YACHAY TECH UNIVERSITY

# SYLLABUS

## 1. General Information

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|---|---|---|---|---|---|
| A. | **SCHOOL** | Physical Sciences and Nanotechnology | B. | **MAJOR** | Physics<br>Nanotechnology |
| C. | **COURSE** | Computational Physics II | D. | **CODE** | PHYSEDH05<br>PHYSEDN22 |
| E. | **SEMESTER** | 8th | F. | **ACADEMIC TERM** | Noviembre 2022 – Marzo 2023 (02SEM2022) |
| G. | **CURRICULAR UNIT** | Professional | H. | **MODALITY** | Face to face |
| I. | **HOURS** | 200 | J. | **PROFESSORS** | Wladimir Eduardo Banda Barragán |
| K. | **WEEKLY CLASS SCHEDULE** | 12:00 – 14:00 Tuesday<br>14:00 – 16:00 Wednesday<br>10:00 – 12:00 Friday | L. | **WEEKLY TUTORING SCHEDULE** | 16:00 – 17:00 Tuesday<br>15:00 – 16:00 Thursday |

## 2. Prerequisites and Corequisites

| PREREQUISITES | | COREQUISITES | |
|---|---|---|---|
| **COURSES** | **Code** | **COURSES** | **Code** |
| | | | |

## 3. Course Description

This is an advanced course on object-oriented programming for physics. It is the second module of the computational physics series taught at Yachay Tech. The course focuses on introducing advanced numerical methods and simulation techniques used in physics, and provides an overview of recent progress made in several areas of scientific computing. The course includes detailed step-by-step examples of how to design software and use parallel programming to solve problems in physics. Topics range from advanced data analysis, through ordinary and partial differential equations, nonlinear dynamics and chaos, basic thermodynamics and fluid simulations, to an introduction to machine learning. Each section of the course includes practical examples from different areas of science and technology in which computational physics and high performance computing have played an important role in recent years.

## 4. Course Contribution to professional training

This course helps students improve programming skills for the design and implementation of parallel software dedicated to applications in physics.

## 5. Course objectives

- Improve object-oriented programming skills to solve physics problems within Linux environments.
- Design algorithms, implement and debug parallel software within the message passing interface in Python language.
- Apply numerical methods and computational techniques to simulate physical systems via reusable and extensible code packages.
- Use high-performance computing in research applications on thermodynamics, fluid dynamics, astrophysics, electromagnetism, particle physics, classical mechanics, quantum mechanics, and other areas of physics.

## 6. Units / Contents / Hours / Evaluation Instruments

| CURRICULAR UNITS | CONTENTS | TEACHING HOURS | HOURS OF INTERNSHIP AND EXPERIMENTAL LEARNING | HOURS OF INDEPENDENT LEARNING | EVALUATION INSTRUMENTS |
|---|---|---|---|---|---|
| **UC.1** Ordinary differential equations in physics | Ordinary differential equations, and initial value problems | 3 | 3 | 6 | Classwork (quizzes), homework (assignments), and exams. |
| | Euler methods, Runge-Kutta methods, and applications | 4 | 4 | 8 | Classwork (quizzes), homework (assignments), and exams. |
| | Boundary value problems, shooting and finite difference methods, applications | 4 | 4 | 8 | Classwork (quizzes), homework (assignments), and exams. |
| **UC.2** Partial differential equations in physics | Partial differential equations, generalities and classification | 3 | 3 | 6 | Classwork (quizzes), homework (assignments), and exams. |
| | Methods of solving partial differential equations | 4 | 4 | 8 | Classwork (quizzes), homework (assignments), and exams. |
| | Applications to electromagnetism, heat flow, and quantum mechanics | 4 | 4 | 8 | Classwork (quizzes), homework (assignments), and exams. |
| **UC.3** Computational fluid dynamics | Discretisation, meshing and conservation in computational fluid dynamics | 3 | 3 | 8 | Classwork (quizzes), homework (assignments), and exams. |
| | Advection, shocks and solitons | 4 | 4 | 8 | Classwork (quizzes), homework (assignments), and exams. |
| | Introduction to hydrodynamics and computational fluid dynamics (CFD) applications | 2 | 2 | 6 | Homework (Project), Classwork (Laboratory), Exam. |

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|---|---|---|---|---|---|
| **UC.4**<br>Special topics in computational physics | Thermodynamic simulations and introduction to molecular dynamics | 3 | 3 | 7 | Classwork (quizzes), homework (assignments), and exams. |
| | Nonlinear dynamics, chaotic systems, fractals and statistical growth | 4 | 4 | 7 | Classwork (quizzes), homework (assignments), and exams. |
| | Introduction to machine learning | 2 | 2 | 6 | Classwork (quizzes), homework (assignments), and exams. |
| **UC.5**<br>Software design and parallel computing for physics | Software design using object-oriented programming | 2 | 2 | 6 | Classwork (quizzes), homework (assignments), and exams. |
| | Message Passing Interface (MPI) and parallel computing | 4 | 4 | 6 | Classwork (quizzes), homework (assignments), and exams. |
| | High Performance Computing (HPC) | 2 | 2 | 6 | Classwork (quizzes), homework (assignments), and exams. |
| | **TOTAL** | 48 | 48 | 104 | 200 |

## 7. Learning outcomes of the course

| **LEARNING OUTCOMES** | | **STUDENT IS REQUIRED TO:**<br>**(EVIDENCE OF LEARNING)** |
|---|---|---|
| A. | Improve object-oriented programming skills to solve physics problems within Linux environments. | Submit quizzes on reading material and code developed in class (classwork).<br>Hand in routines of code, scripts, and group reports (homework).<br>Solve programming problems in exams (mid-term and final exams). |
| B. | Design algorithms, implement and debug parallel software within the message passing interface in Python language. | Submit quizzes on reading material and code developed in class (classwork).<br>Hand in routines of code, scripts, and group reports (homework).<br>Solve programming problems in exams (mid-term and final exams). |
| C. | Apply numerical methods and computational techniques to simulate physical systems via reusable and extensible code packages. | Submit quizzes on reading material and code developed in class (classwork).<br>Hand in routines of code, scripts, and group reports (homework).<br>Solve programming problems in exams (mid-term and final exams). |
| D. | Use high-performance computing in research applications on thermodynamics, fluid dynamics, astrophysics, electromagnetism, particle physics, classical mechanics, quantum mechanics, and other areas of physics. | Submit quizzes on reading material and code developed in class (classwork).<br>Hand in routines of code, scripts, and group reports (homework).<br>Solve programming problems in exams (mid-term and final exams). |

## 8. Methodology

1. Interactive lectures including theory and programming tasks.
2. Laboratory classwork including programming exercises and quizzes on reading material.
3. Individual and group projects including programming homework and research.

## 9. Information Sources (Bibliography)

### 9.1 Main

| Author/s | Title of Work | Edition | Year of Publication | Publishing house - Country | Availability at YACHAY TECH Library |
|---|---|---|---|---|---|
| Landau, Rubin | Computational physics : problem solving with python | 3rd | 2015 | Wiley-VCH; John Wiley - Germany | 530.0113 L2539c 2015 |

### 9.2 Complementary

| Author/s | Title of Work | Edition | Year of Publication | Publishing house - Country | Availability at YACHAY TECH Library |
|---|---|---|---|---|---|
| Pang, Tao | An introduction to computational physics | 2nd | 2006 | Cambridge University Press – United States | 530.0285 P1917a 2006 |
| Kong, Qingkai<br>Siauw, Timmy<br>Bayen, Alexandre | Python Programming and Numerical Methods - A Guide for Engineers and Scientists | 1st | 2020 | https://pythonnumericalmethods.berkeley.edu | Online |

## 10. Student's Evaluation

### 10.1. Evaluation during the course*

| Midterm Exam (MT) | | Formative Evaluation (FO) | | Laboratory (LAB) ** | | Final Exam (FI) | | Total |
|---|---|---|---|---|---|---|---|---|
| 1 Midterm Exam | 30 % | Homework average (code routines and project reports) | 20 % | Classwork average (reading quizzes and programming exercises) | 20 % | 1 Final Exam | 30 % | 100 % |
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| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | 30 % | Subtotal | 20 % | Subtotal | 20 % | Subtotal | 30 % | |

### 10.2. Makeup Exam

N/A

| 11. General considerations |
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| • Students are responsible for ensuring the academic integrity of their submitted assignments and exams.<br>• Cheating in exams, plagiarising, and copying solutions from other students or from previous years' solutions are all breaches of academic integrity.<br>• Academic misconduct will be penalised according to the University's regulations.<br>• Assignment deadlines and exam dates will be discussed and agreed upon in class. |

Based on the Academic Regime Regulation issued by the Higher Education Council (CES in Spanish) and the Academic Regime Regulation of Yachay Tech.
(*) The percentages of each item are established in Art. 35 of Academic Regime Regulation of Yachay Tech.
(**) In courses in which there is no laboratory item, place: N/A

| Prepared by: | Reviewed by: | Approved by: |
|---|---|---|
| **PROFESSOR - PROFESSORS** | **MAJOR COORDINATOR - MAJOR DIRECTOR** | **DEAN – DIRECTOR** |
| **SIGNATURE AND DATE:** | **SIGNATURE AND DATE:** | **SIGNATURE AND DATE:** |