B.Eng. (Computer Science)
Content of Subjects
Applicable to Students Matriculating in 2011 or later

FIRST YEAR

CZ1001 DISCRETE MATHEMATICS
Acad Unit: 3
Pre-requisite: Nil

Elementary number theory; Sets; Predicate logic; Linear recurrence relation; Relations; Functions;
Graphs; Complex numbers, vectors and matrices; Elementary Combinatorics

CZ1002 INTRODUCTION TO COMPUTING SYSTEMS
Acad Unit: 3
Pre-requisite: Nil

Introduction; Computer Pioneers and their contributions; Evolution of Computers – Part I; Basic CPU
operation and programming language evolution; Evolution of Computers– Part II; CPU Performance
Enhancement techniques; Programming Languages and Database; Programming Paradigms; The
internet; Networks and communications; Multi-tasking and Operating Systems; Classifications of
Computer Systems; Computing Trends; e-learning

CZ1003 INTRODUCTION TO COMPUTATIONAL THINKING
Acad Unit: 3
Pre-requisite: Nil

Computing and Algorithms; Introduction to Python; Basic syntax and meaning; Variables, Data types,
and Operators; More on numbers and built-in functions; Flow control; Program Development Issues
(supplementary); Strings and character access; Composite types; User defined functions and
modules; File management; Exceptions

CZ1004 GREAT IDEAS IN COMPUTING
Acad Unit: 2
Pre-requisite: Nil

Applications and directions in scientific computing; The impact of personal computer; Highly-
Integrated microcontrollers and their applications; Neural Networks and Artificial Intelligence;
The influence of Military activities on modern computing; Computers, telecommunications
and environmental impact; How computers are used in financial markets; Memory
technologies and prospects

CZ1005 DIGITAL LOGIC
Acad Unit: 3
Pre-requisite: Nil
Binary integers and arithmetic; Boolean Variables and Logic; Combinatorial circuits; Implementation technologies; Digital design using hardware description languages; Sequential circuits; Sequential circuits to building blocks; Finite state machines

CZ1006 COMPUTER ORGANISATION AND ARCHITECTURE

Acad Unit: 3
Pre-requisite: CZ1005 (can be taken concurrently)

Computer Hardware Decomposition; Data Representation, Memory Allocation and Access; Central Processing Unit; Assembly Programming and Instruction Set Architecture; High-level Software to Low-level Instructions; Computer Memory; Data Transfer and Input/Output (I/O) Techniques; Computer Arithmetic; Measuring system performance; Towards higher speed

CZ1007 DATA STRUCTURES

Acad Unit: 3
Pre-requisite: CZ1003

Basic Constructs in CC program structure, Syntax and semantics; Built-in Data Structures; Recursion; Memory Management in C; Linked Lists; Stacks and Queues; Tree Structures; Implementing other data abstractions

CZ1008 ENGINEERING MATHEMATICS

Acad Unit: 3
Pre-requisite: Nil

Precalculus: Functions and graphs; Limits and continuity; Derivatives and applications; Integrals and applications; First order differential equations; Infinite series; Descriptive statistics; Probability theory Probability and sampling distributions; Inferential statistics; Experimental and Numerical Methods

CZ0001 ENGINEERS AND SOCIETY

Acad Unit: 3
Pre-requisite: Nil

This course raises issues pertinent to engineers as professionals as well as members of society. It discusses the requirements and issues of the IT profession, examining the key role professionals play with their contributions to society. Current concerns will be raised of interest to any person living in Singapore.
SECOND YEAR

CZ2001 ALGORITHMS
Acad Unit: 3
Pre-requisite: CZ1001, CZ1007

Introduction to algorithms, basics for analysis of algorithms, sorting, searching, graphs, basic computability and complexity theory

CZ2002 OBJECT ORIENTED DESIGN AND PROGRAMMING
Acad Unit: 3
Pre-requisite: CZ1007

Introduction to Object Orientated Programming; Interface and implementation; Designing with Classes and Objects; Inheritance and polymorphism; Object Relationships; Framework and Reuse; Persistent Objects; Design patterns; Object Oriented Programming Language

CZ2003 COMPUTER GRAPHICS AND VISUALISATION
Acad Unit: 3
Pre-requisite: CZ1001

Introduction to computer graphics and foundation mathematics; Virtual Reality Modelling Language (VRML) and Extensible 3D (X3D); Geometric shapes; Visual appearance; Transformations and motions; Efficient rendering; Putting it all together

CZ2004 HUMAN COMPUTER INTERACTION
Academic Unit: .3
Pre-requisite: Nil

Introduction; Usability and application spaces; Guidelines and principles for text-based interactions; Hardware devices for interaction; Development processes and assessments; Software tools in user interface development; Interaction styles; Practical UI development concepts; Design Issues

CZ2005 OPERATING SYSTEMS
Acad Unit: 3
Pre-requisite: CZ1007

Overview of Operating Systems (OS); Processes and Threads; Process Scheduling; Deadlock and Starvation; Memory Organization; Virtual Memory Management; File System Organization and Implementation; Input/Output (I/O) Management and Disk Scheduling; Issues in Real-time Operating Systems; Protection and Security

CZ2006 SOFTWARE ENGINEERING
Acad Unit: 3
Pre-requisite: CZ2002 (can be taken concurrently)
Introduction to Software Engineering; Software Engineering Process; Introduction to Requirements; Introduction to Software Specifications; Software Design and Construction; Testing and Integration; Software Maintenance; Software Project Management; Software Quality; Dependability and Security

CZ2007 INTRODUCTION TO DATABASES

Acad Unit: 3
Pre-requisite: CZ2001

Introduction to Databases; Entity-Relationship Data Model; Relational Data Model; Functional Dependencies (FD) and Normalization; Relational Algebra; Querying Relational Databases; Semistructured Data and XML; Querying XML Data; XML to Relational Storage; Introduction to Database Security

CZ0002 GREEN COMPUTING

Acad Unit: 3
Pre-requisite: Nil

Introduction to Green Computing; eLearning; Energy; Green design; Green manufacturing; Green use; Green disposal; Other issues; Common sense approaches to green computing; Green applications
THIRD YEAR

CZ3001 ADVANCED COMPUTER ARCHITECTURE
Acad Unit: 3
Pre-requisite: CZ1006
Introduction to Computer System; The CPU Architecture; Performance Enhancements & Instruction-Level Parallelism; Memory Systems; Data-Level Parallelism in Vector, SIMD, and GPU Architectures; Multiprocessors and Thread-Level Parallelism; Warehouse-Scale Computing: Exploiting Request-Level and Data-Level Parallelism; Future directions

CZ3002 ADVANCED SOFTWARE ENGINEERING
Acad Unit: 3
Pre-requisite: CZ2006
Introduction; Software Quality; Project Management; Maintenance; Software Testing; Configuration Management

CZ3003 SOFTWARE SYSTEM ANALYSIS AND DESIGN
Acad Unit: 3
Pre-requisite: CZ2006 (can be taken concurrently)
Introduction to Software System Analysis and Design; Requirement Engineering; Software Quality and Design Principles; Design Issues; Software Architecture Design; Design Quality Analysis and Evaluation; Software Construction; System Validation and Verification; System Deployment and Use

CZ3004 MULTIDISCIPLINARY DESIGN PROJECT (MDP)
Acad Unit: 4
Pre-requisite: At least Third Year Standing
MDP is a group-based design and development project undertaken by a mixed group of students comprising of undergraduates from the CE and CS programmes. The project is practical-oriented and multi-disciplinary in nature, requiring system level integration of sub-systems developed by different team members. Topics covered will include Microprocessors, Signals and Interfaces, Sensors and Communication, Software engineering, Data structures and Algorithms, Open-source frameworks.

NB: MDP is to be done over one semester by students who have reached at least a year 3 standing. Eligible students will be automatically registered by the school and will be allocated to their respective project group based on a composition of students from different programmes. Students cannot choose to defer the MDP.

Course Schedule: Twelve two-hour weekly slots and five full days during the entire recess week.
The group-based nature of MDP makes it important that the disruptive absence of members is strongly discouraged. Attendance for all scheduled MDP activities is thus compulsory. Students who do not satisfy at least 80% of the overall attendance without valid reasons (e.g. MC) will be deemed to have failed MDP. Students who miss more than 50% of the scheduled MDP sessions will not be deemed to have fulfilled the learning outcomes of MDP and they will be required to re-take MDP in the next available offering. In other words, an "I" will be reflected in the result transcript for MDP.
CZ3005 ARTIFICIAL INTELLIGENCE

Acad Unit: 3
Pre-requisite: CZ1003, CZ2001

Human brain and Cognitive structure; Foundations of AI; Agent paradigm, Agent tasks and environments; Procedural Representation (Algorithmic); Symbolic Representation (Knowledge Engineering); AI in the Real World, Case studies of intelligent systems

CZ3006 NET CENTRIC COMPUTING

Acad Unit: 3
Pre-requisite: CZ1006, CZ1007 (both can be taken concurrently)

Introduction to net-centric computing; the physical layer and data link layer; the MAC Layer and Local Area Networks; the network layer and Internet IP protocols; the transport layer and Internet TCP protocols; web architecture and protocols; web documentation technologies; client application programming techniques; server application programming techniques

CZ3007 COMPILER TECHNIQUES

Acad Unit: 3
Pre-requisite: CZ2001, CZ2006

Introduction to Compilers; Lexical Analysis; Parsing; Semantic Analysis; Code Generation; Optimisation
FOURTH YEAR

TECHNICAL ELECTIVES

CE/CZ4001 Virtual and Augmented Reality

Acad Unit: 3
Pre-requisite: CZ2003

Introduction; Graphical Scene; Animation and Sensing; Light and Sound; Controlling Environment; Programming Scripts; Introduction to Augmented Reality; Displays for Augmented Reality; Tracking, Recognition and Registration; Rendering and Augmentation; Examples of Augmented Reality System

CE/CZ4002 VISUAL MEDIA COMPRESSION AND PROCESSING

Acad Unit: 3
Pre-requisite: Nil

Introduction to media management & processing; Entropy coding; Digital image coding techniques; Motion Estimation; Digital video coding techniques; Advanced topics for visual signal compression; Image retrieval and indexing

CE/CZ4003 COMPUTER VISION

Acad Unit: 3
Pre-requisite: Nil

Introduction to computer vision; Principles of Camera Systems; Image Enhancement in the Spatial domain; Image Enhancement in the Frequency domain; Colour; Image Edge Processing; Image Segmentation; Imaging Geometry and 3D Stereo Vision; Object Recognition

CE/CZ4004 3D MODELING AND ANIMATION

Acad Unit: 3
Pre-requisite: CZ2003

Introduction to History of 3D graphics and animation; applications; Computer Graphics Pipeline; Graphics Programming; 3D Shape Representation; Geometric Processing; Rendering; Basic Animation Techniques; Kinematic Animation; Physics Based Simulation; Motion Capture

CE/CZ4005 AUDIO AND SPEECH PROCESSING

Acad Unit: 3
Pre-requisite: Nil

Introduction to audio and speech science; Principles of audio and speech science; Spectrograms; Linear Predictive Coding; Mel Frequency Cepstral Coefficients (MFCC); Gaussian Mixture Models; HMM models; Classification of audio signal
Acoustic modeling for speech recognition
CE/CZ 4011 PARALLEL COMPUTING
Acad Unit: 3
Pre-requisite: CZ/CE2001 & CZ/CE3001

Foundations & Theory; Distributed Memory Programming; Shared Memory Programming; Massively Parallel Programming; Synchronous computations

CE/CZ4013 DISTRIBUTED SYSTEMS
Acad Unit: 3
Pre-requisite: CZ/CE2005 & CE3005 or CZ3006

Characteristics of distributed systems and system models; Interprocess communication; Distributed objects and remote invocation; Distributed file systems; Peer-to-peer systems; Name services; Time and global states; Coordination and agreement; Replication and consistency

CE/CZ4015 SIMULATION AND MODELLING
Acad Unit: 3
Pre-requisite: CZ/CE1007 & CZ/CE1008

Introduction; Different Types of Simulation; Simulation World View and Simulation Software; Basic Probability and Statistical Models for Simulation; Random Numbers and Random Variate Generation; Input Modelling; Verification and Validation of Simulation Models; Output Analysis; Comparison of Alternative Designs; Queueing Models

CE/CZ4016 ADVANCED TOPICS IN ALGORITHMS
Acad Unit: 3
Pre-requisite: CZ2001

Analysis Techniques; Dynamic Programming; Search Techniques; Computational Geometry; Min Cut /Max Flow; Lower Bounds and NP-completeness; Approximation Algorithms and Heuristics; Randomized Algorithms

CE/CZ4021 PERVASIVE NETWORKS
Acad Unit: 3
Pre-requisite: CE3005 or CZ3006

The objective of this course is to introduce different types of wireless network technologies and some important mobile services and applications to support pervasive computing. The subject consists of two complementary components, i.e., wireless network protocol and mobility management. In the wireless network protocol part, various protocols in different layers designed to support wireless data transfer will be presented. In the mobility management, the required mechanisms to support data transfer with users’ mobility will be discussed. After attending this course, the students will be able to appreciate the various technical challenges associated with wireless networking and develop a basic understanding of the solutions proposed to overcome the challenges, and the principles behind them. In addition, the students will acquire working knowledge of the principles of and issues related to location management, and mobile multimedia services.

CE/CZ4022 PERSONAL MOBILE NETWORKS
Acad Unit: 3
Pre-requisite: CE3005 or CZ3006
Fundamentals of Wireless Mobile Communications: concepts, challenges and components; radio frequency transmission, data and carrier signal components; channel bandwidth and data rate; modulation; signal propagation, data transmission (modulation, spread spectrum, multiple access); Overview of mobile networks, Wireless Personal Area Networks (WPAN); Wireless Local Area Networks (WLAN); Wireless Wide Area Networks (WWAN): cellular communications networks, satellite communications.

CE/CZ4023 ADVANCED COMPUTER NETWORKS
Acad Unit: 3
Pre-requisite: CE3005 or CZ3006

Top-Down View of Computer Networks; Application Layer Protocols; Multimedia Networking; Advanced Network Protocols; QoS and Traffic Management; Network Deployment and Design

CE/CZ4024 CRYPTOGRAPHY AND NETWORK SECURITY
Acad Unit: 3
Pre-requisite: CE3005 or CZ3006

The course aims at exposing computer engineering students to principles and efficient implementations of cryptographic techniques/components for protection of networked computers and secure communications over an open network. Coverage include: Threats and security services in an opened computer network; foundation mathematics underlying practical cryptographic techniques (basic number theory and algebraic finite fields); Established cryptographic algorithms including AES, RC4, RSA, and other public key algorithms that based on discrete logarithm of finite algebraic groups, Cryptographic hashes; Message authentications and block cipher chaining; Lightweight cryptography, Cryptographic protocols for authentication and key distribution; Key management. The course does not address other important network security techniques that are built upon firewalls, intrusion detections and security auditing. Students who dislike mathematics and logic (for reasoning) and/or computer arithmetic are advised to consider carefully when enrolling this course.

CZ4031 DATABASE SYSTEM PRINCIPLES
Acad Unit: 3
Pre-requisite: CZ2007

Overview of Database Management Systems (DBMS); Storage of Relational Data; Indexing Techniques; Query Processing; Query Optimization; Failure Recovery; Transaction; Management and Concurrency Control; Advanced topics

CZ4032 DATA ANALYTICS AND MINING
Acad Unit: 3
Pre-requisite: CE/CZ2001

Introduction of Data Analytics & Mining; Data Pre-processing; Data Analytics & Visualization; Cluster Pattern Analysis; Predictive Pattern Mining; Association Rule Mining; Anomaly Detection

CZ4033 ADVANCED DATA MANAGEMENT
Acad Unit: 3
Pre-requisite: CZ4031
Overview of data management in the 21st century; Data warehousing; Column-oriented DBMS; Spatial data management; Graph data management; Distributed data management; Data management in the cloud

**CZ4034 INFORMATION RETRIEVAL**

Acad Unit: 3  
Pre-requisite: CE/CZ2001

Introduction; Boolean Retrieval; Term Vocabulary and Posting; Dictionaries and Tolerant Retrieval; Index Construction and Compression; Scoring, Term Weighting, and Vector Space Model; IR Evaluation; Relevance Feedback and Query Expansion; Probabilistic IR and Language Model  
Web Search; Link Analysis and Crawling

**CZ4041 MACHINE LEARNING**

Acad Unit: 3  
Pre-requisite: Nil

Introduction to Machine Learning; Decision Theory; Density Estimation; Dimension Reduction; Classification; Feature Selection and Classifier Evaluation; Clustering

**CZ4042 NEURAL NETWORKS**

Acad Unit: 3  
Pre-requisite: Nil

Introduction to neural networks; Basic Perceptron; Multi-layer Perceptron networks; Performance estimation and model selection; Kernel-based network; Hopfield network; Self-Organizing Neural Network; Neural Networks at Work

**CZ4045 NATURAL LANGUAGE PROCESSING**

Acad Unit: 3  
Pre-requisite: CE/CZ2001

Introduction to Natural Language Processing; Spelling checking; Word Prediction; Word Classes; Introduction to Classification Methods; Information extraction; Formal grammars; Syntactic parsing; Computational semantics

**CZ4046 INTELLIGENT AGENTS**

Acad Unit: 3  
Pre-requisite: Nil

Introduction to Intelligent Agents; Deductive Reasoning Agents; Practical Reasoning Agents; Reactive and Hybrid Architectures; Introduction to Multi-Agent Systems and Applications; Working Together; Multi-Agent Interaction; Allocating Scarce Resources – Auctions; Making Group Decisions; Forming Coalitions

**CE/CZ4062 COMPUTER SECURITY (SYSTEM SECURITY)**

Acad Unit: 3  
Pre-requisite: CE/CZ2005
This course is concerned with security mechanisms in modern computer systems. Concepts and Terminology; Security Models; Implementation of Mechanisms; User authentication; Case Studies; Operating system vulnerabilities; Software security

CE/CZ4064 SECURITY MANAGEMENT

Acad Unit: 3
Pre-requisite: CE/CZ2006

This course introduces network security at an elementary level. What is security and why is it necessary? ; Security management - systems, models and frameworks; Internal control, audit and security; Risk analysis; Business continuity planning; Information security, governance and the law