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| **MODULE TITLE** | **Differential Equations** | **CREDIT VALUE** | **15** |
| **MODULE CODE** | **ECM2903** | **MODULE CONVENER** | **Dr Saptarshi Das (Coordinator)** |

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|---|---|---|---|
| **DURATION: TERM** | **1** | **2** | **3** |
| **DURATION: WEEKS** | **11** | **0** | **0** |

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| **Number of Students Taking Module (anticipated)** | **40** |

## DESCRIPTION - summary of the module content

This module introduces various types of ordinary and partial differential equations and a number of analytical and numerical techniques used to solve them. Differential equations are at the heart of countless modern applications of mathematics to natural phenomena and man-made technology. Computational implementation plays a vital role in many areas of engineering, science, finance, health care, etc.
Differential equations develop ideas from Dynamics further, considering rates of change of a model's variables (in one or multiple dimensions) in systems of equations, which relate these rates of change to expressions (functions) of the model's variables. For example, in mechanical systems the rate of change of position, that is velocity, and the rate of change of velocity, that is acceleration, may be set in relation through physical laws. Building on your knowledge of dynamics, calculus and advanced calculus, and using algebraic methods, you will model systems of differential equations, develop an understanding on how to find solutions applying analytical or numerical methods.
The development of an understanding of the theoretical foundation will be accompanied by applications including the growth of plants and organisms, the spread of diseases, physical forces acting on an object or models describing the fluctuations of financial markets. In this, the module will enable you to demonstrate an understanding of, and the competence in, a range of analytical tools for posing and solving differential equations.
Prerequisite modules: "Calculus and Geometry" (ECM1901) and "Advanced Calculus" (ECM1905) or equivalent

## AIMS - intentions of the module

The aim of this module is to introduce you to some representative types of ordinary and partial differential equations, how these are relevant in many fields of applied sciences and engineering, and will introduce you to a number of techniques used to solve differential equations exactly (analytical methods) or approximately (numerical algorithms). You will also develop the computational skills to implement numerical algorithms in Matlab/Python and use these to solve applied problems.

## INTENDED LEARNING OUTCOMES (ILOs) (see assessment section below for how ILOs will be assessed)

On successful completion of this module ***you should be able to***:

**Module Specific Skills and Knowledge**

1 demonstrate an understanding of analytic and numerical techniques for solving basic forms of ordinary differential equations;
2 demonstrate a basic understanding of analytic and numerical techniques for solving low order partial differential equations;
3 demonstrate competency in modelling basic applied problems with differential equations;
4 demonstrate competency in developing and applying quantitative and computational techniques for differential equations;

**Discipline Specific Skills and Knowledge**

5 demonstrate a clear understanding of fundamental mathematical concepts and analytical techniques for ordinary and partial differential equations;
6 demonstrate competency in the development of numerical techniques for differential equations;
7 demonstrate a basic understanding of the relevance of differential equations within the mathematical sciences, and skills to use differential equations for modelling and solving applied problems from engineering and science;

**Personal and Key Transferable / Employment Skills and Knowledge**

8 reason using abstract ideas;

9 formulate and solve problems and communicate reasoning and solutions effectively in writing and presentation;

10 make appropriate use of learning resources;

11 develop self- and time management skills.

## SYLLABUS PLAN - summary of the structure and academic content of the module

- Review of integration methods for separable ODEs, analytical and numerical methods for solving first and second order ordinary differential equations (ODEs), integrating factors, homogeneous and non-homogeneous ODEs, general solutions, particular solutions, reduction of order, variation of parameters method, Existence and uniqueness of ODEs [6 hours];
- Higher order linear ODEs, systems of ODEs, Laplace transform for solving ODEs, stability and qualitative methods for ODEs [3 hours];
- Special functions and their use in series solution of ODEs, Orthogonal functions including Legendre, Bessel and trigonometric functions, Sturm-Liouville Boundary value problems, review of Fourier analysis [9 hours];
- Numerical methods for ODEs: Euler methods, Runge-Kutta methods, Adams-Bashforth methods, Implementation in Matlab/Python [3 hours];
- Examples of partial differential equations (PDEs) and their solutions; examples: Laplace's equation, heat conduction equation and the wave equation, separation of variables, Cartesian, spherical and cylindrical coordinate systems in 1D, 2D, 3D and simple applications, solution of PDEs using series expansions including Fourier series; applications to boundary value problems including polar coordinates [6 hours];
- Numerical methods for PDEs: elliptic, parabolic and hyperbolic PDEs, finite difference method, Dirichlet, Neumann and mixed boundary conditions, Implementation in Matlab/Python [3 hours].

# LEARNING AND TEACHING

## LEARNING ACTIVITIES AND TEACHING METHODS (given in hours of study time)

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|---|---|---|---|---|---|
| **Scheduled Learning & Teaching Activities** | 44.00 | **Guided Independent Study** | 106.00 | **Placement / Study Abroad** | 0.00 |

## DETAILS OF LEARNING ACTIVITIES AND TEACHING METHODS

| Category | Hours of study time | Description |
|---|---|---|
| Scheduled Learning & Teaching activities | 22 | Formal lectures of new material |
| Scheduled Learning & Teaching activities | 11 | Worked examples |
| Scheduled Learning & Teaching activities | 11 | Tutorials for individual and group support |
| Guided Independent Study | 106 | Lecture & assessment preparation, wider reading |

# ASSESSMENT

## FORMATIVE ASSESSMENT - for feedback and development purposes; does not count towards module grade

| Form of Assessment | Size of Assessment (e.g. duration/length) | ILOs Assessed | Feedback Method |
|---|---|---|---|

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|---|---|---|---|
| Weekly exercise | 10 x 1 hours | 1-11 | Exercises discussed in class, solutions provided. |

## SUMMATIVE ASSESSMENT (% of credit)

| Coursework | 40 | Written Exams | 60 | Practical Exams | 0 |
|---|---|---|---|---|---|

## DETAILS OF SUMMATIVE ASSESSMENT

| Form of Assessment | % of Credit | Size of Assessment (e.g. duration/length) | ILOs Assessed | Feedback Method |
|---|---|---|---|---|
| Two sets of problems (1 analytical and 1 numerical problem in Matlab/Python) | 2 x 20 | Each problem set (1 analytical and 1 numerical) consists of a number of questions set in parallel with formative assessment questions. | 1-11 | Written and Oral |
| Written exam - Closed book | 60 | 2 hours | 1-3, 5, 7-11 | Written/Verbal on request |

## DETAILS OF RE-ASSESSMENT (where required by referral or deferral)

| Original Form of Assessment | Form of Re-assessment | ILOs Re-assessed | Time Scale for Re-assessment |
|---|---|---|---|
| All above | Written examination (100%) | All | August Ref/Def period |

## RE-ASSESSMENT NOTES

If a module is normally assessed entirely by coursework, all referred/deferred assessments will normally be by assignment. If a module is normally assessed by examination or examination plus coursework, referred and deferred assessment will normally be by examination. For referrals, only the examination will count, a mark of 40% being awarded if the examination is passed. For deferrals, candidates will be awarded the higher of the deferred examination mark or the deferred examination mark combined with the original coursework mark.

# RESOURCES

## INDICATIVE LEARNING RESOURCES - The following list is offered as an indication of the type & level of information that you are expected to consult. Further guidance will be provided by the Module Convener

**Basic reading:**
**ELE:** http://vle.exeter.ac.uk

**Reading list for this module:**

| Type | Author | Title | Edition | Publisher | Year | ISBN | Search |
|---|---|---|---|---|---|---|---|
| Set | Arfken G.B. & Weber H.J. | Mathematical Methods for Physicists | Electronic | Harcourt/ Academic Press | 2005 | 000-0-120-59825-6 | [Library] |
| Set | O'Neil P.V. | Advanced Engineering Mathematics | 2nd | Wadsworth | 1987 | 000-0-534-06792-1 | [Library] |
| Set | K. F. Rileym, M.P. Hobson, S.J. Bence | Mathematical Methods for Physics and Engineering | 3rd | Cambridge University Press | 2006 | 978-0521679718 | [Library] |
| Set | Stephenson G. & Radmore P.M. | Advanced mathematical methods for engineering and science students | | Cambridge University Press | 1990 | 000-0-521-36860-X | [Library] |
| Set | Stroud K.A. & Booth Dexter J. | Advanced Engineering Mathematics | 5th | Palgrave Macmillan | 2011 | 978-0-230-27548-5 | [Library] |
| Set | Richard Bronson | Differential Equations (Schaum's Outlines) | 4th | McGraw-Hill Education | 2014 | 978-0071824859 | [Library] |
| Set | Paul Duchateau | Partial Differential Equations (Schaum's Outlines) | 3rd | McGraw-Hill Education | 2011 | 978-0071756181 | [Library] |

| CREDIT VALUE | 15 | ECTS VALUE | 7.5 |
|---|---|---|---|
| PRE-REQUISITE MODULES | ECM1901, ECM1905 | | |
| CO-REQUISITE MODULES | | | |
| NQF LEVEL (FHEQ) | 5 | AVAILABLE AS DISTANCE LEARNING | No |
| ORIGIN DATE | Thursday 06 July 2017 | LAST REVISION DATE | Wednesday 05 December 2018 |
| KEY WORDS SEARCH | Differential equations, ODEs, PDEs, numerical methods, special functions. | | |