COURSE COMPACT FOR CHE 325

Course
Course code: CHE 325
Course title: Chemical Engineering Thermodynamics I (3 units)
Course status: Compulsory

Course Duration
Three (3) hours per week for 15 weeks (45hours)

Lecturer Data

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Consultation Hours: Tuesday – Thursday, 10:00 – 12:00p.m.

Course Content:
Introduction (definition, scope and aims); Work (quasi-static process; PVT system; path dependency); First law (work and heat, adiabatic work, internal energy, enthalpy, heat capacity); Second law (inter-conversion of work and heat, heat engines and cyclic processes, heat reservoirs/sinks, thermal efficiency, refrigeration cycle, coefficient of performance); entropy; Helmholtz and Gibbs functions; theory of corresponding states; chemical reaction equilibrium; phase equilibrium and phase rule.

Course Description:
This is a core chemical engineering course that introduces the students to chemical engineering thermodynamics. Chemical engineering thermodynamics is a fundamental course for would be process engineers because of its usefulness in all area of chemical engineering.

Course Justification:
Thermodynamics being the study of the relationship between energy changes and the properties of material(s) involved in the transformation, it affects every area of process changes. Chemical engineering on the global perspective involves the transformation of raw materials into useful products through physical and chemical transformation processes, hence the knowledge of thermodynamics cannot be ignored.

Course objectives
At the end of this course, students should be able to:

1. **Recall**
   - Basic definitions and terminology
   - Special definitions from the thermodynamics point of view.
   - Why and how natural processes occur only in one direction unaided.
2. **Explain**
   - Concept of property and how it defines state.
   - How change of state results in a process?
   - Why processes are required to build cycles?

- Differences between work producing and work consuming cycles.
- What are the coordinates on which the cycles are represented and why?
- How some of the work producing cycles work?
- Evaluate the performance of cycle in totality.
- How to make energy flow in a direction opposite to the natural way and what penalties are to be paid?
- How the concept of entropy forms the basis of explaining how well things are done?
- How to gauge the quality of energy?

3. **Calculate and determine:**
   - heat requirements of thermal power plants and other heat engines.
   - efficiencies and relate them to what occurs in an actual power plant.
   - properties of various working substances at various states.
   - what changes of state will result in improving the performance.
   - how much of useful energy can be produced from a given thermal source.
4. **Analysis**
   - Compare the performance of various cycles for energy production.
   - Explain the influence of temperature limits on performance of cycles.
   - Draw conclusions on the behavior of a various cycles operating between temperature limits.
   - How to improve the energy production from a given thermal source by increasing the number of processes and the limiting conditions thereof.
   - Assess the magnitude of cycle entropy change.
   - What practical situations cause deviations form ideality and how to combat them.
   - Why the temperature scale is still empirical?
   - Assess the other compelling mechanical engineering criteria that make thermodynamic possibilities a distant dream.
5. **Evaluation**
   - Assess which cycle to use for a given application and source of heat
   - Quantify the irreversibilites associated with each possibility and choose an optimal cycle.
   - chemical reaction equilibrium;
   - phase equilibrium and phase rule.

Course Requirement:
To be able to flow well in this course, students should have at least attended lectures in the following courses GEC 220, GEC 221 and CHE 221 which would provide a good basis for them to better comprehend the knowledge that will be acquired in the course.

Method of Grading:

S/N	Grading	Score (%)
1	Test	10
2	Assignment	10
3	Group project	10
4	Final Examination	70
	Total	100

Course Delivery Strategies:
Lecture and group assignment method complimented with tutorials will be adopted. In the tutorials, practice questions will be treated by the students guided by the course instructor.

Students may sometimes be grouped for the tutorial classes and group assignment will also be given to students.

LECTURE CONTENT

Week	Topic	Objectives	Description
1	Introduction (definition, scope and aims)	At the end of this topic, students should be able to: ➢ Identify the various terminologies associated with thermodynamics through the precise definition of basic concepts to form a sound foundation for the development of the principles of thermodynamics. ➢ Explain the basic concepts of thermodynamics such as system, state, state functions, equilibrium, process, and cycle. ➢ Discuss and review properties of a system and define various thermodynamic properties.	First Hour: Thermodynamics; Terminology; definition and scope, System and Control Volume; Characteristics of system boundary and control surface; surroundings; fixed, moving and imaginary boundaries, examples. Second Hour: Thermodynamic state, state point, identification of a state through properties; definition and units, intensive and extensive properties Third Hour: Thermodynamic equilibrium; definition, mechanical equilibrium; thermal equilibrium, chemical equilibrium. Zeroth law of thermodynamics, Temperature as an important property. Study Question: P1.1, 1.3, 1.4, 1.5, 1.17
2	Work (quasi-static process;	At the end of this topic, students should be able to:	First and Second Hour: Path and process, quasi-static process, cyclic and noncyclic processes; Third Hour: Restrained and unrestrained processes; Study Question:
3	PVT system; path dependency); theory of corresponding states I	At the end of this topic, students should be able to: ➢ Define and identify pure substances ➢ Explain the behaviour of pure substances using the PV, PT and TV diagrams. ➢ Differentiate between ideal and real gases ➢ Evaluate the properties of ideal and real gases using equation of state.	First Hour: Definition of a pure substance, phase of a substance, triple point and critical points. Sub-cooled liquid, saturated liquid, vapour pressure, two phase mixture of liquid and vapour, saturated vapour and superheated vapour states of a pure substance, Second Hour: Representation of pure substance properties on p-T and p-V diagrams. Differences between perfect, ideal and real gases. Equation of state. Evaluation of properties of perfect and ideal gases Third Hour: Class activity Study Question: P3.1, 3.30 – 3.35
4	PVT system; path dependency); theory of corresponding states II	At the end of this topic, students should be able to: ➢ apply the generalized expressions of the equation of state of the 3-Parameter corresponding states.	First Hour: Introduction. Van der Waal’s Equation of state, Van der Waal's constants in terms of critical properties, Other equations of state (cubic and higher order) Second Hour: law of

			corresponding states, compressibility factor; compressibility chart. Third Hour: Class activity and Tutorials
5	First law (work and heat, adiabatic work, internal energy, enthalpy, heat capacity) I	At the end of this topic, students should be able to: ➢ define and derive the 1st law of thermodynamics for closed and open systems ➢ apply the 1st law expression in solving thermodynamic problem ➢ explain and use the concept of internal energy and enthalpy in estimating process parameters.	First Hour: Statement of the First law of thermodynamics for a cycle, derivation of the First law of processes, Second Hour: Energy, internal energy as a property, components of energy, thermodynamic distinction between energy and work; concept of enthalpy, definitions of specific heats at constant volume and at constant pressure. Third Hour: Tutorials Study Question:
6	First law (work and heat, adiabatic work, internal energy, enthalpy, heat capacity) II	At the end of this topic, students should be able to: ➢ apply the 1st law expression in solving thermodynamic problem ➢ analyse thermal systems using the first law of thermodynamics.	First Hour: Extension of the First law to control volume; steady state-steady flow energy equation, Second Hour: Important applications such as flow in a nozzle, throttling, and adiabatic mixing etc. analysis of unsteady processes, case studies. Third Hour: Tutorials Study Question:
7	Mid-Semester Continuous Assessment/Test		
8	Second law (inter-conversion of work and heat, heat engines and cyclic processes, heat reservoirs/sinks, thermal efficiency,	At the end of this topic, students should be able to: ➢ critique and discuss the limitations of the first law that led to the postulation of the second law. ➢ define the various statements of the second law of thermodynamics ➢ illustrate reversible and irreversible processes by identifying the factors that may be responsible ➢	First Hour: Identifications of directions of occurrences of natural processes, Offshoot of 2nd law from the Ist law. Kelvin-Planck statement of the Second law of Thermodynamic; Second Hour: Clasius's statement of Second law of Thermodynamic; Equivalence of the two statements; Third Hour: Definition of Reversibility, examples of reversible and irreversible processes; factors that make a process irreversible, Reversible heat engines; Study Question:
9	Second law (inter-conversion of work and heat: refrigeration cycle, coefficient of performance)	At the end of this topic, students should be able to: ➢ List various devices that converts work to heat and vice versa ➢ Discuss thermodynamic cycles that operate within each	First Hour: Devices converting heat to work and vice versa in a thermodynamic cycle, thermal reservoirs. heat engine Second Hour: heat pump systems and their analyses. Third Hour: Class activity and

		device. ➢ estimate the efficiencies and coefficient of performances of heat engines and heat pumps respectively.	tutorials Study Question:
10	Entropy; Helmholtz and Gibbs functions;	At the end of this topic, students should be able to: ➢ define entropy and discuss its significance to thermodynamic processes ➢ explain irreversibility in processes ➢ interprete degradation of energy in thermal system and compute efficiencies of thermal systems.	First Hour: Entropy; definition, a property, principle of increase of entropy, entropy as a quantitative test for irreversibility, Second Hour: Calculation of entropy, role of T-s diagrams, representation of heat quantities; Third Hour: Tds relations, Available and unavailable energy. Study Question:
11	chemical reaction and Phase equilibria I	At the end of this topic, students should be able to: ➢ explain the basic concept of chemical reaction equilibrium ➢ Determine the equilibrium composition for a system with a single chemical reaction and with multiple chemical reactions given the reaction stoichiometry, temperature, and pressure. ➢ Describe the role of thermodynamics vs. the role of kinetics in the consideration of chemical reactions in chemical processes. ➢ Write a balanced chemical reaction given a complete or incomplete set of reactants and products. Define the extent of reaction and the stoichiometric coefficient. ➢ Use thermochemical data to determine the equilibrium constant for a chemical reaction at any given temperature.	First Hour: introduction to Chemical reaction equilibrium Second Hour: Stoichiometry and chemical equilibrium constant determination Third Hour: Balancing of chemical reactions given complete or incomplete set of reactants and products. Study Question:
12	chemical reaction and phase equilibria II	At the end of this topic, students should be able to: ► For a determined reaction stoichiometry and initial reactant composition, write the equilibrium constant in terms of the extent of reaction for gas phase, liquid-phase, and heterogeneous reactions for ideal or non-ideal systems.	First Hour: Introduction to phase equilibria Second Hour: Application of phase rule and Gibbs function Third Hour: Use of minimization of Gibbs energy. Study Question:

		► Given a set of species in a system, apply the Gibbs phase rule to determine how many independent reactions need to be specified to constrain the system. Write an appropriate set of reactions and solve them using the equilibrium constant formulation. Alternatively, solve for the equilibrium composition using the minimization of Gibbs energy.	
13	Chemical reaction and phase equilibrium III	At the end of this topic, students should be able to: ➢ explain the basic concept of phase equilibrium ➢ Explain and apply Phase rule in determining degree of freedom	<u>First and Second Hour:</u> Application of phase rule to thermodynamic processes <u>Third Hour:</u> Tutorials <u>Study Question:</u>
14	Revision	Revision and tutorials for all that has been taught	
15	Examination	To examine the students on all that has been taught during the semester.	

Reading List - Books and materials students can read:

1. Smith, Van Ness & Abbot Introduction to Chemical Engineering Thermodynamics - 7th ed, McGraw Hills Chemical Engineering Series.
2. Cengel, Y.A. and Boles, M.A. (2015) Thermodynamics: An Engineering Approach, 8th ed, McGraw Hill Education, USA