Computing, Artificial Intelligence, and Systems

Part 1: (Compulsory) Engineering Mathematics

Discrete Mathematics: Propositional and first order logic. Sets, relations, functions, partial orders and lattices. Monoids, Groups. Graphs: connectivity, matching, colouring. Combinatorics: counting, recurrence relations, generating functions.

Linear Algebra: Matrices, determinants, system of linear equations, eigenvalues and eigenvectors, LU decomposition.

Calculus: Limits, continuity and differentiability, Maxima and minima, Mean value theorem, Integration.

Probability and Statistics: Random variables, Uniform, normal, exponential, Poisson and binomial distributions. Mean, median, mode and standard deviation. Conditional probability and Bayes theorem.

Part 2: (Core) Student needs to attend any three of the following sections

Section 1: Digital Logic Number Representations: Binary, integer and floating-point- numbers. Combinatorial circuits: Boolean algebra, minimization of functions using Boolean identities and Karnaugh map, logic gates and their static CMOS implementations, arithmetic circuits, code converters, multiplexers, decoders. Sequential Circuits: Latches and flip-flops, counters, shift-registers, finite state machines, propagation delay, setup and hold time, critical path delay. Data Converters: Sample and hold circuits, ADCs and DACs. Semiconductor Memories: ROM, SRAM, DRAM. Verilog Hardware Description Language (HDL): Types of modelling: Gate-level modelling, Data- flow modelling; Behavioural modelling; Structural modelling; Basic constructs and syntax of Verilog language, related to hierarchical and modular modelling; Concept of test-bench; Verilog implementation of combinational circuits/modules, sequential-logic circuits and RTL structures.

Section 2: Computer Architecture and Embedded Systems Computer Organization: Machine instructions and addressing modes; Building blocks of processor: Data memory, Instruction Memory, Register File, Address decoding, Arithmetic- logic Unit (ALU), timing pulse generator, Program Counter (PC), Stack Memory and stack pointers, I/O registers, control unit, data-path structures; Instruction pipelining, pipeline hazards. Memory hierarchy: cache, main memory and secondary storage; I/O interface (interrupt and DMA mode). Assembly Language Programming; Multicore systems; Embedded Systems and microcontroller interfacing: AVR internal architecture and features like GPIOs, timers/counters, interrupts, communication protocols (SPI, I2C, UART), A/D, D/A, Real Time Clock, PWM, and other peripherals; Embedded C programming;

Section 3: Programming, Data Structures and Algorithms Programming in C. Recursion. Arrays, stacks, queues, linked lists, trees, binary search trees, binary heaps, graphs. Searching, sorting, hashing. Asymptotic worst case time and space complexity. Algorithm design techniques: greedy, dynamic programming and divide-and-conquer. Graph traversals, minimum spanning trees, shortest paths.

Section 4: Theory of Computation Regular expressions and finite automata. Context-free grammars and push-down automata. Regular and context-free languages, pumping lemma. Turing machines and undecidability.

Section 5: Operating System System calls, processes, threads, inter-process communication, concurrency and synchronization. Deadlock. CPU and I/O scheduling. Memory management and virtual memory. File systems.

Section 6: Database Management and Warehousing Database Management and Warehousing: ER-model, relational model: relational algebra, tuple calculus, SQL, integrity constraints, normal form, file organization, indexing, data types, data transformation such as normalization, discretization,

sampling, compression; data warehouse modelling: schema for multidimensional data models, concept hierarchies, measures: categorization and computations.

Section 7: Computer Networks Concept of layering: OSI and TCP/IP Protocol Stacks; Basics of packet, circuit and virtual circuit- switching; Data link layer: framing, error detection, Medium Access Control, Ethernet bridging; Routing protocols: shortest path, flooding, distance vector and link state routing; Fragmentation and IP addressing, IPv4, CIDR notation, Basics of IP support protocols (ARP, DHCP, ICMP), Network Address Translation (NAT); Transport layer: flow control and congestion control, UDP, TCP, sockets; Application layer protocols: DNS, SMTP, HTTP, FTP, Email.

Section 8: Machine Learning Supervised Learning: regression and classification problems, simple linear regression, multiple linear regression, ridge regression, logistic regression, k-nearest neighbour, naive Bayes classifier, linear discriminant analysis, support vector machine, decision trees, bias-variance trade-off, cross-validation methods such as leave-one-out (LOO) cross-validation, k-folds cross-validation, multi-layer perceptron, feed-forward neural network; Unsupervised Learning: clustering algorithms, k-means/k-medoid, hierarchical clustering, top-down, bottom-up: single-linkage, multiple-linkage, dimensionality reduction, principal component analysis.

Section 9: AI Search: informed, uninformed, adversarial; logic, propositional, predicate; reasoning under uncertainty topics — conditional independence representation, exact inference through variable elimination, and approximate inference through sampling.

Section 10: Signal-Processing Systems Circuit Analysis: Node and mesh analysis, superposition, Thevenin's theorem, Norton's theorem, reciprocity. Sinusoidal steady state analysis: phasors, complex power, maximum power transfer. Time and frequency domain analysis of linear circuits: RL, RC and RLC circuits, solution of network equations using Laplace transform. Linear 2-port network parameters, wye-delta transformation. Continuous-time Signals: Fourier series and Fourier transform, sampling theorem and applications. Discrete-time Signals: DTFT, DFT, z-transform, discrete-time processing of continuous-time signals. LTI systems: definition and properties, causality, stability, impulse response, convolution, poles and zeroes, frequency response, group delay, phase delay.

Section 11: Communications Systems Random Processes: Auto correlation and power spectral density, properties of white noise, filtering of random signals through LTI systems. Analog Communications: Amplitude modulation and demodulation, angle modulation and demodulation, spectra of AM and FM, super heterodyne receivers. Information Theory: Entropy, mutual information and channel capacity theorem. Digital Communications: PCM, DPCM, digital modulation schemes (ASK, PSK, FSK, QAM), bandwidth, inter-symbol interference, MAP, ML detection, matched filter receiver, SNR and BER. Fundamentals of error correction, Hamming codes, CRC.