UCLouvain

lmat1261

2021

Lagrangian and Hamiltonian mechanics

5.00 credits	22.5 h + 30.0 h	Q1

Teacher(s)	Walmsley Hagendorf Christian ;
Language :	French
Place of the course	Louvain-la-Neuve
Prerequisites	Mathematical analysis courses LMAT1121 and LMAT1122, linear algebra course LMAT1131, mathematical physics course LMAT1161. Proficiency in the French language at the senior high school level. *The prerequisite(s) for this Teaching Unit (Unité d'enseignement – UE) for the programmes/courses that offer this Teaching Unit are specified at the end of this sheet.*
Main themes	Lagrangian mechanics. Variational principles in analytical mechanics and canonical formalism. Symmetries and conservation laws. Solid body motion.
Learning outcomes	**At the end of this learning unit, the student is able to :** **Contribution of the course to the learning outcomes of the bachelor's degree program in mathematics.** **By the end of this activity, the student will have progressed in his/her ability to :** (a) Know and understand a fundamental foundation of mathematics. In particular, he/she will have developed the ability to : • i. Select and use fundamental computational methods and tools to solve mathematical problems. • ii. Recognize the fundamental concepts of some current mathematical theories. • iii. Establish the major connections between these theories, explain and motivate them with examples. (b) Identify, through the abstract and experimental approach of the exact sciences, the unifying aspects of different mathematical situations and experiences. 1 (c) Demonstrate abstraction and critical thinking skills. In particular, the student will have developed the ability to: • i. Recognize the key arguments and structure of a demonstration. • ii. Distinguish between the intuition of the validity of a result and the different levels of rigorous understanding of the same result. **Course Specific Learning Outcomes.** **At the end of this activity, the student will be able to :** • (a) Write the Euler-Lagrange equations for a system with several degrees of freedom. • (b) Solve elementary variational problems, be familiar with the Hamiltonian formalism. • (c) Determine and exploit the symmetries of a mechanics problem to describe its motion and characteristics. • (d) Describe and analyze solid body motion.
Evaluation methods	The evaluation is based on a written exam and a continuous evaluation conducted during the semester. The written exam focuses on theoretical concepts and their application to analytical mechanics problems. It tests the understanding of the concepts seen in the course, the ability to analyze an analytical mechanics problem through mathematical modeling, the mastery of computational techniques and the coherent presentation of solutions. The result of the continuous assessment will be used for each session and cannot be represented. The evaluation methods may be adapted and modified according to the evolution of the Covid-19 pandemic.
Teaching methods	The learning activities consist of lectures and practical sessions. The lectures aim to introduce the fundamental concepts, to motivate them by giving examples and establishing results, to show their reciprocal links and their relationship with other courses in the Bachelor's program in mathematical and physical sciences. The practical sessions aim to learn how to model physical problems, choose and use computational methods for their analysis and interpret the results obtained.

Content	The aim of LMAT1261 is to present an overview of the concepts of analytical mechanics. The course's topics play an important role in other disciplines of the bachelors in physics and mathematics. Their presentation is adapted to the students of both these bachelors. The course treats the following topics : 1. Lagrangian mechanics • constrained systems, generalised coordinates; • d'Alembert principle, the Euler-Lagrange equations; • Hamilton's principle, elements of the calculus of variations; • symmetries and conservation laws. 2. Hamiltonian mechanics • the Legendre transformation; • canonical equations of motion; • Poisson brackets; • canonical transformations. 3. Hamilton-Jacobi theory • the Hamilton-Jacobi equation; • separation of variables; • action-angle variables; • towards quantum mechanics.
Inline resources	The course's Moodle website provides lecture notes, exercise sheets, a detailed syllabus and an ample bibliography.

Bibliography	• Arnold, *Mathematical methods of classical mechanics.* Springer 1997 Ouvrage à recommander aux étudiants avec une préférence pour la rigueur mathématique. Il est très détaillé et dépasse largement le cadre du cours. • Fomin, *Calculus of variations.* Dover Publications 2000. Ouvrage classique sur le calcul variationnel et ses applications à la mécanique classique, contient de nombreux exemples et exercices. • Landau, Lifshits, *Cours de physique théorique. Tome 1 : Mécanique*. Edition Mir 1994. Ceci est une référence standard pour physiciens. Il couvre tous les sujets des cours LMAT1161 et LMAT1261 (et bien plus), contient des exercices et leurs solutions. • Morin, *Introduction to Classical Mechanics: With Problems and Solutions.* Cambridge University Press 2008. Ouvrage récent très pédagogique, contient beaucoup d'exercices et leurs solutions. • Nolting, *Theoretical Physics 2: Analytical mechanics.*Springer-Verlag 2016. Ouvrage très pédagogique, contient beaucoup d'exercices et leurs solutions. • Goldstein, *Classical mechanics*. Addison-Wesley 2007. Référence classique pour physiciens avec de nombreux exemples, applications et exercices (sans solutions). ---------- • Arnold, Mathematical methods of classical mechanics. Springer 1997 A book to be recommended to students with a preference for mathematical rigor. It is very detailed and goes far beyond the scope of the course. • Fomin, Calculus of variations. Dover Publications 2000. A classic work on variational calculus and its applications to classical mechanics, with many examples and exercises. • Landau, Lifshits, Theoretical Physics. Volume 1: Mechanics. Mir edition 1994. This is a standard reference for physicists. It covers all the topics of LMAT1161 and LMAT1261 (and more), contains exercises and their solutions. • Morin, Introduction to Classical Mechanics: With Problems and Solutions. Cambridge University Press 2008. Recent book, very pedagogical, contains many exercises and their solutions. • Nolting, Theoretical Physics 2: Analytical mechanics.Springer-Verlag 2016. Very pedagogical book, contains many exercises and their solutions. • Goldstein, Classical mechanics. Addison-Wesley 2007. Classic reference for physicists with many examples, applications and exercises (without solutions).
Faculty or entity in charge	SC

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Learning outcomes
Minor in Mathematics	MINMATH	5		🔍
Bachelor in Physics	PHYS1BA	5	LPHYS1111	🔍
Bachelor in Mathematics	MATH1BA	5	LMAT1121	🔍
Additionnal module in Mathematics	APPMATH	5		🔍