Fakultät für Ingenieurwesen
Facoltà di Ingegneria
Faculty of Engineering

COURSE DESCRIPTION – ACADEMIC YEAR 2024/2025

Course title	**Machine Design**
Course code	42179
Scientific sector	IIND-03/A - Progettazione Meccanica e Costruzione di Macchine (ex ING-IND/14)
Degree	Bachelor in Industrial and Mechanical Engineering (L-9)
Semester	2
Year	3
Credits	6
Modular	No

Total lecturing hours	36
Total lab hours	
Total exercise hours	24
Attendance	Strongly recommended
Prerequisites	Students should be familiar with the basic knowledge of: - Materials science and structural mechanics - Manufacturing Technology - Technical Drawing - Mechanics of Machinery - Fundamentals of Machine Design
Course page	https://www.unibz.it/it/faculties/engineering/academic-staff/person/37418-lorenzo-maccioni

Specific educational objectives	The Machine Design course has a dual objective. On one hand, the course aims to provide students with the technical skills necessary to design, size, select, and/or verify, from a structural perspective, the most common Machine Components (MCs) with a particular focus on ensuring both the reliability and efficiency under specific operating conditions. On the other hand, it seeks to develop students' scientific expertise in formulating and solving mathematical problems related to the analysis of stresses and deformations in MCs, enabling an essential understanding of their mechanical behavior and resistance. In the initial part of the course, fundamental concepts for the dimensioning of shafts are reviewed, with a focus on different design solutions for transmitting torque between coaxial components. This is followed by an analysis of stress distributions in MCs with high curvature, pressure vessels, and rotating disks. Subsequently, the course addresses elastic line problems, including the deformation of elastic bodies and the design of various types of springs. The topic of stresses caused by contact between elastic bodies (Hertzian Theory) is then introduced, along with the fundamentals of applied tribology, with particular attention to journal bearings. A detailed exploration of rolling-element bearings is included, covering their types, assembly, dimensioning, and related design considerations. The course also provides an overview of different types of gears, focusing on the forces they transmit and their effects on shafts and bearings. Eventually, belt and chain drives are examined, with an emphasis on their dimensioning and the forces they exert on shafts and bearings.

Lecturer	Dr. Lorenzo Maccioni
Contact	lorenzo.maccioni@unibz.it
Scientific sector of the lecturer	IIND-03/A - Progettazione meccanica e costruzione di macchine (ex ING-IND/14)
Teaching language	English
Office hours	Monday through Friday by appointment. No office hours will be granted in the 7 days prior to the exam.
Lecturing Assistant	No
Contact LA	
Office hours LA	
List of topics	**1. Shaft-Hub Connections** - Design and selection of components/features to transmit torque between shaft and hub: pins, keys and splined shafts. - Analysis of stress concentration effects on key seats and shafts. **2. High-Curvature Beams** - Determination of the stress state in high-curvature beams subjected to bending. - Design of hooks, curved plates, and clamps. **3. Pressure Vessels and Rotating Rings** - Analysis of the stress state in thin-walled and thick-walled cylindrical pressure vessels and criteria for their design. - Stress analysis of thin rotating rings and rotating disks. **4. Elastic Line, Deflection, and Springs** - Derivation of the deflection equation by integrating the elastic line equation and applying appropriate boundary conditions. - Presentation of concepts related to stiffness-based design. - Introduction to different spring types, characteristic dimensions, geometric properties, arrangements in series or parallel, design and selection criteria. - Calculation of stiffness, stored energy, utilization coefficient, and stress state for various spring types. - Hints at advanced computer-assisted methods - Detailed study of cylindrical helical springs, leaf springs, torsion bars, flat spiral springs, and disk springs. **5. Contact Stresses Between Curved Elastic Bodies (Hertz Theory)** - Presentation of the assumptions underlying Hertz theory, stress distribution in contacts, and related deformations. - Calculation of maximum and average contact pressure. - Detailed study of stress states for sphere-sphere, roller-roller, and double-curvature surface contacts. **6. Tribology and Journal Bearings** - Exploration of lubrication principles, characteristics of mineral and synthetic lubricants, and additive properties. - In-depth study of the Stribeck curve, friction coefficient, lubrication regimes, and the effects of surface roughness.

	7. Rolling Element Bearings - Demonstration of the advantages of rolling friction and Stribeck's formula. - Overview of different bearing types, their properties, applications, assembly solutions, sealing and lubrication methods. - Calculation of bearing reactions. - Presentation of the Lundberg and Palmgren theory, rating life, and adjustment factors. - Application of static load carrying capacity and operating life criteria for selecting bearings from catalogs based on operating conditions. - Calculation of stiffness, friction effects, efficiency estimation, and heat dissipation analysis. **8. Fundamentals of Gear, Belt, and Chain Design** - Review of gear geometry and kinematics. - Overview of gear types and calculation of transmitted forces. - Wear-based design of cylindrical gears. - Analysis of stresses and design under varying operating conditions. - Overview of chain and belt types and criteria for design, catalog selection, and lubrication choices.
Teaching format	Theory lessons are alternated with practical exercises to reinforce the concepts covered and demonstrate their practical utility. Teaching material will be given to the students; additional material will be provided by the professor.

Learning outcomes	**Intended Learning Outcomes (ILOs)** <u>Knowledge and understanding</u>: 1. Recognize and categorize MCs understanding their critical features, mechanical behavior, and operational principles. 2. Acquire a thorough understanding of the fundamental principles of mechanical sizing and their application to MCs. 3. Comprehend the theoretical foundations and mathematical models for evaluating critical stresses, deformations, and the performance of MCs under various operating conditions. 4. Understand the methods and technologies related to lubricated systems, tribology, and contact mechanics, including Hertzian stress theory and lubrication regimes. <u>Applying knowledge and understanding</u>: 5. Analyze and solve complex design problems involving multiple interconnected components ensuring mechanical reliability and operational efficiency. 6. Perform the dimensioning and verification of MCs based on specific operating conditions, applying criteria for static, fatigue, and wear resistance. <u>Making judgments</u>: 7. Critically evaluate the appropriateness of design choices for MCs in terms of reliability, efficiency, and cost-effectiveness under given design requirements.

	8. Identify potential design improvements or alternative solutions based on a systematic assessment of the mechanical behavior of components. 9. Assess the implications of simplifying assumptions in theoretical models, recognizing their impact on the accuracy of results and the validity of conclusions. Communication skills: 10. Prepare and deliver clear and concise technical presentations on mechanical design topics, effectively communicating results, methodologies, and critical assessments to an audience. 11. Engage in discussions, demonstrating the ability to explain, defend, and refine design decisions or theoretical approaches. 12. Produce technical reports that document the analysis, design, and evaluation of MCs and systems. Learning skills: 13. Independently explore advanced topics in mechanical design, utilizing academic literature and technical standards and handbooks. 14. Adapt and apply theoretical principles to different machine design problems, developing solutions based on sound engineering judgment.

Assessment	The student's evaluation will be based on both a written and an oral exam. The written exam consists of two exercises: **Simple-System**: A design problem involving a simple system, where the student will be required to calculate either the forces transmitted between two components, the stress state, or the deformation of a specific component under given operating conditions. **Complex-System**: A design problem involving a complex system in which multiple components interact, exchanging forces and/or mechanical power. The student will be required to verify and/or design these components based on specified operating conditions. During the written exam, students may consult instructional materials and the formula sheets provided by the professor during the academic year. The oral exam is divided into two phases: **Oral-Presentation**: In this phase, the student delivers a 10-minute presentation to the professor on a pre-approved topic. Following the presentation, a discussion will take place where the professor will ask 1-2 questions related to the chosen topic. The topic should involve an in-depth analysis of a subject covered in class and/or the application of methodologies studied in class to the design of a real-world system. If the student does not prepare a presentation, the professor will instead ask a total of four questions at the professor's discretion. **Oral-Theory**: In this phase, the professor will ask the student to discuss a theoretical aspect, demonstrating their understanding of the assumptions underlying the derivation, the mathematical steps involved, and the implications of the results for the design of machine components.

Formative Assessment

Form	Duration	ILOs assessed
In class exercises	24 h	1, 2, 3, 5, 6, 7, 8, 9

Summative Assessment

Form	%	Duration	ILOs assessed
Written Simple-System	15%	Up to 4 hours	1, 2, 6
Written Complex-System	45%		1, 2, 5, 6, 7, 9, 12
Oral Presentation	25%	Up to 30 min	4, 7, 8, 9, 10, 11
Oral Theory	15%	Up to 15 min	1, 2, 3, 9

Assessment language	English
Assessment Typology	Monocratic

Evaluation criteria and criteria for awarding marks

Students regularly enrolled in the third year of the Bachelor in Industrial and Mechanical Engineering are eligible to attend lessons and take the exam. Exceptional cases must be discussed and approved by the professor.

Written Simple-System: This exercise is designed to evaluate the student's fundamental knowledge and understanding of the concepts taught during the Machine Design course.

Assessment Criteria:

- Correctness of the dimensioning procedure: The student must demonstrate the ability to translate the problem requirements into an appropriate model for sizing the required system.
- Correctness of the numerical solution: The student is required to perform accurate calculations related to the machine's design and performance and evaluate the validity of the numerical results. Significant numerical errors, such as those off by an order of magnitude, will be considered severe.
- Appropriate use of measurement units: Mistakes in the use of measurement units will be deemed highly critical.

Written Complex-System: This exercise evaluates the student's ability to apply theoretical knowledge to practical, real-world applications, demonstrating an understanding of theoretical concepts, critical judgment, and communication skills through clear and organized responses.

Assessment Criteria:

- Correctness of the design choices: The student is required to size or verify multiples interconnected mechanical components. This includes justifying design decisions based on the problem's requirements and making well-reasoned assumptions where data are incomplete. The ability to discuss the trade-offs of chosen solutions compared to possible alternatives will be particularly valued.

	- Correctness of the numerical solution: The student is expected to perform accurate calculations related to the system's design and/or performance, critically assessing the plausibility of the results. Numerical errors off by an order of magnitude will be considered severe. - Appropriate use of measurement units: Errors in measurement units will be regarded as highly critical. Students will be allowed to take the oral exam only if they achieve a score of 18 or higher in the written tests. If the oral exam is deemed insufficient, it may be repeated up to two times before the written part must also be repeated. **Oral-Presentation:** This phase enables the professor to assess the student's communication skills and learning abilities, as outlined in the course's ILOs. Additionally, it provides students with an opportunity to delve deeply into a specific topic and begin the oral examination with a presentation. A critical perspective that evaluates the models discussed, highlighting both their strengths and limitations, is particularly appreciated. Assessment Criteria: - Theoretical knowledge: The student must demonstrate a solid understanding of the theoretical concepts underlying the topic. - Ability to provide examples or applications: The student is encouraged to illustrate theoretical concepts with real-world examples or practical applications. - Communication skills and mastery of technical language: Clear and effective communication, along with proficient use of technical terminology, will be positively evaluated. **Oral-Theory:** This phase allows the professor to assess the student's knowledge and understanding of the theoretical content orally, complementing the written evaluation. Responses that start with a general overview of the problem and then delve into a more detailed modelling approach, supported by a clear explanation of the underlying assumptions, are preferred. Assessment Criteria: - Theoretical knowledge: The student must demonstrate a solid understanding of the theoretical concepts underlying the topic. - Communication skills and mastery of technical language: Clear and effective communication, along with proficient use of technical terminology, will be positively evaluated.

Required readings	Lecture notes, slides, and documents that will be available on the course site
Supplementary readings	- Shigley's mechanical engineering design. Budynas, R. G., & Nisbett, J. K.; McGraw-Hill. (ENG) - Fundamentals of Machine Component Design. Juvinall, R. C., Marshek, K. M. John Wiley & Sons (ENG)

	- Fundamentals of Machine Component Design. Altabey, W. A. John Wiley & Sons (ENG) - Costruzione di machine. Pierini, M. & Nerli, G. Esculapio (ITA) - Lezioni sugli organi delle macchine. Diavoli, P., Filippini, M., Gorla, C., Lo Conte, A. Hoepli (ITA) - Maschinenelemente. Höhn, B. R., Niemann, G., Winters, G. Springer (GER)
Software used	Spreadsheets, Matlab, CalculiX