1. **Title of the module**

MAST6001 (MA690) - Symmetry Methods for Differential Equations

MAST7001 (MA790) - Symmetry Methods for Differential Equations

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 6 (MAST6001)

Level 7 (MAST7001)

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)**

Autumn or Spring

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

Level 6:

For delivery to students completing Stage 1 before September 2016:

Pre-requisite modules: MA321 (Calculus and Mathematical Modelling); MA588 (Mathematical Techniques and Differential Equations)

Co-requisite modules: None

For delivery to students completing Stage 1 after September 2016:

Pre-requisite modules: MAST5005 (Linear partial differential equations), MAST5012 (Ordinary differential equations)

Co-requisite modules: None

Level 7:

Pre-requisite modules: Students are expected to have studied material equivalent to that covered in the modules above.

Co-requisite modules: None

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

For the level 6 module, BSc Mathematics (including programme with a Year in Industry), BSc Mathematics with a Foundation Year, MMath Mathematics, Graduate Diploma in Mathematics, International MSc in Mathematics and its Applications, MSc in Mathematics and its Applications (including programmes with an Industrial Placement).

For the level 7 module, MMath Mathematics, MMathStat Mathematics and Statistics, International MSc in Mathematics and its Applications, MSc in Mathematics and its Applications (including programmes with an Industrial Placement).

1. **The intended subject specific learning outcomes.  
   On successfully completing the level 6 module students will be able to:**

8.1 demonstrate systematic understanding of key aspects of symmetry methods for solving and simplifying scalar ordinary differential equations;

8.2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: calculation of Lie point symmetry generators, canonical coordinates and differential invariants; identification of invariant solutions; successive reduction of order, where the Lie algebra is solvable; construction of the general solution of a given ordinary differential equation;

8.3 apply key aspects of Lie symmetry methods in well-defined contexts, showing judgement in the selection and application of tools and techniques.

**On successfully completing the level 7 module students will be able to:**

8.4 demonstrate systematic understanding of techniques for finding and using Lie point symmetries to obtain exact solutions of given equations;

8.5 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: calculation of Lie point symmetry generators, canonical coordinates and differential invariants; identification of invariant solutions; successive reduction of order, where the Lie algebra is solvable; construction of the general solution of a given ordinary differential equation;

8.6 apply a range of concepts and principles in Lie symmetry methods in loosely defined contexts, showing good judgment in the selection and application of tools and techniques.

1. **The intended generic learning outcomes.  
   On successfully completing the level 6 module students will be able 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 competent use of information technology skills such as using online resources (Moodle);

9.7 communicate technical material competently;

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

9.9 demonstrate the acquisition of the study skills needed for continuing professional development.

**On successfully completing the level 7 module students will be able to:**

9.10 work competently and independently, be aware of their own strengths and understand when help is needed;

9.11 demonstrate a high level of capability in developing and evaluating logical arguments;

9.12 communicate arguments confidently with the effective and accurate conveyance of conclusions;

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

9.14 solve problems relating to qualitative and quantitative information;

9.15 make effective use of information technology skills such as using online resources (Moodle);

9.16 communicate technical material effectively;

9.17 demonstrate an increased level of skill in numeracy and computation;

9.18 demonstrate the acquisition of the study skills needed for continuing professional development.

1. **A synopsis of the curriculum**

Over a century ago, the Norwegian mathematician Sophus Lie made a simple but profound observation: each well-known method for solving a class of ordinary differential equations (ODEs) uses a change of variables that exploits symmetries of the class. Lie went on to develop this idea into a systematic method for attacking the problem of solving unknown differential equations. Essentially, one can use mathematical tools to force a given differential equation to reveal whether or not it has certain symmetries – provided it has, they can be used to simplify or solve the equation. This module is designed to enable students to understand the mathematics behind Lie’s methods and to become proficient in using these powerful tools.

Indicative content: symmetries of geometrical objects; symmetries of first-order ODEs; how to find Lie symmetries; differential invariants; reduction of order. At level 7, topics will be studied and assessed in greater depth.

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

P. E. Hydon, Symmetry Methods for Differential Equations, Cambridge University Press, (2000).

H. Stephani, Differential Equations: Their Solution Using Symmetries, Cambridge University Press, (1989).

G. W. Bluman and S. C. Anco, Symmetry and Integration Methods for Differential Equations, Springer, (2002)

1. **Learning and teaching methods**

Total contact hours: 42

Private study hours: 108

Total study hours: 150

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

**Level 6**

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 3 hours 80%

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

**Level 7**

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 3 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)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Level 6 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 | 9.9 |
| **Learning/ teaching method** |  |  |  |  |  |  |  |  |  |  |  |  |
| Private Study and Assessment | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** |
| Lectures/exercise classes | **x** | **x** | **x** | **x** | **x** | **x** |  | **x** | **x** | **x** | **x** |  |
| Revision classes | **x** | **x** | **x** |  | **x** | **x** |  | **x** | **x** | **x** | **x** |  |
| **Assessment method** |  |  |  |  |  |  |  |  |  |  |  |  |
| Examination | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** |  | **x** | **x** | **x** |
| Coursework | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Level 7 Module learning outcome** | 8.4 | 8.5 | 8.6 | 9. 10 | 9. 11 | 9.12 | 9.13 | 9.14 | 9.15 | 9. 176 | 9.187 | 9.198 |
| **Learning/ teaching method** |  |  |  |  |  |  |  |  |  |  |  |  |
| Private Study and Assessment | **x** | **X** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** |
| Lectures | **x** | **X** | **x** | **x** | **x** | **x** |  | **x** | **x** | **x** | **x** |  |
| Revision classes | **x** | **X** | **x** | **x** | **x** | **x** |  | **x** | **x** | **x** | **x** |  |
| **Assessment method** |  |  |  |  |  |  |  |  |  |  |  |  |
| Examination | **x** | **x** | **x** | **x** | **x** | **x** | **x** | **x** |  | **x** | **x** | **x** |
| Coursework | **x** | **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 8.6, 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) |
| 16/12/2019 | Major | September 2020 | 8, 9, 10, 12, 13, 14 | No |
|  |  |  |  |  |

Revised FSO Jan 2018