The University of Western Ontario  
Faculty of Engineering  

DEPARTMENT OF CHEMICAL AND BIOCHEMICAL ENGINEERING  

CBE/GPE 3310B - Process Dynamics and Control  
Course Outline 2014 - 2015  

Description  
The course covers the dynamic behaviour, modelling and control of chemical/biochemical processes. The principles of feedback and feedforward and cascade control of the commonly-encountered systems such as level, flow, temperature, and pressure control systems are described. Theory is introduced to illustrate current practices. Simulations of dynamic behaviour of processes will make use of the MATLAB/SIMULINK programming environments. LabView programming will be covered and control of an actual process using LabView and NI-data acquisition (National Instrument DAQ) systems will be implemented.  

Prerequisites  
Applied Mathematics 2411 or 2415, CBE 2291A/B.  

Unless you have either the requisites for this course or written special permission from your Dean to enrol in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.  

Corequisites  
None  

Antirequisite  
The former CBE 4410A/B  

Contact Hours  
3 lecture hours, 2 computer laboratory/experimental lab hours, 0.5 course.  

Instructor  
Dr. S. Rohani (TEB 457) Telephone: 519-661-2111 ext: 84116 email: srohani@uwo.ca  

Teaching Assistant(s)  
Syed Bukhari – Experimental Lab/Marker, sbukha3@uwo.ca, office: SEB 2026  
Hecham Omar – Computer Lab and Experimental Lab/Marker, homar7@uwo.ca:  
Mahshid Attari – Marker, mhshd.attari@gmail.com  
Nicholas Hou, Marker, nickh@live.com  

Lab Technician  
Souheil Afara (SEB 1081C) 519-661-2111 ext 88457 email: safara@uwo.ca
Undergraduate Assistant
Ingrid Timusk (TEB 477) Telephone: 519- 661-2111 ext: 82131 email: ingrid.timusk@uwo.ca

Recommended Text
Extensive Course Notes will be provided on WebCT.

Reference Texts
“Principles and Practice of Automatic Process Control”, Smith & Corripio, John Wiley

Course Notes
Course notes and problem sets will be available for download from the course website.

Lab Notes
Lab notes will be available for download from the course website.

Laboratory
Students are expected to attend 2 laboratory hours every week. The laboratory component of the course consists of both Computer labs/Tutorials using MATLAB and SIMULINK, as well as experimental implementation of a feedback control system using LabView.

Units
Both SI and English units will be used.

General Learning Objectives

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Learning Objectives
• Students should be able to develop dynamic models of chemical processes based on material and energy balances
• Students will become proficient in solving differential systems using Laplace Transforms and Matlab
• Students should be able to set up simple feedback loops using PID controllers and models developed
• Students will analyze the stability of these feedback systems using both the time and Laplace domains
• Students will implement various tuning methods for controllers
• Students will be able to analyze feed forward controllers
• Students will use MATLAB/SIMULINK to implement and test out their controller designs
• Students will run feedback control experiments on a control system using LabView

Specific Learning Objectives:
Introduction to Control Systems and Mathematical Methods for Control (Chapters 1 and 2)
At the end of this topic, students should be able to:
• Draw the piping and instrumentation diagram (P&ID) and Block diagrams for feedback and feedforward control systems
• Write energy and mass balances for simple chemical/biochemical processes
• Conduct a degree of freedom analysis for chemical/biochemical processes
• Solve the resulting ordinary differential equations using Matlab software

Laplace Transforms, Linear Dynamic Models and Transfer Functions (Chapters 3 and 4)
At the end of this topic, students should be able to:
• Solve linear differential equations using the Laplace method
• Invert given Laplace functions into the time domain
• Use properties of Laplace transform operation
• Develop transfer functions for dynamic processes

Dynamic Behaviour of 1st Order Systems and 2nd Order Systems (Chapter 5)
At the end of this topic, students should be able to:
• Convert ordinary differential equations (ODE’s) into deviation variables
• Linearize terms in ODE’s that are non-linear in one or more variables
• Develop differential equations describing 1st order chemical processes using mass and energy balances
• Classify and solve interacting and non-interacting systems
• Use Matlab/Simulink and LabView to simulate simple chemical engineering process systems
• Classify 2nd order dynamics using terms such as damping ratio, natural frequency
• Solve for step and impulse function of 2nd order systems

Dynamic Behaviour of More Complicated Systems (Chapter 6)
At the end of this topic, students should be able to:
• work with the transfer function in the form of Poles and Zeros
• work with the transfer function with Time Delays
• work with the transfer function of Higher Order Systems
• work with the transfer function of Multi-Input Multi-Output Systems

Development of Empirical Models using Process Input-Output Data (Chapter 7)
At the end of this topic, students should be able to:
• Implement Linear and non-linear regression to obtain transfer function of systems using input-output data
• Obtain transfer function of systems using input-output data and Graphical approximation using Step
Response Tests

**Feedback Controllers (Chapter 8)**
At the end of this topic, students should be able to:
- Use features of PID and On-Off controllers and tune them
- Use block diagram
- Use Simulink for analysis, linearization and simplification of complex block diagrams
- Analyze typical responses of feedback control systems
- Use digital version of PID controllers

**Control System Instrumentation (Chapter 9)**
At the end of this topic, students should be able to be aware of several types of instrumentation and their use in typical feedback control systems

**Overview of Control System Design (Chapter 10)**
The students will be introduced to:
- The concept of control system design for an entire plant
- The role of control system in the process safety

**Stability in Laplace Domain (Chapter 11)**
At the end of this topic, students will be able to:
- Analyze the characteristic equation of a closed loop system and determine the system stability
- Calculate it for closed loop systems
- Apply Routh criteria to analyze the stability of systems without dead time

**Closed Loop Systems and Design of PID controllers (Chapter 12)**
At the end of this topic, students should be able to:
- Understand how to manipulate closed loop block diagrams to calculate overall transfer functions
- Understand PID control and the role integration in offset removal
- Analyze the effect of chemical process dead time on control quality
- Tune a PID controller by trial and error as well as by using other analytical methods
- Perform stability analysis of Closed Loop systems
- Perform Root-Locus Diagrams
- Use Simulink/Matlab tools to develop closed loop tuning simulations

**Feedforward and Ratio Control (Chapter 15)**
- Implement feedback plus feedforward control on simple chemical/biochemical processes

**Enhanced Single-Loop Controllers (Chapter 16)**
At the end of this topic, students should be able to:
- Design and Implement Cascade Control
- Design and Implement Time Delay Compensation controllers
- Design and implement Selective Control/Override Systems

**Evaluation**
The final course mark will be determined as follows:
Assignments 10%
Laboratory 10%
Mid-term Examination 30%
Final Examination 50%

The final examination will be 3 hours in length. Calculators of any kind will be permitted during examinations.

**Notes**
1) **Students must pass the final examination to pass this course.** Students who fail the final examination will be assigned 48% if the aggregate mark is higher than 50%, or the aggregate mark.
2) **Students must turn in all laboratory reports, and achieve a passing grade in the laboratory component, to pass this course.**
3) **Assignments are to be handed in the CBE 3310B locker (#453) in TEB on the specified due date provided by the Instructor.**

**Repeating All Components of the Course**
In accordance with Senate and Faculty Policy, students who have failed an Engineering course (i.e. <50%) must repeat all components of the course. No special permissions will be granted enabling a student to retain laboratory, assignment or test marks from previous years. Previously completed assignments and laboratories cannot be resubmitted for grading by the student in subsequent years.

**Use of English**
In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for the improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

**Attendance**
Attendance at lectures, tutorials and labs is mandatory. Any student, who, in the opinion of the instructor, is absent too frequently from class or laboratory periods in any course, will be reported to the Dean (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Dean, the student will be debarred from taking the regular examination in the course.

**Cheating**
University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalties, which might include expulsion from the program. If you are caught cheating, there will be no second warning (see Scholastic Offence Policy in the Western Academic Calendar).

**Plagiarism**
Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence (see Scholastic Offence Policy in the Western Academic Calendar). The University of Western Ontario has software for plagiarism checking. Students may be required to submit their work in electronic form for plagiarism checking.
**Conduct**
Students are expected to arrive at lectures on time, and to conduct themselves during class in a professional and respectful manner that is not disruptive to others.

**Sickness and Other Problems**
Students should immediately consult with the instructor or Department Chair if they have any problems that could affect their performance in the course. Where appropriate, the problems should be documented. The student should seek advice from the Instructor or Department Chair regarding how best to deal with the problem. Failure to notify the Instructor or Department Chair immediately (or as soon as possible thereafter) will have a negative effect on any appeal.

Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x 82147 for any specific questions regarding an accommodation.

**Notices**
Students are responsible for regularly checking their Western email and notices posted on Instructors' doors.

**Consultation**
Students are encouraged to discuss problems with their teaching assistant and/or instructor in tutorial sessions. Office hours will be arranged for the students to see the instructor and teaching assistants. Other individual consultation can be arranged by appointment with the appropriate instructor.

**Accreditation (AU) Breakdown**
- Engineering Science 70%
- Engineering Design 30%

November 26, 2014/sr
INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED

IF, ON MEDICAL OR COMPASSIONATE GROUNDS, YOU ARE UNABLE TO WRITE TERM TESTS OR FINAL EXAMINATIONS OR COMPLETE COURSE WORK BY THE DUE DATE, YOU SHOULD FOLLOW THE INSTRUCTIONS LISTED BELOW. YOU SHOULD UNDERSTAND THAT ACADEMIC ACCOMMODATION WILL NOT BE GRANTED AUTOMATICALLY ON REQUEST. YOU MUST DEMONSTRATE TO YOUR DEPARTMENT (OR THE UNDERGRADUATE SERVICES OFFICE IF YOU ARE IN FIRST YEAR) THAT THERE ARE COMPELLING MEDICAL OR COMPASSIONATE GROUNDS THAT CAN BE DOCUMENTED BEFORE ACADEMIC ACCOMMODATION WILL BE CONSIDERED. DIFFERENT REGULATIONS APPLY TO TERM TESTS, FINAL EXAMINATIONS AND LATE ASSIGNMENTS. READ THE INSTRUCTIONS CAREFULLY. (SEE THE 2014 UWO ACADEMIC CALENDAR).

A. GENERAL REGULATIONS & PROCEDURES

1. Check the course outline to see if the instructor has a policy for missed tests, examinations, late assignments or attendance.

2. Bring your request for academic accommodation to the attention of the chair of your (or the Undergraduate Services office if you are in first year) PRIOR to the scheduled time of the test or final examination or due date of the assignment. If you are unable to contact the relevant person, leave a message with the appropriate department (or with the Undergraduate Services Office if you are in first year). The address, telephone and fax numbers are given at the end of these instructions. Documentation must be provided as soon as possible.

3. If you decide to write a test or an examination you should be prepared to accept the mark you earn. Rewriting tests or examinations or having the value of a test or examination reweighted on a retroactive basis is not permitted.

B. TERM TESTS

1. If you are unable to write a term test, inform your instructor and the Chair of your Department (or the Undergraduate Services Office if you are in first year) PRIOR to the scheduled date of the test. If the instructor is not available, leave a message for him/her at the department office and inform the Chair of the Department (or the Undergraduate Services Office if you are in first year).

2. Be prepared to provide supporting documentation to the Chair and the Undergraduate Services Office (see next page for information on documentation).

3. Discuss with the instructor if and when the test can be rescheduled. N.B. The approval of the Chair (or the Undergraduate Services Office if you are in first year) is required when rescheduling term tests.

C. FINAL EXAMINATIONS

1. If you are unable to write a final examination, contact the Undergraduate Services Office PRIOR TO THE SCHEDULED EXAMINATION TIME to request permission to write a Special Final Examination. If no one is available in the Undergraduate Services Office, leave a message clearly stating your name & student number (please spell your full name).

2. Be prepared to provide the Undergraduate Services Office with supporting documentation (see next page for information on documentation) the next day, or as soon as possible (in cases where students are hospitalized). The following circumstances are not considered grounds for missing a final examination or requesting special examinations: common cold, sleeping in, misreading timetable and travel arrangements.

3. In order to receive permission to write a special examination, you must obtain the approval of the Chair of the Department and the Associate Dean and in order to apply you must sign a "Recommendation for a Special Examination Form" available in the Undergraduate Services Office. The Undergraduate Services Office will then notify the course instructor(s) and reschedule the examination on your behalf.

N.B. It is the student’s responsibility to check the date, time and location of the special examination.

D. LATE ASSIGNMENTS

1. Advise the instructor if you are having problems completing the assignment on time (prior to the due date of the assignment).

2. Be prepared to provide documentation if requested by the instructor (see reverse side for information on documentation).

3. If you are granted an extension, establish a due date. The approval of the Chair of your Department (or the Associate Dean if you are in first year) is not required if assignments will be completed prior to the last day of classes.

4. i) Extensions beyond the end of classes must have the consent of the instructor, the department Chair and the Associate Dean. Documentation is mandatory.

ii) A Recommendation of Incomplete Form must be filled out indicating the work to be completed and the date by which it is due. This form must be signed by the student, the instructor, the department Chair and the Associate Dean.
E. **SHORT ABSENCES**

If you miss a class due to a minor illness or other problems, check your course outlines for information regarding attendance requirements and make sure you are not missing a test or assignment. Cover any readings and arrange to borrow notes from a classmate.

F. **EXTENDED ABSENCES**

If you are absent more than one week or if you get too far behind to catch up, you should consider reducing your workload by dropping one or more courses. (Note drop deadlines listed below). You may want to seek advice from the academic counsellor in your Department or Ms Karen Murray in the Undergraduate Services Office if you are in first year.

G. **DOCUMENTATION**

If you consulted an off-campus doctor or Student Health Services regarding your illness or personal problem, **you must provide the doctor with a Student Medical Certificate** to complete at the time of your visit and then bring it to the Department (or the Undergraduate Services Office if you are in first year). **This note must contain the following information:** severity of illness, effect on academic studies and duration of absence.

**In Case of Serious Illness of a Family Member:** Provide a Student Medical Certificate to your family member's physician to complete and bring it to the Department (or the Undergraduate Services Office if you are in first year).

**In Case of a Death:** Obtain a copy of the death certificate or the notice provided by the funeral director's office. You must include your relationship to the deceased and bring it to the Department (or the Undergraduate Services Office if you are in first year).

**For Other Extemating Circumstances:** If you are not sure what documentation to provide, ask the Departmental Office (or the Undergraduate Services Office if you are in first year) for direction.

**Note:** Forged notes and certificates will be dealt with severely. To submit a forged document is a scholastic offence (see below).

H. **ACADEMIC CONCERNS**

You need to know if your instructors have a policy on late penalties, missed tests, etc. This information may be included on the course outlines. If not, ask your instructor(s).

You should also be aware of attendance requirements in some courses. You can be debarred from writing the final examination if your attendance is not satisfactory.

If you are in academic difficulty, check out the minimum requirements for progression in the calendar. If in doubt, see your academic counsellor.

**Calendar References:** Check these regulations in your 2014 Western Academic Calendar available at [www.westerncalendar.uwo.ca](http://www.westerncalendar.uwo.ca).

- Absences Due to Illness: [http://www.westerncalendar.uwo.ca/2014/pg117.html](http://www.westerncalendar.uwo.ca/2014/pg117.html)
- Academic Accommodations for Students with Disabilities: [http://www.westerncalendar.uwo.ca/2014/pg118.html](http://www.westerncalendar.uwo.ca/2014/pg118.html)
- Academic Accommodations for Religious or Holy Days: [http://www.westerncalendar.uwo.ca/2014/pg119.html](http://www.westerncalendar.uwo.ca/2014/pg119.html)
- Examinations: [http://www.westerncalendar.uwo.ca/2014/pg129.html](http://www.westerncalendar.uwo.ca/2014/pg129.html)
- Scheduling of Term Assignments: [http://www.westerncalendar.uwo.ca/2014/pg197.html](http://www.westerncalendar.uwo.ca/2014/pg197.html)
- Scholastic Offences: [http://www.westerncalendar.uwo.ca/2014/pg113.html](http://www.westerncalendar.uwo.ca/2014/pg113.html)
- Student Medical Certificate: [http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf](http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf)
- Engineering Academic Regulations: [http://www.westerncalendar.uwo.ca/2014/pg142.html](http://www.westerncalendar.uwo.ca/2014/pg142.html)

**Note:** These instructions apply to all students registered in the Faculty of Engineering regardless of whether the courses are offered by the Faculty of Engineering or other faculties in the University.

**Drop Deadlines:**

- First term half course (i.e. “A” or “F”): November 5, 2014
- Full courses and full-year half courses (i.e. “E”, “Y” or no suffix): November 30, 2014
- Second term half or second term full course (i.e. “B” or “G”): March 7, 2015

Undergraduate Services Office: SEB 2097 telephone: (519) 661-2130 fax: (519) 661-3757
- Dept. of Chemical and Biochemical Engineering & Green Process Engineering TEB 477 telephone: (519) 661-2131 fax: (519) 661-3498
- Dept. of Civil and Environmental Engineering: SEB 3005 telephone: (519) 661-2139 fax: (519) 661-3779
- Dept. of Electrical and Computer Engineering, Software Engineering, Mechatronics Engineering TEB 279 telephone: (519) 661-3758 fax: (519) 850-2436
- Dept. of Mechanical and Materials Engineering: SEB 3002 telephone: (519) 661-4412 fax: (519) 661-3020

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