NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

COURSE CONTENT

Academic Year	2023/2024	**Semester**	1
Course Coordinator	Dr. Raman, Balajee / Dr. Reddy, Chirla Chandra Sekhara		
Course Code	CH3121		
Course Title	Chemical, Biological & Plant Safety		
Pre-requisites	Nil		
No of AUs	2		
Contact Hours	*22 hours lecture, 4 hours workshop (Projects)*		
Proposal Date	*5 May 2023*		

Course Aims

This course aims to teach you about process plant safety systems at an advanced level; to understand and application of fundamental tools used to design, manage, operate safely and to quantify risks in chemical and biological plants. The intent is also for you to learn about safer design for error tolerance and not just prevention or mitigation.

Intended Learning Outcomes (ILO)

By the end of the course, you should be able to:

(1) Apply the core Process Safety Engineering skills to design, maintain and operate the chemical process plants via Identification, quantification and management of risks through various industrial examples and problems
(2) Apply engineering and analytical techniques to establish the scheme to identify risks.
(3) Recommend safety measures at chemical and biological plants.

Course Content

Brief content of course includes:

- Introduction to process plant safety, Industrial disasters and Inherent safety principles,
- Toxicology-: classification, entry, response, measurement and control in body.
- Industrial Hygiene: Identification, evaluation and control from systems
- Hazards Identification: Hazop Technique Introduction and learn the basic skills of tool application.
- Consequence Analysis: Source modelling Techniques, Toxic release and dispersion models
- Likelihood Analysis: Introduction to probability theories, Risk quantification techniques via Fault Tree Analysis
- Risk Assessment Techniques: Learn to apply LOPA (Layers of Protection Analysis) as a Risk Assessment tool including Safety Instrumented System design layers.
- Fires and explosions: Flammability characteristics, design techniques to Prevent Fires and explosions.
- Introduction to Pressure protection requirements, relief devices and relief Sizing
- Accident Investigation: RCA Process, Methods and analyze steps of the incident investigation process
- Sustainability: Appreciation of environmental problems, climate changes and ozone depletion, energy efficiency and renewable energy for chemical industry.

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/ Individual	Assessment Rubrics
1. Final Examination (60%)	1,2,3	a,b,c,d,f,g,h,j,l	60%	Individual	
2. Continuous Assessment (40%) (2 Projects: 2X20%)	1,2,3	a,b,c,d,e,f,g,h,l,j ,k,l	40%	Team	Appendix 1
Total			100%		

Formative feedback

Examination results;
Marker's report on overall examination performance will be uploaded to NTUlearn;
Students will get feedback on their performance in the project.

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.
Projects/Quiz Workshops	Workshops conducted to enable your skill-based tool application and project management process. Team based project is guided and evaluated for the content, understanding of requirements, your ability to apply the tools effectively to achieve expected results and your concise project report as a professional output.

Reading and References

1) Chemical Process Safety: Fundamentals with Applications (3rd Edition) by Daniel A. Crowl, Joseph F. Louvar
2) Living in the Environment by G. T. Miller, S. E. Spoolman

Course Policies and Student Responsibilities

General: You are expected to complete all online activities and take all scheduled assignments and tests by due dates. You are expected to take responsibility to follow up with course notes, assignments and course related announcements. You are expected to participate in all tutorial discussions and activities.

Continuous assessments: You are required to attend all continuous assessments.
Absenteeism: Continuous assessments make up a significant portion of your 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
Raman Balajee		+65-97263600	rbalajee@ntu.edu.sg
Reddy, Chirla Chandra Sekhara			chandrasekhar.reddy@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Introduction to process safety, Lessons from industrial disasters resulted in major societal, economic and environmental problems. Introduction to Engineering ethics, accident and loss statistics (OSHA Recordable and FAR Metrics), acceptable vs unacceptable risks, public perception, nature of accident processes and Inherent Safety Principles.	1.2	Students to read lecture Notes and course text book. Example problems are solved in class. Few exercises and forms posted in IVLE for additional practice Compile all similar queries exchanged from email and response posted back in IVLE
2	Toxicology: Classifications, How toxicant enters in or removed from biological organisms' effects on biological organisms, toxicological studies, dose versus response curves, threshold limits (TLV), toxic release model (Probit) and mitigation, etc.	1.2.3	Same as above
3	Industrial hygiene & Hazards identification: regulatory requirements, Intermittent and continuous evaluations, controls-understand and apply the hierarchy in hazard control, ventilation methods to control toxicant concentration in the workplace. Understand major hazards, preventive and mitigative methods to counter the Industrial Hygiene issues.	1.2.3	Same as above
4	Process Hazard Analysis: objectives and main steps to build PHA strategy, Introduction to Hazop (Hazard and	1,2,3	Students to read lecture Notes and course text book.

	Operability Analysis) tool: Process Safety Information, Team establishment with roles, Nodal classification, checklist compilation, application of deviations, identification of causes, consequences, safeguards and recommendations based on risk matrix, etc.,		Example problems are solved in class. Few exercises and forms posted in IVLE for additional practice Compile all similar queries exchanged from email and response posted back in IVLE
5	Hazop Workshop: To enable the application of skills necessary for the application of tool to \achieve the results expected. Team based approach requires a project management approach on top of the technical requirements. An example problem is practiced as part of the workshop.	2,3	Same as above
6	Source modelling: consequence modelling with respect to source terms by calculating the discharge rate for different physical discharge scenarios, such as flow of liquid through a hole, through hole in a tank, through pipes, vapor through holes and flashing liquids. Understand the assumptions inherent in the source term calculations.	1,2	Same as above
7	Toxic release and Dispersion modelling: Understand the concepts of dispersion modelling based on prevailing wind conditions and atmospheric stability. Apply the Pasquill-Gifford (P-G) Model to calculate dispersion of ideal puffs and plumes (Puff with Instantaneous Point source at ground level or at height above ground level, Plume with continuous, steady-state source at ground level or at height above the ground level). Know the assumptions and limitations of the P-G models.	2,3	Same as above
8	Probability theory, Fault tree analysis: Risk Quantification criteria, Probability concepts, component failure theory, Interactions between components, describe the terms risk, risk analysis, risk assessment, calculate probability of failure, reliability, MTBF, failure rate for fault trees and aids for recommendation.	1,2,3	Same as above
9	LOPA(Layer of Protection analysis) and SIS (safety Instrumented system) : Describe the purpose of LOPA,	1,2,3	Same as above

	characteristics of independent layers of protection (IPL) Identify and to understand the difference between safeguards and independent layers of protection with an example to relate the expansion of Hazop into a LOPA. Learn about SIS, when we need it, Concepts of SIS Life Cycle, Safety Integrity level and Safety Requirements Specifications are defined.		
10	LOPA workshop: To enable the application of skills necessary for the application of tool to achieve the results expected. Team based approach requires a project management approach on top of the technical requirements. An example problem is practiced as part of the workshop.	2.3	Same as above
11	Fire, explosion, and prevention: The fire triangle, flammability characteristics of liquids and vapours, minimum oxygen concentration and inerting, autoignition, spray & mists, explosions, static electricity and controlling, explosion proof equipment and instrument, ventilation, sprinkler system.	1,2,3	Same as above
12	Pressure Reliefs: Concepts, locations, scenarios, installation practices, relief sizing for liquid, vapour or gas service and rupture disc relief.	1,2,3	Same as above
13	Accident/Incident Investigation: RCA Process, Methods and analyze steps of the incident investigation process. Sustainability: Appreciation of the cause of environmental problems, climate changes and ozone depletion due to industrialization as well as energy efficiency and renewable energy for chemical industry.	2,3	Same as above

Appendix 1: Assessment Criteria for Project 1 and 2:

A final report is expected as an outcome for the two mini projects. This is a Team exercise. Maximum score is 20 marks per Project.

Standard	**Criteria**
Excellent (18-20 marks)	Excellent work which is clearly outstanding and characterized by : (a) highly creative, practical, and cost-effective design solution concepts (b) deep understanding of problem, skilful application of engineering knowledge, and thorough analysis of problem/solution (c) excellent build quality, performance, and aesthetics of prototype (d) strict observance of lab/workshop rules and safety, and excellent project/time management (e) excellent presentation of results in report
Good (14-17 marks)	Good work characterized by : (a) creative, practical, and cost-effective design solution concepts (b) proficient understanding of problem, application of engineering knowledge, and analysis of problem/solution (c) high build quality, performance, and aesthetics of prototype (d) good observance of lab/workshop rules and safety, and good project/time management (e) good presentation of results in report
Satisfactory (10-13 marks)	Satisfactory work characterized by : (a) somewhat creative, practical, and cost-effective design solution concepts (b) some understanding of problem, application of engineering knowledge, and analysis of problem/solution (c) moderate build quality, performance, and aesthetics of prototype (d) satisfactory observance of lab/workshop rules and safety, and acceptable project/time management (e) satisfactory presentation of results in report
Poor (0-9 marks)	Work that does not meet minimum criteria and characterized by : (a) lack of creativity, practicality, or cost effectiveness in design solution concepts (b) lack of understanding of problem, application of engineering knowledge, or analysis of problem/solution (c) poor build quality, performance, or aesthetics of prototype (d) unsatisfactory observance of lab/workshop rules and safety, or poor project/time management (e) poor presentation of results in report

Points to Note for report Submission:

a. *Content* – Ensure your team's effort to feature in the report conveys understanding of problem, application of engineering knowledge and analysis of problem. You want to highlight good and practical design attributes that you have incorporated into your system to make it more robust, flexible and intelligent. Especially features that gives your system a superior performance over other team. This information in your report will contribute towards the **Content** component of the assessment.

b. *Teamwork* - Ensure that all team members participate and is seen to be participating in the production of report. Think carefully how you can convey a strong sense of teamwork within your group when composing your report. This will contribute towards the **Teamwork** component of the assessment.

c. *Presentation* - Use the analysis and tools medium effectively. Use these capabilities to convey the resolution of problem, proposed system design via calculations, tabulations, screenshots, schematic drawings, etc. Ensure text and narratives (if used) are correct, concise and clearly articulated. Your effective use of all these elements will contribute towards the **Presentation** component of the assessment.

d. *Creativity* - Be as creative as possible in putting together your report. Remember, this is a pragmatic resolution of engineering problem which allows you much more scope to think out of the box. Ask yourself, "How can I be original in reporting the work done, demonstrate teamwork and highlight our achievements?" Think carefully what you want to feature first before putting the report together. Discuss as a team how you can make the presentation of the content interesting. All these elements will contribute towards the **Creativity** component of the assessment.

Assessment Form for Peer Evaluation
Please indicate your perceptions of other team member's contribution during the project development. Use the scale below for assessing each team member.

Scoring: Your personal score for the project would be moderated based on your peer assessment based on the following formula:

$$Your\ Individual\ Project\ Score\ = \frac{Individual\ Peer\ Score}{Average\ Team\ Peer\ Score} \times Team\ Score$$

10-9	8-7	6-4	3-1	0
Demonstrate outstanding contributions and efforts during teamwork.	Exhibited appropriate effort in contributions during teamwork.	Made some contributions but greater effort could have been exhibited during teamwork.	Did not contribute much effort during teamwork.	Made no effort to contribute during teamwork.

Team member:											
Preparation for work accomplishment: completed readings.	10	9	8	7	6	5	4	3	2	1	0
Task-related collaborative behaviour: task-focused, respectful of others, and cooperative.	10	9	8	7	6	5	4	3	2	1	0
Team adjustment behaviours: intra-team coaching, problem solving	10	9	8	7	6	5	4	3	2	1	0
Work behaviours: involved and participatory	10	9	8	7	6	5	4	3	2	1	0
Communication: information shared and exchanged, engaged in process, and made verbal contributions.	10	9	8	7	6	5	4	3	2	1	0
Provide constructive feedback for this team member. (Consisting of two to three sentences):											

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