Course Code: Instrumentation

Instructor's name

Semester, Year

Total Hours: 64 Hours
Number of ECTS: 10
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Course Description

In the areas of science and engineering it is of vital importance to carry out measurements of different kinds. This course is an introduction to scientific instrumentation

Instrumentation covers the fundamental knowledge needed to understand how a data acquisition system works, how to design virtual instruments. The main objective is to train the student in analyzing and simulating electronic circuits, understand the characteristics of AD and DA converters and introduce the basic techniques for programming data acquisition systems, data acquisition and visualization.
The course is divided in 8 sessions (2 hours each) covering topics detailed below. Each session is self-contained and includes a series of activities that can be performed independently either in the lab or in remote.

Topics Overview

- Particle and Radiation detection
- Complex systems
- Data Acquisition Systems (DAQ)
- Signal Processing
- Virtual Instrumentation
- Data visualization and processing

Prerequisites/Corequisites

- Prerequisites:
- Corequisites:

Course Objectives

Successful students will be able:

1. To describe the fundamentals of radiation-matter interactions
2. To understand the basic concepts of complex systems
3. To configure DAQ systems for different applications
4. To understand the basics of signal processing
5. To build interfaces to visualize and process data from sensors

Schedule

Class Structure

- Each session is a self-contained module[1]
- A set of questions and exercises are proposed at the end of each session as individual work

Assessments

...

Lecture

Lab

...

Hands-On Projects

Students must be involved in advanced projects

- PMTs Applications
  - YT - KM3NeT
  - UIS - LAGO
- Gaseous Detectors
  - USFQ - MATHUSLA
- Scintillators and SiPMs
  - UAN
  - ??

[1] except for sessions 6 and 7

- Complex Systems
  - ??
  - ??
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Grading Policy

The grade will count the assessments using the following proportions:

- **30%** of your grade will be determined by 2 in class midterm exams (15% each).
- **5%** of your grade will be determined by ...
- **5%** ...
- **10%** ...
- **15%** ...
- **15%** ...

Grading

-

Schedule and weekly learning goals

The schedule is tentative and subject to change. The learning goals below should be viewed as the key concepts you should grasp after each session, and also as a study guide before each exam, and at the end of the course.

- **Week 1:** Interaction between particle and matter
  - Session 1: Interaction between particle and matter I
    - *
    - *
  - Session 2: Particle detection techniques II
    - *
    - *
- **Week 2:** Lab 1
  - Practice 1: γ Spectroscopy
    - Detecting γ Radiation
    - Poisson and Gaussian Distribution
    - Energy Resolution

    - Calibration: Linearity and Resolution
  - Practice 2: β Spectroscopy
    - Response of a Plastic Scintillating Tile
    - β Spectroscopy
    - Transmission through Matter
    - β Radiation as a Method to Measure Paper Sheet Grammage and Thin Layer Thickness

- **Week 3:** Voltage and current detection
  - Session 3: Basic concepts
    - Sensors and transducers
    - Conditioning circuits
  - Session 4: Light detection techniques
    - Photo-diodes, LDRs, APDs
    - PMTs and SiPMs

- **Week 4:** Lab 2
  - Practice 3: Light detection I
    - Photo-diode circuits & LDRs
    - Quantum Nature of Light
    - Hands-on Photon Counting Statistics
  - Practice 4: Light detection II
    - SiPM Characterization
    - Dependence of the SiPM Properties on the Bias Voltage

- **Week 5:** Complex systems
  - Session 4: Basic concepts
    -
    -
  - Session 5:
    -
    -
    -

- **Week 6:** Lab 3
  - Practice 3: Complex systems I
    - Chaos in Dripping faucet.
    - Chaos in Double pendulum.
  - Practice 4: Light detection II

        * Chaos in chua circuit.

- **Week 7:** Signal Acquisition
  - Session 6: Signal conditioners
    * Passive components conditioner circuits
    * Active components conditioner circuits
  - Practice 5: Amplifying & Filtering
- **Week 8:** Data Acquisition
  - Session 7: Analog to Digital Converters
    * Conversion.
    * Resolution.
    * Sample rate.
  - Practice 6: ADC characterization
    * Single measurement.
    * Measurement with signal conditioners.
    * Measurement with signal conditioners and DAQ.
- **Week 9:** Data Acquisition Techniques
  - Session 8: Data Acquisition Techniques I
    * Noise figure
    * Time domain representation
    * Frequency domain representation
  - Practice 6 : Cosmic Ray detection
    * Muons Detection
    * Muons Vertical Flux on Horizontal Detector
- **Week 10:** Data Visualization
  - Session 9: Introduction to data Visualization
    * Data Visualization
    * Gnuplot
  - Session 10 : MatLab (or Open Source alternative)
    *
    *
- **Week 11:** Virtual Instrumentation
  - Session 11: LabVIEW ((or Open Source alternative)
    *
    *
    *

  - Practice 7:

- **Week 12:** Data Processing I
  - Session 12: Phyton
    *
    *
    *
  - Practice 8:

- **Week 13:** Data Processing II
  - Session 13 :
    *
    *
    *
  - Practice 9 :

- **Week 14:** Data Processing III
  - Session 14:
    *
    *
    *
  - Practice 10:

- **Week 15:** Advanced Experiences
  - Practice 11 : Nuclear Imaging PET
    * γ Spectroscopy and System Linearity
    * Positron Annihilation Detection
    * Two-dimensional Reconstruction of a Radioactive Source
    * Spatial Resolution

- **Week 16:** Complex Systems
  - Practice :
    *
    *
    *

Course Material Required

- Eggleston D.L., **Basic Electrinics for scientists and engineers** Cambridge University Press,2011 ISBN ISBN 978-0-521-76970-9
- Boylestad R.,Nashelsky L. **Electronic devices and circuit theory**. 11th Ed. Pearson Prentice Hall, 2013. ISBN 9780132622264
- Di Paolo Emilio, M. **Data Acquisition Systems**. 1st. Ed. Springer 2013, ISBN 978-1-4614-4214-1
- Pelgrom Marcel J.M., **Analog-to-Digital Conversion**. 2nd Ed. Springer, 2013 ISBN 978-1-4614-1371-4
- Rashid Muhammad H. **Introduction to PSpice using OrCAD for circuits and electronics** 3rd Ed. Pearson/Prentice Hall, 2004, ISBN 9780131019881
- Sensores y acondicionadores de señal, Ramón Pallas Areny, Marcombo, 2003.
- Elements of Electrical And Electronic Instrumentation, Kurt S. Lion, McGraw-Hill, 1975
- Data Acquisition and Control Handbook,. keithley.
- CURSO DE INSTRUMENTACION, Alfonso Pérez García, INSTITUTO TECNOLÓGICO DE SAN LUIS POTOSI.

Further Reading

- Del Rio Fernandez J. , **LabView programación para sistemas de instrumentación**, Alfa Omega 2016, ISBN 9789587781236
- Moore Holly. **Matlab for Enginners**, 5th Ed., Pearson Education. 2018. ISBN 9780134589640
- GPIB programming tutorial NI website