Welcome to EngrD 2190 - Chemical Process Design & Analysis

Professor T. M. Duncan

The Robert Frederick Smith School
of Chemical & Biomolecular Engineering

Today:
Course Content
Course Objectives
Course Organization

Chemical Engineering Core Concepts

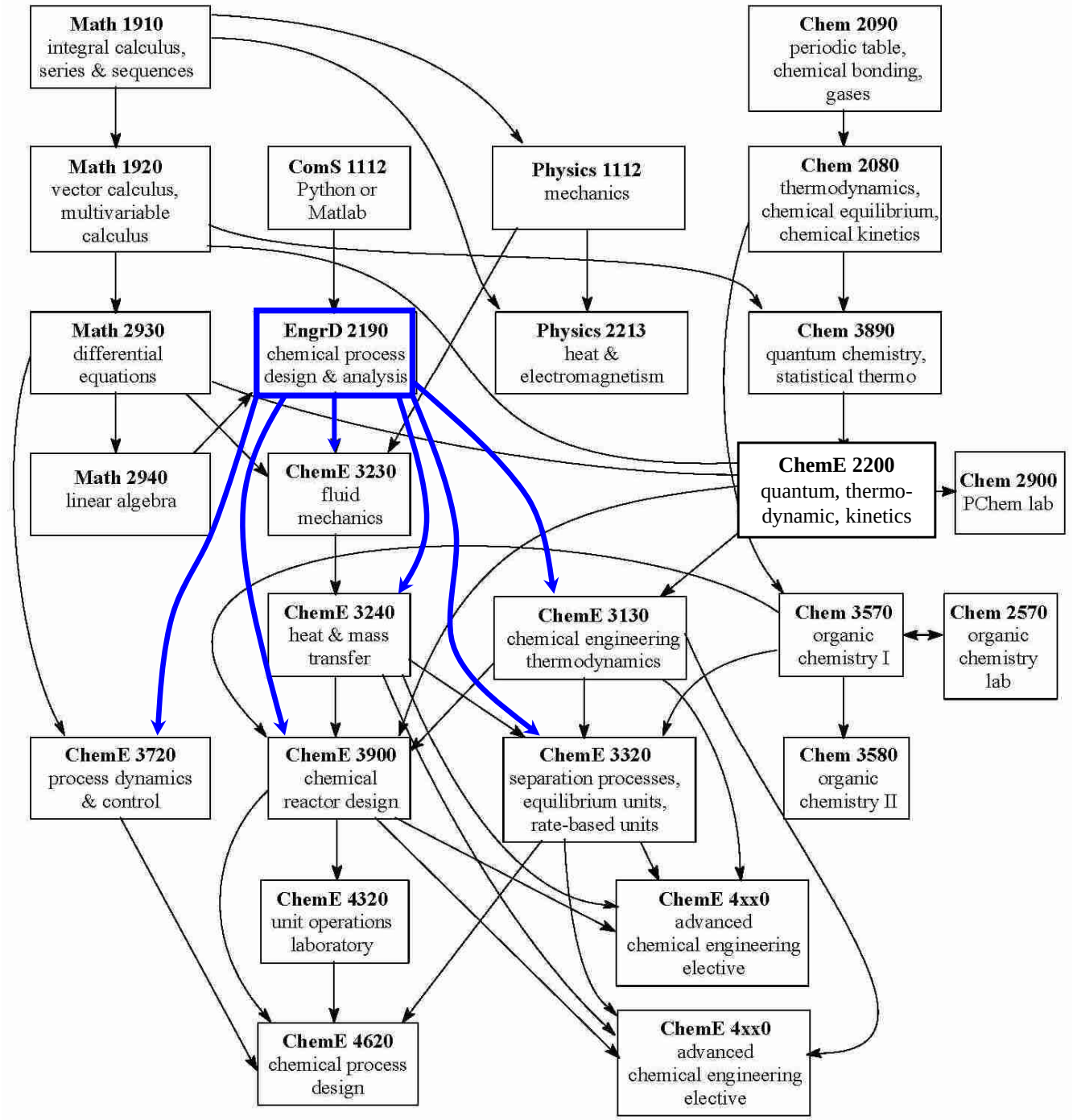
Mass, Energy, and Economic Balances

Transport Phenomena - Heat & Mass Transfer

Chemical Thermodynamics

Chemical Kinetics

The Chemical Engineering Curriculum



The Progression of Topics in the Chemical Engineering Core Curriculum

Mathematics & Science
- Calculus
- Physics
- Chemistry
- Biology

Fundamentals
Freshman and
Sophomore Years

Engineering Sciences
- Mass & Energy Balances
- Fluid Mechanics
- Chemical Thermodynamics
- Chemical Kinetics

Engineering Tools
Sophomore and
Junior Years

Chemical Process Units
- Heat & Mass Transfer
- Separation Processes
- Chemical Reactor Design
- Unit Operations Laboratory

Building Blocks of Chemical Processes
Junior Year

Chemical Processes
- Process Design
- Optimization & Control

Chemical Processes
Senior Year

EngrD 2190 Prerequisites

- Freshman Engineering Curriculum: an EngrI, Math 1910, Math 1920, Phys 1112, Intro to CS, and a year of general chemistry.

- EngrD 2190 cannot be taken concurrently with EngrI 1120.

- If you intend to affiliate with chemical engineering, you should also be enrolled in Chem 3890.

“The scientist describes what is.
The engineer creates what never was.”

Theordore von Karman (1881-1963)

EngrD 2190 Theme

Chemical and Biomolecular Engineers design and analyze processes based on chemical and biomolecular change.

Chemical and Biomolecular Engineers design and analyze processes based on chemical and biomolecular change.

Chemical and Biomolecular Engineers design and analyze processes and products based on chemical and biomolecular change.

A Petrochemical Refinery

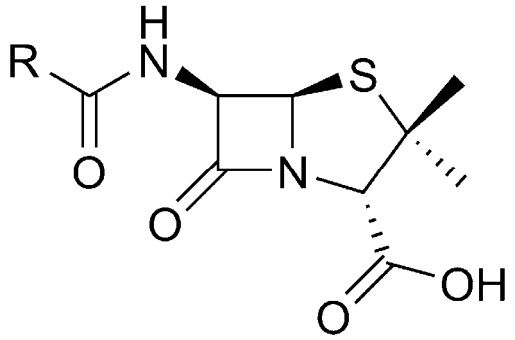
A Petrochemical Refinery at Night

A Distillation Column at Night

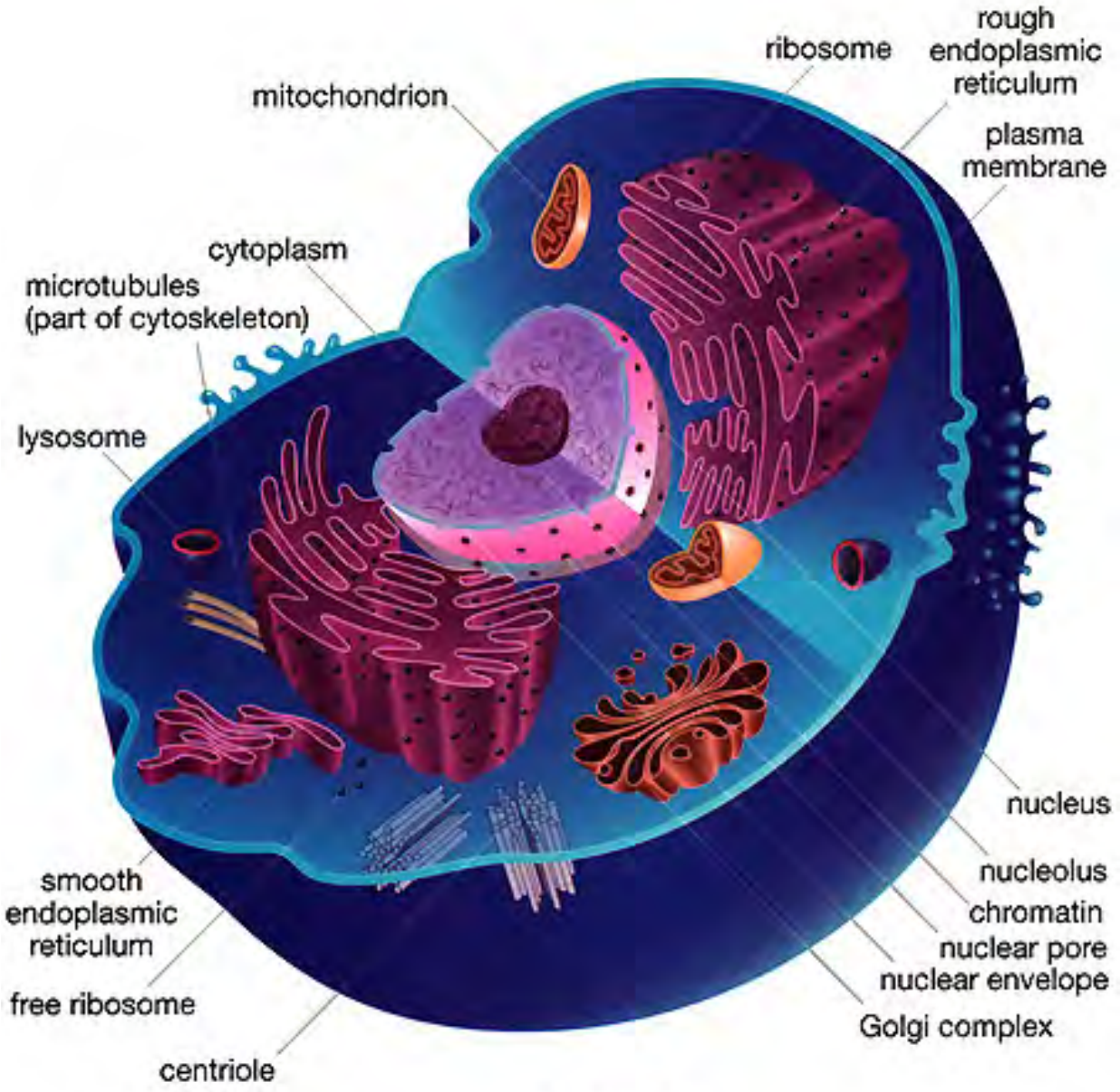
Traditional Chemical Engineering

bulk chemicals and processes

- Petroleum products - fuels, oils, chemicals
- Polymers - plastics, synthetic elastics, synthetic fibers
- Fertilizers - ammonia, phosphates, nitrates
- Energy - power plants
- Antibiotics - penicillin, polio vaccine, covid vaccine



An Animal Cell is a Chemical Processing System

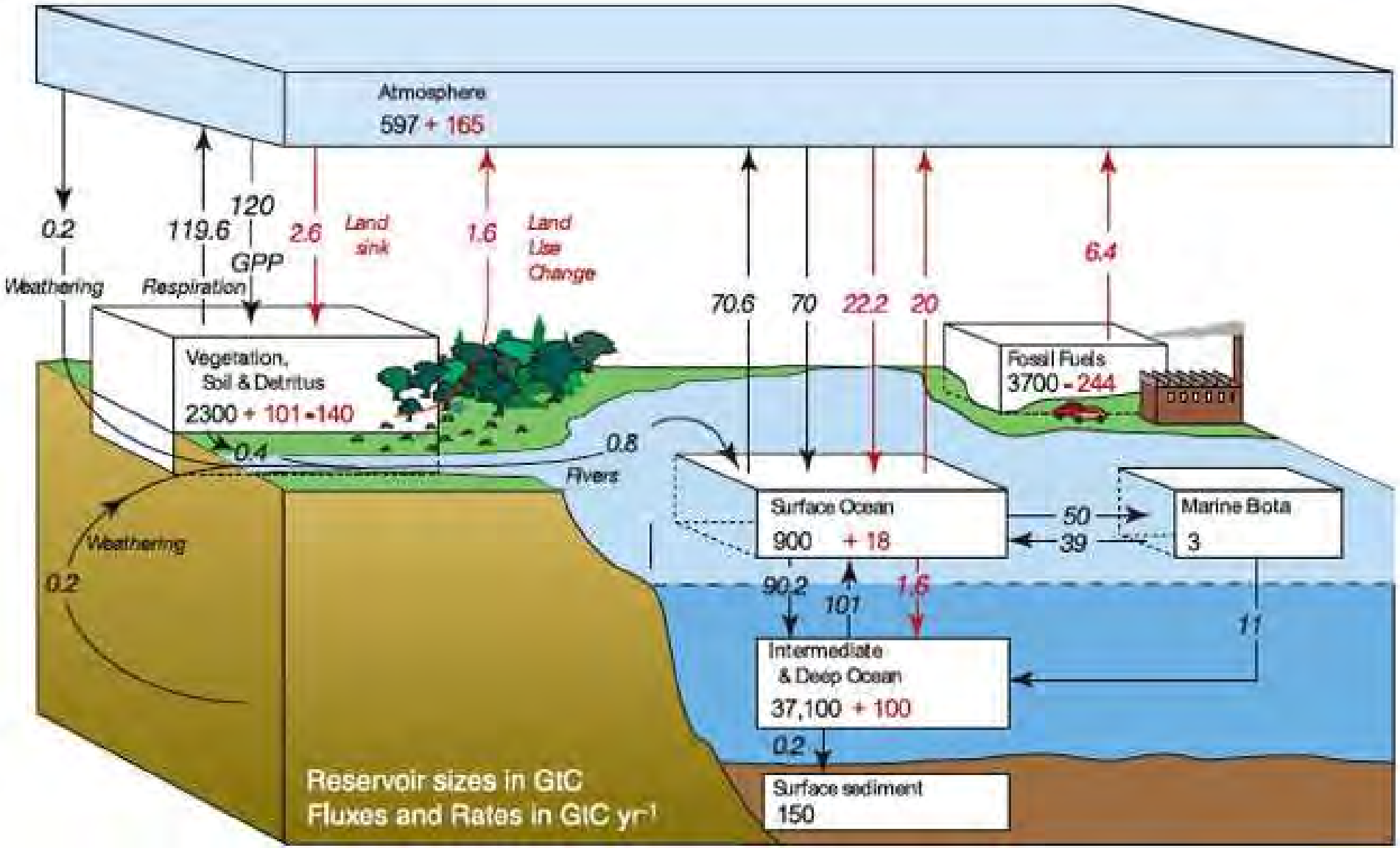


BIOLOGY: Life on Earth, Fifth Edition
by Teresa Audesirk and Gerald Audesirk

Lab on a Chip

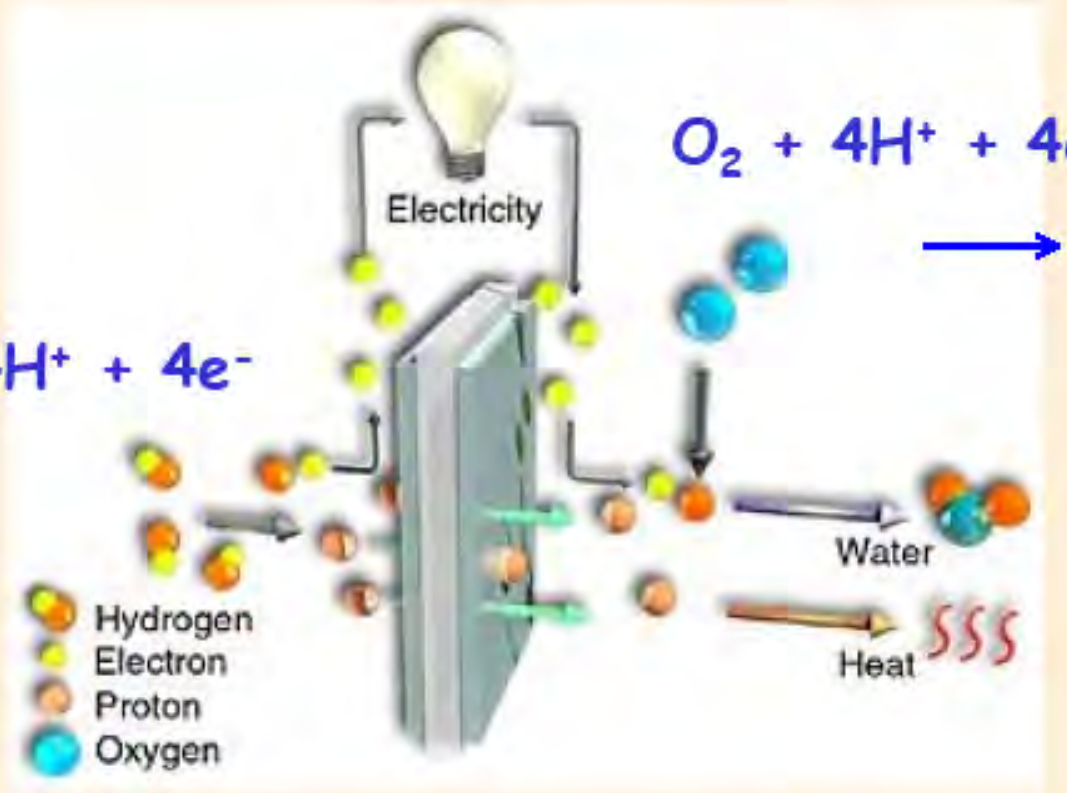

Micro- & nano-fluidic research for chemistry, physics, biology, & bioengineering
www.rsc.org/loc
Volume 11 | Number 10 | 21 May 2011 | Pages 1701–1840
ISSN 1473-0197
RSC Publishing
PAPER
Ram et al.
Microfluidic chemostat and turbidostat with flow rate, oxygen, and temperature control for dynamic continuous culture

The Global Carbon Cycle is a Chemical Process System



A Hydrogen-Oxygen Electrochemical Cell

Proton Exchange Membrane (PEM) Fuel Cell



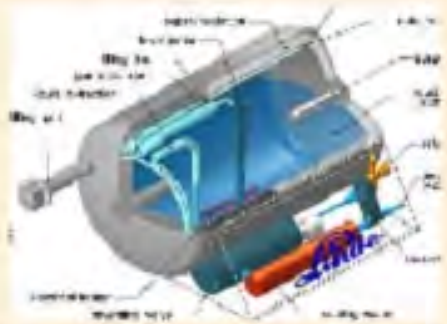
$2H_2 + O_2 \longrightarrow 2H_2O$

SRS

savannah river site

How to Store Hydrogen Fuel?

- Cryogenic Liquid Storage (-253 C)
- Compressed Gas (5,000-10,000 psi)
- Solid-State Storage
  - Intermetallic Hydrides
  - Complex Hydrides
  - Carbon or other Advanced Materials



Liquid Hydrogen Storage

Compressed Storage

Metal Hydride Powder

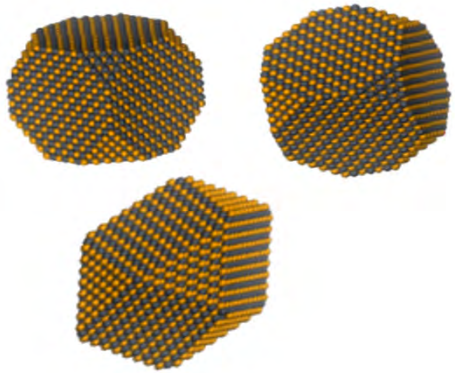
Carbon Nanotube

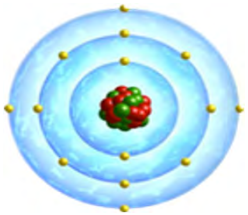
SRS

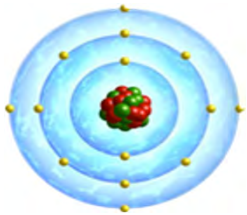
savannah river site

Designing ‘Elements’ for Photovoltaic Panels

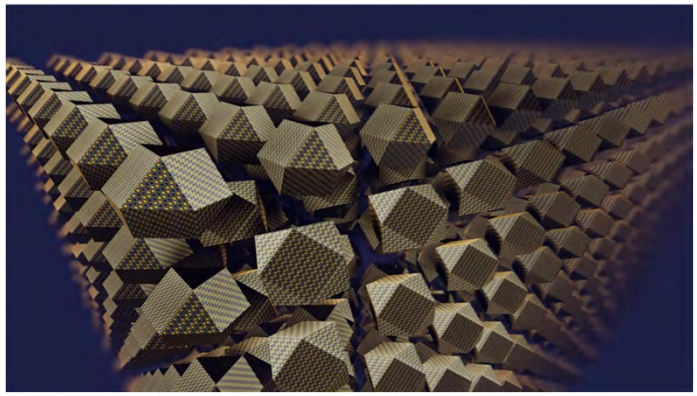
building blocks

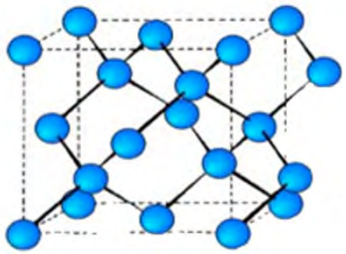






crystals

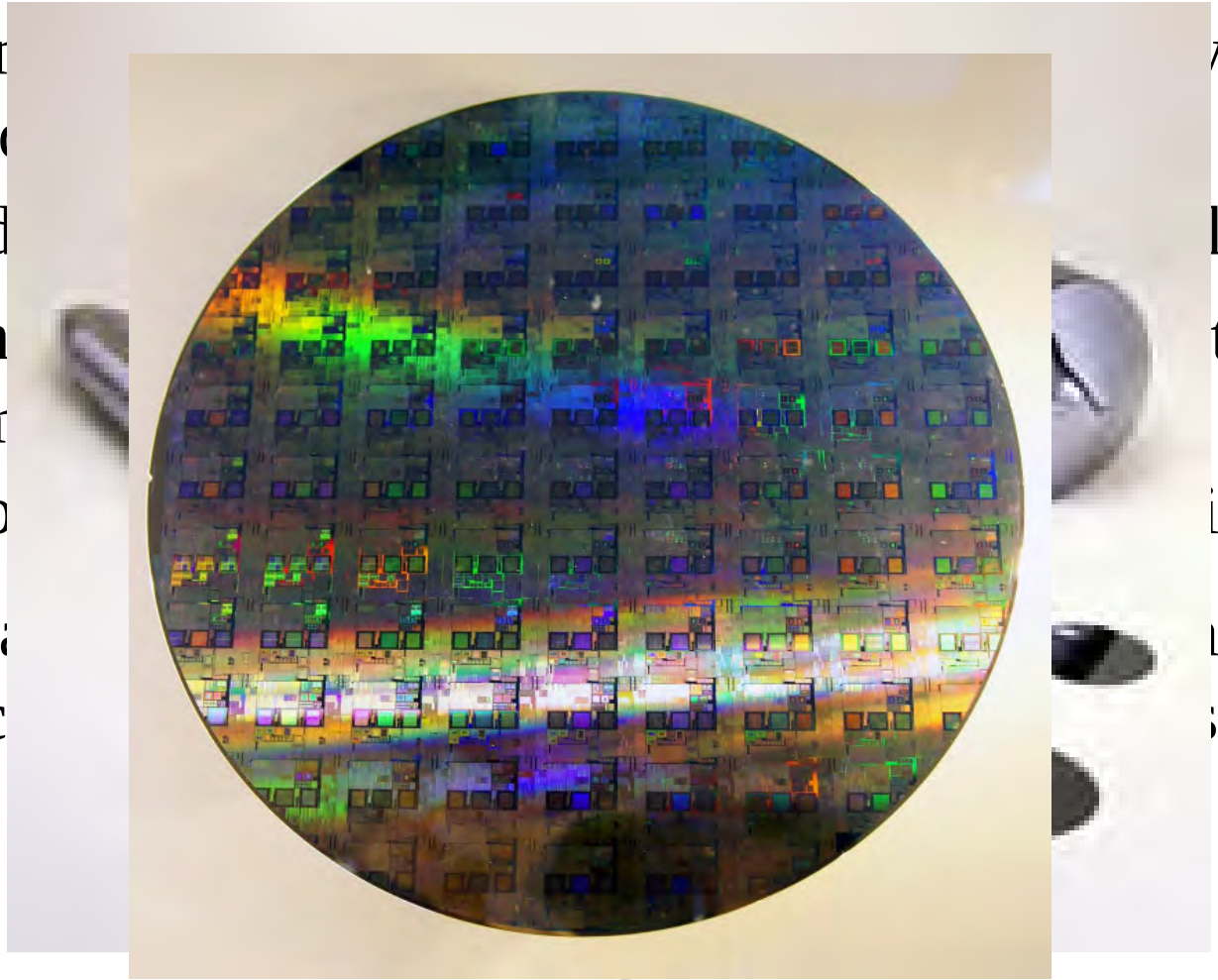




Contemporary Chemical Engineering

specialty chemicals and processes

- Electronics - semiconductors, photolithographic coatings, device encapsulation
- Biochem ymes, mon
- Biomed livery
- Nanoch tection, chem
- Pollutio imization
- Sustaina lysis, recyc
- Energy



Chemical Engineering Core Concepts

Mass, Energy, and Economic Balances

Transport Phenomena - Heat & Mass Transfer

Chemical Thermodynamics

Chemical Kinetics

EngrD 2190 - Chemical Process Design & Analysis

Course Objectives

Overall

To introduce chemical process design and analysis.

Engineering Skills

To design a chemical or biomolecular process by the following steps:

define the real problem
generate ideas
create a design
analyze the design.

To analyze a chemical or biomolecular process with three methods:

mathematical modeling
graphical modeling
dimensional analysis / dynamic scaling.

Analyzing Designs

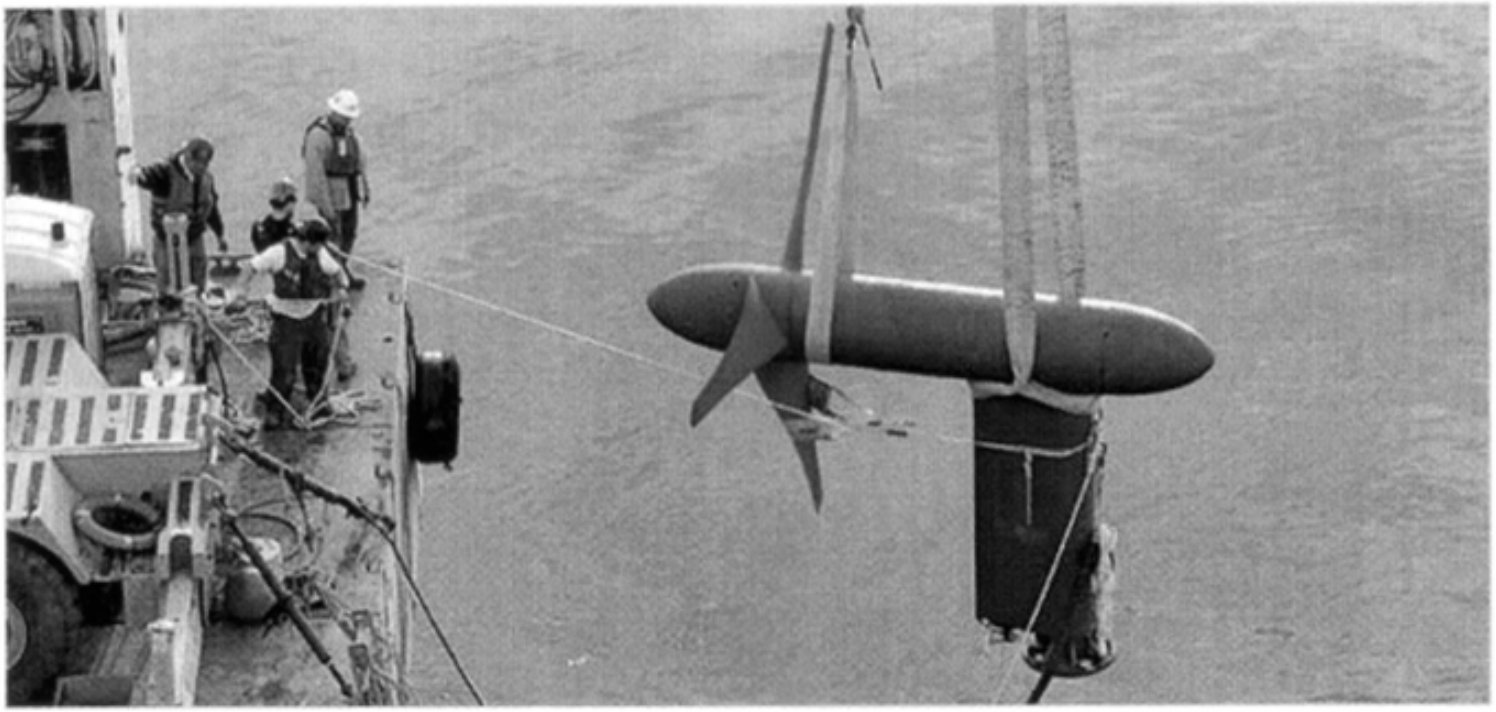
Analyzing Designs

East River Fights Bid to Harness Its Currents for Electricity

By Anthony DePalma

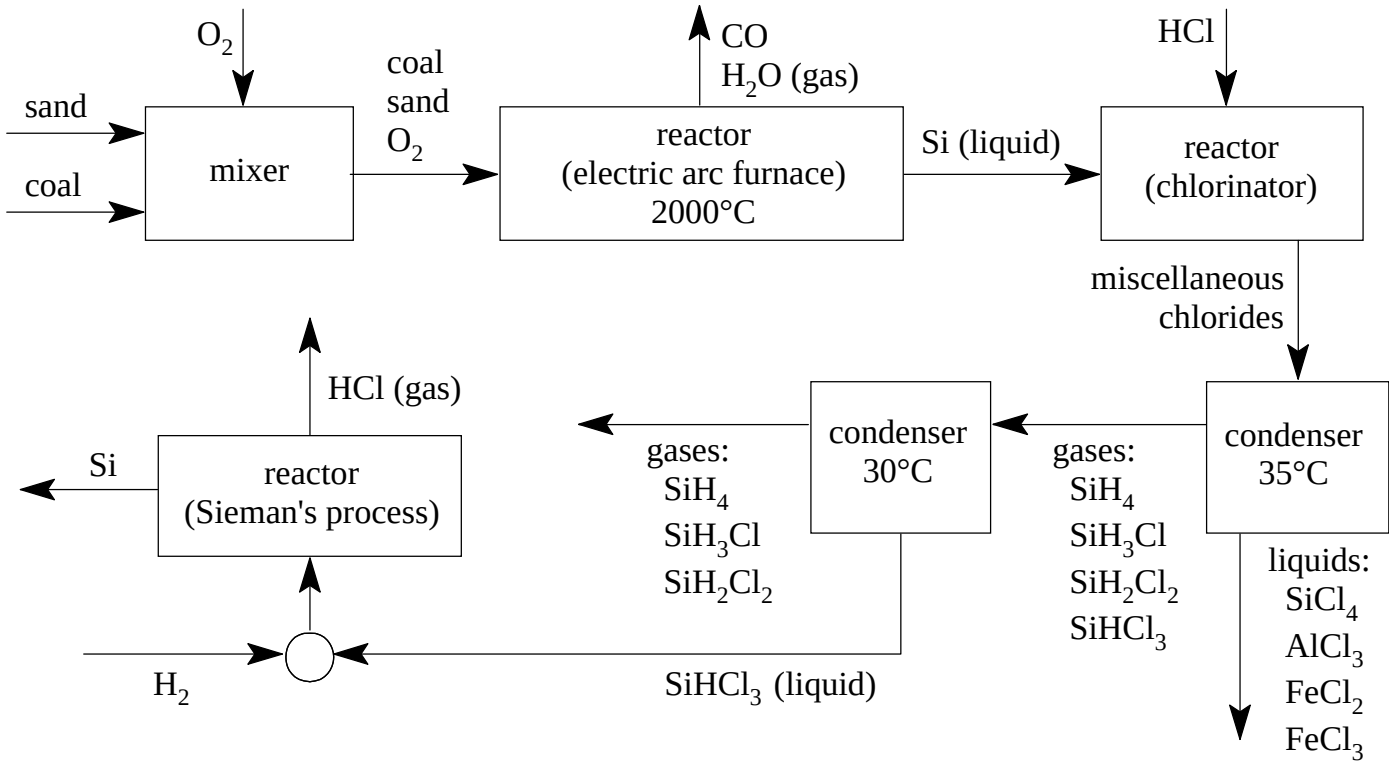
NY Times - August 13, 2007

"The only way for us to learn is to get the turbines into the water and start breaking them," said Trey Taylor, the habitually optimistic founder of Verdant Power.



Mathematical Modeling

"To subordinate the phenomena of nature to the laws of mathematics." Isaac Newton



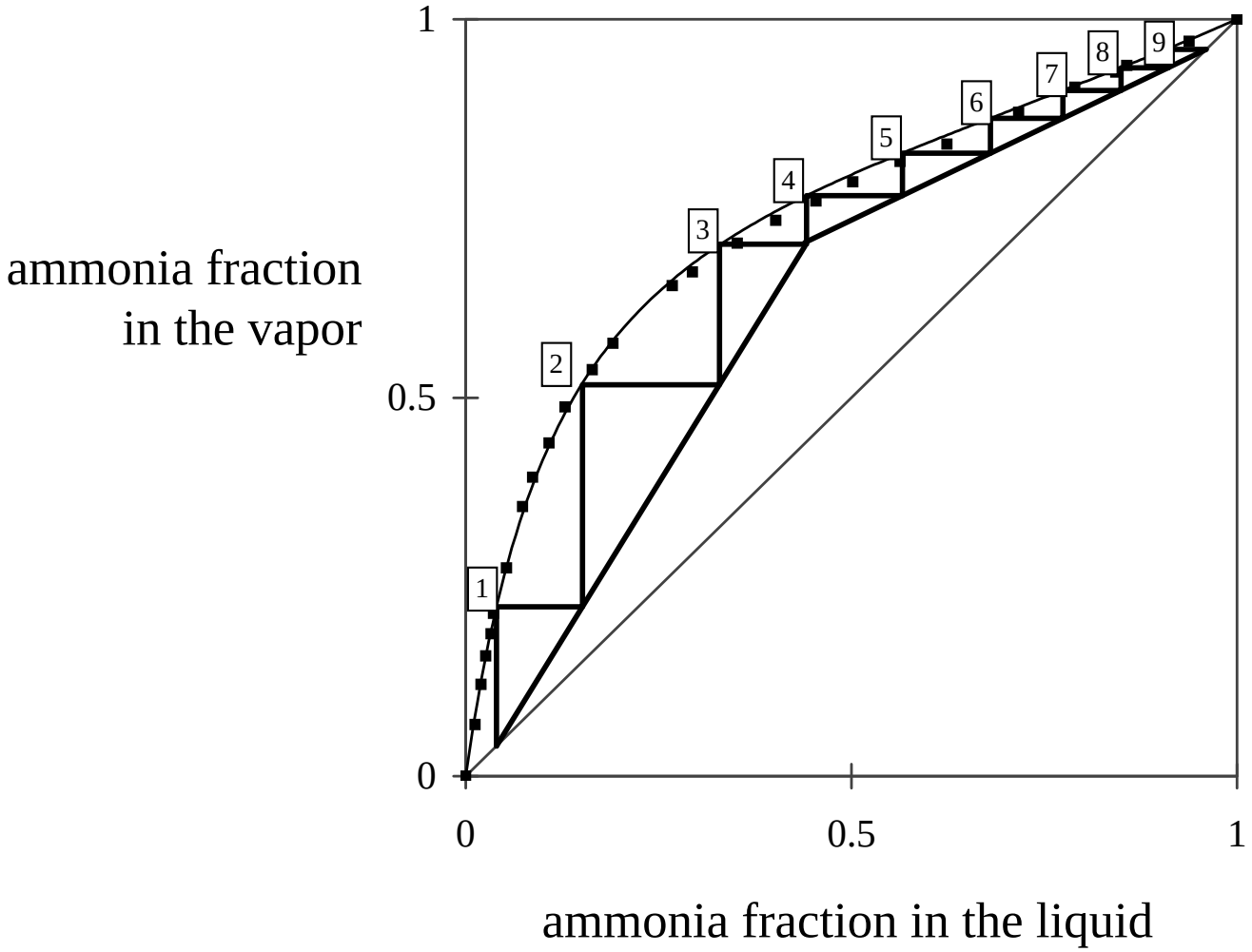
Rate of Silicon Production = ...

Energy Consumption = ...

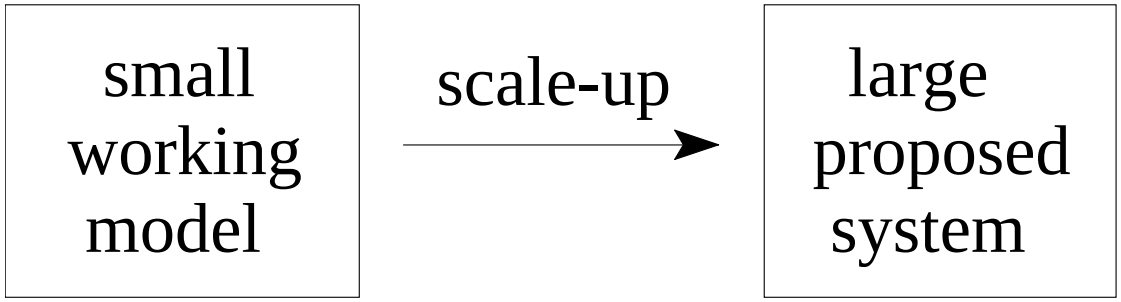
Return on Investment = ...

Graphical Analysis

Example: Mixtures of Water and Ammonia



Dynamic Scaling
(Dimensional Analysis)



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Learning Skills

To know your natural learning style, to recognize the learning style of a presentation or document, and to translate into your preferred learning style. For example, visual vs. verbal, active vs. reflective.

3 x 5 Card

Name: David Caughey

Name spelled foe-NET-ick-lee: DAY-vid KOY

Nickname: Dave

Probable Major: ChemE

Academic Advisor: Professor Bland

EngrD 2190 - Chemical Process Design & Analysis - Fall 2025

Instructors: T. M. Duncan 344A Olin Hall 255-8715 or tmd10@cornell.edu
Office Hours: Monday noon – 2:00 p.m. or by appointment
M. C. Kowal 248A Olin Hall 255-8611 or mcl238@cornell.edu
Office Hours: Thursday 1:30 – 3:30 p.m.

Teaching Assistants: Office Hours: 7:30-9:30 p.m. Sunday (245 Olin) and Wednesday (128 Olin)

Preston Holopeter (grad) ph443@cornell.edu

Lara Capellino	lc834@cornell.edu	Angel Liang	al799@cornell.edu
James Chen	jzc28@cornell.edu	Johnny Lowry	jjl326@cornell.edu
Kong Chen	kc823@cornell.edu	Sean McInnis	scm254@cornell.edu
Liam Gillespie	lgg49@cornell.edu	Amy Wu	asw254@cornell.edu

Text: *Chemical Engineering Design and Analysis - An Introduction, 2nd edition*
T. M. Duncan and J. A. Reimer, Cambridge University Press (2019).

Schedule: Lectures: Mon, Wed, and Fri 9:05 - 9:55 a.m. 245 Olin Hall
Calculation Session: Wed 2:30 - 4:25 p.m. 128 and 245 Olin Hall

Homework: There will be 8 to 10 homework assignments, due Friday at noon. Homework may be submitted before lecture Friday or delivered to the EngrD 2190 mailbox. Late work will not be graded. Solutions will be posted and will be discussed in the calculation section.

Experiential Modules: There will be 4 experiential modules which will meet at times outside of lectures and calculation sessions. Lectures will be cancelled these weeks.

Examinations: There will be three preliminary examinations:

Tuesday, October 7, 7:30 - 9:30 p.m.	128 and 245 Olin Hall
Thursday, October 30, 7:30 - 9:30 p.m.	128 and 245 Olin Hall
Tuesday, November 25, 7:30 - 9:30 p.m.	128 and 245 Olin Hall

No make-up exams are scheduled. A student that misses an exam without an official university excuse or medical excuse will be penalized. A student excused from a preliminary exam will take a make-up exam during the last session of final exams, Saturday, December 20, 9:00-11:30 a.m.

Final Exam: *to be scheduled by the University Registrar* 128 and 245 Olin Hall

Grading: The final grade will reflect performance on homework, preliminary exams, professional participation, and the final exam, with the following weighting:

Homework	20%
Experiential Modules	10%
Preliminary Examinations	45%
Final Examination	20%
Professional Participation	5%

Information On Line: course homepage: https://duncan.cbe.cornell.edu/cheme2190/
Textbook errata and blank graphs: https://duncan.cbe.cornell.edu/Graphs/

Academic Integrity: http://theuniversityfaculty.cornell.edu/academic-integrity/guidelines-for-students/
It is a violation of academic integrity to submit material that you did not create. It is a violation to be compensated for intellectual property you obtained from this course. For example, you are forbidden to trade course material for a subscription to CourseHero or StuDocu.

Inclusivity: We are committed to an inclusive and supportive learning environment in this course. Individual differences are recognized and respected. We will venerate all thoughtful questions and comments. We will endeavor to learn differences in teaching and learning styles and how these differences enhance team-based design. We welcome suggestions to sustain and improve an inclusive and supportive environment.

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Liam Gillespie	guh-LES-pee	Amy Wu	asw254@cornell.edu

ChemE
Seniors

Course Information – Text, Schedule, and Homework

First 5 minutes are key!

78$ at Amazon

Late? Use back door.

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In the hallway on the first floor,
directly across from 111 Olin Hall,
next to the loading dock.

Homework protocols to be announced later.

Course Information – Experiential Modules

Experiential Modules: There will be 4 experiential modules which will meet at times outside of lectures and calculation sessions. Lectures will be cancelled these weeks.

Heat Exchanger – Energy Balance

Start-Up Corporate Competition – Process Economics

Multi-Stage Distillation – Graphical Modeling

Dimensional Analysis of Walking and Running

Course Information – Exams

Examinations: There will be three preliminary examinations:

Tuesday, October 7, 7:30 - 9:30 p.m.	128 and 245 Olin Hall	6 weeks hence
Thursday, October 30, 7:30 - 9:30 p.m.	128 and 245 Olin Hall	3 weeks later
Tuesday, November 25, 7:30 - 9:30 p.m.	128 and 245 Olin Hall	4 weeks later

No make-up exams are scheduled. A student that misses an exam without an official university excuse or medical excuse will be penalized. A student excused from a preliminary exam will take a make-up exam during the last session of final exams, Saturday, December 20, 9:00-11:30 a.m.

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Course Information

NOT Canvas

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Textbook errata and blank graphs: https://duncan.cbe.cornell.edu/Graphs/

Academic Integrity: http://theuniversityfaculty.cornell.edu/academic-integrity/guidelines-for-students/
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Read "Frequently Asked Questions" and
"Advice from EngrD 2190 Sophomores - Fall 2023"
"Advice from EngrD 2190 Sophomores - Fall 2022"
"Advice from EngrD 2190 Sophomores - Fall 2021"
"Advice from EngrD 2190 Sophomores - Fall 2019"
"Advice from EngrD 2190 Sophomores - Fall 2018" and
"Advice from EngrD 2190 Sophomores - Fall 2017"

Course Objectives

Overall

To introduce chemical process design and analysis.

Engineering Skills

To design a chemical or biomolecular process by the following steps:

- define the real problem
- generate ideas
- create a design
- analyze the design.

To analyze a chemical or biomolecular process with three methods:

- mathematical modeling
- graphical modeling
- dimensional analysis / dynamic scaling.

Learning Skills

To know your natural learning style, to recognize the learning style of a presentation or document, and to translate into your preferred learning style. For example, visual vs. verbal, active vs. reflective.

To gain teamwork skills for design, analysis and learning.

Professional Perspective

To examine contemporary applications such as microchemical devices, hydrogen fuel cells, global warming, drug delivery, green chemistry, sustainable technology, cellular metabolic pathways, polymer design for photolithography and bone replacement, and soil remediation.

To examine different roles such as research and development, design, operations, economics, and policy making.

Course Objectives

AI Is Wrecking an Already Fragile Job Market for College Graduates.

Wall Street Journal, July 29, 2025

"Companies have long leaned on entry-level workers to do grunt work that doubles as on-the-job training. Now ChatGPT and other bots can do many of those chores."

Researchers Measure ChatGPT's Performance in College Engineering Class

Inside Higher Education, May 15, 2025.

The chatbot "achieved a B grade (82%), slightly below the class average of 85%." The chatbot excelled in multiple-choice questions but struggled with programming projects, "lacking the optimization and robustness" of high-quality submissions.

ChatGPT fails at open-ended design, "particularly in synthesizing information and making practical judgements."

Course Organization

Lectures MWF 9:05 - 9:55 a.m.

Material to complement the textbook. Example applications of the textbook concepts.

Calculation Sessions Wednesday 2:30 - 4:25 p.m.

Work exercises in ad hoc teams of four. Exercises are typically design and will be similar to the current homework assignment. Solutions will be presented in class and posted at the course homepage.

Weekly Homework

Work exercises in assigned in teams of three.
Submit one solution per team.

Due Wednesday after Calculation Session

EngrD 2190 - Chemical Process Design & Analysis - Fall 2025
Cooperative Learning

If you do not submit a questionnaire, you will work independently

Name _____ Cornell NetID _____

Homework is assigned Friday and due the following Friday at noon. Shade the cells for ***all*** times you ***c*** meet each week. ***Circle the day*** you prefer for your first team meeting each week.

	Fri	Sat	Sun	Mon	Tues	Wed	Thurs	Fri
morning: 10 am. - noon								
afternoon: 1 - 4 p.m.								HW due
late afternoon: 4 - 7 p.m.								
evening: 7-10 p.m.								

How would you prefer to work the homework?

Complete the exercises individually and then compare *final* answers as a team.

Start together as a team, separate to work the exercises individually, and then reconvene to compare answers.

Work together as a team from start to finish.

I have no preference.

How many times would you like to meet with your homework team each week?

One long session (perhaps two hours).

Two or three shorter sessions.

I have no preference.

Where would you like to meet with your homework team each week?

North Campus West Campus

Engineering Quad Collegetown

Other: (please specify)

During team meetings, informal conversation not germane to completing the team's task is …

essential for building camaraderie.

tolerable - enjoyable but unproductive.

frustrating and unproductive.

Can you attend TA Office Hours Sunday 7:30-9:30 p.m.? Yes No

Can you attend TA Office Hours Wednesday 7:30-9:30 p.m.? Yes No

What level of emphasis do you plan for EngrD 2190, relative to your other courses?

1 2 3 4 5
low high

Do you have a preference for your teammate(s)? If so, list the names of your preference(s).

Potential teammates must submit your name.

Are you participating in team athletics or other extracurricular activities (band, ROTC, etc)? If so, list the sport or activity and list the times you **cannot** meet with a homework team.

Which issues should the TAs emphasize when they select your teammates? Circle the important issue(s). Cross out insignificant issue(s).

Syllabus

Reading for Wednesday's lecture

week	date		lecture	dates	calculation session
1	8/25	1	course content, course objectives, and course organization. reading: chapter 1, pp. 1-7, chapter 2, pp. 8-19.		
	8/27	2	Concept: process design - unit operations and process flowsheets. Context: green chemistry for hydrazine synthesis. reading: chapter 2, pp 20-25.	CS 1 8/27	process analysis & design by incremental evolution. exercises 2.9 and 2.22.
	8/29	3	Concept: process design - problem solving Context: strategies for separation - purification of Br_2 reading: chapter 2, pp 25-42. homework 1: exercises 2.xx, 2.xx, and 2.xx.		
2	9/1		*Labor Day - no lecture*		
	9/3	4	Concept: process design - devising chemical cycles. Context: producing CH_4 from CO_2 and thermal energy. reading: chapter 2, pp 42-48.	CS 2 9/3	problem redefinition: exercises 2.45, 2.38, and 2.40. process analysis & design by incremental evolution: exercises 2.34 and 2.32. professional development - part 1: résumés
	9/5	5	Concept: process design - reactors for solid reactants and products; reactants in excess to simplify separations. Context: CH_4 from CO_2 and thermal energy, cont'd. homework 2: exercises 2.xx, 2.xx, 2.xx, 2.xx, and 2.xx.		

Updates posted at course homepage

CornellEngineering
Robert Frederick Smith School of Chemical and Biomolecular Engineering

"I have had the privilege of being a Cornell graduate with a degree in engineering. I credit much to my career success to being an engineer by training. Engineers solve problems and fix things."

"Chemical Engineers are just like regular people … only smarter."