

## Engineering Tripos Part IA, 1P1: Mechanics, 2018-19

### Lecturer

[Dr T Butlin](#) [1]

### Timing and Structure

Weeks 1-8, Michaelmas term, 2 lectures/week

### Aims

The aims of the course are to:

- Convey the fundamental role of mechanics in engineering.
- Introduce the concepts of kinematics to describe the motion of particles and rigid bodies.
- Introduce the concepts of dynamics and apply these to particles and to planar motion of rigid bodies.
- Develop an understanding of different methods for solving mechanics problems: Newton's Laws, Momentum and Energy.
- Develop skills in modelling and analysing mechanical systems using graphical, analytical and numerical approaches.

### Objectives

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

- Apply concepts of kinematics to particles and rigid bodies in two dimensions.
- Specify the position, velocity and acceleration of a particle in 2-D motion in cartesian, polar and intrinsic coordinates using graphical, algebraic and vector methods.
- Differentiate a rotating vector.
- Understand and apply Newton's laws and the equations of energy and momentum of particles.
- Apply Newton's laws to variable mass problems.
- Apply the concept of angular momentum of a particle, and recognise when it is conserved.
- Apply the principles of particle dynamics to satellite motion.
- Determine the centre of mass and moment of inertia of a plane lamina
- Understand and apply the perpendicular and parallel axes theorems
- Understand and apply Newton's laws to rotational motion of planar motion of rigid bodies.
- Understand the concepts of energy, linear momentum and angular momentum of a rigid body, and recognise when they are conserved.
- Apply concepts of relative velocity, angular velocity and instantaneous centre of rigid bodies.
- Apply Newton's laws and d'Alembert's principle to determine the acceleration of a rigid body subject to applied forces and couples
- Be able to apply the concepts of linear momentum, angular momentum, impulses and energy to planar motion of rigid bodies, including impact problems.

### Content

The course structure is summarised below: the square brackets are topic codes that correspond to the textbook reference table.

## Introduction

- Newton's laws of motion [I1]
- Units [I2]
- Forces [I3]
- Free Body Diagrams [I4]
- Frames of reference [I5]

## Kinematics of Particles

- Cartesian coordinates [KP1]
- Polar coordinates [KP2]
- Intrinsic coordinates [KP3]
- Differentiation of a unit vector [KP4]
- Velocity and acceleration in different coordinate systems [KP5]
- Numerical differentiation [KP6]
- Relative position, velocity and acceleration [KP7]

## Dynamics of Particles

- Newton's Laws applied to particles [DP1]
- D'Alembert force for a particle [DP2]
- Equations of motion [DP3]
- Numerical solution methods [DP4]
- Conservation of Energy [DP5]
- Potential energy, equilibrium and stability [DP6]
- Linear momentum [DP7]
- Variable mass systems [DP8]
- Angular momentum [DP9]
- Satellite motion in steady circular and elliptical orbits [DP10]

## Kinematics of Rigid Bodies

- Relative motion [KRB1]
- Angular velocity as a vector [KRB2]
- Rotating reference frames [KRB3]
- Instantaneous centres for planar motion [KRB4]

## Dynamics of Rigid Bodies

- Centre of mass of a rigid body [DRB1]
- Moment of inertia of a planar rigid body [DRB2]
- Dynamics of a rigid body with a fixed axis of rotation [DRB3]
- D'Alembert forces and moments for planar motion of a rigid body [DRB4]
- Linear and angular momentum of rigid bodies in planar motion [DRB5]
- Kinetic energy of a translating and rotating planar body [DRB6]
- Impact problems in plane motion [DRB7]

## REFERENCES

- [1] Gregory, R. D. Classical Mechanics  
[2] Malthe-Sorensen, A. Elementary Mechanics Using Python  
[3] Hibbeler, R.C. Engineering Mechanics: Statics / Dynamics (two books with continuing chapters)  
[4] Meriam, J.L. & Kraige, L.G., Engineering Mechanics. Vol.2: Dynamics  
[5] Prentis, J.M. Dynamics of Mechanical Systems

## Comments:

Gregory [1] is a rigorous textbook with a physics perspective.

Malthe-Sorensen [2] has many numerical examples.

Hibbeler [3] contains many illustrative diagrams and examples.

Meriam and Kraige [4] contains many illustrative diagrams and examples.

Prentis [5] has a different perspective with a strong emphasis on mechanism analysis and graphical methods.

**Topic cross references**

Topic codes with textbook section numbers (incomplete treatment denoted by parentheses)	Gregory	Malthe-Sorensen
I1	3.1	5.3, 5.8, 5.9
I2	3.1	3.1, 3.2
I3	3.3	5.4 - 5.7
I4		5.2, 7.1
I5	3.2	5.8, 6.4
KP1	(1.1 - 1.2)	6.2
KP2	2.3	
KP3		
KP4	2.3	
KP5	(2.3)	
KP6		4.1 - 4.2
KP7	(2.6)	
DP1	4.1 - 4.5	5.3, 7.2 - 7.6
DP2	12.4	
DP3	4.1-4.5	(7.2 - 7.6)
DP4		4.2, 7.4, 7.5, 7.10.3
DP5	6.1,6.2, 6.4	(11.1, 11.2)
DP6	6.3	11.3
DP7	10.1 - 10.4	12.2 - 12.6
DP8	(10.5)	12.7
DP9	11.1 - 11.2	16.4
DP10	7.1, 7.2, 7.3, 7.5, 7.6	(5.5, 7.6)
KRB1	2.6	
KRB2	16.1	14.6
KRB3	17.1	
KRB4		
DRB1	3.5, A.1	13.2
DRB2	9.4, A.2, A.3	15.2

	Gregory	Malthe-Sorensen	Hibbeler	Meriam Kraige	Prentis			
						DRB3	11.6, 16.1	15.1
						DRB4	(11.6)	
						DRB5	11.4, 11.5, 11.6	15.1
						DRB6	9.4	15.2, 15.4, 15.5
						DRB7	10.6	

## Booklists

Please see the [Booklist](#) [2] or Part IA Courses for references to this module.

## Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [3].

## UK-SPEC

The [UK Standard for Professional Engineering Competence \(UK-SPEC\)](#) [4] 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](#) [5] which sets out the standard for degree accreditation.

The [Output Standards Matrices](#) [6] 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:tb267@cam.ac.uk>

[2] <https://www.vle.cam.ac.uk/mod/book/view.php?id=364071&chapterid=41891>

[3] <http://teaching.eng.cam.ac.uk/content/form-conduct-examinations>

[4] <http://www.engc.org.uk/ukspec.aspx>

[5] <http://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahp/>

[6] <http://teaching.eng.cam.ac.uk/content/output-standards-matrices>