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

Dr. M.S. Olakunle

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Office Location: Room A005 First College Building. 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.

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

LECTURE CONTENT

5	First law (work and	At the end of this topic, students	correspondingstates,compressibility factor;compressibility chart.Third Hour: Class activity andTutorialsFirst Hour: Statement of the First
	neat, adiabatic work, internal energy, enthalpy, heat capacity) I	 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. 	law of thermodynamics for a cycle, derivation of the First law of processes, <u>Second Hour:</u> 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. <u>Third Hour:</u> 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, <u>Second Hour:</u> Important applications such as flow in a nozzle, throttling, and adiabatic mixing etc. analysis of unsteady processes, case studies. <u>Third Hour:</u> Tutorials <u>Study Question:</u>
7		Mid-Semester Continuous Assess	sment/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 ➤ 	FirstHour:Identificationsofdirectionsofoccurrencesofnaturalprocesses,Offshootof2ndprocesses,Offshootof2ndlawfromtheIstlaw.Kelvin-PlanckstatementoftheSecondlawofThermodynamic;SecondHour:Clasius'sstatementofSecond lawofThermodynamic;Equivalenceofthetwo statements;ThirdHour:DefinitionofReversibility,examplesofreversibleandirreversibleprocesses;factorsthatprocessirreversible,Reversibleheatengines;Study Question:FirstHour:Davisesconverting
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 <u>Second Hour:</u> heat pump systems and their analyses. <u>Third Hour:</u> Class activity and

Pestimate the efficiencies and coefficient of performances of heat engines and heat pumps respectively. Shudy Question: 10 Entropy; Helmholz and Gibbs functions; At the end of this topic, students significance to thermodynamic processes First Hour: Entropy; definition, a quantitative test for increase of entropy, ned of Tes diagrams, representation of cenergy in thermal system and compute efficiencies of thermal systems. First Hour: Calculation of entropy, role of Tes diagrams, representation of heat quantities; Third Hour: Tes diagrams, representation of thermal systems. 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 aquilibrium > Determine the cquilibrium composition for a system with a single chemical reaction aquilibrium processes. First Hour: introduction to Chemical equilibrium Second Hour: Stoichiometry and chemical equilibrium constant incomplete set of reactants and products. Define the consideration determinat for a chemical reaction given a complete or incomplete set of reactants and products. Define the extent of reaction at any given temperature. 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 should be able to: > For a determine dreaction stoichiometry and initial reactant should be able to: > For a determined reaction stoichiometry and initial reactant should be able to: > For a determined reaction stoichiometry and initial reactant should be able to: > For a determined reaction stoichiometry and initid reactant should be able to: > For a determined reaction			device.	tutorials
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or non-ideal			composition, write the equilibrium constant in terms of the extent of reaction for gas phase, liquid-phase, and heterogeneous reactions for ideal	Third Hour: Use of minimization of Gibbs energy. <u>Study Question:</u>
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		► 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 	First and Second Hour: Application of phase rule to thermodynamic processes <u>Third Hour:</u> Tutorials <u>Study Question:</u>
14	Revision	Revision and tutorials for all that ha	as 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.
 Cengel, Y.A. and Boles, M.A. (2015) Thermodynamics: An Engineering Approach, 8th
- ed, McGraw Hill Education, USA