Engineering Tripos Part IA, 1P1: Mechanics, 2024-25

Course Leader

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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-Sorenssen, 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-Sorrensson [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-Sorrenssen
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,	(5.5, 7.6)

	Gregory	Malthe-Sorrenssen	Hibbeler	Meriam Kraige	Prentis
	7.5, 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			
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.			
DRB7	10.6				

Booklists

Please refer to the Booklist for Part IA 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 [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] 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.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

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.

E4

Understanding of and ability to apply a systems approach to engineering problems.

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.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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