1. **Title of the module**

MAST5004 (MA5504) - Lagrangian and Hamiltonian Dynamics

1. **School or partner institution which will be responsible for management of the module**

School of Mathematics, Statistics and Actuarial Science

1. **The level of the module (Level 4, Level 5, Level 6 or Level 7)**

Level 5

1. **The number of credits and the ECTS value which the module represents**

15 credits (7.5 ECTS)

1. **Which term(s) the module is to be taught in (or other teaching pattern)**

Spring

1. **Prerequisite and co-requisite modules**

Pre-requisite: MAST4006 (Mathematical Methods 1), MAST4007 (Mathematical Methods 2) and MAST4002 (Applications of Mathematics)

Co-requisite: None

1. **The programmes of study to which the module contributes**

BSc Mathematics, BSc Mathematics and Statistics (including programmes with a Year in Industry), BSc Mathematics with Secondary Education, BSc Mathematics with a Foundation Year, MMath Mathematics, MMathStat Mathematics and Statistics

1. **The intended subject specific learning outcomes.  
   On successfully completing the module students will be able to:**

8.1 demonstrate knowledge and critical understanding of the well-established principles within Lagrangian and Hamiltonian formulations of Newtonian mechanics, particularly the dynamics of conservative systems;

8.2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: variational calculus, use of generalised coordinates, application of constraints, Euler-Lagrange equations, conserved quantities, Hamiltonian formulation, the Legendre Transform, interpretation of phase portraits;

8.3 apply the concepts and principles in basic Lagrangian and Hamiltonian dynamics in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

1. **The intended generic learning outcomes.  
   On successfully completing the module students will be able to:**

Demonstrate an increased ability to:

9.1 manage their own learning and make use of appropriate resources;

9.2 understand logical arguments, identifying the assumptions made and the conclusions drawn;

9.3 communicate straightforward arguments and conclusions reasonably accurately and clearly;

9.4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;

9.5 solve problems relating to qualitative and quantitative information;

9.6 make use of information technology skills such as online resources (Moodle), internet communication;

9.7 communicate technical material competently.

9.8 demonstrate an increased level of skill in numeracy and computation.

1. **A synopsis of the curriculum**

This module will present a new perspective on Newton's familiar laws of motion. First we introduce variational calculus with applications such as finding the paths of shortest distance. This will lead us to the principle of least action from which we can derive Newton's law for conservative forces. We will also learn how symmetries lead to constants of motion. We then derive Hamilton's equations and discuss their underlying structures. The formalisms we introduce in this module form the basis for all of fundamental modern physics, from electromagnetism and general relativity, to the standard model of particle physics and string theory.

Indicative syllabus:

Review of Newton mechanics: Newton's law; harmonic and anharmonic oscillators (closed and unbound orbits, turning points); Kepler problem: energy and angular momentum conservation

Lagrangian Mechanics: Introdution to variational calculus with simple applications (shortest path - geodesic, soap film, brachistochrone problem); principle of least action: Euler-Lagrange equations (Newtonian mechanics with conservative forces); constraints and generalised coordinates (particle on a hoop, double pendulum, normal modes); Noether's theorem (energy and angular momentum conservation)

Hamiltonian Dynamics: Hamilton's equations; Legendre transform; Hamiltonian phase space (harmonic oscillator, anharmonic oscillators and the mathematical pendulum); Liouville's theorem; Poisson brackets.

1. **Reading list (Indicative list, current at time of publication. Reading lists will be published annually)**

Douglas Gregory, "Classical Mechanics", Cambridge University Press 2006.

Herbert Goldstein, Charles P Poole; John L Safko; "Classical mechanics", Pearson/Addison Wesley, Third edition, 2002.

Patrick Hamill, "A student's guide to Lagrangians and Hamiltonians", Cambridge University Press 2014.

Emmanuele DiBenedetto, "Classical Mechanics Theory and Mathematical Modeling", Boston, MA : Birkhäuser Boston : Imprint: Birkhäuser 2011.

1. **Learning and teaching methods**

Total contact hours: 42

Private study hours: 108

Total study hours: 150

1. **Assessment methods**
   1. Main assessment methods

Assessment 1 Exercises, requiring on average between 10 and 15 hours to complete 10%

Assessment 2 Exercises, requiring on average between 10 and 15 hours to complete 10%

Examination 2 hours 80%

The coursework mark alone will not be sufficient to demonstrate the student’s level of achievement on the module.

13.2 Reassessment methods

Like-for-like

1. **Map of module learning outcomes (sections 8 & 9) to learning and teaching methods (section12) and methods of assessment (section 13)**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Module learning outcome** | *8.1* | *8.2* | *8.3* | *9.1* | *9.2* | *9.3* | *9.4* | *9.5* | *9.6* | *9.7* | *9.8* |
| **Learning/ teaching method** |  |  |  |  |  |  |  |  |  |  |  |
| Private Study | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Lectures/Exercise classes | **X** | **X** | **X** |  | **X** | **X** |  | **X** |  | **X** | **X** |
| Revision classes | **X** | **X** | **X** |  | **X** | **X** |  | **X** |  | **X** | **X** |
| **Assessment method** |  |  |  |  |  |  |  |  |  |  |  |
| Examination | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |  | **X** | **X** |
| Coursework | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

1. **Inclusive module design**

The School recognises and has embedded the expectations of current equality legislation, by ensuring that the module is as accessible as possible by design. Additional alternative arrangements for students with Inclusive Learning Plans (ILPs)/declared disabilities will be made on an individual basis, in consultation with the relevant policies and support services.

The inclusive practices in the guidance (see Annex B Appendix A) have been considered in order to support all students in the following areas:

a) Accessible resources and curriculum

b) Learning, teaching and assessment methods

1. **Campus(es) or centre(s) where module will be delivered**

Canterbury

1. **Internationalisation**

Mathematics is an international language with techniques developed and refined by mathematicians across the globe. Mastery of the subject-specific learning outcomes, 8.1 to 8.3, will equip students to apply the theories and techniques of this module in a wide range of international contexts. The module team is drawn from the School of Mathematics, Statistics and Actuarial Science, which includes many members of staff with international experience of teaching and research collaboration.

In compiling the reading list, consideration has been given to the range of texts that are available internationally and a selection of texts has been identified to complement the delivery of the material.

Examples with an international dimension are included in the module where appropriate.

The support SMSAS provides to its students is also internationally attuned given our international student body.

**FACULTIES SUPPORT OFFICE USE ONLY**

**Revision record – all revisions must be recorded in the grid and full details of the change retained in the appropriate committee records.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Date approved | Major/minor revision | Start date of the delivery of revised version | Section revised | Impacts PLOs (Q6&7 cover sheet) |
|  |  |  |  |  |
|  |  |  |  |  |

Revised FSO Jan 2018