



Course Syllabus: Special Topic: Advanced Comp. Physics - CS 290C

Division	Computer, Electrical and Mathematical Sciences & Engineering
Course Number	CS 290C
Course Title	Special Topic: Advanced Comp. Physics
Academic Semester	Spring
Academic Year	2016/2017
Semester Start Date	01/22/2017
Semester End Date	05/18/2017
Class Schedule (Days & Time)	04:00 PM - 05:30 PM Sun Wed

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Dominik Ludewig Michels	dominik.michels@kaust.edu.sa	+966128080256		TBA

Teaching Assistant(s)

Name	Email
Dmitry A. Lyakhov	dmitry.lyakhov@kaust.edu.sa

Course Information

Comprehensive Course Description	<p>Euler-Lagrange Equations of Second Kind: Phase Space, Generalized Coordinates, Constraints, Calculus of Variations and Euler-Lagrange Equations of Second Kind</p> <p>Lagrangian Formalism: Lagrangian Formalism, Particle Systems, Friction and Dissipation</p> <p>Symmetries and Conservation Laws: Generalized Momenta, Cyclic Coordinates, Noether's Theorem, Conservation of Energy</p> <p>Stability and Bifurcation: Chaotic and Nonchaotic Dynamics, Sensitivity to Initial Conditions and Deterministic Chaos, Lyapunov Stability, Lyapunov's First Method, Lyapunov's Second Method, Bifurcations, Attractors</p> <p>Euler-Lagrange Equations of First Kind: Lagrange Multiplier, Euler-Lagrange Equations of First Kind, SHAKE and RATTLE</p> <p>Multi-body Problems and Rigid Bodies: Central Force, Two-body Problem, Effective Potential, Multi-body Problems, Center of Mass Theorem, Angular Momentum Theorem, Euler Angles, Lagrangian Equations of the Rigid Body</p> <p>Linear and Nonlinear Oscillations: Oscillators with a Single Degree of Freedom, Transition to the Continuum, Linear and Non-linear Forces, Calculation of Perturbations, Harmonic Balance, Enforced Non-linear Oscillation, Self- and Parameter-excited Oscillation</p> <p>Hamiltonian Formalism: Legendre Transformation, Hamiltonian mechanics, Poisson Brackets</p> <p>Canonical Transformations and Invariances: Point Transformations, Canonical Transformations, Generators, Canonical Invariances of Poisson Brackets, Canonical Invariances of the Phase Volume</p> <p>Liouville's Theorem: Phase Space Trajectories, Foundations of Statistical Mechanics, Liouville's Theorem and its Consequences</p> <p>Discrete Lagrangian and Hamiltonian Formalisms: Symplectic Transformations, Symplecticity and Variational Integrators</p> <p>Hamilton Jacobi Theory: Hamilton-Jacobi Formalism, Principal Function, Integrability, Level Set Method</p> <p>Transition to Quantum Mechanics: Quantum Objects, Copenhagen Interpretation, Time-independent Schrödinger Equation, Time-dependent Schrödinger Equation, Single Configuration Ansatz, Time-dependent Self-consistent Field System, Ehrenfest's Molecular Dynamics</p> <p>Relativity: Space and Time, Galileo's principle, Einstein's Postulates, Lorentz Transformation, Time Dilation and Length Contraction, Minkowski Diagrams, Doppler Effect, Spacetime and Four-vectors, Relativistic Momentum, Mass and Energy, Photons</p> <p>Fields: Classical View on Gravitation, Electrostatics, Magnetostatics, Electrodynamics, Maxwell's Equations, Gravitation in General Relativity, Quantum Fields</p>
Course Description from Program Guide	<p>This course covers a selection of advanced topics related to computational physics. Based on prior knowledge in calculus and linear algebra, the following topics are considered: Lagrangian formalism, symmetries and conservation laws, stability and bifurcation, multi-body problems and rigid bodies, linear and nonlinear oscillations, Hamiltonian formalism, canonical transformations and invariances, Liouville's theorem, discrete Lagrangian and Hamiltonian formalisms, Hamilton Jacobi theory, transition to quantum mechanics, relativity, fields.</p>
Goals and Objectives	<p>The course is problem oriented, aiming to enable the students to develop accurate solutions for practically relevant problems, based on solid theoretical foundations and mathematically precise modeling. It prepares the students to study and understand advanced literature and state of the art publications on topics related to computational physics.</p>
Required Knowledge	<p>The course will assume basic knowledge (calculus and linear algebra) such as taught in undergraduate mathematics courses.</p>
Reference Texts	<p>J.-L. Basdevant. Variational Principles in Physics. Springer, 2007.</p> <p>E. Hairer, C. Lubich. Geometric Numerical Integration: Structure-Preserving Algorithms for Ordinary Differential Equations. Springer, 2010.</p> <p>L.D. Landau, E.M. Lifshitz. Mechanics, Third Edition, Course of Theoretical Physics, Volume 1. Butterworth-Heinemann, 1982.</p> <p>R.H. Landau, M.J. Páez, C.C. Bordeianu. Computational Physics: Problem Solving with Computers. Wiley, 2007.</p> <p>The Feynman Lectures on Physics: http://www.feynmanlectures.caltech.edu/.</p>
Method of evaluation	<p>0.00% - Final exam 25.00% - Homework /Assignments 75.00% - Course Project(s)</p>
Nature of the assignments	<p>There will be a problem set assigned each week, which will be graded. This homework track is mostly theoretical, but it will include a final project and smaller programming tasks along the way. The final project will consist of writing a physically-based simulation.</p>
Course Policies	<p>Students have to pass a final oral or written exam.</p>

Additional Information

Please do not hesitate to contact the instructor if you have any question.

Tentative Course Schedule*(Time, topic/emphasis & resources)*

Week	Lectures	Topic
1	Sun 01/22/2017 Wed 01/25/2017	Euler-Lagrange Equations of Second Kind: Phase Space, Generalized Coordinates, Constraints, Calculus of Variations and Euler-Lagrange Equations of Second Kind
2	Sun 01/29/2017 Wed 02/01/2017	Lagrangian Formalism: Lagrangian Formalism, Particle Systems, Friction and Dissipation
3	Sun 02/05/2017 Wed 02/08/2017	Symmetries and Conservation Laws: Generalized Momenta, Cyclic Coordinates, Noether's Theorem, Conservation of Energy
4	Sun 02/12/2017 Wed 02/15/2017	Stability and Bifurcation: Chaotic and Nonchaotic Dynamics, Sensitivity to Initial Conditions and Deterministic Chaos, Lyapunov Stability, Lyapunov's First Method, Lyapunov's Second Method, Bifurcations, Attractors
5	Sun 02/19/2017 Wed 02/22/2017	Euler-Lagrange Equations of First Kind: Lagrange Multiplier, Euler-Lagrange Equations of First Kind, SHAKE and RATTLE
6	Sun 02/26/2017 Wed 03/01/2017	Multi-body Problems and Rigid Bodies: Central Force, Two-body Problem, Effective Potential, Multi-body Problems, Center of Mass Theorem, Angular Momentum Theorem, Euler Angles, Lagrangian Equations of the Rigid Body
7	Sun 03/05/2017 Wed 03/08/2017	Linear and Nonlinear Oscillations: Oscillators with a Single Degree of Freedom, Transition to the Continuum, Linear and Non-linear Forces, Calculation of Perturbations, Harmonic Balance, Enforced Non-linear Oscillation, Self- and Parameter-excited Oscillation
8	Sun 03/12/2017 Wed 03/15/2017	Hamiltonian Formalism: Legendre Transformation, Hamiltonian mechanics, Poisson Brackets
9	Sun 03/19/2017 Wed 03/22/2017	Canonical Transformations and Invariances: Point Transformations, Canonical Transformations, Generators, Canonical Invariances of Poisson Brackets, Canonical Invariances of the Phase Volume
10	Sun 03/26/2017 Wed 03/29/2017	Liouville's Theorem: Phase Space Trajectories, Foundations of Statistical Mechanics, Liouville's Theorem and its Consequences
11	Sun 04/02/2017 Wed 04/05/2017	Discrete Lagrangian and Hamiltonian Formalisms: Symplectic Transformations, Symplecticity and Variational Integrators
12	Sun 04/09/2017 Wed 04/12/2017	Hamilton Jacobi Theory: Hamilton-Jacobi Formalism, Principal Function, Integrability, Level Set Method
13	Sun 04/16/2017 Wed 04/19/2017	Transition to Quantum Mechanics: Quantum Objects, Copenhagen Interpretation, Time-independent Schrödinger Equation, Time-dependent Schrödinger Equation, Single Configuration Ansatz, Time-dependent Self-consistent Field System, Ehrenfest's Molecular Dynamics
14	Sun 04/23/2017 Wed 04/26/2017	Relativity: Space and Time, Galileo's principle, Einstein's Postulates, Lorentz Transformation, Time Dilation and Length Contraction, Minkowski Diagrams, Doppler Effect, Spacetime and Four-vectors, Relativistic Momentum, Mass and Energy, Photons
15	Sun 04/30/2017 Wed 05/03/2017	Fields: Classical View on Gravitation, Electrostatics, Magnetostatics, Electrodynamics, Maxwell's Equations, Gravitation in General Relativity, Quantum Fields
16	Sun 05/07/2017 Wed 05/10/2017	Final Projects: Talks
17	Sun 05/14/2017 Wed 05/17/2017	Final Projects: Talks
18		Final Exams: Exams

Note

The instructor reserves the right to make changes to this syllabus as necessary.