Course Syllabus: Advanced Computational Physics - AMCS 255

Division	Computer, Electrical and Mathematical Sciences & Engineering
Course Number	AMCS 255
Course Title	Advanced Computational Physics
Academic Semester	Spring
Academic Year	2017/2018
Semester Start Date	01/28/2018
Semester End Date	05/24/2018
Class Schedule (Days & Time)	10:30 AM - 12:00 PM | Tue Thu

Instructor(s)

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

Teaching Assistant(s)

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

Course Information

Comprehensive Course Description	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. -detailed information are availalbe via http://csg.kaust.edu.sa/teaching/amcs255-2018.html
Course Description from Program Guide	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.
Goals and Objectives	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.
Required Knowledge	The course will assume basic knowledge (calculus and linear algebra) such as taught in undergraduate mathematics courses or in AMCS 101, 131, and 151.

Reference Texts	-J.-L. BasdevantVariational Principles in PhysicsSpringer, 2007 -E. Hairer and C. LubichGeometric Numerical Integration: Structure-Preserving Algorithms for Ordinary Differential EquationsSpringer, 2010 -L. D. Landau and E. M. LifshitzMechanics, Third Edition, Course of Theoretical Physics, Volume 1Butterworth-Heinemann, 1982 -R. H. Landau, M. J. Paez, and C. C. BordeianuComputational Physics: Problem Solving with ComputersWiley, 2007 -The Feynman Lectures on Physics
Method of evaluation	**75.00**% - Course Project(s) **25.00**% - Homework /Assignments
Nature of the assignments	There will be a problem set assigned each week. This homework track is mostly theoretical, but it will include a final project and smaller programming tasks along the way. A final project will consist of writing a physically-based simulation.
Course Policies	The students may collaborate on the assignments and the final project provided each student writes up his or her own solutions and clearly lists the names of all the students in the group (grading policy: 25% homework assignments and 75% final project). If a student misses or anticipates missing more than three days of classes, she or he should contact the instructor to ensure the student is still on track.
Additional Information	

Tentative Course Schedule

(Time, topic/emphasis & resources)

Week	Lectures	Topic
1	Tue 01/30/2018 Thu 02/01/2018	-Euler-Lagrange Equations of Second KindPhase Space, Generalized Coordinates, Constraints, Calculus of Variations and Euler-Lagrange Equations of Second Kind.
2	Tue 02/06/2018 Thu 02/08/2018	-Lagrangian FormalismLagrangian Formalism, Particle Systems, Friction and Dissipation.
3	Tue 02/13/2018 Thu 02/15/2018	-Symmetries and Conservation LawsGeneralized Momenta, Cyclic Coordinates, Noether's Theorem, Conservation of Energy.
4	Tue 02/20/2018 Thu 02/22/2018	-Stability and BifurcationChaotic and Nonchaotic Dynamics, Sensitivity to Initial Conditions and Deterministic Chaos, Lyapunov Stability, Lyapunov's First Method, Lyapunov's Second Method, Bifurcations, Attractors.
5	Tue 02/27/2018 Thu 03/01/2018	-Euler-Lagrange Equations of First KindLagrange Multiplier, Euler-Lagrange Equations of First Kind, SHAKE and RATTLE.
6	Tue 03/06/2018 Thu 03/08/2018	-Multi-body Problems and Rigid BodiesCentral 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	Tue 03/13/2018 Thu 03/15/2018	-Linear and Nonlinear OscillationsOscillators 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	Tue 03/20/2018 Thu 03/22/2018	-Hamiltonian FormalismLegendre Transformation, Hamiltonian mechanics, Poisson Brackets.
9	Tue 03/27/2018 Thu 03/29/2018	-Canonical Transformations and InvariancesPoint Transformations, Canonical Transformations, Generators, Canonical Invariances of Poisson Brackets, Canonical Invariances of the Phase Volume.
10	Tue 04/03/2018 Thu 04/05/2018	-Liouville's TheoremPhase Space Trajectories, Foundations of Statistical Mechanics, Liouville's Theorem and its Consequences.
11	Tue 04/10/2018 Thu 04/12/2018	-Discrete Lagrangian and Hamiltonian FormalismsSymplectic Transformations, Symplecticity and Variational Integrators.

12	Tue 04/17/2018 Thu 04/19/2018	-Hamilton Jacobi TheoryHamilton-Jacobi Formalism, Principal Function, Integrability, Level Set Method.
13	Tue 04/24/2018 Thu 04/26/2018	-Transition to Quantum MechanicsQuantum 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	Tue 05/01/2018 Thu 05/03/2018	-RelativitySpace 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	Tue 05/08/2018 Thu 05/10/2018	-FieldsClassical View on Gravitation, Electrostatics, Magnetostatics, Electrodynamics, Maxwell's Equations, Gravitation in General Relativity, Quantum Fields.
16	Tue 05/15/2018 Thu 05/17/2018	-Discussion of final projects
17	Tue 05/22/2018 Thu 05/24/2018	-Discussion of final projects
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Note
The instructor reserves the right to make changes to this syllabus as necessary.