Objectives for PHYS 2101

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

1.1 Relate position, displacement, average and instantaneous speed, average and instantaneous velocity, average and instantaneous acceleration, and time. Use these concepts in problems involving the motion of objects.

1.2 Use graphical methods to analyze one-dimensional motion.

1.3 Describe physical quantities that can be represented using vectors. Calculate the components of vectors in a given coordinate system and the magnitude and direction of a vector given its components. Combine two or more vectors using vector addition, vector subtraction, the dot product of two vectors, and the cross product of two vectors.

1.4 Given several forces acting on a single object, use Newton’s Second Law to determine the object’s acceleration; or, given the motion of an object, determine an unknown force.

1.5 Given a physical situation, apply Newton’s Second and Third Laws following these steps: a) sketch the situation, b) identify forces, c) construct a free-body diagram, d) determine the net force on the object, and e) apply Newton’s Second Law to solve for unknowns.

1.6 Correctly use the various properties of weight forces, normal forces, tensions, spring forces, friction forces, and drag forces in analyzing problems.

1.7 Analyze uniform circular motion by relating period, velocity, radius, and centripetal acceleration, including the directional properties of an object’s velocity and acceleration.

1.8 Given a constant force and the straight-line motion of an object, calculate the work done on the object.

1.9 Estimate or calculate the work done during one-dimensional motion either by determining the area under a force-vs-displacement graph or by integration.

1.10 Apply the work-kinetic energy theorem to a moving object subject to one or more forces.

1.11 Use the definition of power to relate power, work, and time.

1.12 State the definition of potential energy and describe the types of forces with which a potential energy may be associated. From a given one-dimensional potential energy, find the associated force.

1.13 Given a graph of an object’s potential energy versus position, determine the direction and approximate magnitude of the associated force and determine the object’s kinetic energy, turning points, and points of equilibrium for a given constant value of the object’s mechanical energy.

1.14 State and recognize the conditions under which conservation of mechanical energy applies.

1.15 For situations in which mechanical energy is not conserved, relate the change in mechanical energy to the work done by non-conservative forces.

1.16 Calculate the momentum and change of momentum of various objects, recalling that momentum is a vector quantity.

1.17 State and recognize the conditions under which conservation of linear momentum applies.

1.18 Apply conservation of momentum of linear momentum to various isolated systems, including explosions and collisions in one- or two-dimensions. For elastic collisions, be able to use both conservation of momentum and conservation of energy to solve for unknowns.
1.19 Relate angular position $\theta$, angular velocity $\omega$, angular acceleration $\alpha$, and time $t$. Relate linear speed to angular speed and distance. Relate angular velocity and angular acceleration to linear acceleration. Use the no-slip condition to relate linear motion to angular motion.

1.20 Relate rotational kinetic energy to moment of inertia and angular velocity. Solve conservation of energy problems involving rotational kinetic energy, and use the rotational work-kinetic energy theorem.

1.21 Calculate torque from the force and the position that the force is applied. Calculate angular momentum for particles from linear momentum and position, and angular momentum for extended objects from moment of inertia and angular velocity. Calculate the change in the angular momentum of a particle or an extended object from the change in its motion.

1.22 Use Newton’s 2nd Law for rotational motion to relate net torque to the product of the moment of inertia and angular acceleration or to the rate of change of angular momentum. Also, combine this with $\vec{F}_{\text{net}} = m\vec{a}$ for systems with both angular and linear motion.

1.23 Correctly use the right hand rules to determine the direction of vector cross products and the direction of angular quantities.

1.24 Apply the conservation of angular momentum to situations where the net external torque equals zero or has a component equal to zero.

1.25 Define mechanical equilibrium for an object and use the definition to solve for unknown forces or torques acting on an object.

1.26 Calculate the gravitational force acting between point-like or spherical objects using Newton’s law of gravitation.

1.27 Using the expression for gravitational potential energy and conservation of energy, relate speed and distance for objects in free flight and in orbit, including the concept of escape velocity.

1.28 Use Kepler’s laws to relate distance, velocity, and period of revolution for planetary systems or satellites.

1.29 Apply Newton’s second law and Newton’s law of gravity to circular orbit problems.

1.30 Relate pressure and pressure differences to the forces acting on a surface.

1.31 Apply the definitions of density and pressure to determine differences in pressure at different points in a fluid.

1.32 Solve problems involving buoyant forces on completely submerged or partially submerged objects.

1.33 Recognize the form of the equation for the displacement of a simple harmonic oscillator as a function of time. Given such an equation, be able to determine the frequency $f$, period $T$, angular frequency $\omega$, amplitude $A$, phase constant $\phi$, and maximum speed and acceleration for the oscillator.

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

1.35 Using Newton’s second law, rewrite the general form for the equation of motion of a simple harmonic oscillator as $a = -(\text{const})x$ for linear and angular SHOs. From this determine the angular frequency of oscillation.

1.36 Given a specific expression for a traveling transverse or longitudinal harmonic wave, determine amplitude, angular frequency, frequency, wavenumber, wavelength, period, and wavespeed. For a particle within a medium, calculate the transverse displacement, transverse speed, and transverse acceleration at a particular point in space as a given transverse wave passes by.
1.37 For standing wave modes on strings: sketch the wave pattern, identify nodes and antinodes, and determine wavelength, wave-number, frequency or wave speed.

1.38 For interference problems, determine phase difference from path length differences.

1.39 Correctly use the Kelvin temperature scale and translate other temperature scales to the Kelvin scale.

1.40 Given heat capacity or specific heat and heats of transformation, calculate thermal energy added or removed for various temperature changes or changes of phase.

1.41 Solve calorimetry problems by determining the final state of a system when materials at different temperatures are mixed.

1.42 Use the First Law of Thermodynamics to relate the change in internal energy of a system to the thermal energy added or removed from the system and the work done by or on the system.

1.43 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.

1.44 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.

1.45 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) straight line process on a $P-V$ diagram, (d) isothermal process, (e) adiabatic process.

1.46 Relate pressure ($P$), volume ($V$), temperature ($T$), and number of molecules ($N$) or moles ($n$), or changes in these quantities, using the ideal gas law.

1.47 Relate average molecular kinetic energy, rms speed, and temperature of a gas.

1.48 For a series of such 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.

1.49 Calculate $Q_C$, $Q_H$, $W$, and efficiency for a cyclic process using an engine diagram.

1.50 Determine entropy changes of a system and nearby reservoirs as heat is added or removed. Apply specifically to cyclic engines or refrigerators.

1.51 State and use the Second Law of Thermodynamics in terms of entropy. Be able to state how entropy of a system changes for reversible and irreversible thermodynamic processes.