PHY3115: INTRODUCTION TO COMPUTATIONAL PHYSICS

Effective Term
Semester B 2023/24

Part I Course Overview

Course Title
Introduction to Computational Physics

Subject Code
PHY - Physics

Course Number
3115

Academic Unit
Physics (PHY)

College/School
College of Science (SI)

Course Duration
One Semester

Credit Units
3

Level
B1, B2, B3, B4 - Bachelor's Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
MA2158 Linear Algebra and Calculus or
MA2170 Linear Algebra and Multi-variable Calculus or
MA2172 Applied Statistics for Sciences and Engineering or
MA2177 Engineering Mathematics and Statistics or
MA2181 Mathematical Methods for Engineering

Precursors
Nil

Equivalent Courses
Nil

Exclusive Courses
MSE3114 Computational Methods for Physicists and Materials Engineers

Part II Course Details

Abstract

Computational simulations play an essential role in many areas of physics. This course aims to introduce students the principles of commonly used numerical techniques, such as root finding, integration and differentiation, solving ordinary differential equations, Fourier analysis, etc., and their applications in physics. The course also trains students with hands-on programming skills in Python by implementing the learned concepts into workable codes to solve the programming exercises. This course builds the foundations of the advanced-level computational physics course.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	To analyse and formulate the mathematical models for problems in Physics.		x	x	x
2	To attain an intermediate level of scientific programming skills in Python.			x	x
3	To implement common numerical techniques, such as root finding, differentiation and integration, solution to ordinary differential equations, matrix operations, and apply them to solve physics problems.			x	x
4	To acquire basic data analysis skills.			x	x
5	To understand and appreciate the role of computational simulation in Physics.		x		

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Teaching and Learning Activities (TLAs)

	TLAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Explain the concepts and math of the numerical methods and their application to solving problems in Physics.	1, 3, 4, 5	2 hours/week
2	Tutorials	Demonstrate how to program, help students debug their code	1, 2, 3, 4	1 hours/week

3	Assignments	Individual works to be done by the students. The students are required to compose their own program to implement the methods taught in the lectures to solve physical problems.	1, 2, 3, 4, 5	2 hours/week

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Assignments (4-6)	1, 2, 3, 4, 5	30	
2	Mid-term test	1, 2, 3, 4, 5	20	

Continuous Assessment (%)

50

Examination (%)

50

Examination Duration (Hours)

2

Additional Information for ATs

For a student to pass the course, at least 30% of the maximum mark for the examination must be obtained.

Assessment Rubrics (AR)

Assessment Task

1. Assignments

Criterion

The student’s capacity in understanding the concepts and his/her ability to compose programs to solve physical problems.

Excellent (A+, A, A-)

High

Good (B+, B, B-)

Significant

Fair (C+, C, C-)

Moderate

Marginal (D)

Basic

Failure (F)

Not reaching marginal level

Assessment Task

2. Mid-term test

Criterion

The student’s ability to identify and explain the principles of the numerical methods and their applications to solve scientific problems.

Excellent (A+, A, A-)

High

Good (B+, B, B-)

Significant

Fair (C+, C, C-)

Moderate

Marginal (D)

Basic

Failure (F)

Not reaching marginal level

Assessment Task

3. Examination

Criterion

The student’s ability to identify and explain the principles of the numerical methods and their applications to solve scientific problems.

Excellent (A+, A, A-)

High

Good (B+, B, B-)

Significant

Fair (C+, C, C-)

Moderate

Marginal (D)

Basic

Failure (F)

Not reaching marginal level

Part III Other Information

Keyword Syllabus

- Basic Python for physics
- Root finding methods
  - Bisection method, Newton-Raphson method, applications (e.g. finite square well in quantum mechanics)
- Numerical integration
  - Rectangular and trapezoid integration, Gaussian integration, applications (e.g. in electrostatic)
- Numerical differentiation
  - Forward difference, central difference and higher order methods, higher order derivatives

- Numerical solutions to ordinary differentiation equations
  - Euler methods, Runge-Kutta methods, applications (e.g. damped oscillators)
- Numerical methods for matrices
  - Linear systems of equations, Gaussian elimination, Eigenvalue problems, applications (e.g. in quantum mechanics)
- Fourier analysis
  - Fourier series, Fourier transform, discrete Fourier transform, Fast Fourier transform, spectral analysis, applications (e.g. non-linear oscillators)

Reading List

Compulsory Readings

	Title
1	Paul L. DeVries, "A First Course in Computational Physics", Wiley, 1994
2	Mark Newman, "Computational Physics", CreateSpace, 2013

Additional Readings

	Title
1	A. Klein and A. Godunov, Introductory Computational Physics (Cambridge University Press, Cambridge, UK ; New York, 2006).
2	William H. Press, Numerical Recipes 3rd Edition: The Art of Scientific Computing, 3rd ed. (Cambridge University Press, Cambridge, UK ; New York, 2007).