University of Pittsburgh

Kenneth P. Dietrich School of Arts and Sciences

College in High School

2024-2025

Basic Physics for Science and Engineering 1

PHYS 0174--4 Credits

Description: This is the first term of a two-term introductory sequence in physics for science and engineering students.

Prerequisites: Calculus is needed and should be taken at least concurrently. The laboratory course associated with this sequence is taken after Physics 0174.

Grading: The grade is determined primarily by three exams during the term and a cumulative final exam. Other work, such as quizzes and homework, may make some contribution to the grade. Approximately half of the class time each week is spent in covering new material. The remaining time is devoted to activities such as problem solving, demonstrating experiments, questions, and discussion.

Textbook: At the University of Pittsburgh, the latest edition of *Fundamentals of Physics* by Halliday, Resnick, and Walker is used. Any comparable, calculus-based text that covers all the material in this course outline is acceptable as an alternative.

The following topics should be covered. The order of topics may be altered if all the material listed before each exam is covered before that exam is given.

1. Measurement

- Units of length, time, mass; specifically, the SI system
- Unit checking
- Changing units
- Systems of coordinates

2. Vectors

- Vectors vs. scalars
- Magnitude, direction, Cartesian components
- Unit vectors i, j, k
- Addition and subtraction by geometric and algebraic methods
- Multiplication by a scalar
- Scalar (dot) product
- Vector (cross) product

3. Motion along a straight line

- Position and displacement
- Average velocity and average speed
- Instantaneous velocity and instantaneous speed
- Average acceleration and instantaneous acceleration
- Kinematics of constant acceleration
- Freely falling bodies

4. Motion in two and three dimensions

- Position and displacement
- Average velocity and average speed
- Instantaneous velocity and instantaneous speed
- Average acceleration and instantaneous acceleration
- Projectile motion
- Uniform circular motion
- Relative velocity and acceleration (it is sufficient to do only the one-dimensional case)

5. Newton's laws of motion
- Newton's First Law and inertial frames of reference
- Newton's Second Law and concepts of force and mass
- Newton's Third Law

6. Applications of Newton's laws
- Free-body diagrams
- Tension and pulleys
- Static and kinetic friction
- Inclined planes
- Uniform circular motion and centripetal force

EXAM I

7. Work and Kinetic Energy
- Work as a scalar product
- Work done by weight
- Work done by a variable force
- Hooke's law and work done by a spring
- Kinetic energy and the work-energy theorem
- Power

8. Potential energy & conservation of energy
- Conservative forces and potential energy
- Examples: mgh and $(1/2)kx^2$
- Conservation of mechanical energy
- Work done by nonconservative forces and $W_{noncon} = \Delta E$
- Conservation of energy (including internal energy)

9. Systems of particles
- Center of mass
- Newton's second law for a system of particles
- Linear momentum of a particle and of a system
- Conservation of momentum

10. Collisions
- Impulse and the impulse-momentum theorem
- Elastic and inelastic collisions in one dimension
- Collisions in two dimensions

EXAM II

11. Rotation
- Kinematics of fixed-axis rotation
- Linear and angular variables
- Moment of inertia and rotational kinetic energy
- Torque (including definition as a cross product) and rotational dynamics
- Rolling; translational and rotational kinetic energy; conservation of energy
- Angular momentum of a particle, a system of particles, and a rigid body
- Conservation of angular momentum

12. Oscillations
- Simple harmonic motion resulting from Newton's second law and Hooke's law
- Position, velocity, and acceleration in simple harmonic motion
- Energy considerations in simple harmonic motion
- Simple pendulum

EXAM III

13. Gravitation
- Newton's law of universal gravitation
- Gravitational potential energy and escape speed
- Planets and satellites
- Kepler's laws and their relation to conservation laws

14. Mechanical Waves
- Transverse and longitudinal waves
- Wavelength and frequency

- Speed of a traveling wave
- Waves on a stretched string
- Speed, energy, and power of a traveling wave on a stretched string
- Principle of superposition; interference
- Standing waves
- Sound waves
- Speed of sound
- Interference of sound waves

15. Doppler effect

FINAL EXAM (Cumulative)

PHYS 0174 Learning Objectives

1. Make a graph of the instantaneous displacement, velocity, and/or acceleration of a system based on a description of the motion or using another graph.
2. Apply the equations of 1-D kinematics to one or more objects with constant acceleration. Examples include free-fall, two objects that meet one another, and an object that has different constant acceleration at different times.
3. Add or subtract two or more vectors. (Relative velocity problems are an application of this category.)
4. Find the dot product or cross product of two vectors.
5. Describe the behavior of an object undergoing projectile motion based on the equations of 2-D kinematics.
6. Apply a conceptual understanding of Newton's first and third law.
7. Draw a free-body diagram and solve for an unknown force or acceleration of a system under the influence of two or more forces.
8. Calculate the force of static/kinetic friction or the coefficient of friction.
9. Calculate the drag force or terminal speed of an object.
10. Identify the centripetal force that acts on a system undergoing circular motion.
11. Find the work done by a force in cases where integration is not required (perhaps by inspecting a graph of force versus displacement). Alternately, find the force given work and displacement.
12. Calculate the average power provided by a force.
13. Apply conservation of mechanical energy to describe the motion of a system.
14. Use the work-energy theorem to identify the amount of mechanical energy that has been lost.
15. Calculate the average force or impulse during a collision or series of collisions.
16. Apply conservation of momentum to an explosion or collision. Be able to identify whether a collision is elastic, inelastic, or completely inelastic.
17. Answer a conceptual question about momentum, rockets, and/or the motion of the center of mass.

18. Apply kinematics to a rotating system. Be able to convert between the tangential values of s, v, a and θ, ω, using the radius r.
19. Distinguish between angular, tangential, and centripetal acceleration.
20. Determine the net torque acting on a body about a given axis and/or the angular acceleration of that body. Doing so may require the use of one or more moments of inertia.
21. Use the definition of static equilibrium to solve for one or more unknown forces or torques acting on a system.
22. Calculate the motion of a rolling object using torques and/or energy conservation. "Rolling" could be caused by a cord wrapped around the object, like in a yo-yo.
23. Find the rotational kinetic energy of an object.
24. Identify whether angular momentum is or is not conserved, and if appropriate, apply conservation of angular momentum to a rotating system.
25. Calculate the gravitation acceleration for an object inside or outside of a planet, given some combination of mass, radius, and density.
26. Apply energy conservation to a system with gravity to describe the motion of an object in a case where $U = mg$ is *not* an appropriate assumption.
27. Use Kepler's laws of planetary motion to describe the motion of a planet, moon, or satellite about its parent body.
28. Apply the concepts of stress, strain, and ultimate strength to a deformed object.
29. Calculate a spring constant given the elastic properties of a material.
30. Identify when a system (spring, simple pendulum, or physical pendulum) is undergoing simple harmonic motion, and find the amplitude, period, frequency, angular frequency, phase angle, displacement, velocity, and/or acceleration.
31. Apply conservation of mechanical energy to a simple harmonic oscillator (spring, simple pendulum, or physical pendulum). Damping may be involved.
32. Determine the amplitude, period, frequency, angular frequency, wave number, wave length, and/or propagation speed of a transverse traveling wave. If the wave is on a string, be able to calculate the propagation speed using the tension and linear density.
33. Predict the result of interference between two waves with identical amplitude and frequency. Specifically, be able to identify constructive, destructive, and intermediate interference—determining the amplitude and/or phase difference in the later case.
34. Identify the resonant frequencies and/or harmonics of a string or open/closed pipe.
35. Apply the equation for the Doppler effect to determine the shift in frequency caused by motion.

College in High School

Academic Integrity: All College in High School teachers, students, and their parents/guardians are required to review and be familiar with the University of Pittsburgh's Academic Integrity Policy located online at https://www.as.pitt.edu/faculty/policies-and-procedures/academic-integrity-code.

Grades: Grade criteria in the high school course may differ slightly from University of Pittsburgh standards. A CHS student could receive two course grades: one for high school and one for the University transcript. In most cases the grades are the same. These grading standards are explained at the beginning of each course.

Transfer Credit: University of Pittsburgh grades earned in CHS courses appear on an official University of Pittsburgh transcript, and the course credits are likely to be eligible for transfer to other colleges and universities. Students are encouraged to contact potential colleges and universities in advance to ensure their CHS credits would be accepted. If students decide to attend any University of Pittsburgh campuses, the University of Pittsburgh grade earned in the course will count toward the student grade point average at the University. At the University of Pittsburgh, the CHS course supersedes any equivalent AP credit.

Drops and Withdrawals: Students should monitor progress in a course. CHS teacher can obtain a Course Drop/Withdrawal Request form from the CHS office or Aspire. The form must be completed by the student, teacher and parent/guardian and returned to teacher by deadlines listed. Dropping and withdrawing from the CHS course has no effect on enrollment in the high school credits for the course.