a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA
Chemical & Biological Engineering
Faculty of Applied Science

WELCOME TO CHBE 474!
PROCESS CONTROL ENGINEERING
(3 credits)

Why Taking This Course?

Chemical engineering is the study of designing ways to convert raw material into valuable products in a safe, sustainable, environmentally responsible, and profitable manner, at a commercial scale.
In this course, together, we will explore designing **advanced control systems** to keep the operation of chemical and biological processes within optimal conditions.

Throughout the term, we will follow the **systematic approach** to solve control engineering problems:

i. Breaking a process down into its components, Drawing schematics, and Listing assumptions
ii. Identifying the control objective along with the controlled, disturbance and manipulated variables
iii. Determining the most appropriate control design system
iv. Tuning the controllers

In this course we will take a **practical approach** to control engineering and use industry standard terminology and advanced strategies to address various challenging control problems. We will also have many hands-on opportunities to run real-time simulations using Matlab Simulink.
The topics covered in this course include:

- PID Controller Tuning
- Feedforward and Ratio Control
- Enhanced Single Loop Control Strategies
- Digital Sampling, Filtering, and Control
- Multiloop and Multivariable Control
- Real-Time Optimization
- Model Predictive Control
- Plant-wide Control

You will be continually asked to practice thinking like a *control engineer*. Learning will be evaluated based on a combination of **individual** quizzes and exams as well as **collaborative** assignments and term project. Join us in studying *the most applied control course*!

PRE-REQUIISTE CHBE 356

Inside This Syllabus

Quick Facts: Where? When?

Classes are held M-W-F in HEBB 114, 13:00 to 13:50.
Attendance is expected and is necessary for success. Show respect for your fellow learners and leaders, including arriving *on time* and leaving *after* official dismissal. Bring your paper and writing tools. You may choose to bring a computer, but beware of its tendency to side-track attention and decrease comprehension – yours and others' (Fried, 2008; Sana, Weston, & Cepeda, 2013).

Meet Your Teaching Team

INSTRUCTOR | Dr. S. Alireza Bagherzadeh

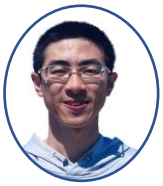
⌖: CHBE Building | Room 433
Welcome to my in-person office hours:
Mon 4 – 5 pm

✉: alireza.bagherzadeh@ubc.ca
I try to responds as quickly as possible, but 48 hours for a reply is about typical. I suggest general questions be posted on the Discussion Board in canvas, so everyone can help each other quickly. If you need to email me or the TAs directly, please put "**CHBE 474**" in the **Subject Line** and use your UBC email account or your message could get misdirected.

Dr. Bagherzadeh in ≤ 20 words: Iranian-born; father of two; likes: early mornings, podcasts, hiking, soccer, volleyball, coffee, tea, BC, teaching, chemical engineering; dislikes: negative energy, cheating

TEACHING ASSISTANTS | TAs are here to help you learn and to help me to evaluate your learning. They will be answering questions on Canvas, grading tests and assignments, and holding office hours (if you cannot make that time, email them to see if you can work out an alternative appointment).

Shuyuan Wang



⌖: CHBE Building Room 517
Office hour: *see canvas*
✉: wshuyuan@student.ubc.ca

***Jingyi** in ≤ 20 words: Chinese; Expertise on oboe; Likes: meditation, music and cycling; Now self-learning piano*

Ibrahim Yousef

⌖: CHBE Building Room 517
Office hour: *see canvas*
✉: iy641@mail.ubc.ca

***Ibrahim** in ≤ 20 words: CHBE graduate student, Emirati born, organized, enjoys facing new challenges, likes action movies, soccer, positive attitude; dislikes winter, and rain*

Learning Goals

Where Are We Going?

I designed this course with specific goals in mind. *If you are willing and able to meet the requirements, by the end of this course, you will be able to:*

1. Specify proper manipulated variable (MV), controlled variable (CV) and disturbance variables (DV) for a complex control problem
2. Design a single loop PID control and tune it for effective setpoint tracking and disturbance rejection
3. Apply advanced control strategies including feedforward, ratio control, cascade control and multivariable control for practical challenging control problems
4. Properly pair MV and CV to minimize loop interactions for multi-loop multi-variable control systems
5. Design discrete PID controllers

What Resources Do You Need?

REQUIRED TEXBOOK: Seborg D. E., Mellichamp D. A., Edgar T. F., and Doyle F. J., "**Process Dynamics and Control**" 3rd ed., Wiley, NY (2011)

Other Suggested Readings:

- Smith C. A., Corripio A. B., "Principles and Practice of Automatic Process Control", 3rd ed., Wiley (2006)
- Marlin, T. E., "Process Control: Designing Processes and Control Systems for Dynamic Performance", 2nd ed., McGraw-Hill (2000)
- Ogata K., "Discrete-Time Control Systems" 2nd ed., Pearson (1995)

Technology-Enhanced Learning

Throughout this course, we'll be using various technologies to help us communicate, assess your learning, and keep organized. They are all accessible via a central platform: *Canvas*.

Canvas canvas.ubc.ca Keep organized here. Log in regularly and frequently for lecture notes, assignments, announcements, your grades, calendar, Piazza, **and links and instructions for all other resources**. Log in often using your CWL. *Free*.

Matlab We will use *Simulink package* to graphically simulate the control systems and run real-time simulations. Installation instructions can be found on the "**Getting Access to CHBE Computers**" page on canvas. As a UBC student, you can also download Matlab onto your computer at no cost: https://it.ubc.ca/news/matlab-free-ubc-students

ZOOM We may use zoom for some of the office hours.

LAPTOP/TABLET Exams are accessible on *Lockdown browser*. While using Lockdown browser, you won't be able to open any other program on your laptop/tablet. Download and install via this link. Watch this video to get a basic understanding. Student Quick Start Guide can also be accessed here.

How Will We Know If We Have Met Our Goals?*

Item	Date	% of Final Grade	Note
Assignments	*~ every 2 weeks*	*20*	*You will work with a partner*
Midterm	***Oct. 17***	*25*	***Two-staged** exam (see below for more)*
Final Exam	*TBA*	*35*	*Individual, **LockDown Browser** needed*
Term Project	***Dec. 9***	*20*	*group work*

** the marking scheme is intended to provide flexibility so that you can prioritize your health and still succeed.*

TUTORIALS
🕐 Thu 11 – 12
⌖ LIFE 2302

An essential part of the course. Some course materials may be covered during the tutorials. During each session, we will work on one or two conceptual multiple-choice questions as well as one or two long answer questions (*learn by doing approach*). These should help you deepen your understanding, and sharpen your problem-solving skills.

ASSIGNMENTS
Submitted on canvas
by ONE partner only

- You will work on your assignments **with a partner**. You may work with a different partner for different sets of assignment. You must obtain permission from the instructor for submitting your assignment individually, otherwise your grade will be scaled by a factor of 0.8. Permission is granted only under special/extenuating circumstances.
- Your submission, preferably a NEAT single PDF file, should be clear, legible, and reasonably organized (e.g. include page #s). Remember, *if it can't be read, it can't be graded*! Your assignment should have a cover page, clearly showing your names, student numbers, course number, assignment number, and due date. A sample cover page is available on canvas. **5% of the mark is always allocated to the overall professionalism**.
- Phone photos are NOT acceptable. You may use regular scanners or apps such as Simple Scanner, iScanner, Tiny Scanner, or Office Lens to create a PDF file of your work.
- In this course, YOU choose the submission date. Assignments that are submitted by the due date are eligible for 100 points. Otherwise, your mark is adjusted by a **lateness factor** of 0.8, 0.6, or 0.4 for submissions that are 1, 2, or 3 days after the due date, respectively. After 4 days, your assignment will still be accepted and receive feedback, but you are eligible for 0 points.

MIDTERM EXAM
In-person only

Two-Stage Exam. The exam is **open-book**, **open-notes** (only **hard copies**) and written in two stages. You will need LockDown browser to access the exam questions.

- In the first stage, you will write the exam individually, and answer MC questions on canvas and hand in **your handwritten answers** to long answer questions at the end of individual stage.
- After finishing the individual stage, you will be randomly assigned to groups of 4 or 5. Then you re-write the exam with your team; same questions but only 2/3 of the individual stage time limit.
- Once again you answer the MC questions on canvas (each member of the team must do so) and hand in just one handwritten answer to the long-answer questions. Make sure the names of all team members are on the cover page.
- Your exam grade will be **weighted 90% individual and 10% team**.

FINAL EXAM
In-person only

The final exam is **open-book**, **open-notes** (only **hard copies**) and written individually. You will need LockDown Browser to access exam questions. You will hand in ***your handwritten answers*** to long-answer questions at the end of the examination period.
You will be challenged to push beyond memorization of facts and to ***integrate*** and ***apply*** course material. Research shows greater long-term retention when people expect a final test in the future (Szpunar, McDermott, & Roediger, 2007). Therefore, to best prepare you to apply course material in future related courses and in your future career, the final exam is **cumulative**.

TERM PROJECT

You will work in groups of 2 or 3 to design an advanced control system for your choice of a common unit operation in a chemical or biochemical process. You will also need to create a working Simulink file and tune your controllers. Two options for submitting your report: written technical report or a technical video report (maximum length: 15 min). More details will be posted on canvas.

Tips for Success

Making Choices to Learn

I believe you can master this course material at a high level, if you consistently choose to put in the effort required to do so. Here's a rough guideline for how much time you should be spending on this (and each of your) courses this year: **2-3 hours out of class for every 1 hour in class.** Note that some people will need more time than this.

WHAT CAN YOU DO *IN CLASS*?

- ~~**Take**~~ **Make notes** about what's being discussed. Avoid just copying exactly what you see on the slides; you'll have access to lecture slides.
- **Keep focused**. For example, avoid opening other programs or browser tabs if it will be a distraction for you. Get adequate sleep and nutrition. Be present!
- **Actively participate in demonstrations and discussions; thoughtfully answer questions**. The point of all of these is to help you think about the material so you can master it and make it meaningful for yourself.
- **Ask questions**, lots of it. Be brave! If you would like clarification or are interested in how a concept connects or applies in some way… ask!

WHAT CAN YOU DO DURING THOSE 6-9 HOURS PER WEEK YOU SPEND ON THIS COURSE *OUTSIDE CLASS?*

- **Add to your class notes**. Fill in any missing gaps before you forget. Integrate your notes with the slides posted online. *Build your notes so you can use them to study later.*
- **Actively read the text.** Try the examples on your own. Take every chance available to test yourself. Attempt end-of-chapter problems; after each chapter, close your book and write down the main points you can remember, then go back and check them against the learning objectives.
- **Allocate time to work on assignments with your partner**. Solve all questions yourself then try explaining and teaching about half of questions to your partner. *Teaching is the best way to learn!*
- **Come to office hours and post questions on Canvas.** Get to know your Leaders in Learning, ask questions about course material, and find out more about chemical and biological engineering!

Diversity Statement

The Department of Chemical and Biological Engineering adheres to the philosophy that a thriving intellectual and educational environment is enriched and enhanced by diversity along a number of dimensions, including race, ethnicity and national origins, gender and gender identity, sexuality, class, religion, Indigeneity, and neurodiversity. We support an **inclusive learning environment** where diverse perspectives, including those of underrepresented populations, are recognized, respected and seen as source of strength.

My intent is that ALL of you are well served by this course and your learning needs are addressed both in and out of class. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups.

COVID-19

MASKS, VACCINE & HEALTH CONSIDERATIONS The University is taking guidance from the BC Public Health Office. The information in this syllabus is based on the current public health orders at the time this syllabus was created. Should this information change, we will adapt accordingly. For the most up to date information, please refer to the UBC COVID-19 website.

- **If sick, stay home** If you feel unwell, you are strongly encouraged to stay home. Please do your daily health self-assessment for key Covid-19 symptoms on UBC Safe Vancouver App. Rest assured that all course material will be available on canvas.
- **Masks** UBC no longer requires its community members to wear non-medical masks, but continues to recommend that masks be worn in indoor public spaces.
- **Vaccine** UBC strongly recommends all community members get vaccinated and if eligible, receive their booster dose, which minimizes the severity of illness and transmission to others.

Expectations and Course Policies

What We Expect from You

ATTEND CLASS Please come to every class prepared to actively participate in your learning. Bring a pen and some paper. *If you must miss class,* you are responsible for obtaining missed notes and important announcements.

PARTICIPATE Success in this class depends upon your active participation. **I will often pose questions to get you thinking and help you develop a deeper understanding of the material**. You should also feel free to **ask questions** (lots of them!). Class time is designed to mix lecture-based explanations with lots of step-by-step worked examples to help you develop engineering problem-solving skill.

TREAT OTHERS RESPECTFULLY You are expected to treat all your classmates, the teaching team, and yourself with respect at all times, both in and out of the classroom, face-to-face, screen-to-screen and in writing (e.g., on email). This includes arriving to live class on time and minimizing distractions for other students.

ACT ETHICALLY You are responsible for your own learning. Cheating of any kind will **not** be tolerated, including copying other's work. See the syllabus section on *Ethical Conduct* for more information.

WRITE ALL MIDTERM TESTS. Presence at tests is expected. In most cases, if you miss a *test* you will receive a zero. There will be *no* make-up tests. **Exceptions:** In documented cases of varsity athletic commitments (as per UBC policy), severe illness or other extenuating circumstance verified by UBC Academic Advising as warranting Concession, or a conflict with a major religious holiday, obtain appropriate official documentation. *If approved, the worth of the missed exam will be added to the final exam*.

WRITE THE FINAL EXAM Presence at the final exam is ***mandatory***. If you absolutely must miss the final exam due to an extenuating circumstance like severe illness, you must apply for Academic Concession through Engineering Students Services. If you have 3 or more exams scheduled to *start and finish* within a 24-hour period you may request to write the second exam on a different day. However, you must give the instructor of the second exam one-month notice.

SHARE CONSTRUCTIVE FEEDBACK We invite you to share your ideas and suggestions with us, particularly about things we are able to change, and be open to working together to make this course a positive experience for all of us. Roughly in the middle of the term I will send out a **mid-course feedback** form to collect your anonymous comments.

What You Can Expect from Us

BE AVAILABLE We are here to help you in your choice to succeed. Visiting us in person is typically more effective than email for clearing up questions. If office hours absolutely cannot work for you, please email us **a few** time and day **options** to make an appointment. Because of our class size, there may be limits on the number of appointments possible.

POST MATERIALS AND GRADES ONLINE PowerPoint slides, recordings, handouts, and other teaching materials will be available on canvas. Assignments will be graded by the TAs and grades will be posted on course website, **10 days after the due date, at the latest**. If you have questions about your grade, please see the grading TA first and if your issue is not resolved then contact the instructor.

ARRANGE FOR AND PROVIDE FEEDBACK Your peers will be an important source of feedback throughout this course. In addition, we will attempt to provide you with feedback on learning appraisals as promptly and as with as much detail as possible, given the size of our class. *See us for more details*.

ACT RESPECTFULLY & ETHICALLY At all times, we aim to treat each of you with respect, and to make all course decisions with the highest standard of ethics in mind. If you feel you are being treated unfairly or disrespected by us or a classmate, we invite you to talk to us so we can sort out the issue together. To be clear: *such a discussion would not impact your grade*.

Ethical Conduct

The academic enterprise is founded on **honesty**, **civility**, and **integrity**. As members of this enterprise, all of us are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means **submitting only original work and acknowledging all sources of information or ideas, and attributing them to others** as required. This also means we should not cheat, copy, or mislead others about what is our work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore severe consequences arise, and harsh sanctions are imposed. **Incidences of plagiarism or cheating [will] result in a mark of zero on the assignment or exam and more serious consequences may apply**. **They will also be reported to the Dean's office**. Careful records are kept in order to monitor and prevent recurrences.

For details on pertinent University policies and procedures, please see Chapter 5 in the UBC Calendar.

From http://vpacademic.ubc.ca/integrity/ubc-regulation-on-plagiarism/:

CHEATING This includes but is not limited to dishonest or attempted dishonest conduct at tests or examinations.

PLAGIARISM This includes but is not limited to the presentation or submission of the work of another person, without citation or credits, as the student's own work.

IRON PIN Some of you may also be an Iron Pin Founder or Supporter.[1] It is anticipated that you will uphold the UBC Engineering Code of Ethics. For the full code, please see: http://ubcengineers.ca/eus/traditions/ironpin/

P. ENG You may also wish to become a **Professional Engineer** in the future. Therefore, you should also remember Principle 7 of EGBC's Code of Ethics which reads:

> "Members and licensees shall act at all times with fairness, courtesy and **good faith** to their associates, employers, employees and clients… They shall uphold the values of **truth**, **honesty** and **trustworthiness** … In keeping with these basic tenets, members and licensees shall: conduct themselves with fairness, courtesy and good faith towards clients, colleagues and others [and] **give credit where it is due**..."[2]
>
> The Code of Ethics Guidelines further explains "Whenever possible, members should **acknowledge contributions of others** for work with which the member is associated and name those who were individually responsible for designs, inventions, writings or other accomplishments."[3]

Visit the Learning Commons' guide to academic integrity UBC offers an online guide to preventing unintentional plagiarism and organizing your writing. Visit http://learningcommons.ubc.ca/resource-guides/avoiding-plagiarism/

Why is Academic Misconduct Treated So Harshly?

Some people don't feel like cheating on a test or taking a sentence or two from someone else's paper without citing it is a big deal. Here's a bit of insight into why we care so much. In the academic community – a community of which you are now a part – **we deal in ideas**. That's our currency, our way of advancing knowledge. By representing others' ideas in an honest way, we are (1) respecting the rules of this academic community, and (2) showcasing how our own novel ideas are distinct from but relate to their ideas. ***Welcome to the academic community. You are expected to act honestly and ethically, just like the rest of us.***

1. UBC Engineering Undergraduate Society. http://ubcengineers.ca/eus/traditions/ironpin/ Retrieved Jan 2/2015.
2. Association of Professional Engineers and Geoscientists of British Columbia. Appendix C – Code of Ethics Guidelines. http://www.apeg.bc.ca/enforcement/documents/codeofethicsguidelines.pdf Retrieved Dec 6/2012.
3. Ibid, Retrieved Dec 6/2012.

Course Outline

Subjects	Relevant Textbook Chapter(s)	
Quick Review • What is control engineering? • Developing dynamic models (theoretical, from process data) • Feedback controller design and tuning	Chapters 1-12	[weeks 1-2]
Feedforward and Ratio Control • Design based on steady-state models • Design based on dynamic models • Ratio controller design and simulation	Chapter 15	[weeks 3-4]
Enhanced Single-Loop Control Strategy • Cascade Control Design and Tuning • Time-Delay Compensation • Selective Control • Nonlinear Control Systems • Inferential Control • Adaptive Control	Chapter 16	[weeks 5-8]
Multiple Input Multiple Output Systems • Process and Control Loop Interactions • Effective Pairing of CVs and MVs • Tuning of Multiloop PID Control Systems • Decoupling Strategies • Plant-wide Control	Chapters 18	[weeks 9-11]
Digital Control • Sampling • Filters • z-transform • Discrete PID Controller Design	Chapter 17	[weeks 12-13]

Resources to Consider

YOUR SUCCESS IS IMPORTANT TO US. Reach out and ask for help if you need it. University students often encounter setbacks from time to time. *It is completely normal*.
If you run into difficulties and need assistance, I encourage you to contact me by email or during my office hours. I will do my best to support you during the term, including identifying concerns I may have about your academic progress or wellbeing through *Early Alert* to connect you with specialized advisors who offer confidential support and assistance to help you get back on track to success. Early Alert does not affect your academic record. For more information, visit earlyalert.ubc.ca

Take Care of Yourself. For information about addressing mental or physical health concerns, including *counseling services* and more, visit https://students.ubc.ca/health

Scholarships & Bursaries UBC and its donors provide a range of financial support options to reward your academic and extracurricular achievements and meet your financial needs. Visit https://students.ubc.ca/enrolment/finances/awards-scholarships-bursaries

Centre for Writing and Scholarly Communication CWSC provides *consultations*, *workshops* and *other resources* for UBC Vancouver community members with varying levels of academic English proficiency. A writing consultation is a personalized conversation about your work. Find out more at https://writing.library.ubc.ca/

Chapman Learning Commons is UBC's online hub for study and research support. This interactive website provides you with a wealth of academic resources, from *tutoring* and *workshops* to study groups and online technology tools. It also offers plenty of information on a variety of academic topics, and links to nearly all of the academic resources offered at UBC. *Make the Learning Commons your first stop for all things academic!* http://learningcommons.ubc.ca

APSC Student Clubs & Affinity Groups Find APSC student, faculty and staff-led organizations and initiatives that support equity deserving groups. Opportunities for allies to engage. Find out more at https://apsc.ubc.ca/EDI.I/get-engaged

First Nations Longhouse Serves as a "home away from home," as well as an academic, social, spiritual, and cultural hub for Indigenous students attending UBC. Find out more at https://indigenous.ubc.ca/longhouse/

Sexual Assault Support Centre SASC is committed to the education, support, and empowerment of people of all genders who are survivors of sexualized violence, as well as their friends and family. For more information, visit https://www.amssasc.ca/

Physical or Learning Disabilities UBC is committed to equal opportunity in education for all students and so are we! If you have a documented disability that affects your learning in the classroom or your performance on tests or exams, please contact **Center for Accessibility** in Brock Hall 1203, 1874 East Mall, Contact: 604.822.5844, www.students.ubc.ca/access

Let's work together to make this course a positive experience for all of us.

Land Acknowledgement
UBC's Point Grey Campus is located on the *traditional*, *ancestral*, and *unceded* territory of the xʷməθkʷəy̓əm (Musqueam) people. The land it is situated on, has always been a place of learning for the Musqueam people, who for millennia have passed on their culture, history, and traditions from one generation to the next on this site.

ACKNOWLEDGEMENTS AND COPYRIGHT Thanks to all of my previous students and Teaching Assistants for their helpful suggestions and experiences, which have influenced the design of this course. In addition, this course and syllabus design and formatting were informed by those from similar courses designed by J. Verrett (UBC), P. Ostafichuck et al. (UBC), H. Trajano (UBC), D. Posarac (UBC), P. Englezos (UBC), C. J. Lim (UBC), C. Rideout (UBC), and C. D. Rawn (UBC).

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