Co-funded by the Erasmus+ Programme of the European Union

Erasmus + Project No598241-EPP-1-2018-1-RS-EPPKA2-CBHE-JP

**Strengthening Educational Capacities by Building Competences and Cooperation in the Field of Noise and Vibration Engineering**

**SENVIBE**

# Review and analysis of the existing MSc Vibro-Acoustic Engineering programmes in EU

**Deliverable 1.4**

**Date: 02/04/2019**

## Content:

# 1. Introduction

The project SENVIBE 'Strengthening Educational Capacities by Building Competences and Cooperation in the Field of Noise and Vibration Engineering' (598241-EPP-1-2018-1-RS-EPPKA2-CBHE-JP):

https://senvibe.uns.ac.rs/

has been approved for financing under the call Erasmus+ Capacity Building in Higher Education EAC/A05/2017, and will be coordinated by University of Novi Sad during the period 15 November 2018 – 14 November 2021.

This Report is the deliverable associated with Task 1.4[1] of the SENVIBE project and covers the review and analysis of the existing MSc programmes in Vibro-Acoustic Engineering (VAE) or Sound/Noise and Vibration (No&Vib) in EU. It also includes some facts about MSc programmes and courses in No&Vib in Serbia. This Report complements the Report on Survey and Comparison of Serbian and EU Education in No&Vib[2] related to Task 1.1, which provides facts about the comparative survey of the education in No&Vib in Europe and Serbia during first two educational cycles in Higher Education. Both Reports are organised methodologically in an analogous form and are focused on six engineering disciplines: Mechanical Engineering, Electrical Engineering, Environmental Engineering, Occupational Safety and Health Engineering, Civil Engineering and Traffic Engineering.

As already emphasized in the Report on Survey and Comparison of Serbian and EU Education in No&Vib, MSc No&Vib programmes do not exist in Serbia. On the other hand, there are a few MSc courses related to No&Vib taught in Serbia. Bearing in mind the wider aim of the SENVIBE project[3], these courses are included in this report for comparison with the related courses taught in Europe.

[1]The tasks can be seen at the SENVIBE web-site, https://senvibe.uns.ac.rs/about/#Outcomes.

[2]The Reports can be downloaded from the project web-site https://senvibe.uns.ac.rs/blog/.

[3]The wider aim of the SENVIBE project is to improve and build national educational capacities, cooperation and competences in dealing with environmental and occupational Noise and Vibration (No&Vib) engineering issues in accordance with ongoing EU integration strategies and the needs identified in Serbia.

# 2. Representative Master programmes in Sound and Vibration in Europe

This section provides details of four representative Master programmes in Sound and Vibration offered at the following European universities:

- University of Southampton, Southampton, UK;
- KTH Royal Institute of Technology, Stockholm, Sweden;
- Technical University of Denmark, Lyngby, Denmark;
- University of Le Mans, Le Mans, France.

An overview of each of them is given respectively in Sections 2.1, 2.2, 2.3 and 2.4, while detailed descriptions of their courses are given in the table in **Appendix I**.

## *2.1 University of Southampton (Southampton, UK)*

MSc degrees in the UK, normally taken after an undergraduate BSC or BEng degree, and are designed around the Credit Accumulation and Transfer Scheme (CATS), where nominally 10 CATS are equivalent to 5 ECTS (European Credit Transfer and Accumulation System) points. To complete and have awarded an MSc from a UK university there needs to be successful completion of 180 CATS, typically 120 taught CATS followed on in parallel with a research project worth 60 CATS points. Taught modules per semester are typically worth 15 CATS, but a double module taught over both semesters can be worth either 15 or 30 CATS dependent on the taught and assessed volume of the content[4].

There is only one MSc course in the area of sound and vibration namely the MSc in Acoustical Engineering:

https://www.southampton.ac.uk/engineering/postgraduate/taught_courses/engineering/msc_sound_and_vibration_studies.page),

having been renamed approximately three years ago from its previous title of Sound and Vibration Studies. It is a full time course, although like the environmental acoustics MSc courses at the University of Salford:

See https://beta.salford.ac.uk/courses/postgraduate/environmental-acoustics ), it can be studied on a part-time basis. The formal document detailing the accreditation and university approval, including a list of the modules is at:

https://www.southampton.ac.uk/engineering/postgraduate/taught_courses/engineering/msc_sound_and_vibration_studies.page)

the programme specification for this course for 2019/20 entrants.

The web pages giving the overview is also at:

https://www.southampton.ac.uk/engineering/postgraduate/taught_courses/engineering/msc_sound_and_vibration_studies.page

There are three possible exit degree titles, the generic title of Acoustical Engineering and the alternatives namely Structural Vibration or Signal Processing. The latter can be

[4] https://www.conted.ox.ac.uk/about/cats-points

considered as themes, where a particular set of modules have to be studied with a subsequent research project also in the area of the theme. The Applied Digital Signal Processing theme or pathway provides in-depth training on modern signal processing techniques for biomedical applications and audio signal processing. The Structural Vibration theme or pathway emphasizes advanced techniques to model, measure and control vibration in mechanical systems such as railways and automotive applications.

For simplicity, this report will just present the modules forming the content of the generic programme in **Appendix I**, as the choices and compulsory modules for the other awards are just reduced subsets of these modules. Apart from the Research Project (60 CATS or 30 ECTS), all of the taught modules are worth 15 CATS or 7.5 ECTS, so requiring 180 CATS or 90 ECTS for completion of a full MSc degree.

### *2.2. KTH Royal Institute of Technology (Stockholm, Sweden)*

The traditional Swedish engineering degree is a five-year programme leading to a MSc in engineering. These days the five-year programmes are split into three years for a BSc and two additional years in an MSc programme. The students at major engineering universities such as KTH are admitted directly to a five-year MSc programme where they need to choose a Master programme for the last two years. They can get a BSc after the first three years, which would make it possible to apply to a Master programme at another university in Sweden or in another country. It is however very rare that students do this. There are also some three-year BSc in Engineering programmes which are less theoretical and more focused on engineering skills. A student in these programmes is, different from the students admitted to the five-year (Master of Science in Engineering) programmes, not guaranteed a place at a Master programme but must apply in competition with other external students. The education during the first three years (the BSc part) is completely in Swedish, even though there may be course books in English. The education in all Master programmes is completely in English.

**Appendix I** lists courses in Sound and Vibration, within the Master programme in Technical Acoustics, given in KTH Royal Institute of Technology.

Details are also available at the following web-address:

https://www.kth.se/en.

### *2.3. DTU Technical University of Denmark (Lyngby, Denmark)*

The Engineering Acoustics programme at DTU Technical University of Denmark covers a wide range of topics within Acoustics, including the fundamentals of sound propagation, advanced measurement techniques, and understanding and modelling of the normal and impaired human hearing system.

The MSc Eng is a two-year programme with a workload of 120 ECTS credit points. DTU's master's programmes cover most modern engineering fields and are taught exclusively in English. The programmes comprise four categories of courses: General competences, Technological specialization, Electives, and Thesis.

DTU also offers a Corporate MSc Eng programme as a part-time study where students obtain the 120 ECTS points over a 4-year period.

Details are also available at the following web-address:

https://www.dtu.dk/english/Education/msc.

### *2.4. University of Le Mans (Le Mans, France)*

The International Master's Degree in Electroacoustics at University of Le Mans, offers students the possibility to learn the fundamentals in Electroacoustics and in related fields. The courses are organized in four semesters:

- Semester 1 enables to discover Acoustics & Electroacoustics.  First month (September) is dedicated to Refresher Courses.
- Semester 2 enables to strengthen your skills, especially by doing the first year project.
- Semester 3 is dedicated to professional courses dealing with Electroacoustics and to the second year project (during which you can meet professionals).
- Semester 4 enables to apply your knowledge during a 5 months internship in a company or a laboratory.

Details are also available at the following web-address:

https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FPNgOa#pdfviewer.

# 3. Existing MSc programmes and courses in Noise and Vibration in Serbia

There is no MSc programme in Sound and Vibration, No&Vib or Vibro-Acoustic Engineering in Serbia. However, there are courses related to Acoustics, Vibrations and Noise at the various MSc engineering programmes, such as Electrical Engineering, Civil Engineering, Environmental Engineering, Mechanical Engineering, Mining Engineering, Occupational Safety and Traffic Engineering.

The Master module for Audio and Video Communications at the University of Belgrade is focused on Acoustics, i.e. sound propagation, room acoustic, noise control, design of microphones, speakers and sound systems, and digital audio processing. Its content is very similar to the MSc in Acoustical Engineering at the University of Southampton, but it does not cover vibrations. In Environmental and Occupational Safety Engineering, as well as in Mining Engineering and Traffic Engineering, studies are oriented towards noise and its influence of people and environment. In Mechanical Engineering, courses are focused more on vibrations. The full list of subjects and their content is presented in **Appendix II**.

Since the BSc engineering programmes usually last four years, MSc studies are organized in two semesters, where a student can obtain 60 ECTS points. The only exception is University of Kragujevac, Faculty of Engineering, where BSc studies lasts three years, and MSc studies lasts two years.

## 4. Summary and conclusions

This report gives an overview of four representative MSc programmes in Sound and Vibrations at four EU universities. The Report also covers MSc courses taught in these fields at different public universities in Serbia. It should be noted that, unlike in Europe, there are no MSc programme in these fields in Serbia. This is not surprising, since the Serbia Skilled Occupation List neither contain a Vibro-Acoustic or Acoustic Engineer nor closely related qualifications. Thus, one important step in the SENVIBE project will be a formal recognition of a Vibro-Acoustic Engineer as an occupation in Serbia designed in a way that corresponds to the existing analogous EU models. It should be then followed by the design on an MSc programme that will lead to this qualification and its formal accreditation.

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**Novi Sad, 02/04/2019**

**Approved by the Quality Assurance Group Leader**
**Sremska Kamenica, 04/04/2019**

**Approved by Project Coordinator**
**Novi Sad, 04/04/2019**

*"This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein"*

## APPENDIX I

## REVIEW OF THE EXISTING MSC COURSES RELATED TO THE NO&VIB FIELDS TAUGHT ON REPRESENTATIVE MSC PROGRAMMES IN EU

| **University**<br><br>**Faculty**<br><br>**Study program** | **Course** | **Course content** | **Educational outcomes/ Purpose** | **Teaching methods** | **Reference** | **Date** |
|---|---|---|---|---|---|---|
| **KTH – Sound and Vibration** | Engineering Acoustics | Theory for elastic waves in fluids and solids. Human response to sound and vibration. Fourier methods, linear systems and frequency response functions. Vibration isolation. Vibrations in beams and plates. Spherical and cylindrical sound waves. Energy methods and room acoustics. Flow Acoustics. Sound in ducts and mufflers. Measurement methods. | After the course students should be able to:<br>Describe fundamental concepts of engineering noise and vibration, measurement techniques and instruments. Explain the effect of noise and vibrations on humans and equipment.<br>Apply Fourier analysis to solve coupled differential equations, calculate the frequency content of periodic and transient signals and implement this knowledge to analyse mechanical systems. Describe methods to distinguish between linear and non-linear mechanical systems.<br>Understand the physical foundations and the mathematical models of sound waves in fluids and solids, wave propagation, transmission, reflection and radiation and understand how to apply these models to sound and | Lectures, measure-ment exercises | https://www.kth.se/student/kurser/kurs/SD2111-20122.pdf?l=en | 21/02/2019 |

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| | | | vibration problems in mechanical and vehicle engineering. | | | |
| **KTH – Sound and Vibration** | Acoustical Measurements | The course consists of theoretical and practical parts. In the theoretical part, students will learn basics of measurement techniques and the physics behind, principles of sensors, error analysis and the ways to reduce measurement errors, and the relevant International Standards. On the practical side, students will carry out around six experiments covering the following topics: Basic acoustic measurements, influence of environment Sound power measurements: sound pressure and sound intensity methods Air-borne and structure-borne sound transmission loss Basic vibration measurements, influence of the sensors Sound absorption and surface acoustic impedance Reverberation time and different ways to measure structural loss factor. | The aim of the course is to teach students basic knowledge of sound and vibration measurements as well as analyses. Students will learn the ability to handle common acoustical measurements and to design new experiments in their future work. After the course students shall be able to: Perform standard measurements in acoustics and in vibration, understand physics behind the measurements. Design new measurements according to requirement Criticize and find possible problems in measurements | Lectures and home assignment, Laboratory work | https://www.kth.se/student/kurser/kurs/SD2165-20072.pdf?l=en | 21/02/2019 |
| **KTH – Sound and Vibration** | Vibro-Acoustics | Wave types in solids. Excitation of vibrations. Modes of vibrations in solids. The mobility concept. Wave propagation and attenuation. Transmission between structures. Acoustical radiation from transmission through structures. Prediction models. | Vibrations are often generated by dynamical and acoustical forces exciting large complex constructions. The aim of the course is to illustrate how these disturbances are excited and how the mechanical energy is transmitted by various wave types in and between structures, how various wave types interact and finally how acoustical energy is radiated from a structure to a surrounding fluid. | Lectures | https://www.kth.se/student/kurser/kurs/SD2140-20072.pdf?l=en | 21/02/2019 |

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| | | | Students graduating from the course shall be able to:<br>Explain free and forced vibrations of a system.<br>Discuss and explain how a structure can be excited.<br>Discuss models for energy flow between structural elements.<br>Explain the response of a structure excited by a harmonic or random forces.<br>Explain kinetic and potential energy of a structure as function of the input power to the system.<br>Discuss some possible methods for the reduction of the transmission of structure-borne sound to a mechanical system.<br>Use some different methods for the prediction of the response of a structure | | | |
| **KTH – Sound and Vibration** | Flow Acoustics | Mathematical tools. The fundamental equations of fluid mechanics. The classical wave equation and its solutions. The inhomogeneous wave equation. Lighthills theory for aerodynamic sound. Curles equation. The convective wave equation. Sound propagation in ducts and pipes. Multi-port theory. Sound from moving sources. Fluid driven self-sustained oscillators – Whistles. Applications with focus on fluid machines and vehicles. | To present the fundamental theories for sound generation and propagation in fluids with non-stationary (turbulent) flow fields.<br>Students graduating from the course should:<br>Be able to derive the classical wave equation and be familiar with the solutions under plane and spherical symmetry including Greens functions.<br>Be able to explain and apply a multipole-expansion and know the | Lectures, Laboratory exercise, Project assignment | https://www.kth.se/student/kurser/kurs/SD2155?l=en | 21/02/2019 |

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| | | | character of the simplest point sources (monopole, dipole, quadrupole).<br>Know about Lighthills acoustic analogy and its limitations and be able to explain the physical mechanisms that generate sound in a flow.<br>Know how flow and motion affects sound propagation and generation and be able to explain phenomena such as the Doppler-shift and the Mach-cone.<br>Be able to apply Lighthills analogy to fluid machines and vehicles and know how the different mechanisms scale with the flow speed.<br>Be able to explain how fluid driven self-sustained oscillators ("whistles") are created and how they can be eliminated.<br>Be able to apply 2-port theory to analyse sound propagation in pipe and duct systems in particular with application to vehicle exhaust systems.<br>Have obtained training in experimental techniques for analysis of sound in ducts. | | | |
| **KTH – Sound and Vibration** | Experimental Structure Dynamics – Project Course | Part 1. Theory: Theoretical basis. Measurement and analysis of dynamic properties of mechanical structures. Analytical and numerical methods to determine the modal parameters of mechanical structures. Applications: Analysis of forced motion. Analysis of | After reading the course students shall, be able to analyse a real engineering problem using experimental modal analysis. More specifically students shall be able to, account for details as well as the overall structure in the principles of experimental structure dynamics, | Lectures, Computer exercise, Laboratory excercise | https://www.kth.se/student/kurser/kurs/SD2150-20182.pdf?l=en | 21/02/2019 |

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| | | coupled structures. Sensitivity analysis. Structural modifications. Computer exercise: Determination of beam vibration modes from experimental data. Part 2. Laboratory exercise and project exercise: Instrumentation and experimental setup. Methods for data acquisition. Measurement of mobility functions. Estimation of frequency modal parameters. Evaluation and presentation of modal results | choose an appropriate physical model to represent the test object, define and measure the input data required for the analysis, account for and use graphical and numerical curve-fitting techniques to extract structure dynamic model parameters, use an appropriate advanced model parameter extraction method implemented in a commercial software, illustrate the analysis results, i e the structure dynamic model, judge the reliability of the analysis results consciously and critically and report the results in a written report. | | | |
| **KTH – Sound and Vibration** | Numerical Methods for Acoustics and Vibration | Introduction to numerical methods in engineering. Mathematical models versus numerical models. Finite difference method. Galerkins method and method of weighted residuals. Simple elements. Stiffness method. Element formulations. Coordinate transformations. Isoparametry. Numerical interpolation. Convergence properties for dynamic problems. Hierarchical elements. Direct and iterative solvers. Eigenvalue analysis. Modal superposition. Integral equations. Examples of acoustic radiation and scattering using BEM. Simple fluid-structure interaction. Response analysis of a coupled problem. Modelling of damping and its effect on the response. | After completing this course, students should be able to:<br>Explain the key concepts behind numerical methods for acoustics and vibrations, such as finite element and finite difference methods, and discuss them in terms of simplifications, accuracy, performance and validation.<br>Apply numerical theory to acoustics and vibrations problems by implementing it in numerical programs, and perform numerical calculations using computational software such as Matlab and ComsolMultiphysics.<br>Reflect on numerical implementations, choose appropriate modelling | Lectures, home assignments | https://www.kth.se/student/kurser/kurs/SD2175-20182.pdf?l=en | 21/02/2019 |

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| | | | approaches and troubleshoot problems that arise.<br>Evaluate and critically judge numerical results in order to suggest improvements from both physical and numerical modelling perspectives.<br>Present the outcome of their work in group discussions, formal oral presentations and written reports. | | | |
| **KTH – Sound and Vibration** | Energy Methods | Introduction to the "high-frequency" response of engineering structures. Free vibrational energy as a response variable. Statistical estimates of the maximum and mean response. Fuzzy structure attachments. The potential flow model and its failure for strong coupling and non-resonant motion. Asymptotic methods for modal density and vibration conductivity. SEA formulations for basic structures. The approximate solution to some "impossible" problems including: acoustic fatigue of space rockets, damage to colliding houses, vibro-acoustic transmission in multi-storey buildings and ships. Introduction to current areas of research and to complementary formulations such as the Wave Intensity Method, the Smooth Energy Method, the Power Injection Method, Transient SEA, the exact power balance formulation, hybrid SEA-FEM formulations. Introduction to commercial software and a computer exercise. | Students graduating from the course shall be able to:<br>Explain and communicate the implications of uncertainty and complexity on the predictability of vibro-acoustic response.<br>Formulate the law of vibrational energy conservation in SEA form for some common structural and acoustic systems.<br>Explain and communicate the capability of the potential flow model for energy.<br>Explain and communicate the limitations of the potential flow model.<br>take a decision on whether to use a commercial software for a particular problem | Lectures, computer exercises | https://www.kth.se/student/kurser/kurs/SD2170-20072.pdf?l=en | 21/02/2019 |

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| **KTH – Sound and Vibration** | Non-linear acoustics | Conservative and non-conservative systems, forced oscillations of systems, continuous systems and travelling waves. Perturbation methods – such as straightforward expansion, Lindstedt-Poincaré method, method of multiple scales, method of harmonic balance, method of averaging – and basic numerical methods. | After the course, the participant shall be able to:<br>Apply perturbation methods to new situations.<br>Predict the response of a novel, non-linear system – approximated by a conservative, finite degree-of-system – using a perturbation method.<br>Predict the response of a novel, non-linear system – approximated by a non-conservative, finite degree-of-system – using a perturbation method.<br>Calculate all the resonance frequencies of a forced, novel, non-linear system – approximated by a non-conservative, single degree-of-system – using a perturbation method.<br>Demonstrate a correct use of a perturbation method in the prediction of the standing wave response of a novel, non-linear continuous system – such as string, beam, plate or shell.-<br>Predict the travelling wave response of a novel, non-linear continuous system using a perturbation method.<br>Analyze non-linear acoustic phenomena.<br>Identify the non-linear phenomena for finite degree-of-freedom systems. Point out the reasons for the non-linear phenomena for finite degree-of-freedom systems. | Lectures, excersises | https://www.kth.se/student/kurser/kurs/SD2180-20132.pdf?l=en | 22/02/2019 |

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| | | | Identify the non-linear phenomena for continuous systems.<br>Point out the reasons for the non-linear phenomena for continuous systems.Judge the value of applied perturbation methods for a given application.<br>Write a short exposition evaluating the relative merits of the applied perturbation methods.<br>Compare the response results predicted by a perturbation method with those of a basic numerical method.<br>Explain the reasons for a good match between results obtained by a perturbation method and those of a basic numerical method.<br>Explain the reasons for any mismatch between results obtained by a perturbation method and those of a basic numerical method.<br>Also after the course, for higher grades (A-C), the participant shall be able to:<br>Display a scientific attitude towards non-linear problems.<br>Demonstrate curiosity in identifying non-linear problems.<br>Seek natural causes of non-linear phenomena.<br>Demonstrate open-mindedness when seeking solutions. | | | |

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| | | | Suspend judgments until all evidence is available.<br>Show objectivity in analyzing evidence and drawing conclusions.<br>Show willingness to revise conclusions as new evidence becomes available. | | | |
| **KTH – Sound and Vibration** | Vehicle Acoustics and Vibration | Review of current methods for the noise, vibration and harshness (NVH) design of passenger vehicles. Load cases, analysis types and CAE (Computer Aided Engineering) optimization processes. NVH analysis with relationship to other vehicle function CAE processes. Modeling, analysis procedures and accuracy of results in "virtual" vehicle development process. Variability in actual vehicle structures. Materials, modeling and design, for NVH treatment. Sound quality. Source identification | Understand the basic principles of the design aspects for NVH in cars.<br>To know the most dominant sources of noise and vibration in cars, the dominant transmission paths including their relative importance at different driving conditions.<br>To understand the critical design issues and their relations for NVH, in particular the aspects of objective and subjective design.<br>To get a basic knowledge in the process driving concurrent design, in particular in view of vehicle acoustics.<br>To get an overview of state-of-the art in Computer Aided Engineering applied to NVH together with examples of NVH issues treated by CAE and to understand the limitations of the models used.<br>To get a basic understanding of the difference between objective and subjective (human response) design criteria and how they influence the design process.<br>To get an overview of modern design solutions in NVH, the materials used | Lectures, home assignments | https://www.kth.se/student/kurser/kurs/SD2190-20072.pdf?l=en | 22/02/2019 |

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| | | | and their principle function, together with the current trends in the development of new solutions | | | |
| **KTH – Sound and Vibration** | Building Acoustics and Community Noise | Perception of sound, different measurements and measurement methods. Room acoustics, sound propagation, reflexes, reverberation time, etc. Building acoustic fundamental knowledge, sound insulation and how this is affected by walls, floor joists, resonances, windows, etc. Traffic noise, how sounds from different of traffic sources are calculated and modified with e.g. noise screens. Community noise fundamental knowledge, WHO's Research Compilations, Guidelines, Health Impact, etc. Ground vibrations and vibrations in buildings. | Students will, after passing the course:<br>Be aware of the main features of the hearing system and how sound is experienced.<br>Know and be able to use space acoustic terminology.<br>Be able to formulate and execute calculations of basic building acoustic problems e.g. sound insulation and how this is affected by walls, floor joints, resonances, windows, etc.Implement methods for calculating traffic noise.<br>Know the causes of current guidelines for noise, such as annoyance and medical reasons.<br>Be able to explain how soil vibration and vibrations in buildings arise, reproduce and calculate | Lectures | https://www.kth.se/student/kurser/kurs/SD2166-20182.pdf?l=en | 22/02/2019 |
| **University of Southampton**<br><br>**Acoustical Engineering** | Fundamentals of Acoustics | Introduction to Acoustics: Acoustic pressure. rms and mean square pressures. Definition and use of the decibel, and the reasons for its use. Addition of quantities (coherent and incoherent) in decibels. Third-octave bands. Human hearing. A-weighting. Sound level meters. Other acoustic metrics. Introduction to the propagation of acoustic disturbances: Longitudinal wave motion, introduction to plane acoustic waves. Speed of sound, frequency, wavelength, wavenumber, particle velocity, | Having successfully completed this module you will be able to:<br>Read, understand and interpret the literature relating to basic topics in acoustics.<br>Model simple acoustical problems involving sources of sound in simple geometries.<br>Undertake acoustic measurements and provide critical analysis and conclusions. | Tutorial classes, lectures, practical classes and workshops, laboratory work | https://www.southampton.ac.uk/courses/modules/isvr6136.page | 21/02/2019 |

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| | | characteristic acoustic impedance. Thermodynamics of acoustic compressions. Linear relationships between basic acoustic quantities. Variation of speed of sound with temperature and pressure. One-dimensional acoustic wave motion: Conservation equations in one dimension; linearisation of governing equations; derivation of one-dimensional wave equation. Solutions to the one-dimensional wave equation. Complex exponential representation of wave motion. Helmholtz equation. Linearity and the superposition principle. Specific acoustic impedance. Acoustic energy density and intensity. Standing waves. Application to impedance tube measurements. Concepts of nonlinear propagation. Waves in three dimensions: Conservation equations in three dimensions; derivation of the three-dimensional wave equation. Solutions to the three-dimensional wave equation. Spherical waves. Impedance of spherical waves. Sound radiation from a pulsating sphere. The point monopole source. Sound intensity due to a spherical wave. Sound power output of a pulsating sphere and its radiation efficiency. Sound Intensity measurement. Sound in enclosures: Solution to the three-dimensional wave equation in a room with rigid walled boundaries. Room modes and their natural frequencies. Modal statistics; modal density, modal overlap and the Schroeder | Manipulate complex numbers in the solution of problems associated with wave motion.<br>Produce a formal technical report. | | | |

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| | | frequency. The concept of a diffuse field. Average absorption coefficient and the energy balance equation, reverberation time. Sound radiation: The Rayleigh integral for the solution of sound radiation problems. Radiation from a plane vibrating piston. On axis radiation in near and far fields of a circular piston. Directivity and interference. Radiation impedance. Multipole sources: The point monopole source. The point dipole source; vector dipole strength. Quadrupoles. Green Function. Kirchoff-Helmholtz Integral. Sound reflection, transmission, refraction and attenuation: Reflection and transmission at a fluid-fluid interface. The transmission and reflection coefficients. Normal and oblique incidence. Refraction in the atmosphere and underwater: Snell's law. Sound attenuation. | | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Fundamentals of Vibration | Introduction. Vibration problems in engineering. Terminology. Basic principles. Single degree of freedom system. Free vibration of mass-spring system: natural frequency. Free vibration with damping: damping factor. Energy methods. Time harmonic forced vibration: resonance. Isolation, base excitation and other applications. Structural damping. Transient vibration; response to transient excitation; Duhamel's Integral; forced vibration with various loads including earthquake; impulse response. Multiple degree of freedom systems. Free vibration of two degree of | Having successfully completed this module you will be able to:<br>Interpret the behaviour of vibrating systems through an understanding of basic principles and the role of mass, stiffness and damping.<br>Select appropriate techniques for the solution of analytical problems in vibrations.<br>Undertake measurement of vibration quantities and measure modes of vibration on a simple structure<br>Describe the behaviour of structures by modal and wave approaches. | Lectures, laboratory sessions | https://www.southampton.ac.uk/courses/modules/isvr6141.page#aims_and_objectives | 21/02/2019 |

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| | | freedom systems: developing stiffness and mass matrices for lumped parameter systems, modes of vibration, natural frequencies and mode shapes. Multiple degree of freedom systems: matrix methods. Time harmonic forced vibration with damping: modal decomposition. Time domain solutions. Multi-storey structure. Introduction to vibration treatment and dynamic vibration absorbers. Modelling methods Rayleigh's method. Lagrange's equations for free undamped vibration. Applications. Finite Element Method (FEM) basis. Continuous system. Free vibrations of strings, bars and shafts: equation of motion, boundary conditions. Modes of vibration: natural frequencies and mode shapes. Bending vibration of beams. Forced vibration of continuous systems: modes and resonance. Introduction to structural wave motion in one dimension: propagation, reflection and transmission; coincidence. Fundamentals of Vibration Control. Sources of vibration. Mobility/Impedance Methods. Vibration Isolation: mobility approach, energy considerations. Vibration Damping (different types of damping, viscoelastic damping, damping treatments, measurements of damping). Vibration measurement and analysis (Lab sessions) Vibration transducers and measurement of frequency response functions and modal damping. | Develop the equations of motion for free and forced vibration of simple systems.<br>Show understanding of the benefits and limitations of basic vibration control methods. | | | |

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| **University of Southampton**<br><br>**Acoustical Engineering** | Noise Control Engineering | Noise control requirements: Motivation for noise control, EC directives on machinery noise and outdoor equipment, specification of noise control targets.<br>Units of noise measurement: Overview of decibels for sound pressure, intensity and power levels; combining sound pressures (incoherent and coherent); basic frequency analysis including one-third octave bands; A-weighting and other measures of sound.<br>Characterization of noise sources: Physical nature of noise sources, idealizations; acoustical efficiency; frequency spectrum; parametric dependencies including operational speed; directivity; estimation of source sound power (including engines, fans etc.). Summary of sound power measurement methods.<br>Sound propagation outdoors and indoors: Point source and line source; geometric spreading; ground effects; meteorological effects; noise barriers; sound in rooms, reverberant field.<br>Principles of passive noise control: Effect of multiple sources and multiple paths; noise path models; control at source; airborne transmission; structure-borne transmission.<br>Sound radiation from vibrating structures (engineering approach)<br>Definition of radiation ratio; radiation from monopole and dipole sources; radiation from bending waves in plates; corner | Ability to use common units of noise measurement, characterise noise sources, be familiar with standard methods for the measurement of sound power - use appropriate formulae for sound propagation, radiation from vibrating sources, transmission through partitions, absorption by porous materials, vibration isolation and damping, attenuation by silencers -select appropriate noise control techniques for the solution of practical noise problems and evaluate their performance -apply the noise control techniques considered in an integrated way to a practical design case | lectures; Various practical demonstrations | https://www.southampton.ac.uk/courses/modules/isvr3064.page#aims_and_objectives | 21/02/2019 |

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| | | modes, edge modes, coincidence; means of reducing radiation ratio.<br>Transmission of airborne sound through partitions<br>Transmission loss of a single partition, mathematical derivation for normal incidence; coincidence and the transmission loss for particular angles of incidence and for a diffuse field (qualitative); double partitions (qualitative); measurement methods for sound reduction index; machinery enclosures using Sabine formula.<br>Sound absorbent materials and applications: Surface impedance and its relation to absorption coefficient; qualitative treatment of dissipation mechanisms; practical forms of sound absorber; measurement techniques for absorption.<br>Vibration control: Force and velocity excitation, blocked force and free velocity; vibration isolation - low and high frequency models; damping treatments; effects of damping; structural modification; vibration absorbers and neutralisers.<br>Silencer design: Acoustic impedance; insertion loss; reactive silencers: side branches, expansion chambers; flow-generated noise; lined ducts, splitter attenuators; pressure drop; break-out noise. | | | | |

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| **University of Southampton**<br><br>**Acoustical Engineering** | Electroacoustics | Description of electrical, mechanical and electroacoustic systems as two-port networks. Coupling. Analogies. Acoustic networks. Reciprocity. Microphone and loudspeaker arrays. Hydrophones. Equivalent models for moving coil loudspeakers, and relationship to practical loudspeakers. Loudspeaker performance in terms of frequency response, directivity, and distortion, and their measurement. The influence of an infinite baffle, closed box and tuned cabinets. Crossover networks. The horn equation, simple solutions and application, loudspeaker specifications. Power output and mutual coupling. Diaphragm dynamics.<br>Microphones:<br>Pressure and pressure gradient principles. Diffraction. Diaphragm dynamics and transduction mechanisms hence complete frequency responses for various microphone types. Methods of calibration. Directivity of first order microphones. Diffuse field response. Highly directional microphones. Microphone specifications. Laboratory: Estimation of the Thiele Small parameters of a loudspeaker driver. | Ability to:<br>Describe the general two-port description of transducers including their electrical, mechanical and acoustic properties.<br>Describe the principles of operation of condenser, ceramic, electret and dynamic microphones.<br>Microphone calibration methods.<br>Understand and interpret the literature relating to loudspeaker and microphone design and operation.<br>Recognise and select appropriate techniques for the analysis of electroacoustic problems.<br>Understand product specifications for electroacoustic transducers and interpret manufacturers' catalogues.<br>Recognise and use electroacoustic analogies.<br>Predict changes to the electrical behaviour of a transducer by its mechanical environment and vice-versa.<br>Describe equivalent models for moving coil loudspeakers.<br>Recognise and use the Thiele-Small parameters.<br>Discuss loudspeaker and microphone performance in terms of frequency response, directivity and distortion.<br>Predict the influence of a baffle, a | Lectures; class and a laboratory session | https://www.southampton.ac.uk/courses/modules/isvr6137.page#aims_and_objectives | 21/02/2019 |

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| | | | closed box and a tuned enclosure on the response of a loudspeaker.<br>Discuss the use of crossover networks in loudspeaker systems.<br>Describe the principles of pressure and pressure gradient microphones and be aware of the frequency limits due to equalisation and diffraction. | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Architectural and Building Acoustics | Building acoustics: Legal framework: building regulations, particular requirements for schools and hospitals. - Sound insulation (laboratory tests, in-situ tests, single number ratings Rw and Dw, typical building constructions). Absorption and reverberation time (Sabine and Eyring models, air absorption, typical absorption spectra, and requirements for different purposes). Background noise criteria (NR, PNC, STI); sources of external noise (rain noise, traffic, etc.); sources of noise within buildings (heating, ventilation and air-conditioning noise sources; fans; boilers; chillers; packaged units). Vibration isolation (of noisy equipment, of buildings); ground-borne noise from underground railways.<br>Laboratory sessions: measurement of sound insulation; measurement of sound absorption.<br>Auditorium acoustics: Subjective and objective requirements for different rooms (concert halls, theatres, opera houses, | Ability to:<br>Understand standard measurement methods that are used in building acoustics.<br>Apply prediction methods to assess the transmission of noise in buildings and its mitigation.<br>Apply prediction methods to assess the reverberation of sound in rooms.<br>Select appropriate building constructions for the solution of practical noise problems and evaluate their performance.<br>Make basic room acoustic measurements and determine the various indicators used for auditorium acoustics.<br>Use room acoustics software to model simple auditoria | lectures; laboratory and tutorial classes; Visiting lectures from Arup Acoustics staff | https://www.southampton.ac.uk/courses/modules/feeg6011.page#aims_and_objectives | 21/02/2019 |

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| | | multi-purpose halls). Reverberation (T20, T30, EDT); other indicators (clarity C80, D50, lateral energy fraction, sound strength). - Absorption of seats, audience, other materials, variable absorption. - Scattering and diffusion. Measurement of impulse responses; determination of room acoustic parameters from the IR. Sound source characteristics (musical instruments, speech, singing; sound power, directivity). - Prediction methods (image sources, ray tracing, beam/cone tracing, finite differences, modal methods, physical scale modelling). Public address system design for buildings and auditoria. - Laboratory sessions: measurement of room impulse responses; use of CATT-Acoustic to predict room acoustics.<br>Optional introductory sessions will be provided for students with no background in acoustics.<br>Special Features Guest lectures by practicing auditorium designers. Practical activity measuring the acoustic performance of an auditorium. | | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Human Responses to Sound and Vibration | Sound; The human auditory system. Noise and health Hearing damage risk. Non-auditory health risks, vegetative responses. Disturbance of speech communication Prediction. Standards.; Annoyance at home and in other environments. Sleep disturbance. Planning and noise. | Ability to demonstrate knowledge and understanding of: - principal responses to noise (i.e., perception, loudness, annoyance, speech interference, noise-induced hearing loss).<br>Understand the principal responses to whole-body vibration (i.e., perception, comfort, motion sickness, performance, | Lectures on Sound and lectures on Vibration. | https://www.southampton.ac.uk/courses/modules/isvr3061.page#aims_and_objectives | 21/02/2019 |

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| | | Vibration; Principles of the measurement and evaluation of human vibration exposures. Standards and Directives for whole-body vibration and hand-transmitted vibration. Health effects of whole-body vibration. Effects of whole-body vibration on activities. Discomfort produced by whole-body vibration. Vibration thresholds. Building vibration. Biodynamics (body transmissibility, apparent mass, models). Seating dynamics (transmissibility, SEAT value, models). Health effects of hand-transmitted vibration, their diagnosis, and prevention. Measurement, evaluation, and assessment of the vibration of powered hand-held tools. Causes of motion sickness in marine, land and air transport. | and health) and hand-transmitted vibration (i.e., the hand-arm vibration syndrome, including vibration-induced white finger).<br>Understand the principal methods of measuring and evaluating noise and vibration with respect to human responses.<br>Recognise and select appropriate standards, recommendations, or regulations that apply to particular environments (e.g., domestic, commercial, transport, industrial).<br>Subject Specific Intellectual and Research Skills: Having successfully completed this module you will be able to:<br>Read, understand, and interpret the literature relating to noise and vibration effects upon people - Understand the principles of measuring, evaluating, and assessing both noise and vibration.<br>Apply current standards, limits, and regulations for both noise and vibration.<br>Recognise and select appropriate techniques for the investigation of noise and vibration effects.<br>Transferable and Generic Skills: Having successfully completed this module you will be able to:<br>Access and understand British, European, and International standards. | | | |

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| | | | Access and understand European Union Directives.<br>Deal with logarithmic quantities, SI units, and reference values.<br>Contribute confidently and appropriately to discussions on similar topics.<br>Discuss noise and vibration issues in a multi-disciplinary environment.<br>Assess risk based on technical knowledge and legal requirements.<br>Subject Specific Practical Skills: Having successfully completed this module you will be able to:<br>Measure noise and vibration (both whole-body vibration and hand-transmitted vibration) to which people are exposed.<br>Evaluate noise and vibration to which people are exposed.<br>Assess the severity of noise and vibration to which people are exposed.<br>Recognise means of preventing, or minimising, undesirable effects of noise and vibration on people. | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Numerical Methods for Acoustics | Review of fluid mechanics, derivation of the multi-dimensional equations for linear acoustics. Simple solutions of the unsteady equations. Time-harmonic acoustics. Complex notation and the Helmholtz eqn. Acoustic boundary conditions on finite and infinite boundaries. Time-harmonic benchmark solutions. Acoustic Finite | Ability to:<br>Understand the equations that govern the propagation of sound in a stationary medium.<br>Formulate boundary conditions for practical acoustic problems.<br>Understand and evaluate some simple benchmark solutions for acoustics. | Lectures; exercises; weekly 'tutorial' class; revision lectures; | https://www.southampton.ac.uk/courses/modules/isvr6142.page#aims_and_objectives | 21/02/2019 |

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| | | Elements for the Helmholtz problem. Numerical dispersion and dissipation, the pollution effect. Acoustic Finite Elements for the Helmholtz problem: 2-D and 3-D elements. Boundary element methods for Helmholtz problems. Particular issues for unbounded problems. Finite Difference time-domain methods. Numerical methods based on Ray acoustics. | Understand the underpinning theory and practical application to acoustics of: frequency domain Finite Elements; frequency-domain Boundary Elements; The Finite Difference time domain method; numerical methods based on ray acoustics.<br>Assess the cost, accuracy and practical limitations of the above.<br>Define the equations which govern different classes of acoustical problems.<br>Obtain analytic solutions for simple benchmark problems.<br>Be able to assess the suitability of different numerical methods for a wide range of practical acoustical problems<br>Be able to further develop and apply the numerical methods presented in the course to new types of analysis in acoustics and other areas.<br>Write simple computer programs and reports.<br>To apply critical analysis and evaluation skills.<br>To read, understand and interpret scientific papers.<br>To synthesise information from a range of sources.<br>To communicate clearly in written reports.<br>Ability to: | marked coursework | | |

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| | | | Reduce real world acoustical problems to more simple problems amenable to numerical solution.<br>Select an appropriate numerical method for a broad range of problems in acoustics.<br>Determine the mesh or grid resolution required for different numerical methods.<br>Validate a numerical code against a relevant benchmark problem.<br>Read and understand user documentation for commercial acoustic code | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Applied Audio Signal Processing | Introduction/review of normal and impaired hearing (psychoacoustics), room acoustics and key signal processing techniques. Audio effects. Comb and all-pass filters. Audio effects processing (including equalization, artificial reverb, non-linear and time-variant effects).<br>Automatic gain control and feedback cancellation. Audio compression.Speech processing (including speech enhancement, recognition, synthesis).Real-time audio processing<br>Spatial Audio. Binaural audio. Cross-talk canceller and OPSODIS. Wavefield synthesis and Ambiosonics<br>Array Signal Processing. Uniform linear arrays. Delay sum beamformer. Optimal beamforming. Direction of arrival estimation. Signal detection | Ability to:<br>Identify and apply appropriate signal processing techniques to analyse audio signals to achieve desired outcomes.<br>Argue the advantages and limitations of different signal processing techniques in a given context.<br>Select, implement, apply and evaluate signal processing algorithms to create a range of audio effects.<br>Select, implement, apply and evaluate signal processing algorithms to analyse signals from sensor arrays.<br>Describe the basic working principles of human speech production and use signal processing techniques to simulate the process. | Formal lectures;<br>Tutorials;<br>Recorded video lectures;<br>Flipped classroom activities;<br>Practical signal processing exercises;<br>Signal processing assignments | https://www.southampton.ac.uk/courses/modules/isvr3071.page#aims_and_objectives | 21/02/2019 |

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| | | Case studies, such as:; Hearing aids and cochlear implants | Select, implement, apply and evaluate signal processing algorithms for spatial audio reproduction.<br>Describe and critique the use of signal processing techniques in hearing aids.<br>Describe, select and evaluate digital audio compression techniques. | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Active Control of Sound and Vibration | Active control of plane waves in ducts. Strategies for active control including reflection and absorption. The use of quadratic optimisation in determining the performance of control systems. The principles of single-channel control systems for tonal and random signals. The use of the LMS algorithm in active control systems. Active control of free field sound. Multichannel control of tones and random disturbances. Active control of enclosed sound fields. Active structural acoustic control using integrated actuators and sensors. Stability, performance and robustness of feedback systems. Active headsets. Active vibration isolation systems. Active control of waves in structures. Adaptive signal processing and identification. Control of nonlinear systems. Modal control. | Ability to:<br>Understand the equations that govern the propagation of sound in a stationary medium active control of sound in ducts.<br>Develop reacceptance method for feedback control.<br>Understand nonlinear control strategies and their potential applications.<br>Understand multivariable feedback control system.<br>Formulate independent modal space control.<br>Understand the fundamentals of harmonic control.<br>Apply active structural acoustic control.<br>Formulate single channel control systems.<br>Understand and formulate active control of free field sound field.<br>Understand and formulate active control of enclosed sound fields. -<br>Understand the principle of single-channel control systems. | Series of lectures, Laboratory sessions. Problem based-learning – Simulation in MATLAB using measured data. | https://www.southampton.ac.uk/courses/modules/isvr6139.page#aims_and_objectives | 21/02/2019 |

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| | | | Formulate multi-channel feedforward of tones and random disturbances.<br>Analyse stability in feedback control. -Understand and analyse performance and robustness of feedback systems.<br>Understand how active headsets work.<br>Transferable and Generic Skills: Having successfully completed this module you will be able to:<br>Able to write simple computer programs and reports.<br>Able to Apply critical analysis and evaluation skills.<br>Able to read, understand and interpret scientific papers.<br>Able to synthesise information from a range of sources.<br>Able to communicate clearly in written reports.<br>Subject Specific Practical Skills: Having successfully completed this module you will be able to:<br>Develop simple control algorithms to control both sound and vibration through simulation.<br>Select an appropriate control strategy.<br>-Develop simulation models to predict the behaviour of the system under control.<br>Read and understand user documentation for commercial codes. | | | |

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| | | | Cognitive Skills: Having successfully completed this module you will be able to:<br>Define the equations which govern feedback and feedforward control strategies.<br>Obtain active control solutions for simple benchmark problems.<br>Be able to assess the suitability of different control strategies for a wide range of practical applications.<br>Be able to further develop and apply the control algorithms presented in the course to other areas. | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Advanced Vibration | Introduction; Terminology. Review of single degree of freedom systems. Difficulties of applying conventional numerical methods at high frequency. Alternatives available for high frequencies. Applicability of the methods covered in the module<br>Continuous Systems. Equations of motion, characteristic equations, free vibration, forced vibration, modal summation. Shafts. Timoshenko beam theory and then reduction to Euler-Bernoulli beam theory. Love-Kirchhoff plate theory. Difficulties at high frequencies, high frequency approximations. Mean square response, kinetic energy. Frequency/space averaging of input power and mobility of finite and infinite systems.<br>Discrete Multiple Degree of Freedom (MDOF) systems; Review of 2 DOF & | Have an in-depth knowledge of the theoretical framework for both continuous and discrete structural dynamic models.<br>Understand the benefits and limitations of characterising the dynamics of a structure in terms of its vibration modes and wave behavior.<br>Understand the process and limitations of Finite Element Analysis (FEA) and Statistical Energy Analysis (SEA) for built-up structures.<br>Subject Specific Intellectual and Research Skills:<br>Analyse the free and forced behaviour of simple structures using modal and wave approaches.<br>Transferable and Generic Skills:<br>Translate mathematical formulations | PowerPoint based lectures, tutorials, an in-class quiz and a supervised hands-on laboratory. The three assignments facilitate independe nt study in the areas of analytical, numerical and | https://www.southampton.ac.uk/courses/modules/isvr6133.page | 21/02/2019 |

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| | | extension to n DOF systems. Free response (eigen problem), orthogonality and scaling of modes. Forced response (direct and modal summation). Use of finite element analysis to obtain system matrices. Model reduction techniques (Guyan reduction). Damping matrices, normal and complex modes, loss factor.<br>Experimental techniques - Vibration testing (instrumentation, shaker & hammer testing). Experimental modal analysis (quad picking, circle fitting, rational fraction polynomial method).<br>Waves. Free wave propagation in shafts, beams and plates. Non-dispersive vs. dispersive waves, cut-off frequencies. Dispersion equation and curves; Phase/group velocity. Characteristic impedances. Wave energy and power. Reflection & transmission coefficients. Wave excitation.<br>Statistical energy analysis - Introduction: power and energy, power balance, coupling power proportionality. SEA equations, weak and strong coupling. Energy equations of a simple oscillator, coupled oscillators and multi-modal systems. Wave transmission and coupling loss factors, structural-acoustic coupling. SEA modelling. Problems and pitfalls with SEA. Experimental SEA.<br>Special Features: The module includes a practical laboratory to perform a vibration | into computer code such as Python or MATLAB.<br>Question the validity of modelling assumptions in the light of experimental data.<br>Subject Specific Practical Skills:<br>Perform a vibration based transfer function measurement using an instrumented hammer and a commercial frequency analyser.<br>Assess the reliability of measured transfer functions.<br>Process/interpret measured transfer functions using an experimental modal analysis technique. | experiment al methods. | | |

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| | | test on a structure using typical state-of-the-art equipment and techniques that are used in industry. | | | | |
| **University of Southampton**<br><br>**Acoustical Engineering** | Aeroacoustics | Brief review of fluid mechanics: conservation laws, thermodynamics, vortex dynamics. Propagation of linear waves in moving media: linearized Euler equations, acoustics, vortical and entropy waves, the convected wave equation, basic properties of sound waves in moving media, sound refraction by non-uniform flows. Acoustic impedance with flow: definition and properties of acoustic impedance, Helmholtz resonator, Ingard and Myers conditions for impedance with flow. Methods for solving the wave equations: Green's functions, Green's formula, far field approximations, compact sources, and interferences. Noise radiation by simple sources: types of sources, effect of source motion, convective amplification, the Doppler effect. Sound radiation by free shear flows: Lighthill's analogy, application to noise from turbulence. Noise radiation from solid surfaces: general theory of Flows Williams Hawkings and application to wave extrapolation. Rotor noise: description of source mechanisms from aerofoils, Duct acoustics: sound field in ducts and wave guides, properties of duct modes. Turbo-machinery noise: fan rotor-alone tones, | Discuss the generation and propagation of sound in fluids.<br>Explain the principle of the Lighthill's acoustic analogy, and how this is related to sound generated by turbulent flows.<br>Explain how scaling laws may be derived and to interpret these.<br>Explain how mean flow and boundaries can affect sound generation and propagation.<br>Apply aeroacoustics theory to new problems.<br>Understanding of some of the current state-of-the-art research in aeroacoustics.<br>Transferable and Generic Skills:<br>Write computer programs and reports.<br>Apply critical analysis and evaluation skills.<br>Ability to read, understand and interpret scientific papers.<br>Synthesise information from a range of sources. Communicate clearly in written reports.<br>Subject Specific Practical Skills:<br>Recognize and define terms specific to aeroacoustics. | Sessions which will be used to present the theory and worked examples; Tutorial classes | https://www.southampton.ac.uk/courses/modules/feeg6004.page | 21/02/2019 |

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| | | interaction tones, buzz-saw noise. Aeolian tones: cavity noise, flow-acoustic feedback loops. | Use relevant mathematical methods to solve problems in aeroacoustics.<br>Synthesise theory from different fields of study (e.g. fluid dynamics, acoustics, mathematical methods).<br>Model some complex noise generation problems.<br>Appreciate the limitations of different modelling techniques.<br>Cognitive Skills:<br>Analyseaeroacoustics problems and select appropriate methods for solution of the problems.<br>Assess whether the complexity of a problem in aeroacoustics may be reduced, e.g. by the use of scaling laws.<br>Improved ability to read and interpret scientific textbooks and papers related to aeroacoustics. | | | |
| **DTU Denmark Technical University**<br><br>**Engineering Acoustics** | Fundamentals of acoustics and noise control | Fundamental acoustic concepts and measuring units. Human hearing and speech. Measurement and evaluation of sound, A-weighting, time constants and equivalent sound pressure level. Octave and one-third octave band analyses of noise. Addition of noise from uncorrelated sound sources. The use of complex notation. Energy density, sound intensity and sound power. Impedance concepts. Plane and spherical sound waves, interference fields. Reflection and | A student who has met the objectives of the course will be able to:<br>Describe fundamental acoustic concepts such as the sound pressure, the particle velocity, the speed of sound, the characteristic impedance of the medium.<br>Describe and interpret plane sound fields, including standing waves.<br>Describe and interpret the sound field generated by monopoles and dipoles | Lectures, problem solving and compulsory hand-ins (problem sets and laboratory exercise reports) | http://kurser.dtu.dk/course/31200 | 22/02/2019 |

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| | | transmission of sound. Sound radiation from monopole and dipole sources, sound radiation from a piston in a baffle. Normal modes in a rectangular room. The diffuse sound field, the energy balance equation in a room and the reverberation time. Sound absorbing materials. Natural modes and resonances in simple mechanical and acoustic systems. Structure-borne sound, vibration isolation of machinery. Sound insulation of single and double constructions. Elektrodynamic loudspeakers | Describe the fundamental properties of transducers.<br>Calculate sound transmission between two fluids.<br>Explain the effect of a reflecting plane.<br>Explain how sound is measured, describe the decibel scale, A-weighted levels, and octave and one-third octave bands<br>Explain the usefulness of the concept of sound power and describe how this quantity is used.<br>Describe and interpret resonances and modes in rooms.<br>Describe and interpret acoustic energy balance considerations in a room.<br>Describe fundamental properties of our hearing, hearing threshold, masking<br>Calculate sound transmission through simple constructions | | | |
| **DTU Denmark Technical University**<br><br>**Engineering Acoustics** | Acoustic signal processing | This course provides the fundamental knowledge in digital signal processing techniques relevant in (but not limited to) modern acoustical engineering and hearing science. The following topics will be covered:<br>• Sampling in time and space<br>• Fourier analysis<br>• Windowing and zero-padding<br>• Orthogonal signal spaces<br>• Linear system analysis<br>• Filters and filter banks | A student who has met the objectives of the course will be able to:<br>Explain the principles of sampling of continuous-time signals.<br>Describe signals in terms of orthonormal continuous and discrete signal space bases.<br>Use a Fourier transform to analyze signals in the frequency domain in one and two dimensions.<br>Analyze, modify and synthesize signals using the short-time discrete Fourier transform and other filter banks. | Lectures, matlab exercises, laboratory exercises | | 22/02/2019 |

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| | | • Auto- and cross-correlation and coherence<br>• Noise and statistical moments | Apply linear system theory to simulate processing of signals through acoustic systems.<br>Analyze and characterize stochastic signals and systems through power-spectral density, coherence and auto- and cross spectral analysis.<br>Design and perform impulse response measurements to characterize an acoustic system.<br>Design and perform transfer function measurements to characterize an acoustic system.<br>Implement computer programs and visualize results using Matlab. | | | |
| **DTU Denmark Technical University**<br><br>**Civil Engineering**<br><br>**Architectural Engineering** | Building acoustics | Basic acoustic concepts. Noise effects on human beings. Measurement of sound and noise rating methods. Outdoor sound propagation. Traffic noise. Noise barriers. Room acoustics and reverberation time. Sound absorbing materials. Airborne sound and impact sound insulation. Vibrations and noise from building services. Sound transmission through ducts, noise from ventilation equipment. Noise regulations and noise control in the environment and in buildings. Principles for acoustical design of rooms. | A student who has met the objectives of the course will be able to:<br>Describe the fundamental acoustic concepts such as the sound pressure, sound power, sound energy density, sound intensity<br>Describe fundamental properties of hearing and effects of noise on human beings<br>Explain how sound is measured, Describe the decibel scale, A-weighted levels, and octave and one-third octave bands.<br>Explain the influence of wind and temperature gradients on outdoor sound propagation and the effect of noise barriers. | Lectures, problem solving | http://kurser.dtu.dk/course/31241 | 22/02/2019 |

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| | | | Calculate the attenuation of sound with distance in a free field and in a room.<br>Interpret resonances and modes in a room.<br>Calculate the reverberation time in a room.<br>Describe the sound absorptions properties of porous absorbers, panel absorbers, and resonant absorbers.<br>Calculate the sound insulation of single and double constructions, and describe the critical frequency and the resonance frequency of a double construction.<br>Describe and calculate resonance frequency and the attenuation by a simple vibration isolator.<br>Describe and calculate the sound attenuation through a ventilation duct.<br>List the basic principles for good acoustical design of rooms. | | | |
| **DTU Denmark Technical University**<br><br>**Civil Engineering**<br><br>**Engineering Acoustics** | Architectural acoustics | The reflection and absorption of sound. Panel absorbers, resonance absorbers and porous absorbers. Theoretical and subjective room acoustics. Acoustics in new and old theatres, churches and concert halls. Room acoustic parameters. Designing of rooms for speech and music. The use of scale models and computer models as design tools. Variation of room acoustics by physical changes and by electronic means. | A student who has met the objectives of the course will be able to:<br>Explain the principles and basic assumptions behind theories used for sound insulation, such as sound radiation and structural waves in plates and statistical energy analysis (SEA).<br>Predict the flanking transmission and sound propagation in buildings with homogeneous single walls. | Lectures, laboratory exercises, excursion and project work. The projects are similar to real consultant projects, | http://kurser.dtu.dk/course/31240 | 22/02/2019 |

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| **Architectural Engineering** | | The sound insulation of buildings and building elements from external and internal noise, including forced and resonant transmission, and single and double walls. Sound radiation from vibrations in walls. Introduction to structure borne sound and statistical energy analysis (SEA). Floating floors and impact sound insulation. Flanking transmission and sound propagation in building constructions. Sound insulation of older buildings and of modern lightweight constructions. Building acoustic test measurements.<br>About one third of the time is used on a building project in which the acoustical conditions are solved by using the knowledge gathered during the course. | Calculate the air borne and impact sound insulation of common single and double building constructions, including elements such as floor coverings, floating floors, doors and windows.<br>Describe the sound insulation of older buildings and of modern lightweight constructions.<br>Calculate the sound absorption coefficient for common sound absorbers, including porous-, panel- and resonant absorbers.<br>Relate the objective acoustic parameters with the subjective impression of the acoustics of a room or building (such as early decay time, clarity, sound reduction index etc.)<br>Predict the influence of room geometry and absorption, reflection, diffraction and diffusion properties of surface on the impulse response and perceived acoustic condition<br>Design the acoustics of rooms for speech and music in cooperation with architects and building engineers.<br>Understand the basic principles regarding introducing loudspeaker systems for amplification and reverberation enhancement in rooms.<br>Describe the principles and basic assumptions of computer prediction | and when possible, include cooperation with external partners. | | |

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| | | | programs such as "Odeon" and "Bastian" and operate these.<br>Explain the basic assumptions and principles of and apply measurement methods in architectural acoustics, including sound insulation, reverberation time, speech intelligibility, sound absorption etc. | | | |
| **DTU Denmark Technical University**<br><br>**Electrical Engineering**<br><br>**Architectural Engineering**<br><br>**Engineering Acoustics** | Environmental acoustics | Human hearing in relation to annoyance and risk of hearing damage due to noise exposure. Types of environmental noise sources. Noise exposure metrics. Acoustic regulation of workrooms. Outdoor sound propagation and noise screens. Noise from roads, railways and airports. Noise from industrial plants. Environmental requirements for noise and vibration. Sound insulation of windows and facades. Sound level measurements and noise analysis. On-site noise investigation. | A student who has met the objectives of the course will be able to:<br>Classify environmental noise sources.<br>Evaluate potential health effects of noise exposure depending on the nature and level of the sound source.<br>Analyze traffic, industrial, and workplace noise and quantify their degree of annoyance.<br>Describe noise limits for different areas.<br>Describe outdoor sound propagation and explain by which factors it is influenced.<br>Plan and perform a noise investigation.<br>Justify the metrics used as noise indicators for the chosen situation<br>Relate the investigation results to noise regulations, perceived annoyance, and potential health effects.<br>Evaluate possible means for reduction of the noise.<br>Communicate the motivation, methods, results, and interpretation of the noise investigation. | Overview lectures, excursions, and project work | http://kurser.dtu.dk/course/31250 | |

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| **DTU Denmark Technical University**<br><br>**Electrical Engineering**<br><br>**Engineering Acoustics** | Advanced acoustics | Plane waves and higher-order modes in ducts. The modal theory of room acoustics; statistical room acoustics. Sound power determination. Measurement of sound intensity. Numerical acoustics (finite element and boundary element methods). Radiation of sound from point sources and plane, cylindrical and spherical sources. Scattering of sound. An introduction to near field acoustic holography and beamforming. Spatial sound, ambisonics and sound field reproduction with loudspeaker arrays. | A student who has met the objectives of the course will be able to:<br>Analyze the sound field inside a duct at low frequencies and design silencer systems. Analyze the timbre of wind musical instruments.<br>Examine the sound field inside a duct, derive the Green's function and explain the propagation of sound inside it.<br>Analyze the sound field in a room based on the modal theory. Derive the Green's function in a room and use it to explain the central acoustic processes that occur in a room.<br>Examine the sound field in a room based on statistical wave models, and how these methods are used in practical applications of room acoustics.<br>Analyze and interpret the decay of sound in a room, based on the modal and statistical theories.<br>Examine a sound field based on its active and reactive intensity, and evaluate the usefulness and limitations of intensity measurement.<br>Describe the radiation from point sources, and how coherent sources affect each other.<br>Interpret the expression for the sound field radiated by a spherical source.<br>Illustrate the use of spherical harmonic | Lectures, problem solving, project work (laboratory exercises, MATLAB simulations and finite element calculations | http://kurser.dtu.dk/course/31260 | 22/02/2019 |

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| | | | expansions for sound radiation and scattering.<br>Analyze the sound field radiated by a planar source, using space domain and wave number domain formulations.<br>Illustrate the fundamentals of microphone array methods (beamforming and acoustic holography). Describe how these methods are used to analyze sound fields. | | | |
| **DTU Denmark Technical University**<br><br>**Engineering Acoustics** | Numerical Acoustics | The course focuses on theoretical lectures combined with computer exercises using Matlab programming. The students will use and adapt existing BEM and FEM code in Matlab. The Comsol FEM package may also be used.<br>The formulation of the FEM and BEM in acoustics will be examined and developed with practical programming examples related with acoustical problems. There will be short exercises every week in connection with the theory, plus a larger assignment during the course that includes handing-in of a report.<br>The coupling of the acoustic model with other elements in the setup defined in different physical terms, such as mechanical systems, will be outlined. | A student who has met the objectives of the course will be able to:<br>Select the appropriate numerical tool for any given acoustic problem: FEM, BEM or a combination of them.<br>Define the model to contain the relevant features, excluding unnecessary details.<br>Formulate and construct numerical simulations in acoustics using FEM and BEM.<br>Identify the boundary conditions and, if appropriate, define the coupling properties.<br>Assemble a FEM model based on weighted residuals, Galerkin's method.<br>Evaluate the particularities of the BEM direct collocation formulation, such as singular and near-singular integrals.<br>Define and solve multidomain problems in BEM. | Lectures and computer exercise | http://kurser.dtu.dk/course/31265 | 22/02/2019 |

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| | | | Define and solve FEM/BEM coupling. Analyze simulation results and draw conclusions from them. | | | |
| **DTU Denmark Technical University**<br><br>**Engineering Design and Applied Mechanics** | Advanced vibration and stability analysis | Static and dynamic stability of pendulum systems, columns, beam columns, rotors, and fluid-carrying tubes. General eigenvalue theory for mechanical vibration and stability problems. Discretization of continuous systems. Mechanical nonlinearities. Nonlinear oscillations and phenomena (e.g. super- and subharmonic resonance, internal resonance, modal interaction, saturation, amplitude jumps, multi-solutions). Post-critical analysis: perturbation methods and bifurcation theory, local geometrical theory, and model reduction. Chaos theory for mechanical systems. Effects of high-frequency excitation. Vibroimpact. Computer simulation. | A student who has met the objectives of the course will be able to:<br>Identify sources of inertia, stiffness, energy dissipation, external loads, nonlinearity, and instability for specific mechanical systems.<br>Use Newton's laws, Lagrange's equations, and Hamilton's principle for determining equations of motion for linear and nonlinear mechanical systems having a finite or infinite number of degrees of freedom.<br>Identify potential dynamical phenomena for specific mechanical systems.<br>Set up and solve eigenvalue problems for determining natural frequencies and mode shapes for linerized mechanical systems having a finite or infinite number of degrees of freedom.<br>Use theoretical modal analysis for approximating / discretizing equations of motions for linear or nonlinear mechanical systems having a finite or infinite number of degrees of freedom.<br>Use perturbation analysis for analyzing weakly nonlinear systems having few degrees of freedom.<br>Use theoretical and numerical bifurcation analysis for analyzing | Lectures, demos, problem solving, exercises, project work, seminars | http://kurser.dtu.dk/course/41521 | 22/02/2019 |

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| | | | systems having few degrees of freedom.<br>Use computer based tools for simulating and analyzing nonlinear dynamical systems, including solving nonlinear ordinary differential equations, frequency spectra, phase plane plots, Poincaré maps, and Lyapunov exponents.<br>Give practically useful interpretations and assessments of analytical and numerical results, including frequency response plots, phase plane plots, Poincaré maps, Lyapunov exponents, fractal dimension, and bifurcation diagrams.<br>Solve a major and realistic exercise problem, which involves application of most of the course syllabus to a specific physical system.<br>Present written problem solutions and reports that are well structured, complete, clear and concise, critically assessing / concluding, and otherwise confirming to accepted standards for written presentation in the subject area. | | | |
| **University of Le Mans**<br><br>**Acoustics and Vibration** | Acoustics Refresh | Basic notions about waves, sound and hearing.<br>Harmonic plane waves, reflection and transmission of plane waves.<br>Pressure, particle velocity, power, intensity and levels (dB). | To know the basic concepts and vocabulary used in acoustics | tutorial, personal work | https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FP | 21/02/2019 |

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| | | Spherical waves and multipoles.<br>Dissipation mechanisms and how to take them into account.<br>Eigenmodes and resonance. | | | NgOa#pdf viewer | |
| **University of Le Mans**<br><br>**Acoustics and Vibration** | Acoustic Project Refresh | Plane wave propagation.<br>Outgoing and incoming wave characterization.<br>Estimation of reflection coefficient of a single duct - comparison with theoretical law.<br>Estimation of reflection and transmission of a discontinuity between two ducts connected in series - comparison with theoretical law.<br>Spherical wave propagation.<br>Pressure level attenuation characterization - comparison with theoretical law.<br>Estimation of acoustic power emitted by a source.<br>Estimation of loudspeaker efficiency (%). | At the end of this project, students should be characterize experimentallythe acoustic propagation of plane waves and spherical waves. | practical, personal work | https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FPNgOa#pdfviewer | 21/02/2019 |
| **University of Le Mans**<br><br>**Acoustics and Vibration** | Vibration Refresh | Free vibrations of single degree of freedom (undamped and damped).<br>Electromechanical analogy: RLC circuit.<br>Forced vibrations of single degree of freedom (undamped and damped).<br>Two degrees of freedom: eigenvalues and eigen modes, modal analysis, frequency response function.<br>Generalization with multiple degrees of freedom. | Know the basic concepts in vibrations of two and N degreesof freedom systems | tutorial, personal work | https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FPNgOa#pdfviewer | 21/02/2019 |
| **University of Le Mans** | Acoustics I | Fundamental equations of acoustics (in fluids).<br>Plane waves. | The main objective of this course is that students have solid | tutorial, practical, | https://umbox.univ-lemans.fr/in | 21/02/2019 |

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| **Acoustics and Vibration** | | Cylindrical and spherical waves.<br>Guided waves.<br>Modal analysis. | backgrounds on fundamental aspects of acoustics including:<br>The fundamental equations of acoustics (backgrounds in fluid mechanics and thermodynamics).<br>The derivation of the wave equation (mostly for the usual case of uniform fluids at rest).<br>The acoustics of the gas column (resonance, free oscillations, coupling etc.).<br>Reflexion, transmission, and diffraction phenomena.<br>Guided waves and the modal theory<br>Spherical and cylindrical waves (sound radiation, diffraction, guided waves in cylindrical ducts, etc.). | personal work | dex.php/s/3NE4dyE74FPNgOa#pdfviewer | |
| **University of Le Mans**<br><br>**Acoustics and Vibration** | Room Acoustics | Room modelling: statistical models, geometrical models, modal behaviour.<br>Objective and subjective criteria.<br>Measurement of reverberation time and objective criteria from impulse response (RT, STI, C80, D50).<br>Introduction to Catt Acoustics software. | Be able to understand the physical phenomena involved in the sound propagation in a room.<br>Know the acoustical objective and subjective criteria which describe a room.<br>Be able to control the room acoustics by passive materials.<br>Be able to measure the room characteristics.<br>Be able to build a numerical model of a room. | tutorial, practical, personal work | https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FPNgOa#pdfviewer | 21/02/2019 |
| **University of Le Mans** | Acoustics II-a | 1. INTRODUCTION<br>(a) Non homogeneous differential equations: various examples in physics | Knowledge:<br>Green’s function theory. | tutorial, practical, | https://umbox.univ-lemans.fr/in | 21/02/2019 |

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| **Acoustics and Vibration** | | (b) Toolbox<br>i. Linear differential operator<br>ii. Boundary conditions<br>iii. Fourier transform<br>iv. Green's identities<br>v. Dirac distribution<br>2. TIME-INDEPENDENT PROBLEM<br>(a) Definition of the Green's function<br>(b) Interpretation<br>(c) Homogeneous Boundary Conditions<br>(d) Reciprocity<br>(e) Solution<br>i. Method of Variations of Parameters<br>ii. Sturm-Liouville Problem<br>iii. Eigenmode Expansion<br>iv. Direct Method<br>3. 3D (and 2D) free space Green's function<br>(a) Integral Formalism in Acoustics<br>(b) Introduction<br>(c) Green's theorem<br>(d) Integral formalism in time domain<br>(e) Integral formalism in frequency domain<br>(f) Solving integral equations<br>(g) Boundary conditions<br>(h) Examples of application | integral formalism in time and frequency domain.<br>Skills: be able to write and use the Green's function in usual cases:<br>Free space (1d to 3d).<br>Reflecting boundaries and image sources.<br>Use the integral formalism in different simple applications.<br>Acoustic field in small cavity.<br>Acoustic field between two infinite walls. | personal work | dex.php/s/3NE4dyE74FPNgOa#pdfviewer | |
| **University of Le Mans**<br><br>**Acoustics and Vibration** | Continuous Systems Vibrations | From discrete to continuous systems, elementary model for the longitudinal vibrations of a bar.<br>Transverse vibrations of strings.<br>Flexural vibrations of beams.<br>Transverse vibrations of membranes.<br>Flexural vibrations of plates. | To be able to read specialized literature in the field, as wellas to be in a position to develop small models related to vibrations in continuous media and structures. | tutorial, personal work | https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FPNgOa#pdfviewer | 21/02/2019 |

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| | | Energy based methods: Lagrange, Rayleigh, Rayleigh – Ritz, Galerkin. | | | | |
| **University of Le Mans**<br><br>**Acoustics and Vibration** | Vibrations experiments | Free and forced oscillations of a system having a single or two degrees of freedom.<br>Determination of mode parameters of a beam / Chladni's vibrating plates.<br>Forced vibrations of a beam.<br>Free oscillations of a string.<br>Revving of an engine / order analysis.<br>Dynamic balancing. | Information not available | practical, personal work | https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FPNgOa#pdfviewer | 21/02/2019 |
| **University of Le Mans**<br><br>**Acoustics and Vibration** | Numerical Vibroacoustics | Introduction of BEM principles. Introduction to ABEC (Acoustic Boundary Element Calculator). Study of simple cases.<br>Simple models of acoustics in closed and opened systems by FEM and/or BEM approaches with Comsol. Computation of vibrations modes for structures and acoustic modes for closed cavities by FEM, vibroacoustic coupling on the solid / fluid interface, Applications to more complex systems. | Be able to use Boundary Elements Modelling and Finite Elements Modelling software (ABEC, COMSOL) for simple applications. | tutorial, personal work | https://umbox.univ-lemans.fr/index.php/s/3NE4dyE74FPNgOa#pdfviewer | 21/02/2019 |

**APPENDIX II**

**REVIEW OF THE EXISTING MSC COURSES RELATED TO THE NO&VIB FIELDS TAUGHT ON MSC PROGRAMMES IN SERBIA**

| University<br>Faculty<br>Study program | Course | Course content | Educational outcomes/ Purpose | Teaching methods | Reference | Date |
|---|---|---|---|---|---|---|
| **University of Belgrade School of Electrical Engineering Master module: Audio and Video Communications** | Electroacoustics | Appearances in sound propagation: terms, reflection, acoustic impedance concept, diffraction. Hearing sense and human voice. Sound field in space: acoustical response, mathematical models. Electro acoustic converters: general theory, speakers, microphones. Subjective aspects of the sound field, acoustic in ecology. | Student will be able to understand problems which are resent when using electro acoustic devices in telecommunications and appearances in sound field. This is the basis for some other courses from audio system fields and multimedia telecommunications. | lectures, demonstrations, laboratory exercises | https://www.etf.bg.ac.rs/en/fis/karton_predmeta/13E033E | 07.02.2019. |
| **University of Belgrade School of Electrical Engineering Master module: Audio and Video Communications** | Acoustic Design of Rooms | Sound field in front of the wall. Mathematical models of sound field in rooms: wave theory, geometrical model and statistical model. Sound absorption and sound absorbers. Subjective effects of combined sound fields. Acoustic design of a real classroom. | Fundamental knowledge about acoustic design of rooms | presentations and laboratory work | https://www.etf.bg.ac.rs/en/fis/karton_predmeta/13M031ADP | 07.02.2019. |

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| **University of Belgrade School of Electrical Engineering Master module: Audio and Video Communications** | Sound Reinforcement | Classification of systems for sound reinforcement. Loudspeaker systems in sound reinforcement. Structure of audio systems in sound reinforcement. Microphones in sound reinforcement. Practical examples of systems. Measurements at one system for sound reinforcement. Design of a simple system. | Ability to design simple systems for sound reinforcement | presentations and laboratory work | https://www.etf.bg.ac.rs/en/fis/karton_predmeta/13M031O | 07.02.2019. |
| **University of Belgrade School of Electrical Engineering Master module: Audio and Video Communications** | Audio Signal Processing | Audio signals: characteristics acquisitions. Audio processors, acoustic echo cancelling. Signal processing in music acoustic, sound effects in music. Filter bank equalization system for sound reproduction. Signal processing in the noise protection.Hearing aids. Implementation of audio signal processing algorithms on DSP processor | Through practical realizations students will be introduced to specific techniques in audio signal processing systems. | Practical project work, lectures | https://www.etf.bg.ac.rs/en/fis/karton_predmeta/13M031OAS | 07.02.2019. |
| **University of Belgrade School of Electrical Engineering Master module: Audio and Video Communications** | Noise Control | Introduction to noise control, noise as ecological factor, noise annoyance, psychological and physiological factors. Effects of noise on speech. Criteria for noise protection, acoustic dilemma, legislation. Noise measurement: procedures, microphones, preamplifiers. | Knowledge about criteria for annoyance by noise, methods for its diagnostics and technical methods for noise reduction. | presentations and laboratory work | https://www.etf.bg.ac.rs/en/fis/karton_predmeta/13M031ZOB | 07.02.2019. |

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| **University of Novi Sad Faculty of Technical Sciences Civil engineering**<br><br>**Hydrotechnics/ Road Networks** | Noise, Vibration and Earthquakes in Surroundings | Notions of a sound source, elastic environment and sound wave. Characteristic wave sizes: amplitude, period, frequency, circle frequency, wave distribution velocity, wave length. Air and structural waves. Musical tone, complex sound, sound wave spectre. Notion of acoustic space, characteristic sizes of sources and space: sound force of the source, sound intensity, sound energy density, density and pressure of an acoustic space, movement, velocity and acceleration of elastic environment particles, level of power, intensity and pressure, constant level of sound pressure – equivalent value, acoustic dose. Sound distribution in an open acoustic space, super-penetration of acoustic influences from multiple sources. Sound distribution in a closed acoustic space: reflection, breaking, diffraction, absorption and reverberation time. Quantitative and qualitative evaluation of sound effects. Measuring and research equipment for measuring and researching phenomena related to sound. Contemporary trends in the field of sampling, processing and acquisition of results of acoustic researches – acoustic map. Monitoring of acoustic parameters. Strategy of protection from vibrations and earthquakes. Methods and means of vibration protection. Methods and means of vibration protection applied for the protection of people, structures and sensitive equipment. Perspectives in developing methods and means of vibration protection. | Acquired knowledge is used in professional courses and engineering practice. Student is capable of analysing and solving problems in the field of protection from noise in the living and working environment. | At lectures students are delivered theoretical and practical explanations predicted by the course content. At auditory practice students are presented with the possibilities of software and equipment for solving problems in the field of technical acoustics, vibrations, and earthquakes. Students have an obligation to do one graphic paper during the semester. Examination has an oral part (theoretical and practical). During the semester, oral examination can be taken as two partial examinations. Examination can be taken in the exam terms. Students who do not pass the oral part of the examination via partial examinations, | http://www.ftn.uns.ac.rs/n551189326/noise--vibration-and-earthquakes-in-surroundings | 07.02.2019. |

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| | | | | has to pass it during the exam terms. | | |
| **University of Novi Sad Faculty of Technical Sciences**<br><br>**Environmental engineering** | Noise and Vibration | The concept of sound and noise. Propagation of sound waves. Plane waves. Spherical waves. Sound intensity and sound pressure. Acceptable sound pressure level from the noise. Acoustic impedance. Sound power levels of noise sources and characteristics. Diffraction and reflection of sound. Noise spectrum. Acoustics of enclosed space. Absorption characteristics. Reverberation time. The size, shape and design of the rooms as the acoustic parameters. Noise isolation. Transmissibility. Vibration isolation. Technical measures of protection against noise and vibration. Active methods of protection. Passive methods of protection. Identification of noise sources. Calculation of the sound field of industrial plants. Criteria for evaluating security solution. Design methods of protection. Equipment for protection against noise and vibration. | Creating a deep insight into the phenomena related to noise and vibration, training students to recognise and detect them as well as to remove or control unwanted consequences. | Lectures. Auditory exercises. Laboratory exercises. Consultation. Continuous monitoring of the level of students knowledge through four tests (mandatory) and laboratory exercises. Examination. | http://www.ftn.uns.ac.rs/1205010321/noise-and-vibration | 07.02.2019. |
| **University of Novi Sad Faculty of Technical Sciences**<br><br>**Postal Traffic and Telecommunications** | Acoustics and Audio Engineering in Traffic | The physical characteristics of sound (the rules for the production and propagation of sound waves). Sound perception and its influence on the human being (auditory area; characteristics of speech, music and noise). Room acoustics (absorption/reverberation and their impact on sound level and intelligibility, acoustical quality of professional rooms). Electro-acoustic transducers (microphones, loudspeakers and headphones), measurement devices, tools for audio signal analysis and processing. Recording of audio signals (speech, music, and noise; selection and placement of microphones). Noise (sources and ways of propagation, noise | Students will learn how sound waves are produced and how they propagate, what a human being can hear and how sound affects humans, as well as how sound is recorded, | Lectures are conducted using Power Point presentations available to students in .pdf format. Presentations with specially created audio and video clips and animations demonstrate | http://www.ftn.uns.ac.rs/n1305943244/acoustics-and-audio-engineering-in-traffic | 07.02.2019. |

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| | | characteristics, calculating sound pressure level and noise protection methods). Traffic noise (road, rail, and aircraft noise; noise monitoring and mapping; traffic noise protection). Instrumentation for noise measurements and analysis (sound level meters, filters, noise spectrum (N-curves), dosimeters, software). Speech and audio technologies in navigation systems (ASR and TTS, GPS, RDS – digital radio). | transmitted and reproduced. They will understand the differences in the behavior of sound both indoors and outdoors. They will be able to evaluate the acoustic environment (in terms of speech intelligibility, quality of listening to music, noise level), and to select and place audio-equipment for recording of speech, music, and noise. Students will learn the standards for measurements and techniques for the suppression of traffic noise, as well as the application of both speech and audio technologies in navigation and digital radio. | and illustrate key details in the lectures. auditory exercises. Laboratory exercises. | | |

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| **University of Nis**<br><br>**Faculty of Occupational Safety**<br><br>**Occupational Safety** | Noise and Vibration Control | Basic principles of vibration isolation. Vibro-absorption. Vibroinsulation. Calculation of the system for vibration isolation and absorption. Diagnostics of the state of machine systems by monitoring vibrations. Diagnostic Tools: FFT, CPB, Kepstrum, Envelop, Order Analysis. Noise level in the working environment. Noise sources and their characteristics. Models for forecasting noise in the braking area. Structure of the model. Noise control. Basic principles. Sound absorption and sound insulation. Elements and materials for noise control. Noise control. Folding of the source. Control on the transmission paths. Screens. Control at the receiving point. Application of personal protective equipment. Sound insulation and absorption, sound protection of buildings. Resonant area of homogeneous single processing. The area of mass law. Effect of coincidence. Sound insulation of double endless processing, real double processing. The impact of the lateral implementation on the sound insulation of the suburb. Sound laxity of interlayer structures. Reduction of sound throughput. . Calculation of the sound permeability of floating floors. Reducing noise by increasing the absorption of rooms. Design of sound protection of building elements, protection against noise of installations, noise of mechanical elements. | Students' competence and skills acquisition for: Advanced noise and vibration measurement techniques. Application of noise and vibration for diagnostic purposes. Calculation of sound absorption and absorption of vibrations. Calculation of sound insulation and vibration isolation. | Theoretical lectures, computational and laboratory exercises with multimedia presentation and interactive work with students | http://www.znrfak.ni.ac.rs/SERBIAN/010-STUDIJE/MAS/PREDMETI/ZNR/I%20GODINA/120-KONTROLA%20BUKE%20I%20VIBRACIJA/120-KONTROLA%20BUKE%20I%20VIBRACIJA.html | 22/02/2019 |
| **University of Kragujevac Faculty of Engineering Mechanical Engineering/** | Testing of motor vehicles and engines II | Theoretical study: Vehicle testing – types, methodologies, measures and technical regulations. Basic design of measurement systems for vehicle testing. Measurement signals, sensors, computer based data acquisition – CAT systems. Analysis of measurement results, influences on measurement results, influence of human factor, modern software for experimental data analysis. Experimental installations for testing of operational loads, performances, reliability. Identification of vehicle's influence on environment – vibration comfort parameters, noise, exhaust emission gases, road damage. Methods for monitoring the traffic flow. Testing | Student should learn to analyse the problem from the area of testing of motor vehicles and engines from the aspect of measuring system, to design corresponding measuring | Lectures. Auditory exercises. Laboratory exercises. | http://www.mfkg.rs/eng/sajt/Downloads/Studije/Akreditacija/Diplomske/M3/Izborni/mm3331_testing_of_motor_vehicles_and_engines_ii.pdf | 13.2.2019. |

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| | | the indices of active and passive vehicle safety. Practical Studies: Verbal and laboratory exercises: Practical work with measurement equipment – use of sensors, forming of experimental installations, data acquisition, analysis and processing of recorded data. Demonstration of modern experimental installations and installations from the laboratory for motor vehicles assigned for testing of operational loads, performances, reliability and vehicle safety and its influence on environment. Within the framework of study research, the students will be qualified for basic research in the area of this course. | installation, to analyse experimental data and to present the experimental results. | | | |
| **University of Kragujevac Faculty of Engineering Mechanical Engineering/** | Machinery Condition Monitoring | Theoretical study: Significance of machinery condition monitoring, the concept, classification and digital signal processing, Machinery system condition and the basic methods for its identification, Significance of vibro- diagnostic, identification of malfunctions according to vibration measuring and analysing, noise as diagnostic parameter, oil and wear particle analyses, infrared thermography, observation of processing parameters, non-destructive testing methods. Practical Studies: Working with A/D converter, noise and vibration measuring, dynamic balancing, thermography, oil and wear particle analyses, video-scope, and ultrasound examinations. Students are capable to perform some basic examinations within the course field. | After successfully ended obligations, each student should be able to understand the concept of machinery condition monitoring, and to know its position and significance, and to be able to apply some of basic machinery condition monitoring methods, to be able to evaluate condition of machinery systems according to measured parameters, to have the knowledge of | Teaching is performed through lectures, auditorium and laboratory exercises. For teaching presentation a modern teaching facilities are used. For each teaching filed a variety of different industrial field examples are taken in consideration through different case studies, and due to that students are capable to obtain a very wide range of practical technical knowledge for further independent | http://www.mfkg.rs/eng/sajt/Downloads/Studije/Akreditacija/Diplomske/M1/Izborni/mm3111_machinery_condition_monitoring.pdf | 13.2.2019. |

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| | | | signal and to understand some basic methods for signal processing, and also to know some basic methods for improvement of machinery system's working condition. | work within the field of machinery condition monitoring. For examination performing the most modern training equipment (PULSE, Data Collector, infrared camera etc.) and software (Sentinel, PULSE FFT Analysis etc.) are used. Development of this course is supported by WUS Austria. | | |
| **University of Kragujevac Faculty of Engineering Environmental Engineering** | Physical parameters of the living and working environment | Theory classes:<br>1. Physical noise properties<br>2. Harmful effect of noise<br>3. Noise standards and regulations<br>4. Room acoustics<br>5. Noise measurement<br>6. Principles and methods for control and noise protection<br>7. Concept and basic properties of vibrations<br>8. Vibration measurement and standardization<br>9. Risk assessment and management of harmful vibration effects<br>10. Illumination<br>11. Room illumination measurement and assessment<br>12. Electromagnetic radiation<br>13. Harmful effects of electromagnetic radiation<br>14. Electromagnetic radiation measurement in the environment<br>15. Principles and methods of protection against harmful effects of EM radiation<br>Practice sessions: Noise measurement, acoustic zoning of urban space, vibration measurement, | Starting from theoretical foundations and practical exercises, students are trained for independent work in the area of identification of sources of harmful physical parameters in living and working environment and assessment and management of appropriate | Teaching consists of lectures, auditory and laboratory exercises. Contemporary teaching materials - video presentations - are used for teaching. Within each teaching unit, practical examples from the industry and public utilities systems are also being processed, thus acquiring a wide range of practical | http://www.fink.rs/images/stories/PDF/2018_nove_knjige_predmeta/novo_2509/Prilog_5.2_Knjiga_predmeta_Inzenjerstvo_zastite_zivotne_sredine_MAS_1.pdf | 13.2.2019. |

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| | | illumination measurement, thermal radiation measurement by IC thermography, measurement and mapping of the source of EM radiation | risks. | knowledge required for independent work. On the practical exercises, modern measuring equipment for noise, vibration, illumination, IC thermography and EM radiation is used. | | |
| **University of Kragujevac Faculty of Engineering Mechanical Engineering/ Environmental Engineering** | Traffic and environment | Principles of combustion and combustion products. Otto engines. Diesel engines. Alternative propulsion systems. Emissions from vehicles and air quality. Global warming. Noise emissions. Recycling of transport vehicles and their life cycle. Emission reduction regulation. Fuels and their impact on the emissions of vehicles as mobile sources. | After successful completion of the course, the student will be able to evaluate the impact of traffic and transport vehicles on the environment throughout the life cycle of a vehicle. | Interactive lectures and exercises, writing 2 seminar papers. One in the field of transport vehicle emissionand the other in the field of recycling of them and their life cycle. The final seminar paper includes making a presentation of the previous 2 papers and their public defence. | http://www.fink.rs/images/stories/PDF/2018_nove_knjige_predmeta/novo_2509/Prilog_5.2_Knjiga_predmeta_Inzenjerstvo_zastite_zivotne_sredine_MAS_1.pdf | 13.2.2019. |
| **University of Pristina Kosovska Mitrovica Faculty of Technical Sciences Mechanical Engineering** | Vehicle Dynamics - selected chapters | Theory classes:<br>Braking: braking and braking performance, grip and slip, stability, maximum performance, brakeforce distribution, real performance and safe distance, dynamic control devices. Collision: collision theory, impact on a stationary obstacle, central and non-cantered vehicle collisions, collision modelling, passive vehicle safety. Lateral dynamics: elastic wheel, stability, turning, gradient of submissiveness, active vehicle safety. Vertical dynamics: vehicle as oscillatory system, vehicle oscillations, impact | After successful completion of the course, a student will be able to analyse the most important physical relationships between vehicle, | Lectures, exercises and open-office hours. The lectures outline the basic principles and general methods of dynamics vehicles. On the exercises, | https://drive.google.com/file/d/1cWXDUwHSKZqZUkRDSFUlIDI7EwLxTc33/view | 14.2.2019. |

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| | | oscillation on the user - determination of exposure time by oscillations.<br>Practical classes:<br>Exercises follow lectures and prepare students to solve complex and combined tasks; homework as preparation for colloquiums, colloquiums with test and tasks from relevant teaching areas, Study research work in the form of seminars in the field of dynamic vehicle behaviour. | vehicle and user and calculate the features specific for the given movement and collision. | specific problems that illustrate the application of these methods are solved. More complex examples present to students in the form of simulations on the PC. During the semester students do homework (individual exercises) being a condition for taking a colloquium. During the semester, 3 colloquia are organized, which replace written (practical) part of the exam. | | |
| **University of Pristina Kosovska Mitrovica Faculty of Technical Sciences Mechanical Engineering** | Machine construction | Objective and content of the design process. Basic terms. Development of means and principles of construction.Construction process structure. Construction process phases and operations. Machine construction types. Construction systems, goals and approaches. Project task definition. Technical and economic stimulus for the development of new mechanical systems. Development of needs, products and technologies. Creation of new ideas. List of requests. Conceptual solution design. Elements of the technical systems theory: technical system abstraction, function structure, technical system properties, approaches in the search for new principles. Executives of machine system functions. | Ability to independently and creatively use acquired knowledge and skills from the machine construction, solving specific problems and extending scientific achievements, especially in the field of analysis of the | Lectures, audio exercises, solving exam tasks, creating technical documentation. | https://drive.google.com/file/d/1cWXDUwHSKZqZUkRDSFUlIDI7EwLxTc33/view | 14.2.2019. |

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| | | Formation of conceptual solutions. Choosing the optimal variant. Evaluation and decision making. Development of the shape and dimensions of machine parts. Development procedure for machine part forms. Criteria for selecting machine part dimensions. Standardization, typification, unification and modular construction. Deciding in construction. Principles of decision-making. Optimization of dimensions and mass of machine parts. Mass as a function of the target. Selection of the conditions of machine part reliance and joints, cross-sectional shapes, materials, methods of production, boundary conditions for the selection of dimensions. Rationalization of the mass. Light constructions. The technological design and rationality of the utilization of welded machine parts. Remaining welding forces - formation and elimination. Technological design of melded machine parts. Technological design of forged and cut machine parts. Modelling the shape of machine parts. Workloads and forces. Substitution of machine parts. Analysis of force distribution and deformation by volume of machine parts. Fundamentals of finite element methods. Analysis of geometry of mechanical parts and assemblies. Deviations, the influence of deviation on the operation of the mechanical systems. Measuring chains, types of measuring chains, application areas. Construction from the aspect of reliability. The likelihood of destruction of mechanical parts in the field of time durability and in the field of permanent durability. Probability of destruction for work endurance. Endurance test, determination of probability of destruction. Calculation of reliability of machine parts. Vibration induction in machine systems. Structural solutions for reducing vibrations. The process of noise generation in the machine system. Characteristics of oscillation of machine parts. Modal analysis using finite element method, experimental modal analysis. Isolation of the noise of mechanical systems. | state of machine elements, which are used as parts of machines. | | | |

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| **University of Pristina Kosovska Mitrovica Faculty of Technical Sciences Mechanical Engineering** | Oscillations of mechanical systems | Small oscillations of the system with one degree of freedom of oscillations. Linear harmonic oscillations. Non-linear harmonic oscillations. Oscillations of nonconvertible systems with one degree of freedom of oscillations. Free forced oscillation of a system with one degree of freedom of oscillation and without resisting force and phenomenon of resonance. A simple forced oscillation of the system with one with one degree of freedom of oscillation with a resistive force. Complex forced oscillations of the system with one degree of freedom of oscillations, and Lagrange method of coefficient variation. Phenomenological mapping and mathematical analogy between mechanical and electrical oscillatory systems. Small oscillations of the holonomic conservative system with several degrees of freedom of oscillations. Forced oscillations of the holonomic conservative system with several degrees of freedom of oscillations. Phenomena of resonance and dynamic absorption. Examples of oscillator systems with finite number of degrees freedom of oscillations and corresponding frequency equations. Small oscillations of a non-conservative system. An eigenvalue equation of small oscillations of a non-conservative system. Movement stability and basic methods for stability testing. Critical speeds of high-speed shafts. Waveform of deformable continuum and D'Alambert's solution. Transverse oscillations of strings. Bernoulli's method of particular integrals. Longitudinal oscillations of prismatic beams. Torsion oscillations of the shaft of the circular cross-section. Free transverse oscillations of beams with one and more ranges. Boundary and initial conditions. Orthogonality of own amplitude functions. | Acquiring the ability to apply analytical methods and knowledge of Theory of linear oscillations of mechanical systems for the analysis of oscillatory phenomena in real engineering systems and the ability to set up appropriate models of oscillatory systems by abstraction of real engineering systems. | Lectures, exercises and open-office hours. The lectures outline the basic principles and general methods of oscillation of mechanical systems. The exercises solve tasks that illustrate the application of these methods in solving specific problems. More complex examples present students with simulation simulations on a computer. During the semester two colloquiums are organized that replace the taking of the written (practical) part of the exam. | https://drive.google.com/file/d/1cWXDUwHSKZqZUkRDSFUlIDI7EwLxTc33/view | 14.2.2019. |

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| **University of Pristina Kosovska Mitrovica Faculty of Technical Sciences Mining engineering** | Environmental management systems | The problem of environmental protection. Overview of the causes of environmental damage. Sources of noise and vibration. Assessing the previous state of the environment. State of the flora, fauna, land, atmosphere, watercourses and groundwater. Population, standard of occupation. Cultural and historical sights. Air pollution control. Standards, equipment measurement procedures. Equipment for automatic sampling. Measures for reducing emissions of harmful substances. Control of pollution of surface waters. Classification of waters. Standards, equipment and procedures for measuring water pollution. Measures to reduce surface water pollution. Control of pollution of groundwater. Processing of industrial wastewater. Land pollution control. Remediation, remediation and recultivation of degraded surfaces. Protection against noise and vibration. Equipment and measurement procedures. Measures to reduce noise and vibration. The role and role of monitoring in environmental protection. Monitoring systems in the environment. Autonomous monitoring systems. Post-application environmental protection systems ISO 14001: 2005. | After successful completion of this course, a student is capable and trained to participate in a team for the establishment, implementa-tion, maintenance and improvement of the environmental management system. | Lectures, exercises, open-office hours, independent work and group work with the use of audio-visual means. | https://drive.google.com/file/d/0B_Hn-Zw3UTauTU9DMy1NZm1QWGM/view | 14.2.2019. |