INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

FOUNDATIONS OF CYBER-PHYSICAL SYSTEMS								
VII Semester: CSE(DS)								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
		L	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
ACDD33	**Elective**	3	0	0	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisites: Basic knowledge of embedded systems, differential equations, state machines, control systems, and programming in C/C++ or Python.								

I. COURSE OVERVIEW:

This course introduces the foundational principles of Cyber-Physical Systems (CPS) that integrate computation, networking, and physical processes. It explores models of computation, control, concurrency, time, and hybrid dynamics that underlie CPS behavior. Students will learn how to formally model, analyze, and implement CPS using mathematical tools, software simulations, and embedded hardware. The course lays the groundwork for designing reliable, safe, and time-sensitive cyber-physical applications in domains such as automotive, aerospace, robotics, and smart infrastructure.

II. COURSE OBJECTIVES:

The students will try to learn:

I. The fundamental concepts of cyber-physical systems, their architecture, and real-world applications.
II. The modeling of CPS using state machines, timed systems, and hybrid dynamical systems.
III. The integration of computation and physical processes through control and feedback mechanisms.
IV. The formal analysis of CPS models for verification, safety, and real-time behavior.

III. COURSE OUTCOMES:

CO1 **Describe** the architecture and components of cyber-physical systems.
CO2 **Model** system behavior using finite-state machines, differential equations, and hybrid automata.
CO3 **Apply** control theory and time modeling techniques to simulate CPS behavior.
CO4 **Analyze** the correctness and safety of CPS using formal verification and simulation tools.
CO5 **Design** CPS prototypes integrating computation and physical dynamics.
CO6 **Evaluate** CPS performance in real-world case studies involving smart systems.

IV. COURSE CONTENT:

Module I: Introduction to CPS and Modeling (10)
Definition and characteristics of CPS, Components of CPS, CPS vs embedded systems, Real-world CPS applications, Modeling concepts, Transition systems, Finite-state machines (FSMs), Modeling in Simulink, Safety and liveness properties, CPS design challenges.

Module II: Time and Discrete Models (10)
Discrete-time systems, Time modeling techniques, Synchronous and asynchronous systems, Event-driven models, Timed automata, Real-time systems, Determinism and concurrency, Clocks and time advances, Scheduling in real-time CPS, Temporal logic for CPS.

MODULE III: MEMORY AND PERFORMANCE OPTIMIZATION (10)
Continuous dynamics, Ordinary differential equations (ODEs), Feedback control systems, Linear time-invariant systems.

Hybrid systems, Hybrid automata, Stability analysis, Lyapunov functions, Simulation of hybrid systems, Reachability and verification.

Module IV: CPS Architecture and Communication (10)
Hardware platforms for CPS, Sensors and actuators, Embedded processors, Communication protocols (CAN, ZigBee, Wi-Fi), Networked control systems, Latency and packet loss, Middleware for CPS, Cyber-security in CPS, Fault tolerance, Time-triggered vs event-triggered systems.

Module V: CPS Applications and Case Studies (8)
Smart transportation systems, Autonomous vehicles, Medical CPS (pacemakers, infusion pumps), Smart grids and industrial automation, Internet of Things (IoT) and CPS, Human-in-the-loop systems, UAV and drone applications, Case studies using simulation tools, Ethical and societal impacts.

V. TEXTBOOKS:

1. **Rajeev Alur**, *Principles of Cyber-Physical Systems*, MIT Press, 2015.
2. **Edward A. Lee and Sanjit A. Seshia**, *Introduction to Embedded Systems: A Cyber-Physical Systems Approach*, 2nd Edition, MIT Press, 2017.
3. **Karl Johan Åström and Richard M. Murray**, *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton University Press, 2008.

VI. REFERENCE BOOKS:

1. **Raj Rajkumar et al.**, *Cyber-Physical Systems*, Addison-Wesley, 2012.
2. **Insup Lee, Oleg Sokolsky, Howard Shrobe**, *The Science of Cyber-Physical Systems*, ACM Reports, 2016.
3. **Thomas A. Henzinger**, *Principles of Cyber-Physical Systems Design*, Springer Lecture Notes, 2011.

VII. WEB REFERENCES

1. **NPTEL Course – Embedded Systems and Cyber-Physical Systems**
   https://nptel.ac.in/courses/108105057
2. **Coursera – Cyber-Physical Systems by University of Colorado Boulder**
   https://www.coursera.org/learn/cyber-physical-systems
3. **MIT OpenCourseWare – 6.832 Underactuated Robotics (CPS-focused)**
   https://ocw.mit.edu/courses/6-832-underactuated-robotics-spring-2020/
4. **Cyber-Physical Systems Virtual Organization (CPS-VO)**
   https://cps-vo.org

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open-ended experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
8. Model question paper – II
9. Lecture notes
10. PowerPoint presentation
11. E-Learning Readiness Videos (ELRV)