Engineering Tripos Part IIA, 3C5: Dynamics, 2019-20

Module Leader

Prof R S Langley [1]

Lecturers

Prof R Langley and Prof J Woodhouse

Lab Leader

Dr J P Talbot [2]

Timing and Structure

Michaelmas term, 16 lectures. Introduction and Rigid-body Dynamics: 2 lectures/week, weeks 1-5 (Prof J Woodhouse); Lagrangian Mechanics: 2 lectures/week, weeks 6-8 (Prof R S Langley)

Aims

The aims of the course are to:

- Introduce the ideas and methods of 3D dynamics: the motion of rigid bodies in three dimensions under given forces and moments.
- Introduce the Lagrange and Hamiltonian formulations of mechanics.
- To show how to apply these methods in a straightforward way to a wide range of problems.

Objectives

As specific objectives, by the end of the course students should be able to:

- Represent the inertia of a rigid body by an inertia matrix, be able to calculate the moments and products of inertia for simple shapes, be able to find the principal axes of inertia.
- Derive Euler's equations for the motion of a rigid body under prescribed moments.
- Apply these equations to the motion of symmetrical rotors, to explain the phenomena of precession, nutation and the rate gyroscope.
- Analyse simple problems involving the rolling of rigid bodies, for example a spinning penny on a table.
- Explain the concepts of generalised coordinates and generalised forces.
- Express the kinetic and potential energies of a system in term of the generalised coordinates, and to use these to obtain Lagrange's equations of motion.
- Approximate the kinetic and potential energies by quadratic forms, and hence deduce the mass and stiffness matrices for small vibration of a system about its equilibrium position.
- Explain the concept of generalized momentum and show how the Hamilton's equations can be used to find the equations of motion.
- Explain the concepts of Poisson brackets, conserved quantities, and canonical transformations.

Content

This module aims to present a systematic approach to the study of dynamics. Once the main techniques have been grasped, a very wide range of problems can be tackled with confidence. The first part of the course presents the tools required to analyse rigid-body motion in three dimensions. These are necessary for a proper understanding of gyroscopic systems, inertial navigation, satellites in space and the stability of high-speed rotating systems such as turbines and compressors.

The second part of the course deals with Lagrangian and Hamiltonian mechanics, a systematic way to formulate dynamical problems using energy functions.

Introduction and Rigid-body Dynamics (10L)

- Equations of motion of a rigid body in three dimensions.
- The inertia tensor; principal axes.
- Gyroscopes and their application.
- Problems involving rolling bodies.

Lagrangian Mechanics (6L)

- Lagrange's equations; connection to Newton's laws; generalised coordinates and generalised forces.
- Applications to a range of problems.
- Hamilton's equations, Poisson brackets, conserved quantities, canonical transformations.
- Example applications.

Coursework

Gyroscopic Phenomena

Learning objectives:

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Practical information:

- Sessions will take place in [Location], during week(s) [xxx].
- This activity [involves/doesn't involve] preliminary work ([estimated duration]).
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Full Technical Report:

Students will have the option to submit a Full Technical Report.

Booklists

Please see the Booklist for Part IIA Courses [3] for references for this module.

Examination Guidelines

Please refer to Form & conduct of the examinations [4].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [5] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US4

An awareness of developing technologies related to own specialisation.

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