Important Notice:
From the undergraduate program, only the courses included in the table below are available to incoming students participating in the Erasmus program.

Offering Courses for Students Erasmus +					
CODE	COURSE	SEMESTER	ECTS	PROFESSOR	CONTACT
8254	Elements of Finance / Special Topics in Ship Finance	8	4	D. Lyridis	dsvlr@mail.ntua.gr
8252	Maritime Transport Logistics	9	4	D. Lyridis	dsvlr@mail.ntua.gr
8185	Economics of Maritime Transport I	7	4	D. Lyridis	dsvlr@mail.ntua.gr
8248	Course Stability and Maneuverability	8	4	K. Spyrou	k.spyrou@central.ntua.gr
8280	Roll Stability and Regulations Background	9	4	K. Spyrou N. Themelis	k.spyrou@central.ntua.gr nthemelis@naval.ntua.gr
8205	Computational Hydrodynamics	8	4	G. Papadakis	papis@fluid.mech.ntua.gr
8209	Wave Phenomena in the Sea Environment	9	4	K. Belibassakis	kbel@fluid.mech.ntua.gr
8260	Artificial and Computational Intelligence in Ship Design and Operation	8	4	G. Grigoropoulos G. Papalambrou	gregory@central.ntua.gr george.papalambrou@lme.ntua.gr
8207	Hydrodynamic Design of Small Vessels	9	4	G. Grigoropoulos	gregory@central.ntua.gr
8256	Measurements in Marine Environment	8	4	G. Grigoropoulos	gregory@central.ntua.gr
8284	Ship Behavior in Waves	9	4	G. Grigoropoulos	gregory@central.ntua.gr
8292	Ship Performance and Efficiency Monitoring	8	4	N. Themelis	nthemel@mail.ntua.gr
8041	Electrical Technology	3	4	J. Prousalidis	jprousal@naval.ntua.gr
8058	Electrotechnical Application	4	4	J. Prousalidis	jprousal@naval.ntua.gr
8294	Metallic Materials	2	5	A. Zervaki	annazervaki@mail.ntua.gr
8158	Science and Technology of Welding	8	4	A. Zervaki	annazervaki@mail.ntua.gr
8235	Mooring Systems of Floating Structures	9	4	J. Chatzigeorgiou D. Konispoliatis	chatzi@naval.ntua.gr dkonisp@naval.ntua.gr
8137	Design of Floating Structures	8	4	I. Chatzigeorgiou D. Konispoliatis	chatzi@naval.ntua.gr dkonisp@naval.ntua.gr
8181	Marine Structures	6	6	K. Anyfantis	kanyf@naval.ntua.gr
8276	Ports and Multimodal Transport	8	4	N. Ventikos	niven@deslab.ntua.gr
8282	The Human Element – Introduction to Human Reliability for Maritime Transport	9	4	N. Ventikos	niven@deslab.ntua.gr
8286	Risk Analysis and Assessment of the Environmental Impacts in Maritime Transport	9	4	N. Ventikos	niven@deslab.ntua.gr
8279	Development and Growth	8 & 9	2	N. Ventikos	niven@deslab.ntua.gr
8301	Advanced Dynamics-Diagnostics of Complex Mechanical Systems with Machine Learning Applications to Fault Diagnostics of Marine Technological Systems	9	4	J. Georgiou	georgiou.yannis@gmail.com

Courses Description

8254 Elements of Finance – Special Topics in Ship Finance

Introduction to finance. Present value and cost of capital. Investment decisions. Risk and return. Planning of capital availability. Financing of large shipping companies. Shareholding policy and capital structure. Shipping investment. Sources of capital, bank lending, capital markets. Risk management.

Instructor: D. Lyridis

8252 Maritime Transport Logistics

Introduction to logistics and supply chain management, historical review. International transportation system. Modern requirements and strategy of companies. Methods and solutions. Operational strategies. Selection of means of transport. Nodal stations-warehouses. Intermodal transport. Institutional framework and policy. Examples.

Instructor: D. Lyridis

8185 Economics of Maritime Transport I

Brief Microeconomics Review. Elements of production and consumption theory. Investment evaluation criteria. The charter market. The concept of perfect competition. Types of charters and contracts. The tanker charter market. Spot market freight rates. Market structure. Institutional structure. Time charters.

The dry cargo market. Oil distribution network. Freight rates and prices in the oil market. The liner market. Conferences. Cost structure. Monopoly freight rates. Institutional structure. Internal competition. Components of transport cost. Intermodal transport. Container transport. Ports as transshipment nodes. Elements of international trade theory.

Instructor: D. Lyridis

8248 Course Stability and Maneuverability

Maneuvering and course stability considerations in ship design. Specific requirements and Maneuvering and course stability considerations in ship design. Specific requirements and problems by type of vessel.
Development of linear and nonlinear models. Determination of satisfactory behavior criteria. Course stability using active steering control. Ship maneuvering and course keeping in restricted waters. The problem of squat in shallow water. Other environmental effects. Developing a model for the stopping maneuver. Influence of design parameters. Criteria for satisfactory behavior within as well as out of the framework of international regulations.
Course assignments (compulsory):
- Laboratory exercise: The course includes use of a maneuvering motion simulator towards filling-in, with the required information, a ship's wheelhouse poster or a pilot card.
- Coursework with two parts: the first is computational requiring basic calculation of maneuvering behavior (some programming is required). The second is based on a critical literature review.

Lecture notes: "Ship Maneuvering and Course-keeping (in Greek), K. Spyrou, NTUA publications, Athens, 2022.

Instructor: K. Spyrou

8280 Roll stability and regulations background

Historical development of ship stability theory. Moseley's concept of dynamic stability. Overview of ship dynamic stability problems. Interface with classical nonlinear dynamical systems' stability theory. General stability analysis of equilibrium positions and of periodic responses. Coexistence of responses. Modeling the effect of wind on a ship (steady and gusty). The basic equation of ship roll motion for beam seas. The classical Froude approach with the analog of the rotational oscillator. Solution of the linear problem, qualitative and quantitative effect of non-linear terms, permanent and transient behavior, effect of ship loading bias on dynamic stability. Stability consideration for large heel angles. Nonlinear resonance and hysteretic effects. Predictions of roll motions through numerical simulation and approximate analytical solutions based on perturbation theory. Instabilities due to time-varying righting-arm in longitudinal waves. The phenomenon of parametric instability, types and design features of ships where it occurs. Development of a simplified mathematical model and analytical determination of the principal region of parametric instability. Effect of damping and motion coupling.

Design criteria. Conditions for "pure loss of stability" in following waves. Other instability phenomena and description of the IMO guidelines to avoid dangerous situations. The scientific background of the "weather criterion" of ship stability according to IMO. Review of other criteria in force and future trends. Basic concepts of probabilistic approach and application examples. Introduction to damage Stability, historical development, comparison of the deterministic and the probabilistic approach. Calculation of subdivision index according to Wendel's theory. Current regulations, design aids, and modern developments.

Course assignment (compulsory):

- Towing tank laboratory exercise: Free rolling experiment with a ship model to calculate the damping.

Forced rolling experiments under periodic excitation and examination of stability. Comparison of results with numerical simulations using a nonlinear model of ship rolling (preparation of a detailed report is required).

- Exercises (optional) are also given to students during the course.

Lectures based on eBook: "Dynamic Stability of Ships" (in Greek), K. Spyrou, Kallipos Publisher,

https://repository.kallipos.gr/handle/11419/5206, Athens, 2015.

Instructors: K. Spyrou and N. Themelis

8205 Computational Hydrodynamics

Fundamental partial differential equations (PDE's) in fluid dynamics and discretization. Regarding spatial discretization, finite difference and finite volume methods are presented. Focus on convection-diffusion equations using the finite volume approach. Explicit-Implicit schemes for time discretization. Various options are presented for the spatial discretization with focus on the numerical properties of the schemes (error and stability). Solution of system of equations using the previous techniques- basic introduction to the Navier-Stokes equations and turbulence modelling using the RANS approach. The course has compulsory assignments.

Notes: "Numerical Simulations of Hydrodynamic Flows", G. Tzabiras, Athens, 1998.

Instructor: G. Papadakis

8209 Wave Phenomena in the Marine Environment

Wave phenomena in the sea environment. Water waves and acoustic waves. Physical properties of sea water. The underwater acoustic waveguide. Overview of basic Fluid Mechanics concepts and equations. Derivation of the wave equations governing certain categories of dynamic phenomena in the sea (gravity waves, hydro-acoustic waves). Analytical solutions of the wave equations in simple cases (plane wave, cylindrical wave, spherical wave, point sources of waves in free space and in waveguides). Basic wave phenomena: propagation, reflection, refraction, diffraction (scattering) of waves, Huygens' principle. General methods for solving wave equations (analytical, semi-analytical, numerical, hybrid).

Ray theory. Derivation of the wave equations as a high-frequency asymptotic approximation of the wave equations. Ray equations. Amplitude equations (for gravity waves and for acoustic waves). The Heron-Fermat principle: An alternative way of deriving the geometrical-optics analogy of wave equations. Analytical solutions of the wave equations. Refraction in an inhomogeneous medium with slowly varying refractive index. Rays in stratified media. Acoustic channeling in the sea. Technological and environmental applications of gravity waves: Effects of water waves on structures and the coastal environment, Wave energy, Wave conditions and energy potential in marine/coastal areas. Technological and environmental applications of sound waves in the ocean.

Computational exercise: Numerical simulation of wave propagation in waveguides

Notes: G. Athanassoulis and K. Belibassakis, "Wave Phenomena in the Sea Environment", Athens,

2019.

Instructor: K. Belibassakis

8260 Artificial and Computational Intelligence in Ship Design and Operation

A. Introduction to the basic principles of development and operation of Artificial and Computational Intelligence systems. Summary of centralized and distributed intelligence. Knowledge (structure, representation, manipulation), reasoning, intelligent behavior. Presentation of the structure, operation and exploitation of modern knowledge-based software systems that allow easy integration of rules, regulations, empirical guidelines and various restrictive provisions.

B. Genetic algorithms and evolutionary systems. Genetic structures and evolutionary agents. Parameters of evolutionary systems. Behavior and convergence of evolutionary systems. Optimization and other applications of evolutionary systems. Other techniques (Neural networks, Fuzzy Logic, Self-organizing systems). Fuzzy systems, meta-heuristics, artificial immune networks.

C. Applications in ship design and operation. Hull shape optimization with the help of Computational Intelligence and ES. Ship systems design support. Presentation and laboratory familiarization with two expert systems that support ship loading and optimal ship routing.

D. General principles of Machine Learning. Introduction to the field of machine learning-the different types. Supervised learning. Unsupervised learning. Prediction (linear, logistic regression). Support Vector Machines. Reinforcement learning. Bayesian learning.

E. Deep Learning Neural Networks. Learning complex representations with data. Review. Big data. Examples of structures. Applications in technological and scientific areas.

G. Programming Tools for Neural Networks. The NN/DNN toolbox in MATLAB. Modern hardware platforms.

The course includes two laboratory exercises.

Instructors: G. Grigoropoulos, G. Papalambrou

8207 Hydrodynamic Design of Small Vessels

Part A, High-Speed Craft: Types of high-speed vessels. Semi-displacement and planning craft.

Hydrodynamic lift. Resistance of semi-displacement and planning vessels. Empirical and semi-empirical methods of its estimation. The method of Savitsky. Systematic series of speedboat hull forms. Propulsion, and dynamic behaviour of High-Speed ships (HSS) in waves. Design elements and procedures in the preliminary design phase.

Part B, Sailing yachts: The geometry of sailing. Forces on a sailing yacht. Resistance, stability, and seaworthiness of sailing yachts. Equations describing the operation of sailing yachts. Experimental investigation of their performance. Polar diagram and evaluation VMGMAX for various true wind speeds VT. Gimcrack diagram for correlation of the aerodynamic and the hydrodynamic performance of a sailing yacht. Design of hull form and main appendages (keel, rudder). Velocity prediction programs. Systematic series of sailing yachts.

The course includes a laboratory exercise accompanied by the delivery of a technical report.

Lecture-Notes: G. Grigoropoulos, Hydrodynamic Design of Small Craft, 2021

Instructor: G. Grigoropoulos

8256 Measurements in Marine Environment

Statistical background of Measurements. Error Theory. Statistical analysis of correlation of dependent variables. Derivation and evaluation of measured data. Design and execution of experiments. Comparative experiments. Multi-parametric experimental campaigns. Computer Simulation of experimental procedures. Recording arrangements for real-time data collection. Measurement, evaluation, and analysis of stochastic quantities. Spectral analysis. Theoretical background and design of Digital filters. Measurements in the marine environment and in the laboratory. Data acquisition systems. Standardization in data acquisition and processing. The course includes three laboratory exercises concerning: Connections, reception, processing, spectral and statistical analysis of stochastic measurements in the experimental NTUA Towing Tank. Also, transformer wiring, estimation of measurement errors and adjustment of results.

Instructors: G. Grigoropoulos

8058 Electrotechnical Application

Transformers (Single Phase – Three Phase) – Equivalent circuits of transformers – Parallel operation of transformers – Principles of operation of rotating electric machines – Types of electric machines – Motors and generators (operation, single-phase equivalent circuits) – Synchronous machines – Asynchronous machines – Direct current machines – Parallel operation of direct and alternating current generators – Basic principles of speed and torque control systems of electric machines – Power

Electronics – Introduction to the operating principles of electric propulsion motors.

As part of the course, the following laboratory exercises are carried out with delivery of a technical

report:

1. Measurements of characteristic operating quantities in electric machines

2. Operation of static and rotating electric machines – Measurements of characteristic quantities

3. Simulations in computer programs of operation of electric machines in steady and transient state

Instructor: I. Prousalidis

8294 Metallic Materials

Chemical bonds and crystal structure of metals. Crystal structure defects. Main physical and mechanical properties. Mechanical tests. Surface properties, metrology. Phase diagrams at equilibrium. Study of the binary system Fe-C. Solid state structure transformations. Methods of hardening metallic materials. Heat treatments of metallic materials. Surface treatments of metal materials. Industrial alloys (steels, cast irons, aluminum, titanium, copper alloys).

Laboratory: Two Mandatory laboratory exercises entitled "Measurement Techniques" and "Identification of Metal Alloys", the second with delivery of a technical report.

Bibliography: "Science and Technology of Metallic Materials", I. Chrysoulakis and D. Pantelis, Ed. Papasotiriou, Athens, 2007.

Workshop notes: "Measurement techniques", D. Pantelis, NTUA, Athens, 2014.

"Identification of metallic alloys", NTUA, Athens, 2013.

Instructor: A. Zervaki

8158 Science and Technology of Welding

Introduction. Modern Welding Methods. Physics of Electric Arc Welding. Material Transfer during Welding and Melting of Electrodes. Delivery and Heat Transfer in Welding. Residual Stresses in Welding. Deformations in Welded Structures. Mechanical Behavior of Welded Structures. Welding Quality Control. The Welding Cost. The Iron-Coal System. Metallurgical Phenomena during Welding. Welding of Common Carbon Steels. Welding of Stainless Steels. Aluminum alloy welding. Special Welding techniques (thesis, Laser, etc.).

Laboratory exercises: a) GMAW arc welding. Mass transfer mechanisms. B) GTAW/FCAW arc welding, c) NDT methods (LP, MP, UT, RT), d) Classification of arc welds in terms of imperfections (macrostructure, microstructure, hardness measurements), e) Computational exercise to determine temperature distributions in welds , the last two with the submission of a technical report.

Notes: "Science and Technology of Welding", V. Papazoglou and D. Pantelis, University Traditions, NTUA, Athens, 2013.

Instructor: A. Zervaki

8284 Ship Behavior in Waves

Long-term stochastic consideration. Assessment of long-term maximum and design values for motions and loadings. Class rules and regulations. Added resistance and random incidents. Voluntary and involuntary speed reduction in waves. Impact of ship motion on crew and passengers, criteria for comfort, questionnaires. Operational efficiency. Route selection, based on weather and sea state predictions. Impact of hull form on the dynamic behavior in waves. Roll absorption and methods to reduce roll. Sea trials for the behavior in waves (on board, with models in the laboratory and at sea.) The course includes an assignment on the analytical design of the allowable operational field of a vessel using a computer code for strip theory.

Instructor: G. Grigoropoulos

8292 Ship Performance and Efficiency Monitoring

Introduction to the problem of systems evaluation. Areas of application in ship design and operation (indicative: energy efficiency, safety, environmental protection). Performance evaluation criteria and metrics. Development of computational procedures using indices. Fundamentals and tools of data analysis in evaluation. Data collection methods. Data quality control and pre-processing. Using theoretical and statistical models to calculate expected return. Uncertainty estimation and confidence level calculation. International regulatory framework and standards. Behavioral evaluation in the context of alternative design.

Tasks: a) Examination of ship hull fouling by analysis of operational high frequency sampling data.

b) Calculation of ship energy efficiency indicators during design and operation.

Instructor: N. Themelis

8041 Electrical Technology

Electricity, Signals and Systems, Electrical Circuits, Electrical Circuit Analysis, Steady State Sine Analysis (EMF), Power and Energy, Three-Phase Networks, Solving Electrical Networks with Laplace Transform, Methods of Electrical Network Analysis with Computer Programs, Solving Magnetic Circuits, Effects of electricity on the human body. Signals and systems, electric circuits and networks, electric circuit analysis, Sinusoidal Steady State Analysis, Electric power and energy, Three-phase networks, Electric Network analysis via Laplace transform, Electric Network analysis via computer programs, interference of electric current with the human body and tissues, magnetic circuits.

Laboratory exercises with delivery of a technical report: a) Familiarity with an electrical laboratory –

Measurements of electrical quantities, b) Symmetrical and Asymmetrical three-phase circuits.

Tasks: Series of computational exercises, report-presentation of bibliographic search on general topics of marine electrical engineering.

Instructor: J. Prousalidis

8235 Mooring Systems of Floating Structures

Types of anchoring systems. Permanent and temporary moorings. Description of the elements that make up an anchoring system (anchoring branches, anchors, materials). Static analysis of anchorage systems of single and multiple branches (inelastic and elastic catenary equation, intermediate floats, different materials). Design of anchorage systems of single and multiple branches (design loads from wind, currents and waves on the floating structure, preliminary selection of geometric and inertial characteristics of the anchorage branches, determination of the stiffness of the anchorage system, responses of the anchored structure, construction of the characteristic external load-displacement curve, proficiency checks). Design regulations for anchorage systems according to classification societies and other organizations.

Exercises for students to practice: Three due date exercises are given which relate to the analysis and design of simple and multiple anchorage systems.

Notes: “Analysis and Design of Mooring Systems”, S. Mavrakos, I. Chatjigeorgiou, University Lectures, NTUA, Athens, 2002.

Instructors: I. Chatzigeorgiou, D. Konispoliatis

8137 Design of Floating Structures

Successive stages in the design of floating structures and offshore facilities. Description of environmental data (wind, currents, waves). Determination of loads from the action of the environment (loads of wind, currents, waves). Morison equation and applications for hydrodynamically “thin”, rigid and deformable structures. Hydrodynamic analysis using three-dimensional dynamic flow. First and second order diffraction and radiation problems. Exact and approximate methods and solutions. Method of hydrodynamic analysis of floating semi-submerged platforms. Examples. Static analysis of simple anchor moorings.

Notes: “Elements of the Study of Floating Structures (Hydrodynamic Analysis)”, S. Mavrakos, University Traditions, NTUA, Athens, 1995.

Instructor: I. Chatjigeorgiou, D. Konispoliatis

8181 Marine Structures

Introduction to the study of ship structural arrangements. Bending and buckling of prismatic bodies. Shear lag. The concept of equivalent cross section is based on the attached plating. Bending of rectangular plates. Behavior of stiffened panels under compressive loading. Ship structural arrangement of various modern ship classes. The regions of a ship hull structure of the modern merchant ship. Design of transverse bulkheads. Design of the ship hull structure based upon fundamental engineering principles. Elements of the theory of cylindrical shells. Application to submarine design. Reliability analysis of marine structures. Book: “The Metal Construction of the Ship: Topics of Local Strength”, P. Karydis, Athens, 2001.

Instructor: K. Anyfantis

8276 Ports and Intermodal Transport

Study of port functions and presentation of their role in the combined transport chain. Presentation and analysis of issues related to the administration, planning and development of ports, cargo handling and handling and the application of related optimization methods. Institutional port models. The ISPS code for port security. Competitiveness of ports and access to the port services market. Recording of institutional and other developments in the international and Greek space. Maritime traffic management issues, ship-port interface, and environmental improvement and immunity.

Instructor: N. Ventikos

8282 The Human Element – Introduction to Human Reliability for Maritime Transport

Study of the human factor and introduction to human reliability in maritime transport. Valuing and quantifying the role of the human element. Presentation of first- and second-generation theory and methodologies for assessing and improving human reliability and their application to maritime transport. Human as a source of risks, but also as a measure of de-escalation of critical situations: reference to the modern consideration of the integrated assessment of the human factor. Presentation of comparative approaches to applications in maritime transport and maritime accidents.

Instructor: N.P. Ventikos

8286 Risk Analysis and Assessment of Environmental Impacts from Maritime Transport

Introduction and study of maritime and marine safety. Analysis of the concepts SAFETY I and SAFETY II. Introduction and analysis of the Formal Safety Assessment (FSA) methodology of the International Maritime Organization (IMO). Analysis of risk engineering and the concept of resilience engineering in maritime transport. Study and management of risk in shipping: social risk, individual risk, perceived risk and consequence assessment (including environmental evidence, oil pollution). Recording the dimensions of risk and studying acceptance limits (for the design and operation of ships). Quantified methodologies for risk analysis, valuation and management – including risk-benefit analyses. Analysis of maritime accidents. Sustainability elements of shipping. Presentation and critical analysis of maritime and marine safety and environmental protection regulations from ships. Organization of anti-fouling operations and design/operation of anti-fouling vessels and equipment.

Instructor: N.P. Ventikos

8279 Environment and Growth

Interdisciplinary course dealing with the management of environmental problems arising from the activities of the engineer.

Instructors: Faculty members of the Schools of the University. School representative: N. Ventikos

8301 Advanced Dynamics-Diagnostics of Complex Mechanical Systems with Machine Learning Applications to Fault Diagnostics of Marine Technological Systems

1. Introduction: Overview of motion-energy transmission technologies in Naval Architecture and Aerospace science-technology. Engines as complex mechanical systems. Industrial motion transmission mechanisms: Piston-Connecting Rod-Flywheel, propeller shaft, gear reducer, clutch, and brake. Factors driving the evolution of historical simple machines. Overview of robotic entities and vehicle technology. Advanced propulsion and motion transmission machinery. Generalizations.

2. Analytical Dynamics of Mechanisms: Spatial arrangement of eccentric masses and eccentric rotors. Geometric complexity and nonlinearity. Linkages as kinematic constraints. Inertial force-kinetic energy. Force-work function relationship. Degrees of freedom. Virtual displacements-Principle of Virtual Work.

Physical quantities: Lagrangian and Hamiltonian. Constraints-augmented Lagrangian-Lagrange multipliers. Euler-Lagrange equations of motion. Constrained double and triple pendulums: (1) Piston-Connecting Rod-Flywheel (PCF) and (2) Opposing Pistons-Connecting Rods-Flywheel (OPCF). Nonlinear equations of motion (Euler-Lagrange). Strongly nonlinear rotors. Response-resonance under periodic force pulse sequences. Power output calculation of mechanisms. Generalizations.

3. Analytical Dynamics of Mechanism Systems: Spatial configurations (banks) of motion transmission mechanisms of type (PCF) and (OPCF). Crankshaft. Support bearings—inertial forces and moments. Optimization of configurations. Equation of motion (Euler-Lagrange) for engines. Response-resonance under periodic force pulse sequences. Camshaft. Industrial multicylinder engines. The role of opposing piston engines in advanced propulsion technologies. Generalizations.

4. Vibrations of Complex Systems: Natural vibrations of basic complex systems: (1) Disks-elastic shaft-Disks, (2) Masses-elastic rod-Masses, (3) Masses-elastic beam-Masses, (4) Disks-elastic crankshaft-Disks, (5) Configurations of coupled engines-propeller shafts-gear reducers-clutches-brakes-peripheral auxiliary energy systems (Euler-Lagrange). Generalizations.

5. Resonance Physics: Forced torsional oscillator. Dynamics of resonance and irreversible energy flow. Resonance in nonlinear oscillators. Categories of nonlinear resonances—bifurcations. Subharmonic and superharmonic resonances. Physical complexity of combinatorial resonances—nonlinearity. Resonances in a laboratory elastic beam interacting with an electromagnetic field.

6. Passive Vibration-Wave Control: Modeling of supports—vibration isolation in machinery-structures. Linear vibration dampers. Nonlinear vibration dampers in mechanical engineering. Bifurcations, nonlinear resonances, chaos, complexity. Nonlinear oscillators with multiple static equilibrium states or chaotic attractors—resonance diffusion. System nonlinearization. Irreversible flow of mechanical energy. Laboratory demonstration. Generalizations.

7. Transformations: Fourier Transform. Computational algorithm for Fast Fourier Transform (FFT). Wavelet Transform. Computational algorithms for Wavelets. Decomposition of natural vibration modes. Optimal transformation of orthogonal decompositions-projections. Experimental Modal Analysis (EMA). Operational Modal Analysis (OMA).

8. Data Science: Mathematical-geometrical structure of data sets (cloud). Geometric spectral analysis of clouds. Union-intersection-augmentation-nesting of clouds. Classical fault diagnostics. Advanced fault diagnostics. Application-analysis in experimental data.

9. Machine Learning: Experimental-empirical-theoretical mechanics. Foundations and topography of digital data. Experiences and biological learning. From biological to machine learning. Categories of machine learning. Fundamental machine learning algorithms. Neural network computations. Training-testing-prediction with neural networks. Architecture of the convolutional neural network AlexNet. Evolution of classical mechanics with convolutional neural networks for deep learning.

10. Generalizations: Machine learning of the physics of mechanical motion transmission systems and interaction with the environment.

11. Technological Marine Systems: Instabilities in marine load transfer machines (cranes). Early fault detection in renewable energy machines (wind turbines). The prospects of Artificial Intelligence. Generalizations.

Instructor: J. Georgiou