Engineering Tripos Part IIA, 3C5: Dynamics, 2021-22

Module Leader
Prof H.E.M. Hunt

Lecturers
Prof H.E.M. Hunt, Prof R.S. Langley

Lab Leader
Prof H.E.M. Hunt

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]).

**Full Technical Report:**

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

**Booklists**

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

**Examination Guidelines**

Please refer to Form & conduct of the examinations [2].

**UK-SPEC**

The UK Standard for Professional Engineering Competence (UK-SPEC) [3] describes the requirements that have
to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [4] which sets out the standard for degree accreditation.

The Output Standards Matrices [5] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links
[1] mailto:hemh1@cam.ac.uk