

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

### Lecturer

[Prof R Langley](#) [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  $\exp(i\omega t)$  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 href="#">a</a> | 2          | (212)    | (57, 556)  | -               | 25, 27  |
| <a href="#">b</a> | 10         | 212      | 537        | 543             | 25, 27  |
| <a href="#">c</a> | 17         | 174      | -          | -               | -       |
| <a href="#">d</a> | 17         | 186      | -          | -               | -       |
| <a href="#">e</a> | 46         | 197      | -          | -               | -       |
| <a href="#">f</a> | 19, 47, 66 | -        | -          | -               | 11      |
| <a href="#">g</a> | 18         | 210      | 533        | 521             | 23      |
| <a href="#">h</a> | 24         | 216      | 534        | 522             | 31, 37  |
| <a href="#">i</a> | 50         | 219, 306 | 551        | 538             | 42, 47  |
| <a href="#">j</a> | 24, 30, 53 | (215)    | 540        | (545)           | 38, 40  |
| <a href="#">k</a> | 107        | 331      | -          | -               | 79      |
| <a href="#">l</a> | 107        | 331      | -          | -               | 79      |
| <a href="#">m</a> | 109, 145   | -        | -          | -               | -       |
| <a href="#">n</a> | 110        | 335      | -          | -               | 79      |
| <a href="#">o</a> | 161        | -        | -          | -               | -       |
| <a href="#">p</a> | 123        | -        | -          | -               | 84      |
| <a href="#">q</a> | 129        | -        | -          | -               | 130     |
| <a href="#">r</a> | 67, 131    | 313, 338 | -          | -               | 69, 87  |

**Booklists**

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

## **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.

### **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:rsl21@cam.ac.uk>

[2] <https://www.vle.cam.ac.uk/mod/book/view.php?id=364071&chapterid=41881>

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

[4] <https://teaching.eng.cam.ac.uk/content/uk-spec>