociological Studies

COMP 319 Introduction to UNIX (1 Credit Hour)
Pre-requisites: COMP 170 and COMP/MATH 215. An introduction to the UNIX operating system.
Topics include files and directories, electronic mail, security, advanced file systems, network utilities, network file sharing, text utilities, shell programming, UNIX internals, UNIX system administration (essentials), the X windowing system, systems programming, and secure shell (SSH). Outcome: After taking this course, students will develop working knowledge of UNIX and be able to use modern UNIX operating systems such as Linux, OS X, or Solaris.
Course equivalencies: COMP219/COMP319

COMP 321 Computational Aspects of Modeling and Simulation (3 Credit Hours)
Pre-requisites: STAT 203 or STAT 335. Outcomes: Students will gain practical experience and knowledge in real-world statistical situations for which underlying theory is cumbersome or intractable.
This course uses SAS and R languages to address statistical modelling and to conduct statistical simulations to assess linear, generalized linear, nonlinear and complex models and experimental designs.
Course equivalencies: X-STAT356/COMP321/STAT321

COMP 322 Software Development for Wireless and Mobile Devices (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 271. Outcomes:
1. This course will focus on the unique challenges, methods, tools, and technologies for developing software applications for wireless and mobile devices, smart mobile phones, and the growing world of mobile connected devices. Understand challenges of software design for resource limited devices; 2. Know the architecture of one or more state-of-the-art mobile operating systems; 3. Gain experience designing, developing, testing embedded software.

COMP 323 Game Design and Development (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 271. Outcomes: Students will acquire an awareness of different game design and development methods, technologies, and techniques suitable for the development of a variety of game-based environments.
This course studies design, development, and publication of games and game-based applications. This includes example games and designers, industry practices, and team-based project development.

COMP 324 Client-Side Web Development (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 271. Outcomes: Familiarity with the most common effective tools for creating responsive, dynamic, and interactive web content with client-side tools.
This course covers the design and implementation of the presentation layer of dynamic web applications. Topics include visual design and usability, multi-channel and multi-modal applications, markup of static and dynamic content, and client-side executable content. HTML/CSS/JavaScript are introduced quickly, followed up with the stack of current JavaScript frameworks and libraries used in practice.
COMP 325  Rapid Application Development Methodology (3 Credit Hours)
This course will teach students how to effect rapid application development using a software framework such as the .NET Framework. Particular emphasis will be placed on enhancing object-oriented programming skills using a language such as C# .NET. Pre-requisite: COMP 271 with a grade of C- or above
Outcomes:
Students will gain enhanced skill in object-oriented programming and development of such applications as database applications, web applications, Microsoft .NET services, Silverlight applications, and WCF Services

COMP 328  Algebraic Coding Theory (3 Credit Hours)
Pre-requisites: MATH 212 Codes with algebraic structure for error control are examined
Block codes including Hamming codes and Reed-Muller codes, BCH codes, and other cyclic codes with algebraic structure and other cyclic codes are treated. Other topics may include: convolutional codes, efficiency considerations, and Shannon's fundamental theorem of information theory.
Course equivalencies: X-MATH328/COMP328

COMP 329  Natural Language Processing (3 Credit Hours)
This course provides an introduction to the field of natural language processing (NLP). NLP is concerned with computational approaches to analyzing, generating, and understanding human language. This course will introduce the students to the problems, methods, and applications of NLP. Prerequisites - (COMP 231 or COMP 271) and (MATH 131 or MATH 161) and (STAT 103 or STAT 203 or ISSCM 241 or PSYC 304 or instructor permission) Outcomes - Students will become familiar with such areas of natural language processing as information retrieval, sentiment analysis, machine translation, document classification, and question answering.

COMP 330  Software Engineering (3 Credit Hours)
Pre-requisites: COMP 271
Students learn real-world theory and techniques organizations use to create high-quality software on time. Students work on a large programming team to create plans, review progress, measure quality, and make written and oral analyses of their project. Outcome: Students will experience process based development, understand the dynamics of a professional software organization, and develop skills for implementing software with others.

COMP 331  Mathematical Foundations of Cryptography (3 Credit Hours)
Pre-requisites: Theoretical Foundations: MATH 201 or COMP 363; Programming Foundations: COMP125 or COMP150 or COMP170 or COMP 180 or COMP/MATH 215
This course introduces the formal foundations of cryptography and also investigates some well-known standards and protocols, including private and public key cryptosystems, hashing, digital signatures, RSA, DSS, PGP, and related topics. Outcome: Students will gain an understanding of cryptosystems widely used to protect data security on the internet, and be able to apply the ideas in new situations as needed.
Course equivalencies: X-COMP331/MATH331

COMP 332  Requirements Engineering (3 Credit Hours)
This course aims to equip students with techniques for successful requirements analysis and requirements engineering (RE) of software-intensive systems. Students will learn a systematic process of developing requirements through co-operative problem analysis, representation, and validation. Prerequisite(s): COMP 330
Outcomes:
Students will learn and apply the current state of the art in requirements engineering and a systematic method for engineering high-quality requirements on realistic large-scale projects

COMP 333  Web Services Programming (3 Credit Hours)
Pre-requisites: COMP 313 Outcomes: An understanding of the design space of software architecture
Web services are building blocks for enterprise applications that use open data exchange standards and transport protocols to exchange data with calling clients. This course studies the architectures, frameworks, and tools required to develop and compose web services and clients, as well as integrate service-oriented systems with legacy systems. Proficiency in designing, implementing, deploying and composing systems from web services.

COMP 335  Formal Methods in Software Engineering (3 Credit Hours)
Pre-requisites: Comp 313 As embedded and networked systems are becoming ever more ubiquitous, we depend increasingly on the correctness of the software that controls such systems This course studies the formal specification, verification, and synthesis of software.
Outcomes:
An understanding of the role of formal methods in the construction of software systems; proficiency in representative methods and tools, such as UML and ESC

COMP 336  Markup Languages (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 271 This course is concerned with XML and its various component frameworks
The core frameworks to be covered include Document Object Model (DOM), Simple API for XML processing (SAX), the XML Path language (XPath), and XSLT. Outcome: After taking this course, students will have working knowledge of XML and its connections to other ideas such as HTML, object models, relational databases, and network services.

COMP 337  Concurrent Programming (3 Credit Hours)
Pre-requisites: Comp 313
Many real-world software systems rely on concurrency for performance and modularity. This programming-intensive course covers analysis, design, implementation, and testing of concurrent software systems. Outcome: An in-depth understanding of event-based and thread-based views of concurrency; the ability to develop concurrent software components using suitable languages, frameworks, and design patterns; familiarity with object-oriented modeling and development tools and test-driven development.

COMP 338  Server-based Software Development (3 Credit Hours)
Pre-requisites: COMP 313 Server-based web applications and services have become part of everyday life
This programming-intensive course covers analysis, design, implementation, and testing of multi-tiered server-based software systems along with typical tier-specific technologies. Outcome: An understanding of software architecture and integration in the development of multi-tiered server-based software; familiarity with object-oriented modeling and development tools and test-driven development.
**COMP 339 Distributed Systems (3 Credit Hours)**
*Pre-requisites:* COMP 313 or COMP 263 or COMP 310 This course covers topics in modern distributed systems.
This course places special emphasis on scalability (performance), reliability/fault tolerance, and security. Outcome: After taking this course, students should understand the essential ingredients of distributed systems and how to build distributed systems that are resilient to transient network failures and other potential anomalies.

**COMP 340 Computer Forensics (3 Credit Hours)**
*Pre-requisites:* (COMP 150 or COMP 170 or COMP/MATH 215) and (COMP 264 or COMP 317 or COMP 343) The course introduces the fundamentals of computer/network/internet forensics, analysis and investigations.
Outcome: The student will learn computer software and hardware relevant for analysis, and investigative and evidence-gathering protocols.

**COMP 341 Human-Computer Interaction (3 Credit Hours)**
*Pre-requisites:* COMP 231 or COMP 271 Outcomes: Students will be exposed to a wide array of non-traditional computing interfaces, and be able to evaluate, design and develop better human-computer interfaces using research-based, systematic approaches.
Limitations in human-computer interaction are as much due to human factors, cognitive limits, expectations, motivations, and inertia as technological capabilities. Systematic methods will be used to evaluate and improve designs through both qualitative feedback and statistical, hypothesis-driven testing on web pages, GUIs, mobile apps and many non-traditional interfaces.

**COMP 342 Introduction to Web Application Development (3 Credit Hours)**
*Pre-requisites:* COMP 170 Outcomes: Students will be able to create webpages using JavaScript and related tools and protocols, and interface a webpage with a database.
An introduction to webpage development using JavaScript, jQuery and associated client-side tools.
*Course equivalencies:* X- DIGH403/CPST342/COMP342

**COMP 343 Computer Networks (3 Credit Hours)**
*Pre-requisites:* COMP 264 or COMP 271 or instructor permission This course surveys packet-switched computer networks and attendant communication protocols, using the TCP/IP protocol suite on which the Internet is based as the primary model.
Some programming may be required. Outcome: Students will understand how the Internet is constructed, how data is routed to its destination, how connections are made, how congestion is handled, and how security can be addressed.

**COMP 344 Hands-on Approach to Security & Privacy (3 Credit Hours)**
This course will introduce students to privacy, cybersecurity competitions, and how computers can be compromised and secured. Pre-requisite: COMP 301
Outcome: Students will start thinking like an adversary, learn how to find exploits in software and computer networks, and how to be a cybersecurity professional.

**COMP 345 Internet of Things Device and Application Security (3 Credit Hours)**
*Pre-requisites:* COMP 301 It introduces the Internet of Things (IoT) comprising embedded devices and cloud-based resources. The course studies concepts and techniques used in designing and implementing IoT systems providing valuable functionality to consumers and valuable data to organizations. The course discusses methods for addressing related safety, security, reliability, and privacy concerns. Ability to visualize and analyze data from an IoT system.
Outcome: Ability to design and implement secure software and establish safety, security, reliability, and privacy goals for embedded and IoT-based systems.

**COMP 346 Telecommunications (3 Credit Hours)**
*Pre-requisites:* COMP 264 or COMP 271 This course introduces the fundamental concepts of telecommunication networks, including requirements of voice networks, analog versus digital transmission, data link protocols, SONET, ATM, cellular phone systems, and the architecture of the current telephone network.
Outcome: Students will understand how modern telephone systems work.

**COMP 347 Intrusion Detection and Security (3 Credit Hours)**
*Pre-requisites:* COMP 301 This course covers techniques and algorithms for detecting unusual usage patterns that typically signal a break-in, including techniques for detecting evasive or stealthy attacks. Also covered are differences in detecting local versus network intruders.
Additional topics: computer viruses, computer security management, computer forensics. SNORT) and analyze their output. They will also understand both network-based and host-based monitoring techniques.
Outcome: Students will understand how modern telephone systems work.

**COMP 348 Network Security (3 Credit Hours)**
This course involves a discussion of network security through the following areas which lead to an overall security posture: Security Frameworks, Implementation Security, System Best Practices, a Case for Centralized Configuration Management, Network Security Architecture, Standards Adherence, Risk Assessments, Testing and Review and Application Security. Pre-requisite: COMP 301
Outcome: An understanding of how to secure networks using encryption, authentication, perimeter protection, restricted access policies, intrusion detection/prevention and other security frameworks.

**COMP 349 Wireless Networking and Security (3 Credit Hours)**
*Pre-requisites:* COMP 301 This course will explore the wireless standards, authentication issues, and common configuration models for commercial versus institutional installations and analyze the security concerns associated with this ad-hoc method of networking.
Outcome: Students will gain an understanding of wireless networking, protocols, and standards and security issues.

**COMP 351 Network Management (3 Credit Hours)**
Pre-requisite: COMP 264 or COMP 271 This course introduces the current state of the art in automated management of computer networks, including protocols such as SNMP and its attendant naming conventions, network management systems, and important issues in administrative network configuration. Outcome: Students will become familiar with the SNMP protocol, with how large-scale Network Management Systems operate and are configured, and with advanced network configuration.
COMP 352 Computer Vulnerabilities (3 Credit Hours)
Pre-requisites: COMP 264 and COMP 301 This course will introduce students to computer vulnerabilities at the machine-code level, including viruses, browser vulnerabilities, buffer and heap overflows, return-to-libc attacks and others.
Run a virus in a virtual-machine sandbox with appropriate monitoring.
Outcomes:
Describe some recent computer software vulnerabilities at the machine-code level and how they can be leveraged into an attack

COMP 353 Database Programming (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 251 or COMP 271 This course introduces relational and object databases to support database creation and application development.
Use of commercial database products will give a practical orientation.
Outcome: Students will learn SQL, database design and application development using the latest software tools. Students will also learn techniques for web-based data retrieval and manipulation.
Interdisciplinary Option: Bioinformatics
Course equivalencies: COMP353/BIOI353

COMP 358 Big Data Analytics (3 Credit Hours)
In this course, large data sets will be leveraged to solve challenging analytics problems. With more samples, analytics can use more complex learning models to automate more feature combinations for more robust model tuning, selection, and validation. Parallel, distributed processing will be performed with Apache Spark and Hadoop. (Database experience: COMP 251 OR COMP 305 OR COMP 353) AND (Analytics experience: COMP 300 OR COMP 379 OR STAT 338 OR STAT 308) OR permission of instructor.
Outcomes:
Python or R will be used with parallel frameworks to perform proper model selection when testing large combinations of features, models, hyperparameters, and ensembles, with additional emphasis on deep learning

COMP 362 Computer Architecture (3 Credit Hours)
This course covers computer design from the level of digital logic and circuit design to high-level computer organization. Outcome: A basic understanding of how computers work at many levels and how to use various analytical tools and techniques to design computer components.
Course equivalencies: COMP 260 / COMP 275 / COMP 362

COMP 363 Design and Analysis Computer Algorithms (3 Credit Hours)
Pre-requisites: COMP 272 and (MATH 132 or MATH 162) Theoretical design and analysis of computer algorithms may be supplemented by small amounts of programming.
Outcome: The ability to design and analyze efficient algorithms; understanding of the necessary models and mathematical tools; understanding of a variety of useful data structures and fundamental algorithms; exposure to the classification of computational problems into different complexity classes.
Interdisciplinary Option: Bioinformatics
Course equivalencies: X-COMP363/BIOI363

COMP 364 High Performance Computing (3 Credit Hours)
Pre-requisites: COMP 264 and COMP 272 This course covers parallel architectures and parallel models of computation.
Algorithms for achieving high performance in various computational contexts are discussed. Models such as shared memory, message passing, and hybrid modes of computing are introduced. Outcome: Students will learn how to engineer solutions to practical problems in multiprocessor architectures and using large physical memories.

COMP 366 Microcomputer Des & Interfac (3 Credit Hours)
Pre-requisites: COMP 271 Outcomes: Students will gain a working knowledge of interfacing techniques and design, hands-on experience with professional interfacing hardware and software, and the ability to document and report experimental results.
This course covers computer architecture, CPU logic, data acquisition, signal conditioning, analog/digital conversion and computer interfacing.
Course equivalencies: X-PHYS366/COMP366

COMP 367 Robotics Software Development (3 Credit Hours)
This course is an introduction to robotics and robotic software development using humanoid robots. The course will use modern robot platforms and provide hands on experience with robotic sensor systems, motion and navigation, robot behavior planning and implementation.
Pre-requisites : COMP 271. COMP 313 recommended. Outcomes:
Outcomes:
Students will explore the history of robotics, overview the theory of autonomous robotic systems, and develop complete robot projects.

COMP 369 Physical Design and Fabrication (3 Credit Hours)
This course explores the role of products in the economy and how things are made, including: product conceptualization and design, physical design vs. design of things that are not physical, rapid prototyping, 3D printing, 2D conceptualization and sketching, 3D modeling, and design reviews.
Outcomes:
Students will be able to visualize ideas via sketching basic shapes, create 3D models using 3D modeling software, use a 3D Printer, and give constructive feedback in peer review sessions

COMP 370 Software Quality (3 Credit Hours)
Pre-requisites: COMP 330 The course teaches software testing and quality control concepts, principles, and techniques including black box and white box testing, coverage testing, test case development, and regression testing.
Outcome: Students will learn how to prevent errors, how to get 'bugs' out of software, and be able to apply this knowledge in other courses and projects.

COMP 371 Programming Languages (3 Credit Hours)
Pre-requisites: COMP 264 and COMP 272 There are over two thousand programming languages.
This course studies several languages that represent the much smaller number of underlying principles and paradigms. Outcome: An understanding of key principles and paradigms underlying the design and implementation of commonly used programming languages; exposure to formal mechanisms for describing language syntax and semantics; programming experience in several representative languages.

COMP 373 Advanced Object-Oriented Programming (3 Credit Hours)
Pre-requisites: Comp 313
Object-orientation continues to be a dominant approach to software development. This advanced programming-intensive course studies object-oriented analysis, design, and implementation from a design patterns perspective. Outcome: Proficiency in the use of object-oriented languages, frameworks, and patterns; advanced understanding of key language mechanisms such as delegation, inheritance, polymorphism, and reflection; familiarity with object-oriented modeling and development tools and test-driven development.
COMP 376 Formal Lang & Automata (3 Credit Hours)
Pre-requisites: COMP 163 or MATH 201 or MATH 212 or MATH 266
This course introduces formal language theory, including such topics as finite automata and regular expressions, pushdown automata and context-free grammars, Turing machines, undecidability, and the halting problem.
Outcome: An understanding of the theoretical underpinnings of computability and complexity in computer science.
Course equivalencies: X-COMP376/MATH376

COMP 377 IT Project Management (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 251 or COMP 271
This course is an introduction to the philosophy and practice of project management. The course involves a student project group to investigate and plan a ‘real world’ IT project that specifies project objectives, schedules, work breakdown structure and responsibilities, a written interim report, and a final oral and written report.
Outcomes:
Students will learn time management, work-flow management, and team dynamics to design, implement and test large-scale software projects.

COMP 378 Artificial Intelligence (3 Credit Hours)
Pre-requisites: COMP 231 or COMP 271
This course introduces artificial intelligence theory and programming.
Outcome: Student will learn basic theory of artificial intelligence and be able to build small applications based on it.

COMP 379 Machine Learning (3 Credit Hours)
Pre-requisites: (COMP 231 or COMP 271) and (STAT 103 or STAT 203 or ISSCM 241 or PSYC 304 or instructor permission)
Outcomes: Students in this course will learn how to apply sophisticated algorithms to large data sets to make inferences for prediction or decision making.
Machine learning is the process of making predictions and decisions from data without being explicitly programmed. Topics include a variety of supervised learning methods. Ensemble approaches are used to combine independent models efficiently. Unsupervised and semi-supervised methods demonstrate the power of learning from data without an explicit training goal.

COMP 380 Computer Graphics (3 Credit Hours)
Pre-requisites: COMP 271
This course introduces modern theory and practices in 3-D computer graphics, stressing real-time interactive applications using libraries like OpenGL.
Outcome: Student will learn how to program real-time interactive applications using libraries like OpenGL.

COMP 381 Bioinformatics (3 Credit Hours)
Students will engage in the applications of computer-based tools and database searching to better understand the fields of genetics, genomics, evolutionary biology, and personalized medicine. Students will be introduced to scripting programming languages for analyzing biological data sets.
Interdisciplinary Option: Bioinformatics
Course equivalencies: X-BIOL388/COMP381/BIOI388
Outcomes:
Students will be able to appropriately use computer software and databases to accurately analyze biological data and interpret the results, applying their understanding of genetic processes.

COMP 382 Compiler Construction (3 Credit Hours)
Pre-requisites: COMP 264 and 272
This course covers the basics of writing a compiler to translate from a simple high-level language to machine code.
Topics include lexical analysis, top-down and LR parsing, syntax-directed translation, and code generation and optimization. Students will write a small compiler. Outcome: students will learn how a compiler is built.

COMP 383 Computational Biology (4 Credit Hours)
Pre-requisites: (COMP 231 or COMP 271) and COMP 381
(Equivalencies: BIOI/BIOI 388)
This course presents an algorithmic focus to problems in computational biology.
It is built on earlier courses on algorithms and bioinformatics. Problems and solutions covered in this course include gene hunting, sequence comparison, multiple alignment, gene prediction, trees and sequences, databases, and rapid sequence analysis.
Outcome: Students will learn, in detail, foundational methods and algorithms in bioinformatics.
Interdisciplinary Option: Bioinformatics
Course equivalencies: COMP383/BIOI383

COMP 386 Computational Neuroscience (3 Credit Hours)
Pre-requisites: C- or better in COMP 150 or COMP 170 or COMP 180
Introduces computational methods to understand neural processing in the brain. Levels of representation from low-level, temporally precise neural circuits to systems-level rate-encoded models, to information-theoretic approaches. Emphasis on sensory systems, primarily vision and audition, most readily demonstrating the need for such computational techniques.
Interdisciplinary Option: Neuroscience
Outcomes:
Appreciation that many aspects of neuroscience cannot be understood without appropriate mathematical or computational frameworks, and ability to adeptly apply these frameworks in the various domains of neuroscience.

COMP 388 Topics in Computer Science (1-6 Credit Hours)
This course is used to introduce emerging topics in computer science that do not yet have a regular course number. Content of the course varies. Outcome: Understanding of an emerging area of Computer Science.

COMP 390 Broaden Particip STEM (Computing, Math & Science) (1-3 Credit Hours)
Students will learn about underrepresentation of various population groups in STEM fields (science, technology, engineering, mathematics), as well as some of the reasons and negative effects of this situation. They will learn about techniques and educational materials for ameliorating this situation and will engage in relevant service learning activities.
This course satisfies the Engaged Learning requirement.
Outcomes:
Students gain first-hand experience with broadening STEM participation and seeing how they can make a difference in the lives of other students and contribute to national needs.

COMP 391 Internship in CS (1-6 Credit Hours)
Students work outside the classroom applying and extending their computer science skills, typically for at least 150 hours for 3 credits.
A memorandum of understanding is required between a student, his or her employer, and the Undergraduate Program Director, followed by final reports from the student and the employer. Outcome: Application of classroom skills to real-world situations.
This course satisfies the Engaged Learning requirement.

COMP 392 Metagenomics (3 Credit Hours)
Pre-requisites: BIOL 282
Outcomes: Students will gain hands-on experience with metagenomic methodologies while working in an interdisciplinary, collaborative setting.
Exploration of next-generation sequencing technologies for assessing microbial diversity in ecological niches.
Interdisciplinary Option: Bioinformatics
This course satisfies the Engaged Learning requirement.
Course equivalencies: X-COMP 384/BIOL 392/COMP 392
COMP 395 Professional Development & Career Growth in CS/IT (1 Credit Hour)
Pre-requisites: Sophomore standing and any COMP course
This course is designed specifically for students pursuing a degree in computing-related fields, for example, Computer Science, Information Technology, Software Engineering, and Cybersecurity. They will learn about ways to develop themselves professionally, communicate their strengths, expand their contacts, and advance their careers. Students should acquire skills to professionally brand themselves, successfully network in technical circles, perform an effective job/internship search, and conduct themselves well in interviews.

COMP 397 Research Methods in Computer Science (1 Credit Hour)
Supplements CS Seminar by targeting students directly engaging in research and facilitating contributions in ongoing projects. Progress in outside projects tracked through milestones such as abstracts, small fellowship-style proposals, informal updates, and outcome-oriented goal setting. Emphasizes creating lasting impacts through establishing project continuity and presenting posters, papers, and slide shows.
Outcomes:
Regular progress on research projects and final presentations of results for demonstration to department faculty and students, and potential use at professional conferences

COMP 398 Independent Study (1-6 Credit Hours)
The student and a sponsoring faculty member will determine an advanced topic for the student to work on. Outcome: Knowledge of an advanced topic.
This course satisfies the Engaged Learning requirement.

COMP 399 Computer Science Seminar (1 Credit Hour)
The department seminar is designed to bring together students interested in understanding and engaging in extracurricular applications of computer science, with a focus on ongoing research. Speakers will include department faculty, research students, and invited outside speakers. Students will be asked to read relevant literature and participate in discussions. Outcome: Students will be exposed to a wide range of topics in computer science, participate in discussions, and provide feedback to assess their general understanding of the presented material.
Course equivalencies: COMP 399H / COMP 399

COMP 400A Object-Oriented Programming (3 Credit Hours)
This course explores advanced abstract data types in depth, such as sets, maps, and graphs, and reproduces their implementation using arrays and dynamically allocated nodes in an object-oriented language. The course also analyzes the performance of the data structures' built-in operations and related algorithms such as sorting, searching, and traversing. Pre-requisite: COMP 400B and COMP 400D
Outcomes:
Students describe non-linear data structures and analyze the runtime performance of their operations, solve computational problems by synthesizing and integrating suitable data structures, and implement algorithms within the object-oriented paradigm

COMP 400B Data Structures I (3 Credit Hours)
Pre-requisites: COMP 400A
Outcomes: Students describe non-linear data structures and analyze the runtime performance of their operations, solve computational problems by synthesizing and integrating suitable data structures, and implement algorithms within the object-oriented paradigm

COMP 400C Data Structures II (3 Credit Hours)
This course explores advanced abstract data types in depth, such as sets, maps, and graphs, and reproduces their implementation using arrays and dynamically allocated nodes in an object-oriented language. The course also analyzes the performance of the data structures' built-in operations and related algorithms such as sorting, searching, and traversing. Pre-requisite: COMP 400B and COMP 400D
Outcomes:
Students describe non-linear data structures and analyze the runtime performance of their operations, solve computational problems by synthesizing and integrating suitable data structures, and implement algorithms within the object-oriented paradigm

COMP 400D Computing Tools and Techniques (1 Credit Hour)
This course introduces students to the Unix shell environment and essential tools.
Outcomes:
Students who complete this course will develop fluency in the Unix (Linux) environment

COMP 400E Discrete Structures (3 Credit Hours)
This course provides the mathematical foundations for graduate-level study in computer science, including such topics as complexity of algorithms, modular arithmetic, induction and proof techniques, graph theory, combinatorics, Boolean algebra, logic circuits, and automata.
Outcomes:
To analyze properties of functions, relations, graphs, trees, paths; evaluate Boolean Expressions; apply induction towards proving correctness of algorithm and classifying resource usage; synthesize finite-state machines and logic circuits

COMP 401 Computer Security (3 Credit Hours)
Pre-requisites: COMP 170 or instructor permission
Outcomes: Students will find and exploit vulnerabilities in computer and network systems; articulate cryptography and security goals, and synthesize the knowledge of different tools and techniques by applying them to an intensive real-world project
This is a foundations course on computer security, covering a comprehensive range of concepts and technologies, including security goals, encryption, penetration testing, software exploitation, reverse engineering, packet sniffing, and secure coding. The final project requires a presentation and technical report where the students will show and describe what they accomplished.

COMP 403 Operations Management (3 Credit Hours)
Application of concepts and methods for managing production and service operation. Topics include demand forecasting, aggregate and capacity planning, inventory management, facility layout and location, just-in-time, managing quality, project planning, resource allocation, logistics. Emphasis on decision support Pre-requisites: COMP 150 or COMP 170
Outcomes: Understanding of the role of operations management in organizations, and applying models of production and operations management to decision making.

COMP 404 Organizational Development (3 Credit Hours)
Pre-requisites: COMP 251 or COMP 271
Outcomes: To understand the dynamics of change in organizations; learn techniques and strategies in managing change; develop skills that will enable a change agent mentality within the context of IT leadership
This course focuses on the manager's role in leading Organization Development and Change to maximize organization and individual effectiveness with a focus on Information Technology. The class explores Organization Development and Change theory, change practices, and discusses considerations a manager will face as a change agent in today's computing ecosystem.
COMP 405 Database Administration (3 Credit Hours)
Pre-requisites: COMP 251 or COMP 271 Outcomes: Students will learn how to manage database performance, including topics such as the query optimizer, SQL EXPLAIN, table statistics, concurrency and transaction isolation levels, and security. Knowledge of the configuration and management skills needed for successful administration of a database server. The database administrator manages hardware, backup, security, tables and indexes, performance monitoring, query performance and optimization, and transaction performance. This course takes a user through the stages of maximizing the performance of a database server.

COMP 406 Data Mining (3 Credit Hours)
This course covers theory and practice of the analysis (mining) of extremely large datasets. With data growing at exponential rates knowledge gathering and exploration techniques are essential for gaining useful intelligence. Pre-requisites: COMP 251 or COMP 271 Outcomes: Students will be able to define and critically analyze data mining approaches for fields such as security, healthcare, science and marketing.

COMP 409 Advanced Numerical Analysis (3 Credit Hours)
Prerequisites (COMP 170 or COMP/MATH 215), MATH 212, and Math 264 Course equivalencies: X-COMP409/MATH409

COMP 410 Operating Systems (3 Credit Hours)
The course introduces advanced operating system concepts including distributed, real-time and multi-threaded in addition to reviewing memory management, files, and processes. Prerequisites COMP 271 and COMP 264 Outcome: Students will learn important topics in advanced operating systems and be able to make presentations on the topics.

COMP 412 Open Source Computing (3 Credit Hours)
This course will cover the fundamentals of Free and Open Source software development. Topics to be addressed include licensing, Linux, typical software development tools, applications, and techniques for managing remote servers. Prerequisite COMP 271 Outcome: Students will learn to implement projects involving free and open-source software and learn how to participate in open-source projects effectively.

COMP 413 Intermediate Object-Oriented Development (3 Credit Hours)
Pre-requisites: COMP 271 Outcomes: Use of interfaces in design; ability to recognize applications for design patterns, ability to refactor when necessary; ability to make effective use of test-driven development Principles of object-oriented design and implementation, including object modeling (UML or equivalent), interface design, refactoring and test-driven development. Study of design patterns, including Adapter, Decorator, Iterator, Abstract Factory, etc. Coverage of implementation tools including IDEs, source-code control and testing.

COMP 417 Social and Ethical Issues in Computing (3 Credit Hours)
This course covers social, legal, and ethical issues commonly arising in key areas related to computing technologies. Outcome: Understanding of laws and issues in areas such as privacy, encryption, freedom of speech, copyrights and patents, computer crime, and computer/software reliability and safety; understanding of philosophical perspectives such as utilitarianism versus deontological ethics and basics of the U.S. legal system.

COMP 418 Combinatorial Mathematics (3 Credit Hours)
The course covers basic combinatorial theory including permutations and combinations, the inclusion-exclusion principle and other general counting techniques, partitions, generating functions, recurrence relations, Burnside's Theorem, the cycle index, and Polya's formula. Prerequisite MATH 313 or COMP 163 Outcome: Students will learn mathematical techniques in discrete mathematics and applied combinatorics. Course equivalencies: X-COMP418/MATH418

COMP 420 Software Systems Analysis (3 Credit Hours)
Pre-requisites: COMP 271 This course uses Unified Modeling Language and similar notation to model the early software analysis and design phases, from collection of user requirements to determination of class needs through object-oriented design. No course description is available. Outcomes: Students will be able to capture business requirements in a software modeling document, and determine appropriate object-oriented classes suitable for final project implementation.

COMP 421 Math Models & Simulation (3 Credit Hours)
This course covers tools for analyzing problems that are mathematically difficult. Discrete event simulation techniques and software tools for simulating processes are covered. Outcome: Student will learn foundations of discrete event simulation Course equivalencies: X-COMP421/MATH421/STAT421

COMP 422 Software Development for Wireless and Mobile Devices (3 Credit Hours)
This course will focus on the methods, tools, and technologies for developing software applications for wireless and mobile devices, such as personal digital assistants (PDA) and smart mobile phones. Outcome: Students will learn user interface design for small screens, programming techniques for devices with limited memory and processing power, data synchronization for mobile databases, and wireless network programming.

COMP 424 Client-Side Web Design (3 Credit Hours)
This course provides an in-depth study of the concepts and methods required for the design and implementation of the presentation layer of a web application. Coursework includes several substantial programming projects. Prerequisite COMP 271 Outcome: Students will learn markup of static and dynamic content, content transformation, client-side executable content including client-side scripting and embedded applets, and web-based content management systems.

COMP 425 Rapid Applications Development (3 Credit Hours)
This course will teach students how to design Rapid Application Development using an integrated development environment such as the .NET framework and methodology. It is designed to support object-oriented programming concepts. Pre-requisite: COMP 271 Outcome: Students will create database applications and web applications using server-side technologies.

COMP 428 Algebraic Coding Theory (3 Credit Hours)
Pre-requisites: MATH 212 or Permission Outcome: Students will learn both the theory and application of error-correcting codes. In this course, major types of error-correcting codes, encoding and decoding, and their main properties will be studied. The codes examined will include the Hamming, Golay, BCH, cyclic, quadratic residue, Reed-Solomon, and Reed-Muller codes. Course equivalencies: X-COMP428/MATH428
COMP 429 Natural Language Processing (3 Credit Hours)
Pre-requisites: (COMP 231 OR (COMP 271 or COMP 402)) AND (MATH 131 OR 161) and (STAT 103 OR STAT 203 OR ISSCM 241 OR PSYC 304 OR instructor permission)
In this course, students examine in depth the problems, methods, and applications of NLP. Topics will include information retrieval, sentiment analysis, machine translation, document classification, and question answering. We will also cover the underlying theory from probability, statistics, and machine learning that are crucial for the field.
Outcomes:
- Students will explain areas of NLP such as information retrieval, sentiment analysis, machine translation, document classification, question answering.
- Students will apply tools of NLP to a domain of their choice

COMP 431 Cryptography (3 Credit Hours)
This course introduces the formal foundations of cryptography and also investigates some well-known standards and protocols, including private and public key cryptosystems, hashing, digital signatures, RSA, DSS, PGP, and related topics. Prerequisites COMP 271 and (Comp 163 or MATH 313 or MATH 201) or Permission Outcome: Students will gain an understanding of cryptosystems widely used to protect data security on the internet, and be able to apply the ideas in new situations as needed.
Course equivalencies: X-COMP431/MATH431

COMP 432 Web Services Programming (3 Credit Hours)
This course considers the safety, security, reliability, and privacy concerns of the embedded devices and cloud-based resources of the Internet of things. The course discusses methods for addressing these concerns.
Outcomes:
- Understand security and privacy concerns of embedded systems and the IoT
- Design/implement secure software for embedded systems and the IoT
- Establish safety, security, reliability, privacy goals for IoT-based systems

COMP 433 Web Services Programming (3 Credit Hours)
Web services are Web-based enterprise applications that use open, XML-based standards and transport protocols to exchange data with calling clients. This course provides the APIs and tools you need to create and deploy interoperable Web services and clients using .NET and Java WSDP. Outcome: Students will learn the standards and protocols for deploying web services.

COMP 434 Enterprise Software Development (3 Credit Hours)
The course shows how to use Enterprise JavaBeans to develop scalable, portable business systems. The technologies taught in the course include: component models, distributed objects, asynchronous messaging, and component transaction monitors. Outcome: Students will learn the architecture of EJB, entity and message and session beans.

COMP 436 Markup Languages (3 Credit Hours)
This course is concerned with XML and its various component frameworks. The core frameworks to be covered include Document Object Model (DOM), Simple API for XML processing (SAX), the XML Path language (XPath), and XSLT. Prerequisite COMP 271 Outcome: After taking this course, students will have working knowledge of XML and its connections to other ideas such as HTML, object models, relational databases, and network services.

COMP 437 Intro Concurrent Programming (3 Credit Hours)
Many real-world software systems rely on concurrence for performance and modularity. This programming-intensive course covers analysis, design, implementation, and testing of concurrent software systems. Outcome: An in-depth understanding of event-based and thread-based views of concurrency; the ability to develop concurrent software components using suitable languages, frameworks, and design patterns; familiarity with object-oriented modeling and development tools and test-driven development.

COMP 439 Distributed Systems (3 Credit Hours)
This course presents a modern discussion of distributed computing systems. Distributed computation, interactive services, collaborative computing, peer-to-peer sharing, and grid/utility computing are just a handful of distributed technologies that go beyond the capabilities of the traditional client/server model by allowing a collection of computers to be leveraged as a collective resource. Prerequisites COMP 313 and COMP 264; COMP 374 recommended Outcome: Students will learn design and implementation, scalability of performance, reliability, and security of loosely interconnected systems.

COMP 440 Computer Forensics Investigations (3 Credit Hours)
Pre-requisites: (COMP 150 or COMP 170 or COMP/MATH 215) AND (COMP 264 or COMP 317 or COMP 343)
This course introduces the fundamentals of computer/network/internet forensics, analysis and investigations.
Outcomes:
- The student will learn computer software and hardware relevant for analysis, and investigative and evidence-gathering protocols

COMP 441 Human-Computer Interaction (3 Credit Hours)
Pre-requisites: COMP 271 Outcome: Students will acquire an awareness of different design and evaluation methods as well as practical, effective, and cost-conscience methods for improving systems and their interfaces.
This course studies the interaction between humans and computer-based systems. The course will provide students with the methods for evaluating, designing, and developing better interfaces between humans and systems.

COMP 442 Server-Side Software Development (3 Credit Hours)
Server-based web applications and services have become part of everyday life. This programming-intensive course covers analysis, design, implementation, and testing of multi-tiered server-based software systems along with typical tier-specific and technologies. Outcome: An understanding of software architecture and integration in the development of multi-tiered server-based software, familiarity with object-oriented modeling and development tools and test-driven development.

COMP 443 Computer Networks (3 Credit Hours)
This course surveys packet-switched computer networks and attendant communication protocols, using the TCP/IP protocol suite on which the Internet is based as the primary model. We will also study general high-level network issues such as security, authentication, fault tolerance, and congestion. Prerequisite COMP 271 or COMP 264 Outcome: Students will understand how the Internet is constructed, how data is routed to its destination, how connections are made, how congestion is handled, and how security can be addressed.

COMP 445 Internet of Things Device and Application Security (3 Credit Hours)
Pre-requisites: COMP 348 AND (COMP 264 or COMP 271)
This course considers the safety, security, reliability, and privacy concerns of the embedded devices and cloud-based resources of the Internet of things. The course considers methods for addressing these concerns.
Outcomes:
- Understand security and privacy concerns of embedded systems and the IoT
- Design/implement secure software for embedded systems and the IoT
- Establish safety, security, reliability, privacy goals for IoT-based systems
COMP 446 Telecommunications (3 Credit Hours)
This course introduces the fundamental concepts of telecommunication networks. Underlying engineering principles of telephone networks, computer networks and integrated digital networks are discussed. Prerequisite COMP 271 or COMP 264 Outcome: Students will learn how telephone and data networks work. They will also learn voice networks, analog versus digital transmission, data link protocols, SONET, ATM, cellular phone systems, and the architecture of the current telephone system.

COMP 447 Intrusion Detection and Computer Forensics (3 Credit Hours)
This course will cover techniques for detecting the unusual usage patterns that typically signal a break-in. The course will also consider differences in detection of local intruders versus intrusion over networks. Finally issues in the prosecution of those breaking in to computers, particularly evidentiary issues are explored. Co-requisite or prerequisite COMP 271 Outcome: Students will learn to configure ID systems (eg., snort) and analyze their output. They will also understand both network-based and host-based monitoring techniques.

COMP 448 Network Security (3 Credit Hours)
Prerequisites: COMP 271 or COMP 447 Outcome: Students will gain an understanding of how to secure computers and network environments. This course will involve a discussion of the methods and tactics used to keep attackers at bay as well as the mechanisms by which we can identify and potentially stop potential intruders. The course covers topics such as Encryption, authentication, firewalls, NAT/PAT, restricted access policies, intrusion detection and other security frameworks.

COMP 449 Wireless Networking and Security (3 Credit Hours)
Prerequisites: COMP 271 Outcome: Students will gain an understanding of wireless networking, protocols, and standards and security issues. This course will explore the wireless standards, authentication issues, common configuration models for commercial versus institution installs and analyze the security concerns associated with this ad-hoc method of networking.

COMP 450 Enterprise Networking (3 Credit Hours)
Prerequisites: COMP 271 Management of complex, high-speed, heterogeneous computer networks Device management using SNMP and related protocols. Configuration and use of Network Management Systems. Data-flow management using LARTC and similar tools. Outcomes:
Ability to interpret SNMP network data, ability to implement a Network Management System and use it to identify bottlenecks, familiarity with traffic-control principles and mechanisms.

COMP 451 Introduction to Computer Vulnerabilities (3 Credit Hours)
Prerequisites: COMP 264 and COMP 347 Outcomes: Describe some recent computer software vulnerabilities. Describe how vulnerabilities can be leveraged into an attack. Describe a vulnerability or attack at the machine-code level. This course will introduce students to computer vulnerabilities at the machine-code level, including viruses, browser vulnerabilities, buffer and heap overflows, return-to-libc attacks and others.

COMP 452 Database Programming (3 Credit Hours)
This course will cover advanced concepts in database access and programming including SQL, JDBC, SQLJ, JSP and servlets. Oracle 10g is used for projects. Outcome: Students will learn application development using the latest software tools. Students will also learn techniques for web based data retrieval and manipulation.

COMP 453 Database System Design (3 Credit Hours)
The course covers both relational and object databases. Issues of physical storage and use of indexes as well as optimization of queries are discussed. The course also covers transaction processing, concurrency, data warehousing, data mining, and distributed databases. Outcome: Students learn the theory and practice of advanced database design and implementation. They will also gain an understanding of using commercial database environments such as Oracle.

COMP 454 High-Performance Computing (3 Credit Hours)
This course will use a blend of foundational understanding as well as a set of practical tools to gain insight into performance engineering of software. The course introduces techniques to gain performance boost in Java programs and C++ (or C) programs by discussing the use of multiple processors. Outcome: Students will learn shared memory, message passing and hybrid models of programming in both tightly-coupled and loosely-coupled computer systems.

COMP 455 Advanced Computer Architecture (3 Credit Hours)
The course will focus both on presenting general techniques for designing correct and efficient algorithms, as well as on formal methods for proving the correctness and analyzing the complexity of such algorithms. Outcome: Students learn: the ability to design and analyze efficient algorithms; understanding of the necessary models and mathematical tools; understanding of a variety of useful data structures and fundamental algorithms; exposure to the classification of computational problems into different complexity classes.

COMP 456 Big Data Analytics (3 Credit Hours)
Pre-requisites: At least a C in the following courses
In this course, large data sets will be leveraged to solve challenging analytics problems. With more samples, analytics can use more complex learning models to automate more feature combinations for more robust model tuning, selection, and validation. Parallel, distributed processing will be performed with Apache Spark and Hadoop. (COMP 405 or COMP 453) AND (COMP 406 or COMP 479 or STAT 338 or STAT 408) Outcomes:
Python or R will be used with parallel frameworks to perform proper model selection when testing large combinations of features, models, hyperparameters, and ensembles, with additional emphasis on deep learning.

COMP 457 Algorithms & Complexity (3 Credit Hours)
This course will focus both on presenting general techniques for designing correct and efficient algorithms, as well as on formal methods for proving the correctness and analyzing the complexity of such algorithms. Outcome: Students learn: the ability to design and analyze efficient algorithms; understanding of the necessary models and mathematical tools; understanding of a variety of useful data structures and fundamental algorithms; exposure to the classification of computational problems into different complexity classes.

COMP 458 Data Science (3 Credit Hours)
Prerequisites: COMP 446 or COMP 456 or COMP 457 Outcomes: Students will learn to apply advanced techniques to real-world problems.

COMP 460 Introduction to Database Systems (3 Credit Hours)
Prerequisites: COMP 264 and COMP 347 Outcomes: Students will learn the fundamentals of database systems and query languages. Outcome: Students will learn to design and implement database systems.

COMP 462 High-Performance Computing (3 Credit Hours)
This course will cover the basics of high-performance computing, including parallel computing, message passing, and distributed systems. Outcome: Students will learn the fundamentals of high-performance computing.

COMP 464 Advanced Computer Architecture (3 Credit Hours)
The course will cover advanced topics in computer architecture, including pipelined and parallel processing. Outcome: Students will learn the fundamentals of advanced computer architecture.

COMP 466 Database System Design (3 Credit Hours)
The course covers both relational and object databases. Issues of physical storage and use of indexes as well as optimization of queries are discussed. The course also covers transaction processing, concurrency, data warehousing, data mining, and distributed databases. Outcome: Students learn the theory and practice of advanced database design and implementation. They will also gain an understanding of using commercial database environments such as Oracle.

COMP 468 Database System Design (3 Credit Hours)
The course covers both relational and object databases. Issues of physical storage and use of indexes as well as optimization of queries are discussed. The course also covers transaction processing, concurrency, data warehousing, data mining, and distributed databases. Outcome: Students learn the theory and practice of advanced database design and implementation. They will also gain an understanding of using commercial database environments such as Oracle.

COMP 469 Physical Design and Fabrication (3 Credit Hours)
This course explores how things are made, including: physical design vs. design on non-physical things; rapid prototyping; 3D printing; 2D conceptualization and sketching; modeling. Outcome:
Student will be able to: Visualize ideas via sketching basic shapes; Create 3D models using 3D modeling software; Use a 3D Printer; Give constructive feedback in peer review sessions.
COMP 470 Software Quality and Testing (3 Credit Hours)
**Pre-requisites:** COMP 163 or COMP 271 or permission of instructor
In this programming intensive course, students will learn effective automation, testing, and use of software metrics through the practices of Test Driven Development and Continuous Deployment.

**Outcomes:**
Students will be able to perform rigorous testing techniques that contribute to operational reliability, and identify programming practices that both contribute to software maintainability and help to avoid errors.

COMP 471 Theory of Programming Languages (3 Credit Hours)
There are over two thousand programming languages. This course studies several languages that represent the much smaller number of underlying principles and paradigms.

COMP 472 Compiler Construction (3 Credit Hours)
This course covers the basics of writing a compiler to translate from a simple high-level language to machine code. Topics include lexical analysis, top-down and LR parsing, syntax-directed translation, and code generation and optimization. Students will write a small compiler.

**Outcome:** Students will learn the theory and practice of how to build a compiler.

COMP 473 Advanced Object Oriented Programming (3 Credit Hours)
Object-orientation continues to be a dominant approach to software development. This advanced programming-intensive course studies object-oriented analysis, design, and implementation from a design patterns perspective.

**Outcome:** Proficiency in the use of object-oriented languages, frameworks, and patterns; advanced understanding of key language mechanisms such as delegation, inheritance, polymorphism, and reflection; familiarity with object-oriented modeling and development tools and test-driven development.

COMP 474 Software Engineering (3 Credit Hours)
The course discusses real-world theory and techniques organizations use to create high-quality software on time. Students work on a large programming team to create plans, review progress, measure quality, and make written and oral analyses of their project.

**Outcome:** Students will experience process based development, understand the dynamics of a professional software organization, and develop skills for implementing software with others.

COMP 476 Automata & Formal Languages (3 Credit Hours)
**Pre-requisites:** MATH 201 or MATH 212 or COMP 163
This course introduces formal language theory, including such topics as finite automata and regular expressions, pushdown automata and context-free grammars, Turing machines, undecidability, and the halting problem.

**Outcome:** An understanding of the theoretical underpinnings of computability and complexity in computer science.

**Course equivalencies:** X-COMP476/MATH476

COMP 477 IT Project Management (3 Credit Hours)
This course is an introduction to the philosophy and practice of project management. The course involves a student group project to investigate and plan a ‘real world’ IT project that specifies project objectives, schedules, work breakdown structure, and responsibilities, an written interim report, and a final oral and written report.

**Outcome:** Students will learn time management, workflow management, and team dynamics to design, implement and test large-scale software projects.

COMP 479 Machine Learning (3 Credit Hours)
Topics include a wide variety of supervised learning methods, both regression and classification, with an emphasis on those that perform well on large feature sets.

**Outcomes:**
Students in this course will learn how to apply sophisticated algorithms to large data sets to make inferences for prediction or decision making.

COMP 480 Computer Graphics (3 Credit Hours)
This course introduces advanced topics in modern theory and practices in 3-D computer graphics, stressing real-time interactive applications using libraries like OpenGL.

**Outcome:** Students will learn how to program real-time interactive applications using libraries like OpenGL.

COMP 483 Computational Biology (4 Credit Hours)
**Pre-requisites:** BIO 488
Outcomes: Students will learn, in detail, foundational methods and algorithms in bioinformatics. This course presents an algorithmic focus to problems in computational Biology. As such it is built on earlier courses on algorithms and bioinformatics. Current algorithmic approaches, software tools, and scientific literature are discussed.

COMP 484 Artificial Intelligence (3 Credit Hours)
This course advanced artificial intelligence concepts including theory, search techniques and programming. Outcome: Student will learn the theory of artificial intelligence, search techniques, and be able to build small applications based on it.

COMP 486 Computational Neuroscience (3 Credit Hours)
**Pre-requisites:** COMP 150 or COMP 170 or COMP 180 or Permission of Instructor
Outcomes: Students will be able to adeptly apply mathematical and computational frameworks in the various domains of neuroscience.

**Introduces computational methods to understand neural processing in the brain. Levels of representation from low-level, temporally precise neural circuits to systems-level rate-encoded models, to information-theoretic approaches.** Emphasis on sensory systems, primarily vision and audition, most readily demonstrating the need for such computational techniques.

COMP 487 Deep Learning (3 Credit Hours)
**Pre-requisites:** COMP 479
Outcomes: Students will analyze popular modern neural architectures such as convolutional and recurrent neural networks, design and evaluate their own neural networks, and apply neural network models to a practical task. Deep learning is part of a broader family of machine learning methods based on artificial neural networks. This course will include key concepts of neural network algorithms as well as their applications in computer vision and natural language processing.

COMP 488 Computer Science Topics (1-4 Credit Hours)
This course is used to introduce emerging topics in computer science that do not yet have a regular course number. Content of the course varies. Outcome: Understanding of an emerging area of Computer Science.

COMP 490 Independent Project (1-6 Credit Hours)
**Pre-requisites:** Approval of the Computer Science faculty member supervisor
An independent project in computer science or related disciplines, under the supervision of a member of the faculty.
**COMP 499 Internship (1-6 Credit Hours)**
An opportunity to obtain experience in software development, design, networks, or related activities in computer science in a professional setting. The student must obtain the approval of the Graduate Program Director and the student's work supervisor. A final report from the student and the supervisor are required.

**COMP 501 Equitable and Inclusive Computer Science Pedagogy (3 Credit Hours)**
This class covers the design of computer science courses through an equity and inclusion lens, and covers evidence-based best practices as applied to specific student concerns. Includes basics of teaching and learning theory and pedagogical techniques, and equity, diversity, and justice concerns. Pre-requisites: COMP 400C. Graduate standing.

*Outcomes:*
Ability to explain justice-centered CS education; understand pedagogical frameworks; understand assessment approaches; understand Active Learning and Peer Instruction

**COMP 502 Structure of Research Management and Funding (3 Credit Hours)**
This class covers grant-proposal development, University compliance regulations, and laboratory and research management. Pre-requisites: COMP 400C. Graduate standing.

*Outcomes:*
Ability to create successful grant proposals and to understand research management

**COMP 503 Technology Entrepreneurship (3 Credit Hours)**
This course provides aspiring researchers with the skills to pursue new ventures and technology commercialization. Students learn how to transition an innovation from the lab to the marketplace. Pre-requisites: COMP 400C. Graduate standing.

**COMP 595 Thesis Supervision (0 Credit Hours)**
Supervision for students working on a thesis while not for other classes. Restricted to students enrolled in the MS in Computer Science.

**COMP 605 Master of Science Study (0 Credit Hours)**
Course for continuing master's degree students engaged in study.