1. **Course number and name - CHBE 2140 – Chemical Engineering Thermodynamics** (*required*)

2. **Credits and contact hours** - 4 credit hours, 4 lecture hours (4-0-0-4)

3. **Instructor's or course coordinator's name** – Dr. Yonathan Thio

4. **Textbook, title, author, and year**
   Introduction to Chemical Engineering Thermodynamics; Smith, Van Ness, Abott, and Swihart, McGraw-Hill

5. **Specific Course Information**
   a. **Catalog Description** First and second laws of thermodynamics, equations of state, PVT properties, power cycles and refrigeration. Phase equilibrium. Fugacity and activity coefficients. Multi-reaction equilibrium.
   b. **Prerequisites or co-requisites** MATH 2551 Multivariable Calculus (grade "C" or better); CHBE 2100 Chemical Process Principles (grade "C" or better), Pre-requisite w/ concurrency: Biological Principles, BIOS 1107 and 1107L
   c. **Required, elective, or selected elective course** - Required

6. **Specific goals for the course**
   a. **Specific outcomes of instruction**
   By the end of the course, a student should be able to:
      1) Define complex thermodynamic systems including transient materials and energy balances for open and closed systems.
      2) Be able to correctly use the First Law of Thermodynamics to find heat, work, and changes in internal energy and enthalpy for the analysis of any system, open or closed, undergoing irreversible processes.
      3) Apply the Second Law of Thermodynamics and the concept of entropy production to the analysis of reversible and real systems.
      4) Use equations of state for gases and liquids to determine changes in PVT properties. Understand molecular concepts.
      5) Understand the relationships among the internal energy, enthalpy, heat capacities, entropy, Gibbs and Helmholtz free energies.
      6) Perform thermodynamic analyses of power and refrigeration cycles, and be able to calculate ideal efficiencies for these cycles.
      7) Understand partial molar properties of components in a particular phase and apply to calculations of the heat of mixing, volume, and entropy changes on processing of ideal and real mixtures.
      8) Understand the origin of chemical potential and fugacity
      9) Determine the fugacity of a pure component non-ideal gas and of pure liquids and solids under high pressure.
      10) Understand the molecular basis for ideal mixtures and calculate equilibrium phase compositions by relating chemical potential of fugacity to composition.
      11) Calculate phase compositions for real mixtures at equilibrium based on EOS for gas phases, and activity coefficient models for non-ideal liquid or solid behavior, including colligative properties.

12) Understand when phase equilibrium calculations require use of an EOS applicable to all phases.
13) Determine the equilibrium composition of single and multi-phase reaction mixtures, and how they are affected by temperature, pressure, composition, and other variables.
14) Perform calculations of fluid properties and phase equilibrium of pure components and mixtures using computer software.

b. Connection with Student Outcomes

CHBE 2140							
	Student Outcomes						
Course Outcomes	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Course Outcome 1	X						
Course Outcome 2	X						
Course Outcome 3	X						
Course Outcome 4	X						
Course Outcome 5	X						
Course Outcome 6	X	X					
Course Outcome 7	X						
Course Outcome 8	X						
Course Outcome 9	X						
Course Outcome 10	X					X	
Course Outcome 11	X					X	
Course Outcome 12	X	X				X	
Course Outcome 13	X	X					
Course Outcome 14	X	X				X	

Student Outcomes

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

(3) an ability to communicate effectively with a range of audiences

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

(5) *an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives*
(6) *an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions*
(7) *an ability to acquire and apply new knowledge as needed, using appropriate learning strategies*

7. Brief list of topics to be covered

a. First Law: Energy balance in open and closed systems; steady state and transient processes
b. Second Law: reversible and irreversible processes; entropy balance for open and closed, steady-state and transient systems
c. Properties of pure fluids: phase diagrams, equations of state, compressibility factor, generalized correlations, residual properties, equations of state for gases and liquids
d. Ideal gas and real fluids: cubic equations; departure functions
e. Relationship among thermodynamic functions: fundamental relationships between thermodynamic properties; Maxwell equations; thermodynamic property calculations
f. Thermodynamics of devices: turbines, tubes, throttling, nozzles, pumps
g. Thermodynamics of energy conversion: power production
h. Refrigeration: Carnot and vapor compression cycles
i. Pure-component multi-phase systems
j. Ideal multi-component systems: Raoult's law; flash calculations
k. Partial molar properties; Gibbs-Duhem equation
l. Chemical potential; fugacity: fugacity of pure component, fugacity of component in a mixture
m. Excess properties and activity coefficients: definition and models
n. Non-ideal multi-component systems: VLE, LLE; relating models to experimental data
o. Reacting systems: reaction coordinates; equilibrium constant from Gibbs energy; pressure and temperature effects