Department of Computer Science

Punjabi University, Patiala 147002
(Established under Punjab Act No. 35 of 1961)

Syllabus for Ph. D. Entrance Test for Session 2024-25
Section-A
(Research Methodology)

Basics of Research methodology: objectives and types of research, research approaches, research methods versus methodology, research process. Defining the research problem: techniques involved in defining a problem. Research design: features of good research design, concepts relating to research design, different research designs, basic principles of experimental designs, and various experimental designs.
Design of sample surveys: Sample design, sampling and non-sampling errors, types of sampling designs. Data collection and preparation: Experiments and surveys, collection of primary and secondary data, data cleaning, data adjusting, problems in data preparation process, missing values and outliers, types of analysis.

Measures of central tendency, measures of dispersion, measures of skewness, measures of kurtosis.

Probability: Random variables and probability distribution :Discrete probability distributions: Binomial and multinomial distributions, hypergeometric distribution, negative binomial and geometric distributions, Poisson distribution. Continuous probability distributions: Normal distribution, areas under the normal curve, normal approximation to the binomial, gamma and exponential distributions, chi-squared distribution, lognormal distribution, two-dimensional or joint probability distributions, transformation of one-dimensional and two-dimensional random variables.

Mathematical expectation: Mean of a random variable, variance and co-variance of random variables, means and variances of linear combinations of random variables, Chebyshev's theorem.

Sampling distributions and data descriptions: Sampling distribution of means and central limit theorem, sampling distribution of χ^2, t-distribution, F-distribution. One-and two-sample estimation problems: Statistical inference, classical methods of estimation, single sample: estimating mean, standard error of a point estimate, prediction intervals, two samples: estimating the difference between two means, paired observations, single sample: estimating a proportion, two samples: estimating the difference between two proportions, single sample: estimating the variance, two samples: estimating the ratio of two variances, maximum likelihood estimation.

Tests of hypotheses: Significance level, types of errors in tests, null hypothesis, alternative hypothesis, test for mean with and without known variance, comparison of means and variances, choice of sample size for testing means.

Correlation: Karl Pearson's coefficient of correlation, correlation coefficient for bivariate frequency distribution, probable error of correlation coefficient, rank correlation.

Analysis of variance: One-way ANOVA, two-way ANOVA, Latin-square design, analysis of co-variance.

Factor analysis: Centroid method, principal components method, maximum likelihood method, rotation in factor analysis, R-type and Q-type factor analysis.

Regression: Linear regression, regression coefficient, properties of regression coefficients, standard error of estimate, curvilinear regression, and regression curves.

Design of experiments: Completely randomized design, random block design, Latin-square design, Interpretation and report writing.

Section-B
(Subject)

Computer Science
Discrete Structures

Sets, Relations, Functions. Pigeonhole Principle, Inclusion-Exclusion Principle, Equivalence and Partial Orderings, Elementary Counting Techniques, Probability. Measure(s) for information and Mutual information. Graph: walks, paths, trails, connected graphs, regular and bipartite graphs, cycles and circuits. Tree and rooted tree. Spanning trees. Eccentricity of a vertex radius and diameter of a graph. Central Graphs. Centre(s) of a tree. Hamiltonian and Eulerian graphs, Planar graphs. Groups: Finite fields and Error correcting/detecting codes.

I. **Computer System Architecture** Combinational Circuit Design, Sequential Circuit Design, Hardwired and Micro-programmed processor design, Instruction formats, Addressing modes, Memory types and organization, Interfacing peripheral devices, Interrupts. Microprocessor architecture, Instruction set and Programming (8085, P-III/P-IV), Microprocessor applications.

II. Computer Arithmetic

Propositional Logic, Predicate Logic, Well-formed-formulae (WFF), Satisfiability and Tautology. Logic Families: TTL, ECL and C-MOS gates. Boolean algebra and Minimization of Boolean functions, Flip-flops—types, race condition and comparison. Design of combinational and sequential circuits. Representation of Integers: Octal, Hex, Decimal, and Binary. 2's complement and l's complement arithmetic. Floating point representation.

III. Programming Languages

Programming language concepts, paradigms and models. Elements of a program-Tokens, identifiers, data types, Variables and constants, Operators, Control structures: Sequence, selection and iteration(s). Functions and parameter passing. Object-oriented Programming Concepts: Class, object, instantiation. Constructors and destructors, Inheritance, polymorphism and overloading. Exception handling. Principles of parallelism, co-routines, communication and execution. Parallel Virtual Machine (PVM) and Message Passing Interface (MPI) routines and calls. Parallel programs in PVM paradigm as well as MPI paradigm. Preconditions, post-conditions, axiomatic approach for semantics, correctness, denotational semantics.

IV. Relational Database Design and SQL

Database Concepts, Data Models, Design of Relational Database, E-R diagrams and their transformation to relational design, Normalization. SQL and QBE, Database objects-Views, indexes, sequences, synonyms, data dictionary. Query Processing and Optimization, Centralized and Distributed Database, Security, Concurrency and Recovery in Database Systems, Object Oriented Database Management Systems, Spatial and temporal databases.

V. Data structures and Algorithms

Programming in C/C++, Recursion, Asymptotic notations – Properties of big oh notation – asymptotic notation with several parameters – conditional asymptotic notation – amortized analysis – NP completeness – NP-hard– recurrence equations – solving recurrence equations. Arrays, linked lists, trees and sparse matrices. Heap Structures: Min-max heaps – D-heaps – Leftist heaps –Binomial heaps – Fibonacci heaps –Skew heaps. Search Structures Binary search trees – AVL trees – 2-3 trees – 2-3-4 trees – Red-black trees –B trees. Graph Algorithms: Topological sort, minimum Spanning tree, single-source shortest paths, all-pairs shortest paths, biconnected components, strongly connected components, cycles, articulation points, bridges. Applications: Huffman coding – Garbage collection and compaction – Topological sort –Mincutmaxflow algorithm – Activity networks – Set representation – Set union and find operations. Sorting Algorithms, File Structures: Fields, records and files. Sequential, direct, index-sequential and relative files. Hashing, inverted files and multi-lists. Analysis of Algorithms, Asymptotic notations—big oh, omega and theta. Recursion. Design of Algorithms- Divide and Conquer, Greedy method, Dynamic programming, Backtracking, Branch and Bound. Lower bound theory, Non-deterministic algorithm—Non-deterministic programming constructs. Simple non-deterministic programs. NP—hard and NP—complete problems.

VI. Computer Networks

Data communication Techniques, Synchronous-Asynchronous Transmission, Digital Transmission, Transmission Media, Impairments, Data encoding Techniques. Multiplexing and Concentration, Switching techniques. X.25, LAN Technologies, Virtual Circuits. Topologies, Networking Devices, Wireless Networks, Internetworks. Network Reference models – OSI and TCP/IP, Layered architecture. Narrow-band ISDN, broadband ISDN, ATM, High speed LANS. Cellular Radio. Internetworking: Tunneling, Fragmentation, Firewalls. Routing algorithms, Congestion control. Network Security: Cryptography and other techniques. Domain Name System (DNS)—Electronic Mail and Worldwide Web (WWW).Resource Records, Name servers. E-mail-architecture and Servers. Network administration.

VII. System Software and Compilers

Assembler. Macros and macro processors. Loading, linking, relocation, program relocatability. Linkage editing. Text editors. Programming Environments. Debuggers and program generators. Compilation and Interpretation. Bootstrap compilers. Compilation process. Lexical analysis. Lex package on Unix system. Context free grammars. Parsing and parse trees. YACC package on Unix system. Intermediate codes-Quadruples, Triples, Intermediate code generation, Code generation and Code optimization.

VIII. Operating Systems

OS Structure, services and components, Process management, CPU scheduling, Memory Management, threads, Inter-process Communication, Concurrent Processing and concurrency control. I/O and Device management, buffering and spooling file management, file storage, Access methods and free space management. Operating system security and privacy. Distributed & Multiprocessor system, Recovery and Fault Tolerance.

IX. **Software Engineering**

Approaches to software development. Software Metrics, Software Project Management: Principles of software projects management; Organizational and team structure; Project planning; Project initiation and Project termination; Technical, quality, and management plans; Project control; Cost estimation methods. Software Design: function-oriented design, object-oriented design, user-interface design. Design level metrics. Coding and Testing: Testing level metrics. Software quality and reliability. Software Quality Management: verification & validation; Total quality management; SEI maturity model. CASE tools. Configuration Management. Software reengineering.

X. Computer Graphics

Display systems, Input devices, Scan conversion algorithms, Region Filling, 2D Geometry, Graphic operations, Three Dimensional Object Representations: Polygon surfaces, Curved lines and surfaces, Quadric and Super-quadrics, Spline representation, Bezier and B-Spline curves, Fractal-Geometry methods. Projections. Three Dimensional Viewing and Clipping: 3-D Viewing, Clipping, Visible Surface Detection. Illumination and Surface-Rendering Methods: Basic Illumination models, Halftone patterns and Dithering Techniques, Polygon-Rendering methods, adding surface details. Computer-assisted animation. Color models.

XI. Theory of Computation

Formal language, Need for formal computational models, Non-computational problems, diagonal argument and Russell's paradox. Deterministic Finite Automaton (DFA), Non-deterministic Finite Automaton (NFA), Regular languages and regular sets, Equivalence of DFA and NFA. Minimizing the number of states of a DFA. Non-regular languages, and Pumping lemma. Pushdown Automaton (PDA), Deterministic Pushdown Automaton (DPDA), Non-equivalence of PDA and DPDA. Context free Grammars: Greibach Normal Form (GNF) and Chomsky Normal Form (CNF), Ambiguity, Parse Tree Representation of Derivations. Equivalence of PDA's and CFG's. Parsing techniques for parsing of general CFG's-Early's, Cook-Kasami-Younger (CKY), and Tomita's parsing. Linear Bounded Automata (LBA): Power of LBA. Closure properties. Turing Machine (TM): One tape, multitape. The notions of time and space complexity in terms of TM. Construction of TM for simple problems. Computational complexity. Chomsky Hierarchy of languages: Recursive and recursively-enumerable languages.

XII. Cloud Computing

Web Service as distributed application, SOAP Based Web Services, Web Services Security, Wire-Level Security, WS-Security. Architecting on AWS, Building complex solutions with Amazon Virtual Private Cloud (Amazon VPC), Leverage bootstrapping and auto configuration in designs, Architect solutions with multiple regions.

XIII. Data Science and Machine Learning

Basic probability, Random variables, Sampling, Parameter estimation, Regression. Machine learning tasks, Overfitting, Parameter estimation, Gradient descent, etc. Supervised, Unsupervised and Reinforcement Learning; Single Perceptron, Multi Layer Perceptron Classification and regression algorithms, clustering techniques. Feature Engineering

XIV. **Current Trends and Technologies**

Parallel Computing: Parallel virtual machine and message passing interface libraries and calls. Advanced architectures. Mobile Computing: Mobile connectivity-Cells, Framework, wireless delivery technology and switching methods, mobile information access devices, mobile data internetworking standards, cellular data communication protocols, mobile computing applications. Mobile databases-protocols, scope, tools and technology. M-business. E-Technologies: Electronic Commerce Framework, Media Convergence of Applications, Consumer Applications. Electronic Payment Systems, Risks in Electronic Payment System. Electronic Data Interchange and Electronic Commerce, Standardization and EDI, EDI Envelope for Message Transport, Internet-Based EDI. Digital Libraries and Data Warehousing: Concepts, Types of Digital documents, Issues behind document Infrastructure, Corporate Data Warehouses. Data Mining. Software Agents: Characteristics and Properties of Agents, Technology behind Software Agents (Applets, Browsers and Software Agents). Cloud computing.

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