TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

ADVANCED COMPUTATIONAL PHYSICS

by

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PREFACE

This Teaching Instructional Design is compiled to be used as a teaching reference for the Advanced Computational Physics course. The Advanced Computational Physics course is one of several compulsory courses in the Undergraduate Program in Physics. The Advanced Computational Physics course is given in the 6^{th} term.

The Advanced Computational Physics course aims to have participants able to apply numerical approaches, make microprogramming algorithms, and translate them to a computer program using the Fortran programming language or its equivalent, to solve problems in physics. To take this course students are expected to have prior knowledge of computational physics.

Depok, October 2020

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I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Advanced Computational Physics
3.	Course Code	:	SCFI603416
4.	Semester	:	6
5.	Credit	:	3 credits
6.	Teaching Method(s)	:	Lecturing
7.	Prerequisite course(s)	:	SCFI602021 Computational Physics
8.	Requisite for course(s)	:	-
9.	Integration Between Other Courses	:	(See two rows above)
10.	Lecturer(s)	:	Muhammad Aziz Majidi, Imam Fachruddin
11.	Course Description	:	This course aims to have participants able to apply numerical approaches, make microprogramming algorithms, and translate them to a computer program using the Fortran programming language or its equivalent, to solve problems in physics. The study materials in this course include finding the roots of functions, solving systems of linear equations, fitting using the least-square method, interpolation, numerical integration, solving ordinary and partial differential equations with boundary conditions, solving eigenvalue problems using the power method, solving secular equations or characteristic polynomial matrices.

II. Course Learning Outcome (CLO) and Sub-CLOs

A. CLO

After finishing this course, students are able to apply numerical methods in calculations to solve problems in Physics and use the Fortran programming language or its equivalent to do calculations using numerical methods.

B. Sub-CLO

It is hoped that after the completion of this course students are able to:

1. Make computer programs in the Fortran programming language or its equivalent,
2. Make computer programs in the Fortran programming language or its equivalent,
3. Solve systems of linear equations using the Gauss elimination, LU decomposition, Jacobi iteration, and Gauss-Seidel iteration method,
4. Do data fitting using the least square method,
5. Make multidimensional interpolation using the Lagrange, cubic Lagrange, cubic Hermite, and cubic spline method,
6. Calculate integrals using the trapezoid, Simpson, and Gaussian method,
7. Calculate the solution to ordinary differential equations using the Euler, modified Euler, improved Euler, Runge-Kutta, and finite differences method,
8. Calculate the solution to elliptical, parabolic, and hyperbolic partial differential equations,
9. Solve eigenvalue equations.

III. Teaching Plan

Week	Sub-CLO	Study Materials	Teaching Method	Time Required	Learning Experiences (*O-E-F)	Sub-CLO Weight on Course (%)	Sub-CLO Achievement Indicator	References
1	Make computer programs in the Fortran programming language or its equivalent (part 1)	Program structure, types of data, constants and variables, operators, branches, loops.	Discussion	150 minutes	Presentation of materials – question and answer discussion	8	Students can explain program structure, types of data, constants and variables, operators, branches, and loops.	M. Metcalf & J. Reid, Fortran 90/95 Explained (Oxford University Press, New York, 1998)
2	Make computer programs in the Fortran programming language or its equivalent (part 2)	Subprograms, input and output, double-precision, and dynamic allocation of variable arrays.	Discussion	150 minutes	Presentation of materials – question and answer discussion	8	Students can make a simple program.	M. Metcalf & J. Reid, Fortran 90/95 Explained (Oxford University Press, New York, 1998)
3	Calculate the roots of functions using the bisection, false position, Newton-Raphson, and secant method.	Bisection and false position methods, absolute and relative error.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can calculate the roots of functions using the bisection method.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
4	Calculate the roots of functions using the bisection, false position, Newton-Raphson, and secant method.	Newton-Raphson and secant methods.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can calculate the roots of functions using the secant method.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)

5	Solve systems of linear equations using the Gauss elimination, LU decomposition, Jacobi iteration, and Gauss-Seidel iteration method.	Gauss elimination and basic LU decomposition methods.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can explain the solution to systems of linear equations using the Gauss elimination and basic LU decomposition methods.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
6	Solve systems of linear equations using the Gauss elimination, LU decomposition, Jacobi iteration, and Gauss-Seidel iteration method.	Relation between the T matrix, M matrix, S matrix, and scattering amplitude. Representation and basis.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can solve systems of linear equations using the complete LU decomposition and Jacobi iteration methods.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
7	Do data fitting using the Least-square method.	Least-square method.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can do data fitting using the least square method and make relevant graphs.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
8	**Midterm Exam**							
9	Make multidimensional interpolation using the Lagrange, cubic Lagrange, cubic Hermite, and cubic spline method.	Lagrange, cubic Lagrange, cubic Hermite, and cubic spline methods.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can make multidimensional interpolations using the Lagrange and cubic Hermite methods.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)

10	Calculate integrals using the trapezoid and Simpson method.	Trapezoid, Simpson, and composite integration methods.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can calculate numerical integrals using the trapezoid and composite Simpson methods.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
11	Calculate integrals using the Gaussian method.	Gauss-Legendre method, special cases in numerical integration.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can explain integrals using the Gauss-Legendre method.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
12	Calculate the solution to ordinary differential equations using the Euler, modified Euler, and improved Euler method.	Euler, modified Euler, and improved Euler methods.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can explain the solution to 1st order ordinary differential equations using the improved Euler method.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
13	Calculate the solution to ordinary differential equations using the Runge-Kutta, and finite differences method.	Runge-Kutta and finite differences methods.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can calculate the solution to 2nd order ordinary differential equations using the Runge-Kutta and finite differences methods.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
14	Calculate the solution to elliptical, parabolic, and hyperbolic partial	Numerical formulation of elliptical, parabolic, and hyperbolic partial differential equations.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can calculate the solution to parabolic partial	P. L. DeVries, A First Course in Computational Physics (John

	differential equations.						differential equations.	Wiley & Sons, Inc., New York, 1994)
15	Solve eigenvalue equations.	Power method, and secular equations or polynomial characteristic matrices.	Discussion	150 minutes	Presentation of materials – question and answer discussion	7	Students can calculate eigenvalues using the power method.	P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)
16	**Final Exam**							

*) O : Orientation
E : Exercise
F : Feedback

References:

1. P. L. DeVries, A First Course in Computational Physics (John Wiley & Sons, Inc., New York, 1994)

I. Assignment Design

Week	Assignment Name	Sub-CLO	Assignment	Scope	Working Procedure	Deadline	Outcome
2	Assignment 1	Make computer programs in the Fortran programming language or its equivalent	Making a simple program in the Fortran language or its equivalent	Simple program	Individual Assignment	1 week	Program file
3	Assignment 2	Calculate the roots of functions using the bisection, false position, Newton-Raphson, and secant method.	Making a bisection program	Finding the roots of functions using the bisection method	Individual Assignment	1 week	Program file
4	Assignment 3	Calculate the roots of functions using the bisection, false position, Newton-Raphson, and secant method.	Making a secant program	Finding the roots of functions using the secant method	Individual Assignment	1 week	Program file
6	Assignment 4	Solve systems of linear equations using the Gauss elimination, LU decomposition, Jacobi iteration, and Gauss-Seidel iteration method.	Making a LU decomposition program	Solving systems of linear equations using the LU decomposition method	Individual Assignment	1 week	Program file, inputs, and outputs
7	Assignment 5	Do data fitting using the Least-square method.	Making a least-square program	Data fitting using the Least-square method	Individual Assignment	1 week	Program file, inputs, outputs, and graphs
9	Assignment 6	Make multidimensional interpolation using the Lagrange, cubic Lagrange, cubic Hermite, and cubic spline method.	Making an interpolation program	Interpolation using the Lagrange and cubic Hermite method	Individual Assignment	1 week	Program file, inputs, outputs, and graphs

10	Assignment 7	Calculate integrals using the trapezoid, Simpson, and Gaussian method.	Making a Simpson program	Calculating integrals using the Simpson method	Individual Assignment	1 week	Program file
11	Assignment 8	Calculate the solution to ordinary differential equations using the Euler, modified Euler, improved Euler, Runge-Kutta, and finite differences method.	Making a Runge-Kutta program	Solving 2nd order ordinary differential equations using the Runge-Kutta method	Individual Assignment	1 week	Program file, inputs, outputs, and graphs
12	Assignment 9	Calculate the solution to elliptical, parabolic, and hyperbolic partial differential equations.	Making a parabolic program	Solving parabolic partial differential equations	Individual Assignment	1 week	Program file, inputs, outputs, and graphs
13	Assignment 10	Solve eigenvalue equations.	Making an eigenvalue program	Calculating eigenvalues using the power method	Individual Assignment	1 week	Program file

II. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Assignment 1	Sub-CLO 1	Fully functional computer program	1	4
Assignment 2	Sub-CLO 1 and 2	Fully functional computer program	1	4
Assignment 3	Sub-CLO 1 and 2	Fully functional computer program	1	4
Assignment 4	Sub-CLO 1 and 3	Fully functional computer program	1	4
Assignment 5	Sub-CLO 1 and 4	Fully functional computer program	1	4
Assignment 6	Sub-CLO 1 and 5	Fully functional computer program	1	4
Assignment 7	Sub-CLO 1 and 6	Fully functional computer program	1	4
Assignment 8	Sub-CLO 1 and 7	Fully functional computer program	1	4
Assignment 9	Sub-CLO 1 and 8	Fully functional computer program	1	4
Assignment 10	Sub-CLO 1 and 9	Fully functional computer program	1	4
Midterm Exam	Sub-CLO 1 to Sub-CLO 4	Fully functional computer program	1	30
Final Exam	Sub-CLO 1, Sub-CLO 5	Fully functional computer program	1	30

	to Sub-CLO 9			
Total				**100**

III. Rubric

A. Criteria for Presentation Score

Score	Presentation Delivery
85-90	The group is able to deliver the explanation logically, fluently, in a timely manner and is able to answer questions from other students and the lecturer.
75-84	The group is able to deliver the explanation logically and fluently and is able to answer questions from other students and the lecturer but delivers the explanation in a less timely manner.
65-74	The group is able to deliver the explanation fluently but is less able to deliver the reasoning behind the explanation.
55-64	Group is less able to deliver the explanation fluently, deliver it in a timely manner, and deliver the reasoning behind the explanation.
<55	

B. Criteria for Assignment and Exam Scores

Score	Answer Quality
100	The answer is very precise, and all the concepts and main components are explained completely.
76-99	The answer is fairly precise, and the concepts and main components are explained fairly completely.
51-75	The answer is less precise, and the concepts and main components are explained less completely.
26-50	The answer is poorly precise, and the concepts and main components are explained very incompletely.
<25	The answer is incorrect.