

## BACHELOR IN INDUSTRIAL AND MECHANICAL ENGINEERING

### Course Contents

#### Mathematical Analysis I

- Introduction to real and complex numbers
- Real functions of a single real variable, limits and continuity
- Differential calculus
- Local comparison and Taylor expansions
- Real sequences and numerical series
- Integral calculus of real valued functions in one variable

#### 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
- Quantum mechanics
- Crystal structures
- Thermodynamics
- 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, dimensions of physical quantities.
- Kinematics: Average and instantaneous velocity and acceleration. Uniformly accelerated movement.
- Dynamics: The three Newtonian axioms, work, energy, conservation of energy, oscillations, momentum.
- Statics: Static equilibrium, stress-strain, Young's modulus.
- Fluidics: Ideal fluids, Pascal's and Archimedes' principles, Bernoulli's equation.
- Thermodynamics: Thermal extension, kinetic gas theory, heat, ideal gases, first and second laws 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)

## **Technical Drawing and Industrial Engineering Methods**

- Lines used in technical drawing according to standards;
- Orthographic projections;
- Sections;
- Dimensioning;
- Dimensional tolerances.

## **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 2/12
- 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 circuit components;
- Circuit topologies (graphs, Kirchhoff's laws, general theorems of circuits);
- Analysis methods;
- Analysis of DC and 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 efficient Energy Conversion in Fluid Machines
- Design of hydraulic machines: pumps and hydropower
- Compressible fluids behavior; 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 Design**

- 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: orthogonal cutting, cutting forces, tool wear, tooling, milling;
- Working cycle;
- Foundry, 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**

- Present Subjunctive forms and uses
- Subjunctive Pasts: forms and uses
- Language for specific purposes vocabulary and syntax
- Discursive markers.

### **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**

- Sizing of electrical distribution lines;
- Principles of operation of electrical machinery;
- Applications and choice of electrical machinery;
- Electrical energy static conversion.

### **Advanced Methods for Fluid Machine Design**

- Conservation equations and Finite volume method;
- Computational approach for fluid dynamics: from geometry to post-processing;
- Evaluation and choice of spatial discretization, temporal discretization, and turbulence models;
- Practical applications to turbomachinery design.

### **Engineering Energetics**

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

### **Optimisation**

- Preliminaries of linear algebra
- Fundamentals of multivariate calculus
- Practical optimization models
- Fundamentals of optimization
- Linear programming: geometric analysis

- Linear programming: the simplex algorithm
- Linear programming: Duality and sensitivity analysis
- Nonlinear programming: fundamentals of unconstrained optimization
- Nonlinear programming: unconstrained optimization algorithms
- Nonlinear programming: fundamentals of constrained optimization
- Nonlinear programming: constrained optimization algorithms

### **Operations Research**

- Preliminaries of the linear algebra and algorithmic
- Linear programming: modelling
- Linear programming: geometric interpretations
- Linear programming: the simplex algorithm
- Linear programming: duality and sensitivity analysis
- Transportation and assignment models
- Network flow problems
- Integer programming: modelling
- Integer programming: algorithms
- Dynamic programming
- Heuristic algorithms
- Goal 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.

### **Logistics and transport**

- Supply Chain Management;
- Procurement Logistics (strategic purchasing & supplier management);
- Warehouse Logistics (packaging technology, warehouse system technology, warehouse organisation and processes);
- Distribution Logistics;
- Transport Logistics (incl. international logistics).

### **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.

### **Reverse engineering and rapid prototyping**

- Introduction to the Engineering Design process and CAD;
- Reverse Engineering and 3D scanning;
- Additive Manufacturing technologies;
- Special applications of and new trends in Additive Manufacturing;
- Design for Additive Manufacturing;
- Employment of Reverse Engineering and Rapid Prototyping technologies in different industrial fields;
- Other technologies for the prototyping and the design of products.

### **Systems and Control**

- 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;
- Computer-aided analysis and design.