SUMMARY REPORT

TEACHING OF UNDERGRADUATE
PROCESS DYNAMICS AND CONTROL

A mini-session presented at the
Annual Meeting

American Institute of Chemical Engineers
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Committee Members
Dr. Edwin O. Eisen, Chairman
Gulf Oil Corporation
Dr. Robert M. Hubbard
University of Virginia
Dr. Angelo J. Perna
N.J. Institute of Technology
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 Coughanour 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:

TEXTBOOK SELECTION (Cont'd)


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 labora-
tory work in the designated area, and the average number of hours per semes-
ter on quarter devoted to experiments by the remaining universities. Labora-
tory work may be in the process control laboratory course or in another
laboratory, such as unit operations or process design.

<table>
<thead>
<tr>
<th>Experimental Area</th>
<th>No Work</th>
<th>Hr/Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumentation based hardware</td>
<td>43</td>
<td>6.9</td>
</tr>
<tr>
<td>Process based hardware</td>
<td>39</td>
<td>8.7</td>
</tr>
<tr>
<td>Digital computer simulation</td>
<td>56</td>
<td>6.2</td>
</tr>
<tr>
<td>Analog computer simulation</td>
<td>42</td>
<td>8.1</td>
</tr>
<tr>
<td>Other areas</td>
<td>89</td>
<td>4.5</td>
</tr>
</tbody>
</table>

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 re-
action 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 unenthusiastic, 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'"
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
      2. Process based
   B. Digital computer simulation
   C. Analog computer simulation
   D. Others (please specify)

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 ARKON
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. Model physical system.
   b. Convey analogies between systems.
   c. Achieve good background in students, but not becoming experts.
   d. Include both continuous and discrete control; also instrumentation.

UNIVERSITY OF ARIZONA
I: "Industrial Process Control" (Sr, Sem 1) 3/6
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 application.
   b. Understanding of feedback vs. feedforward vs. cascade control.
   c. Understanding of stability and linear control theory.
   d. Apply techniques to actual problems.
   e. Better integration of concepts is needed.

UNIVERSITY OF ALABAMA
I: "Process Dynamics" (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 loop; 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, feedforward and cascade control schemes.
   d. Modern methods of controller tuning.
   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 model from experimental testing of a system.
   c. Use of analog computer for solving differential equations and transfer functions.
   d. Use of digital simulation for the above objective.

UNIVERSITY OF ALBERTA
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. Comprehension of dynamics - time dependence of stable and unstable systems.
   b. Limitations of control analysis.
   c. Modern facility with requisite mathematics - Laplace transforms, root locus, Bode plots, time dependence of process.
   d. Practical applications are needed - "how it is really done."

UNIVERSITY OF CALGARY
I: "Process Dynamics & Control" (Sr, Sem 2) 3.12
TX: Luyben: "Process Modeling, Simulation & 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 model 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 problems into mathematics is the difference.

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.
CATHOLIC UNIVERSITY OF AMERICA

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

DIFFICULT CONCEPTS
STABILITY
ALT. COVERAGE
CHE laboratory, one experiment dealing with control.

OBJECTIVES

UNIVERSITY OF CINCINNATI

I: "Process Dynamics & Control" (Sr, Qtr 1) 4/0
TI: 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

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

Clemson University

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

ALT. COVERAGE

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
TI: Coughanowr & Koppel

DIFFICULT CONCEPTS
SIGNIFICANCE OF FREQUENCY RESPONSE AND BODE ANALYSIS

OBJECTIVES
None

OBJECTIVES

University of Colorado

I: "Instrumentation & Process Control" (Sr, Sem 2) 3/0
TI: Layben; Andrew: "Applied Instrumentation in the Process Industries"

II: "Process Dynamics" (Sr, Sem 1) 3/0
TI: Notes

DIFFICULT CONCEPTS
Frequency response, especially root locus and Nichols plots.

OBJECTIVES

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

Cornell University

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

DIFFICULT CONCEPTS
DYNAMICS OF 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 practical and economic control schemes.

TEXT
Emphasizes 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" (Sr & Sr, Qtr 14) 3/2
TI: Coughanowr & Koppel

DIFFICULT CONCEPTS
DIFFERENCES BETWEEN OPEN-LOOP AND CLOSED-LOOP PROCESS VERSUS AS RELATED TO FREQUENCY RESPONSE

ALT. COVERAGE
Real 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 integrates previous courses in mathematics, chemistry, physics and engineering.

University of Florida

I: "Process Systems Analysis" (Sr, Qtr 2) 2/3
TI: Tyner & May: "Process Engineering Control"

II: "Process Control Theory" (Sr, Qtr 3) 3/3
TI: Tyner & May: "Process Engineering Control"
DIFFICULT CONCEPTS
Frequency response and root locus, both because of poor training in complex number.

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

DIFFICULT CONCEPTS
Meaning of frequency response; connection and Gains and dynamics and control;
Mathematics required for analysis.

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.

UNIVERSITY OF MICHIGAN
I: "Engineering Operations Laboratory" (Sr, Sem 2) 3/3
TX: Notes
II: "Process Control in Chemical Industry" (Sr, Sem 2) 3/3
TX: Harriott: "Process Control"

DIFFICULT CONCEPTS
Mathematical operations; ultimate gain and stability in closed feedback loop; sensitivity of design.

UNIVERSITY OF MICHIGAN STATE UNIVERSITY
I: "Process Dynamics & Control" (Sr, Qtr 2) 3/0
TX: Coughanowr & Koppell

DIFFICULT CONCEPTS
Frequency response.

UNIVERSITY OF MICHIGAN TECH UNIVERSITY
I: "Process Dynamics & Control" (Sr, Qtr 1) 6/0
TX: Coughanowr & Koppell
II: "Process Control Laboratory" (Sr, Qtr 2) 2/3
TX: Coughanowr & Koppell

DIFFICULT CONCEPTS
Unsteady state mass and energy balances.

MC GILL UNIVERSITY
I: "Chemical Process Control" (Sr, Sem 2) 3/1
TX: Coughanowr & Koppell

DIFFICULT CONCEPTS
Overall process analysis; disturbance and control inputs; multiple outputs.

LOWELL UNIVERSITY
I: "Process Dynamics & Control" (Sr, Sem 1) 3/0
TX: Coughanowr & Koppell

DIFFICULT CONCEPTS
Mathematical modeling and, in general, the math is involved.

LOWELL UNIVERSITY
I: "Process Control Laboratory" (Sr, Sem 2) 1/3
TX: None

DIFFICULT CONCEPTS
Mathematical operations; ultimate gain and stability in closed feedback loop; sensitivity of design.

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

DIFFICULT CONCEPTS
Overall process analysis; disturbance and control inputs; multiple outputs.

LOWELL UNIVERSITY
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.

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

DIFFICULT CONCEPTS
Overall process analysis; disturbance and control inputs; multiple outputs.

LOWELL UNIVERSITY
I: "Chemical Engineering Process Dynamics & Control" (Sr, Sem 2) 3/6
TX: Notes
II: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Model development.

LOWELL UNIVERSITY
I: "Introduction to Process Dynamics & Control" (Sr, Sem 2) 3/0
TX: Notes
II: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Model development.

LOWELL UNIVERSITY
I: "Chemical Engineering Process Dynamics & Control" (Sr, Sem 2) 3/6
TX: Notes
II: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Model development.

LOWELL UNIVERSITY
I: "Chemical Engineering Process Dynamics & Control" (Sr, Sem 2) 3/6
TX: Notes
II: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Model development.

LOWELL UNIVERSITY
I: "Chemical Engineering Process Dynamics & Control" (Sr, Sem 2) 3/6
TX: Notes
II: "Introduction to Process Dynamics & Control"

DIFFICULT CONCEPTS
Model development.
DIFFICULT CONCEPTS
There is no steady state; Time and frequency responses are convertible one into the other.

ALT. COVERAGE
Maths; 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

UNIVERSITY OF HOUSTON
I: "Chemical Process Control" (Sr, Sem 12) 3/1
TX: Coughanowr & Koppel

DIFFICULT CONCEPTS
Quasi-steady state assumption; effects of interaction among the control loops.

ALT. COVERAGE
Undergraduate laboratory.

OBJECTIVES

TEXT
More needed on special characteristics of chemical processes and less on process analogs of electrical devices.

HAWARD 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

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 Control 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

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

TEXT
More material on modeling is desirable.

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

DIFFICULT CONCEPTS
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
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

UNIVERSITY OF KENTUCKY
I: "Process Control" (Sr, 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" (Sr, Sem 1) 3/0
TX: Rochman; "Industrial Process Control"

DIFFICULT CONCEPTS
Complex transfer functions in relation to Nyquist or Bode diagrams.

ALT. COVERAGE
Process design.

OBJECTIVES

LEHIGH UNIVERSITY
I: "Mathemtical Modeling & Simulation" (Sr, Sem 2) 3/0
TX: Luyben; Process Modeling, Simulation and Control for CHE

I: "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

I: "Process Simulation" (Sr, Sem 1) 1.5
TX: Corripio & Smith; Class Notes
MONTANA STATE UNIVERSITY

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

OBJECTIVES


DIFFICULT CONCEPTS

Change from time domain to Laplace transform domain.

UNIVERSITY OF NEBRASKA

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

OBJECTIVES

a. Concept of the unsteady state neighborhood of an operating point.

DIFFICULT CONCEPTS

Closed loop negative feedback stability.

UNIVERSITY OF NEW BRUNSWICK

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

OBJECTIVES


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 wind-up; physical intuition for control system behavior.

NEW JERSEY INSTITUTE OF TECHNOLOGY

I: "Process Dynamics & Control" (Sr, Sem 12) 2/2
TX: Perlmutter: "Introduction to Chemical Process Control"

DIFFICULT CONCEPTS

Application of control theory to Chemical Engineering Problems.

NEW MEXICO STATE UNIVERSITY

"Process Analysis" (Sr, Sem 1) 3/0
TX: Couhnanow & Koppel
II: "Process Laboratory" (Sr, Sem 12) 0/3

DIFFICULT CONCEPTS

Process Analysis (process dynamics, modeling, etc.)

UNIVERSITY OF NORTH DAKOTA

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

DIFFICULT CONCEPTS

Mathematical requirements.
UNIVERSITY OF OKLAHOMA
I: "Process Dynamics & Control" (Sr, Sem 2) 3/0 (Self-paced)
TX: Notes

DIFFICULT CONCEPTS
a. Hybrid computation circuits
b. Feedback control

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: Coughanour & Koppel

DIFFICULT CONCEPTS
Meter control loop problems and applications.

OBJECTIVES
Non."Plant design.

TEXT
Needs more emphasis on applications.

PENNSYLVANIA STATE UNIVERSITY
I: "Process Control and Dynamics" (Sr & Sr, Qtr 2) 4/0 (Elective)
TX: Coughanour & Koppel

DIFFICULT CONCEPTS
None in particular.

POMONA COLLEGES
Process Dynamics is not taught at present.

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

DIFFICULT CONCEPTS
Intuitive feel for dynamics-structure relationship.

OBJECTIVES
a. Linear systems analysis.
b. Feeling for the dynamics of chemical process systems.
c. Techniques of modern process control.

TEXT
Use of modern systems of process control.

PURDUE UNIVERSITY
I: "Process Dynamics and Control" (Sr, Sem 1) 2/3
Coughanour & Koppel

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: Coughanour & Koppel

DIFFICULT CONCEPTS
Linearization; Nyquist criterion and plots; modeling of realistic processes.

OBJECTIVES
Non.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
I: "Chemical Engineering Plant Design" (Sr, Sem 2) 2/6
TX: Coughanour & Koppel

OBJECTIVES
a. Learn principles.
b. Solve problems.
c. Gain laboratory and process experience.

UNIVERSITY OF SOUTH FLORIDA
I: "Process Control I" (Sr, Qtr 142) 2/3
TX: Luyben
II: "Process Control II" (Sr, Qtr 243) 3/0
TX: Luyben

DIFFICULT CONCEPTS
Frequency response.

OBJECTIVES
Non.

STEVEN'S 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.

OBJECTIVES
Non.

TEXT
Non.

TENNESSEE TECHNOLOGICAL UNIVERSITY
I: "Process Dynamics & Control" (Sr, Qtr 3) 4/0
TX: Coughanour & Koppel

OBJECTIVES
Non.

TEXAS A&M UNIVERSITY
I: "Process Control and Instrumentation" (Sr, Sem 1)
TX: Notes

DIFFICULT CONCEPTS
Frequency response.

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.
TULANE UNIVERSITY

I: "Process Dynamics & Control"
(Sr, Sem 1) 3/0
TX: Hougton: "Measurements and Control Applications"

OBJECTIVES
- Frequency response; learning to think in the frequency domain; visualization of process behavior.
- Simulation course and computer applications course.

DIFFICULT CONCEPTS
- Unsteady state balance.

UT. COVERAGE
None.

OBJECTIVES
- Appreciation of unsteady state balances.
- Awareness that processes never run at design rates. G. Processing systems tend to become unstable when overcontrolled.

TEXT
- Need for good examples, as well as good theory coverage.

UNIVERSITY OF UTAH

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

DIFFICULT CONCEPTS
- Linearization; unsteady state systems.

ALT. COVERAGE
- None.

OBJECTIVES
- 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: Coughanour & Koppel

DIFFICULT CONCEPTS
- Frequency response.

ALT. COVERAGE
- Laboratory: Kinetics.

OBJECTIVES

WASHINGTION 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.
WILLIAM AND MARY

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

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

UNIVERSITY OF WINDSOR

I: "Process Dynamics and Control" (Sr, Sem 12) 3/3
TX: Coughanour & 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" (Sr & Sr, Sem 12) 3/4
TX: Coughanour & 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

UNIVERSITY OF WISCONSIN-MILWAUKEE

No course.

WORCESTER POLYTECHNIC INSTITUTE

I: "Control Engineering I" (Sr & Sr, Otr 22) Self-paced
TX: Ogata: "Modern Control Engineering" + Modules
II: "Control Engineering II" (Sr, Otr 2) Self-paced
TX: Ogata: "Modern Control Engineering" + Modules

DIFFICULT CONCEPTS
Frequency response.
ALT. COVERAGE
Undergraduate projects are offered after course completion.
OBJECTIVES
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

<table>
<thead>
<tr>
<th>Grade</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>200</td>
</tr>
<tr>
<td>A</td>
<td>171</td>
</tr>
<tr>
<td>B</td>
<td>123</td>
</tr>
<tr>
<td>C</td>
<td>96</td>
</tr>
<tr>
<td>D</td>
<td>63</td>
</tr>
<tr>
<td>F</td>
<td>63</td>
</tr>
</tbody>
</table>

A student getting this score 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

<table>
<thead>
<tr>
<th>Unit</th>
<th>Regular Schedule</th>
<th>Accelerated Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17 September 1974</td>
<td>13 September 1974</td>
</tr>
<tr>
<td>2</td>
<td>24 September 1974</td>
<td>18 September 1974</td>
</tr>
<tr>
<td>3</td>
<td>1 October 1974</td>
<td>24 September 1974</td>
</tr>
<tr>
<td>4</td>
<td>8 October 1974</td>
<td>27 September 1974</td>
</tr>
<tr>
<td>5</td>
<td>15 October 1974</td>
<td>3 October 1974</td>
</tr>
<tr>
<td>6</td>
<td>18 October 1974</td>
<td>8 October 1974</td>
</tr>
<tr>
<td>7</td>
<td>22 October 1974</td>
<td>14 October 1974</td>
</tr>
<tr>
<td>8</td>
<td>29 October 1974</td>
<td>18 October 1974</td>
</tr>
<tr>
<td>9</td>
<td>1 November 1974</td>
<td>22 October 1974</td>
</tr>
<tr>
<td>10</td>
<td>7 November 1974</td>
<td>25 October 1974</td>
</tr>
<tr>
<td>11</td>
<td>12 November 1974</td>
<td>31 October 1974</td>
</tr>
<tr>
<td>12</td>
<td>15 November 1974</td>
<td>6 November 1974</td>
</tr>
</tbody>
</table>
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