Physics 157/158

OVERALL LEARNING GOALS

1. Being able to describe a physical situation with a mathematical model
2. identify the appropriate physical concepts that describe a situation, object, or system
3. and calculate the relevant parameters describing the system

GRAPHS

- reading/taking values off a graph
- identifying a critical point or area on a graph
- recognizing the axes of a graph (and the relationship between the graphed quantities)
- connecting aspects of the curve with a physical meaning
- using the trend in the data to help solve a problem
- being able to genearte a graph

EQUATIONS

- identifying which variables change and which stay constant in the problem
- being able to predict how the changes of one variable might affect the other variables
- being able to identify what physical conditions influence a variable
- applying a defintion or standard equation
- being able to manipulate vector quantities
- setting up an equation of conservation (e.g., energy, mass, momentum) and specifically identify and evaluate the before and after pictures
- knowing the conditions for which energy an equation does and does NOT hold true
- being able to apply and explain a rate of change
- being able to qualitatively describe parts of an equation
- setting up the initial conditions

COMBINING IDEAS & SELF CHECKS

- combining content themes in the course, e.g., SHM motion and thermodynamics, to solve a given problem
- including integrating previous expected knowledge !!
- devise problem-solving strategy (identifying the correct process from a choice of 2 or 3, e.g., themo process)
- being able to explain -- in words -- the problem solving method (including all steps)

EVALUATE

- making appropriate estimates of physical quantities describing a physical object (e.g., length, mass, frequency, etc.)
- analytical result should be consistent with your knowledge of the physical system
- evaluating limiting cases of a formula
- solve for relevant parameters in a real physical situation
- construct a qualtitative assessment of a physical situation (e.g., a prediction).
- rationalizing if your answer makes sense e.g., order of magnitude, units, plausible realistic numbers or makes sense physically
- being able to identify all the forces acting in a problem

FIGURES

- being able to generate a simplified figure
- being able to construct a free body diagram when necessary
- being able to draw a diagram reprsenting a physical problem with specific criteria, e.g., weightlessness conditions
- interpretting the figure and how it may change between different regions or at different times according to the problem
- being able to understand a reduced picture (figure) of a physicsal situation and using information from it
- being able to approximate parts of a problem with the correct geometric reprsentation
- being able to draw vectors

Phys 157 Learning goals

Content level goals: THERMODYNAMICS

1. **Heat and temperature and the Zeroth law of thermodynamics:**
    1.1. Be able to explain the difference between heat and temperature
    1.2. Apply the concept of heat flow to real world situations
    1.3. Apply concept of thermometry, ie. using a thermal property to measure temperature
    1.4. Be able to recognize and apply the concept of thermal equilibrium
2. **Thermometry:**
    2.1. Apply concept of thermal equilibrium, for example in thermometry
    2.2. Use a graphical calibration of an instrument (specifically in this case for a thermometer)
    2.3. Apply the ideal gas law as a method of measuring temperature from another measurable property of a gas
    2.4. Judge when an instrument is not appropriate for the measurement
    2.5. Calculate the slope and intercept from a graph
3. **Temperature Scales:**
    3.1. Distinguish the difference between absolute and differential temperature scales (ie. Celsius and Kelvin)
    3.2. Know what “absolute zero” is
4. **Thermal expansion and thermal stress:**
    4.1. Be able to describe and calculate linear, area and volume thermal expansion
    4.2. Be able to explain the importance of thermal expansion and thermal stress in engineering situations
    4.3. Calculate thermal stress
    4.4. Evaluate whether thermal stress and/or thermal expansion is important in given engineering situations
5. **Heat, quantitative:**
    5.1. Be able to describe the flow of energy due to objects that are at different temperatures (equivalent to asking: how do objects come into thermal equilibrium?)
    5.2. Understand that mechanical energy can be converted into thermal energy
    5.3. Be able to define specific heat
    5.4. Perform calculations relating the mass, temperature and heat required to produce temperature changes of objects
    5.5. Define what a phase change is
    5.6. Perform calculations relating heat and phase changes of an object
6. **Pathways for heat:**
    6.1. Know how convection, conduction and radiation provide a pathway for heat
    6.2. Calculate the flow of heat through an object with a simple geometry by conduction
    6.3. Know that electromagnetic waves (ie. light) carry energy
    6.4. Recognize that objects at a given temperature emit a blackbody spectrum of light related to the object’s temperature
    6.5. Apply the relationships between the blackbody spectrum and temperature to determine the temperature of an object (Wien’s law and Stefan-Boltzmann Law)
    6.6. Perform calculations to describe radiative heat transfer
7. **Integration:**
    7.1. Relate the area under a curve to an integral

7.2. Apply the concept that an integral is the area under a curve to solve or estimate the solution to physical problems that require integration

8. Work:
- 8.1. Relate Work to the area under a force-distance or pressure-volume diagram (integral)
- 8.2. Be able to describe the work done by or on a gas
- 8.3. Calculate the work done by or on a gas from a P-V diagram through a process

9. Work-Energy Theorem and the First law of thermodynamics:
- 9.1. Calculate the change in kinetic energy for a mechanical process
- 9.2. Recognize that energy can only be transferred, not destroyed (conservation of energy)
- 9.3. State the First law of thermodynamics

10. Thermodynamic system and state variables:
- 10.1. Identify the state variables for an ideal gas and other systems
- 10.2. Distinguish thermodynamic state variables, which are path independent quantities, from path dependent quantities (like heat and work)
- 10.3. Interpret and use PVT diagrams to describe thermodynamic systems
- 10.4. Use the first law to relate heat, work and change in internal energy
- 10.5. Know the vocabulary of thermodynamic processes: isothermal, isobaric, isochoric, adiabatic, isentropic
- 10.6. Calculate work, heat an internal energy changes for isothermal, isobaric, isochoric and adiabatic processes

11. Heat Engines:
- 11.1. Definition of efficiency
- 11.2. Know that efficiency must be less than 100%
- 11.3. Calculate net work done by a heat engine cycle
- 11.4. Calculate net heat transferred during a heat engine cycle
- 11.5. Derive Carnot engine efficiency from P-V description
- 11.6. Derive efficiency of a given heat engine
- 11.7. Recognize that a real heat engine has less than the thermodynamically defined efficiency and performance is based on external factors

12. Entropy and the 2nd law of thermodynamics
- 12.1. Know that perpetual motions machines are non-physical (somewhere, energy is being added)
- 12.2. Identify what is the thermodynamic system
- 12.3. Definition of the 2nd law: The entropy of a closed system cannot decrease
- 12.4. Know the mathematical definition of entropy (relation to heat and temperature)
- 12.5. Recognize that entropy is related to the degree of disorder of matter
- 12.6. Recognize that entropy is a thermodynamic state variable
- 12.7. Relate changes in entropy to reversibility
- 12.8. Calculate changes in entropy for reversible processes
- 12.9. Relate the area under a process curve in S-T representation to the change in entropy
- 12.10. Derive Carnot engine efficiency from S-T description

Phys 157 Learning goals

Content level goals: Simple Harmonic Motion

1. Simple Harmonic Oscillator:

1. Students should be able to recognize when a motion can be approximated by the motion of simple harmonic oscillator:
   (a) by noticing sinusoidal character of the time dependence of position, velocity, or acceleration
   (b) by noticing that restoring force is proportional and opposite to displacement (at least in some range)
   (c) by noticing that the restoring torque is proportional and opposite to the rotation angle
2. Given the time dependence of <u>one</u> of the following:
   (a) position
   (b) velocity
   (c) acceleration
   Students, should be able to find the time dependence of the other two quantities.
3. Given the time dependence for position, or velocity, or acceleration, students should be able to extract the following parameters of oscillation: frequency, period, amplitude and phase.
   Be able to describe how the parameters of the Simple Harmonic Oscillator (SHO) depend of the mass of the oscillating object **and** characteristic of restoring force (e.g. elastic force, force of gravity, buoyant force, etc)
4. Be able to perform simple experiments to characterize the restoring force and find parameters of the SHO
5. Be able to draw free body diagram for the oscillating object at any point of its trajectory and infer its corresponding time dependence for the acceleration (or velocity and position)
6. Be able to properly identify the restoring force for the vertical spring oscillator and calculate the corresponding parameters of oscillations
7. Be able to recognize when the vertical motion of a real oscillating object can be approximated by a vertical simple harmonic oscillator and find the corresponding parameters of oscillation

2. Simple pendulum:

1. Be able to calculate the restoring force for the simple pendulum and using appropriate approximations, show that is can be treated as a simple harmonic oscillator for small angular displacement
2. Be able to recognize when the angular motion of a real object can be modeled as a simple *physical* pendulum

3. Energy of a simple harmonic oscillator:

1. Be able to calculate the potential and kinetic energy at any point of the trajectory of an object undergoing SHM

2. Be able to describe that while the total mechanical energy of a SHO is constant, the energy of a SHO is constantly changing from potential to kinetic and vice versa

4. Damped oscillations

1. Be able to recognize when the motion of the real physical object can be described as a damped harmonic oscillator given:
    (a) the plot for position, or velocity, or acceleration
    (b) the mathematical expression for position, or velocity, or acceleration

2. Be able to infer all the descriptive parameters of the damped motion (γ, ω, etc) given:
    (a) the plot for position, or velocity, or acceleration
    (b) the mathematical expression for position, or velocity, or acceleration

3. Be able to infer from the graph or parameters of the motion if it is: underdamped, critically damped, or overdamped.
4. Be able to describe the motion (mathematically) of a real object undergoing damped oscillation
5. Be able to calculate the potential and kinetic energy at any point of the trajectory of an object undergoing damped oscillation
6. Be able to calculate the Q factor and relate its value to the characteristic behavior of the damped oscillator

5. Driven oscillators:

1. Be able to recognize and describe the motion of a real physical object undergoing driven oscillations
2. Be able to describe how the driven motion depends on the frequency of the driving force and the Q factor of the oscillator

Phys 157 **Learning goals**

Content level goals: WAVES

1. Wave definitions: Students should know the (definitions of the) parameters describing waves: wavelength, wave vector, frequency, period, phase, speed, intensity, energy, power
   - 1.1. Be able to estimate or calculate these parameters from graph
   - 1.2. Be able to estimate or calculate these parameters from mathematical descriptions (formulas) or description
   - 1.3. Be able to estimate or calculate these parameters from photographs or movies
2. Sound waves:
   - 2.1. Be able to describe in words how sound waves propagate through air
   - 2.2. Know the decibel (db) scale for sound intensity
   - 2.3. Be able to convert from db to W/m^2 and vice versa
   - 2.4. Be able to calculate the dependence of sound intensity on the distance from the source
3. Mechanical waves:
   - 3.1. Be able to identify the parameters defining the speed of mechanical wave
   - 3.2. Be able to calculate the speed of mechanical waves in various situations, e.g., inside a rod, in gas, along a string of varying density, etc.
4. Energy and Power in waves:
   - 4.1. Be able to explain how a wave can carry energy and power
   - 4.2. Be able to calculate the energy and power that a wave carries
5. Superposition of waves:
   - 5.1. Be able to describe AND predict quantitatively what happens when two waves (spatially) overlap
   - 5.2. Be able to calculate the result of superposition of waves
   - 5.3. Be able to distinguish between a propagating and standing wave based on the characteristics
6. Standing waves and musical instruments:
   - 6.1. Be able to calculate the parameters of a standing wave
   - 6.2. Be able to correlate the parameters of the mechanical waves like amplitude and frequency with the once generally used in acoustics like volume and pitch
   - 6.3. Be able to describe (comparatively) the situations which lead to the standing waves in bars, strings or air columns
   - 6.4. Be able to calculate the wavelength and frequencies corresponding to standing waves in bars, strings, and air columns
   - 6.5. Be able to recognize which situations lead to standing waves in bars, strings, and air columns
7. Beats:
   - 7.1. Be able to recognize the situations which lead to the observation of beats
   - 7.2. When two sound waves of different frequencies are combined students should be able to calculate the beat frequency of two waves.

7.3. Be able to calculate oscillation frequencies and from there calculate the beat frequency.

8. Doppler Effect

8.1. Be able to describe and calculate how the frequency of the wave reaching a recever depends on the velocity of the source and the receiver

8.1.1. for sound waves

8.1.2. for electromagnetic waves

9. Interference

9.1. Be able to quantitevely predict and calculate the wave patterns resulting from wave interference