

## **BACHELOR IN INDUSTRIAL AND MECHANICAL ENGINEERING**

### **Course Contents from 2025-2026**

#### **Mathematical Analysis I**

- Introduction to real and complex numbers.
- Basic notions on real functions of one real variable.
- Real sequences and numerical series.
- Limits and continuity.
- Differential calculus and its applications.
- Local comparison and Taylor expansions.
- Antiderivatives and integral calculus for functions of one real variable.
- Definite and improper Riemann integrals.

#### **General and inorganic Chemistry**

- Atomic theory, the chemical bond, and the periodic table
- States of matter and phase transitions
- Stoichiometry, reaction equations, basic thermodynamics and catalysis
- Chemical reactions (solvation, acid-base, redox incl. electrochemistry)
- The chemical equilibrium
- Crystal structures
- Macromolecular chemistry and nanotechnology
- Biomolecules
- Reaction kinetics

#### **Linear Algebra**

- Vector spaces
- Geometry of space
- Matrices
- Linear systems
- Determinant and rank
- Linear transformations

#### **Fundamentals of Information Science and Microcontroller Programming**

- Basics of programming in the C/C++ language
- Introductory analog and digital electronics
- Introductory motor control and sensor reading
- Introduction to computer architecture

### **Physics I**

- Measurement and vectors: units of measurement, dimensions of physical quantities, mathematical operations with vectors.
- Kinematics: average and instantaneous velocity and acceleration, uniformly accelerated motion.
- Dynamics: Newton's three axioms, gravitation, work, energy, law of conservation of energy, linear momentum, collisions, centre of mass. Rotational dynamics: angular displacement, average and instantaneous angular velocity and acceleration, torque, moment of inertia, angular momentum, general motion.
- Statics: Static Equilibrium, stress-strain, Young's modulus.
- Fluids: Ideal fluids, Pascal's and Archimedes' principles, Bernoulli's equation.
- Thermodynamics: thermal expansion, kinetic theory of gases, heat, ideal gases, zeroth, first and second law of thermodynamics, thermodynamic cycles, entropy.

### **Mathematical Analysis II**

- Functions of several variables (differential calculus)
- Vector functions, curves and vector fields
- Double and triple integrals
- Line integrals and surface integrals
- Elements of Ordinary Differential Equations (essentially, linear equations)

### **Fundamentals of Technical Drawing**

- Lines used in technical drawing according to standards
- Orthographic projections
- Sections
- Dimensioning
- Introduction to 2D CAD modelling
- Introduction to mechanical components

### **CAD Modelling of industrial products**

- Axonometric and oblique views to show the three dimensions of objects
- From 2D to 3D CAD
- Parametric 3D CAD for parts, assemblies and drafting
- Modelling of complex shapes with parametric and non-parametric CAD
- CAD-supported drafting of industrial and technical products
- Interaction between different CAD platforms
- CAD modelling of parts belonging to a complex system (proposed example: UAV)

### **Representation of Mechanical Components with CAD Software**

- Tolerancing and errors

- Threaded connections and other joints
- Bearings
- Other mechanical components
- 2D CAD modelling for the drafting of mechanical assemblies

### **Materials science and structural Mechanics – Module 1 – Mechanics of Structures**

- Equilibrium of forces with a common point of application, and of rigid bodies
- Determination of support reactions and internal forces
- Centre of forces, mass, and gravity
- Elementary theory of tension/compression, bending, and torsion
- Stresses, stress resultants, strains, and Hooke's law

### **Materials science and structural Mechanics – Module 2 – Material Science and Technology**

- Introduction: the materials and their use in the industrial production
- Technological properties of materials: different type of materials and their typical properties;
- correlation between microstructure and mechanical properties;
- basis of thermodynamics and equilibrium diagrams
- Metals: characteristics and properties of iron alloys (steel and cast iron);
- non ferrous metals
- Ceramics and glasses;
- the production and utilization of ceramic materials
- the characteristics of glass; the production of glass components.
- Polymers: production and properties of polymeric materials;
- production of components in polymeric matter; utilization of polymers.
- The composite materials: production, properties, utilization of composite materials

### **Economics for Engineers**

- The company: objectives and context
- Essentials of financial accounting;
- Investment analysis;
- Other economic evaluation analyses.

### **Physics II**

- Electrostatics, Charge, Coulomb force, Electric field, Electric potential
- Electric currents, AC/DC currents, Ohm's laws, Kirchhoff's laws
- Capacitors, Semiconductor devices, AC/DC circuits
- Magnetostatics, Lorentz force, Electromagnetism, Induction
- Electromagnetic waves, Optics

### **Production Systems and Industrial Logistics**

- Classification and systematisation of industrial production systems; Basic concepts and definitions of production science;

- Lean Production Systems: Value Stream Mapping and Optimization, other basic concepts of the Lean Production Toolbox (5S, seven sources of waste, Kaizen, TPM);
- Material flow optimization and layout planning;
- Manufacturing systems: single manufacturing cells, group technology, cellular manufacturing, flexible manufacturing systems;
- Assembly systems: manual-hybrid-automated assembly systems;
- Methods of time measurement.
- Introduction to Industry 4.0

### **Electrical circuits and machines**

- Electrical phenomena and circuit components (resistors, capacitors, inductors);
- Circuit topology (graphs, Kirchhoff's laws) and general theorems of circuits;
- Electrical networks analysis methods with exercises;
- Analysis of DC circuits, magnetic circuits and sinusoidal AC circuits;
- Electrical machines: transformers and electro-mechanical conversion principles.

### **Engineering Thermodynamics and Heat Transfer**

- Fundamentals of Thermodynamics;
- Energy conversion;
- Energy of open and closed systems
- Heat transfer;
- Mass transfer
- Ideal gases
- process
- Irreversibility

### **Classical Mechanics**

- Linear and angular momentum equations;
- Euler angles, inertia tensor and rigid body dynamics;
- Holonomic systems;
- Lagrange equations;
- Lyapunov stability.

### **Fluid Mechanics**

- Fluid statics;
- Fluid kinematics;
- Fluid dynamics;
- Integral and differential conservation laws;
- Bernoulli equation and energy conservation law;
- Flows in ducts;
- Hydraulic measures.

### **Mechanics of Machinery**

- Mechanisms, degrees of Freedom, kinematic pairs, kinematic scheme of a mechanism;

- Kinematic analysis of (planar) mechanisms: position, velocity, acceleration;
- Static and dynamic analysis of (planar) mechanisms. Lagrange's equations;
- Mechanical Transmissions and Components (kinematics and transmitted forces/torques);
- Flexible power transmission elements (belts, ropes and chains);
- Fundamentals of Mechanical Vibrations.

### **Fluid Machines**

- Fundamentals of work exchange and energy conversion in Fluid Machines
- Design of hydraulic machines: pumps and hydropower machines
- Compressible fluids behavior: ducts design for gases and vapors; airfoils and aerodynamics principles
- Design of gas and steam turbines and volumetric compressors.

### **Fundamentals of Machine Design**

- Equilibrium of complex structures
- Stresses and strains, stress intensification (Kt)
- Material characterization - Constitutive law - Traction test
- Von Mises equivalent stress
- Fatigue - Wöhler diagram, Multiaxial fatigue criteria

### **Machine Desing**

- Machine Elements: Shafts;
- Machine Elements: Springs
- Machine Elements: Gears
- Machine Elements: Bearings
- Finite Element Method: basic theory

### **Manufacturing Technology**

- Deformation processes: forging, rolling, drawing, extrusion, sheets metalworking;
- Machining operations: ortogonal cutting, cutting forces, tool wear, turinin, milling;
- Working cycle;
- Founduary, casting processes;
- Non conventional machining processes: EDM, laser cutting, waterjet, additive manufacturing;
- Welding processes.

### **Factory and Plant Planning**

- Site planning;
- Layout and space planning;
- Investment decisions;
- Plant and equipment maintenance.

### **Specialized Italian**

- Technical language: terminology, morphology, syntax, text structure

- access to the world of the work: cv, company structure, application, cover letter, job interview
- reports/presentations on discipline-specific topics;
- writing academic (reports/emails): formal/informal language.

### **Specialized English**

- Writing academic emails: formal language/making polite requests/format & language of formal emails;
- Writing academic reports: formal language/discourse markers/structure & organization;
- Making academic presentations on a discipline-specific topic;
- Discipline-specific vocabulary: word formation & collocations;
- Paragraph writing: topic sentences, discourse markers & other organisational features.

### **Specialized German**

- Technical language: terminology, morphology, syntax, text structure;
- Informal and formal e-mails within the academic sector;
- Application and cover letter;
- Graphics on specific technical topics;
- Reports/ presentations on discipline-specific topics;

### **Industrial electrical applications**

- Production, transmission and distribution of electrical energy
- Sizing of electrical distribution lines
- Electrical energy static conversion
- Principles of operation of electrical machines;
- Applications and choice of electrical motors for simple applications

### **Numerical and Data Driven Methods for fluid Machines**

- Introduction to Computational Fluid Dynamics (CFD);
- Fundamentals of numerical methods for Fluid Dynamics
- Introduction to Turbulence
- The Finite Volume Method (FVM)
- Fluid volume discretization
- Solution methods for CFD problem
- Practical applications to turbomachinery problems

### **Engineering Energetics**

- Moist air thermodynamics;
- HVAC systems;
- Exergy;
- Reversed cycles.

### **Optimisation**

- Practical Optimization Models
- Least Squares Models

- First Order Algorithms
- Second Order Algorithms
- Convexity and Convex Optimization
- The KKT Conditions and Duality Theory
- Topics in Data Mining and Regression Analysis

### **Operations Research**

- Linear Programming
- Transportation and Assignment Models
- Network Flow Problems
- Integer Programming
- Dynamic Programming
- Goal Programming
- Nonlinear Programming

### **Programmable controllers for Industrial Automation**

- Design of logic circuits. Canonical Normal Forms. Optimal synthesis: Karnaugh maps;
- Fundamental combinatorial and sequential circuits: building blocks of a Programmable Logic Controller (PLC);
- PLCs: structure, IO modules, applications. PLC programming using IDEs;
- Languages of the IEC 61131-3 standard: Ladder Diagram (LD), Functional Block Diagram (FBD), (Structured Text (ST));
- Moore and Mealy state machines and their implementation in the LD language;
- Hands-on development of supervisory controls using state-of-the-art toolchain and hardware (laboratory activity).

### **Digital production planning and quality control**

- Forecast planning methods (sales and operations planning);
- Lot size calculation (static, dynamic);
- MRP, Re-Order Point Calculation;
- Scheduling of production orders;
- Production control methods (Kanban, BOA, OPT,...);
- Capacity planning methods.

### **Ergonomics and safety of Manufacturing and Logistics Systems**

- Occupational Health and Safety
- Risk assessment in sociotechnical systems
- Safety of machinery
- Anthropocentric production and logistics
- Human Factors in production and logistics systems
- Biomechanical load assessment
- Digital Ergonomics

- Human Modeling and Simulation

### **Fundamentals of hydraulics and Pneumatics**

- General principles. Hydraulic power transmission. Head and fluid loss. Hydraulic fluid classification;
- Graphic symbols and standardisation. Hydraulic open and closed circuits. Pumps and engines with pistons, blades, gears. Hydraulic jacks;
- Main flow and power control valves in hydraulic and pneumatic applications (Pressure regulation valves, Sequential valves, Flow regulation valves, Flow dividers. etc.);
- Rotary and case distributors. Feeding groups. Utilizing groups. Parallel, in series and mixed circuits. Circuits for sequences;
- Compressors. Compressor and tank choice. Pneumatic jacks and hammers.

### **Mechanics of machines and mechanism for automation**

- Degrees of Freedom, kinematic pairs, kinematic scheme of a mechanism, structure equation;
- Kinematic analysis of mechanisms (position, velocity, acceleration);
- Static and dynamic analysis of (planar) mechanisms. Lagrange's equations;
- Mechanisms for automatic machines: motion generation; cam mechanisms; periodic motion and balancing;
- Mechanics of Drives: motor-gear-load coupling (introduction);
- Mechanics of Robots: introduction to 3D kinematics and industrial robots.

### **Engineering thermodynamics and heat transfer for Mechatronics**

- Fundamentals of Thermodynamics;
- Energy conversion;
- Energy of open and closed systems;
- Heat transfer;
- Mass transfer;
- Ideal gases;
- Process;
- Irreversibility

### **Systems and Control**

#### **Module I**

- Dynamic system modelling in frequency domain;
- Dynamic system response;
- Stability of linear control systems;
- Root-locus analysis and design methods;
- Frequency-response analysis and design methods;
- Digital control systems (time permitting).

#### **Module II**

- Introduction to Matlab;
- Introduction to Simulink;
- Simulation of dynamic systems in the frequency domain with the Control System Toolbox;

- Computer-aided analysis and design in Matlab/Simulink;
- Real experiments of control in the lab.