Programme: B.Tech. (CSE)	Course Title: Programs Analysis and Verification using Formal Methods			Course Code: CSE-XXX
Type of Course: Program Elective	Prerequisites: Discrete Mathematics			Total Contact Hours: 40
Year/Semester: 5/Odd	Lecture Hrs/Week: 3	Tutorial Hrs/Week: 0	Practical Hrs/Week: 0	Credits: 3

Learning Objective:

Today we are surrounded by software systems ranging from simple web applications to critical software systems such as banking, healthcare, defense, nuclear plants, etc. Failures of the software systems have catastrophic impacts on our society. One of the primary causes of the failures is the presence of bugs in the programs. Formal analysis and verification using formal methods are promising techniques to remove bugs from the programs. This course is an introduction to formal analysis and verification techniques to analyze the flaws in software systems at the early stages of development. The course will start by discussing the fundamentals of set theory, proof techniques, logics and then introduction to formal analysis and verification and their approaches such as dataflow analysis, and deductive reasoning. At the end of the course, the students should be able to formalize, model, and develop tools to detect bugs in the software.

Course outcomes (COs):

On completion of this course, the students will have the ability to:		Bloom's Level
CO-1	**Define and describe the** formal syntax and semantics of programs, and their specifications/requirements.	1,2
CO-2	**Apply** formal analysis techniques to analyze safety and security properties of software systems.	3
CO-3	**Analyzing** formal analysis and verification techniques/tools to improve the quality of the software systems	4
CO-4	**Evaluating** various existing formal analysis and verification techniques and tools.	5
CO-5	**Developing** formal analysis and verification techniques tools to verify the safety and security properties of emerging technologies such as blockchain, smart contracts, AI, etc.,	6

Topics		Hours
UNIT – I **1. Mathematical Foundation and Logics**		6
1.1 Universe, Terminologies, Operations, Sequences, Functions	1	
1.2 Proof Systems: Direct Proof, Proof by Contradiction, Proof by Induction	2	
1.3 Propositional logic: Introduction, Arguments, Well Formed Formulas, Inference rules, Equivalences	1	
1.4 Predicate Logic: Introduction, Predicate Quantifiers, Bound and Free Variables, Prenex Form, First Order Logic, Soundness and Completeness	2	
UNIT – II **2. Program Semantics**		6
2.1 Denotational Semantics	3	
2.2 Operational Semantics	3	
UNIT – III 3. **Programs Analysis**		10
3.1 Introduction to Program Analysis, Static and Dynamics Analysis	2	
3.2 Control Flow Graphs, Program traces	2	
3.3 Program Dependence Graphs, Data Flow Analysis	6	
UNIT-IV **4. Programs Verification**		12
4.1 Introduction to Formal Verification, Testing vs Verification	2	
4.2 Single Assignment (SA): Static Single Assignment (SSA), Dynamic Single Assignment (DSA)	2	
4.3 Program Properties: Safety and Security Properties, Requirement/Specification, Specification Languages, Program Annotations, Assertion Languages	2	
4.4 Verification Conditions, Theorem Provers, Satisfiability, Validity	2	
4.5 Deductive Reasoning: Symbolic Execution, Conditional Normal Form, Hoare Logics, Predicate Transformer: Weakest Precondition, and Strongest Postcondition	4	
UNIT – V **5. Case Studies**		6
7.1 Critical Software Systems	2	
7.2 Database Applications	2	
7.3 Network Protocols	2	

Textbook references:
Text Books:

1. Flemming Nielson, Hanne R. Nielson, Chris Hankin. Principles of Program Analysis, Springer, 1999.

2. José Bacelar Almeida, Maria João Frade, Jorge Sousa Pinto, Simão Melo de Sousa. Rigorous Software Development: An Introduction to Program Verification. Springer-Verlag London, 2011.

Reference books:

1. Glynn Winskel. The formal semantics of programming languages: an introduction, The MIT Press, 1993.

2. Michael Huth and Mark Ryan. Logic in Computer Science: Modelling and Reasoning about Systems, Cambridge Univ. Press, 2004

3. Research Papers

Evaluation Method	
Item	**Weightage (%)**
Quiz/Assignments/Mini-Projects	30
Case Studies/ Research Papers	10
Mid-Term Examination	25
End –Term Examination	35

*Please note, as per the existing institute's attendance policy the student should have a minimum of 75% attendance. Students who fail to attend a minimum of 75% lectures will be debarred from the End Term/Final/Comprehensive examination.

CO and PO Correlation Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1															
CO2															
CO3															
CO4															
CO5															

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Approved By: