NAZARBAYEV UNIVERSITY
SCHOOL OF ENGINEERING AND DIGITAL SCIENCES

Bachelor of Science in Robotics and Mechatronics

Nazarbayev University

Degree requirements for the AY 2020-2021 Graduation Cohort

	Course		ECTS
General Requirements (36 credits)	*Kazakh History*	HST 100 History of Kazakhstan	6
	Kazakh Language 1	Any course with KAZ designation	6
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	HSS Elective		6
	HSS Elective		6
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Major Requirements (162 credits)	MATH 161 Calculus I		8
	MATH 162 Calculus II		8
	MATH 273 Linear Algebra with Applications		8
	MATH 274 Introduction to Differential Equations		6
	MATH 321 Probability		6
	PHYS 162 Physics I with Lab		8
	PHYS 162 Physics II with Lab		8
	CSCI 151 Programming for Scientists and Engineers		8
	CSCI 152 Performance and Data Structures		8
	ROBT 201 Mechanics: Statics and Dynamics		6
	ROBT 202 System Dynamics and Modeling		6
	ROBT 203 Electrical and Electronics Circuits I with Laboratory		8
	ROBT 204 Electrical and Electronics Circuits II with Laboratory		8
	ROBT 205 Signals and Sensing with Laboratory		8
	ROBT 206 Microcontrollers with Laboratory		8
	ROBT 301 Mechanical Design with CAD and Machining Laboratory		8
	ROBT 303 Linear Control Theory with Laboratory		8
	ROBT 304 Electromechanical Systems with Laboratory		8
	ROBT 312 Robotics I: Kinematics and Dynamics		6
	ROBT 402 Robotic/Mechatronic System Design		6
	ROBT 403 Robotics II: Control, Modeling and Learning with Lab.		8
	ROBT 491 Graduation Project		6
Natural Science Electives	Can be satisfied by any non-required PHYS, CHEM, BIOL or GEOL course at 100-level or above not designated for "non-science majors"		**12**
Technical Electives	Can be satisfied by any non-required ROBT course at 200-level or above, and other SEDS courses with the consent of the academic advisor.		**30**
	Total		**240**

DETAILED COURSE DESCRIPTIONS

MATH 161: Calculus I
Credits: 8 ECTS
Overview:
The purpose of this course is to provide the student with an understanding of basic calculus concepts and problem-solving methods for use in his/her chosen field or in further mathematics studies. This course covers the main subjects on limits, continuity, derivatives and integrals of the real functions in one variable with application in different fields. This course covers limits and continuity as well as differentiation and integration of polynomial, rational, trigonometric, logarithmic, exponential and algebraic function. The application areas include slope, velocity, extrema, area, and volume.

By the end of the course the student will be expected to be able to:
1) Use both the limit definition and rules of differentiation to differentiate functions;
2) Sketch the graph of a function using asymptotes, critical points, the derivative test for increasing/decreasing functions, and concavity;
3) Apply differentiation to solve applied max/min problems;
4) Apply differentiation to solve related rates problems;
5) Evaluate integrals both by using Riemann sums and by using the Fundamental Theorem of Calculus;
6) Apply integration to compute arc lengths, and areas between two curves;
7) Use L'Hospital's rule to evaluate certain indefinite forms.

MATH 162: Calculus II
Credits: 8 ECTS
Overview:
This course covers transcendental functions, advanced integration techniques, improper integrals, area and arc length in polar coordinates, infinite series, power series and Taylor's theorem.

By the end of the course the student will be expected to be able to:
1) Integrate functions whose antiderivative is given by elementary functions;
2) Use integrals in a variety of area and volume computations;
3) Solve first order differential equations by separation of variables or the method of integrating factors;
4) Analyze the convergence of series which are either absolutely convergent or alternating;
5) Know the most usual Maclaurin series expansions and their intervals of convergence, together with how to derive them;
6) Work with curves in parametric form, especially polar coordinates;
7) Identify types of conic from their equation in cartesian or polar coordinates

MATH 273: Linear Algebra with Applications
Credits: 8 ECTS
Overview:
This course covers systems of linear equations, matrices and inverses, determinants, eigenvalues and eigenvectors, inner product spaces and orthogonal matrices, and an introduction to vector spaces as the theoretical portion of the course.

MATH 274: Introduction to Differential Equations
Credits: 6 ECTS
Overview:
This course covers first order differential equations; mathematical models and numerical methods; linear systems and matrices; higher-order linear differential equations; linear systems of differential equations; and Laplace transform methods.

MATH 321: Probability
Credits: 6 ECTS
Overview:
This course covers foundations of probability theory, combinatorial and counting methods, conditional probability, random variables, discrete and continuous distributions, expectation, moment generating functions, multivariate distributions, variable transformations, the Law of Large Numbers and the Central Limit Theorem.

PHYS 161: Physics I for Scientists and Engineers
Credits: 8 ECTS
Overview:
This is an introductory calculus-based course covering Mechanics and Thermodynamics. The students will learn to identify fundamental laws of mechanics and thermodynamics in everyday phenomena and to apply these laws to solving basic physics problems and to describing laboratory experiments. The course includes three hours of lectures per week, accompanied by recitations and laboratory experiments.

PHYS 162: Physics II for Scientists and Engineers
Credits: 8 ECTS
Overview:
This is an introductory algebra-based course covering Electricity, Magnetism and elements of Optics. The students will learn to identify fundamental laws in everyday electromagnetic phenomena and to apply these laws to solving basic physics problems and to describing laboratory experiments. The course includes three hours of lectures per week, accompanied by recitations and laboratory experiments.

CSCI 151: Programming for Scientists and Engineers
Credits: 8 ECTS
Overview:
The course introduces students to imperative programming and the development of basic algorithms using the C programming language. A detailed presentation of the language syntax will be given, along with the proper use of control structures, loops, functions, and recursion to solve problems. The creation and use of structures and arrays will also be covered, along with the development of libraries and multi-file programs. By the end of the course student should be able to describe and implement good data structures for each of these ADTs, including array, list, tree, and hash table implementations when appropriate. Also, student should be able to analyze program correctness using preconditions, postconditions, and invariants.

1) Students will be able to utilize modern software development tools and methods. Such skills will be useful in students' future computer science courses, as well as in their future careers.
2) Students will have proficiency in writing, understanding, and explaining small to mid-sized structured programs which will incorporate fundamental language elements.
3) Students will be able to solve abstract computational problems through the use of programs.
4) Students will understand the concept and use of recursion. By the end of the course, students should be able to write their own recursive functions and analyze other's recursive code for correctness
5) Students will have a basic understanding of common algorithms used in searching and sorting, and learn how to implement them in C.
6) Students will know how to use pointers and memory management in the C language and be able to implement and understand code using these features.

CSCI 152: Performance and Data Structures
Credits: 8 ECTS
Overview:
Students will learn about common abstract data types such as stacks, queues, and maps, study how they can be utilized to solve different problems and implement them using the C++ language. The pros and cons of using different internal representations such as vectors, linked-lists, binary search trees, and hash tables will be examined. Students will be required to assess problems and choose appropriate data structures and relevant algorithms to improve performance and understand the practical limits of computability

1) Students will understand the concept of abstract data types, and how they can be implemented in C++ using vectors and dynamically linked data structures.
2) Students will be familiar with the most important abstract data types used in the storage and retrieval of information in modern software systems, including stack, queue, set, and map.
3) Students will be able to examine and quantify the relative performance of the data structures and underlying algorithms, and the scalability of the structures as the size of data sets increases;
4) Students will be able to develop and test the data structures using component-based software engineering techniques;
5) Students will understand and be able to apply basic concepts of component-based design (e.g., encapsulation, data hiding, invariants) through their use of the C++ language.
6) Students will be able to write proper C++ code that can be read, understood, and modified by others.

ROBT 201: Mechanics: Statics and Dynamics
Credits: 6 ECTS
Overview:
In this course students are introduced to engineering mechanics. The first part of the course covers statics, including equilibrium of a particle and of a rigid body in 2-D and 3-D, force and moment resultants, internal forces and moments, trusses and frames, basics of structural analysis. The second part of the course introduces students to dynamics, and in particular to particle kinematics and kinetics in 2-D and 3-D, to rigid body kinematics and kinetics in 3-D, to concepts of work energy, impulse-momentum, force-acceleration and to translational and rotational motion.

By the end of the course the student will be expected to be able to:
1) Understand concepts of equilibrium, motion, work, energy, and momentum.
2) Solve engineering problems related to statics and dynamics of particles and rigid bodies
3) Intuitively grasp simple mechanical problems

ROBT 202: System Dynamics and Modeling
Credits: 6 ECTS
Overview:
In this course, students are introduced to the theory of linear dynamic systems. First, you will learn fundamentals about Laplace transform. Then you will study how to obtain a mathematical model that describes the behavior of a physical system. Then different techniques will be introduced to understand how the system will evolve in the future, given its initial conditions and under the presence of external inputs. For example, state-space and transfer function representations of dynamic systems will be covered. The topics of this course are found in any technological application where we need to forecast the time evolution of a system, or to get the necessary information to design automatic control systems (widely used in robotics and mechatronics applications).

By the end of the course, the student will be expected to be able to:
1) Understand concepts of Laplace transform, Inverse Laplace Transform, state-space, and transfer function methods.
2) Solve engineering problems related to the analysis of the dynamics of mechanical and electrical systems.
3) Analyze controllability and observability of linear systems, learn essentials of linearization and discretization methods.

ROBT 203: Electrical And Electronics Circuits I With Laboratory
Credits: 8 ECTS
Overview:
ROBT 203 is the first course in the Robotics and Mechatronics Program curriculum that provides background for all future required circuits, electronics and systems courses. The 4 credit course consists of two 75 minute lectures and one three hour lab/recitation session. Topics include analysis of resistive circuits, circuit theorems, operational amplifiers, response of first and second order circuits, AC steady state analysis and three phase circuits. Matlab software will be used to solve circuit analysis and design problems, and also for simulations.

By the end of the course, the student will be expected to be able to:
1) Apply Ohm's Law, Kirchhoff's Current Law, and Kirchhoff's Voltage Law, equivalent resistance calculation, voltage divider, current division in the analysis of linear circuits consisting of resistors, inductors, and capacitors driven by constant and sinusoidal voltage and current sources.
2) Apply the Node Voltage and Mesh Current circuit analysis techniques.
3) Calculate voltages, currents, and gains of circuits containing operational amplifiers.
4) Calculate the Thevenin or Norton equivalent of a circuit.
5) Demonstrate skills to use oscilloscopes, signal generators, multi-meters and power supplies, individually or as part of a team.
6) Solve circuit analysis and design problems using Matlab software.

ROBT 204: Electrical And Electronics Circuits II With Laboratory
Credits: 8 ECTS
Overview:
ROBT 204 is the second course in the Electrical Engineering area of the Robotics and Mechatronics Program curriculum. The 4 credit course consists of three 50 minute lectures and one three hour lab/recitation session. Topics include frequency response, Laplace Transform, diodes and its applications, bipolar junction transistors, field effect transistors, operational amplifiers and its applications. Altium Circuit Designer will be used extensively to simulate circuits and also to implement printed circuit board schematics.
By the end of the course, the student will be expected to be able to:
1) Describe gain, phase shift, and Bode plots for electrical circuits and be able to apply Laplace Transform for the solution of electrical circuits.
2) Illustrate the operating principles of semiconductor diodes and be able to apply diodes in different applications.
3) Describe the operating principles of bipolar junction transistors and field effect transistors

ROBT 205: Signals and Sensing with Lab
Credits: 8 ECTS
Overview:
ROBT205 is an introduction to signal processing for discrete-time and continuous-time signals. The main topics covered are filtering, frequency response, Fourier Transform, and Z-Transform. Students will learn the fundamental role played by sinusoidal or complex exponential signals for connecting these domains. Students will learn properties of signal processing systems, including linearity and time-invariance, and the operation of linear, time-invariant systems in the time and frequency domains. Lectures are coupled with a laboratory that emphasizes computer-based signal processing. Laboratory experiments aim to provide a practical working knowledge of different sensors and data acquisition systems that are used in the engineering field. Matlab software will be used extensively for data acquisition and computer implementation of various signal processing algorithms.

By the end of the course, the student will be expected to be able to:
1) Analyze continuous-time and discrete-time signals and systems in the frequency domain using mixed-signal classes.
2) Understand the concept of sampling and the concepts that link continuous-time and discrete-time signals and systems. Use MATLAB and laboratory experiments to simulate and to analyze signals and systems for this situation.
3) Understand the effect of system poles and zeros on the frequency responses of systems
4) Analyze discrete-time signals and system responses using the concepts of transfer function representation by use of Z and inverse-Z transforms
5) Apply time-domain and frequency-domain analysis tools to design analog and digital filters. Use MATLAB and laboratory experiments for applications of filters.

ROBT 206: Microcontrollers with Lab
Credits: 8 ECTS
Overview:
ROBT 206 is the first course in the Computer Engineering area of the Robotics and Mechatronics Program curriculum. This 8 credit course consists of two 75 minute lectures and one (two) three hour lab session per week. The course covers both the fundamentals of the logic and computer system design and the practical aspects of the microcontroller programming. Topics include Boolean algebra, combinational logic circuit design, sequential logic circuit design, computer design basics; instruction set concept, peripherals of microcontrollers. Matlab/Simulink will be used extensively to simulate logic circuits. Microchip Explorer Demo Board and MPLAB Integrated Development Environment will be used in the laboratory sessions to learn practical aspects of microcontroller programming.

By the end of the course, the student will be expected to be able to:
1) Design and Analyze combinational logic circuits
2) Understand the fundamentals of digital circuit elements such as registers, multiplexers, decoders, encoders.
3) Implement/Design and optimize synchronous/asynchronous sequential circuits
4) Understand how the central processing unit (CPU) in a computer works.
5) Demonstrate necessary skills in practical aspects of digital circuits and systems, and their use in more complex systems.
6) Demonstrate an understanding of the various hardware realizations of the essential digital circuit elements.
7) Demonstrate necessary skills in using computer tools to design simple microcontroller systems

ROBT 301: Mechanical Design I with CAD Laboratory
Credits: 8 ECTS
Overview:
This course focuses on the fundamentals of mechanical design which lays the analytical foundation needed for the design of machine elements. The topics include the fundamentals of mechanical design, materials and processes, solid mechanics, stress, strain and deflections, static and fatigue failure theories and FEA. The topics arranged to be taken up in the order presented and build upon each other except FEA.
Laboratory sessions of the course teach students basic skills of computer-aided design (CAD) and exposes them to different manufacturing processes with major emphasis on additive and subtractive manufacturing technologies. SolidWorks CAD software is used to introduce 3D solid modeling, assembling, structural analysis and motion simulation of common machine elements, such as shafts, bearings, gears, springs, screws, and fasteners. Drafting standards, geometric dimensioning and tolerancing (GD&T) are discussed in the process of generation of machine shop ready engineering drawings in SolidWorks. After mastering basic skills of computer-generated design students will engage in the process of 3D printing with plastic and machining with metal. Machine shop safety is explained prior introducing machine shop facilities to the students. Machining methods that are explained include drilling, cutting, bending, turning, milling, grinding, and basis of CNC machining. The integrated approach of 3D design and manufacturing concludes with discussion on inspection and measuring techniques used for the final validation of the created components.

By the end of the course, the student will be expected to be able to:
1) Illustrate the need, process, and professional/safety requirement in mechanical design.
2) Describe the material properties and processes required for designing machine elements.
3) Describe and analyze different types of loading, stress, strains and deflections on machine elements.
4) Outline the static, fatigue, and surface failure theories.
5) Design mechanical parts and systems using 3D computer-aided design tools with proper documentation and realize these components using rapid prototyping techniques.
6) Apply Finite Element Analysis (FEA) to evaluate the mechanical properties of mechanical parts with different materials.
7) Recognize and understand essential of mechanical elements and select them for specific applications
8) Analyze standard and manufacturer catalog graphs, tables, and data sheets.
9) Learn how to utilize the CAD software to design 3D parts and assemblies.
10) Learn about proper machine shop ready sketches based on GD& T and surface finishing standards.
11) Gain an understanding of the typical mechanical elements and their standard namely, shafts, bearings, spur gears, helical, bevel, and worm gears, springs, screws, and fasteners.
12) Learn different machining and fabrication methods, metals and plastics, manufacturability of parts or components and inspection and measuring techniques

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ROBT 303: Linear control theory with Lab
Credits: 8 ECTS
Overview:
This course is intended to introduce students to concepts and techniques of classical control and to briefly introduce some concepts of modern control and discrete-time. The main goal is to enable students to analyze, design, and synthesize linear control systems. Students will become familiar with analytical methods and will be exposed extensively to the use of computers for analysis and design of control systems.

By the end of the course, the student will be expected to be able to:
1) Analyze the stability and performance properties of single-input-single-output (SISO) linear control system, both using the root locus and the frequency-domain techniques, both analytically and using numerical simulation.
2) Synthesize controllers for single-input-single-output (SISO) linear control system, both using the root locus and the frequency-domain, both analytically and using numerical simulation.
3) Design PID controllers, using any of the previously mentioned methods, knowing about the practical issues in their implementation (anti wind-up, discretization, etc.)
4) Analyze systems in the state-space framework, and be aware of the main design methods design related to the state-space domain

ROBT 304: Electromechanical Systems With Laboratory
Credits: 8 ECTS
Overview:
This course will introduce students with the theoretical and technological foundations of classical and modern electromechanical systems. Particular emphasis will be given to electrical drives and machines that are employed in robotics and automation. Students will gain basic knowledge in electromagnetics and magnetic circuits analysis to predict electromagnetic characteristics of electric machines and permanent magnet materials. Using principles of electromechanical energy conversion they will be able to predict forces and torques for different kind of electric machines. For the lab sessions of this class, the students will design and build their own electric servo-drive based on brushless DC motors. By using Matlab software and the real-time capability of Simulink they will implement torque, velocity, and position control.

By the end of the course, the student will be expected to be able to:
1) Analyze and solve magnetic circuits, which include soft and hard ferromagnetic materials, coils, and moving mechanical parts (plungers, rotors).
2) Use the basic principles of electromechanical energy conversion to predict forces and torques in rotational and linear electric machines.
3) Learn fundamentals and basic operating characteristics of common electrical machines.
4) Understand, evaluate, and compare different motor technologies such as AC synchronous/asynchronous, induction, and DC brushed/brushless.
5) Design and control a servo drive by using rapid prototyping techniques based on Matlab/Simulink software.

ROBT 312: Robotics I: Kinematics And Dynamics
Credits: 6 ECTS
Overview:
This course covers classical topics in robotics with particular emphasis on the kinematics, and dynamics of industrial manipulators. Different kinematics architectures are introduced together with classical modeling techniques based on homogeneous transformations. Alternative methods, such as the fixed and Euler angle conventions, quaternions and the vector-angle representation, are explained to represent the orientation of rigid bodies. Analysis of velocities, static forces, and kinematic singular configurations is carried out by means of differential kinematics. The equations of motion of a manipulator are derived using Newton-Euler and Lagrange methods. The analytical closed form solution for the inverse dynamic problem is obtained ready to be used as the core block for model based control techniques and for simulation purposes.

By the end of the course, the student will be expected to be able to:
1) Describe the working principles, features, and usages of industrial manipulators and related safety issues
2) Formalize and analyze the forward and inverse kinematics of open-chain manipulators
3) Obtain the differential kinematic model of a manipulator and calculate the correspondent Jacobian Matrix
4) Formalize the inverse dynamic model using Newton-Euler and Lagrange methods

ROBT 402: Robotics/Mechatronics System Design
Credits: 6 ECTS
Overview:
This course brings together aspects of design in mechanical, control and electrical/electronic systems so that students will have a good idea of the range of advanced techniques available in designing robotic and mechatronic systems integrating methods and skills acquired in previous courses. The students will learn about the theory of the different components (including some sensors and actuators) employed in the Festo MPS 500 system and will get familiar with their actual application in the lab environment. The material transportation system which consists of a conveyer belt operated by 4 AC motors will be used to keep the flow of the parts in the manufacturing process. The students will learn about controlling the transportation system, using the AC motor drives and the ways to communicate between the transportation system and other stations in the setup.

By the end of the course, the student will be expected to be able to:
1) Analyze and understand the interaction of mechanics, pneumatics, electrical engineering, control technology and communication interfaces.
2) Use AC/DC motors, electrical drive technology, pallet identification systems and fieldbus technology in an assembly line.
3) Use pneumatic linear and rotary drives, pneumatic switches, wire electrical components, use limit switches, optical and inductive sensors, use analogue sensors and pneumatic grippers
4) Program and apply PLC as the controller of a process, use enhanced I/O communications, individually and as a team
5) Program an industrial robot using a teaching pendant and through the programming environment and simulate the movements of the robot, individually and as a team
6) Integrate an industrial robot in an assembly process, teach the industrial robot in complex assembly environments, program the industrial robot combined with the integration of sensors and additional actuators, individually and as a team

ROBT 403: Robotics II: Control, Modeling And Learning With Laboratory
Credits: 8 ECTS
Overview:
This course introduces control and simulation techniques suitable for industrial manipulators and mobile robots. Motion control and trajectories planning are formalized in the joint and task space. Linear and Non Linear control schemes are applied to industrial manipulators and tested with the support of different simulation environments, such as Matlab, VREP and Gazebo. A state-of-the-art operative system for robotics applications (ROS) is introduced. Modern learning techniques are presented to acquire and adapt the inverse kinematic and dynamic model of the robot in order to implement model-based feedback control schemes in the joint and in the Cartesian space. The course is structured around weekly lectures that are complemented by exercises and computer labs.

By the end of the course the student will be expected to be able to:
1) Describe the working principles, features, and usages of industrial manipulators.
2) Implement Trajectory Planning in the Cartesian and the Joint Space.
3) Develop feedback and model-based control systems for robotics.
4) Set up ROS-based control architectures.
5) Use different simulation software to design and test motion planning and control systems for robotics endowed with learning capabilities.

ROBT 491: Graduation Project
Credits: 6 ECTS
Overview:
The course objective is to practice industrial project work within the robotics and mechatronics engineering field. Projects include problem definition, making time schedule, information retrieval, work coordination, problem solving, report writing and oral presentation. Student should demonstrate ability both to apply knowledge acquired earlier in the education and within a project team ability to acquire and apply more knowledge.

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By the end of the course, the student will be expected to be able to:
1) identify, formulate, and solve engineering problems related to robotics and mechatronics disciplines
2) design robotic/mechatronic systems or components to meet desired needs within realistic constraints.
3) communicate effectively with a range of audiences.
4) familiarize with research methods and acquire research skills, recognize ethical and professional responsibilities in engineering situations and make informed judgements
5) work effectively in teams