NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

COURSE CONTENT

Academic Year	2022/2023	**Semester**	2
Course Coordinator	Prof. Xu Rong / Assoc. Prof. Tan Thatt Yang Timothy		
Course Code	CH1104		
Course Title	Materials and Energy Balances		
Pre-requisites	Nil		
No of AUs	3		
Contact Hours	26 hours lecture, 13 hours tutorial		
Proposal Date	15 Nov 2019		

Course Aims

This subject focuses on the material and energy balances in chemical processes and lays that foundation in other chemical engineering subjects such as thermodynamics, unit operations, reaction kinetics, etc. It introduces the engineering approach to problem solving: Breaking a process down into its components, establishing the relations between known and unknown process variables, assembling the information needed to solve for the unknowns, and finally obtaining the solution using appropriate computational methods.

Intended Learning Outcomes (ILO)

Upon successful completion of this course, you should be able to:

1) Check the units in an equation for consistency and convert values between different unit systems.
2) Calculate process flow rates in mass, molar, and volumetric units given the appropriate process data.
3) Construct a flow chart from a written description of a process.
4) Balance material flow sheets incorporating multiple process units with recycle, purge, and bypass streams for processes without chemical reactions.
5) Balance a material flow sheet incorporating multiple process units, and recycle, purge, and bypass streams for reactive processes given extents of reaction and/or yield and selectivity data for the reactions.
6) Use the ideal gas law to calculate properties of pure gases and gas mixtures.
7) Estimate the properties of real gases/liquids using a non-ideal equations and compressibility chart.
8) Perform mass balance calculations for processes involving gas-liquid phases. Understand colligative properties (vapour pressure, boiling point and melting point) of solid-liquid systems.
9) Apply the first law of Thermodynamics and use it to perform energy balances on closed/open systems to calculate the changes in Energy/Work/Other system parameters.
10) Use the Property Tables of steam/humid air and other important molecules/systems.
11) Design the hypothetical paths for the computation of energy balance for steady state energy balances in a system with phase changes and chemical reactions.
12) Compute the energy balance for transient state mass & energy balances in a system without phase changes and chemical reactions.

Course Content

Material Balance: Process variables calculations; Material balance Calculation; Degree of Freedom analysis; Non-reactive and reactive processes for single & multiple unit processes with recycle, purge and bypass; Combustion processes; Ideal and non-ideal gas equation of states; Material balance for single and multi-component phase equilibria.

Energy Balance: Energy and energy balances for closed and open systems, steam table, energy balance for mechanical processes, hypothetical path, humidity chart, heat capacity, mixing and solution, heat of reaction, Hess's law, heat of formation, heat of combustion, energy balance for reactive process, mass & energy balance for transient process.

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team /Individual	Assessment rubrics
1. CA (40%) a. Class Quiz (Mass Balance) (20%)	ILO 1-5.	a, b, c	20%	Individual	refer to Appendix A
b. Class Quiz (Energy Balance) (20%)	ILO 9-11.	a, b, c	20%	Individual	refer to Appendix A
2. Final Examination (60%) (2hrs Closed Book)	ILO 1-12	a, b, c	60%	Individual	refer to Appendix A
Total			100%		

Mapping of Course ILOs to EAB Graduate Attributes

Course Intended Learning Outcomes	Cat	EAB's 12 Graduate Attributes*											
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	Core	●	●	●									

Course Intended Learning Outcomes	EAB's Graduate Attributes
Check the units in an equation for consistency and convert values between different unit systems.	a, b
Calculate process flow rates in mass, molar, and volumetric units given the appropriate process data.	a, b
Construct a flow chart from a written description of a process.	a, b, c
Balance material flow sheets incorporating multiple process units with recycle, purge, and bypass streams for processes without chemical reactions.	a, b
Balance a material flow sheet incorporating multiple process units, and recycle, purge, and bypass streams for reactive processes given extents of reaction and/or yield and selectivity data for the reactions.	a, b
Use the ideal gas law to calculate properties of pure gases and gas mixtures.	a, b
Estimate the properties of real gases/liquids using a non-ideal equations and compressibility chart.	a, b
Perform mass balance calculations for processes involving gas-liquid phases. Understand colligative properties (vapour pressure, boiling point and melting point) of solid-liquid systems.	a, b, c
Apply the first law of Thermodynamics and use it to perform energy balances on closed/open systems to calculate the changes in Energy/Work/Other system parameters.	a, b, c
Use the Property Tables of steam/humid air and other important molecules/systems.	a

Design the hypothetical paths for the computation of energy balance for steady state energy balances in a system with phase changes and chemical reactions.	a, b, c
Computation of energy balance for transient state mass & energy balances in a system without phase changes and chemical reactions.	b, c

Legend: ● Fully consistent (contributes to more than 75% of Intended Learning Outcomes)
◐ Partially consistent (contributes to about 50% of Intended Learning Outcomes)
š Weakly consistent (contributes to about 25% of Intended Learning Outcomes)
Blank Not related to Student Learning Outcomes

Formative feedback

Examination results;
Marker's report on overall examination performance will be uploaded to NTUlearn;
Quiz performance and solutions will be provided.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lecture	Demonstrate how to carry out a procedure such as working through a problem, use incomplete handouts which enabling students participating in class.
Tutorial	Discussion sessions on tutorial questions and related topics

Reading and References

Text:
"Elementary Principles of Chemical Processes," 4th edition, R.M. Felder and R.W. Rousseau, John Wiley and Sons, 2017.
Reference:
Numerical Methods for Engineers by Steve Chapra, Raymond Canale, McGraw-Hill Science/Engineering/Math; (January 1998)

Course Policies and Student Responsibilities

General: Students are expected to take responsibility to follow up with course notes, assignments and course related announcements. Students are expected to participate in all tutorial discussions and activities.

Continuous assessments: Students are required to attend all continuous assessments.
Absenteeism: Continuous assessments make up a significant portion of students' course grade. Absence from continuous assessments without officially approved leave will result in no marks and affect students' overall course grade.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Timothy Tan	N1.2 B1-22	63168829	tytan@ntu.edu.sg
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Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Unit conversion and process variable	1, 2, 6, 7	Text: Chp 2, 3, 5
2	Material balance for physical process	3, 4, 8	Text: Chp 4, 6
3	Material balance for chemical processes	3, 5	Text: Chp 4, 6
4	Material balance for single and multi-phase systems	3, 4, 5, 8	Text: Chp 4, 6
5	Energy balance	9,10	Text: Chp 7,8
6	Balances on nonreactive processes	9, 10	Text: Chp 8
7	Balances on reactive processes	11	Text: Chp 9
8	Balance on transient processes	12	Text: Chp 11

Appendix 1: Assessment Criteria

Criteria	Unsatisfactory: <40%	Borderline: 40% to 49%	Satisfactory: 50% to 69%	Very good: 70% to 89%	Exemplary: >90 %
Check and calculate units for process flow rates in mass, molar, and volumetric and different states in the ideal and non-ideal equation of states, given the appropriate process data and convert values between different unit systems.	Unable to perform check and calculations	Barely able to perform check and calculations	Able to perform check and calculations on simple questions	Able to perform check and calculations on complex questions	Able to perform check and calculations on highly complex questions requiring design and synthesis
Construct a flow chart from a written description of a process, and solve for material balance involving physical and chemical processes, and process involving gas-liquid phases.	Unable to construct and solve	Barely able to construct and solve	Able to construct flow chart based on simple process description and solve simple problems	Able to construct flow chart based on indirect process description and solve complex problems	Able to construct flow chart based on complex process description and solve highly complex problems
Apply Property Tables of steam/humid air and other important molecules/systems to perform energy balance calculations	Unable to apply the properties	Barely able to apply the properties	Able to apply some properties	Able to apply most of the properties	Able to apply all the properties
Construct a flow chart from a written descript of a process, set up energy balance, and solve for energy balance for open and closed systems involving phase change, heat of mixing and chemical reactions.	Unable to construct and solve	Barely able to construct and solve	Able to construct flow chart based on simple process description and solve simple problems	Able to construct flow chart based on indirect process description and solve complex problems	Able to construct flow chart based on complex process description and solve highly complex problems

Appendix 2: The EAB (Engineering Accreditation Board) Accreditation SLOs (Student Learning Outcomes)

a) **Engineering knowledge:** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems
b) **Problem Analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
c) **Design/development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d) **Investigation:** Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
e) **Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations
f) **The engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
g) **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.
h) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
i) **Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.
j) **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
k) **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
l) **Life-long Learning:** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change