

# SYLLABUS

## 1. Information regarding the programme

1.1 Higher education institution	Babeş–Bolyai University of Cluj–Napoca
1.2 Faculty	Chemistry and Chemical Engineering
1.3 Department	Chemical Engineering
1.4 Field of study	Chemical Engineering
1.5 Study cycle	Master
1.6 Study programme / Qualification	Advanced Chemical Process Engineering

## 2. Information regarding the discipline

2.1 Name of the discipline	<b>Advanced Process Control – CME7322</b>						
2.2 Course coordinator	Prof.dr.ing. Cristea Vasile Mircea						
2.3 Seminar coordinator	Prof.dr.ing. Cristea Vasile Mircea						
2.4. Year of study	I	2.5 Semester	2	2.6. Type of evaluation	E	2.7 Type of discipline	Compulsory

## 3. Total estimated time (hours/semester of didactic activities)

3.1 Hours per week	4	Of which: 3.2 course	2	3.3 laboratory	2
3.4 Total hours in the curriculum	56	Of which: 3.5 course	28	3.6 laboratory	28
Time allotment:					hours
Learning using manual, course support, bibliography, course notes					25
Additional documentation (in libraries, on electronic platforms, field documentation)					18
Preparation for seminars/labs, homework, papers, portfolios and essays					20
Tutorship					3
Evaluations					3
Other activities:					-
3.7 Total individual study hours	69				
3.8 Total hours per semester	125				
3.9 Number of ECTS credits	5				

## 4. Prerequisites (if necessary)

4.1. curriculum	<ul style="list-style-type: none"> <li>Basic Process control, Basic Chemical Engineering.</li> </ul>
4.2. competencies	<ul style="list-style-type: none"> <li>Basic computer using skills (Matlab).</li> </ul>

## 5. Conditions (if necessary)

5.1. for the course	<ul style="list-style-type: none"> <li>Presence at classes favours the final notation.</li> </ul>
5.2. for the seminar /lab activities	<ul style="list-style-type: none"> <li>Minimum average allowed for entering the examination is 5.</li> <li>All lab hours and seminar are compulsory.</li> </ul>

## 6. Specific competencies acquired

<b>Professional competencies</b>	<ul style="list-style-type: none"> <li>• capacity of conceiving a control system dedicated to a specific process, capacity of conceiving and writing a mathematical model of high complexity dedicated to a certain specific process, capacity of choosing an appropriate control solution based on the analysis of the process model, economic analysis of efficiency of the chosen control solution, capacity of operating a complex plant</li> </ul>
<b>Transversal competencies</b>	<ul style="list-style-type: none"> <li>• ability of systemic thinking, holistic thinking, critical thinking, argumentative, problem solving orientation, high level of computer skills, analysis of a process based on a mathematical model.</li> </ul>

## 7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	<ul style="list-style-type: none"> <li>• To make the student understand the behaviour of a complex process based on a mathematical model and to implement a control scheme</li> </ul>
7.2 Specific objective of the discipline	<ul style="list-style-type: none"> <li>• To develop a control system adequate to a specific process</li> </ul>

## 8. Content

8.1 Course	Teaching methods	Remarks
<b>8.1.1. Cascade control. Feedforward control. Examples.</b> <i>Basic concepts, key words:</i> controllability, cascade, disturbance, parameters' tuning, energy consumption saving.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
<b>8.1.2. Feedforward control, Ratio control , Inferential control. Examples.</b> <i>Basic concepts, key words:</i> Feedforward, ratio, inferential control, economic justification.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
<b>8.1.3. Automatic control of the main process parameters. Examples.</b> <i>Basic concepts, key words:</i> temperature control, pressure control, level control, flow control, concentration control.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
<b>8.1.4. Chemical reactors' control. Types of reactors. Thermal instability of the reactors. Temperature control for the thermally unstable and stable reactors. Examples.</b> <i>Basic concepts, key words:</i> reaction kinetics, reaction rate, conversion, equilibria, enthalpy, thermal instability, Continuous Stirred Tank Reactor, Plug Flow Reactor, Mass Transfer Reactor, Electrochemical Reactor.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
<b>8.1.5. Chemical reactors' control.</b> <i>Basic concepts, key words:</i> steady state mathematical model, continuous /batch stirred tank reactors, plug flow reactors, mass transfer reactors, electrochemical reactors, microreactors, control design scheme.	Lecture Computer simulations Power point presentations Interactive exercises	PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.
<b>8.1.6. pH control. Control of the distillation/rectification processes. Control of the</b>	Lecture Computer simulations	PowerPoint presentations, Matlab

<p><b>distillation/rectification processes.</b>  <i>Basic concepts, key words:</i> pH, instability. Economic considerations of the distillation processes, high value product recovery, material and energy balances, continuous/batch distillation.</p>	<p>Power point presentations  Interactive exercises</p>	<p>and Toolboxes for exemplification and applications.</p>
<p><b>8.1.7. Control of the distillation/rectification absorption/ desorption processes. Control of extraction processes.</b>  <i>Basic concepts, key words:</i> : Material and energy balances, control schemes. Absorption/ desorption, mathematical model, exothermal processes, liquid- liquid extraction, solid-liquid extraction, separation interface.</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>
<p><b>8.1.8. Control of the drying process.</b>  <i>Basic concepts, key words:</i> relative and absolute humidity, psychometric method, adiabatic drying.</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>
<p><b>8.1.9. Control of bioprocesses.</b>  <i>Basic concepts, key words:</i> biochemical reactors, biomass, drying at low temperatures, mathematical model, sensitivity, control schemes.</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>
<p><b>8.1.10. Control of the thermally integrated processes.</b>  <i>Basic concepts, key words:</i> controllability, instability, thermally integrated systems dynamics, economic analysis.</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>
<p><b>8.1.11. Linear Model Predictive Control (MPC); optimisation with constraints. MPC Tuning.</b>  <i>Basic concepts, key words:</i> models, objective function, constraints, linear programming, quadratic programming, explicit solution, weighting matrices.</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>
<p><b>8.1.12. Nonlinear Model Predictive Control (MPC); optimisation with constraints, stability, adaptive MPC, hierarchical MPC, linearization.</b>  <i>Basic concepts, key words:</i> continuous/discrete models, linearization, sequential and simultaneous nonlinear programming methods, end-point (terminal) terms (constraints).</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>
<p><b>8.1.13. Control systems implementing fuzzy-logic.</b>  <i>Basic concepts, key words:</i> fuzzy sets, membership functions, fuzzy rules, fuzzification, inference, defuzzification, control.</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>
<p><b>8.1.14. Control systems based on Artificial Neural Networks (ANNs).</b>  <i>Basic concepts, key words:</i> dynamic models built with ANNs, MPC using ANN models.</p>	<p>Lecture  Computer simulations  Power point presentations  Interactive exercises</p>	<p>PowerPoint presentations, Matlab and Toolboxes for exemplification and applications.</p>

## Bibliography

1. Paul Şerban Agachi, Mircea Vasile Cristea, Alexandra Ana Csavdári, Botond Szilágyi, Advanced Process Engineering Control, De Gruyter Publishing House, Editura De Gruyter GmbH, Berlin, 2016,
2. Agachi P.S., Cristea M.V, Basic Process Engineering Control, Editura De Gruyter GmbH, Berlin, ISBN:

978-3-11-028981-7, e-ISBN: 978-3-11-028982-4, 360 p., 2014,

3. V. M. Cristea, S. P. Agachi, *Elemente de Teoria Sistemelor*, Editura Risoprint, Cluj-Napoca, 2002,

4. P.S. Agachi, Z.K. Nagy, M.V. Cristea, A. Imre-Lucaci – *Model Based Control, Case studies in process engineering*, Ed. Wiley-VCH, Weinheim, 2006.

#### Supplementary Bibliography

5. F. Greg Shinskey - *Process Control Systems Application, Design and Tuning*, Ed. Mc.Graw Hill, New York, 1996,

6. Paul Serban Agachi – *Automatizarea Proceselor Chimice*, Ed. Casa Cărții de Știință, Cluj-Napoca, 1994,

7. P. Serfelis, M.C. Georgiadis, *The Integration of Process Design and Control*, Elsevier, 2004.

Note: titles can be accessed at the Library of the Department of Chemical Engineering of the Faculty of Chemistry and Chemical Engineering, at the Central University Library “Lucian Blaga” and at the Library of the Technical University of Cluj

8.2 Seminar / laboratory	Teaching methods	Remarks
<b>8.2.1. Cascade control. Design.</b> <i>Basic concepts, key words:</i> temperature cascade control, flow ratio control, parameters tuning.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.2. Ratio control. Design.</b> <i>Basic concepts, key words:</i> temperature cascade control, flow ratio control, parameters tuning.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.3. Feed forward of a CSTR. Design.</b> <i>Basic concepts, key words:</i> disturbance, disturbance transducer, disturbance controller, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.4. Feedback and feedforward of a CSTR. Design.</b> <i>Basic concepts, key words:</i> disturbance, disturbance transducer, disturbance controller, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.5. Feedforward control of a distillation column. Control of a binary distillation column.</b> <i>Basic concepts, key words:</i> heat transfer, mass transfer, impulse transfer, feed disturbance, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.6. Control of the bio-reactor.</b> <i>Basic concepts, key words:</i> bioreactor, mass of reaction, bio-mass, reaction kinetics, analysers, control structures.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.7. Control of the Waste Water Treatment Plant WWTP (I).</b> <i>Basic concepts, key words:</i> modelling nitrification and denitrification bioreactors, bioreaction kinetics, control structures.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.8. Control of the Waste Water Treatment Plant WWTP (II).</b> <i>Basic concepts, key words:</i> control of the settler (secondary and primary), aeration control strategies, control for minimizing energy costs and maximizing effluent quality.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.9. Developing application for MPC with and without constraints,</b> using both CETM and command prompt. Simulink implementation. Tuning SISO and	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving

MIMO MPC. <i>Basic concepts, key words:</i> nonlinear process, Simulink MPC block, tuning, stability, command prompt developed MPC.		the homework.
<b>8.2.10. MPC Control of the Fluid Catalytic Cracking Unit (I)</b> <i>Basic concepts, key words:</i> heat transfer, mass transfer, impulse transfer, feed disturbance, stability.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.11. MPC Control of the Fluid Catalytic Cracking Unit (II)</b> <i>Basic concepts, key words:</i> Control of the riser, stripping vessel, regenerator, air blower, wet-gas compressor, main fractionator.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.12. Application and implementation demonstration of a Fuzzy Controller, using Fuzzy Logic Toolbox.</b> <i>Basic concepts, key words:</i> fuzzy sets, membership functions, fuzzy rules, fuzzification, inference, defuzzification, control.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.13. Application and implementation demonstration of MPC using ANN models (I).</b> <i>Basic concepts, key words:</i> training, dynamic ANN, nonlinear model.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.
<b>8.2.14. Application and implementation demonstration of MPC using ANN models (II).</b> <i>Basic concepts, key words:</i> FCCU application, drying electric insulators.	Practical laboratory Seminar Interactive discussions	Student's obligations: course and bibliography (selective) study, solving the homework.

#### Bibliography

1. Paul Şerban Agachi, Mircea Vasile Cristea, Alexandra Ana Csavdári, Botond Szilágyi, Advanced Process Engineering Control, De Gruyter Publishing House, Editura De Gruyter GmbH, Berlin, 2016,
2. G. Stephanopoulos, Chemical Process Control An Introduction to Theory and Practice, Prentice Hall, 1984,
3. Mihaela Iancu, P.Ş.Agachi, M.Mogoş, M.Cristea, Automatizarea Proceselor Chimice – Lucrări de Laborator, Presa Universitară Clujeană, UBB, 2012.

#### Supplementary Bibliography

4. *Control System Toolbox*, Matlab, Documentation accompanying toolbox,
5. *Model Predictive Control Toolbox*, Matlab, Documentation accompanying toolbox,
6. *Fuzzy Logic Toolbox*, Matlab, Documentation accompanying toolbox,
7. Paul Serban Agachi – Automatizarea Proceselor Chimice, Ed. Casa Cărţii de Ştiinţă, 1994.

### 9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

- Curriculum was elaborated after consultancy with the PC groups from the universities in Iasi, Bucuresti, Ploieşti and Timişoara
- Process Engineering was introduced based on a WB program of Computer Aided Process Engineering (1998-2002)

### 10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the
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			grade (%)
10.4 Course	Understanding of the processes discussed Specificity of the answers Holistic thinking and approach	Written examination	75
10.5 Seminar/lab activities	Understanding of the processes discussed Specificity of the answers Holistic thinking and approach	Practical examination at the site	15
	Capacity of using different sources of information	Practical examination at the site	10
10.6 Minimum performance standards			
<ul style="list-style-type: none"> <li>• 5 is the minimum average accepted for both types of examination</li> </ul>			

Date

Signature of course coordinator

Signature of seminar coordinator

16.02.2018

Cristea V.M.

Cristea V.M.

Date of approval

Signature of the Director of the Department

26. 02. 2018