Engineering Tripos Part IA, 1P1: Mechanical Vibrations, 2023-24

Course Leader

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Lecturer

Dr James Talbot [1]

Timing and Structure

Weeks 7-8 Lent term and weeks 1-4 Easter term, 12 Lectures

Aims

The aims of the course are to:

- Describe mathematically the behaviour of simple mechanical vibrating systems.
- Determine the response of these systems to transient and harmonic excitation.
- Analyse systems with more than one degree of freedom.

Objectives

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

- Obtain differential equations for mechanical systems comprising masses, rigid bodies, rotors, springs and viscous dashpots, noting the analogy with tuned electric circuits.
- Reduce all differential equations to a standard form.
- Solve these standard-form equations for the response to step, ramp, impulsive and harmonic excitation.
- Understand the concept of damping and the meaning of damped natural frequency, damping factor and logarithmic decrement.
- Obtain and solve differential equations in matrix form for mechanical systems with more than one degree of freedom.
- Apply the rudimentary principles of modal analysis to the free vibration of a two-degree-of-freedom oscillator subject to initial conditions.
- Apply these results to the design of a vibration absorber and to methods of vibration isolation.

Content

For each topic, the letter in parentheses is the link to the table at the bottom of the page, giving page numbers in the references.

Introductory material

- The system elements: masses, rigid bodies, rotors, springs and dashpots and their analogies in tuned electric circuits: inductors, resistors and capacitors (a)
- Obtaining differential equations for the motion of linear mechanical systems (b)

First order systems

Go to (c) for book reference pages (c)

- Response to step, ramp and impulsive inputs (d)
- Response to harmonic excitation (e)
- Using the exp(iwt) notation for harmonic response calculations (f)

Second order systems

Go to (g) for book reference pages (g)

- Response to step and impulsive inputs; free vibration and damped SHM (h)
- Response to harmonic excitation (i)
- Damping factor, logarithmic decrement, loss factor (j)

Systems with Two or more Degrees of Freedom

Go to (k) for book reference pages (k)

- Degrees of freedom (l)
- Equations of motion in matrix form, obtaining mass and stiffness matrices (m)
- Natural frequencies and mode shapes (n)
- Eigenvalues and Eigenvectors (o)
- Free vibration and the superposition of modes (p)
- Harmonic excitation (q)
- Vibration isolation and absorption (r)

References

(1) DEN HARTOG, J.P. MECHANICAL VIBRATIONS
(2) HIBBELER, R.C. ENGINEERING MECHANICS: DYNAMICS (SI UNITS)
(3) MEIROVITCH, L. ELEMENTS OF VIBRATION ANALYSIS
(4) MERIAM, J.L. & KRAIGE, L.G. ENGINEERING MECHANICS. VOL.2: DYNAMICS
(5) PRENTIS, J.M. DYNAMICS OF MECHANICAL SYSTEMS

Relevant page numbers are given for each topic in the table. Parentheses indicate an incomplete treatment.

Topic	Den Hartog	Hibbeler	Meirovitch	Meriam & Kraige	Prentis
a	2	(212)	(57, 556)	-	25, 27
b	10	212	537	543	25, 27
c	17	174	-	-	-
d	17	186	-	-	-
e	46	197	-	-	-
f	19, 47, 66	-	-	-	11
g	18	210	533	521	23
h	24	216	534	522	31, 37
i	50	219, 306	551	538	42, 47
j	24, 30, 53	(215)	540	(545)	38, 40
k	107	331	-	-	79
l	107	331	-	-	79
m	109, 145	-	-	-	-
n	110	335	-	-	79
o	161	-	-	-	-
p	123	-	-	-	84
q	129	-	-	-	130
r	67, 131	313, 338	-	-	69, 87

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 [2].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] 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.

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.

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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Links
[1] mailto:jpt1000@cam.ac.uk
[2] https://teaching.eng.cam.ac.uk/content/form-conduct-examinations
[3] https://teaching.eng.cam.ac.uk/content/uk-spec