Course Objectives

This is a calculus-based course emphasizing analytical reasoning and problem-solving techniques. After completing this course students will be able to:

- ☐ define density and pressure (gauge & absolute)
- ☐ calculate the pressure at depth in a fluid.
- ☐ calculate buoyant forces.
- ☐ explain how Archimedes's Principle makes the calculation of buoyant forces easy.
- ☐ describe the difference between laminar and turbulent fluid flow.
- ☐ apply Bernoullis equation and continuity to relate pressure and speed at different points in a flowing fluid.
- ☐ describe how viscous flow and turbulent flow differ from ideal flow.
- ☐ apply complex numbers to describe waves and oscillations.
- ☐ use complex numbers to solve the differential equation for a damped oscillator.
- ☐ describe the difference between a longitudinal and a transverse wave.
- ☐ apply the equation relating velocity, frequency, and wavelength to wave motion.
- ☐ apply the mathematical expression for sinusoidal periodic waves to calculate displacements, speeds, and accelerations of particles in the waves medium.
- ☐ calculate the speed of transverse waves.
- ☐ calculate the rate of energy transport in a mechanical wave.
- ☐ apply boundary conditions and the principle of superposition to describe wave interference.
- ☐ analyze standing waves on a string.
- ☐ describe a sound wave in terms of particle displacements and pressure variations.
- ☐ calculate the speed of sound in different materials.
- ☐ calculate the intensity of a sound wave.
- ☐ apply the principle of standing waves to determine normal modes for a pipe or wind instrument.
- ☐ describe why resonance occurs.
- ☐ calculate points of constructive and destructive interference of sound waves.
- ☐ calculate beat frequencies.
- ☐ apply the Doppler effect equation to determine wavelength, frequency, or velocity.
- ☐ describe how shock waves occur.
- ☐ apply Fourier superposition to describe complex oscillations.

☐ describe the relationship between light rays and wavefronts.

☐ apply the laws of reflection and refraction.

☐ define index of refraction.

☐ apply the concept of total internal reflection to calculate critical angles or indices of refraction.

☐ describe how the speed of light in a material leads to dispersion.

☐ apply Malus law to determine intensities of light.

☐ apply Brewsters law to calculate polarizing angles or indices of refraction.

☐ apply the principles of reflection and refraction to determine object distance, image distances, focal lengths, and magnifications from plane and curved surfaces.

☐ construct ray diagrams to determine object distance, image distances, focal lengths, and magnifications from plane and curved surfaces.

☐ apply the lensmakers equation to determine focal length, index of refraction, or radius of a lens.

☐ apply the principles of geometric optics to describe how eyes, cameras, magnifiers, microscopes, and telescopes work.

☐ analyze double slit interference patterns to determine slit spacing, wavelength of light, fringe spacing, or light intensity.

☐ analyze thin film interference to determine film thickness or wavelength of light.

☐ explain diffraction in terms of Huygens principle.

☐ analyze single slit diffraction patterns to determine slit width, wavelength of light, fringe spacing, or light intensity.

☐ analyze diffraction gratings to determine slit spacing, wavelength of light, and resolving power.

☐ determine the resolving power of a circular aperture.

☐ calculate changes in temperatures or state of objects using specific heats and latent heats.

☐ calculate thermal expansions.

☐ describe mechanisms of heat transfer: convection, conduction, radiation.

☐ identify if a process is reversible or irreversible.

☐ identify if internal energy changes are due to heat, work, or some other form of energy transfer.

☐ describe the nature of temperature and how it is measured (0^{th} Law of Thermodynamics).

☐ apply the 1^{st} Law of Thermodynamics.

☐ describe the difference between microstates and macrostates of a system.

☐ apply the Einstein model of a solid to determine the final state of solids in thermal contact.

☐ use the probabilities of macrostates to explain irreversibility.

☐ calculate entropy using statistical mechanics.

- ☐ explain the 2^{nd} Law of Thermodynamics using statistical mechanics.
- ☐ calculate a systems internal energy temperature dependence, $U(T)$.
- ☐ use Boltzmann factors to calculate the probabilities of macrostates.
- ☐ use the partition function to calculate internal energies and heat capacities of Einstein solids.
- ☐ use the partition function to calculate internal energies and heat capacities of ideal gases.
- ☐ apply kinetic theory to derive the ideal gas law.
- ☐ apply the Maxwell-Boltzmann distribution to calculate molecular speeds in a gas.
- ☐ apply the Planck distribution to calculate photon emission rates.
- ☐ calculate heat transfer, work done, and change in internal energy, entropy change for a gas undergoing constrained processes (isothermal, isobaric, isochoric, adiabatic) and draw them on a PV diagram.
- ☐ calculate the entropy of an ideal gas using the Sackur-Tetrode equation.
- ☐ calculate changes in entropy of an ideal gas using replacement processes (adiabatic, isothermal, isochoric heating).
- ☐ define and use Carnot cycles.
- ☐ calculate efficiencies of heat engines.
- ☐ calculate coefficients of perfomance of refrigerators and heat pumps.
- ☐ apply physical concepts to model climate change.