SUMMARY REPORT

TEACHING OF UNDERGRADUATE PROCESS DYNAMICS AND CONTROL

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INTRODUCTION

The appended questionnaire was sent in May, 1975 to the Chairman of each Chemical Engineering Department in the United States and Canada, together with a cover letter asking that the appropriate faculty member complete and return the questionnaire. A follow-up letter was sent in August to those schools (about 100) which had not responded by that time. Of the 155 universities contacted, 101 questionnaires were returned. This compares with seventy-one responses to the 1972 mini-session (Mass and Energy Balances), fifty-nine replies to the 1973 mini-session (Thermodynamics), and ninety replies to the 1974 mini-session (Reaction Kinetics).

TEXTBOOK SELECTION

Textbooks were named for 104 courses at the 101 universities surveyed. The book by Coughanowr and Koppel was used in 51.9% of the courses. W. Luyben's book was used in 12.5% of the courses. The texts by Weber and by Harriott were each used in 7.7% of the courses. Collectively, these four books are used in 80% of the process control courses. No other book was used in more than four courses. A complete list of texts mentioned in the questionnaires follows:

Andrew, W.G., "Applied Instrumentation in the Chemical Process Industry", 3 vols., Gulf Publishing Co., 1973.

Coughanowr, D.R. and Koppel, L.B., "Process Systems Analysis and Control", McGraw-Hill, 1963.

Douglas, J.M., "Process Dynamics and Control", 2 vols., Prentice-Hall, 1973.

Eckman, D.P., "Industrial Instrumentation", Wiley, 1950.

Harriott, P., "Process Control", McGraw-Hill, 1964.

Johnson, E.F., "Automatic Process Control", McGraw-Hill, 1967.

Luyben, W.L., "Process Modeling, Simulation and Control for Chemical Engineers", McGraw-Hill, 1973.

Ogata, K., "Modern Control Engineering", Prentice-Hall, 1970.

Perlmutter, D.D., "Introduction to Chemical Process Control", Wiley, 1965.

Raven, F.H., "Automatic Control Engineering", 2nd ed., McGraw-Hill, 1968.

Shilling, G.D., "Process Dynamics and Control", Holt, Rinehart & Winston, 1963.

TEXTBOOK SELECTION (Cont'd)

Shinskey, F.G., "Process Control Systems", McGraw-Hill, 1967.

Smith, C.L., "Digital Computer Process Control", Intext, 1972.

Spiegel, M.R., "Laplace Transforms", (Schaum's Outline Series), McGraw-Hill, 1965.

Tyner, M. and May, F.P., "Process Engineering Control", Ronald, 1968.

Weber, T.W., "Introduction to Process Dynamics and Control", Wiley, 1973.

NUMBER AND LEVEL OF COURSES

Seventy-two percent of the universities surveyed offer a single course in undergraduate process control. Twenty-six percent offer two courses and six percent offer no course. In a few instances, a university offered a separate laboratory course in the same semester as the lecture course. This situation was counted as one course having both laboratory and lecture hours.

About 1/3 of the courses are offered more than once during the academic year. Some are open to juniors as well as seniors. Considering all the opportunities for taking the courses, nine percent of the courses are open to juniors only, nine percent are open to juniors and seniors, and eighty-two percent are open only to seniors.

LECTURE AND LABORATORY PERIODS

The average weekly lecture time per course is 2.94 hours. Seventy-three percent of the courses have three hours per week lecture, while seventeen percent have two hours and ten percent have four hours. Exactly fifty percent of the courses have no scheduled laboratory period, although many of these indicated that one or more process control experiments are performed in the unit operations laboratory. The other schools spent an average of 2.70 hours per week on the laboratory portion of the course.

COURSE CONTENT

Seventy-eight percent of the courses place strong emphasis on analytical techniques of mathematical modeling while only thirty-three percent stress the empirical aspects of modeling. Eighty-eight percent emphasize control and twenty-seven percent stress instrumentation. Eight percent deal with other areas, particularly analog and digital simulation. Comments on the textbooks indicate an increasing interest in digital simulation and direct digital process control and less emphasis on analog computer methods. The need for practical applications of process control was also frequently cited.

About 1/3 of the courses use classroom demonstrations and audio-visual aids to reinforce class lectures. Three-fourths of the courses rely on laboratory work to complement classroom lectures.

LABORATORY CONTENT

The table below lists the percentage of universities offering no laboratory work in the designated area, and the average number of hours per semester or quarter devoted to experiments by the remaining universities. Laboratory work may be in the process control laboratory course or in another laboratory, such as unit operations or process design.

Experimental Area	No Work	Hr/Semester
Instrumentation based hardware	43	6.9
Process based hardware	39	8.7
Digital computer simulation	56	6.2
Analog computer simulation	42	8.1
Other areas	89	4.5

STUDENT REACTION

The following representative replies, each quoted in its entirety, were given by the instructors to the question, "What is the typical student's reaction upon completing the course?"

"I believe most feel that the coverage is worthwhile to them. This course is necessarily more mathematically oriented, especially from the differential equations' standpoint, than others, and this causes trouble. The students have rarely been forced to use their differential equations background for anything until they encounter this course, and some students are turned off by having to dredge up knowledge from past courses for use in this one. Most of the students who are at least moderately conscientious, though, feel the course is good for them"

"50% think it's great, relevant, etc.; 25% think it's a waste of time."

"Let down. They expect some magic show."

"The typical reaction is unethusiastic, but without any antagonism. The course material does not correlate well with the student's experience, and many are not persuaded that it will be of much use. There is also a fairly frequent complaint over the volume of material included. In every class, however, there are the few students who are "turned on" by the course."

"It is one of the most enjoyed courses in the curriculum. Students enjoy practical courses."

"Relief from the "mathematics" of dynamic systems and the design techniques."

"Too much material covered. They would like to have it spread out into two semesters."

"The course is poorly received--too mathematical and too little relation to the real world."

"The course is too mathematical. They have difficulty relating the theory to practice."

"Frustration, since they are only starting to grasp the material."

"Students enjoy this course."

STUDENT REACTION (Cont'd)

"Enjoy 'practical' part of course, no theory."

"Everything seems foggy or hazy."

"It was difficult. Co-op students with industrial experience seem to more appreciate the significance of control and process dynamics. First (or nearly so) application of differential equations, especially Laplace transforms (!) (so they say)."

"The key reaction so far is that they don't get the 'big picture' until about 2/3 of the way through the course."

"Most students are enthusiastic about the field and seek employment related to process control."

"Aside from general relief, they seem to feel that I have been a bit too theoretical in approaching the subject."

"About 20% of them develop an enthusiastic interest; about 50% of them are just glad it's over; the others feel they have gotten something but lack confidence."

"Not enough time. Concepts are lost in obtaining a mathematical solution."

"Hope I never need to use that."

"The fact that this is a last quarter senior course influences the student's outlook. In general, students' opinions run to the effect: 'I didn't like this course as much as kinetics. I find the course does not interest me as much as some or most of the other chemical engineering courses'."

QUESTIONNAIRE ON TEACHING OF

UNDERGRADUATE PROCESS DYNAMICS AND CONTROL

1. Identification

Instructor ____________________ University ____________________

8. Course Title(s) Class Hr/Week Lab Hr/Week

1. ____________________ __________ __________

2. ____________________ __________ __________

9. Level of Course

Course 1 (Circle 2): Jr/Sr 1st/2nd Semester 1st/2nd/3rd Quarter

Course 2 (Circle 2): Jr/Sr 1st/2nd Semester 1st/2nd/3rd Quarter

10. Text(s) and Resources (Author/Title)

Course 1 ____

Course 2 ____

11. Students

Class Size: Course 1 __________ Course 2 __________

Major (Che,ME): Course 1 __________ Course 2 __________

12. How long is your quarter or semester?

__________ weeks per semester/quarter (circle 1)

13. Is there a need for a better textbook in Process Dynamics and Control? In what areas can the text you now use be improved?

14. Please attach a copy of your course outline.

15. _____ I (do, do not) plan to attend the L.A. meeting.

1. Area(s) of primary instructional emphasis (circle answers)

A. Mathematical modeling-analytical
B. Mathematical modeling-empirical
C. Control
D. Instrumentation
E. Others (please specify)

2. Do you reinforce class lectures with any of the following (circle answer)?

A. Classroom demonstrations
B. Audio-visual aids
C. Laboratory experiments
D. None of the above
E. Others (please specify)

3. For the areas of question 2, are any of the following used (circle answers)? Please indicate approximate class hours per semester.

A. Hardware type experiments

1. Instrumentation based ________ hrs
2. Process based ________ hrs

B. Digital computer simulation ________ hrs
C. Analog computer simulation ________ hrs
D. Others (please specify) ________ hrs

4. Which concept(s) in this course area is most difficult for your students to grasp?

5. Are concepts and/or material covered in process dynamics and control used directly in any other undergraduate courses? If so, where?

6. Based on your experience in teaching this course, what is the typical student's reaction upon completing the course?

7. Please list about three to five principal objectives of the course as you teach it.

UNIVERSITY OF AKRON

I: "Process Dynamics and Control" (Sr, Qtr 2) 3/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Change from steady state to unsteady state; reason for offset in a proportional system.
ALT. COVERAGE
None.
OBJECTIVES
a. Response of systems to changes. b. Selection of control settings for simple systems. c. Communication and further study in control.
TEXT
Needs descriptions of various control elements, such as control valves, sensors, etc.

UNIVERSITY OF ALABAMA

I: "Process Dynamics & Control" (Sr, Sem 1) 3/0
TX: Coughanowr & Koppel; Spiegel: "Laplace Transforms"
II: "Digital Control in the Chemical Process Industry" (Sr, Sem 2) 3/0
TX: Coughanowr & Koppel; Smith, "Digital Computer Process Control"

DIFFICULT CONCEPTS
Translate problem into mathematical language and apply correct solution techniques; specific areas are differential equation usage; relationships between open and closed loops; and translation of physical system into block diagram form.
ALT. COVERAGE
None
OBJECTIVES
a. Present unsteady state operation. b. Process modeling using empirical and analytical approach. c. Present feedback, feed forward and cascade control schemes. d. Modern methods of controller timing. e. Introduce computer control of processes.
TEXT
Coverage of Laplace transforms is sketchy. Better problems are needed. Coverage of digital control should be included.

UNIVERSITY OF ALBERTA

I: "Process Dynamics" (Sr, Sem 1) 3/2
TX: Luyben
II: "Computer Applications in Process Control" (Sr, Sem 2) 3/2
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Relating experimental data to theoretical formulations.
ALT. COVERAGE
Senior design course.
OBJECTIVES
a. Formulation of unsteady state mass and energy balances. b. Establishment of dynamic models from experimental testing of a system. c. Use of analog computer for solving differential equations and for transfer functions. d. Use of digital simulation for the above objective.

ARIZONA STATE UNIVERSITY

I: "Chemical Process Control" (Sr, Sem 1) 2/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Break physical system into smaller systems, model each one, and put back together as a mathematical system.
ALT. COVERAGE
None
OBJECTIVES
a. Modeling of physical systems. b. Convey analogies between systems. d. Achieve good background in students, but not becoming experts.
TEXT
Include both continuous and discrete control; also instrumentation.

UNIVERSITY OF ARIZONA

I: "Industrial Process Control" (Sr, Sem 1) 3/0
TX: Shimskey "Process Control Systems"

ALT. COVERAGE
In "Real Time Computing in the Process Industries", students write programs for DDC and SSP of an alcohol process.
OBJECTIVES
a. Rationale of control and its applications. b. Understanding of feedback vs. feed forward vs. cascade control. c. Understanding of stability and linear control theory. d. Apply techniques to actual problems.
TEXT
Better integration of concepts is needed.

UNIVERSITY OF ARKANSAS

I: "Process Control" (Sr, Sem 1)
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Transient behavior.
ALT. COVERAGE
Plant design course.
OBJECTIVES
a. Cover transient behavior. b. Mathematical modeling - reduction of processes to mathematical functions. c. Control systems - theory/application/operation.

BRIGHAM YOUNG UNIVERSITY

(No formal course in process control)

UNIVERSITY OF BRITISH COLUMBIA

I: " " (Jr, Sem 1) 2/4
TX: Coughanowr & Koppel
II: " " (Sr, Sem 1&2) 2/2
TX: Luyben: "Process Modeling, Simulation & Control"

DIFFICULT CONCEPTS
Loop response characteristics; loop interaction; digital loop closure.
ALT. COVERAGE
Reactor design, major design project.
OBJECTIVES
a. Understanding linear loop transfer functions. b. Understanding basic controller actions. c. Stability determinations. d. Loop responses. e. Process modeling by response techniques. f. Advanced control loops. g. Digital control and stability.

BUCKNELL UNIVERSITY

I: "Process Control" (Sr, Sem 2) 3/3
TX: Coughanowr & Koppel

DIFFICULT CONEPTS
Application of sophisticated mathematics to real situations.
ALT. COVERAGE
None
OBJECTIVES
a. Comprehension of dynamics - time dependence of stable and unstable systems. b. Limitations of control analysis. c. Modest facility with requisite mathematics - Laplace transforms, root locus, Bode plots, time dependence of process.
TEXT
Practical applications are needed - "how it is really done."

UNIVERSITY OF CALGARY

I: "Process Dynamics & Control" (Sr, Sem 2) 3.1.5
TX: Luyben: "Process Modeling Simulation and Control"

DIFFICULT CONCEPTS
Modeling - nature of and need for process models.
ALT. COVERAGE
Modeling is taught in an applied math course.
OBJECTIVES
a. Present characteristics of process control loops, including stability. b. Expose students to process instruments in the laboratory. c. Introduce major analytical techniques. d. Demonstrate the value of mathematical models in predicting transient behavior of chemical processes.
TEXT
Does not cover "modern" control theory or keep up with changing instrumentation technology.

UNIVERSITY OF CALIFORNIA - BERKELEY

I: "Dynamics & Control of Chemical Processes" (Sr, Qtr 1) 3/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Concepts in themselves are not difficult; application of already learned concepts is a severe difficulty. Translation of problem into mathematics is the difficulty.
ALT. COVERAGE
None
OBJECTIVES
a. Learn about cause-effect relationships in dynamic processes. b. Develop ability to formulate elementary models of such processes. c. Apply elementary concepts of feedback control. d. Techniques of dynamic measurements. e. Obtain experience in making control systems work on physical processes.
TEXT
Improvement in process dynamics and chemical process control.

UNIVERSITY OF CALIFORNIA - DAVIS

I: "Process Dynamics and Control" (Sr, Qtr 1) 3/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Theory behind Nyquist Stability Criterion.
ALT. COVERAGE
Broadly, in other courses.
OBJECTIVES
a. Master mathematics of linear systems. b. Master frequency response methods. c. Learn rough controller design rules. d. Learn rudiments of DDC and sampled data systems.
TEXT
Good outline but lacks rigor and depth.

UNIVERSITY OF CALIFORNIA (LOS ANGELES)

I: "Introduction to Process Dynamics" (Sr, 2nd Qtr) 4/0
TX: Johnson: "Automatic Process Control"; Luyben: "Process Modeling, Simulation & Control"

DIFFICULT CONCEPTS
Limitations of a simplified physical model; stability.

ALT. COVERAGE
None
OBJECTIVES
a. Provide experience in modeling physical and chemical systems. [illegible]s is considered more important [illegible]n the control theory itself. [illegible] Develop mathematical skills in handling large-scale problems.

UNIVERSITY OF CALIFORNIA-SANTA BARBARA

I: "Chemical Process Dynamics & Control I" (Sr, Qtr 2) 2/3
TX: Coughanowr & Koppel
II: "Chemical Process Dynamics & Control II" (Sr, Qtr 3) 2/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Unsteady state modeling (differential equations); complex variables.
ALT. COVERAGE
Modeling and digital simulation techniques in Reactor Design course.
OBJECTIVES
a. Application of unsteady state equations (mass, energy, momentum) to chemical systems to derive models for system behavior. b. Techniques for obtaining approximate solutions to transient problems.
TEXT
Lacks up-to-date information on instrumentation, material on digital simulation instead of analog; sufficient information on process modeling; and introductory material on digital computer control.

CALIFORNIA POLYTECHNIC UNIVERSITY

[illegible] "Chemical Process Optimization and Control" (Sr, Sem 1) 3/3
TX: Luyben

DIFFICULT CONCEPTS
Relating material learned in lectures to the laboratory.
ALT. COVERAGE
Unit operations course and plant design course.
OBJECTIVES
a. General concepts of basic control theory. b. Use of Laplace transforms. c. Optimization techniques such as linear and dynamic programming.

CASE WESTERN RESERVE UNIVERSITY

I: "Control Engineering" (Jr & Sr, Sem 2) 3/2
TX: Raven: "Automatic Control Engineering"

DIFFICULT CONCEPTS
Relationship of modeling process to physical devices, probably due to lack of "hands on" experience.
ALT. COVERAGE
None
OBJECTIVES
a. Convey that mathematical models are representations of reality and can describe very different phenomena.
b. Design techniques based on these models are "mechanical" since the performance specifications are made.
c. Design is a recursive process requiring updating of objectives.
d. To achieve good understanding of the basic design techniques.
[illegible]T
[illegible]resentation of basic techniques [illegible]ould be crisper, less ambiguous and [illegible]ch shorter.

CATHOLIC UNIVERSITY OF AMERICA

I: "Process Instrumentation and Control" (Sr, Sem 2) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Stability.
ALT. COVERAGE
ChE laboratory, one experiment deals with control.
OBJECTIVES
Understand principles of a. Transfer functions. b. The three modes of control. c. Feedback, feed forward and open loops. d. Stability of control systems.

UNIVERSITY OF CINCINNATI

I: "Process Dynamics & Control" (Jr, Qtr 3) 4/0
TX: Coughanowr & Koppel
II: "Chemical Engineering Laboratory V" (Sr, Qtr 1) 0/4

DIFFICULT CONCEPTS
Stability

CLARKSON COLLEGE OF TECHNOLOGY

I: "Systems Analysis I" (Sr, Sem 1) 3/0
TX: " "
II: "Systems Analysis II" (Sr, Sem 2) 3/0
TX: " "

CLEMSON UNIVERSITY

I: "Process Dynamics" (Sr, Sem 2) 3/0
TX: Coughanowr & Koppel

ALT. COVERAGE
None
OBJECTIVES
a. Develop an understanding of and a feeling for the concept of unsteady state. b. Acquire a basic knowledge of process control and its application to the process industries. c. To be able to work with simple optimization routines to solve problems.

CLEVELAND STATE UNIVERSITY

I: "Automatic Process Control" (Sr, Qtr 2) 4/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Significance of frequency response and Bode analysis.
ALT. COVERAGE
None
OBJECTIVES
a. Introduce dynamic analysis.
b. Introduce process control equipment and its operation. c. Give restrictions of linear analysis.
TEXT
Needs greater emphasis on non-linear systems.

UNIVERSITY OF COLORADO

I: "Instrumentation & Process Control" (Sr, Sem 2) 3/2
TX: Luyben; Andrew: "Applied Instrumentation in the Process Industries"
II: "Process Dynamics" (Sr, Sem 1) 3/0
TX: Notes

DIFFICULT CONCEPTS
Frequency response, especially root locus and Nichols plots.
ALT. COVERAGE
None.

OBJECTIVES
a. Principles of operation of process instruments. b. Process control strategy. c. Installation, calibration and tuning control systems.
TEXT
Better integration of hardware-oriented material and control theory.

COLORADO SCHOOL OF MINES

DIFFICULT CONCEPTS
Application of frequency response analysis to real (physical) control problems.
ALT. COVERAGE
Use of analog computers is covered in reaction kinetics course.
OBJECTIVES
a. Concept of stability. b. Mathematical modeling of control systems. c. Digital simulation of control systems. d. Analog simulation of control systems.

CORNELL UNIVERSITY

I: "Process Control" (Sr, Sem 2) 2/2 1/2
TX: Barriott: "Process Control" (Req'd); Weber: "Process Dynamics & Control" (Recommended)

DIFFICULT CONCEPTS
Dynamic state; mechanics of closed loop frequency response.
ALT. COVERAGE
Design course and in kinetics-reactor design.
OBJECTIVES
a. To orient thinking to unsteady state, rather than steady state design. b. To predict effects on product quality due to variations in operating input. c. To develop proficiency in suggesting workable and economic control schemes.
TEXT
Needs strong emphasis on process dynamics and modeling; section on basic control schemes and methods of analysis; section on process control design synthesis.

UNIVERSITY OF DENVER

(School of Engineering closed June 30, 1975)

DREXEL UNIVERSITY

I: "Process Systems Engineering" (Jr & Sr, Qtr 1&2) 3/2
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Differences between open-loop and closed-loop processes as related to frequency response.
ALT. COVERAGE
Plant design; Kinetics and Reactor Design, Chem. Engrg. Laboratory.
OBJECTIVES
a. Provide basic knowledge of dynamics and control. b. Show industrial applications. c. Expose to computer simulation and control hardware. d. Review and integrate previous courses in mathematics, chemistry, physics and engineering.

UNIVERSITY OF FLORIDA

I: "Process Systems Analysis" (Jr, Qtr 2) 2/3
TX: Tyner & May: "Process Engineering Control"
II: "Process Control Theory" (Jr, Qtr 3) 3/3
TX: Tyner & May: "Process Engineering Control"

DIFFICULT CONCEPTS
Frequency response & root locus, both because of poor training in complex numbers.
ALT. COVERAGE
None.
OBJECTIVES
a. Mathematical modeling. b. Linearization and Laplace transforms. c. Instrumentation hardware and its design characteristics. d. Functions of feedback controllers. e. Multivariable control, feed forward control and cascade control.
TEXT
Well satisfied with text.

UNIVERSITY OF LOUISVILLE

I: "Process Control" (Sr, Sem 1) 3/3
TX: Harriott: "Process Control"

DIFFICULT CONCEPTS
Stability; determining gains of each part of loop; setting up process block diagrams.
ALT. COVERAGE
Some in senior design course.
OBJECTIVES
a. Understand the response of a basic element or system, a controller, and the combined system. b. Setting up the block diagram for the entire system. c. Indication of the process' stability.
TEXT
Improvement needed in treatment of response of controllers (open loop), formulation of system block diagrams, and determining process gains.

LOWELL UNIVERSITY

I: "Process Dynamics & Control"
(Sr, Sem 1) 3/0
TX: Coughanowr & Koppel
II: "Process Control Laboratory"
(Sr, Sem 2) 1/3
TX: None

DIFFICULT CONCEPTS
Mathematical modeling and, in general, the math involved.
ALT. COVERAGE
None.
OBJECTIVES
a. Model building and simulation. b. Relation of model to real processes. c. Need for unsteady state considerations. d. Unifying aspects of a control course.
TEXT
Could use more problems.

UNIVERSITY OF MAINE-ORONO

I: "Introduction to Process Dynamics & Control" (Sr, Sem 1) 3/0
TX: Luyben

DIFFICULT CONCEPTS
Transition from words and flow chart to block diagram and transfer function; significance of the frequency response of a system.
ALT. COVERAGE
Plant design, Laboratory, Process Simulation.
OBJECTIVES
a. Controller tuning methods. b. Methods of obtaining transfer functions. c. Root locus and Bode methods. d. Hardware selection. e. Characteristics of non-linear processes.
TEXT
Needs more full-sized charts, chapter on hardware, graphical methods for getting transfer function approximations.

UNIVERSITY OF MASSACHUSETTS

I: "Process Dynamics & Control"
(Sr, Sem 2) 3/3
TX: Harriott: "Process Control"

DIFFICULT CONCEPTS
Meaning of frequency response; connection between dynamics and control; mathematics required for analysis.
ALT. COVERAGE
None.
OBJECTIVES
a. Integrate dynamics and control. b. Integrate lecture material with laboratory. c. Discuss application of control to process systems (i.e., real world approach).
TEXT
Needs clearer presentation.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

I: "Dynamics and Control"
(Sr, Sem 2) 3/0
TX: Douglas, J.M.: "Process Dynamics & Control", Vol. 2

DIFFICULT CONCEPTS
Mathematical operations; ultimate gain and stability in closed feedback loop; sensitivity of design.
ALT. COVERAGE
None.
OBJECTIVES
a. A new perspective on unit operations. b. Use of mathematics as a tool for solving problems. c. Use of models and ideal systems and fudge factors to describe real systems. d. Give students a feel for various control modes.

MC GILL UNIVERSITY

I: "Chemical Process Control"
(Sr, Sem 2) 3/1
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Overall process analysis; disturbance and control inputs; multiple outputs.
ALT. COVERAGE
None.
OBJECTIVES
a. Relationship between process analysis and the operability of the process. b. Tuning of controllers. c. Conventional instrumentation and a live process. d. Computer control.
TOPICS NOT COVERED
a. Routh's criterion. b. Root locus. c. Sampled data theory. d. Frequency response.
TEXT
Too much emphasis on technique and not enough on integrated problem solving or design.

UNIVERSITY OF MICHIGAN

I: "Engineering Operations Laboratory"
(Sr, Sem 1&2) 0/5
TX: Notes
II: "Process Control in Chemical Industry" (Sr, Sem 2) 3/0
TX: Harriott: "Process Control"

ALT. COVERAGE
Plant design.
OBJECTIVES
a. Testing of models and concepts taught in rate and separations courses. b. Experience with larger than bench-scale equipment.

MICHIGAN STATE UNIVERSITY

I: "Process Dynamics & Control"
(Sr, Qtr 2) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Frequency response.
ALT. COVERAGE
None.
OBJECTIVES
a. Motivate a need for control and dynamics. b. Dynamics of simple processes. c. Methods of control analysis. d. Simple single loop designs.

MICHIGAN TECH UNIVERSITY

I: "Process Dynamics & Control"
(Sr, Qtr 1) 6/0
TX: Coughanowr & Koppel
II: "Process Control Laboratory"
(Sr, Qtr 2&3) 2/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Unsteady state mass and energy balances.
ALT. COVERAGE
None.
OBJECTIVES
a. Formulate equations for open and closed loop processing systems. b. Use transform techniques to solve these equations. c. Know various modes of operation of process controllers. d. Root locus plots for a given processing scheme.
TEXT
Needs more industrial process examples. Case studies would be helpful.

UNIVERSITY OF MISSISSIPPI

I: "Process Dynamics & Control"
(Sr, Sem 2) 3/0.5
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Frequency response; relating text material to real operating plants.
ALT. COVERAGE
None.
OBJECTIVES
a. Derive a simple linear model and be able to use it to predict dynamic response. b. Importance of feedback control. c. Tuning multimode controllers. d. Use of frequency response in identification and controller design. e. Feed forward control, cascade control, dead time compensation.
TEXT
More detailed example problems; more material on plant control schemes.

UNIVERSITY OF MISSOURI-COLUMBIA

I: "Chemical Engineering Process Dynamics & Control" (Sr, Sem 2) 3/0
TX: Weber: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Model development.
ALT. COVERAGE
None.
OBJECTIVES
a. Development of unsteady state model from balance equations. b. Production of unsteady state responses. c. Concept of feedback control. d. Concept of frequency response.
TEXT
Update of Coughanowr & Koppel would be helpful.

DIFFICULT CONCEPTS
There is no steady state; Time and frequency responses are convertible one into the other.
ALT. COVERAGE
Kinetics; Unit Operations.
OBJECTIVES
a. Cause and effect phenomena are everywhere. b. Importance of mathematics to engineers for problem solving. c. Control of the time behavior of a plant.

GEORGIA INSTITUTE OF TECHNOLOGY

I: "Process Control" (Sr, Qtr 2) 3/3
TX: Weber: "Introduction to Process Dynamics and Control"

DIFFICULT CONCEPTS
Linearization; Frequency response; Environmental control; Principle of superposition.
ALT. COVERAGE
Design course; project course.
OBJECTIVES
a. Understanding of unsteady state behavior. b. Non-linearity of chemical processes. c. Language of process control.

UNIVERSITY OF HOUSTON

I: "Chemical Process Control" (Sr, Sem 1&2) 3/1
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Quasi-steady state assumption; effects of interaction among the control loops.
ALT. COVERAGE
Undergraduate laboratory.
OBJECTIVES
a. Process modeling and characterization. b. Control design. c. Analog computation.
TEXT
More needed on special characteristics of chemical processes and less on process analogs of electrical devices.

HOWARD UNIVERSITY

I: "Process Control" (Sr, Sem 2) 2/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Physical significance of transfer functions; Root locus and frequency response.
ALT. COVERAGE
Process Design.
OBJECTIVES
a. Basic concepts of process control. b. Knowledge of available instruments and controllers. c. Dynamic behavior of processes through experimentation and simulation (analog and digital).
TEXT
Needs stronger emphasis on practical aspects and on instrumentation.

UNIVERSITY OF IDAHO

I: "Process Control" (Sr, Sem 2) 2/1
TX: Harriott

DIFFICULT CONCEPTS
Formulation of conceptual and mathematical understanding of the unsteady state process being controlled.
ALT. COVERAGE
OBJECTIVES
a. Mathematical description of unsteady state processes. b. Analytical solution of process control problems. c. Applications and limitations of process control.
TEXT
Contains many errors and omissions. Chapter 1 is unnecessary.

ILLINOIS INSTITUTE OF TECHNOLOGY

I: "Process Control and Dynamics" (Sr, Sem 1) 3/3
TX: Coughanowr & Koppel

ALT. COVERAGE
Plant Design.

UNIVERSITY OF ILLINOIS (CHICAGO CIRCLE)

I: "Introduction to Chemical Process and Energy Conversion Control" (Sr, 3 Qtr) 4/0
TX: Weber: "Introduction to Process Dynamics and Control"

DIFFICULT CONCEPTS
Modeling & Dynamics.
ALT. COVERAGE
None.
OBJECTIVES
a. Become familiar with concepts and terminology. b. Appreciate the power and necessity of control. c. Learn background and practice in tuning controllers. d. Discover that the whole world does not run at steady state.
TEXT
Feature better interface between dynamics and control without too much emphasis on either.

UNIVERSITY OF ILLINOIS (URBANA/CHAMPAIGN

I: "Introduction to Chemical Process Control" (Sr, Sem 1) 2/2
TX: Perlmutter: "Introduction to Chemical Process Control"

DIFFICULT CONCEPTS
Translation of physical process into a mathematical model.
ALT. COVERAGE
None.
OBJECTIVES
a. Design and analysis of simple control loops. b. Modern control and instrumentation hardware. c. Mathematical tools of process control. d. Limitations and utility of various methods for modeling and simulation.
TEXT
Could be more comprehensive.

INDIANA INSTITUTE OF TECHNOLOGY

I: "Process Dynamics" (Sr, Qtr 1) 4/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Linearization of dynamic model.
ALT. COVERAGE
Design courses.
OBJECTIVES
a. Understand dynamics of systems. b. Control stability. c. Control design. d. Application considerations
TEXT
More material on modeling is desirable.

IOWA STATE UNIVERSITY

I: "Process Dynamics and Control" (Sr, Qtr 2) 3/4
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Root locus; frequency response.
ALT. COVERAGE
Process Optimization.
OBJECTIVES
a. Develop a mathematical model for a physical process. b. Become proficient in the use of block diagrams and Laplace transforms. c. Learn principles of controller adjustment.

UNIVERSITY OF IOWA

No separate course in instrumentation and process control is presently being taught.

KANSAS STATE UNIVERSITY

I: "Chemical Process Dynamics and Control" (Sr, Sem 2) 2/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Physical significance of transforms; root locus; Bode plots; Nyquist plots, etc.
ALT. COVERAGE
None.
OBJECTIVES
a. Limitations of modeling dynamic processes. b. Objectives of process control. c. Proficiency with computational methods for control. d. Experience with simple control systems.

UNIVERSITY OF KENTUCKY

I: "Process Control" (Jr, Sem 1) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Root locus and other modeling techniques.
ALT. COVERAGE
None.
OBJECTIVES
a. To emphasize the importance of a dynamic, rather than a steady state, process description for certain aspects of design. b. To emphasize that most processes can be adequately described by a first or second order equation plus a time delay. c. The generality of PID control. c. That this material could be treated by very non-mathematical methods.

LAVAL UNIVERSITY

I: "Regulation des Procedes" (Jr, Sem 1) 3/0
TX: Eckman: "Industrial Process Control"

DIFFICULT CONCEPTS
Complex transfer functions in relation to Nyquist or Bode diagrams.
ALT. COVERAGE
Process design.
OBJECTIVES
a. Operation of measuring instruments. b. Instrument selection. c. Transfer function. d. Control loop interactions.

LEHIGH UNIVERSITY

I: "Mathematical Modeling & Simulation" (Jr, Sem 2) 3/0
TX: Luyben: Process Modeling, Simulation and Control for ChE"
II: "Process Control" (Sr, Sem 1) 2/3
TX: Luyben

DIFFICULT CONCEPTS
Realistic mathematical modeling.
ALT. COVERAGE
Sr. year courses in design, reactor kinetics, distillation.
OBJECTIVES
See Chapter 1 of text.

LOUISIANA STATE UNIVERSITY

I: "Process Dynamics" (Sr, Sem 2) 3/0
TX: Luyben
II: "Analog Simulation" (Jr, Sem 1) 1/1.5
TX: Corripio & Smith: Class Notes

MONTANA STATE UNIVERSITY

I: "Chemical Engineering Design" (Sr, Qtr 2) 2/0
TX: Notes
II: "Design and Instrumentation" (Sr, Qtr 3) 2/0
TX: Notes

FICULT CONCEPTS
Change from time domain to Laplace transform domain.
ALT. COVERAGE
None.
OBJECTIVES
a. Appreciation of unsteady state phenomena. b. Practical, industrial measurement devices. c. Behavior of common controllers.

UNIVERSITY OF NEBRASKA

I: "Automatic Process Control" (Sr, Sem 2) 3/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Closed loop negative feedback stability.
ALT. COVERAGE
None.
OBJECTIVES
a. Concept of the unsteady state neighborhood of an operating point. b. Various methods of characterizing linear dynamics. c. Model formulation. d. Nature of negative feedback and stability.

UNIVERSITY OF NEW BRUNSWICK

I: "Process Dynamics and Control" (Sr, Sem 1) 3/0
TX: Coughanowr & Koppel
II: "Chemical Process Control" (Sr, Sem 2) 3/0
TX: Harriott

FICULT CONCEPTS
Unsteady state concepts.
ALT. COVERAGE
None.
OBJECTIVES
a. Application of mathematical techniques to instruments and processes. b. Develop appreciation for unsteady state, rather than steady state conditions. c. Acquaintance with modern instrumentation.
TEXT
Needs more practical examples, and discussion of digital control.

NEW JERSEY INSTITUTE OF TECHNOLOGY

I: "Process Dynamics & Control" (Sr, Sem 1&2) 2/2
TX: Perlmutter: "Introduction to Chemical Process Control"

DIFFICULT CONCEPTS
Application of control theory to Chemical Engineering Problems.
ALT. COVERAGE
None.
OBJECTIVES
a. Understand basic control theorems.
b. Apply theory to ChE problems.
c. Provide a general understanding of the dynamic behavior of processes and controlled processes.
TEXT
More examples.

NEW MEXICO STATE UNIVERSITY

"Process Analysis" (Sr, Sem 1) 3/0
TX: Coughanowr & Koppel
II: "Process Laboratory" (Sr, Sem 1&2) 0/3

DIFFICULT CONCEPTS
Process Analysis (process dynamics, modeling, etc.)
ALT. COVERAGE
None
OBJECTIVES
a. Analyze simple chemical processes and derive suitable mathematical models. b. Determine controller settings using frequency response analysis techniques. c. Digital computer simulation. d. Frequency response behavior of process elements.
TEXT
Need for realistic problems.

UNIVERSITY OF NEW MEXICO

I: "Process Dynamics & Control" (Sr, Sem 1) 3/4
TX: Weber: "An Introduction to Process Dynamics and Control"

DIFFICULT CONCEPTS
Mathematics (Laplace transforms).
ALT. COVERAGE
None.
OBJECTIVES
a. Analytical process modeling.
b. Block control diagrams.
c. Analysis of control systems.
d. Computer simulation of control loops. e. Experimental verification of control theory.
TEXT
Need simple experiments plus combined analog and digital control.

STATE UNIVERSITY OF NEW YORK-BUFFALO

I: "Chemical Process Control" (Sr, Sem 1) 4/1.5
TX: Weber: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Offset in proportional control; reset windup; physical intuition for control system behavior.
ALT. COVERAGE
None.
OBJECTIVES
a. Mathematical modeling. b. Development of control theory for simple feedback loops. c. "Hands-on" experience with conventional pneumatic controllers.

NORTH CAROLINA STATE UNIVERSITY

I: "Process Measurement & Control I" (Sr, Sem 1) 3/2
TX: Coughanowr & Koppel
II: "Process Measurement & Control II" (Sr, Sem 2) 3/2
TX: Smith: "Digital Computer Process Control"

DIFFICULT CONCEPTS
Process stability; time and magnitude scaling of analog problems.
ALT. COVERAGE
Sophomore course in measurement and instrumentation.
OBJECTIVES
a. Response of systems to upset.
b. Process modeling and dynamics.
c. Controller settings and design of control systems. d. Instrumentation.
TEXT
Need for a text in computer control, combining theory and applications. Classical control tests need to include cascade and feed forward loops.

UNIVERSITY OF NORTH DAKOTA

I: "Process Dynamics" (Sr, Sem 2) 1.5/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Mathematical requirements.
ALT. COVERAGE
Plant design.
TEXT
Problems are generally math exercises which overshadow the results.

NORTHEASTERN UNIVERSITY

I: "Chemical Process Control" (Sr, Qtr 1) 3.5/0.5
TX: Luyben

DIFFICULT CONCEPTS
Frequency response.
ALT. COVERAGE
Senior process design course.
OBJECTIVES
a. Modeling of unsteady state problems. b. Components of a control loop, their interaction and analysis. c. Stability. d. Comparison of theoretical analogs with operation of real equipment.
TEXT
Revision of Coughanowr & Koppel is needed to include sampled data, digital control and applications.

NORTHWESTERN UNIVERSITY

I: "Process Dynamics & Control" (Jr & Sr, Qtr 2) 4/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Linearization and its application; relation between step response and frequency response.
ALT. COVERAGE
Process Design Course.
OBJECTIVES
a. Use of Laplace transforms. b. Use of dynamic analogies between various types of systems. c. Understanding of closed loop behavior of systems d. Use of analog computer.

OHIO STATE UNIVERSITY

I: "Process Dynamics & Control I" (Sr, Qtr 1) 3/1
TX: Coughanowr & Koppel
II: "Process Dynamics & Control II" (Sr, Qtr 2) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Analog computer simulation.
ALT. COVERAGE
Process Design, Process Development.
OBJECTIVES
a. Models of physical systems.
b. Response of linear systems.
c. Stability and control. d. Utility of simulation.

OHIO UNIVERSITY

I: "Process Control & Simulation I" (Sr, Qtr 1) Self-Paced/2.5
TX: Coughanowr & Koppel
II: "Process Control & Simulation II" (Sr, Qtr 2) Self-Paced/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Modeling.
ALT. COVERAGE
Plant design, applied mathematics.
OBJECTIVES
a. Process modeling. b. Process stability. c. Controller settings. d. Responses due to various disturbances.
TEXT
Particular improvement in modeling root locus approaches.

UNIVERSITY OF OKLAHOMA

I: "Process Dynamics & Control"
(Sr, Sem 2) 3/0 (Self-paced)
TX: Notes

--...ULT CONCEPTS
...g-hybrid computation circuits
...se is found to be a must
prerequisite.
ALT. COVERAGE
None.
OBJECTIVES
a. Determine first order models and their step, ramp and frequency response. b. Choose parameters for controllers based on control specifications. c. Formulate complex process models in vector-matrix form and solve using computer techniques. d. Design simple analog circuits.
TEXT
Need a coherent presentation of matrix-oriented models and solution procedures.

UNIVERSITY OF OTTAWA

I: "Process Control" (Sr, Sem 2) 3/1
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Meter control loop problems and applications.
ALT. COVERAGE
Plant design.
OBJECTIVES
a. Theoretical analysis. b. Empirical analysis. c. Appreciation of the dynamics of process equipment and its specific control problems.
TEXT
Needs more emphasis on applications.

PENNSYLVANIA STATE UNIVERSITY

...rocess Control and Dynamics"
...r & Sr, Qtr 2) 4/0 (Elective)
...X: Coughanowr & Koppel

DIFFICULT CONCEPTS
None in particular.

PMC COLLEGES

Process Dynamics is not taught at present.

PRINCETON UNIVERSITY

I: "Chemical Process Control"
(Jr & Sr, Sem 1) 3/0
TX: Perlmutter: "Introduction to Chemical Process Control"

DIFFICULT CONCEPTS
Intuitive feel for dynamics-structure relationship.
ALT. COVERAGE
Unit operations, reactor design.
OBJECTIVES
a. Linear systems analysis.
b. Feeling for the dynamics of chemical process systems.
c. Techniques of modern process control.
TEXT
Use of more modern systems of process control.

PURDUE UNIVERSITY

I: "Process Dynamics and Control"
(Sr, Sem 1) 2/3
... Coughanowr & Koppel

AL...OVERAGE
Design Course.
OBJECTIVES
a. Modeling and simulation. b. Controllers and tuning, including field testing. c. Control system analysis.

RENSSELAER POLYTECHNIC INSTITUTE

I: "Chemical Process Control"
(Sr, Sem 2) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Linearization; Nyquist criterion and plots; modeling of realistic processes.
ALT. COVERAGE
None.
OBJECTIVES
a. Modeling. b. Stability. c. Analysis by frequency response. d. Non-linear analysis by describing function. e. Digital simulation.
TEXT
a. Need material on digital simulation, analog simulation could be eliminated. b. Need material on feed forward and other modern control concepts. c. Root locus methods could be eliminated. d. Need better applications to real processes.

UNIVERSITY OR RHODE ISLAND

I: "Process Dynamics & Control"
(Jr, Sem 2) 3/0
TX: Luyben + personal notes

DIFFICULT CONCEPTS
Everything
ALT. COVERAGE
Chemical reactor design, Senior Lab.
OBJECTIVES
a. To model a simple process. b. To predict speed and type of response from a model. c. To identify the feedback situations in a process. d. To predict the new dynamic behavior of a process when feedback control is added.
TEXT
Better tie between modeling and linear systems theory; More diagraming of functional relationships.

ROSE-HULMAN INSTITUTE OF TECHNOLOGY

I: "Process Control" (Sr, Qtr 2) 4/0
TX: Coughanowr & Koppel
II: "Intermediate Process Control"
(Sr, Qtr 3) 4/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Analytical modeling; Frequency response.
ALT. COVERAGE
Senior design projects.
TEXT
More hardware; more adaptable to a self-paced course.

UNIVERSITY OF SASKATCHEWAN

I: "Process Control" (Jr & Sr, Sem 1&2)
3/2
TX: Luyben

DIFFICULT CONCEPTS
Bode stability criteria, root locus.
ALT. COVERAGE
Applied mathematics.
OBJECTIVES
a. Mathematical modeling. b. Feedback control. c. Stability and optimum controller settings. d. Feed forward control.
TEXT
Should be more concise in its treatment of mathematical models of processes.

UNIVERSITY OF SOUTH CAROLINA

I: "Process Dynamics and Control"
(Sr, Sem 2) 3/0
TX: Luyben

ALT. COVERAGE
None.

OBJECTIVES
a. Mathematical modeling. b. Limitations of linear model. c. Transfer functions. d. Block diagrams and simple feedback loops. e. Stability, Bode, Nyquist, root locus design.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

I: "Chemical Engineering Plant Design"
(Sr, Sem 2) 2/6
TX: Coughanowr & Koppel

ALT. COVERAGE
None.
OBJECTIVES
a. Learn principles. b. Solve problems. c. Gain laboratory and process experience.

UNIVERSITY OF SOUTH FLORIDA

I: "Process Control I" (Sr, Qtr 1&2)
2/3
TX: Luyben
II: "Process Control II" (Sr, Qtr 2&3)
3/0
TX: Luyben

DIFFICULT CONCEPTS
Frequency response.
ALT. COVERAGE
None.
OBJECTIVES
a. Review dynamic response of process systems. b. Basic components of process control loops. c. Analysis and stability of closed loop systems. d. Root locus and frequency response. e. System identification. f. Advanced control techniques.

STEVENS INSTITUTE OF TECHNOLOGY

I: "Chemical Process Control"
(Sr, Sem 2)
TX: Douglas: "Process Dynamics & Control" Vols. I & II

DIFFICULT CONCEPTS
Mathematical modeling; need to make assumptions in problem solutions.
ALT. COVERAGE
None.
OBJECTIVES
a. Discuss unsteady state behavior in depth. b. Mathematical modeling. c. Unsteady state behavior must always be included in plant design. d. Applications of linear equations to real chemical processes.

TENNESSEE TECHNOLOGICAL UNIVERSITY

I: "Process Dynamics & Control"
(Sr, Qtr 3) 4/0
TX: Coughanowr & Koppel

ALT. COVERAGE
None.
OBJECTIVES
a. Fundamental language of process dynamics and control. b. Mathematical modeling. c. Introduction to instrumentation hardware.

TEXAS A&M UNIVERSITY

I: "Process Control and Instrumentation" (Sr, Sem 1)
TX: Notes

DIFFICULT CONCEPTS
Frequency response.
ALT. COVERAGE
Kinetics, Plant design.
OBJECTIVES
a. Signals and signal flow. b. Concept of a process unit as a mathematical operator. c. Importance of time constants and gain around a loop. d. Stability. e. Critical parameter calculations by frequency response methods.

[UN]IVERSITY OF TEXAS – AUSTIN

[I]: "Automatic Process Control"
(Sr, Sem 2) 3/0
TX: Hougen: "Measurements and Control Applications"

[DIFFI]CULT CONCEPTS
[Fr]equency response; learning to think in the frequency domain; visualization of process behavior.
[A]LT. COVERAGE
Simulation course and computer applications course.
[O]BJECTIVES
a. Transient response. b. Frequency response via Laplace transforms. c. Design simple feedback systems in frequency response domain. d. Methods of testing and reduction for obtaining process dynamics.

[T]EXAS TECH UNIVERSITY

[I]: "Fundamentals of Chemical Processing" (Sr, Sem 2) 3/0
TX: Shilling: "Process Dynamics and Control"
[I]I: "Instrumentation" (Jr, Sem 2) 3/0
TX: Weber: "Process Dynamics & Control"

[D]IFFICULT CONCEPTS
Linearization; unsteady state balances.
[A]LT. COVERAGE
None.
[O]BJECTIVES
a. Appreciation of unsteady state balances. b. Awareness that processes never run at design rates. c. Processing systems tend to become unstable when overcontrolled.
[T]EXT
Need for good examples, as well as good theory coverage.

[UNIV]ERSITY OF TOLEDO

[I]: "Process Design & Control I"
(Sr, Qtr 1) 3/3
TX: Coughanowr & Koppel
[I]I: "Process Design & Control II"
(Sr, Qtr 2) 3/0
TX: Ogata: "Modern Control Systems"

[D]IFFICULT CONCEPTS
Frequency response.
[A]LT. COVERAGE
None.
[O]BJECTIVES
a. Lumped dynamics and unsteady state. b. Feedback control. c. Analog consumption. d. Digital computer control.

[T]RI STATE COLLEGE

I: "Theory of Controls" (Sr, Qtr 1) 3/1
TX: Harrison & Bollinger: "Introduction to Automatic Controls"

DIFFICULT CONCEPTS
Complex variable theory in Nyquist's criterion.
ALT. COVERAGE
Mechanical vibrations course.
OBJECTIVES
a. Mathematical models of different systems. b. Use of different methods to solve control problems. c. Develop a feeling for control action.

TUFTS UNIVERSITY

"Process Dynamics & Control"
(Sr, Sem 1) 3/2
TX: Weber

(New Course)

TULANE UNIVERSITY

I: "Process Dynamics & Control"
(Sr, Sem 1) 3/0
TX: Harriott: "Process Control"
II: "Mathematics of Control"
(Jr, Sem 1) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Frequency response analysis.
ALT. COVERAGE
Design; practice school.
OBJECTIVES
a. Mathematical modeling. b. Transient response of closed loop systems. c. Frequency response of linear systems. d. Nyquist and Bode analysis. e. Tuning of simple closed loop systems.

UNIVERSITY OF UTAH

I: "Process Dynamics" (Sr, Qtr 1) 3/4
TX: Harriott: "Process Control"

DIFFICULT CONCEPTS
Relating abstract mathematics to real systems.
ALT. COVERAGE
Kinetics; Design.
OBJECTIVES
a. Awareness of unsteady state behavior. b. Illustrate principles of feedback control. c. Develop confidence in handling transient phenomena.
TEXT
Needs to be updated and completely proofed.

VANDERBILT UNIVERSITY

I: "Process Dynamics and Control"
(Sr, Sem 1) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Mathematics.
ALT. COVERAGE
Laboratory; Kinetics.
OBJECTIVES
a. Process response. b. Controller response. c. Selection of controllers and instruments.

VILLANOVA UNIVERSITY

I: "Process Control" (Jr & Sr, Sem 2)
3/0
TX: Luyben
II: "Applied Math for ChE's"
(Jr & Sr, Sem 1) 3/0
TX: Luyben

DIFFICULT CONCEPTS
Control system synthesis; elementary modeling; process analysis.
ALT. COVERAGE
Design; Heat transfer.
OBJECTIVES
a. Try to show students that modeling is fun! b. Appreciation for industrial applications of process control. c. Analysis of control loops. d. Teach traditional analytical techniques such as Laplace transforms, Bode plots, etc.
TEXT
a. Needs elementary treatment of differential equations. b. Need elementary treatment of control system synthesis. c. Needs more practical aspects of control.

UNIVERSITY OF VIRGINIA

I: "Process Dynamics and Control"
(Sr, Sem 2) 3/0
TX: John: "Automatic Process Control"

ALT. COVERAGE
None.
OBJECTIVES
a. Principles of process control applicable to single loop linearization systems. b. System characterization and stability. c. Control and analytical hardware, and their capabilities and limitations.

WASHINGTON UNIVERSITY

I: "Chemical Process Dynamics and Control" (Sr, Sem 2) 3/0
TX: Weber: "Introduction to Process Dynamics & Control".

DIFFICULT CONCEPTS
Poor preparation in ordinary differential equations; mathematical modeling.
ALT. COVERAGE
None.
OBJECTIVES
a. Modeling of chemical processes. b. Developing a feel for process dynamics. c. Use of continuous system simulation languages. d. Design of simple, single-loop control systems.
TEXT
Lacks modeling of realistic chemical processes.

WASHINGTON STATE UNIVERSITY

I: "Industrial Instruments"
(Jr & Sr, Sem 2) 3/0.5
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Root locus by computer; basic concept of offset.
ALT. COVERAGE
Unit operations laboratory.
OBJECTIVES
a. Relationship between systems and instruments. b. Basic principles of system design. c. Up-to-date hardware technology. d. System modeling. e. Limitations of linear and undistributed analysis.
TEXT
More emphasis on practical hardware and computer use.

UNIVERSITY OF WASHINGTON

I: "Process Dynamics and Control"
(Sr, Qtr 1) 3/0
TX: Perlmutter: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Mathematical modeling.
ALT. COVERAGE
Design course.
OBJECTIVES
a. Mathematical modeling. b. Use of Laplace transforms. c. System stability. d. Types of control functions. e. Basic instrumentation principles.
TEXT
Even though 10 years old, is best compared with most others.

UNIVERSITY OF WATERLOO

I: "Process Dynamics and Control I"
(Sr, Sem 1) 3/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Mathematical models for physical systems.
ALT. COVERAGE
None.
OBJECTIVES
Basic principles of process dynamics and control.

WAYNE STATE UNIVERSITY

I: "Process Dynamics & Simulation"
(Sr, Qtr 1) 3/0
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Closed loop analysis.
ALT. COVERAGE
Design course.
OBJECTIVES
a. Controls. b. Mathematical modeling.
c. Frequency response techniques.
d. Stability. e. Control design.

UNIVERSITY OF WINDSOR

I: "Process Dynamics and Control"
(Sr, Sem 1&2) 2/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Unsteady state.
ALT. COVERAGE
None.
OBJECTIVES
a. Familiarity with the unsteady state. b. Model building and block diagrams. c. Analog computation.

UNIVERSITY OF WISCONSIN-MADISON

I: "Process Dynamics & Control"
(Jr & Sr, Sem 1&2) 3/4
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Open loop stability analysis from Bode and Polar plots; closed loop stability analysis by root locus methods.
ALT. COVERAGE
Reaction Kinetics; Unit operations; Plant design.
OBJECTIVES
a. Introduction and use of Laplace transforms. b. Use of block diagrams.
c. Linear systems response.
d. Stability analysis. e. Instrumentation and measurement of process variables.

UNIVERSITY OF WISCONSIN-MILWAUKEE

No course.

WORCESTER POLYTECHNIC INSTITUTE

I: "Control Engineering I"
(Jr & Sr, Qtr 2&3) Self-paced
TX: Ogata: "Modern Control Engineering" + Modules
II: "Control Engineering II"
(Sr, Qtr 2) Self-paced
TX: Ogata: "Modern Control Engineering" + Modules

DIFFICULT CONCEPTS
Frequency response.
ALT. COVERAGE
Undergraduate projects are offered after course completion.
OBJECTIVES
a. Mathematical models for process systems. b. Analytical techniques for process stability. c. Transfer functions and input-output relationships. d. Transient response characteristics of systems.

UNIVERSITY OF WYOMING

I: "Process Design" (Sr, Sem 2) 3/0
TX: Coughanowr & Koppel

(New Course)

UNIVERSITY OF MISSOURI-ROLLA

I: "Industrial Instrumentation"
(Sr, Sem 1) 2/3
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Mathematical Modeling.
ALT. COVERAGE
Plant design course.
OBJECTIVES
a. Dynamic characteristics. b. Process testing via frequency response.
c. Control strategies. d. Operation of industrial instrumentation.
TEXT
Lacks practical information.

CM416

Process Dynamics and Control (listed in the catalog as "Systems Engineering in the Instrument and Control Area")

Fall 1973

Course Policy

Instead of the usual dog and pony show -- lectures and exams -- we are going to use a mastery oriented instruction method for CM416. The method has been used at MIT, Michigan State, University of North Carolina, Bucknell, Harvard, and more than 100 other places. Most students having taken a course by this method choose to take other courses by the same method rather than by the lecture method. They say they learn more and have more fun than in courses in which lectures are used as the main instructional method.

Mastery is a simple idea -- all the students learn all the course material. This is what everyone intends but rarely achieves for any course. How can this mastery be attained with a reasonable amount of study? Read on.

Method of Instruction

The course material has been divided into twelve units of work, and a study guide for each unit has been prepared to help you in mastering the material. These study guides tell you exactly what you should learn and how you may proceed to learn it. You can work at home, or in the classroom where there will be people to help you if you need help. All the course material is outlined and the instructor is freed from giving lectures in order to present the course material. This leaves him free to help students learn. Do not hesitate to consult him immediately if you have a problem.

You complete each unit by taking a quiz which will cover all of the objectives of the unit. The quiz will be graded immediately by the instructor or by a tutor. To pass a quiz, you must answer all the questions correctly. If you do not pass a quiz, it is not serious (except that it will delay your progress), because you may repeat a quiz as often as you wish. Each time you repeat a quiz, the questions will be different, though they will cover the same objectives. You may repeat a quiz after waiting one hour. During this waiting period, you should be studying the material again concentrating on the objectives related to the questions you missed.

Staff

There will be tutors. The first priority activity for tutors is grading quizzes. When a tutor is not grading quizzes, he will be available for discussions about the course. The instructor (D.W. Hubbard) is in charge of preparing quizzes and other materials, and at times, he may serve as a tutor. He will also review the work of the tutors and be the final judge when there is a disagreement about the results of a quiz. He will always be available to help you learn by discussing the material with you. You will automatically be referred to him if you fail to pass more than two quizzes on any single unit.

There will be a senior tutor -- a graduate student -- who will give out quizzes and maintain the course records. There will also be junior tutors drawn from the ranks of students taking the course. Students who are farthest ahead may be invited to serve as tutors for a week at a time. If they accept and discharge their duties faithfully, they will receive extra credit for their work. By serving as a tutor, a student will get good drill on all the quizzes for all the units he has passed, not just on the quizzes he took himself. The instructor will serve as the tutor for the junior tutors.

Grades

A grading scheme is shown in table 1 below. To get an A, you need only earn 171 points. You can earn points by passing quizzes, by taking the final exam, by passing quizzes ahead of schedule, and by being a tutor. The recommended schedule is shown in table 2. An accelerated schedule for early completion is also shown. A student must pass unit 4 by the end of the period for dropping courses. Students who do not do this will be requested to drop the course (CM416).

It is fairly easy to get an A, but you will have to work hard. Plan on using the entire class period for working on study units. Also plan on doing some work regularly outside of class. Grades will be assigned at the end of the fall quarter on the basis of the number of points earned by each student.

Table 1: Grading Scheme Details

Passing a study unit - 10 points; maximum possible	+ 120
Final exam 68 points x $\frac{\text{Exam Score}}{100}$; maximum possible	+ 68
Bonus points for passing a study unit early -- 1 point per unit maximum possible	+ 12
Penalty points for passing a study unit more than one week late -- subtract 1 point per unit; maximum possible	− 12
Assisting as a tutor - 2 points/week; maximum possible	+ 14

Grading Scale

A+	$\geq$ 200
A	$\geq$ 171
B	$\geq$ 128
C	$\geq$ 96
D	$\geq$ 63
F	$<$ 63

← A student getting this score (200) will receive a certificate of commendation handwritten by the instructor and a free dinner at an Italian restaurant -- either Gino's or Casa Ubbardi (Hancock) or Locanda Montini (Venice). Transportation to the restaurant is not included in the offer.

Table 2: Recommended Schedule for Passing Units

Unit	Regular Schedule	Accelerated Schedule
1	17 September 1974	13 September 1974
2	24 September 1974	18 September 1974
3	1 October 1974	24 September 1974
4	8 October 1974	27 September 1974
5	15 October 1974	3 October 1974
6	18 October 1974	8 October 1974
7	22 October 1974	14 October 1974
8	29 October 1974	18 October 1974
9	1 November 1974	22 October 1974
10	7 November 1974	25 October 1974
11	12 November 1974	31 October 1974
12	15 November 1974	6 November 1974

Final Examination

A final examination will be given during the final examination period in November. This examination will cover a sampling of all of the objectives stated for the course. Every student must take the final examination. For those students who finish all the study units early, there will be an early final examination given on 8 November 1974. If a student taking the early examination is dissatisfied with his score, he may take the regular final examination and use the better of the two examination scores for computing the final course grade.

Hours

The course hours will be as listed in the schedule booklet. Besides these hours, three more hours during the week will be scheduled. Proficiency tests may be taken only during these scheduled hours. Consultations and discussions with the instructor or tutors about the course material may take place at any time. Since it will be difficult to gather all the students together at one time after the course has started, announcements about the course will be posted on the bulletin board outside Room 203.

Lectures

Several lectures will be given during the quarter, because there are things which the instructor wants to talk about. Attendance at these lectures will be limited to those students who are on schedule or ahead of schedule. This policy serves partly to provide an incentive for students to keep up and partly to give an audience of people who have the proper background to understand the lecture. The time and place for the lectures will be posted.

Attendance at the lectures is not required nor will it be helpful with regard to the final examination or any unit. The lectures are merely for enjoyment and inspiration.

List of Study Units

1. Differential equations revisited

   A review of essential mathematics

2. Transport phenomena strikes again

   Conservation principles and control system terminology

3. The LDEWCC meets its Waterloo at the hands of Laplace

   More mathematical methods

4. Everything you want to know about first-order systems

   Simple open loop system behavior

5. Ditto for higher order systems

   More complex open loop system behavior

6. Closing the loop again

   Describing closed loop systems

7. A little about valves and more about controllers

   Describing loop closing devices

8. Control system response -- back to mathematics at last

   Closed loop system behavior

9. Solving differential equations the easy (?) way

   Analog computer techniques

10. Keeping things under control

    Closed loop system stability

11. The root locus is not a plague -- it's a plot

    More about system stability

12. System response again

    Root locus plot applications