Objectives for Material to be Learned from Unit 3

By the end of this unit, students should be able to:

3.1 (Continuing objective) Be able to relate concepts of oscillations, thermodynamics, and statistical mechanics to "everyday" situations and to discuss various applications of the concepts to practical problems in various fields of science, medicine and engineering.

3.2 Given an equation $x(t)$ for a simple harmonic oscillator, determine the frequency f, period T, angular frequency ω, amplitude A, phase constant ϕ, and maximum speed and acceleration for the oscillator. Conversely, write down the equation for $x(t)$ given enough of these quantities.

3.3 Use conservation of energy to relate position and speed of an undamped oscillator at one moment to position and speed at a different moment.

3.4 Use Newton's second law to determine the acceleration for a simple harmonic oscillator in the form $a_x = -(\text{const})x$. From this determine the angular frequency of oscillation.

3.5 Be able to explain (in your own words) the concept of resonance for a forced oscillator, and be able to approximate the resonant frequency, either from a resonance curve or from information about free (unforced) oscillations of the same system.

3.6 For a molecular system, be able to explain what thermal energy is.

3.7 Given the molecular weight, density, and Young's modulus of a solid, derive the appropriate mass, equilibrium length, and spring constant of the ball-spring model. Use the ball-spring model to describe properties of a solid, including its molar specific head and speed of sound.

3.8 Given two substances, know that thermal energy flows from hot (larger temperature) to cold (smaller temperature) objects. Be able to quantitatively relate the heat flow to a temperature change.

3.9 Use the First Law of Thermodynamics to relate work done on or by a substance, heat flow into or out of the substance, and change in the thermal energy of that substance.

3.10 Give a molecular description of a solid, liquid and a gas; i.e., be able to explain how the motion of individual molecules and the patterns that they form differ between solids, liquids and gases.

3.11 Describe qualitatively why melting and vaporization phase transitions occur, and what their associated latent heats are. Use latent heat of fusion or vaporization to calculate the heat released or absorbed during a phase transition.

3.12 Relate thermal kinetic energy, thermal speed, and temperature for a solid, liquid, or gas.

3.13 Describe the properties of monatomic and diatomic ideal gases, including their molar specific heat and speed of sound.

3.14 Relate pressure, volume, temperature, and number of molecules or moles, or changes in the quantities, using the ideal gas law.

3.15 Draw and/or interpret a P-V diagram for a thermodynamic process or a series of processes occurring in a fixed quantity of ideal gas.

3.16 Calculate the work done by the gas during a thermodynamic process, either from the area under the curve on a P-V diagram or by integration.

3.17 Describe the following ideal gas processes and what quantity is constant (in terms of P, V, and T) for each process: (a) constant volume process, (b) constant pressure process, (c) isothermal process, (d) adiabatic process.

3.18 For a series of ideal gas processes, calculate the pressure, volume and temperature for each state and the change in internal energy, heat added, work done on and work done by for each process, using the ideal gas law or the first law of thermodynamics when needed.

3.19 State and use the definitions of microstates, macrostates, and multiplicity. Understand the connection between multiplicity and probability.

3.20 Calculate the multiplicity of an Einstein solid or two coupled Einstein solids. Determine the temperature of an Einstein solid.

3.21 Understand the implications of the second law of thermodynamics to heat flow and irreversibility. Describe the second law in terms of probability, multiplicity, and entropy.

3.22 State the definition of temperature and show that this definition is consistent with the Clausius statement of the second law.

3.23 Relate the change of entropy of an object to the heat flow into or out of that object.

3.24 For a heat engine, analyze the heat flow in, the work performed, and the heat flow out, keeping track of energy and entropy changes. Use the definition of efficiency and explain the limitations imposed by the second law.

3.25 For a cyclic ideal gas heat engine, identify and calculate Q_H, Q_C, W, and the efficiency.

3.26 Analyze heat flows and work required for a refrigerator, using the second law to determine the best-case scenario.