Subject (course) name: ***Introduction to Control Systems***		
Field of study: **Automatic Control and Robotics** Specialization: **all**		Subject code: **9K** Title graduate: **Engineer**
Type of course: **major course, obligatory**	Course level: **First-cycle studies**	Year: **II** Semester: **III** Semester: **winter**
Form of classes: **Lectures,Classes, Labs, Seminar, Project**	Hours per week: **2L, 1C, 2Lab, 0S, 0P**	Credit points: **5 ECTS**

GUIDE TO SUBJECT

SUBJECT OBJECTIVES

C1. Derive and analysing mathematical models of dynamic systems.

C2. Understand the concept of feedback control and its properties.

C3. Determine stability and evaluating transient and steady-state performance of linear feedback control systems.

C4. Design simple linear feedback control systems.

C5. Use computer-aid tools for analysis and design of feedback control.

SUBJECT REQUIREMENTS

1. Basic knowledge of calculus, complex numbers, linear algebra and differential equations.
2. Basic knowledge in physics and electrical engineering on dynamic systems.
3. Basic knowledge in numerical methods and basic programming skills.

LEARNING OUTCOMES

EK1 - Student is able to derive transfer functions or state-space models of simple electrical and mechanical dynamic systems and knows time and frequency responses of basic models.

EK2 - Student understands properties of feedback and knows components of feedback control systems.

EK3 - Student is able to determine stability and evaluate transient and steady-state performance of linear feedback control systems.

EK4 - Student is able to design a simple feedback control (with PID controller or lead/lag compensation) satisfying specifications in the time and/or frequency domain.

SUBJECT CONTENT

Form of classes - Lectures

Topic	Hours
L1 – Motivation for automatic control. Modeling of continuous-time electrical and mechanical systems dynamic systems.	**2**
L2 – Input-output transfer function representation. Poles and zeros.	**2**
L3 – State-space representation. Local linearization of nonlinear dynamic systems.	**2**
L4 – Basic dynamic blocks. Time domain response.	**2**
L5 – Frequency domain response. Nyquist and Bode plots.	**2**
L6 – Stability. Routh-Hurwitz criteria.	**2**
L7 – Properties of feedback. Disturbance rejection. Command tracking. Sensitivity.	**2**

L8 – Block diagrams, signal flow graphs.	**2**
L9 – Steady-state errors of feedback systems in response to command/disturbance signal. Integral action.	**2**
L10 – Performance specifications in the time domain. Root-locus analysis and design.	**2**
L11 – Performance specifications in the frequency domain. Stability margin.	**2**
L12 – Frequency response analysis and design.	**2**
L13 – Concept of robustness. PID control.	**2**
L14 – State feedback. State estimator (observer). LQR/LQG control.	
L15 – Final test	**2**
Total	**30**

Form of classes - Exercises

Topic	Hours
C1 – Laplace transform - review	**1**
C2,3 – Dynamic models of electrical and mechanical systems. Transfer function and state-space representations.	**2**
C4 – Local linearization of nonlinear dynamic systems.	**1**
C5 – Time responses of simple dynamic systems.	**1**
C6 – Frequency responses of simple dynamic systems.	**1**
C7 – Routh-Hurwitz criteria.	**1**
C8 – Mid-semester test.	**1**
C9 – Transformations of block diagrams.	**1**
C10 – Steady-state errors of feedback systems.	**1**
C11 – Root-locus analysis and design	**1**
C12 – Frequency response analysis and design.	**1**
C13,14 – Design of feedback control to obtain specified performance indices.	**2**
C15 – End-semester test	**1**
Total	**15**

Form of classes – laboratory

Topic	Hours
Lab1 – Time responses of basic dynamic systems – measurement and identification	**2**
Lab2 – Frequency responses of basic dynamic systems – measurement and identification	**2**
Lab3 – Computer simulation of feedback systems	**2**
Lab4 – Approximate methods of setting PID parameters	**2**
Lab5 – Steady-state errors in a DC generator voltage stabilization system	**2**
Lab6 – Angular position control of a DC servo drive	**2**
Lab7 – Design of feedback using the root-locus technique	**2**
Lab8 – Design of feedback using the frequency response technique	**2**
Lab9 – Two-state temperature control system	**2**
Lab10 – Angular velocity control of a DC servo drive	**2**
Lab11 – LQR/LQG control of an active suspension system	**2**
Lab12 – PID control of a mobile robot trajectory	**2**
Lab13,14 – Matlab/Simulink project	**4**
Lab15 – Summary test	**2**
Total	**30**

STUDY METHODS

1. Lectures using multimedia presentation, accompanied by discussion.
2. Exercises **–** solving problems (using computer-aid tool if necessary).
3. Laboratory experiments – work in groups on physical setups or on computers with dedicated software

EDUCATIONAL TOOLS

1. Audiovisual equipment, blackboard, lecture slides in PDF version
2. Computers with Matlab/Simulink software including Control System Toolbox.
3. Laboratory setups **–** physical models, computers, digital measurement and control hardware

METHODS OF GRADING (F – Forming, P – Summary)

F1. Laboratory - group reports with results of the lab experiments (50% of the laboratory grade)

F2. Classes - homework (20% of the classes grade)
P1. Lectures – written final test
P2. Classes – written mid-semester and end-semester tests (80% of the exercises grade)
P3. Laboratory – written summary test (50% of the laboratory grade)

STUDENT WORKLOAD

Form of activity		Averaged workload (hours)		
		[h]	$\sum$ [h]	ECTS
Participation in class activities	lectures classes laboratory	30 15 30	75	3
Studying literature		10	50	2
Preparation to the classes, homework		10		
Preparation of the lab reports		15		
Preparation to the written tests		15		
	Total		**125**	**5**

A. BASIC READING

1. Ogata K.: *Modern Control Engineering*, 5th ed. Prentice Hall, 2009.
2. Nise N.: *Control Systems Engineering*, 6th ed., John Wiley & Sons, 2010.
3. D'Azzo J., Houpis C.: *Linear Control System Analysis and Design with Matlab*, 5th ed., Marcel Dekker, 2003.
4. Lurie B., Enright P.: *Classical Feedback Control with Matlab*, Marcel Dekker, 2003.
5. Tewari A.: *Modern Control Design with Matlab and Simulink*, John Wiley & Sons, 2002.

B. FURTHER READING

1. Dorf R., Bishop R.: *Modern Control Systems,* 12th ed. Prentice Hall, 2011.
2. Franklin G.F., Powell J.D.: *Feedback Control of Dynamic Systems*, 4th ed. Addison Wesley, 2002.
3. Xue D., Chen Y., Atherton D.: *Linear Feedback Control. Analysis and Design with Matlab*, SIAM, 2007.
4. The Mathworks Inc.: *Control System Toolbox. User's Guide, Simulink Control Design.User's Guide*.

Learning outcomes	**In relation to the learning outcomes specified for the field of study**	**Subject objectives**	**Study methods**	**Methods of assessment**
EK1	KAR1A_W05 KAR1A_W14 KAR1A_U10 KAR1A_K02	C1	lectures, classes	**F2, P1, P2**
EK2	KAR1A_W05 KAR1A_W15 KAR1A_U08 KAR1A_U11	C2	lectures, classes	**F2, P1, P2**
EK3	KAR1A_W04 KAR1A_W05 KAR1A_U08 KAR1A_U11	C3, C5	lectures, classes, laboratory	**F1, F2, P1, P2, P3**
EK4	KAR1A_W04 KAR1A_W06 KAR1A_U12 KAR1A_K03	C4, C5	lectures, classes, laboratory	**F1, F2, P1, P2, P3**

II. EVALUATION

Grade	Outcome
EK1	**Student is able to derive transfer functions or state-space models of simple electrical and mechanical dynamic systems and knows time and frequency responses of basic models**
2 (F)	Student is <u>not</u> able to derive models of dynamic systems and does not know characteristics of basic

	models
3 (E)	Student is able to derive only the simplest models and knows their characteristics
4 (C)	Student is able to derive more difficult models and knows characteristics of all basic models
5 (A)	Student is able to derive more difficult models as transfer function and state-space representation, knows characteristics of all basic models and their dependence on dynamic parameters
EK2	**Student understands properties of feedback and knows components of feedback control systems**
2 (F)	Student does not know properties of feedback, cannot derive any representation of the closed-loop system
3 (E)	Student knows basic properties of feedback and is able to derive simple closed-loop transfer functions
4 (C)	Student knows properties of feedback and is able to derive closed-loop transfer functions
5 (A)	Student knows and understands properties of feedback, is able to derive closed-loop transfer functions, knows components of feedback control systems
EK3	**Student is able to determine stability and evaluate transient and steady-state performance of linear feedback control systems**
2 (F)	Student is not able to determine stability and not able to evaluate transient and steady-state performance of linear feedback systems
3 (E)	Student is able to determine stability of linear feedback systems
4 (C)	Student is able to determine stability and evaluate steady-state error of linear feedback systems
5 (A)	Student is able to determine stability and evaluate transient and steady-state performance of linear feedback systems
EK4	**Student is able to design a simple feedback control (with PID controller or lead/lag compensation) satisfying specifications in the time and/or frequency domain**
2 (F)	Student is not able to design any feedback control satisfying given specifications in the time and/or frequency domain
3 (E)	Student is able to design only the simplest feedback control in the time or frequency domain
4 (C)	Student is able to design partially a feedback control satisfying specifications in the time and frequency domain
5 (A)	Student is able to design a correct feedback control satisfying specifications in the time and frequency domain

III. OTHER USEFUL INFORMATION

1. All information for students on the schedule are available on the notice board and on the website: www.el.pcz.pl
2. Information on the consultation shall be provided to students during the first lecture and will be placed on the website www.el.pcz.pl
3. Terms and conditions of credit courses will be provided to students during the first lecture