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Stratford, Connecticut

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Advanced Placement Physics C / UConn PHYS 1401Q

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Advanced Placement Physics C: Mechanics / UConn PHYS 1401Q

Course Overview

AP Physics C: Mechanics / UConn PHYS 1401Q is equivalent to a one-semester, calculus-based, college-level physics course, taught over one full school year. It is especially appropriate for students planning to specialize or major in one of the physical sciences or engineering in college. In order for students to enroll in this course they should have taken or be concurrently taking calculus (Honors or AP level). This College Board course is co-aligned to UConn PHYS 1401Q through the UConn Early College Experience (ECE) program.

The proposed primary textbook for the course for the 2020-2021 school year is University Physics Volumes 1 and 2, published by OpenStax (ISBN-10: 1-947172-20-4 and ISBN-10: 1-947172-21-2), available online:
Volume 1: https://openstax.org/details/books/university-physics-volume-1
Volume 2: https://openstax.org/details/books/university-physics-volume-2

In *AP Physics C: Mechanics / UConn PHYS 1401Q*, students will explore principles of one- and two-dimensional kinematics; Newton's laws of motion; work, energy, and power; systems of particles and linear momentum; rotation; oscillations; gravitation; waves and sound; thermodynamics; and fluids. The course is based on four Big Ideas (BI) from the AP Mechanics C course sequence and three from the UConn PHYS 1401Q course sequence, all of which encompass core scientific principles, theories, and processes that cut across traditional boundaries and provide a broad way of thinking about the physical world. The following are Big Ideas:

- Interactions produce changes in motion. (BI1)
- Forces characterize interactions between objects or systems. (BI2)
- Fields predict and describe interactions. (BI3)
- Conservation laws constrain interactions. (BI4)
- Interactions between systems can result in change in those systems. (BI5)
- Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena. (BI6)
- The mathematics of probability can be used to describe and predict the behavior of complex systems. (BI7)

Throughout the units in this course, students will establish lines of evidence and use them to develop and refine testable explanations and predictions of natural phenomena, promoting an engaging and rigorous experience for AP/UConn ECE physics students. Such Science Practices (SP) are listed on the following page:

AP PHYSICS C: MECHANICS

Science Practices

Practice 1	Practice 2	Practice 3	Practice 4	Practice 5	Practice 6	Practice 7
Visual Representations 1	***Question and Method*** 2	***Representing Data and Phenomena*** 3	***Data Analysis*** 4	***Theoretical Relationships*** 5	***Mathematical Routines*** 6	***Argumentation*** 7
Analyze and/or use (non-narrative/non-mathematical) representations of physical situations, excluding graphs.	Determine scientific questions and methods.	Create visual representations or models of physical situations.	Analyze quantitative data represented in graphs.	Determine the effects on a quantity when another quantity or the physical situation changes.	Solve problems of physical situations using mathematical relationships.	Develop an explanation or a scientific argument.

SKILLS

Practice 1	Practice 2	Practice 3	Practice 4	Practice 5	Practice 6	Practice 7
1.A Describe the physical meaning (includes identifying features) of a representation. **1.B** Describe the relationship between different types of representations of the same physical situation. **1.C** Demonstrate consistency between different types of representations of the same physical situation. **1.D** Select relevant features of a representation to answer a question or solve a problem. **1.E** Describe the effects of modifying conditions or features of a representation of a physical situation.	**2.A** Identify a testable scientific question or problem. **2.B** Make a claim or predict the results of an experiment. **2.C** Identify appropriate experimental procedures (which may include a sketch of a lab setup). **2.D** Make observations or collect data from representations of laboratory setups or results. **2.E** Identify or describe potential sources of experimental error. **2.F** Explain modifications to an experimental procedure that will alter results.	**3.A** Select and plot appropriate data. **3.B** Represent features of a model or the behavior of a physical system using appropriate graphing techniques, appropriate scale, and units. **3.C** Sketch a graph that shows a functional relationship between two quantities. **3.D** Create appropriate diagrams to represent physical situations.	**4.A** Identify and describe patterns and trends in data or a graph. **4.B** Demonstrate consistency between different graphical representations of the same physical situation. **4.C** Linearize data and/or determine a best fit line or curve. **4.D** Select relevant features of a graph to describe a physical situation or solve problems. **4.E** Explain how the data or graph illustrates a physics principle, process, concept, or theory.	**5.A** Select an appropriate law, definition, mathematical relationship, or model to describe a physical situation. **5.B** Determine the relationship between variables within an equation when an existing variable changes. **5.C** Determine the relationship between variables within an equation when a new variable is introduced. **5.D** Determine or estimate the change in a quantity using a mathematical relationship. **5.E** Derive a symbolic expression from known quantities by selecting and following a logical algebraic pathway.	**6.A** Extract quantities from narratives or mathematical relationships to solve problems. **6.B** Apply an appropriate law, definition, or mathematical relationship to solve a problem. **6.C** Calculate an unknown quantity with units from known quantities by selecting and following a logical computational pathway. **6.D** Assess the reasonableness of results or solutions.	**7.A** Make a scientific claim. **7.B** Support a claim with evidence from experimental data. **7.C** Support a claim with evidence from physical representations. **7.D** Provide reasoning to justify a claim using physical principles or laws. **7.E** Explain the connection between experimental results and larger physical principles, laws, or theories. **7.F** Explain how potential sources of experimental error may affect results and/or conclusions.

These Science Practices developed by the College Board parallel the eight practices of science and engineering found in the NRC's *A Science Framework for K-12 Science Education*, upon which the *Next Generation Science Standards* (NGSS) are based. The importance of combining science and engineering practices with disciplinary core ideas is stated in the Framework as follows:

"…students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined. At the same time, they cannot learn or show competence in practices except in the context of specific content." (NRC Framework, 2012, p. 218)

The eight practices of science and engineering that the Framework identifies as essential for all students to learn (and describes in detail in Chapter 3 of the Framework) are listed here:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

In this course, students will also become familiar with the three components of scientific argumentation:

1) The Claim - an explanation or prediction for what, why or how something happens
2) The Evidence – the data or reasoning that supports the claim
3) The Questioning – the process through which claims are examined and defended

Throughout the year, as a result of the scientific argumentation process, students will be expected to revise their claims and make revisions as appropriate to their scientific thinking. Opportunities to engage in scientific argumentation will occur during class discussions (including peer questioning), laboratory work and data analysis presentations (peer critique/questions), project write-ups and presentations (peer critique/questions), and also on in-class assessments (quizzes and tests). Students will regularly be expected to explain not only the "what's", but also the "why's" and "how's" of the content learning in this course through the sighting of both qualitative and quantitative evidence. During lab time in particular, students will engage regularly in peer critique and questioning of experimental procedures, data collection and analysis, and experimental conclusions.

Students will be provided opportunities to apply the Science Practices and demonstrate growth in their scientific argumentation skills through laboratory work and projects. At least twenty-five percent of instructional time in this course is devoted to such work, with an emphasis on inquiry-based investigations that will require students to ask questions, make observations and predictions, design experiments, analyze data, and construct arguments in a collaborative setting. The objective of the course is to have students develop the skills and intuition to be able to understand physics problems and, along with mathematical reasoning, to be able to solve college-level, calculus based physics problems. The lab experiments parallel and support the core concepts of the curriculum. Ultimately most of the lab experimental designs lead to the collection of data that is analyzed through graphical methods to draw conclusions about scientific phenomena, and all have written components to them. Students are expected to record their observations, data, and data analyses as part of their *Lab Portfolio*. Data analyses include identification of the sources and effects of experimental uncertainty, calculations, results and conclusions, and suggestions for further refinement of the experiment as appropriate.

The lab work in this course supports the following Common Core English Language Arts Standards in Science and Technical Subjects:

CCSS.ELA-LITERACY.RST.11-12.3
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

CCSS.ELA-LITERACY.RST.11-12.7
Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

CCSS.ELA-LITERACY.RST.11-12.8
Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

CCSS.ELA-LITERACY.RST.11-12.9
Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

CCSS.ELA-LITERACY.WHST.11-12.1.B
Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.

CCSS.ELA-LITERACY.WHST.11-12.1.D
Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

CCSS.ELA-LITERACY.WHST.11-12.2
Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

CCSS.ELA-LITERACY.WHST.11-12.2.E
Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).

CCSS.ELA-LITERACY.WHST.11-12.4
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

In *AP Physics C: Mechanics / UConn PHYS 1401Q*, students will cultivate their understanding of Big Ideas and Science Practices as they explore the following topics:

- Kinematics (*#)
- Newton's laws (*#)
- Work, energy, and conservation of energy (*#)
- Systems of Particles and Linear Momentum (*#)
- Rotational motion: (*#)
- Oscillations (*#)
- Gravitation (*#)
- Mechanical waves and sound (#)
- Thermodynamics (#)
- Fluids (#)

* AP Mechanics C Topic #UConn PHYS 1401Q Topic

Topics that are UConn PHYS 1401Q specific will be taught as part of the course summer assignment and/or after the AP Mechanics C College Board examination. All students will take a common Stratford District Midterm Exam model on the style of the College Board AP Exam. All students will take the final exam for the course provided by the UConn Physics Department. The student's final grade for this course will be determined by the grading policy of the UConn Physics Department: *Course Work 75%, Final Exam 25%.* There are no final exam exemptions in this course.

AP Mechanics C / UConn PHYS 1401Q Concepts At a Glance

UNIT 1: KINEMATICS		
Guiding Questions	**Topics**	**Enduring Understandings**
How can accelerated motion in one and two dimensions be described qualitatively, quantitatively, and graphically? Why is free fall considered a special case of accelerated motion? How do variables such as launch angle, velocity,	1.1 Motion in One Dimension 1.2 Motion in Two Dimensions	1.1 There are relationships among the vector quantities of position, velocity, and acceleration for the motion of a particle along a straight line. 1.2 There are multiple simultaneous relationships among the quantities of position, velocity, and acceleration for the motion of a particle moving in more than one dimension with or without net forces.

and altitude affect the maximum height and range of a launched projectile?		
UNIT 2: NEWTON'S LAWS OF MOTION		
Guiding Questions	**Topics**	**Enduring Understandings**
How is knowledge of the net force essential to understanding an object's motion? How can a free-body diagram be used to describe and/or create a mathematical representation of the forces acting on an object? Why do you stay in your seat on a roller coaster when it goes upside down in a vertical loop?	2.1 First and Second Law 2.2 Circular Motion 2.3 Third Law	2.1 A net force will change the translational motion of an object. 2.2 The motion of some objects is constrained so that forces acting on the object cause it to move in a circular path. 2.3 There are force pairs with equal magnitude and opposite directions between any two interacting objects.
UNIT 3: WORK, ENERGY, AND POWER		
Guiding Questions	**Topics**	**Enduring Understandings**
How are Newton's Laws related to energy through the concept of work? How can energy be represented with graphs and equations? How does energy conservation inform our understanding of the motion of objects?	3.1 Work-Energy Theorem 3.2 Forces and Potential Energy 3.3 Conservation of Energy	3.1 When a force is exerted on an object, and the energy of the object changes, then work was done on the object. 3.2 Conservative forces internal to the system can change the potential energy of that system. 3.3 The energy of a system can transform from one form to another without changing the total amount of energy in the system.

	3.4 Power	3.4 The energy of an object or a system can be changed at different rates.
UNIT 4: SYSTEMS OF PARTICLES AND LINEAR MOMENTUM		
Guiding Questions	**Topics**	**Enduring Understandings**
How are Newton's laws related to momentum? How can the outcome of a collision be used to characterize a collision as elastic or inelastic? How can changes in momentum be utilized to determine the forces applied to an object?	4.1 Center of Mass 4.2 Impulse and Momentum 4.3 Conservation of Linear Momentum, Collisions	4.1 The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. 4.2 An impulse exerted on an object will change the linear momentum of the object. 4.3 In the absence of an external force, the total momentum within a system can transfer from one object to another without changing the total momentum in the system.
UNIT 5: ROTATIONS		
Guiding Questions	**Topics**	**Enduring Understandings**
How can Newton's law be applied to rotating systems? How does a net torque affect the angular momentum of a rotating system? What does it mean for angular momentum to be conserved?	5.1 Torque and Rotational Statics 5.2 Rotational Kinematics 5.3 Rotational Dynamics and Energy	5.1 When a physical system involves an extended rigid body, there are two conditions of equilibrium—a translational condition and a rotational condition. 5.2 There are relationships among the physical properties of angular velocity, angular position, and angular acceleration. 5.3 A net torque acting on a rigid extended body will produce rotational motion about a fixed axis.

	5.4 Angular Momentum and Its Conservation	5.4 In the absence of an external torque, the total angular momentum of a system can transfer from one object to another within the system without changing the total angular momentum of the system.

UNIT 6: OSCILLATIONS

Guiding Questions	Topics	Enduring Understandings
How can oscillatory motion be represented graphically and mathematically? What factors affect the period of oscillation for a mass oscillating on a spring and for a simple pendulum? How is conservation of energy applied in simple harmonic oscillators?	6.1 Simple Harmonic Motion, Springs, and Pendulums	6.1 There are certain types of forces that cause objects to repeat their motions with a regular pattern.

UNIT 7: GRAVITATION

Guiding Questions	Topics	Enduring Understandings
What does it mean for a force to be fundamental? How can Newton's second law of motion be related to the universal law of gravitation? How do conservation laws govern satellite motion?	7.1 Gravitational Forces 7.2 Orbits of Planets and Satellites	7.1 Objects of large mass will cause gravitational fields that create an interaction at a distance with other objects with mass. 7.2 Angular momentum and total mechanical energy will not change for a satellite in an orbit.

UNIT 8: MECHANICAL WAVES AND SOUND		
Guiding Questions	**Topics**	**Enduring Understandings**
How are waves energy transport phenomena?	8.1 Properties of Waves	8.1 A wave is a traveling disturbance that transfers energy and momentum.
What happens when two or more waves meet?	8.2 Periodic Waves	8.2 A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.
How can wave boundary behavior be used to explain frequencies for standing waves in strings, open pipes, and closed pipes?	8.3 Interference and Superposition (Waves in Tubes and on Strings)	8.3 Interference and superposition lead to standing waves and beats.

Unit 9: Thermodynamics		
Guiding Questions	**Topics**	**Enduring Understandings**
How are heat and temperature explained on a molecular level?	9.1 Pressure, Thermal Equilibrium, and the Ideal Gas Law	9.1 The properties of an ideal gas can be explained in terms of a small number of macroscopic variables, including temperature and pressure.
How do we know thermal energy is transferred or exchanged?	9.2 Thermodynamics, Forces, and Collisions	9.2 Classically, the acceleration of an object interacting with other objects can be predicted by using $a = F_{net}/m$. The linear momentum of a system is conserved.
How is the expansion of a gas related to mechanical work?		
How is the law of conservation of energy applied to the understanding of the laws of thermodynamics?	9.3 Heat and Energy Transfer	9.3 Interactions with other objects or systems can change the total energy of a system.
	9.4 Internal Energy and Energy Transfer	9.4 The energy of a system is conserved.
What are the implications of the	9.5 Thermal Conductivity	9.5 Materials have many macroscopic properties that result

second law of thermodynamics?	9.6 Probability, Thermal Equilibrium, and Entropy	from the arrangement and interactions of the atoms and molecules that make up the material. 9.6 The tendency of isolated systems to move toward states with higher disorder is described by probability.
UNIT 10: FLUIDS		
Guiding Questions	**Topics**	**Enduring Understandings**
Why does liquid pressure vary with depth when gas pressure does not?	10.1 Fluids: Pressure, Forces, and Buoyancy	10.1 Classically, the acceleration of an object interacting with other objects can be predicted by using $a = F_{net}/m$.
How does Archimedes' principle help us to understand why certain objects float in fluids?	10.2 Conservation of Energy in Fluid Flow	10.2 The energy of a system is conserved.
How can conservation of mass and conservation of energy be used to predict the behavior of moving liquids?	10.3 Conservation of Mass Flow Rate in Fluids	10.3 Classically, the mass of a system is conserved.

The specific learning objectives and suggested laboratory activities for the following units can be found within the AP Mechanics C Course and Exam Description published by the College Board:

- Kinematics
- Newton's laws
- Work, energy, and conservation of energy
- Systems of Particles and Linear Momentum
- Rotational motion
- Oscillations
- Gravitation

The AP Mechanics C Course and Exam Description is a 174 page document that, in addition to the course framework and learning objectives for each unit, also includes unit planning guides and sample AP Exam questions. It can be downloaded from the College Board website and is

located here:
https://apcentral.collegeboard.org/pdf/ap-physics-c-mechanics-course-and-exam-description.pdf?course=ap-physics-c-mechanics

Formative assessments for these units are available to instructors on the College Board's AP Classroom website. These assessments model AP Exam multiple choice and Free Response Questions, organized by topic and skills

The remainder of the units in this course are specific to the UConn PHYS 1401Q course and will be taught either as part of the Summer Assignment for this course or after the AP Exams (note: the Thermodynamics and Fluids unit are part of the *AP Physics 2 / UConn 1202Q* course offered by Stratford Public Schools, which can be taken by students who have successfully completed this course). Learning objectives and suggested laboratory activities for these UConn-specific units can be found in the following summary charts:

Unit: Mechanical Waves and Sound
Learning Objectives ● The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave. ● The student is able to describe representations of transverse and longitudinal waves. ● The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples. ● The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave. ● The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example. ● The student is able to use a graphical representation of a periodic mechanical wave (position vs. time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation. ● The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave. ● The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.

- The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.

- The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.

- The student is able to design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves).

- The student is able to design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium.

- The student is able to analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes.

- The student is able to refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively.

- The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.

- The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air.

- The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.

- The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.

- The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.

- The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.

Suggested Laboratory Activities
Open/Closed Tube Tuning Fork Resonance Lab
Boomwacker™ Lab
Vibrating String PhET Simulation Lab
Ripple Tank Lab
Slinky Lab NGSS PE-aligned lab

Unit: Thermodynamics

Learning Objectives

- The student is able to design an experiment and analyze data from it to examine thermal conductivity.
- The student is able to make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level.
- The student is able to describe and make predictions about the internal energy of systems.
- The student is able to design an experiment and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance.
- The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.
- The student is able to design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system.
- The student is able to describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation.
- The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles.

- The student is able to create a plot of pressure versus volume for a thermodynamic process from given data.
- The student is able to use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the first law of thermodynamics).
- The student is able to make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system.
- Treating a gas molecule as an object (i.e., ignoring its internal structure), the student is able to analyze qualitatively the collisions with a container wall and determine the cause of pressure and at thermal equilibrium to quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables.
- The student is able to qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system.
- The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes.
- The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero.
- The student is able to design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables.
- The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$.
- The student is able to construct an explanation, based on atomic-scale interactions and probability, of how a system approaches thermal equilibrium when energy is transferred to it or from it in a thermal process.
- The student is able to connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how it (entropy) behaves in reversible and irreversible processes

Suggested Laboratory Activities
States of Matter PhET Simulation Lab
Gas Laws PhET Simulation Lab
Thermal Conductivity Lab
Thermal Speed and Maxwell Distribution Physics Aviary Sim Lab

Unit: Fluids

Learning Objectives

- The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction.
- The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects.
- The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.
- The student is able to use Bernoulli's equation to make calculations related to a moving fluid.
- The student is able to use Bernoulli's equation and/or the relationship between force and pressure to make calculations related to a moving fluid.
- The student is able to use Bernoulli's equation and the continuity equation to make calculations related to a moving fluid.
- The student is able to construct an explanation of Bernoulli's equation in terms of the conservation of energy.
- The student is able to make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation).

Suggested Laboratory Activities
Determining *g* by using Archimedes' Principle
Torricelli's Theorem Lab
Balloons and Buoyancy PhET Simulation Lab
Flow Rate PhET Simulation Lab