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# Course Handout Part II

**2nd Semester 2022-2023**

In addition to part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

*Course No. :* CS F441

## *Course Title :* Sel. Topics from Comp. Sc. (Cyber Physical Systems and Security)

## *Instructor-in-Charge :* Dr. Rajib Ranjan Maiti

### 1. Scope and Objectives

**Scope:** Just as the Internet transformed the way people interact with information, cyber-physical systems are transforming the way people interact with engineered systems. Cyber-physical systems integrate sensing, computation, control and networking into physical objects and infrastructure, connecting them to the Internet and to each other. This course supports in introducing and advancing the fundamental knowledge and tools to make cyber-physical systems a reality. These advances hold the potential to reshape our world with more responsive, precise, reliable and efficient systems, enabling a revolution of "smart" devices and systems from smart cars to smart grids, collectively giving rise to smart cities -- that can address some of the most pressing national and social priorities. The ability to design and build successful cyber-physical systems will address many national priorities in areas as diverse as aerospace, automotive, energy, disaster response, health care, manufacturing and city management in ways that traditional computer science alone cannot.

**Objectives:** Upon successful completion, you should be able to:

1. Describe the basic concepts of cryptography are used for ensuring security of cyber‐  
   physical systems
2. Describe the basic design, architecture and design principles of cyber physical systems
3. Design CPS, identify safety requirements, understand asynchronous model of CPS, identify sensors and actuators in CPS, learn the dynamics in the systems and create model of CPS using timed automata
4. Identify the sources of vulnerability in a cyber physical system systematically via attack  
   surfaces
5. Determine how security is incorporated at different abstractions and at different  
   components of cyber physical systems

**2. Desirable:** Programming in Python.

##### 3.a. Text Book

* T1: Rajeev Alur, "Principles of Cyber-Physical Systems", MIT Press
* T2: Edward A. Lee and Sanjit A. Seshia, "Introduction to Embedded Systems, A Cyber-Physical Systems Approach", Second Edition, MIT Press, ISBN 978-0-262-53381-2, 2017, available for download [http://leeseshia.org/]

**3.b. Reference Books**

* R1: Derek Molloy, "Exploring Raspberry Pi: Interfacing to the Real World with Embedded Linux", Wiley, ISBN 978-1-119-18868-1, 2016
* R2: Danda B. Rawat, Joel J.P.C. Rodrigues, Ivan Stojmenovic, "Cyber-Physical Systems: From Theory to Practice", CRC Press

**4. Course Plan**

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| Lec. No. | **Learning Outcomes** | **Topics to be covered** | Chapter in the Text Book |
| 1 | To introduce CPS | Features of CPS, Overview of the Topics in CPS | T1: Ch1 |
| 2-5 | To understand the design of CPS | Basics of synchronous model, reactive components, extended state machine, components and their properties, integrating components, Synchronous Designs and examples, | T1: Ch2 |
| 6-9 | To learn safety requirements | Fundamentals of safety requirements, safety specification, role of requirements in system design, system invariants and verification of invariants, enumerative search for property verification, symbolic search for property verification: DFS and BFS, Reduced Ordered Binary Decision Diagrams, | T1: Ch3 |
| 9-12 | To learn asynchronous model of CPS | Introduction to asynchronous model and process, extended state machine, asynchronous design primitives, deadlock handling mechanisms | T1: Ch4 |
| 12-15 | To understand liveliness requirements | Basics of liveliness requirements, temporal logic, LTL specifications, LTL specification for asynchronous process, model checking, Buchi automata | T1: Ch5 |
| 16-17 | To know sensors and actuators | Models of sensors and actuators, common sensors and common actuators, Measuring Tilt and Acceleration, Measuring Position and Velocity, Measuring Rotation, Light-Emitting Diodes, Motor Control | T2: Ch7 |
| 18-21 | Case study on real CPS | Physical structure and communication protocols in water treatment and distribution systems | Lecture Notes |
| 22-24 | To understand dynamical systems | Continuous time models: evolving inputs and outputs, models with disturbance, stability, linear systems: linearity, solutions to linear differential equations, designing controllers: Open-Loop vs. Feedback Controller | T1: Ch6 |
| 25-27 | To understand Real-Time Scheduling | Basics of Real-Time Scheduling, scheduler architecture, periodic job model, schedulability, EDF scheduling, Utilization-Based Schedulability Test, Fixed-Priority Scheduling, Schedulability Test for Rate-Monotonic Policy | T1: Ch8 |
| 28-32 | To learn attack detection in CPS | Physics-Based Attack Detection  in Cyber-Physical Systems, Formal Security Analysis of Industrial Control  Systems | Lecture notes |
| 33-39 | To learn real world CPS systems | Rule-based and axiomatic invariants for securing a water treatment and distribution systems | Lecture notes |
| 40 | To demonstrate CPS projects | Project showcasing | Lecture notes |

##### 5. Evaluation Scheme

**5.a Major Components**

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| **Component** | **Duration** | **Weightage** | **Date&Time** | **Mode** |
| Assignments 1 | - | **15%** | 5:00PM, 10/03/2023 | Open Book |
| Assignment 2 | - | **15%** | 5:00PM, 01/05/2023 | Open Book |
| Mid-Term exam | 90 mins | **25%** | 4:00 – 5:30 PM, 17/03/2023 | Close Book |
| Comprehensive | 3 hours | **45%** | AN, 18/05/2023 | Close Book |

**5.b Evaluation till Mid-Term:** Assignment 1 (15%) + Mid-Term (25%) = 40%

**6. Chamber Consultation:** 5:00PM – 5:30PM every Tuesday till 01/05/2023 with prior appointment over email at room no. H104, Department of CSIS.

**7. Notices:** All the notices and the submission links will be posted in CMS.

**8. Make-up Policy:** No make-up for any open book components. Make-Up for Mid-Term and Comprehensive examination may be considered only in exceptional circumstances subject to prior approval by IC of the course.

**9.Academic Honesty and Integrity Policy:**

Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

**Instructor-in-charge**