Savitrribai Phule Pune University

Faculty of Engineering

Syllabus

T.E. (Information Technology) 2015 Course
(With effect from Academic Year 2017 - 18)

SAVITRIBAI PHULE PUNE UNIVERSITY

The syllabus is prepared by

B.O.S. in Information Technology, Savitribai Phule Pune University
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PROGRAM EDUCATIONAL OBJECTIVES

The students of Information Technology course after passing out will

1. Possess strong fundamental concepts in mathematics, science, engineering and Technology to address technological challenges.
2. Possess knowledge and skills in the field of Computer Science and Information Technology for analyzing, designing and implementing complex engineering problems of any domain with innovative approaches.
3. Possess an attitude and aptitude for research, entrepreneurship and higher studies in the field of Computer Science and Information Technology.
4. Have commitment to ethical practices, societal contributions through communities and life-long learning.
5. Possess better communication, presentation, time management and teamwork skills leading to responsible & competent professionals and will be able to address challenges in the field of IT at global level.
PROGRAM OUTCOMES

The students in the Information Technology course will attain:

a. an ability to apply knowledge of mathematics, computing, science, engineering and technology;

b. an ability to define a problem and provide a systematic solution with the help of conducting experiments, analyzing the problem and interpreting the data;

c. an ability to design, implement, and evaluate a software or a software/hardware system, component, or process to meet desired needs within realistic constraints;

d. an ability to identify, formulate, and provide systematic solutions to complex engineering/Technology problems;

e. an ability to use the techniques, skills, and modern engineering technology tools, standard processes necessary for practice as a IT professional;

f. an ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems with necessary constraints and assumptions;

g. an ability to analyze and provide solution for the local and global impact of information technology on individuals, organizations and society;

h. an ability to understand professional, ethical, legal, security and social issues and responsibilities;

i. an ability to function effectively as an individual or as a team member to accomplish a desired goal(s);

j. an ability to engage in life-long learning and continuing professional development to cope up with fast changes in the technologies/tools with the help of electives, professional organizations and extra-curricular activities;

k. an ability to communicate effectively in engineering community at large by means of effective presentations, report writing, paper publications, demonstrations;

l. an ability to understand engineering, management, financial aspects, performance, optimizations and time complexity necessary for professional practice;

m. an ability to apply design and development principles in the construction of software systems of varying complexity.
T.E. (Information Technology) 2015 Course to be implemented from June 2017

SYLLABUS STRUCTURE

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Grade
SEMESTER-I
314441: THEORY OF COMPUTATION

Teaching Scheme:              Credits              Examination Scheme:
Lectures: 4 Hours/Week         04                      In-Semester : 30 Marks

Prerequisites:
1. Discrete Structures.
2. Data structures and problem solving.

Course Objectives:
1. To understand problem classification and problem solving by machines.
2. To understand the basics of automata theory and its operations.
3. To study computing machines by describing, classifying and comparing different types of computational models.
4. Encourage students to study theory of computability and complexity.
5. To understand the P and NP class problems and its classification.
6. To understand the fundamentals of problem decidability and reducibility.

Course Outcomes:
1. To construct finite state machines to solve problems in computing.
2. To write mathematical expressions for the formal languages
3. To apply well defined rules for syntax verification.
4. To construct and analyze Push Down, Post and Turing Machine for formal languages.
5. To express the understanding of the decidability and decidability problems.
6. To express the understanding of computational complexity.

UNIT – I  FINITE STATE MACHINES 08 Hours
FSM without output: Definition and Construction-DFA, NFA, NFA with epsilon-Moves, Minimization Of FA, Equivalence of NFA and DFA, Conversion of NFA with epsilon moves to NFA, Conversion of NFA With epsilon moves to DFA.
FSM with output: Definition and Construction of Moore and Mealy Machines, Inter-conversion between Moore and Mealy Machines.

UNIT – II  REGULAR EXPRESSIONS 08 Hours
Definition and Identities of Regular Expressions, Construction of Regular Expression of the given L, Construction of Language from the RE, Construction of FA from the given RE using direct method, Conversion of FA to RE using Arden’s Theorem, Pumping Lemma for RL, Closure properties of RLS, Applications of Regular Expressions.

UNIT – III  CONTEXT FREE GRAMMAR AND LANGUAGES 08 Hours
Introduction, Formal Definition of Grammar, Notations, Derivation Process: Leftmost Derivation, Rightmost Derivation, derivation trees, Context Free Languages, Ambiguous CFG, Removal of ambiguity, Simplification of CFG, Normal Forms, Chomsky Hierarchy, Regular grammar, equivalence of RG(LRG and RLG) and FA.

UNIT IV  PUSHDOWN AUTOMATA AND POST MACHINES 08 Hours
Push Down Automata: Introduction and Definition of PDA, Construction (Pictorial/ Transition diagram) of PDA, Instantaneous Description and ACCEPTANCE of CFL by empty stack and final state, Deterministic PDA Vs Nondeterministic PDA, Closure properties of CFLs, pumping lemma for CFL.
Post Machine- Definition and construction.
UNIT – V  TURING MACHINES  08 Hours
Formal definition of a Turing machine, Recursive Languages and Recursively Enumerable Languages, Design of Turing machines, Variants of Turing Machines: Multi-tape Turing machines, Universal Turing Machine, Nondeterministic Turing machines. Comparisons of all automata.

UNIT – VI  COMPUTATIONAL COMPLEXITY  08 Hours
Decidability: Decidable problems concerning regular languages, Decidable problems concerning context-free languages, Un-decidability, Halting Problem of TM, A Turing-unrecognizable language.
Reducibility: Un-decidable Problems from Language Theory, A Simple Un-decidable Problem PCP, Mapping Reducibility

Text Books

Reference Books
314442 : DATABASE MANAGEMENT SYSTEMS

Teaching Scheme:          Credits          Examination Scheme:
Lectures: 4 Hours/Week   04

Prerequisites:
1. Data structures.
2. Discrete structures.

Course Objectives:
1. To understand the fundamental concepts of database management. These concepts include aspects of database design, database languages, and database-system implementation.
2. To provide a strong formal foundation in database concepts, technology and practice.
3. To give systematic database design approaches covering conceptual design, logical design and an overview of physical design.
4. To be familiar with the basic issues of transaction processing and concurrency control.
5. To learn and understand various Database Architectures and Applications.
6. To understand how analytics and big data affect various functions now and in the future.

Course Outcomes:
1. To define basic functions of DBMS & RDBMS.
2. To analyze database models & entity relationship models.
3. To design and implement a database schema for a given problem-domain.
4. To populate and query a database using SQL DML/DDL commands.
5. Do Programming in PL/SQL including stored procedures, stored functions, cursors and packages.
6. To appreciate the impact of analytics and big data on the information industry and the external ecosystem for analytical and data services.

UNIT – I    INTRODUCTION TO DBMS    08 Hours
E-R and EER diagrams: Components of E-R Model, conventions, converting E-R diagram into tables, EER Model components, converting EER diagram into tables, legacy system model.
Relational Model: Basic concepts, Attributes and Domains, Codd's Rules.
Relational Integrity: Domain, Entity, Referential Integrities, Enterprise Constraints, Schema Diagram.
Relational Algebra: Basic Operations, Selection, projection, joining, outer join, union, difference, intersection, Cartesian product, division operations (examples of queries in relational algebraic using symbols).

UNIT – II    DATABASE DESIGN AND SQL     08 Hours
Database Design: Functional Dependency, Purpose of Normalization, Data Redundancy and Update Anomalies, Single Valued Normalization: 1NF, 2NF, 3NF, BCNF. Decomposition: lossless join decomposition and dependency preservation, Multi valued Normalization (4NF), Join Dependencies and the Fifth Normal Form.
Introduction to SQL: Characteristics and advantages, SQL Data Types and Literals, DDL, DML, DCL, SQL Operators, Tables: Creating, Modifying, Deleting, Views: Creating, Dropping, Updating using Views, Indexes, Nulls SQL DML Queries: SELECT Query and clauses, Set Operations, Predicates and Joins, Set membership, Tuple Variables, Set comparison, Ordering of Tuples, Aggregate Functions, Nested Queries, Database Modification using SQL Insert, Update and Delete Queries.
UNIT – III  QUERY PROCESSING AND DATABASE TRANSACTIONS  


UNIT – IV CONCURRENcy Control AND ADvanced DATABASES  


UNIT – V LARGE SCALE DATA MANAGEMENT  


UNIT – VI DATA WAREHOUSING AND DATA MINING  


Text Books

Reference Books
314443 : SOFTWARE ENGINEERING AND PROJECT MANAGEMENT

Teaching Scheme:  Credits  Examination Scheme:
Lectures: 3 Hours/Week  03  In-Semester : 30 Marks

Prerequisites:
1. Problem solving and object oriented programming.
2. Fundamental of data structures.

Course Objectives:
1. To understand the nature of software complexity in various application domains, disciplined way of software development and software lifecycle process models.
2. To introduce principles of agile software development, the SCRUM process and agile practices.
3. To know methods of capturing, specifying, visualizing and analyzing software requirements.
4. To understand project management through life cycle of the project.
5. To understand current and future trends and practices in the IT industry.
6. To learn about project planning, execution, tracking, audit and closure of project.

Course Outcomes:
1. To identify unique features of various software application domains and classify software applications.
2. To choose and apply appropriate lifecycle model of software development.
3. To describe principles of agile development, discuss the SCRUM process and distinguish agile process model from other process models.
4. To analyze software requirements by applying various modeling techniques.
5. To list and classify CASE tools and discuss recent trends and research in software engineering.
6. To understand IT project management through life cycle of the project and future trends in IT Project Management.

UNIT – I  INTRODUCTION TO SOFTWARE ENGINEERING  06 HOURS

UNIT – II  REQUIREMENT ANALYSIS  06 HOURS
Requirements Capturing: requirements engineering (elicitation, specification, validation, negotiation, prioritizing requirements (Kano diagram) - real life application case study.
Requirements Analysis: basics, scenario based modeling, UML models: use case diagram and class diagram, data modeling, data and control flow model, behavioral modeling using state diagrams - real life application case study, software Requirement Specification.

UNIT – III  PROJECT PLANNING  06 HOURS
UNIT – IV  AGILE DEVELOPMENT PROCESS 06 HOURS

Agile Development: Agile manifesto, agility and cost of change, agility principles, myth of planned development, toolset for the agile process.

Extreme Programming: XP values, process, industrial XP, SCRUM - process flow, scrum roles, scrum cycle description, product backlog, sprint planning meeting, sprint backlog, sprint execution, daily scrum meeting, maintaining sprint backlog and burn-down chart, sprint review and retrospective.

Agile Practices: test driven development, refactoring, pair programming, continuous integration, exploratory testing versus scripted testing

UNIT – V  PROJECT MANAGEMENT 06 Hours

Project monitoring and control: tools for project management, Software tools like Microsoft project management or any other open source tools.

The Importance of Project Quality Management: Planning Quality Management, Performing Quality Assurance, Controlling Quality, Tools and Techniques for Quality Control (statistical control, six sigma)

The Importance of Project Risk Management, Planning Risk Management, Common Sources of Risk in IT Projects.

UNIT – VI  RECENT TRENDS IN SOFTWARE ENGINEERING AND PROJECT MANAGEMENT 06 Hours

Software configuration management: SCM basics, SCM repository, SCM process, SCM tools such as GitHub, CASE – taxonomy, tool-kits, workbenches, environments, components of CASE, categories (upper, lower and integrated CASE tools).

Emerging software engineering trends: technology evolution, process trends, collaborative development, test-driven development, global software development challenges


Text Books


Reference Books

Savitribai Phule Pune University

314444 : OPERATING SYSTEM

Teaching Scheme:              Credits:              Examination Scheme:
Lectures: 4 Hours/Week     04               In-Semester: 30 Marks
End-Semester: 70 Marks

Prerequisites:

Course Objectives:
1. To introduce basic concepts and functions of modern operating systems.
2. To understand the concept of process and thread management.
3. To understand the scheduling of processes and threads.
4. To understand the concept of concurrency control.
5. To understand the concept of I/O and File management.
6. To understand various Memory Management techniques.

Course Outcomes:
1. Fundamental understanding of the role of Operating Systems.
2. To understand the concept of a process and thread.
3. To apply the cons of process/thread scheduling.
4. To apply the concept of process synchronization, mutual exclusion and the deadlock.
5. To realize the concept of I/O management and File system.
6. To understand the various memory management techniques.

UNIT – I  OVERVIEW OF OPERATING SYSTEM  08 HOURS

UNIT – II  PROCESS DESCRIPTION AND CONTROL  08 HOURS
Threads: Processes and Threads, Concept of Multithreading, Types of Threads, Thread programming Using Pthreads.
Scheduling: Types of Scheduling, Scheduling Algorithms, and Thread Scheduling.

UNIT – III  CONCURRENCY CONTROL  08 HOURS
Classical synchronization problems: Readers/Writers Problem, Producer and Consumer problem, Inter-process communication (Pipes, shared memory: system V).

UNIT – IV  MEMORY MANAGEMENT  08 HOURS
Virtual Memory: Hardware and Control Structures, Operating System Software.
UNIT – V  Input / Output And File Management  08 Hours

UNIT – VI  The LiNUX Operating System  08 Hours

Text Books

Reference Books
4. Mendel Cooper, Advanced Shell Scripting, Linux Documentation Project
Course Code: 314445

**Human-Computer Interaction**

**Teaching Scheme:**
Lectures: 3 Hours/Week

**Credits:**
03

**Examination Scheme:**
In-Semester: 30 Marks
End-Semester: 70 Marks

**Prerequisites:**
1. Problem Solving and Object Oriented Technologies.

**Course Objectives:**
1. To introduce to the field of human-computer-interaction study.
2. To gain an understanding of the human part of human-computer-interactions.
3. To learn to do design and evaluate effective human-computer-interactions.
4. To study HCI models and theories.
5. To understand HCI design processes.
6. To apply HCI to real life use cases.

**Course Outcomes:**
1. To explain importance of HCI study and principles of user-centred design (UCD) approach.
2. To develop understanding of human factors in HCI design.
3. To develop understanding of models, paradigms and context of interactions.
4. To design effective user-interfaces following a structured and organized UCD process.
5. To evaluate usability of a user-interface design.
6. To apply cognitive models for predicting human-computer-interactions.

**UNIT – I  Introduction**
06 Hours
What is HCI?, Disciplines involved in HCI, Why HCI study is important? The psychology of everyday things, Principles of HCI, User-centred Design.

**UNIT – II  Understanding the Human**
06 Hours

**UNIT – III  Understanding the Interaction**
06 Hours

**UNIT – IV  HCI - Design Process**
06 Hours

**UNIT – V  HCI - Design Rules, Guidelines and Evaluation Techniques**
06 Hours

**UNIT – VI  HCI Models and Theories**
06 Hours
Goal and task hierarchy model, Linguistic model, Physical and device models, Cognitive architectures, Hierarchical task analysis (HTA), Uses of task analysis, Diagrammatic dialog design notations, Computer mediated communication, Ubiquitous Computing, Finding things on web Future of HCI.
Text Books:

Reference Books:
5. Alan Cooper (1 January 1999). The Inmates are running the Asylum, Sam’s. ISBN 978-0-672-31649-4.

Web-links:
1. http://hcibib.org/
314446: SOFTWARE LABORATORY - I

Teaching Scheme:  Credits  Examination Scheme:
Practical: 4 Hours/Week  02  Term Work: 25 Marks

Prerequisites:
1. Data structures and files.
2. Discrete Structure.
3. Software engineering principles and practices.

Course Objectives:
1. Understand the fundamental concepts of database management. These concepts include aspects of database design, database languages, and database-system implementation.
2. To provide a strong formal foundation in database concepts, recent technologies and best industry practices.
3. To give systematic database design approaches covering conceptual design, logical design and an overview of physical design.
4. To learn the SQL and NoSQL database system.
5. To learn and understand various Database Architectures and its use for application development.
6. To programme PL/SQL including stored procedures, stored functions, cursors and packages.

Course Outcomes:
1. To install and configure database systems.
2. To analyze database models & entity relationship models.
3. To design and implement a database schema for a given problem-domain
4. To understand the relational and document type database systems.
5. To populate and query a database using SQL DML/DDL commands.
6. To populate and query a database using MongoDB commands.

Guidelines for Instructor's Manual
1. The faculty member should prepare the laboratory manual for all the experiments and it should be made available to students and laboratory instructor/Assistant.

Guidelines for Student's Lab Journal
1. Student should submit term work in the form of handwritten journal based on specified list of assignments.
2. Practical Examination will be based on the term work.
3. Candidate is expected to know the theory involved in the experiment.
4. The practical examination should be conducted if and only if the journal of the candidate is complete in all respects.

Guidelines for Lab/TW Assessment
1. Examiners will assess the term work based on performance of students considering the parameters such as timely conduction of practical assignment, methodology adopted for implementation of practical assignment, timely submission of assignment in the form of handwritten write-up along with results of implemented assignment, attendance etc.
2. Examiners will judge the understanding of the practical performed in the examination by asking some questions related to theory & implementation of experiments he/she has carried out.
3. Appropriate knowledge of usage of software and hardware related to respective laboratory should be
checked by the concerned faculty member.

As a conscious effort and little contribution towards Green IT and environment awareness, attaching printed papers of the program in journal may be avoided. There must be hand-written write-ups for every assignment in the journal. The DVD/CD containing students programs should be attached to the journal by every student and same to be maintained by department/lab In-charge is highly encouraged. For reference one or two journals may be maintained with program prints at Laboratory.

**Suggested List of Laboratory Assignments**

**Group A: Introduction to Databases (Study assignment – Any 2)**

1. Study and design a database with suitable example using following database systems:
   - Relational: SQL / PostgreSQL / MySQL
   - Key-value: Riak / Redis
   - Columnar: Hbase
   - Document: MongoDB / CouchDB
   - Graph: Neo4J
   Compare the different database systems based on points like efficiency, scalability, characteristics and performance.

2. Install and configure client and server for MySQL and MongoDB (Show all commands and necessary steps for installation and configuration).

3. Study the SQLite database and its uses. Also elaborate on building and installing of SQLite.

**Group B: SQL and PL/SQL**

1. Design any database with at least 3 entities and relationships between them. Apply DCL and DDL commands. Draw suitable ER/EER diagram for the system.

2. Design and implement a database and apply at least 10 different DML queries for the following task. For a given input string display only those records which match the given pattern or a phrase in the search string. Make use of wild characters and LIKE operator for the same. Make use of Boolean and arithmetic operators wherever necessary.

3. Execute the aggregate functions like count, sum, avg etc. on the suitable database. Make use of built in functions according to the need of the database chosen. Retrieve the data from the database based on time and date functions like now (), date (), day (), time () etc. Use group by and having clauses.

4. Implement nested sub queries. Perform a test for set membership (in, not in), set comparison (<some, >=some, <all etc.) and set cardinality (unique, not unique).

5. Write and execute suitable database triggers. Consider row level and statement level triggers.

6. Write and execute PL/SQL stored procedure and function to perform a suitable task on the database. Demonstrate its use.

7. Write a PL/SQL block to implement all types of cursor.
8. Execute DDL statements which demonstrate the use of views. Try to update the base table using its corresponding view. Also consider restrictions on updatable views and perform view creation from multiple tables.

Group C: MongoDB

1. Create a database with suitable example using MongoDB and implement
   - Inserting and saving document (batch insert, insert validation)
   - Removing document
   - Updating document (document replacement, using modifiers, upserts, updating multiple documents, returning updated documents)

2. Execute at least 10 queries on any suitable MongoDB database that demonstrates following querying techniques:
   - find and findOne (specific values)
   - Query criteria (Query conditionals, OR queries, $not, Conditional semantics)
   - Type-specific queries (Null, Regular expression, Querying arrays)

3. Execute at least 10 queries on any suitable MongoDB database that demonstrates following:
   - $ where queries
   - Cursors (Limits, skips, sorts, advanced query options)
   - Database commands

4. Implement Map reduce example with suitable example.

5. Implement the aggregation and indexing with suitable example in MongoDB. Demonstrate the following:
   - Aggregation framework
   - Create and drop different types of indexes and explain () to show the advantage of the indexes.

Group D: Mini Project / Database Application Development

Student group of size 3 to 4 students should decide the statement and scope of the project which will be refined and validated by the faculty considering number of students in the group.

Draw and normalize the design up to at ER Diagram least 3NF in case of back end as RDBMS.

Suggested Directions for development of the mini project.

- Build a suitable GUI by using forms and placing the controls on it for any application. (E.g Student registration for admission, railway reservation, online ticket booking etc.). Proper data entry validations are expected.

- Develop two tier architecture and use ODBC/JDBC connections to store and retrieve data from the database. Make a user friendly interface for system interaction. You may consider any applications like employee management system, library management system etc.

- Implement the basic CRUD operations and execute a transaction that ensures ACID properties. Make use of commands like commit, save point, and rollback. You may use examples like transfer of money
from one account to another, cancellation of e-tickets etc.

References

3. Dr. P. S. Deshpande, SQL and PL/SQL for Oracle 10g Black Book, DreamTech.
**314447 : SOFTWARE LABORATORY – II**

**Teaching Scheme:**
Practical : 4 Hours/Week

**Credits**
02

**Examination Scheme:**
Term Work : 25 Marks
Practical : 50 Marks

**Prerequisites:**
1. C programming.
2. Fundamental of Data Structures.

**Course Objectives :**
1. To introduce and learn Linux commands required for administration.
2. To learn shell programming concepts and applications.
3. To demonstrate the functioning of OS basic building blocks like processes, threads under the LINUX.
4. To demonstrate the functioning of OS concepts in user space like concurrency control (process synchronization, mutual exclusion & deadlock) and file handling in LINUX.
5. To aware Linux kernel source code details.
6. To demonstrate the functioning of OS concepts in kernel space like embedding the system call in any LINUX kernel.

**Course Outcomes :**
1. To understand the basics of Linux commands and program the shell of Linux.
2. To develop various system programs for the functioning of operating system.
3. To implement basic building blocks like processes, threads under the Linux.
4. To develop various system programs for the functioning of OS concepts in user space like concurrency control and file handling in Linux.
5. To design and implement Linux Kernel Source Code.
6. To develop the system program for the functioning of OS concepts in kernel space like embedding the system call in any Linux kernel.

**Guidelines for Instructor’s Manual**
1. The faculty member should prepare the laboratory manual for all the experiments and it should be made available to students and laboratory instructor/Assistant.

**Guidelines for Student’s Lab Journal**
1. Student should submit term work in the form of handwritten journal based on specified list of assignments.
2. Practical Examination will be based on the term work.
3. Candidate is expected to know the theory involved in the experiment.
4. The practical examination should be conducted if and only if the journal of the candidate is complete in all respects.

**Guidelines for Lab /TW Assessment**
1. Examiners will assess the term work based on performance of students considering the parameters such as timely conduction of practical assignment, methodology adopted for implementation of practical assignment, timely submission of assignment in the form of handwritten write-up along with results of implemented assignment, attendance etc.
2. Examiners will judge the understanding of the practical performed in the examination by asking some questions related to theory & implementation of experiments he/she has carried out.
3. Appropriate knowledge of usage of software and hardware related to respective laboratory should be checked by the concerned faculty member.
As a conscious effort and little contribution towards Green IT and environment awareness, attaching printed papers of the program in journal may be avoided. There must be hand-written write-ups for every assignment in the journal. The DVD/CD containing students programs should be attached to the journal by every student and same to be maintained by department/lab In-charge is highly encouraged. For reference one or two journals may be maintained with program prints at Laboratory.

**Suggested List of Laboratory Assignments**

**Assignment No. 1:** Shell programming
Write a program to implement an address book with options given below:
- Create address book.
- View address book.
- Insert a record.
- Delete a record.
- Modify a record.
- Exit.

**Assignment No. 2:** Process control system calls: The demonstration of *FORK, EXECVE* and *WAIT* system calls along with zombie and orphan states.

  a. Implement the C program in which main program accepts the integers to be sorted. Main program uses the *FORK* system call to create a new process called a child process. Parent process sorts the integers using sorting algorithm and waits for child process using *WAIT* system call to sort the integers using any sorting algorithm. Also demonstrate zombie and orphan states.

  b. Implement the C program in which main program accepts an integer array. Main program uses the *FORK* system call to create a new process called a child process. Parent process sorts an integer array and passes the sorted array to child process through the command line arguments of *EXECVE* system call. The child process uses *EXECVE* system call to load new program that uses this sorted array for performing the binary search to search the particular item in the array.

**Assignment No. 3:** Implement multithreading for Matrix Multiplication using pthreads.

**Assignment No. 4:** Thread synchronization using counting semaphores. Application to demonstrate: producer-consumer problem with counting semaphores and mutex.

**Assignment No. 5:** Thread synchronization and mutual exclusion using mutex. Application to demonstrate: Reader-Writer problem with reader priority.

**Assignment No. 6:** Deadlock Avoidance Using Semaphores: Implement the deadlock-free solution to Dining Philosophers problem to illustrate the problem of deadlock and/or starvation that can occur when many synchronized threads are competing for limited resources.

**Assignment No. 7:** Inter process communication in Linux using following.

  a. Pipes: Full duplex communication between parent and child processes. Parent process writes a pathname of a file (the contents of the file are desired) on one pipe to be read by child process and child process writes the contents of the file on second pipe to be read by parent process and displays on standard output.

  b. FIFOs: Full duplex communication between two independent processes. First process accepts sentences and writes on one pipe to be read by second process and second process counts number of characters, number of words and number of lines in accepted sentences, writes this output in a text file and writes the contents of the file on second pipe to be read by first process and displays on standard output.
Assignment No. 8: Inter-process Communication using Shared Memory using System V. Application to demonstrate: Client and Server Programs in which server process creates a shared memory segment and writes the message to the shared memory segment. Client process reads the message from the shared memory segment and displays it to the screen.

Assignment No. 9: Implement an assignment using File Handling System Calls (Low level system calls like open, read, write, etc).

Assignment No. 10: Implement a new system call in the kernel space, add this new system call in the Linux kernel by the compilation of this kernel (any kernel source, any architecture and any Linux kernel distribution) and demonstrate the use of this embedded system call using C program in user space.

References

314448 : SOFTWARE LABORATORY – III

Teaching Scheme: 
Practical : 2 Hours/Week 
01 

Examination Scheme: 
Term Work : 50 Marks

Preamble:
A major component of the course is a Graphical User Interface development. The objective is to develop a GUI by using concepts learned from Software Engineering and Project management. At the beginning of the course, Course Teacher will form project teams with maximum 3 members. During the semester, the project team will work together through all the phases of development cycle up to design, from an initial feasibility study to designing, after designing phase students will deploy the designed system and will make a series of presentations and reports of the work.

Prerequisites:
1. Programming fundamentals.
2. Problem solving skills.

Course Objectives :
1. To understand the nature of software complexity in various application domains, disciplined way of software development and software life cycle process models.
2. To introduce principles of agile software development, the SCRUM process and agile practices.
3. To know methods of capturing, specifying, visualizing and analyzing software requirements.
4. To understand concepts and principles of software design and architecture.
5. To understand user-centric design approach.
6. To apply principles of designing for effective user interfaces.

Course Outcomes :
1. To identify the needs of users through requirement gathering.
2. To apply the concepts of Software Engineering process models for project development.
3. To apply the concepts of HCI for user-friendly project development.
4. To deploy website on live webservice and access through URL.
5. To understand, explore and apply various web technologies.
6. To develop team building for efficient project development.

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Suggested List of Laboratory Assignments

Group A: Website Design (HTML5, CSS, Bootstrap)

Assignment No. 1: Using HTML5 layout tags develop informative page with sections which include various images, links to other pages for navigation, make use of all possible formatting (for example font, color etc.).

Assignment No. 2: Apply CSS properties Border, margins, Padding, Navigation, dropdown list to page created in first assignment.

Group B: Website GUI Validation (JavaScript, PHP)

Assignment No. 3: Create form in HTML with all form elements apply form validations (e.g. Email, mobile, Pin code, Password).

Assignment No. 4: Validate URL, Email, Required using functions empty, preg_match, filter_var in PHP.

Group C: Website Working (Java Servlet)

Assignment No. 5: Understand servlet life cycle, create login page and apply proper validations with appropriate messages using doGet()/ doPost() methods.

Group D: Website Development (Mini-Project)

Assignment No. 6: Develop website using any CMS tool which falls into one of the categories blog, social networking, News updates, Wikipedia, E-commerce store. Website must include home page, and at least 3 forms (with Validation), use at list HTML5, PHP, CSS/Bootstrap, JavaScript web technologies. No database support is needed. Deploy website on live webserver and access through URL.

Write a complete report of web development stages for the chosen topic and attach printout of the same with screen shots of web pages. Proper use of every technique used for web designing should be followed like for designing wireframe is used. Human computer interaction and user experience concepts learned from HCI should be applied while web development process.

Guidelines for Mini project

1. Project group of maximum 3 students should be formed.
2. Every group member should participate in every stage of the web development.
3. Proper compilation of the report should be attached in the file in printed format.
4. Use of CMS should be done for only Assignment no 6 (Mini Project).
5. At the end of the semester, group should give a presentation of the Mini Project.

References:
In addition to credits courses, it is recommended that there should be audit course (non-credit course). Audit course is for the purposes of self-enrichment and academic exploration. Audit courses carry no academic credit. Selection of the audit courses helps the learner to explore the subject of interest in greater details resulting in achieving objective of audit course's inclusion. Evaluation of audit course will be done at institute level. Method of conduction and method of assessment for audit courses is suggested.

**Criteria:**
The student registered for audit course shall be awarded the grade PP and shall be included such grade in the Semester grade report for that course, provided student has the minimum attendance as prescribed by the Savitribai Phule Pune University and satisfactory in-semester performance and secured a passing grade in that audit course. No grade points are associated with this 'PP' grade and performance in these courses is not accounted in the calculation of the performance indices SGPA and CGPA.

**Guidelines for Conduction and Assessment (Any one or more of following but not limited to)**
1. Lectures/ Guest Lectures
2. Visits (Social/Field) and reports
3. Demonstrations
4. Surveys
5. Mini Project
6. Hands on experience on Specific focused topic

**Guidelines for Assessment (Any one or more of following but not limited to)**
1. Written Test
2. Demonstrations/ Practical Test
3. Presentations
4. IPR/Publication
5. Report

**Audit Course 3 Options**

<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>AC3-I</td>
<td>Green Construction &amp; Design</td>
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<tr>
<td>AC3-II</td>
<td>Leadership and Personality Development</td>
</tr>
<tr>
<td>AC3-III</td>
<td>Professional Ethics and Etiquettes</td>
</tr>
<tr>
<td>AC3-IV</td>
<td>Digital &amp; Social Media Marketing</td>
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</table>
Prerequisites:
1. General awareness of environment and eco system.

Course Objectives:
1. To motivate students for undertaking green construction projects, technical aspects of their design, obstacles to getting them done, and future directions of the field.
2. To increase awareness of green construction issues, so that students will know the range of existing knowledge and issues.
3. Proper use of energy, water and other resources without harming environment.
4. To reduce waste pollution and Environment Degradation.

Course Outcomes:
1. To understand the importance of environment friendly society.
2. To apply primary measures to reduce carbon emissions from their surroundings.
3. To learn role of IT solutions in design of green buildings.
4. To understand the use of software systems to complete statutory compliances involved in the design of a new home or office building through green construction.

UNIT I
Introduction to Green Construction, need of green construction, Importance, Government Initiatives, your role in the Green Environment.

UNIT II
How to do Green Construction, Project Definition, Team Building, Education and Goal Setting, Documents and Specification.

UNIT III

UNIT IV
Indian Green Building Council (IGBC), Introduction to IGBC, IGBC rating system, Green building projects in India, Benefits of green building, effects on natural resources.

Team Projects:
Students will be formed into groups to research green construction and design in a particular construction context and report their results to the class. What are the particular obstacles and opportunities to integrating green construction techniques into the following sectors? Be sure to consider technical, social, political and economic issues:
1. Hotels (economy, luxury, resorts)
2. Hospitals
3. Retail (big box, malls, small scale downtown retail)
4. Office
5. Government
6. Schools
7. Universities
8. Housing
9. Transportation Stations (Airport Terminals, Train Stations)
References:
Audit Course 3 - II : Leadership and Personality Development

Prerequisites:

Course Objectives:
1. To develop inter personal skills and be an effective goal oriented leader.
2. To develop personalities of students in order to empower them and get better insights into ones responsibilities in personal life to build better human being.
3. To develop professionals with leadership quality along with idealistic, practical and moral values.
4. To re-engineer attitude and understand its influence on behavior
5. To help Students evolve as leaders and effectively handle real life challenges in and across the dynamic environment.

Course Outcomes:
1. To exhibit responsible decision-making and personal accountability
2. To demonstrate an understanding of group dynamics and effective teamwork
3. To develop a range of leadership skills and abilities such as effectively leading change, resolving conflict, and motivating others.
4. To develop overall personality.

UNIT I
Personality Development: It Is Personality That Matters, Laws of Personality Development, Different Layers of Personality, How to Change Our Character, Influence of Thought, Take the Whole Responsibility on Yourself, How to Work? Attitude: Factors influencing Attitude, Challenges and lessons from Attitude, Personality Traits, Sharpening Memory Skills, Decision-Making, Negotiation and Problem-Solving

UNIT II

UNIT III
Leadership Skills: Working individually and in a team, Levels of Leadership, Making of a leader, Types of leadership, Transactions Vs Transformational Leadership, VUCA Leaders, DART Leadership, Leadership Grid & leadership Formulation. Introduction to Interpersonal Relations, Analysis Relations of different ego states, Analysis of Transactions, Analysis of Strokes, Analysis of Life position.

UNIT IV
Group Dynamics & Team Building
Group Dynamics: Importance of groups in organization, and Team Interactions in group, Group Vs Teams, Team formation process, Stages of Group, Group Dynamics, Managing Team Performance & Team Conflicts. How to build a good team? Team work & Team building Interpersonal skills – Conversation, Feedback, Feed forward Interpersonal skills – Delegation, Humor, Trust, Expectations, Values, Status, Compatibility and their role in building team

References:
2. ShaliniVerma (2014); “Development of Life Skills and Professional Practice”; First Edition; Sultan


Audit Course 3 – III : Professional Ethics and Etiquettes

Prerequisites:
1. Communication and Language Laboratory

Course Objectives:
1. To learn the rules of good behavior for today's most common social and business situations, including the common courtesies of life
2. To imbibe basic knowledge to make informed ethical decisions when confronted with problems in the working environment.
3. To develop an understanding of how a societal moral varies with culture and how this influences ethical thought and action
4. To develop an orientation towards business etiquettes and the proper etiquette practices for different business scenarios.
5. To learn the etiquette requirements for meetings, entertaining, telephone, and Internet business interaction scenario.

Course Outcomes:
1. To summarize the principles of proper courtesy as they are practiced in the workplace.
2. To describe ways to apply proper courtesy in different professional situations.
3. To practice appropriate etiquettes in the working environment and day to day life.
4. To learn and build proper practices for global corporate world.

UNIT I

UNIT II
IT Professional Ethics, Ethics in the Business World, Corporate Social Responsibility, Improving Corporate Ethics, Creating an Ethical Work Environment, Including Ethical Considerations in Decision Making, Ethics in Information Technology, Common Ethical Issues for IT Users, Supporting the Ethical Practices of IT Users.

UNIT III

UNIT IV
Professional Etiquette, Etiquette at Dining, Involuntary Awkward Actions, How to Network, Networking Etiquette, Public Relations Office (PRO)’s Etiquettes, Technology Etiquette: Phone Etiquette, Email Etiquette, Social Media Etiquette, Video Conferencing Etiquette, Interview Etiquette, Dressing Etiquettes: for Interview, offices and social functions.

References:
Audit Course 3 – IV : Digital & Social Media Marketing

Prerequisites:
1. Knowledge of Social Media Networking.

Course Objectives:
1. Get strategic understanding of Digital Marketing and Social Media Marketing.
2. Understand how to use it for branding and sales.
3. Understand its advantages & limitations.
5. Blend digital and social marketing with offline marketing.
6. Plan and manage digital marketing budget.
7. Manage Reporting & Tracking Metrics.
8. Understand the future of Digital Marketing and prepare for it.

Course Outcomes:
1. Develop a far deeper understanding of the changing digital landscape.
2. Identify some of the latest digital marketing trends and skill sets needed for today's marketer.
3. Successful planning, prediction, and management of digital marketing campaigns.
4. Implement smart management of different digital assets for marketing needs.
   Assess digital marketing as a long term career opportunity.

UNIT I

UNIT II
Techniques for effective Email Marketing and pitfalls, Various online email marketing platforms such as Campaign Monitor and Mail Chimp, Web content, web usability, navigation and design, Bookmarking and News Aggregators, Really Simple Syndication (RSS), Blogging, Live Chat, User Generated Content (Wikipedia etc), Multi-media - Video (Video Streaming, YouTube etc), Multi-media - Audio & Podcasting (iTunes etc), Multi-media - Photos/Images (Flickr etc), Google Alerts and Giga Alert (Brand, product and service monitoring online), Crowdsourcing, Virtual Worlds.

UNIT III
Search Engine Optimization (SEO), Search Engine Optimization (SEO) tips and techniques, Google Adwords, Google various applications such as ‘Google Analytics', Maps, Places etc to enhance a brand’s products, services and operations.

UNIT IV
Facebook & LinkedIn and other Social Media for a real marketing, Utilizing Facebook and LinkedIn's Advertising functionality and Applications, Brand reputation management techniques, Systems for 'buzz monitoring' for brands, products and services, Effective Public Relations (PR) online and business development.

References:
SEMESTER-II
Teaching Scheme:
Lectures: 3 Hours/Week

Credits
03

Examination Scheme:
In-Semester : 30 Marks
End-Semester: 70 Marks

Prerequisites:
1. Foundation of Communication and Computer Networks.

Course Objectives:
1. To understand services offered at different layers of network.
2. To understand protocol used at different layers of network.
3. To fathom wireless network and different wireless standards.
4. To recognize differences in between different wireless networks and to learn different mechanism used at layers of wireless network.
5. To know the applications of network and use the understood concepts for new application development.
6. To explore recent trends in networking.

Course Outcomes:
1. To know Responsibilities, services offered and protocol used at each layer of network.
2. To understand different addressing techniques used in network.
3. To know the difference between different types of network.
4. To know the different wireless technologies and IEEE standards.
5. To use and apply the standards and protocols learned, for application development.
6. To understand and explore recent trends in network domain.

UNIT – I NETWORK LAYER
06 Hours

UNIT – II TRANSPORT LAYER
06 Hours

UNIT – III APPLICATION LAYER
06 Hours
Client Server Paradigm: Communication using TCP and UDP, Peer to Peer Paradigm, Application Layer Protocols: DNS, FTP, TFTP, HTTP, SMTP, POP, IMAP, MIME, Network Management: SNMP.

UNIT – IV WIRELESS STANDARDS
06 Hours

UNIT – V ADHOC WIRELESS NEWTWORK
06 Hours
Infrastructure Network and Infrastructure-less Wireless Networks, Issues in Adhoc Wireless Network, Adhoc

UNIT – VI RECENT TRENDS IN COMMUNICATION NETWORKS 06 Hours

Text Books

Reference Books
314451 : SYSTEMS PROGRAMMING

Teaching Scheme: Lectures: 4 Hours/Week

Credit: 04

Examination Scheme:
In-Semester: 30 Marks
End-Semester: 70 Marks

Prerequisites:
2. Processor Architecture and Interfacing.
3. Fundamentals of Data Structures, Data Structures and Files.

Course Objectives:
1. To study and understand different system software like Assembler, Macro-processor and Loaders / Linkers.
2. To design and develop useful system software.
3. To study and understand compiler design.
4. To understand semantic analysis and storage allocation in compilation process.
5. To understand different code generation techniques.
6. To study different code optimization methods.

Course Outcomes:
1. To learn independently modern software development tools and creates novel solutions for language processing applications.
2. To design and implement assemblers and macro processors.
3. To use tool LEX for generation of Lexical Analyzer.
4. To use YACC tool for generation of syntax analyzer.
5. To generate output for all the phases of compiler.
6. To apply code optimization in the compilation process.

UNIT – I  INTRODUCTION TO SYSTEMS PROGRAMMING AND ASSEMBLERS  08 Hours


Assemblers: Elements of Assembly Language Programming, A simple Assembly Scheme, Pass structure of Assemblers, Design of Two Pass Assembler, Single pass assembler.

UNIT – II  MACROPROCESSORS, LOADERS AND LINKERS  08 Hours

Macro Processor: Macro Definition and call, Macro Expansion, Nested Macro Calls and definition, Advanced Macro Facilities, Design of two-pass Macro Processor.

Loaders: Loader Schemes, Compile and Go, General Loader Scheme, Absolute Loader Scheme, Subroutine Linkages, Relocation and linking concepts, Self-relocating programs, Relocating Loaders, Direct Linking Loaders, Overlay Structure.

UNIT - III  INTRODUCTION TO COMPILERS  08 Hours

Phase structure of Compiler and entire compilation process.

Lexical Analyzer: The Role of the Lexical Analyzer, Input Buffering, Specification of Tokens, Recognition of Tokens, Design of Lexical Analyzer using Uniform Symbol Table, Lexical Errors.
LEX: LEX Specification, Generation of Lexical Analyzer by LEX.

UNIT – IV  PARSERS  08 Hours

Role of parsers, Classification of Parsers: Top down parsers- recursive descent parser and predictive parser.

UNIT – V SEMANTIC ANALYSIS AND STORAGE ALLOCATION 08 Hours
Need, Syntax Directed Translation, Syntax Directed Definitions, Translation of assignment Statements, iterative statements, Boolean expressions, conditional statements, Type Checking and Type conversion.
Intermediate Code Formats: Postfix notation, Parse and syntax tress, Three address code, quadruples and triples.
Storage Allocation: Storage organization and allocation strategies.

UNIT – VI CODE GENERATION AND OPTIMIZATION 08 Hours
Machine dependent Issues: Assignment and use of registers, Rearrangement of Quadruples for code optimization.

Text Books

Reference Books
Savitribai Phule Pune University

314452 : DESIGN AND ANALYSIS OF ALGORITHMS

Teaching Scheme: 

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<th>Credits</th>
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<tr>
<td></td>
<td>04</td>
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<tr>
<td></td>
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<td>End-Semester: 70 Marks</td>
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Prerequisites:

1. Fundamentals of Data Structures, Data Structures and Files.
2. Discrete Structures.

Course Objectives:

1. To understand the problem solving and problem classification.
2. To know the basics of computational complexity analysis and various algorithm design strategies.
3. To provide students with solid foundations to deal with a wide variety of computational problems.
4. To provide a thorough knowledge of the most common algorithms and data structures.
5. To analyze a problem and identify the computing requirements appropriate for its solutions.
6. To understand the design of parallel algorithms.

Course Outcomes:

1. To calculate computational complexity using asymptotic notations for various algorithms.
2. To apply Divide & Conquer as well as Greedy approach to design algorithms.
3. To practice principle of optimality.
4. To illustrate different problems using Backtracking.
5. To compare different methods of Branch and Bound strategy.
6. To explore the concept of P, NP, NP-complete, NP-Hard and parallel algorithms.

UNIT – I  INTRODUCTION 08 Hours


Proof Techniques: Minimum 2 examples of each: Contradiction, Mathematical Induction, Direct proofs, Proof by contraposition.


Amortized Analysis: Aggregate, Accounting & Potential method with the example of stack operations.

Analysis of Non-recursive and recursive algorithms: Solving Recurrence Equations (Homogeneous and non-homogeneous).

UNIT – II  DIVIDE AND CONQUER AND GREEDY METHOD 08 Hours

Divide & Conquer: General method, Control abstraction, Merge sort, Quick Sort – Worst, Best and average case. Binary search, Finding Max-Min, Large integer Multiplication (for all above algorithms analysis to be done with recurrence).

Greedy Method: General method and characteristics, Prim’s method for MST, Kruskal’s method for MST (using nlogn complexity), Dijkstra’s Algorithm, Optimal storage on tapes, Fractional Knapsack problem, Job Sequencing.

UNIT - III  DYNAMIC PROGRAMMING 08 Hours

General strategy, Principle of optimality, 0/1 knapsack Problem, Bellman-Ford Algorithm, Multistage Graph problem, Optimal Binary Search Trees, Travelling Salesman Problem.
UNIT – IV BACKTRACKING 08 Hours
General method, Recursive backtracking algorithm, Iterative backtracking method. 8-Queen problem, Sum of subsets, Graph coloring, Hamiltonian Cycle, 0/1 Knapsack Problem.

UNIT – V BRANCH AND BOUND 08 Hours
The method, Control abstractions for Least Cost Search, Bounding, FIFO branch and bound, LC branch and bound, 0/1 Knapsack problem – LC branch and bound and FIFO branch and bound solution, Traveling sales person problem.

UNIT – VI COMPUTATIONAL COMPLEXITY AND PARALLEL ALGORITHMS 08 Hours

Text Books

Reference Books
314453 : CLOUD COMPUTING

Teaching Scheme:  
Lectures: 3 Hours/Week  
Credits: 03

Examination Scheme:  
In-Semester: 30 Marks  
End-Semester: 70 Marks

Prerequisites:  

Course Objectives:  
1. To become familiar with Cloud Computing and its ecosystem.  
2. To learn basics of virtualization and its importance.  
3. To evaluate in-depth analysis of Cloud Computing capabilities.  
4. To give technical overview of Cloud Programming and Services.  
5. To understand security issues in cloud computing.  
6. To be exposed to Ubiquitous Cloud and Internet of Things.

Course Outcomes:  
1. To understand the need of Cloud based solutions.  
2. To understand Security Mechanisms and issues in various Cloud Applications.  
3. To explore effective techniques to program Cloud Systems.  
5. To find challenges in cloud computing and delve into it to effective solutions.  
6. To understand emerging trends in cloud computing.

UNIT – I  FUNDAMENTALS OF CLOUD COMPUTING  
06 Hours  

UNIT – II  VIRTUALIZATION AND COMMON STANDARDS IN CLOUD COMPUTING  
06 Hours  

UNIT – III  CLOUD PROGRAMMING, ENVIRONMENTS AND APPLICATIONS  
06 Hours  
Applications: Moving application to cloud, Microsoft Cloud Services, Google Cloud Applications, Amazon Cloud Services, Cloud Applications (Social Networking, E-mail, Office Services, Google Apps, Customer Relationship Management).

UNIT – IV  CLOUD SECURITY AND ISSUES  
06 Hours  
Basic Terms and Concepts, Threat Agents, Cloud Security Threats and Attacks, Additional Considerations.
**Cloud Security Mechanisms**: Encryption, Hashing, Digital Signature, Public Key Infrastructure (PKI), Identity and Access Management (IAM), Single Sign-On (SSO), Hardened Virtual Server Images.


**UNIT – V**  **UBIQUITOUS CLOUDS AND THE INTERNET OF THINGS**  **06 Hours**


**UNIT – VI**  **FUTURE OF CLOUD COMPUTING**  **06 Hours**


**Docker at a Glance**: Process Simplification, Broad Support and Adoption, Architecture, Getting the Most from Docker, The Docker Workflow.

**Text Books**


**Reference Books**

Prerequisites:
1. Engineering and discrete mathematics.
2. Database Management Systems, Data warehousing, Data mining.
3. Programming skill.

Course Objectives:
1. To introduce basic need of Big Data and Data science to handle huge amount of data.
2. To understand the basic mathematics behind the Big data.
3. To understand the different Big data processing technologies.
4. To understand and apply the Analytical concept of Big data using R and Python.
5. To visualize the Big Data using different tools.
6. To understand the application and impact of Big Data.

Course Outcomes:
1. To understand Big Data primitives.
2. To learn and apply different mathematical models for Big Data.
3. To demonstrate their Big Data learning skills by developing industry or research applications.
4. To analyze each learning model come from a different algorithmic approach and it will perform differently under different datasets.
5. To understand needs, challenges and techniques for big data visualization.
6. To learn different programming platforms for big data analytics.

UNIT – I  INTRODUCTION: DATA SCIENCE AND BIG DATA  08 hours
Introduction to Data science and Big Data, Defining Data science and Big Data, Big Data examples, Data explosion, Data volume, Data Velocity, Big data infrastructure and challenges, Big Data Processing Architectures, Data Warehouse, Re-Engineering the Data Warehouse, Shared everything and shared nothing architecture, Big data learning approaches.

UNIT – II  MATHEMATICAL FOUNDATION OF BIG DATA  08 Hours
Probability theory, Tail bounds with applications, Markov chains and random walks, Pair wise independence and universal hashing, Approximate counting, Approximate median, The streaming models, Flajolet Martin Distance sampling, Bloom filters, Local search and testing connectivity, Enforce test techniques, Random walks and testing, Boolean functions, BLR test for linearity.

UNIT - III  BIG DATA PROCESSING  08 Hours
Big Data technologies, Introduction to Google file system, Hadoop Architecture, Hadoop Storage: HDFS, Common Hadoop Shell commands, Anatomy of File Write and Read, NameNode, Secondary NameNode, and DataNode, Hadoop MapReduce paradigm, Map Reduce tasks, Job, Task trackers - Cluster Setup – SSH & Hadoop Configuration, Introduction to: NOSQL, Textual ETL processing.

UNIT – IV  BIG DATA ANALYTICS  08 Hours
Data analytics life cycle, Data cleaning , Data transformation, Comparing reporting and analysis, Types of analysis, Analytical approaches, Data analytics using R, Exploring basic features of R, Exploring R GUI, Reading data sets, Manipulating and processing data in R, Functions and packages in R, Performing graphical analysis in R, Integrating R and Hadoop, Hive, Data analytics.
UNIT – V     Big Data Visualization 08 Hours
Introduction to Data visualization, Challenges to Big data visualization, Conventional data visualization tools, Techniques for visual data representations, Types of data visualization, Visualizing Big Data, Tools used in data visualization, Proprietary Data Visualization tools, Open –source data visualization tools, Analytical techniques used in Big data visualization, Data visualization with Tableau, Introduction to: Pentaho, Flare, Jasper Reports, Dygraphs, Datameer Analytics Solution and Cloudera, Platfora, NodeBox, Gephi, Google Chart API, Flot, D3, and Visually.

UNIT – VI     BIG DATA TECHNOLOGIES APPLICATION AND IMPACT 08 Hours
Social media analytics, Text mining, Mogile analytics, Roles and responsibilities of Big data person, Organizational impact, Data analytics life cycle, Data Scientist roles and responsibility, Understanding decision theory, creating big data strategy, big data value creation drivers, Michael Porter’s valuation creation models, Big data user experience ramifications, Identifying big data use cases.

Text Books

Reference Books
2. Dana Ron, Algorithmic and Analysis Techniques in Property Testing, School of EE.
8. EMC Education Services, Data Science and Big Data Analytics- Discovering, analyzing Visualizing and Presenting Data.
13. EMC Education Services, Data Science and Big Data Analytics, Wiley India, ISBN: 9788126556533
Teaching Scheme:  
Practical: 2 Hours/Week  
Credits: 01  
Examination Scheme:  
Term Work: 25 Marks  
Oral: 25 Marks

Prerequisites:  
1. Fundamentals of computer Networks.

Course Objectives:  
1. To design and implement small size network and to understand various networking commands  
2. To provide the knowledge of various networking tools and their related concepts  
3. To understand various application layer protocols for its implementation in client/server environment  
4. To understand network layer protocols and its implementations.  
5. To explore and understand various simulations tools for network applications.  
6. To understand the fundamentals of wireless networks and standards.

Course Outcomes:  
1. To implement small size network and its use of various networking commands.  
2. To understand and use various networking and simulations tools.  
3. To configure various client/server environments to use application layer protocols  
4. To understand the protocol design at various layers.  
5. To explore use of protocols in various wired and wireless applications.  
6. To develop applications on emerging trends.

Guidelines for Instructor's Manual  
1. The faculty member should prepare the laboratory manual for all the experiments and it should be made available to students and laboratory instructor/Assistant

Guidelines for Student's Lab Journal  
1. Student should submit term work in the form of handwritten journal based on specified list of assignments.  
2. Practical Examination will be based on the term work.  
3. Candidate is expected to know the theory involved in the experiment.  
4. The practical examination should be conducted if and only if the journal of the candidate is complete in all respects.

Guidelines for Lab /TW Assessment  
1. Examiners will assess the term work based on performance of students considering the parameters such as timely conduction of practical assignment, methodology adopted for implementation of practical assignment, timely submission of assignment in the form of handwritten write-up along with results of implemented assignment, attendance etc.  
2. Examiners will judge the understanding of the practical performed in the examination by asking some questions related to theory & implementation of experiments he/she has carried out.  
3. Appropriate knowledge of usage of software and hardware related to respective laboratory should be checked by the concerned faculty member.

As a conscious effort and little contribution towards Green IT and environment awareness, attaching printed papers of the program in journal may be avoided. There must be hand-written write-ups for every assignment in the journal. The DVD/CD containing students programs should be attached to the journal by
every student and same to be maintained by department/lab In-charge is highly encouraged. For reference one or two journals may be maintained with program prints at Laboratory.

**Suggested List of Laboratory Assignments**

1. **Explore and Study of TCP/IP utilities and Network Commands on Linux.**
   a) Ping
   b) ipconfig / ifconfig
   c) Hostname
   d) Whois
   e) Netstat
   f) Route
   g) Tracert/Traceroute/Tracepath
   h) NSlookup
   i) Arp
   j) Finger
   k) Port Scan / nmap

2. **Using a Network Simulator (e.g. packet tracer) Configure**
   - Sub-netting of a given network
   - Super-netting of a given networks.

3. **Using a Network Simulator (e.g. packet tracer) Configure**
   - A router using router commands,
   - Access Control lists – Standard & Extended.

4. **Using a Network Simulator (e.g. packet tracer) Configure**
   - EIGRP – Explore Neighbor-ship Requirements and Conditions, its K Values Metrics Assignment and Calculation,
   - RIPv2 and EIGRP on same network.
   - WLAN with static IP addressing and DHCP with MAC security and filters

5. **Using a Network Simulator (e.g. packet tracer) Configure**
   - VLAN, Dynamic trunk protocol and spanning tree protocol
   - Network Address Translation : Static, Dynamic & PAT (Port Address Translation)

6. **Socket Programming in C/C++ on Linux.**
   - TCP Client, TCP Server
   - UDP Client, UDP Server

7. **Introduction to server administration (server administration commands and their applications) and configuration any three of below Server : (Study/Demonstration Only)**
   - FTP, Web Server, DHCP, Telnet, Mail, DNS

8. **Using any open source Network Simulator, Implement**
   - MANET / Wireless Sensor Network

9. **Write a program using Arduino / Rasberry Pi Kit for Demonstration of IOT Application on any one of the following Topics.**
   - Appliance Remote Control
   - Time Lapse Camera Controller
   - Security / Automation Sensors
   - The Traffic Light Controller
   - Temperature Controller

**References**

Teaching Scheme:  
Practical : 4 Hours/Week  02

Examination Scheme:  
Term Work : 50 Marks  
Practical : 50 Marks

Prerequisites:  
1. Discrete Structure.  
2. C/ C++ Programming.  
3. Fundamentals of Data Structure and Files.

Course Objectives:  
1. To learn the concepts of assembler to design and implement two pass assembler.  
2. To study use of macros and its expansion process.  
3. To understand lexical analyzer and parser and its applications in compiler design.  
4. To learn the various algorithmic design paradigms.  
5. To apply appropriate algorithmic strategy in problem solving.  
6. To find the space and running time requirements of the algorithms.

Course Outcomes:  
1. To design and implement two pass assembler for hypothetical machine instructions.  
2. To design and implement different phases of compiler (Lexical Analyzer, Parser, Intermediate code generation)  
3. To use the compile generation tools such as “Lex" and "YACC”.  
4. To apply algorithmic strategies for solving various problems.  
5. To compare various algorithmic strategies.  
6. To analyze the solution using recurrence relation.

Guidelines for Instructor’s Manual  
1. The faculty member should prepare the laboratory manual for all the experiments and it should be made available to students and laboratory instructor/Assistant.

Guidelines for Student’s Lab Journal  
1. Student should submit term work in the form of handwritten journal based on specified list of assignments.  
2. Practical Examination will be based on the term work.  
3. Candidate is expected to know the theory involved in the experiment.  
4. The practical examination should be conducted if and only if the journal of the candidate is complete in all respects.

Guidelines for Lab /TW Assessment  
1. Examiners will assess the term work based on performance of students considering the parameters such as timely conduction of practical assignment, methodology adopted for implementation of practical assignment, timely submission of assignment in the form of handwritten write-up along with results of implemented assignment, attendance etc.  
2. Examiners will judge the understanding of the practical performed in the examination by asking some questions related to theory & implementation of experiments he/she has carried out.  
3. Appropriate knowledge of usage of software and hardware related to respective laboratory should be
checked by the concerned faculty member

As a conscious effort and little contribution towards Green IT and environment awareness, attaching printed papers of the program in journal may be avoided. There must be hand-written write-ups for every assignment in the journal. The DVD/CD containing students programs should be attached to the journal by every student and same to be maintained by department/lab In-charge is highly encouraged. For reference one or two journals may be maintained with program prints at Laboratory.

**Suggested List of Laboratory Assignments**

**Group A: System Programming**
1. Write a program to implement Pass-I of Two-pass assembler for Symbols and Literal processing (For hypothetical instruction set from Dhamdhere) considering following cases
   - i. Forward references
   - ii. DS and DC statement
   - iii. START, EQU, LTORG, END.
   - iv. Error handling: symbol used but not defined, invalid instruction/register etc.
2. Write a program to implement Pass-II of Two-pass assembler for output of Assignment 1 (The subject teacher should provide input file for this assignment)
3. Study Assignment for Macro Processor. (Consider all aspects of Macro Processor)
4. Write a program to implement Lexical Analyzer for subset of C.
5. Write a program to implement a Recursive Descent Parser.
6. Write a program to implement calculator using LEX and YACC.
7. Write a program for Intermediate code generation using LEX & YACC for Control Flow statement (Either While loop or Switch case)

**Group B: Design & Analysis of Algorithms**
1. Write a program to find Maximum and Minimum element in an array using Divide and Conquer strategy and verify the time complexity.
2. Write a program to solve optimal storage on tapes problem using Greedy approach.
3. Write a program to implement Bellman-Ford Algorithm using Dynamic Programming and verify the time complexity.
4. Write a program to solve the travelling salesman problem and to print the path and the cost using Dynamic Programming.
5. Write a recursive program to find the solution of placing n queens on chessboard so that no two queens attack each other using Backtracking.
6. Write a program to solve the travelling salesman problem and to print the path and the cost using Branch and Bound.

Note: All the assignments should be conducted on Latest version of Open Source/Proprietary Operating Systems, tools and Multi-core CPU supporting Virtualization and Multi-Threading.

**References :**

Teaching Scheme:
Lectures: 2 Hours/Week

Credits
01

Examination Scheme:
Term Work: 25 Marks
Practical: 25 Marks

Prerequisites:
1. Engineering and discrete mathematics.
2. Database Management Systems, Data warehousing, Data mining.
3. Programming skill.

Course Objectives:
1. To understand Big data primitives and fundamentals.
2. To understand the different Big data processing techniques.
3. To understand and apply the Analytical concept of Big data using R/Python.
4. To understand different data visualization techniques for Big Data.
5. To understand the application and impact of Big Data.
6. To understand emerging trends in Big data analytics.

Course Outcomes:
1. To apply Big data primitives and fundamentals for application development.
2. To explore different Big data processing techniques with use cases.
3. To apply the Analytical concept of Big data using R/Python.
4. To visualize the Big Data using Tableau.
5. To design algorithms and techniques for Big data analytics.
6. To design Big data analytic application for emerging trends.

Guidelines for Instructor's Manual
1. The faculty member should prepare the laboratory manual for all the experiments and it should be made available to students and laboratory instructor/Assistant.

Guidelines for Student's Lab Journal
1. Student should submit term work in the form of handwritten journal based on specified list of assignments.
2. Practical Examination will be based on the term work.
3. Candidate is expected to know the theory involved in the experiment.
4. The practical examination should be conducted if and only if the journal of the candidate is complete in all respects.

Guidelines for Lab/TW Assessment
1. Examiners will assess the term work based on performance of students considering the parameters such as timely conduction of practical assignment, methodology adopted for implementation of practical assignment, timely submission of assignment in the form of handwritten write-up along with results of implemented assignment, attendance etc.
2. Examiners will judge the understanding of the practical performed in the examination by asking some questions related to theory & implementation of experiments he/she has carried out.
3. Appropriate knowledge of usage of software and hardware related to respective laboratory should be checked by the concerned faculty member.

As a conscious effort and little contribution towards Green IT and environment awareness, attaching printed papers of the program in journal may be avoided. There must be hand-written write-ups for every assignment.
in the journal. The DVD/CD containing students programs should be attached to the journal by every student and same to be maintained by department/lab In-charge is highly encouraged. For reference one or two journals may be maintained with program prints at Laboratory.

**Suggested List of Laboratory Assignments**

**Part A : Assignments based on the Hadoop**

1. Hadoop Installation on a)Single Node b)Multiple Node

2. Design a distributed application using MapReduce which processes a log file of a system. List out the users who have logged for maximum period on the system. Use simple log file from the Internet and process it using a pseudo distribution mode on Hadoop platform.

3. Design and develop a distributed application to find the coolest/hottest year from the available weather data. Use weather data from the Internet and process it using MapReduce.

4. Write an application using HBase and HiveQL for flight information system which will include
   1) Creating, Dropping, and altering Database tables
   2) Creating an external Hive table to connect to the HBase for Customer Information Table
   3) Load table with data, insert new values and field in the table, Join tables with Hive
   4) Create index on Flight information Table 5) Find the average departure delay per day in 2008.

**Part B : Assignments based on R and Python**

1. Perform the following operations using R/Python on the Amazon book review and facebook metrics data sets
   5) Create data subsets
   6) Merge Data
   7) Sort Data
   8) Transposing Data
   9) Melting Data to long format
   10) Casting data to wide format

2. Perform the following operations using R/Python on the Air quality and Heart Diseases data sets
   1) Data cleaning
   2) Data integration
   3) Data transformation
   4) Error correcting
   5) Data model building

3. Integrate R/Python and Hadoop and perform the following operations on forest fire dataset
   1) Text mining in RHadoop
   2) Data analysis using the Map Reduce in Rhadoop
   3) Data mining in Hive
4. Visualize the data using R/Python by plotting the graphs for assignment no. 2 and 3

5. Perform the following data visualization operations using Tableau on Adult and Iris datasets
   1) 1D (Linear) Data visualization
   2) 2D (Planar) Data Visualization
   3) 3D (Volumetric) Data Visualization
   4) Temporal Data Visualization
   5) Multidimensional Data Visualization
   6) Tree/ Hierarchical Data visualization
   7) Network Data visualization

   **Part C: Case Study Assignment**

   1) Social Media Analytics
   2) Text Mining/ Text Analytics
   3) Mobile Analytics

   **References:**
   4. Alex Holmes, Hadoop in practice, Dreamtech press.
   5. Online References for data set 1) http://archive.ics.uci.edu/ml/
### 314458 : PROJECT BASED SEMINAR

**Teaching Scheme:**
- Tutorial : 1 Hour/Week

**Credits**
- 01

**Examination Scheme:**
- Oral: 50 Marks

### Introduction:
Graduates of final year IT program are supposed to design and implement projects through knowledge and skills acquired in previous semesters. Students should identify complex engineering problems and find effective, efficient and innovative ways of solving them through their projects.

In a technical seminar, students should aim to review literature in a focused way for identifying a complex problem to be attempted in their final year project. Seminar should make the student attain skills like (a) gathering of literature in specific area in a focused manner (b) effectively summarizing the literature to find state-of-the-art in proposed area (c) identifying scope for future work (d) presenting (arguing) the case for the intended work to be done as project (e) reporting literature review and proposed work in scientific way using good English.

### Prerequisites:
1. Basic Communication, reading and writing skills.

### Course Objectives:
1. To perform focused study of technical and research literature relevant to a specific topic.
2. To study, interpret and summarize literature scientifically.
3. To build independent thinking on complex problems.
4. To build collaborative work practices.
5. To communicate scientific information to a larger audience in oral and written form.
6. To use presentation standards and guidelines effectively.

### Course Outcomes:
1. To Gather, organize, summarize and interpret technical literature with the purpose of formulating a project proposal.
2. To write a technical report summarizing state-of-the-art on an identified topic.
3. Present the study using graphics and multimedia presentations.
4. Define intended future work based on the technical review.
5. To explore and enhance the use of various presentation tools and techniques.
6. To understand scientific approach for literature survey and paper writing.

#### Guidelines for Project Based Seminars
1. A project group consisting of 3 to 4 students shall identify problem(s) in Computer Engineering / Information Technology referring to recent trends and developments in consultation with institute guide.
2. The group must review sufficient literature (reference books, journal articles, conference papers, white papers, magazines, web resources etc.) in relevant area on their project topic as decided by the guide.
3. Internal guide shall define a project statement based on the study by student group.
4. Students should identify individual seminar topic based on the project undertaken in consultation with guide.
5. Seminar topics should be based on project undertaken. Guide should thoughtfully allocate seminar topics on different techniques to solve the given problem (project statement), comparative analysis of the earlier algorithms used or specific tools used by various researchers.
6. Research articles could be referred from IEEE, ACM, Science direct, Springer, Elsevier, IETE,CSI or
from freely available digital libraries like Digital Library of India (dlite.ernet.in), National Science Digital Library, JRD Tata Memorial Library, citeseerx.ist.psu.edu, getcited.org, arizona.openrepository.com, Open J-Gate, Research Gate, worldwidescience.org etc.

7. The group shall present the study as individual seminars in 20 – 25 minutes.

**Guidelines for Seminar Report**

1. Each student shall submit two copies of the seminar report in a prescribed format duly signed by the guide and Head of the department/Principal.
2. First chapter of a project group may talk about the project topic. At the end of the first chapter individual students should begin with introduction of seminar topic and its objectives.
3. Broad contents of review report (20-25 pages) shall be
   i. Introduction of Project Topic
   ii. Motivation, purpose and scope of project and seminar
   iii. Related work (of the seminar title) with citations
   iv. Discussion ( your own reflections and analysis)
   v. Conclusions
   vi. Project definition. (Short version of RUP’s vision document if possible).
   vii. References in IEEE Format
4. Students are expected to use open source tools for writing seminar report, citing the references and plagiarism detection. (Latex, Lex for report writing ; Mendeley, Zaterto for collecting, organizing and citing the resources; DupliChecker , PaperRater, PlagiarismChecker and Viper for plagiarism detection)

**Guidelines for Seminar Evaluation**

1. A panel of examiners appointed by University will assess the seminar externally during the presentation.
2. Attendance for all seminars for all students is compulsory.
3. Criteria for evaluation
   i. Relevance of topic - 05 Marks
   ii. Relevance + depth of literature reviewed- 10 Marks
   iii. Seminar report (Technical Content) - 10 Marks
   iv. Seminar report (Language) - 05 Marks
   v. Presentation Slides - 05 Marks
   vi. Communication Skills - 05 Marks
   vii. Question and Answers - 10 Marks

**Guidelines for Seminar Presentation**

1) A panel of examiner will evaluate the viability of project scope and seminar delivery.
2) Oral examination in the form of presentation will be based on the project and seminar work completed by the candidates.
3) Seminar report must be presented during the oral examination.

**References**

In addition to credits course, it is recommended that there should be audit course (non-credit course) preferably in third year. Audit course is for the purposes of self-enrichment and academic exploration. Audit courses carry no academic credit. Though not mandatory, such a selection of the audit courses helps the learner to explore the subject of interest in greater details resulting in achieving the very objective of audit course's inclusion. Evaluation of audit course will be done at institute level. Method of conduction and method of assessment for audit courses is suggested.

**Criteria:**
The student registered for audit course shall be awarded the grade PP and shall be included such grade in the Semester grade report for that course, provided student has the minimum attendance as prescribed by the Savitribai Phule Pune University and satisfactory in-semester performance and secured a passing grade in that audit course. No grade points are associated with this 'PP' grade and performance in these courses is not accounted in the calculation of the performance indices SGPA and CGPA.

**Guidelines for Conduction and Assessment (Any one or more of following but not limited to)**
- Lectures/ Guest Lectures
- Visits (Social/Field) and reports
- Demonstrations
- Surveys
- Mini Project
- Hands on experience on Specific focused topic

**Guidelines for Assessment (Any one or more of following but not limited to)**
- Written Test
- Demonstrations/ Practical Test
- Presentations
- IPR/Publication
- Report

**Audit Course 4 Options**

<table>
<thead>
<tr>
<th>Course Code</th>
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<tr>
<td>AC 4-I</td>
<td>Intellectual Property Rights and Patenting</td>
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<td>AC 4-II</td>
<td>Social Awareness and Governance Program</td>
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<td>AC 4-III</td>
<td>Sustainable Energy System</td>
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<td>AC 4-IV</td>
<td>Health &amp; Fitness Management</td>
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Audit Course 4 - I : Intellectual Property Rights and Patenting

Prerequisites:
Concepts of Software Engineering

Course Objectives:
1. To gain the knowledge of the different types of Intellectual Property Rights (IPR).
2. To understand Trademark, Industrial Designs, Copyright and Trade Secret.
3. To learn about Patenting Systems in the World – USPTO, EPO.
4. To get Knowledge of Indian Patenting System – IPO.
5. To learn and understand different types of Contracts and Licensing and Open Source Software.

Course Outcomes:
1. To understand Intellectual Property Rights (IPR).
2. To explore applications of Trademark, Industrial Designs, Copyright and Trade Secret.
3. To understand function of USPTO, EPO.
4. To know the process of filing patent with IPO.
5. To understand the process of copyright and licensing.

UNIT I


UNIT II

UNIT III

UNIT IV

References:
2. Open Source and Free Software Licensing by Andrew M. ST. Laurent, O’REILLY Publication

Audit Course 4 - II : Social Awareness and Governance Program

**Prerequisites:**
Awareness about basic terms in Social Science and Governance

**Course Objectives:**
1. To Increase community awareness about social issues and to promote the practice of good governance in both private and public institutions, through policy advocacy and awareness creation in order to ensure proper utilization of public resources and good service delivery.
2. Increase community awareness on health, education, and human rights.
3. Transferring costs of social activities to other various segments of society.
4. To enhance youth participation in decision-making, democracy and economic development.

**Course Outcomes:**
1. Understand social issues and responsibilities as member of society.
2. Apply social values and ethics in decision making at social or organizational level
3. Promote obstacles in national integration and role of youth for National Integration
4. Demonstrate basic features of Indian Constitution.

**UNIT I**
Indian Society as Pluralistic, Fundamentals of unity in diversity, diversity and disparity in Indian society, women in mass media, disparities due to disability.

**UNIT II**
The Indian constitution as unifying factor, Introduction Making of Indian Constitution, Basic features of Indian Constitution, Strengths of Indian Constitution, and Fundamental Duties.

**UNIT III**

**UNIT IV**
Socialization, Ethics, Values and Prejudices, Meaning of Socialization, Functions of Socialization, Agents of Socialization, Importance of Socialization, Role of Ethics In Individual Development, Role of Basic Human Values In Individual Development, Relative Value System.

**Activities:**
2. Public shows on girls’ education and empowerment.
3. Conducting campaigns on adult/disabled education.
4. To support the government to develop policy that encourages youth participation in decision-making through government agencies.

**References:**
Audit Course 4 – III : Sustainable Energy System

Prerequisites:
1. Awareness about energy consumption and energy utilization.
2. Awareness about effects of global warming.

Course Objectives:
1. To understand the impact of engineering solutions on a global, economic, environmental, and societal context.
2. To design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

Course Outcomes:
1. To demonstrate an overview of the main sources of renewable energy.
2. To understand benefits of renewable and sustainable energy systems.

UNIT I

UNIT II

UNIT III

UNIT IV
Building Energy Technologies and Policy, Smart buildings, Lighting and LEDs, Heating/cooling, technologies.

References:
Audit Course 4 – IV : Health & Fitness Management

Prerequisites:
Awareness about healthy living.

Course Objectives:
1. To provide students a general concept of Health education and fitness.
2. To provide knowledge and understanding regarding health and nutrition.
3. To familiarize the students regarding safety education and health primitive measures for day to day life.
4. To promote and understanding of the value of physical and mental fitness for life skill development.

Course Outcomes:
1. Identify the health- and skill-related fitness components.
2. Understand the benefits of physical fitness, and the underlying principles, physiology, and practices for fitness development.
3. Apply of fitness management skills and strategies for the development of physical activity habits and personal fitness by the students.
4. Aware about healthy diet for physical and mental fitness of an individual.
5. Understand importance of mental fitness along with physical fitness by practicing yoga, meditation and relaxation techniques.

UNIT I
Importance of Health and Fitness, Physical fitness and mental fitness, Health and fitness issues in India, Government policies for Healthy Society, World Health Organization (WHO), and practicing good Habits for Healthy living.

UNIT II
Nutrition and Health : Concept of Food and Nutrition, Nutrients and Nutrient types, Balanced Diet, Vitamins – Malnutrition–Deficiency Diseases, Determining Caloric Intake and Expenditure, Obesity, Causes and Preventing Measures – Role of Diet.

UNIT III
Physical Exercise : Physical Activity and Health Benefits, Effect of Exercise on Body systems, Circulatory, Respiratory, Endocrine, Skeletal and Muscular, Role of Physical Education Programme on Community Health Promotion (Individual, Family and Society).

UNIT IV
Mental Health and Relaxation Techniques: Importance of mental health, Perspectives of mental health, Role of Emotional and Ethical Values in Mental Health, Preventing mental illness, Practicing Yoga and Meditation, Relaxation Techniques, Stress management Techniques.

References: