Politechnika Krakowska
im. Tadeusza Kościuszki

Karta przedmiotu

obowiązuje studentów rozpoczynających studia w roku akademickim 2020/2021

Wydział Inżynierii Materiałowej i Fizyki

Kierunek studiów: Fizyka Techniczna w Języku Angielskim — Profil: Ogólnoakademicki

Forma sudiów: stacjonarne — Kod kierunku: FTja

Stopień studiów: II

Specjalności: Computer modelling (modelowanie komputerowe w języku angielskim)

1 Informacje o przedmiocie

Nazwa przedmiotu	Computational methods
Nazwa przedmiotu w języku angielskim	Computational methods
Kod przedmiotu	WIMiF FTJA oIIS D4 20/21
Kategoria przedmiotu	Przedmioty specjalnościowe
Liczba punktów ECTS	3.00
Semestry	2

2 Rodzaj zajęć, liczba godzin w planie studiów

Semestr	Wykład	Ćwiczenia	Laboratorium	Laboratorium komputerowe	Seminarium	Projekt
2	15	0	0	30	0	0

3 Cele przedmiotu

Cel 1 The student learns to understand and design, mainly in a programming language (preferably C or Fortran) and with the help of a symbolic computation language (Mathematica), the standard computational subroutines (black boxes) and applies them to solving various kinds of problems a physicist may encounter.

Cel 2 The student develops dedicated algorithms for non-straightforward computational tasks (such as integration of particular forms of equations with singular points or equations with additional solution-dependent consistency constraints).

Cel 3 The student gets acquainted with the theoretical background behind a given type of equation.

4 Wymagania wstępne w zakresie wiedzy, umiejętności i innych kompetencji

1 The student is expected to have some background in linear algebra and mathematical analysis, as well as some basic background in programming.

5 Efekty kształcenia

EK1 Wiedza The student understands the presented computational algorithms.

EK2 Umiejętności The student is able to design and program the standard computational subroutines for ordinary and partial differential equations and effectively uses symbolic algebra tools to obtain and reduce the required formulas.

EK3 Umiejętności The student is able to solve various computational tasks with the use of the prepared computational routines.

EK4 Umiejętności The student is able to write a (LaTeX) report discussing the solution of home-work tasks or group projects, and to prepare and give an oral presentation of the obtained results.

EK5 Kompetencje społeczne The student develops his or her teamwork skills to achieve a shared goal in problem solving.

6 Treści programowe

Laboratorium komputerowe		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
K1	Devising a tensor-calculus package with the use of a computer symbolic calculus system. Basics of ordinary and covariant calculus: bases and dual bases for sub-manifolds (tangent and cotangent space), induced metric tensor, derivatives of basis vectors, rotation coefficients (connection) and Christoffel symbols, decomposition of arbitrary vector, covariant differentiation of vectors. The concept of curvature. Application to basic sub-manifolds in Euclidean and Minkowski spaces: Laplacian and curvature scalar on a 2-sphere, torus, 3-sphere, 3D Lobachevsky space. Hydrodynamical equations: general spherical and static metric of self-gravitating perfect fluid (deriving a hydrodynamical equilibrium equation). A LaTeX(beamer) project report.	3
K2	Discussing and writing basic auxiliary numerical subroutines (including the interpolation and qubic spline smoothing procedures and simple solvers of nonlinear equations for later use). Approximation of a discrete set of measurements data and best fitting curves (the least squares method). Application in modelling of galactic rotation curves, finding roots of nonlinear equations /"tan(x)=a*x"-type problems, tables of the Lambert W function/, GPS tracking data with path smoothing. A LaTeXbeamer project report.	5

Laboratorium komputerowe		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
K3	A subroutine for generating orthogonal polynomials with the use of a symbolic algebra system. Subroutines for numerical differentiation and integration, testing with applications to simple tasks (the elliptic functions and other special functions defined by integrals).	4
K4	A uniformly step-sized numerical integration subroutine based on the Runge-Kutta approach. Testing with the use of simple ODEs with known exact solutions (e.g. a special integrable n-body problem and its numerical integration). Application to initial problems: 1) the refraction index modelling: the case of an axi-symmetric system of non-uniform lenses and of arbitrarily curved non-uniform optical fibers; numerical integration of the derived equations of light rays, 2) finding solutions of a non-linear ODE with boundary singularities: a shooting method supplemented with an analytic starter on the example of equivariant harmonic maps between three-spheres and Skyrmions on the three-sphere, phase diagrams of solutions. A LaTeX(beamer) project report. A uniformly step-sized numerical integration subroutine based on the leap-frog stepping approach, application to an n-body simulation of a disk-like galaxy. A LaTeX(beamer) project report.	9
K5	A subroutine solving a general elliptic problem on a rectangular grid by the relaxation method. Testing with the help of exact solutions of simple Dirichlet, Neumann, and mixed problems on non-rectangular domains and mappable onto a rectangular domain. The split monopole and dipole solutions of the pulsar equation on a compactified domain and with a singular and solution-dependent consistency constraint on the light cylinder. A LaTeX(beamer) project report.	9

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W1	Differential equations in physics and technology: application of a dedicated tensor calculus package to deriving partial differential equations of hydrodynamics and electrodynamics in various coordinate systems. Differential operators in vector field analysis. Hydrodynamics in relativistic and non-relativistic theory: the concept of a fluid velocity field, local co-moving observers, projection operators onto local spaces of the fluid, the energy-momentum tensor of a perfect fluid; the tensor of the flow velocity derivatives in local spaces of the fluid, decomposition to shear, dilation and vorticity, generalization of the energy-momentum tensor to viscous flow, the local conservation constraint and the resulting relativistic Navier-Stokes equations, the Newtonian limit of viscous flow. Maxwell fields with sources: the energy-momentum tensor and the equations of motion resulting from the local conservation constraint. The vector form of equations in Minkowski spacetime with general and special curvilinear orthogonal coordinates,	2

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W2	Numerical auxiliaries: Weierstrass convergence theorem, the Lagrange interpolation and its error, Neville's algorithm, interpolation by means of rational functions, qubic spline interpolation and smoothing, trigonometric interpolation, The least-squares method and the free parameter uncertainties, approximation of a discrete set of data; roots and extrema: bisection secant and fixed point methods, Newton-Raphson method for a multi-variable set of equations, a minimization scheme for a multi-variable function.	2
W3	Numerical Calculus. Basic and multi-point formulas for the 1st and 2nd order derivatives, the recursive Richardson extrapolation for derivatives; quadratures for single-variable functions and error estimates: basic and higher order methods, Gaussian integration method; error estimates. Generalized Fourier analysis; weighted orthogonal base functions, Gram-Schmidt orthogonalization scheme for special orthogonal polynomials of mathematical physics. Discrete Fourier transform, the fast Fourier transform algorithm.	2
W4	Remarks on the variational calculus for systems with finite and infinite degrees of freedom, conserved quantities. Application to deriving example differential equations of physics: equations for the propagation of light-rays in optically non-uniform media: derivation from the Fermat least-time principle, the resulting ODEs for axially-symmetric optical systems (systems of lenses and curvilinear non-uniform optical fibers), the geodesics equation from the least-arc length principle (Maupertuis principle). Example field-theoretical problems reducible to ordinary differential equations: equivariant harmonic maps between 3-spheres, hedgehog Skyrmions on the 3-sphere.	2
W5	Computational methods for systems of ordinary differential equations. Initial and boundary formulation, basic uniqueness theorems. Finite difference and variational methods (comparison, a worked-out example). Remarks on single- and multi-step methods. The leap-frog/mid-point integration methods, derivation of higher order Runge-Kuta formulas with the use of a computer algebra system, a uniformly step-sized numerical integration code, remarks on controlling the integration step size. The issue of singular boundary points: remarks on singular points of ODEs; bypassing the singularities, analytical starters for numerical integrators. Application of the Runge-Kutta approach to ODEs with regular and singular points. Shooting method for boundary value problems - application to a 2nd order ODE with singularities: a worked-out example.	4
W6	Computational methods for partial differential equations: Remarks on basic analytical methods of solving partial differential equations: elliptic, hyperbolic and parabolic type PDEs and the related initial and boundary problems. Discretization on flat rectangular integration domains, mapping of certain (flat and non-flat) two-dimensional integration domains onto rectangular grids and the resulting transformations of PDEs. The relaxation method for elliptic problems. Numerical solution of typical problems involving PDEs. Numerical solution of some atypical non-linear PDE problems (the pulsar equation).	3

7 Narzędzia dydaktyczne

N1 Lectures

N2 Exercises in Computer Laboratories

N3 Individual or teamwork projects and reports

N4 Discussions, individual consultations

N5 Multimedia presentations

N6 A computer algebra system; an environment for compiling, linking and running computer programs

8 Obciążenie pracą studenta

Forma aktywności	Średnia liczba godzin na zrealizowanie aktywności
Godziny kontaktowe z nauczycielem akademickim, w tym:	
Godziny wynikające z planu studiów	45
Konsultacje przedmiotowe	2
Egzaminy i zaliczenia w sesji	5
Godziny bez udziału nauczyciela akademickiego wynikające z nakładu pracy studenta, w tym:	
Przygotowanie się do zajęć, w tym studiowanie zalecanej literatury	8
Opracowanie wyników	18
Przygotowanie raportu, projektu, prezentacji, dyskusji	12
Sumaryczna liczba godzin dla przedmiotu wynikająca z całego nakładu pracy studenta	**90**
Sumaryczna liczba punktów ECTS dla przedmiotu	3.00

9 Sposoby oceny

Ocena formująca

F1 Student is required to actively take part in the computer laboratory course and attend the lectures

F2 Student is required to prepare complete reports presenting and discussing the results concerning given computational tasks

Ocena podsumowująca

P1 Weighted average of forming grades: (reports/2 + activity/2)

Warunki zaliczenia przedmiotu

W1 All computational tasks must be accomplished

W2 The weighted average of forming grades - at least 3.0

Kryteria oceny

Efekt kształcenia 1	
Na ocenę 3.0	The student has a basic knowledge of presented computational methods
Efekt kształcenia 2	
Na ocenę 3.0	The student has limited skills in designing and programming the standard computational subroutines for ordinary and partial differential equations.
Efekt kształcenia 3	
Na ocenę 3.0	The student has limited skills in solving various computational tasks with the use of the prepared computational subroutines.
Efekt kształcenia 4	
Na ocenę 3.0	The student has limited skills in writing a report and presenting the results
Efekt kształcenia 5	
Na ocenę 3.0	The student at least tries to develop his or her teamwork skills

10 Macierz realizacji przedmiotu

Efekt kształcenia	Odniesienie danego efektu do szczegółowych efektów zdefiniowanych dla programu	Cele przedmiotu	Treści programowe	Narzędzia dydaktyczne	Sposoby oceny
EK1		Cel 1 Cel 2	K1 K2 K3 K4 K5 W1 W2 W3 W5 W6	N1 N2 N3 N4 N5 N6	F1 F2 P1
EK2		Cel 1 Cel 2	K1 K2 K3 K4 K5 W2 W3 W5 W6	N1 N2 N3 N4 N5 N6	F1 F2 P1
EK3		Cel 1 Cel 2 Cel 3	K1 K2 K3 K4 K5 W1 W2 W3 W4 W5 W6	N1 N2 N3 N4 N5 N6	F1 F2 P1
EK4		Cel 3	K1 K4 K5	N3 N4 N5	F2
EK5		Cel 2	K1 K2 K3 K4 K5	N2 N3 N4	F1 F2

11 Wykaz literatury

Literatura podstawowa

[1] **Samuel SM Wong** — *Computational Methods in Physics and Engineering*, London, 1977, World Scientific

[2] **S.E. Koonin, D.C. Meredith** — *Computational Physics*, , 1990, Westview Press

Literatura uzupełniająca

[1] **W.H. Press, S.A Teukolsky, W.T. Vetterling, B.P. Flannery** — *Numerical Recipes 3rd Edition. The Art of Scientific Computing.*, New York, 2007, Cambridge University Press

Literatura dodatkowa

[1] **Robert Wald** — *General Relativity*, Chicago, 1984, University of Chicago Press

[2] **L.D. Landau, F.M. Lifshitz** — *Fluid Mechanics*, Oxford, 1987, Pergamon Press

12 Informacje o nauczycielach akademickich

Osoba odpowiedzialna za kartę

dr hab. Łukasz Bratek (kontakt: lukasz.bratek@pk.edu.pl)

Osoby prowadzące przedmiot

1 dr hab. Łukasz Bratek (kontakt: lukasz.bratek@pk.edu.pl)

13 Zatwierdzenie karty przedmiotu do realizacji

(miejscowość, data) (odpowiedzialny za przedmiot) (dziekan)

Przyjmuję do realizacji (data i podpisy osób prowadzących przedmiot)

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