American University of Beirut
Faculty of Arts and Sciences
Department of Physics

Course Number and Title: **Phys 301, Classical Mechanics**

Course objective and learning outcomes:

Classical Mechanics is the starting course in the Graduate core program in theoretical physics. It introduces students to the mathematical structure of modern theoretical physics where the notions of transformation groups and symmetry play a central role. The main objective of the course is to build a framework based on such recurrent notions as configuration and phase spaces, variational principles, invariance under certain transformations, stability of motion and the loss of it. On the more practical side, the course also aims to develop problem-solving skills with the emphasis on analyzing the solution and exploring its consequences, in particular, as a means of verification.

Students should be able to:

- Explain clearly the notion of degrees of freedom, and identify them for a given mechanical system
- Identify the existing symmetries and the corresponding integrals of motion; analyze the qualitative nature of dynamics (de-coupling of certain degrees of freedom, periodicity, stability, integrability) on the basis of general principles without explicitly solving equations of motion
- Explain the notion of the phase space; explain how the nature of the dynamics is reflected in the properties of the phase space trajectories; understand and use phase portraits to analyze the dynamics
- Find the Lagrangian and the Hamiltonian, set up and solve the equations of motion for any reasonable mechanical system, including two-body systems, rigid bodies, coupled linear and non-linear oscillators, systems with time-dependent constraints.
- Use approximate and numerical methods for solving equations of motion

Resources available to the students:

Main textbooks:
Mechanics by F. Scheck, 2 edition, Springer, 1994.
Classical Mechanics by H. Goldstein, 3 edition, Addison-Wesley, 2001.
Some material is explained in a simple and clear way in *Introduction to Dynamics* by I. Percival and D. Richards, Cambridge U. Press, 1982.

Grading criteria:

The final grade will be a weighted average of the four graded homework sets (12% each), a mid-term exam (17%) and the final exam (35%).

Schedule

Week	Topics	Dates and assignments
1.	Review of basic mechanics; conservation laws; transformation to the center of mass frame; Galilei transformations	
2.	Lagrangian formulation of mechanics; variational principles; symmetries and conservation laws;	
3	Rotations; transformation properties under the rotation group; rotating reference frames	First graded homework due
4	Applications of the Lagrangian mechanics: central force problem; Kepler problem; scattering	
5	Small oscillations, normal modes and normal coordinates	
6	Canonical equations of motion; canonical transformations; symplectic structure of the phase space	Second graded homework due
7	Infinitesimal canonical transformations; Poisson brackets; Liouville theorem	
8	Rigid bodies; tensor of inertia; Euler angles	
9	Torque-free motion, Euler equations, stability; symmetric top	Mid-term exam
10	Hamilton-Jacoby theory; completely integrable systems	
11	Action-angle variables; adiabatic invariants; averaging over fast perturbations	Third graded homework due
12	Dynamical flows, classification of critical points; Lyapunov exponents	
14	Poincare sections, discrete mappings; deterministic chaos	Fourth graded homework (numerical project) due