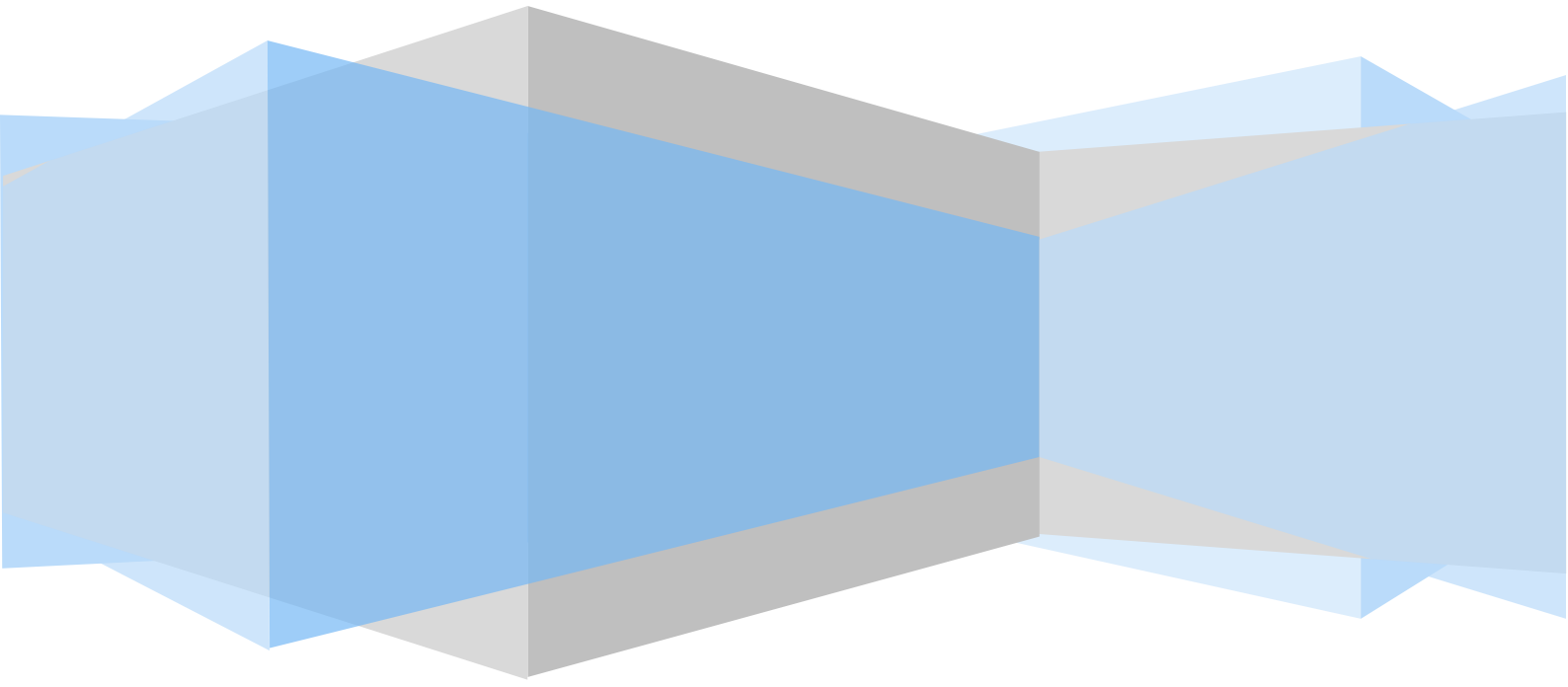
Bjelovar University of Applied Sciences

# COURSE CATALOGUE

## MECHATRONICS - academic year 2022/23



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|---|---|---|---|---|---|---|---|
| **Course title** | **Fundamentals of Electrical Engineering** | | | | | | |
| **Course instructor(s)** | Elizabeth Hedl, Goran Benkek | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 1st | **Semester** | 1st | **ECTS** | 7 | | |
| **Contact hours (L+PS+S)** | 30 + 45 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 30 | 15 | 0 | | |

**Course objectives**

Familiarising students with the basic knowledge and problem solving in the area of electrical engineering.

**Expected learning outcomes**

Upon completion of the course students will be able to:

- O1: define the basic terms of electrostatics,
- O2: define the basic terms of electric circuits,
- O3: analyse DC electric circuits using Ohm's law, Kirchoff's laws and the methods of solving linear networks,
- O4: define the basic terms of electromagnetism,
- O5: analyse the connections of resistors, capacitors and inductors in a DC circuit,
- O6: analyse AC circuits using phasor algebra,
- O7: analyse the three-phase system connections.

**Course content**

**1. Electric charge and electric field** (Outcome 1)
Force between charges. Coulomb's law. Electric field of the point, line and surface charge. Gauss's law, potential and voltage in electric field. Dielectric polarisation, vector of electric translation.

**2. Basic terms related to electric circuits** (Outcome 2)
Electric current, current density, resistance and conductance.

**3. Electric circuits of direct current** (Outcomes 2, 3)
Charge flow. Ohm's law. Static and dynamic resistance. Temperature dependence of resistance. Connecting resistors, connection in series, connection in parallel and mixed connection. Kirchhoff's laws. Current and voltage real sources. Power and energy of electric current, adjustment to the maximum power.

**4. Electric capacitance** (Outcome 3)
Fundamentals of electric capacitance. Types of capacitors. Connection in series, connection in parallel.

**5. Linear electric networks** (Outcome 3)
Notion of electric network, methods of solving. The method of Kirchhoff's laws, method of mesh currents, method of superposition. Thevenin's theorem.

**6. Magnetism and electromagnetism** (Outcome 4)
Magnetic field, magnetic flux, magnetic induction. Force exerted on moving charges, force exerted on a conductor with running electric current. Magnetic induction of a straight conductor, coil and circular coil. The work of the magnetic field, ferromagnetism, magnetization curve, hysteresis loop. Ampere's Flow Law. Electromagnetic induction, Faraday's Law, Lenz's Rule, rotating loop in a homogenous field. Vortical currents, self-induction and mutual induction, inductivity and mutual inductivity. Energy of the magnetic field.

**7. Coil and condenser in a serial circuit** (Outcome 5)
Network's response to commutation, forced and free response of a serial RLC circuit. Charging and discharging of condensers. Connection of the serial RL circuit to a source of constant EMS. Interruption of current through a coil.

**8. Alternating current** (Outcome 6)
Fundamental concepts related to alternating current, instantaneous, effective and average value, frequency. The concept of

a phasor and operations with phasors. Ohmic resistance, inductive and capacitive resistance. The concept of impedance and admittance, phase angle. Resonance, power of alternating current, adjusting to maximal power. Reactive energy compensation.

**9. Three-phase system** (Outcome 7)

The development of the three-phase system, designation, generator and consumer circuits. Symmetrical and asymmetrical consumers. Working out an asymmetrical system, the charge of the star connection.

The power of three-phase current, symmetrical and asymmetrical load.

**Required reading**

- Kuzmanović, Branislav: Osnove elektrotehnike 1, Zagreb, Element, 2006
- Kuzmanović, Branislav: Osnove elektrotehnike 2, Zagreb, Element, 2006

**Further reading**

- Robert L. Boylestad: INTRODUCTORY CIRCUIT ANALYSIS, ISBN: 0-13-173044-4

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Course title** | **Introduction to Informatics** | | | | | | | |
| **Course instructor(s)** | Dario Vidić, Ivan Sekovanić | | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics<br>Undergraduate professional programme of study in Computer Science | | | | | | | |
| **Course status** | Compulsory | | | | | | | |
| **Year** | 1st | **Semester** | 1st | **ECTS** | 4 | | | |
| **Contact hours (L+PS+S)** | 15 + 30 + 0 | | | L | PS | | S | |
| | | | | | APS | LPS | | |
| | | | | 15 | | 30 | | |

**Course objectives**

Familiarising students with information technologies and their application.

**Expected learning outcomes**

Upon completion of the course students will be able to:

| | |
|---|---|
| O1 | analyse the historical development and current significance of computer systems, |
| O 2 | describe and recognise the main components of a computer system, their functions and the role of numeral systems in computer operation, |
| O 3 | describe the role of computer operating systems, |
| O 4 | create a simple database, |
| O 5 | edit and format texts, |
| O 6 | process data in table calculations, |
| O 7 | describe adjustment and maintenance techniques related to the *Windows* operating system and its security settings. |

**Course content**

**1. The notion of computer literacy (O1)**
Innovations that caused the development of information technologies. Numeral systems.
**2. Assemblies and architecture of personal computers (O2)**
Von Neumman's model of a digital computer. CPU processor. Memory (RAM, ROM-BIOS, CASHE). Input units (hard disk, CD, DVD, modem, USB, keyboard, mouse, touchpad, scanner, web-camera, digital camera). Output units (monitor, projector, printers, plotters).
**3. Operating systems (O3)**
Early beginnings and development. Operating systems *Windows* and *Linux* – characteristics and installation. Operating environment in operating systems – GUI, Kernel.
**4. Maintenance and security of the operating systems *Windows* (O7)**
Administration tools. Antivirus protection. Firewall.
**5. MS Office tools (O4, O5, O6)**
*Word. Excel. Access.*

**Required reading**

1. Dario Vidić, Ivan Sekovanić: Presentations for lectures and practical sessions in the course "Introduction to Informatics", Bjelovar University of Applied Sciences
2. Šimović, Maletić, Afrić: Osnove informatike, Zagreb, 2010

**Further reading**

| Course title | Technical English 1 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Course instructor(s) | Ivana Jurković | | | | | | | |
| Programme(s) of study | Undergraduate professional programme of study in Mechatronics | | | | | | | |
| Course status | Elective | | | | | | | |
| Year | 1st | Semester | 1st | ECTS | 2 | | | |
| Contact hours (L+PS+S) | 15 + 30 + 0 | L | PS | | S | | | |
| | | | APS | LPS | | | | |
| | | 15 | 30 | 0 | 0 | | | |

## Course objectives

Developing students' ability to use the English language related to specific technical fields.

## Expected learning outcomes

Upon completion of the course students will be able to use the English language to:

- O1: describe technical functions and applications of products and the manner in which products function,
- O2: describe the properties and application of materials used in various fields of engineering,
- O3: describe the shape and features of components and assemblies as well as joining and fixing procedures,
- O4: demonstrate mastery of simple grammatical structures.

## Course content

**1. Technology applications** (Outcome O1)
Description of technical functions and applications.
Emphasising technical advantages.
Simplifying technical explanations.
**2. Technical materials** (Outcome O2)
Describing technical materials.
Naming and describing the properties of technical materials.
Comparing technical materials.
Describing the application of technical materials.
**3. Components and assemblies** (Outcome O3)
Describing the shape and properties of components.
Describing the procedures of connecting components into assemblies or complex units.
Describing joining and fixing procedures.
Describing the position of elements in assemblies.
**4. Grammar** (Outcome O4)
Present, past and future tenses.
Adjectives.
Modal verbs.
Types of questions and forming questions.
Prepositions.
Relative clauses.

## Required reading

- Ibbotson, Mark: Cambridge English for Engineering, Cambridge University Press, Cambridge, 2008

## Further reading

- Murphy, Raymond: English Grammar in Use, Cambridge University Press, Cambridge, 2004

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|---|---|---|---|---|---|---|---|
| **Course title** | **Communication Skills** | | | | | | |
| **Course instructor(s)** | Tatjana Badrov | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics<br>Undergraduate professional programme of study in Computer Science | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 1st | **Semester** | 1st | **ECTS** | 3 | | |
| **Contact hours (L+PS+S)** | 15+30+0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 15 | 30 | | | | |

**Course objectives**

Improving students' communication skills.

**Expected learning outcomes**

Upon completion of the course students will be able to:

- O1: explain basic concepts, types and difficulties in the field of communication,
- O2: distinguish between the techniques of active listening,
- O3: apply information collection techniques and a balanced feedback,
- O4: identify and compare basic communication styles and apply an assertive I-message,
- O5: distinguish between three types of complaints and complaint resolving techniques,
- O6: prepare and deliver a presentation on a given topic,
- O7: describe and demonstrate the basic elements of the negotiation process,
- O8: explain debate principles and participate in a debate on a given topic.

**Course content**

**1. Introduction to communication** (Outcome 1)
The notion of communication. Levels of communication phenomena (intrapersonal, interpersonal, group, public and mass communication). Objectives, principles and types of communication.
**2. Verbal communication** (Outcome 1)
Factors of efficiency and suitability of verbal communication. Prejudices about communication. Aspects of messages. Criteria of successful verbal communication. Connotative and denotative level of importance of verbal communication.
**3. Non-verbal and paraverbal communication** (Outcome 1)
Types, characteristics and functions of paraverbal communication. Types and functions of non-verbal messages. Communication skills in business communication.
**4. Problems in communication** (Outcome 1)
The communication process. Noisiness, noise, barriers to communication. Types of noise, external and internal barriers to communication.
**5. Techniques and skills of active listening** (Outcome 2)
Listening as a physical and mental activity. Types of (not) listening. Principles of active listening.
**6. Skills of information gathering** (Outcome 3)
Techniques and skills of asking questions. Types of questions according to the objective of communication.
**7. Techniques of giving feedback** (Outcome 3)
The concept and purpose of feedback. The five main categories of feedback. A balanced feedback. Receiving and giving praise.
**8. Communication styles** (Outcome 4)
Aggressive, submissive-aggressive, passive, assertive communication style. The link between communication styles and the outcome of communication. Notion and meaning of assertiveness. Principles of assertive communication. Structure and effect of I-messages in relation to the YOU-message.
**9. Recognizing and resolving complaints** (Outcome 5)
Notion of complaints. Types of complaints. General rules for resolving complaints. Resolving complaints with regard to the type of complaint.
**10. Self-introducing and management of impressions** (Outcome 6)

Skills of impressions management. Five main strategies of self-introducing.

**11. Presentation techniques and skills** (Outcome 6)

Preparation and design of presentations. Delivery structure. Verbal and non-verbal elements of delivery in front of an audience. Answering questions.

**12. Negotiation** (Outcome 7)

Definition of negotiation and negotiation situations. Characteristics of successful negotiators. Preparing for negotiations. Negotiating strategies. Tactics and techniques for the initial, central and final phase of negotiations. Unethical techniques / tactics in negotiations.

**13. Debate** (Outcome 8)

Notion of debate. Participants in a debate. Debate parts. Debate in the development of critical, logical and creative thinking.

**Required reading**

- Reardon, K. (1998): Interpersonalna komunikacija – Gdje se misli susreću, Alineja, Zagreb
- Course materials available in the e-learning system Merlin

**Further reading**

- Fox, R. (2006): Poslovna komunikacija, Hrvatska sveučilišna naklada, Zagreb

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|---|---|---|---|---|---|---|---|
| **Course title** | **Electronic Components and Assemblies** | | | | | | |
| **Course instructor(s)** | Goran Benkek | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 1st | **Semester** | 2nd | **ECTS** | 5 | | |
| **Contact hours (L+PS+S)** | 15 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 15 | 16 | 14 | | | |

**Course objectives**

Familiarising students with basic knowledge about electronic components and assemblies.

**Expected learning outcomes**

Upon completion of this course students will be able to:

O1: explain the basic properties of semiconductors,
O2: analyse an electronic device with a PN diode,
O3: analyse an electronic device with a bipolar and unipolar transistor,
O4: analyse simple assemblies with an amplifier,
O5: analyse the basic components of power electronics,
O6: explain the operation and application of optoelectronic components.

**Course content**

**1. Basic properties of semiconductors** (Outcome 1)
Electrical properties of semiconductors. Types of carriers. Types of semiconductors. Current conduction in semiconductors. Generation and recombination. Concentrations of carriers in semiconductors.
**2. P-N junction and P-N diode** (Outcome 2)
P-N junction in equilibrium. P-N junction under voltage. Static characteristics of diodes. Breaking the P-N barrier. Classification of diodes. Semiconductor diode as a switch. Diode circuits in analogue and pulse electronics.
**4. Bipolar transistors** (Outcome 3)
Operation principles. Areas of operation. Static characteristics. Choosing a location of a static operating point. Transistor parameters in the small signal regime. Transistor as a switch. Amplifier in the common emitter connection. Stability characteristics. Amplifier in the common base connection. Amplifier in the common collector connection. Transistor as a switch. Pulse circuits.
**5. Unipolar transistors** (Outcome 3)
Operation principles and classification. Analysis of basic characteristics and static characteristics of JFET and MOSFET. Amplifiers with unipolar transistors. MOSFET transistor as a switch. Transistor bridge connection. Comparison between unipolar and bipolar transistors.
**7. Amplifiers** (Outcome 4)
Cascade amplifiers. Darlington pair. Circuits with feedback. Differential amplifier. Power amplifier. Stabilisers. Operational amplifier; basic terms and characteristics, typical application.
**8. Power transistors** (Outcome 5)
IGBT. DIAC. Thyristor: operating principle, static characteristics. Switching thyristors on. Switching thyristors off.
**9. Optoelectronic components** (Outcome 6)
Photoresistors. Photodiodes. LED. Laser diodes. Phototransistors. Solar cells. Application of photoelectric semiconductor elements.

**Required reading**

- Butković, Željko; Divković-Pukšec, Julijana; Barić, Adrijan: Elektronika 1 – course material, Faculty of Electrical Engineering and Computing, Zagreb, 2010

| Further reading |
| --- |
| • Biljanović, Petar: Poluvodički elektronički elementi, Školska knjiga, Zagreb 1996<br>• Biljanović, Petar: Elektronički sklopovi, Školska knjiga, Zagreb, 2001<br>• Zulim,Ivan; Biljanović, Petar: Elektronički sklopovi – problem book, Školska knjiga, Zagreb, 1994<br>• Šribar,Julijan; Divković-Pukšec, Julijana: Elektronički elementi, problem book – Parts I and II, Element, Zagreb, 1996 |

| Course title | Fundamentals of Programming | | | | | | |
|---|---|---|---|---|---|---|---|
| Course instructor(s) | Zoran Vrhovski | | | | | | |
| Programme(s) of study | Undergraduate professional programme of study in Mechatronics | | | | | | |
| Course status | Compulsory | | | | | | |
| Year | 1st | Semester | 2nd | ECTS | 4 | | |
| Contact hours (L+PS+S) | 20 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 20 | 0 | 30 | 0 | | |

**Course objectives**

Learning how to use the development environment for the development of computer programs using the structured and procedural programming language C.

**Expected learning outcomes**

Upon completion of this course students will be able to:

O1: use basic and logical types of data,
O2: control the program flow,
O3: use fields in programming solutions,
O4: use strings in programming solutions,
O5: use the existing and define own functions,
O6: code according to a given specification in the programming language C.

**Course content**

**1. Programming languages and programming** (Outcome O1)
History of programming languages. Potential application of programming. Code development.
**2. Programming language C** (Outcome O1)
Writing a code in C. Development environment Visual Studio. Pre-processor commands. Input-output flow commands.
**3. Types of data and arithmetic operators** (Outcome O1, Outcome O6)
Types of data. Declaration of variables. Arithmetic operations. Assignment operators.
**4. Logical types of data and operators** (Outcome O1, Outcome O6)
Logical types of data. Comparison operators. Bitwise operators.
**5. Command blocks and conditional code execution** (Outcome O2, Outcome O6)
Code execution order. Command blocks. If command block. Switch-case command block.
**6. Programming loops** (Outcome O2, Outcome O6)
For loop. While loop. Do-while loop. Commands break and continue.
**7. Fields** (Outcome O3, Outcome O6)
One-dimensional fields. Two-dimensional and multi-dimensional fields.
**8. Strings** (Outcome O4, Outcome O6)
Characters. Strings. Functions for working with strings.
**9. Functions** (Outcome O5, Outcome O6)
Declaration of a function. Definition of a function. Standard headers. Header. Calling a function.

**Required reading**

- Domagoj Kusalić: Napredno programiranje i algoritmi u C-u i C++-u, 5th edition, Element, Zagreb, 2014
- Krunoslav Husak: "Presentations for lectures and practical sessions – Fundamentals of Programming", Bjelovar University of Applied Sciences

**Further reading**

- D. M. Ritchie, B. W. Kernighan (translated by: Ante Denić): Programski jezik C, 2nd edition (https://www.scribd.com/doc/47734390/Programski-jezik-C)
- J. Šribar, B. Motik: Demistificirani C++, 3rd edition, Element, Zagreb, 2010
- Learn C programming, http://www.tutorialspoint.com/cprogramming/ (available on: 21.2.2016)
- C Tutorials, http://www.codingunit.com/category/c-tutorials (available on: 21.2.2016)

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|---|---|---|---|---|---|---|---|---|
| **Course title** | **Technical Documentation** | | | | | | | |
| **Course instructor(s)** | Tomislav Pavlic Elizabeth Hedl | | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | | |
| **Course status** | Compulsory | | | | | | | |
| **Year** | 1st | **Semester** | 2nd | **ECTS** | 3 | | | |
| **Contact hours (L+PS+S)** | 15 + 30 + 0 | | | L | PS | | S | |
| | | | | | APS | LPS | | |
| | | | | 15 | 0 | 30 | | |

**Course objectives**

Acquiring knowledge required for understanding and development of technical documentation as well as knowledge required for performing professional activities in the area of expertise.

**Expected learning outcomes**

Upon completion of this course students will be able to:
O1: acquire basic terms related to technical drawings and development of technical documentation,
O2: use the acquired knowledge for developing and reading technical documentation,
O3: develop 2D drawings of simple positions and assemblies,
O4: develop simple documentation in the area of electrical engineering.

**Course content**

**1. Introduction to technical documentation** (Outcome O1)
Standardisation and norms: lines, technical lettering, paper formats for technical documentation, scales, title block, designating the documentation.
**2. Documentation in mechanical engineering** (Outcome O1, O2)
Description of machine parts by orthogonal and isometric projection. Use of cross-sections and recommendations when designing shapes in technical documentation. Simplifying the presentation of machine elements. Spatial presentation. Dimension lines drawing. Surface roughness and designating it in the documentation. Dimension tolerances. Shape and position tolerances. Fits.
**3. Documentation in electrical engineering** (Outcome O4)
Element designation system. Graphic symbols in drawings and schematics. Electrical schematics (single pole, current, relay, electropneumatic, electrohydraulic, schematics of electronic modules). Connection plans. Material lists. Position drawings. Technical description. Technical specifications of a device and equipment. Instructions for operation and maintenance. Documentation of the functional version. Reading electrical schematics.
**4. Use of computers in technical documentation** (Outcome O3, O4)
Introduction to working with software tools for designing technical documentation.
**5. Types of technical documentation** (Outcome O3, O4)
Project documentation, construction documentation, technological documentation, manufacturing documentation. Design flow and application.

**Required reading**

- Kukec, Đuro: Tehnička dokumentacija, Technical College in Bjelovar, Bjelovar, 2011

**Further reading**

- Padovan, Lukša: "Inženjerska grafika i dokumentiranje", Graphis d.o.o. Zagreb, Zagreb, 2004
- Švigir, Nikola; Sumina, Damir; Padovan, Lukša: "Tehničko crtanje uporabom CAD programa", Graphis d.o.o. Zagreb, Zagreb, 2007
- Žunar, Milan:"Tehničko Crtanje", Profil Mozaik d.o.o. Zagreb, Zagreb, 2008.

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|---|---|---|---|---|---|---|---|
| **Course title** | **Technical English 2** | | | | | | |
| **Course instructor(s)** | Ivana Jurković | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Elective | | | | | | |
| **Year** | 1st | **Semester** | 2nd | **ECTS** | 2 | | |
| **Contact hours (L+PS+S)** | 15 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 15 | 30 | 0 | 0 | | |

**Course objectives**

Developing students' ability to use the English language related to specific technical fields.

**Expected learning outcomes**

Upon completion of the course students will be able to use the English language to:

- O1: describe the procedure of developing an engineering project,
- O2: describe technical problems and malfunctions as well as their causes and possible solutions,
- O3: discuss about technical requirements and describe project feasibility, improvements and redesigns,
- O4: demonstrate mastery of simple grammatical structures.

**Course content**

**1. Developing an engineering project** (Outcome O1)
Describing project design.
Defining a project, precision and tolerance.
Mathematical expressions.
Describing development procedures in an engineering project.
**2. Repair and maintenance** (Outcome O2)
Describing technical malfunctions.
Assessment of faults.
Describing the causes of malfunctions.
Discussing repair and maintenance.
**3. Technical development** (Outcome O3)
Describing technical requirements.
Suggesting ideas and solutions.
Feasibility study.
Describing improvements and redesigns.
**4. Grammar** (Outcome O4)
Numbers.
Conjunctions.
Pronouns.
Present, past and future tenses.

**Required reading**

- Ibbotson, Mark: Cambridge English for Engineering, Cambridge University Press, Cambridge, 2008

**Further reading**

- Murphy, Raymond: English Grammar in Use, Cambridge University Press, Cambridge, 2004

| Course title | Sensors | | | | | | |
|---|---|---|---|---|---|---|---|
| Course instructor(s) | Danijel Radočaj, Goran Benkek | | | | | | |
| Programme(s) of study | Undergraduate professional programme of study in Mechatronics | | | | | | |
| Course status | Compulsory | | | | | | |
| Year | 2nd | Semester | 3rd | ECTS | 6 | | |
| Contact hours (L+PS+S) | 30+30+0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 12 | 18 | | | |

**Course objectives**

Acquiring basic knowledge about sensors that are used in mechatronics.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: interpret the characteristics of sensors,
- O2: describe measurement methods and procedures of non-electrical and electrical quantities,
- O3: describe signal processing in a sensor,
- O4: choose an optimal sensor for a specific mechatronic system,
- O5: connect a sensor with electronic devices.

**Course content**

**1. Basic terms and definitions, sensor characteristics** (Outcome O1)
Definition of measurements, sensors and transducers.
Classification of sensors.
Measurement quantities and units.
Measurement errors.
Statistical analysis of measurement results.
Statistical distributions.
Confidence interval.
Measurable uncertainty.
Error limits and grades of accuracy.
Indication of measurement results.
Mathematical model of a sensor.
Measurement range.
Sensor calibration.
Accuracy.
Sensor nonlinearness.
Hysteresis.
Saturation.
Repeatability.
Reliability.
Uncertainty.
Dead zone.
Resolution.
Output impedance of a sensor.
Sensor output signal.
Collection of sensor data.

**2. Methods and procedures of measuring nonelectrical quantities** (Outcome O2)
Measurement of length.
Measuring the angle.
Measurement of displacement and rotation.
Measurement of speed and speed of rotation.
Flow measurement.
Temperature measurement.
Measurement of humidity.
Pressure measurement.
Vibration measurements.
Measurement of mass and force.
Level measurement.
**3. Methods and procedures of measuring electrical quantities** (Outcome O3)
Measurement of current, voltage and power.
U-I procedures.
Bridge procedures.
Wheatstone Bridge.
**4. Signal processing in a sensor** (Outcome O4)
Signal amplification.
Filtering the signal.
Analogue-to-digital conversion.
Digital-to-analogue conversion.
**5. Sensors in mechatronics** (Outcome O4)
Voltage and current sensors.
Distance sensors.
Speed sensors.
Shift and rotation speed sensors.
Mechanical presence sensors.
Inductive presence sensors.
Capacitive presence sensors.
Ultrasonic presence sensors.
Magnetic presence sensors.
Analogue and digital temperature sensors.
Moisture sensors.
Pressure sensors.
Flow sensors.
Mass and force sensors.
Level sensors.
Optimal sensor selection.
**6. Types of sensor outputs** (Outcome O5)
Continuous sensors.
Discrete sensors.
Voltage output.
Current output.
Sensor communication interface.
RS232.
RS485.
CAN.
I2C.
SPI.
AS-i.

| Required reading |
| --- |
| • Presentations for lectures and practical sessions – Sensors, Bjelovar University of Applied Sciences. |
| **Further reading** |
| • Fraden, Jacob: Handbook of Modern Sensors, Springer, 2010<br>• Webster, John G.: Measurement, Instrumentation, and Sensors Handbook, CRC Press LLC, 1999 |

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|---|---|---|---|---|---|---|---|
| **Course title** | **Elements of Precise Mechanics** | | | | | | |
| **Course instructor(s)** | Tomislav Pavlic, Ivan Korade | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 2nd | **Semester** | 3rd | **ECTS** | 6 | | |
| **Contact hours (L+PS+S)** | 30 + 45 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 35 | 10 | | | |

**Course objectives**

1. Familiarising students with standardised elements of precise mechanics, calculation of elements of precise mechanics and materials used for making them.
2. Familiarising students with power and motion transmissions as well as the basic calculation involving the aforementioned transmissions.

**Expected learning outcomes**

Upon completion of this course students will be able to:
O1: draw standard elements of precise mechanics (machine elements),
O2: recognise and describe elements of precise mechanics,
O3: calculate the stress and dimensions of standard elements of precise mechanics,
O4: recognise and describe motion elements and transmissions,
O5: calculate motion elements and basic relations and dimensions of transmissions.

**Course content**

**1. Basic terms** (Outcome O1)
Standardisation. Allowed stress. Classification of elements of precise mechanics (machine elements). Drawing machine elements.
**2. Permanent and non-permanent joints** (Outcome O2, O3)
Screws, nuts, washers. Hub joints. Pin and bolt connections. Welded, soldered, riveted, interference, glued joints. Other fixing methods.
**3. Energy containers and resistors** (Outcome O2, O3)
Springs, weights, flywheels, jigs, gyroscopes, adjusters, stopcocks, brakes, chokes.
**4. Seals and sealing** (Outcome O2, O3)
Static sealing. Dynamic sealing.
**5. Motion transmission elements** (Outcome O4, O5)
Axles, shafts and sleeves. Lubricants. Sliding bearings. Roller bearings. Clutches.
**6. Transmissions** (Outcome O4, O5)
Friction drives, belt drives, chain drives, gear drives.

**Required reading**

- Karl-Heinz Decker: Elementi strojeva, Tehnička knjiga, Zagreb, 2006
- Golubić, Stjepan: Presentations in the course Elements of Precise Mechanics, Bjelovar University of Applied Sciences, http://vub.hr/elementi-porecizne-mehanike-program/kolegij/

**Further reading**

- Kraut, Bojan: Strojarski priručnik, Tehnička knjiga, Zagreb
- Group of authors: Krautov strojarski priručnik, Sajema, Zagreb, 2009

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course title** | **Signals and Systems** | | | | | | |
| **Course instructor(s)** | Zoran Vrhovski | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 2nd | **Semester** | 3rd | **ECTS** | 5 | | |
| **Contact hours (L+PS+S)** | 30 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 24 | 6 | 0 | | |

**Course objectives**

Familiarising students with the application of the theory of signals and systems.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: mathematically describe signals, draw signals and determine signal properties,
- O2: determine the response of a continuous system by solving a difference equation with constant coefficients,
- O3: apply the Laplace transform in continuous signals and systems,
- O4: apply the Fourier analysis in signals and systems,
- O5: determine the response of a discrete system by solving a difference equation with constant coefficients,
- O6: apply the Z-transform in discrete signals and systems.

**Course content**

**1. Fundamental terms** (Outcome O1)
Types of signals and systems.
Continuous signals and systems.
Discrete signals and systems.
Basic signals.
Basic properties of signals and systems.
Basic signal operations.
Analogue-to-digital signal conversion.
**2. Continuous systems** (Outcome O2, O3, O4)
System description by means of a linear differential equation with constant coefficients. (Outcome O2)
Solving linear differential equations with constant coefficients. (Outcome O2)
Block presentation of a system. (Outcome O2)
The concept of the convolution integral. (Outcome O2)
Laplace transform. (Outcome O3)
Basic characteristics of Laplace transform. (Outcome O3)
Application of Laplace transform. (Outcome O3)
Transfer function of a continuous system. (Outcome O3)
Presentation of a periodical signal by a trigonometric and exponential Fourier series. (Outcome O4)
Fourier transform. (Outcome O4)
**3. Discrete systems** (Outcome O5, O6)
Describing a system using the difference equation with constant coefficients. (Outcome O5)
Solving linear difference equations with constant coefficients. (Outcome O5)

The Z-transform. (Outcome O6)
Basic characteristics of the Z-transform. (Outcome O6)
Application of the Z transform.
The transfer function of a discrete system. (Outcome O6)
**4.Application of the software tool Matlab and Simulink in signals and systems** (Outcome O1, O2, O3, O5, O6)

**Required reading**

- Vrhovski, Zoran; Purković, Dalibor: Signali i sustavi – problem book, Technical College in Bjelovar, Bjelovar, 2016
- Vrhovski, Zoran: Presentations in Signals and Systems, Bjelovar University of Applied Sciences, 2018, https://vub.hr/signali-i-sustavi/ (available on: 5.7.2018)

**Further reading**

- Vrankić, Miroslav: Signali i sustavi – problem book, Graphis, Zagreb, 2007

| Course title | Technical English 3 | | | | | | |
|---|---|---|---|---|---|---|---|
| Course instructor(s) | Ivana Jurković | | | | | | |
| Programme(s) of study | Undergraduate professional programme of study in Mechatronics | | | | | | |
| Course status | Elective | | | | | | |
| Year | 2nd | Semester | 3rd | ECTS | 2 | | |
| Contact hours (L+PS+S) | 15 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 15 | 30 | 0 | 0 | | |

**Course objectives**

To develop students' ability to use the English language related to specific technical fields.

**Expected learning outcomes**

Upon completion of the course students will be able to use the English language to:

- O1: describe regulations, standards procedures and measures related to occupational health and safety
- O2: describe automated systems, measurable parameters, readings and approximate values
- O3: explain testing procedures, conduction of experiments and describe the predicted outcomes of testing
- O4: demonstrate mastery of more complex grammatical structures

**Course content**

**1. Occupational health and safety** (Outcome O1)
Description of occupational health and safety measures.
Protective equipment.
Regulations and standards.
Written instructions.
**2. Automatic control** (Outcome O2)
Describing automated systems.
Describing measurable parameters.
Giving approximate values.
Describing graphs.
**3. Tests and experiments** (Outcome O3)
Describing tests and experiments.
Comparison of results and expectations.
Assumptions.
**4. Grammar** (Outcome O4)
Imperative.
Conditional clauses.
Passive Voice.
Nouns.
Compounds.
Articles.

**Required reading**

- Ibbotson, Mark: Cambridge English for Engineering, Cambridge University Press, Cambridge, 2008

**Further reading**

- Murphy, Raymond: English Grammar in Use, Cambridge University Press, Cambridge, 2004

| Course title | Microcomputers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Course instructor(s) | Zoran Vrhovski, Goran Benkek | | | | | | | |
| Programme(s) of study | Undergraduate professional programme of study in Mechatronics<br>Undergraduate professional programme of study in Computer Science | | | | | | | |
| Course status | Compulsory | | | | | | | |
| Year | 2nd | Semester | 4th | ECTS | 4 | | | |
| Contact hours (L+PS+S) | 15 + 30 + 0 | L | PS | | S | | | |
| | | | APS | LPS | | | | |
| | | 15 | | 30 | | | | |

**Course objectives**

To familiarise students with the application of microcomputers and their programming and usage in the design and production of more complex electronic devices.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: choose a microcomputer that is optimal for a given purpose from the aspect of price, features and availability
- O2: configure microcomputer operation using registers in the development software environment
- O3: create a microcontroller control program for a given purpose in the development software environment
- O4: use microcontroller interrupts when it is required by the functionality of an electronic device
- O5: connect electronic devices to a microcontroller taking into account the purpose of an individual pin of a microcontroller

**Course content**

**1. Fundamental concepts and microcomputer architecture** (Outcome O1)
Application of microcomputers. Historical development of microcomputers. Differences between microcomputers, microcontrollers and microprocessors. Microcomputer structure: CPU, buses. Microcomputer architecture: (CISC, RISC). Execution of microcomputer instructions.
**2. Microcontrollers** (Outcome O1, O2, O4)
Features. Architecture. CPU. Clock rate. Instruction execution. Set of instructions. Memory. Input/output registers. Reset. Watchdog. Interrupts. Digital inputs and outputs. Counters and timers. PWM. Digital-to-analogue converter. Analogue-to-digital converter and analogue inputs. USART (serial communication). I2C communication. SPI communication. External interrupts. Power supply. Producers of microcontrollers. Features of the Atmel ATMega16 microcontroller.
**3. Programming a microcontroller** (Outcome O2, O3, O4)
Programming a microcontroller. Instruction set of the Atmel AVR microcontroller family. Machine code. Main program and infinite loops. Interrupt routines. Functions. Microcontroller programming environments. Fuse bits. Lock bits. In-System Programming.
**4. Connecting electronic devices to a microcontroller** (Outcome O4, O5)
Connecting the following devices to a microcontroller: push buttons, LED diodes, LCD display, potentiometer, NTC resistor, numeric display, optocoupler, transistor as a switch, relay, buzzer, analogue and digital temperature sensors, Bluetooth module, graphic display, GSM module, matrix keyboard, servo motor, ultrasound sensor, real time clock module, H bridge, communication modules. Microcomputer system management using a computer or smartphone application.

**Required reading**


- Vrhovski, Zoran; Miletić, Marko: Mikroračunala - Programiranje mikrokontrolera porodice Atmel u programskom okruženju Atmel Studio 6, Technical College in Bjelovar, Bjelovar, 2014
- Vrhovski, Zoran: Presentations of lectures in Microcomputors, Bjelovar University of Applied Sciences, available on: https://vub.hr/mikroracunala/
- ATMEL: 8-bit AVR Microcontroller with 16K Bytes In-System Programmable Flash – ATMEGA16,

http://ww1.microchip.com/downloads/en/DeviceDoc/doc2466.pdf (available on: 19.7.2018)

**Further reading**


- F. Barrett, Steven; Pack, Daniel; Thornton, Mitchell: Atmel AVR microcontroller primer: programming and interfacing, Morgan &Claypool Publishers, Thornton, 2007

| Course title | Mechanisms | | | | | | |
|---|---|---|---|---|---|---|---|
| Course instructor(s) | Tomislav Pavlic | | | | | | |
| Programme(s) of study | Undergraduate professional programme of study in Mechatronics | | | | | | |
| Course status | Compulsory | | | | | | |
| Year | 2nd | Semester | 4th | ECTS | 4 | | |
| Contact hours (L+PS+S) | (15 + 30 + 0) | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 15 | 20 | 10 | 0 | | |

## Course objectives

Acquiring and being able to use the knowledge necessary for understanding, selection, modification, adjustment and usage of various types of mechanisms within mechatronic systems.

## Expected learning outcomes

Upon completion of this course students will be able to:

O1: acquire the characteristics of basic types of mechanisms,
O2: use the acquired knowledge in designing and dimensioning various types of mechanisms,
O3: analyse the kinematics and dynamics of basic types of mechanisms,
O4: construct mechanisms according to specified requirements and needs.

## Course content

**1. Introduction to the theory of mechanisms (Outcome O1)**
Structure and classification of mechanisms. Mechanism members. Kinematic pairs. Kinematic chains. Motion freedom degrees.
**2. Structure and classification of mechanisms (Outcome O1)**
Methods of shaping mechanisms.
**3. Basic types of mechanisms (Outcome O1 and O2)**
Four-bar mechanisms, reciprocating mechanisms, ridge cam mechanisms, coulisse mechanisms, gear mechanisms etc. Mechanisms driven by electric motors, pneumatic and hydraulic.
**4. Kinematic analysis of mechanisms (Outcome O1, O2, O3)**
Kinematic characteristics of motion laws. Kinematics of drive and working elements of mechanisms. Current speed pole. Velocity and acceleration plan method. Determing the position, velocity and acceleration of mechanisms.
**5. Mechanism dimensioning (Outcome O3)**
Selection and adjustment of mechanical and electrical components for the construction of various types of mechanisms.
**6. Construction of mechanisms (Outcome O4)**
Construction of mechanisms of different kinematics, driven by various drives used in mechatronic systems.

## Required reading


- Husnjak, M.: Teorija mehanizama, Faculty of Mechanical Engineering and Naval Arcitecture in Zagreb, 2003
- Pavlic, Tomislav: Lectures in the course Mechanisms, Bjelovar University of Applied Sciences, Bjelovar, 2018


## Further reading


- Hagedorn, L., Thonfeld, W. and Rankers A.: Konstruktive Getriebelehre, Springer-Verlag, Berlin Heidelberg, 2009
- Bazjanac, D.: Osnovi teorije mehanizama, Zagreb, 1966
- Muftić, O.,Drača, K.: Uvod u teoriju mehanizama, Sveučilišna naklada Liber, Zagreb, 1974

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course title** | **Automated Control** | | | | | | |
| **Course instructor(s)** | Zoran Vrhovski | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 2nd | **Semester** | 4th | **ECTS** | 6 | | |
| **Contact hours (L+PS+S)** | 30 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 24 | 6 | 0 | | |

**Course objectives**

Enabling students to analyse and synthesise a continuous automated control system.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: test the linearity and time invariance of systems
- O2: determine transfer functions, poles, zeros and amplification of time dynamic members in an open and closed automated control system
- O3: parametrise a first-order or second-order system according to defined time response requirements
- O4: analyse an automated control system response within the time and frequency domain
- O5: apply the stability analysis procedures to linear continuos automated control systems
- O6: determine the structure and parameters of a regulator according to the defined time response requirements of a closed automated control circle
- O7: determine the structure and parameters of the Ziegler-Nichols method

**Course content**

**1. Basic terms and definitions** (Outcome O1)
System classification
Linear time-invariant continuous systems
Basic structures of control systems
**2. Mathematical models of linear continuous systems** (Outcome O2)
Description of linear systems using linear differential equations
Description of systems by the transfer function in the Laplace domain
Description of systems using state variables
**3. Block algebra in an automated control system** (Outcome O2)
Block diagram of a system – basic elements
Serial and parallel blocks
Feedback
Open and closed automated control circle
Control system structure
**4. Time response of the system of basic dynamic members** (Outcomes O3, O4)
System response according to the position of system poles (Outcome O4)
Time characteristics of basic dynamic members: P, PT1, PT2, PT2S I, D, DT1, member with transport delay (Outcomes O3, O4)
System quality indicators (Outcomes O3, O4)
**5. Frequency response of basic dynamic members** (Outcome O4)

Nyquist and Bode diagram
Frequency characteristics of basic dynamic members: P, PT1, PT2, PT2S I, D, DT1, member with transport delay
**6. Stability analysis of an automated control system** (Outcome O5)
Algebraic stability criteria: Hurwitz stability criterion and Routh stability criterion
Frequency criterion of stability: Nyquist stability criterion and determining stability using the Bode diagram
**7. Synthesis of the regulation circle of an automated control system** (Outcomes O6, O7)
Synthesis requirements of an automated control system (Outcomes O6, O7)
Basic structure of an automated control system: control system, regulator, actuator, sensor (Outcomes O6, O7)
Parametrisation of basic regulator versions using the Ziegler-Nichols method (Outcome 7)
Parametrisation of PI regulators using the technical optimum method (Outcome 6)
Parametrisation of basic regulator versions according to the defined requirements of time response (Outcome 6)
Cascade control systems (Outcome 6)
**8.Application of the Matlab and Simulink software for the analysis and synthesis of linear continuos automated control systems** (Outcomes O2, O3, O4, O5, O6, O7)

**Required reading**

- Vrhovski, Zoran: Automatsko upravljanje – Analiza i sinteza linearnih kontinuiranih sustava, Technical College in Bjelovar, Bjelovar, 2013
- Vrhovski, Zoran; Glumac, Slaven: Automatsko upravljanje – problem book, Bjelovar University of Applied Sciences, 2018, available on: https://vub.hr/images/uploads/1341/automatsko-upravljanje-zbirka-01.pdf

**Further reading**

- Crnošija, Petar; Bjažić, Toni: Osnove automatike I. dio, Analiza i sinteza kontinuiranih sustava - teorija i primjena, Element, Zagreb, 2011

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course title** | **Electromechanical and Electronic Converters** | | | | | | |
| **Course instructor(s)** | Goran Benkek | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 2nd | **Semester** | 4th | **ECTS** | 4 | | |
| **Contact hours (L+PS+S)** | 30+15+0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 10 | 5 | | | |

**Course objectives**

Familiarising students with the fundamentals of working with electromechanical and electronic converters.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: calculate the magnetic state and load of a metal object,
- O2: select an electric machine with respect to electrical and mechanical loads,
- O3: determine the operating mode of an electric machine and the methods of regulating the machine's operating point,
- O4: classify electronic converters according to the source and consumer type,
- O5: calculate electric parameters of electronic converters according to the specifications.

**Course content**

**1. Conversion of mechanical and electrical energy (Outcome O1)**
Electromagnetic induction.
Generating voltage.
Energy conversion laws.
Torque and angular velocity.
Energy balance.
Law of flow.
Air gap.
Energy status of a machine and signs of voltage, current and power.
**2. Synchronous machine (Outcome O2, O3)**
Operation principle and basic construction parts.
Wind-up methods and mechanical characteristics of the machine.
Operation modes.
Substitute electric model.
**3. Asynchronous machine (Outcome O2, O3)**
Operation principle and basic construction parts**.**
Voltage equations and equivalent schemes.
Measurement of torque and speed of rotation.
Idling, short circuit and load curves.
Single-phase motors.
**4. DC machine (Outcome O2, O3)**
Operation principle and performance of a DC machine.
Motor equations and schematic representation.
Electromechanical characteristic.
Operation modes.
**5. Fundamentals of conversion techniques (Outcome O4)**

The physical principle of disconnecting in the energy circuit.
The notion of commutation.
Power converters. Direct converters.
Conversion process.
Conversion components and u-i characteristics.
Semiconductor valves.

**6. DC converters (Outcome O5)**

DC consumers. DC sources.
Direct DC converters.
Indirect DC converters.
Multidirectional DC converters.

**7. Rectifiers (Outcome O5)**

Classification.
Basic properties.
Inductive and capacitive load.
Uncontrolled rectifiers.
Phase-controlled rectifiers.
Single-phase and three-phase bridge.
Impact on AC network.

**8. Autonomous inverters (Outcome O5)**

Types of AC consumers.
Single-phase inverters.
Uncontrolled and phase-controlled inverters.
Pulse-width modulation.

**Required reading**

- Presentations of lectures and practical sessions in the course Electromechanical and Electronic Converters, Bjelovar University of Applied Sciences
- Petrović, Igor: Elektromehanički i elektronički pretvarači – problem book, Technical College in Bjelovar, Bjelovar, 2015

**Further reading**

- I. Flegar, Elektronički energetski pretvarači, Kigen, Zagreb, 2010

<table>
<tr><td>Course title</td><td colspan="7">Technical English 4</td></tr>
<tr><td>Course instructor(s)</td><td colspan="7">Ivana Jurković</td></tr>
<tr><td>Programme(s) of study</td><td colspan="7">Undergraduate professional programme of study in Mechatronics</td></tr>
<tr><td>Course status</td><td colspan="7">Elective</td></tr>
<tr><td>Year</td><td>2nd</td><td>Semester</td><td>4th</td><td>ECTS</td><td colspan="3">2</td></tr>
<tr><td rowspan="2">Contact hours (L+PS+S)</td><td colspan="3" rowspan="2">15 + 30 + 0</td><td>L</td><td colspan="2">PS</td><td rowspan="2">S</td></tr>
<tr><td>APS</td><td>LPS</td></tr>
<tr><td colspan="4"></td><td>15</td><td>30</td><td>0</td><td>0</td></tr>
</table>

**Course objectives**

To develop students' ability to use the English language related to specific technical fields.

**Expected learning outcomes**

Upon completion of the course students will be able to use the English language to:

- O1: describe examples of advanced technologies and innovative solutions,
- O2: communicate in via e-mail,
- O3: draft a curriculum vitae and job application in standard international formats,
- O4: prepare and give a 10-minute presentation in English on one of the given topics in the technical area.

**Course content**

**1. Advanced technologies** (Outcome 1)
Renewable energy sources. Describing possibility and restrictions. Advanced technology and innovations.
**2. Writing formal and informal e-mails** (Outcome 2)
Levels of formality. Enquiries. Offers. Exchanging information. Deadlines. Confirming deadlines and arrangements.
**3. Curriculum vitae and job application** (Outcome 3)
Writing a curriculum vitae and job application in the English language.
**4. Presentation skills in the English language** (Outcome 4)
Preparing a structured presentation in English on a given topic related to the technical field.

**Required reading**

- Ibbotson, Mark: Cambridge English for Engineering, Cambridge University Press, Cambridge, 2008

**Further reading**

- Murphy, Raymond: English Grammar in Use, Cambridge University Press, Cambridge, 2004

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course title** | **Computer-Aided Process Management and Control** | | | | | | |
| **Course instructor(s)** | Zoran Vrhovski | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 3rd | **Semester** | 5th | **ECTS** | 5 | | |
| **Contact hours (L+PS+S)** | 30 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 9 | 21 | 0 | | |

**Course objectives**

Familiarising students with the automatisation of industrial processes via PLC devices that are programmed using the CoDeSys platform and SCADA system.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: select sensors and actuators and connect them with a PLC device for the purpose of automatisation of simple processes
- O2: program PLC devices using the standard IEC 61131-3
- O3: design a control programme of a PLC device for simple processes using the CODESYS platform
- O4: connect a PLC device and the SCADA system using industrial protocols for the purpose of collecting data, performing measurements and displaying data on a computer
- O5 design a SCADA system for simple processes

**Course content**

**1. Basic terms and definitions** (Outcome O1)
Basic terms.
Historical development of PLC devices.
The role and significance of PLCs in industry.
**2. Programmable Logic Controllers** (Outcome O1)
Operating principle of PLCs.
PLC architecture (CPU, digital inputs and outputs, analogue inputs and outputs).
PLC devices Schneider Electric.
Modules for expanding digital/analogue inputs and outputs.
**3. Sensors and actuators in industrial automatisation** (Outcome O1)
Connecting digital and analogue sensors to a PLC device.
Connecting actuators to a PLC device.
**4. The CODESYS platform for industrial automatisation and standard IEC 61131-3** (Outcome O2, O3)
Standard IEC 61131-3: Programme structure. Variables, Identifiers. Key words. Comments. Types of data. Addressing. (Outcome O2)
Programming languages in the standard IEC 61131-3: Ladder diagram (LD). Function block diagram (FBD). Structured text (ST). Instruction list (IL). Sequential function chart (SFC). (Outcome O2)
CODESYS platform: programming language Continuous Function Chart (CFC). (Outcome O3)
Functions/operators: Logical functions/operators. Arithmetic functions/operators. Conversion of data type. Bit shifting operators. Selection functions/operators. Comparison functions/operators. Numerical functions. (Outcome O2)
Function blocks: Edge detection. Latches. Timers (TON, TOF, TP). Counters. (Outcome O2)
Software development environment for programming PLCs. (Outcome O3)

Other functions and function blocks. (Outcome O3)

**5. Industrial communication networks and protocols** (Outcome O4)

Communication network hierarchy in industry.

Industrial protocols.

**6. SCADA systems** (Outcome O4, O5)

Fundamentals of the system for collecting, processing and displaying data in industrial automatisation (SCADA). (Outcome O5)

Tags. (Outcome O4)

Visualisation. Trends. Alarms. (Outcome O5)

Software development environment for designing the SCADA system. (Outcome O5)

**7. Introduction to Industry 4.0 and industrial Internet of things (IIOT)** (Outcome O4, O5)

**Required reading**


- Vrhovski, Zoran: Presentations of lectures and practical sessions in the course Computer-Aided Process Management and Control, Bjelovar University of Applied Sciences, Bjelovar, 2018, https://vub.hr/racunalno-upravljanje-procesima/ (available: 24.7.2018)
- Schnider Electric: Modicon M241 LogicController, Hardware Guide, Schneider Electric, 2015, http://www.schneider-electric.com/download/ww/en/products/current/ (available: 21.2.2016)
- Schnider Electric: Modicon M241 LogicController, ProgrammingGuide, Schneider Electric, 2015, http://www.schneider-electric.com/download/ww/en/products/current/ (available: 21.2.2016)
- Howlett, Bruce: Getting Started With SoMachine Self Study Manual - SoMachineVer 4.1.1, Schneider Electric, 2015


**Further reading**


- Hanssen, Dag Hâkon: Programmable Logic Controllers: A Practical Approach to IEC 61131-3 using CODESYS, John Wiley&Sons, Ltd, United Kingdom, 2015

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course title** | **Pneumatics and Hydraulics** | | | | | | |
| **Course instructor(s)** | Tomislav Pavlic | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 3rd | **Semester** | 5th | **ECTS** | 5 | | |
| **Contact hours (L+PS+S)** | 30 + 30 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 10 | 20 | 0 | | |

**Course objectives**

Familiarising students with the application of pneumatics and hydraulics.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: analyse pneumatic and electropneumatic components and systems
- O2: select pneumatic and electropneumatic components for a particular purpose
- O3: solve tasks in the area of automatisation using the methods of pneumatic and electropneumatic control
- O4: analyse hydraulic and electrohydraulic components and systems
- O5: draw hydraulic and electrohydraulic system schematics
- O6: solve tasks in the area of automatisation by means of proportional and servohydraulics

**Course content**

1. **PNEUMATICS** (Outcome O1, O2, O3)
   Basic terms of pneumatics. (Outcome O1)
   System for the supply and distribution of pressurised air. (Outcome O2)
   Pressurised air preparation. (Outcome O2)
   Pneumatic executive elements. (Outcome O2, O3)
   Pneumatic control elements. (Outcome O2, O3)
   Pneumatic control methods (Outcome O3)
   Special pneumatic elements. (Outcome O2)
   Pneumatic control. (Outcome O3)
   Electropneumatics. (Outcome O3)
   Maintenance of pneumatic systems. (Outcome O1)
   .
2. **HYDRAULICS** (Outcome O4, O5, O6)
   Basic terms of hydraulics. (Outcome O4)
   Hydraulic elements. (Outcome O4)
   Hydraulic executive elements. (Outcome O4)
   Hydraulic control elements. (Outcome O5)
   Electrohydraulics. (Outcome O5)
   Proportional hydraulics. (Outcome O6)
   Servohydraulics (Outcome O6)
   Maintenance of hydraulic systems. (Outcome O4)

**Required reading**

- Nikolić, Gojko: Pneumatika i hidraulika, Part I, PNEUMATIKA, Školske novine, Zagreb, 2005

- Nikolić, Gojko; Novaković, Jakša.: Pneumatika i hidraulika, Part II, HIDRAULIKA, Školske novine, Zagreb, 2003
- Maleš, N.: Handouts in Pneumatics and Hydraulics, Centre of New Technologies, Zagreb, 2014

**Further reading**

- Koroman, V., Mirković, R.: Hidraulika i pneumatika, Školska knjiga, Zagreb, 1991
- Maleš, Neven: Elektropneumatika, Festo, Zagreb, 2008
- Maleš, Neven: Proporcionalna hidraulika, Festo, Zagreb, 2011
- Catalogues and flyers: Festo, Linde, Danfos, Bosch-Rexroth, Parker etc.

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|---|---|---|---|---|---|---|---|
| **Course title** | **Applied Robotics** | | | | | | |
| **Course instructor(s)** | Tomislav Pavlic | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 3rd | **Semester** | 5th | **ECTS** | 5 | | |
| **Contact hours (L+PS+S)** | (30 + 30 + 0) | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 10 | 20 | 0 | | |

**Course objectives**

Familiarising students with basic knowledge and problem solving in the area of modern robotics.

**Expected learning outcomes**

Upon completion of this course students will be able to:

O1: acquire and use basic terms related to the architecture and kinematic structures of robotic systems
O2: acquire and use basic terms related to robot and machine control types
O3: use the acquired knowledge in designing a model of flexible manufacturing systems and robotic cells
O4: carry out virtual simulations of the motion and behaviour of real robotic systems
O5: program and control real robots and robotic systems of various structures

**Course content**

**1. General facts about robotisation (Outcome O1)**
Definition of a robot. Historical development of robotics. Classification, characteristics, application of robots. Introducing robots into production. Programming tools for modelling and programming a robot and its environment.

**2. Kinematics of robots and machines (Outcome O1, O2)**
Coordinate systems. Standards. Translation. Rotation. Basic concepts of mechanism theory, kinematic pairs, kinematic chains, degrees of movement freedom. Connection between internal and external coordinates. Basic terms related to direct and inverse kinematics. Representation and comparison of kinematics of manipulators / robots and CNC machines with the same number of degrees of movement freedom.

**3. Robotised manufacturing systems (Outcome O1, O2)**
Elements and basic structures of robotised production systems. Industrial and mobile robots in modern production. Examples of production processes where manipulators, robots and robotised systems are most commonly used.

**4. Planning of trajectories and pathlines of movement of robots and similar machines (Outcome O1, O2)**
The notion of trajectory and pathline. The notion of G-code. Description of G and M functions while programming robots and CNC machines. Point-to-point movement of robots and machines - PTP. Continuous movement along a pathline - CP. Interpolated motion. Overview of robotic and machine languages. Levels of robot and machine programming.

**5. Mechanical, energy, measuring and control systems in robots and machines (Outcome O1, O2, O3)**
Mechanical system design in robots and machines. Energy support of robots and machines. Types of measuring systems. Types of control systems.

**6. Drives in robotised systems (Outcome O1, O2) (Outcome O1, O2, O3)**
Electric drives. Hydraulic drives. Pneumatic drives. Overview of the operation of robots and machines with various types of drives. Standards in electropneumatic and electrohydraulic drives.

**7. Types of manipulators, robots and machines in robotised production systems (Outcome O1, O2, O3)**
Industrial robots. Manipulators. CNC machines. Service robots. Technological robots. Assembly robots. Measurement robots. Mobile robots.

**8. Auxiliary tools, devices and machines in robotised production systems (Outcome O1, O2, O3)**
Positioners. Vibratory conveyor. Supply lines. Supply devices. Moving lines. Manipulator and robot grippers. Tool, robot and machine receivers. Accept robot tools and machines. Plasma cutting systems, laser cutting, water-jet cutting. Presses.

Robotic welding equipment.

**9. Sensor technology and robotic vision (Outcome O3, O4)**

Position sensors. Speed sensors. Force sensors. Elements of robotic vision. Image analysis. Object recognition and gripping. Overview of the operation of robots and machines in combination with various types of sensors and robotic vision.

**10. Software tools in robotised production systems (Outcome O5)**

Software tools for modelling robotic cells. Software tools for offline and online robot programming. The role of the CAD/CAM/CNC chain and the integration of modules for programming robotised systems.

**Required reading**


- Šurina, Tugomir; Crneković, Mladen: Industrijski roboti, Školska knjiga, Zagreb, 1990
- Pavlic, Tomislav: Lectures in the course Applied Robotics, Bjelovar University of Applied Sciences, Bjelovar, 2018


**Further reading**


- Nikolić, Gojko; Vranješ, Božo; Kunica, Zoran; Jerbić, Bojan: Projektiranje automatskih montažnih sustava, Kigen, Zagreb, 2009
- Kovačić, Zdenko; Bogdan, Stjepan; Krajči, Vesna: Osnove robotike, Grafis, Zagreb, 2000

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|---|---|---|---|---|---|---|---|
| **Course title** | **Field Practice 1** | | | | | | |
| **Course instructor(s)** | Danijel Radočaj | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 3rd | **Semester** | 5th | **ECTS** | 3 | | |
| **Contact hours (L+PS+S)** | 0 + 80 + 10 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | | | 80 | 10 | | |

**Course objectives**

1. Familiarising oneself with the company, work environment and colleagues.
2. Gaining an insight into the organisation and work in a real work environment.
3. Learning to take on and carry out specific work tasks.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: describe a company/trade/craft and the fundamentals of company functions (activities, management structure, organisational units,…)
- O2: identify the main parts of a production organisation
- O3: explain the production cycle
- O4: present an overview of a mechatronic system at a company/trade
- O5: describe the functionality and maintenance of the chosen mechatronic system

**Course content**

**Required reading**

- Guidelines for Mechatronics students on doing the field practice.
- Field practice journal.

**Further reading**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Course title** | **Virtual Design of Mechatronic Systems** | | | | | | | |
| **Course instructor(s)** | Tomislav Pavlic | | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | | |
| **Course status** | Elective | | | | | | | |
| **Year** | 3rd | **Semester** | 5th | **ECTS** | 4 | | | |
| **Contact hours (L+PS+S)** | (15 + 30 + 0) | L | PS | | S | | | |
| | | | APS | LPS | | | | |
| | | 15 | 0 | 30 | 0 | | | |

**Course objectives**

To acquire and learn how to use the acquired knowledge necessary for understanding, modelling and digital production of positions and assemblies of mechatronic systems as well as the supporting documentation.

**Expected learning outcomes**

Upon completion of this course students will be able to:

O1: acquire basic terms related to the virtual modelling of parts and assemblies
O2: use the acquired knowledge for creating the required documentation
O3: create CAD models according to the rules and needs of digital production
O4: perform simulations of the behaviour of designed mechatronic systems that are identical to the real ones

**Course content**

- Technical documentation in virtual design of mechatronic systems. (Outcome O1 and O2)
- Standards in mechatronics. (Outcome O2)
- Fundamentals of CAD tools for 2D and 3D design. (Outcome O1 and O2)
- Part design. (Outcome O1)
- Assembly design. (Outcome O1)
- Bases of standard parts. (Outcome O2)
- 2D technical documentation. (Outcome O2)
- 3D sheet metal design. (Outcome O1 and O2)
- Rendering and designing photorealistic images of mechatronic systems from the designed 3D models. (Outcome O3)
- Design of mechatronic system animations. (Outcome O3 and O4)
- Intruduction to simulations. (Outcome O4)
- Surface design. (Outcome O3 and O4)
- Design of welded constructions. (Outcome O2, O3 and O4)
- Piping design. (Outcome O3)
- Distribution cabinet wiring. (Outcome O4)
- Transfer from a 3D model to *.dxf and *.dwg industrial standards. (Outcome O4)
- Preparation of a 3D model for the usage and integration in CAD/CAM/CNC systems, i.e. generally for the needs of digital production. (Outcome O4)

**Required reading**

- Pavlic, Tomislav: Lectures in the course Virtual Design of Mechatronic Systems, Technical College in Bjelovar, Bjelovar, 2015, http://vtsbj.hr/virtualno-oblikovanje-program/kolegij (17.3.2016)

**Further reading**

- Lombard, Matt: SolidWorks 2009 do kraja, Kompjuter biblioteka Beograd, 2009
- Shih, Randy; Schilling, Paul: SolidWorks 2008 Parametarsko modelovanje, Kompjuter biblioteka Beograd, 2008

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|---|---|---|---|---|---|---|---|
| **Course title** | **Maintenance of Mechatronic Systems** | | | | | | |
| **Course instructor(s)** | Stjepan Golubić, Goran Benkek | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 3rd | **Semester** | 6th | **ECTS** | 4 | | |
| **Contact hours (L+PS+S)** | 30 + 15 + 0 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | 30 | 15 | | | | |

**Course objectives**

Acquiring basic knowledge about organisation, technology and concept of the maintenance of mechatronic systems.

**Expected learning outcomes**

Upon completion of this course students will be able to:

O1: define the main functions and tasks of the maintenance of mechatronic systems,
O2: explain the most common causes of malfunctions and faults,
O3: explain and describe the methods and approaches to the maintenance of mechatronic systems,
O4: calculate the availability of mechatronic systems,
O5: describe the basic technologies in the maintenance of mechatronic systems,
O6: describe various methods of maintenance organisation.

**Course content**

**1. Basic terms in the theory of the maintenance of mechatronic systems.** (Outcome O1)
**2. User demands while purchasing new equipment.** (Outcome O1)
**3. Preparation for the exploitation of new equipment.** (Outcome O1, O2)
**4. Development of approaches and concepts of the maintenance function as related to the development of mechatronic systems.** (Outcome O3)
**5. Terotechnological approach.** (Outcome O3)
CPO. Planned maintenance.
**6. Theoretical aspects of maintenance.** (Outcome O3)
**7. Equipment classification.** (Outcome O1, O2)
Quality features of the equipment. Theoretical indicators of equipment status.
**8. Standstill and its significance.** (Outcome O2)
Collecting and analysing standstill data.
**9. Maintenance strategy.** (Outcome O3, O4)
Maintenance methods. Planned maintenance. Issues related to spare parts stock for the purpose of maintenance. Maintenance costs. Maintenance IT system. Calculation of effectiveness and reliability of technical systems and the use of results. Maintenance appropriateness.
**10. Technologies in equipment maintenance.** (Outcome O5)
General approach to the design and application of maintenance technologies. Parameters for determining equipment status and types of diagnostic equipment (instruments and methods). Application of various technologies in machine part repair (positions and assemblies).
**11. Lubrication and the fundamentals of technical system conservation.** (Outcome O5)
**12. Defining maintenance processes and their organisational implementation in various fields of industry.** (Outcome O6)
**13. Maintenance centralisation and decentralisation.** (Outcome O6)

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|---|
| **14. Contemporary solutions in the organisation of maintenance and global trends.** (Outcome O6) |
| **Required reading** |
| • Kondić, Živko; Čikić, Ante; Kondić, Veljko: Osnove održavanja mehatroničkih sustava 1, Technical College in Bjelovar, Bjelovar, 2014 |
| **Further reading** |
| • Blanchard, Benjamin: Logistic, Engineering and Management, Prentince Hall, New Jersey, 1990 |

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|---|---|---|---|---|---|---|---|
| **Course title** | **Field Practice 2** | | | | | | |
| **Course instructor(s)** | Danijel Radočaj | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | |
| **Course status** | Compulsory | | | | | | |
| **Year** | 3rd | **Semester** | 5th | **ECTS** | 3 | | |
| **Contact hours (L+PS+S)** | 0 + 80 + 10 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | | | 80 | 10 | | |

**Course objectives**

1. Familiarising oneself with the company, work environment and colleagues.
2. Gaining an insight into the organisation and work in a real work environment.
3. Learning to take on and carry out specific work tasks.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: describe a company/trade/craft and the fundamentals of company functions (activities, management structure, organisational units,…)
- O2: identify the main parts of a production organisation
- O3: explain the production cycle
- O4: analyse the behaviour of a chosen mechatronic system
- O5: evaluate the functionality of the chosen mechatronic system and suggest potential improvements

**Course content**

**Required reading**

- Guidelines for Mechatronics students on doing the field practice.
- Field practice journal.

**Further reading**

| Course title | Thesis | | | | | | |
|---|---|---|---|---|---|---|---|
| Course instructor(s) | Course instructors in the professional programme of study in Mechatronics | | | | | | |
| Programme(s) of study | Undergraduate professional programme of study in Mechatronics | | | | | | |
| Course status | Compulsory | | | | | | |
| Year | 3rd | Semester | 6th | ECTS | 9 | | |
| Contact hours (L+PS+S) | 0 + 0 + 120 | L | PS | | S | | |
| | | | APS | LPS | | | |
| | | | | | 120 | | |

**Course objectives**

1. To individually research and cover a selected topic, using the theoretical and practical knowledge acquired during studies.
2. To use the achieved competences in solving problems related to the field of study and to successfully use professional and scientific literature in the written coverage of the topic.

**Expected learning outcomes**

Upon completion of this course students will be able to:

- O1: cover topics related to the area of mechatronics using the theoretical and practical knowledge acquired in the course of studies,
- O2: document the researched topic related to the field of mechatronics,
- O3: present the researched topic related to the field of mechatronics.

**Course content**

Course content is based on the selected thesis topic.

**Required reading**

- Literature to be used for thesis depends on the topic selected and covered. Literature used in a thesis shall be listed in the printed version thereof.

**Further reading**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Course title** | **Computer Aided Manufacturing** | | | | | | | |
| **Course instructor(s)** | Tomislav Pavlic | | | | | | | |
| **Programme(s) of study** | Undergraduate professional programme of study in Mechatronics | | | | | | | |
| **Course status** | Elective | | | | | | | |
| **Year** | 3rd | **Semester** | 6th | **ECTS** | 4 | | | |
| **Contact hours (L+PS+S)** | (15 + 30 + 0) | L | PS | | S | | | |
| | | | APS | LPS | | | | |
| | | 15 | 0 | 30 | 0 | | | |

**Course objectives**

To acquire and learn how to use knowledge necessary for understanding, programming and digital production of components of mechatronic systems using particle removal processes and additive technologies.

**Expected learning outcomes**

Upon completion of this course students will be able to:

O1: acquire and use basic terms related to the design of technological processes in CNC particle removal processes
O2: acquire and use basic terms related to the design of the CAD/CAM/CNC chain
O3: use the acquired knowledge for manufacturing components using the CNC particle removal processes
O4: manufacture components using various technologies according to the rules and requirements of digital production

**Course content**

1. Role and position of CNC technologies today. (Outcome O1)
2. Historical development of CNC systems. (Outcome O1)
3. Material forming and material removal processes. (Outcome O1)
4. Characteristics of contemporary robotised manufacturing systems. (Outcome O2)
5. Designing technological processes that involve drilling, milling and turning. (Outcome O1, O2)
6. Drive measurements in production during material removal processes. (Outcome O1, O2, O3)
7. Clamping methods, centering methods, methods of producing devices by material removal processes. (Outcome O1, O3)
8. Manual programming of CNC machines and using the G-code. (Outcome O2)
9. Programming of CNC machines using the CAD/CAM system. (Outcome O2)
10. CIM machining systems (Computer Integrated Manufacturing). (Outcome O3, O4)
11. The role of pre-processor and post-processor in using CAD/CAM tools. (Outcome O3)
12. The role of pre-processor and post-processor in using real control units of processing systems. (Outcome O4)
13. The notion of tool trajectory in machining and additive technologies. (Outcome O4)
14. The advantages and disadvantages of a 3-axis CNC machining in comparison with multi-axis machining. (Outcome O4)
15. Differences in machining in wood industry and metal industry, and comparison with additive technologies etc. (Outcome O1, O2, O3, O4)

**Required reading**

- Pavlic, Tomislav: Lectures in the course Computer Aided Manufacturing, Technical College in Bjelovar, Bjelovar, 2015

**Further reading**

- Bošnjaković, Mladen; Stoić, Antun: Programiranje CNC strojeva, College of Slavonski Brod, Slavonski Brod, 2011
- Shih, Randy; Schilling, Paul: SolidWorks 2008 Parametarsko modelovanje, Kompjuter biblioteka Beograd, 2008

<table>
<tr><td>Course title</td><td colspan="6">Additive Technologies</td></tr>
<tr><td>Course instructor(s)</td><td colspan="6">Tomislav Pavlic</td></tr>
<tr><td>Programme(s) of study</td><td colspan="6">Undergraduate professional programme of study in Mechatronics</td></tr>
<tr><td>Course status</td><td colspan="6">Elective</td></tr>
<tr><td>Year</td><td>3rd</td><td>Semester</td><td>6th</td><td>ECTS</td><td colspan="2">4</td></tr>
<tr><td rowspan="2">Contact hours (L+PS+S)</td><td rowspan="2" colspan="2">(15 + 30 + 0)</td><td>L</td><td colspan="2">PS</td><td>S</td></tr>
<tr><td>APS</td><td>LPS</td><td></td></tr>
<tr><td colspan="3"></td><td>15</td><td></td><td>30</td><td>0</td></tr>
</table>

**Course objectives**

To acquire and learn how to use knowledge necessary for understanding, selection and usage of additive technologies required for the development of new and modification of existing products within a mechatronic system.

**Expected learning outcomes**

Upon completion of this course students will be able to:

O1: acquire basic terms related to additive technologies and reverse engineering
O2: acquire basic terms related to materials used in additive technologies
O3: use the acquired knowledge in the application of additive technologies in digital production
O4: design CAD models using the 3D scanning technology, photogrammetry and object visualisation
O5: amend the obtained point clouds and design real models using 3D printing technologies

**Course content**

- General facts about additive technologies. (Outcome O1, O2)
- Properties and types of materials in additive technologies. (Outcome O1, O2)
- 3D printing. (Outcome O3)
- 3D scanning. (Outcome O3)
- Reverse engineering. (Outcome O3)
- Digital production. (Outcome O3)
- Photogrammetry and object visualisation. (Outcome O4)
- Fundamentals of CAD tools for 2D and 3D modelling as related to additive technologies. (Outcome O4)
- Fundamentals of software tools used in additive technologies. (Outcome O4)
- Using CAD tools for modelling parts. (Outcome O4)
- Conversion of the 3D model into industrial standards of additive technologies in engineering and medicine. (Outcome O5)
- Preparation, use and integration of amended 3D models in CAD/CAM/CNC/AM systems. (Outcome O5)

**Required reading**

- Pavlic, Tomislav: Lectures in the course Additive Technologies, Bjelovar University of Applied Sciences, Bjelovar, 2018
- Stjepan Golubić: Lectures in the course Additive Technologies, Bjelovar University of Applied Sciences, Bjelovar, 2018

**Further reading**

- Lombard, Matt: SolidWorks 2009 do kraja, Kompjuter biblioteka Beograd, 2009
- Shih, Randy; Schilling, Paul: SolidWorks 2008 Parametarsko modelovanje, Kompjuter biblioteka Beograd, 2008
- Solidworks – online sources
- Autodesk Meshmixer / Netfabb - online sources
- MakerBot Desktop / MakerWare for Digitizer - online sources
- Makerbot Digitizer - online sources
- Makerbot Replicator 2x - online sources