Advanced Placement Physics B

A. COURSE DESCRIPTION

Advanced Placement Physics (B) is the equivalent of two semesters of college physics. Emphasis is placed on mechanics, kinetic theory and thermodynamics, electromagnetism, waves and optics, and modern physics. A strong background in algebra and trigonometry is required. One of the major goals of the course is the development of understanding of basic physics principles, and the ability to apply these principles in the solution of problems.

B. MATERIALS

Bring a three ring-binder or folder, transparent ruler, pencil, notebook paper, calculator and textbook to class everyday. The textbook used for AP Physics B is:

Giancoli, Douglas C., Physics Principles with Applications, Sixth Edition, Pearson Education, Inc., Upper Saddle River, NJ, 2005.

C. COURSE EVALUATION

1. Chapter Tests/Quizzes

Tests will be 100 points each and account for approximately 45% of the nine week grade. Each test will consist of multiple choice questions, problems, graphing and analysis of data. All tests are partially comprehensive. A missed quiz or test may be completed by scheduling a time with the teacher to make-up the quiz or test. The school policies concerning late work will be strictly enforced.

2. Daily Assignments/Homework

These assignments may include selected questions, problems, reports, quizzes, or projects. These assignments may be given on a daily basis and will account for approximately 20% of the nine week grade. Following an absence, it is the student’s responsibility to ask the teacher about the work that was missed and due dates.

3. Laboratory

The laboratory grade will be approximately 15% of the nine week average. Laboratory safety rules and techniques must be followed at all times in the laboratory.
All lab experiments are “hands-on” activities. Students will be required to keep a lab notebook containing all of their lab reports. Following an absence, it the student’s responsibility to schedule laboratory time to complete a missed laboratory.

4. Nine Week Exam

The nine week exam will be 20% of the average grade. The exam will consist of multiple choice questions, problems, graphing and analysis of data.

The grading scale for grades 11-12 is:

A = 90 to 100 B = 80 to 89 C = 70 to 79 D = 60 to 69

Good attendance is important to success in Advanced Placement Physics B. Students are strongly encouraged to read each chapter and complete all assignments. Student success on each test will be directly related to their understanding of the chapter objectives and their ability to answer the questions and problems from the laboratories and assignments.

PHYSICS

Chapter 1: Introduction and Measurement

A. General aim: To use proper laboratory techniques to collect data, to report measured quantities using correct significant figures, and to convert between metric units.

B. Content

1. The numerical value of a measurement
2. Significant figures
3. Scientific notation
4. Measurement of mass, length, and volume
5. Conversion of units by the factor-label method
6. Graphing data
7. Graphs of linear, quadratic, and inverse relationships
8. Solving equations using algebra

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Name the basic metric units and their symbols.
2. Distinguish between mass and weight.
3. Given conversion tables and given the measurement of length, mass, or volume, in the English or Metric System, use the factor-label method in problem solving to convert the measurement to other stated units in the English or Metric System.
4. Determine the amount of uncertainty in a measured quantity and distinguish between accuracy and precision.
5. Report measurements and the results of calculating with measurements to the correct number of significant figures.
6. Express large and small numbers in scientific notation.
7. Distinguish between dependent and independent variables.
8. Graphically identify direct and inverse relationships.
9. Recognize a graph in which data lie in a straight line as a linear relationship which can be represented by the equation, $y = mx + b$. Calculate the slope, m, of the straight-line graph, $m = (y_2 - y_1)/(x_2 - x_1)$
10. Recognize a graph of a quadratic relationship as a parabolic curve which can be

represented by the equation, $y = kx^2$

D. <u>Laboratory</u>

1. Graphing Lengths of Wires

   Goal: Measurement and usage of graphing calculators

   Time: 55 minutes

   Type of Lab: Student conducted (hands on)

PHYSICS
Chapter 2: Kinematics in One Dimension

A. <u>General aim:</u> To introduce the fundamental concepts of motion along straight lines and to study the pattern of change in velocity called acceleration.

B. <u>Content</u>

1. Average and instantaneous motion
2. Uniformly accelerated motion
3. Accelerated motion due to gravity
4. Graphical analysis of motion

C. <u>Objectives</u>

After reading and participating in the classroom activities, you should be able to:

1. Define and give an example of a frame of reference.
2. Define average velocity and calculate the average velocity given distance and time. $v_{avg} = ½(v_o + v_f)$ or $v_{avg} = \Delta d/\Delta t$
3. Interpret and plot position-time graphs for positive and negative positions.
4. Determine the slope of a curve on a position-time graph and state that the slope of the line is the average velocity.
5. Distinguish displacement from distance and velocity from speed.
6. Plot and interpret a velocity-time graph.
7. Use the area under the curve of a velocity-time graph, to calculate the displacement of an object.
8. Define and use the concept of relativity of velocities.
9. Define instantaneous velocity and determine the instantaneous velocity by drawing the tangent to a curve on a position-time graph.
10. Define and calculate from a velocity-time graph, average and instantaneous acceleration.
11. Given two velocities and the time interval between them, calculate the average acceleration. $a = (v_f - v_o)/t$ or $a = \Delta v/\Delta t$
12. Given the initial velocity, time, and uniform acceleration, calculate the final velocity of an object. $v_f = v_o + at$
13. Calculate the displacement of an object undergoing uniform acceleration, given two

of the three quantities: acceleration, time, or velocity. $d_f = d_o + v_o t + \frac{1}{2}at^2$

14. Solve problems of the motion of objects uniformly accelerated by gravity. $v_f^2 - v_o^2 = 2a(d_f - d_o)$
15. Given a graph of position as a function of time, recognize in what time intervals velocity or acceleration is positive, negative, or zero, and identify or sketch a graph of velocity as a function of time.
16. Given a graph of velocity as a function of time, recognize in what time intervals acceleration is positive, negative, or zero, and identify or sketch graphs of position and acceleration as functions of time.

D. <u>Laboratory</u>

1. Uniform Motion
   Goal: Use graphical methods to analyze the motion of a vehicle
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
2. Motion of Ball on Ramp
   Goal: Measure and graph the acceleration of a ball moving on an inclined plane
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
3. Match the Graph Using a Motion Detector
   Goal: Demonstration of displacement, velocity and acceleration
   Time: 35 minutes
   Type of Lab: Student conducted (hands on)

PHYSICS

Chapter 3: Vectors and Kinematics in Two Dimensions

A. General aim**:** To introduce the vector, a representation for physical quantities that are changing in both magnitude and direction and to study projectile motion.

B. Content

1. Characteristics of vectors and scalars
2. Graphical method of vector addition
3. Independence of perpendicular components of vector quantities
4. Analytical methods of vector addition
5. Subtraction of vectors
6. Equilibrium and the equilibrant force
7. Horizontally launched projectiles
8. Projectiles launched at an angle

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Define resultant as the sum of two or more vectors and be able to graphically determine the resultant vector.
2. Draw vector diagrams to illustrate that perpendicular vector quantities can be treated independently of one another.
3. Add perpendicular vectors analytically by using the Pythagorean relation, $\mathbf{A}^2 = \mathbf{A}_x^2 + \mathbf{A}_y^2$, and the definition of the tangent of an angle, $\tan\theta = A_y/A_x$
4. Resolve a vector into two perpendicular components.
5. Add vectors of any angles by finding their components and adding all vertical and horizontal components separately, and then finding the resultant.
6. Calculate the difference between two vectors by subtraction.
7. Determine the equilibrant, the single force that is equal in magnitude and opposite in direction to the resultant of several forces acting on a point.
8. Solve problems of projectiles launched horizontally using the idea that vertical and horizontal velocities of a projectile are independent.
9. Find the maximum height and range of projectiles launched at an arbitrary angle if initial velocity and angle are given.

D. Laboratory

1. The Paper River

   Goal: To investigate the independence of vector quantities

   Time: 55 minutes

   Type of Lab: Student conducted (hands on)

2. The Football Throw

   Goal: To investigate projectile motion

   Time: 55 minutes

   Type of Lab: Student conducted (hands on)

PHYSICS

Chapter 4: Newton's Laws of Motion

A. General aim: To explain motion using Newton's laws.

B. Content

1. Forces
2. Newton's Laws of Motion
3. Static and Dynamic Applications of Newton's Laws
4. Friction

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Name the four basic forces: gravitational force, electromagnetic force, strong nuclear force, and weak force. State the relative strengths of each force and some familiar examples.
2. State and make application of Newton's three laws of motion.
3. Make calculations using Newton's second law, F = ma.
4. Differentiate between net forces that cause acceleration and action-reaction pairs.
5. Distinguish between weight and mass.
6. Given the mass of an object, calculate the weight. Weight = F_w = mg.
7. Draw and label free-body diagrams.
8. Calculate the force of friction given the coefficient of friction and the normal force. $F_f = \mu F_n$

9. State that the net force is the vector sum of all forces acting on a body. Calculate the acceleration resulting from the net force acting on the object.
10. Define free-fall, air resistance or drag, and terminal velocity and explain the effects of each on a falling object.
11. Calculate the normal force acting on an object that is at rest on an inclined plane given the angle.
12. Calculate the acceleration of an object as it slides down an inclined plane.

D. Laboratory

1. The Old Tablecloth Trick
   Goal: Introduction to inertia and Newton's first law.
   Time: 5 minutes
   Type of Lab: Teacher led demonstration
2. Newton's Second Law
   Goal: Examine the relationships between mass, force, acceleration, and Newton's laws of motion
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
3. Static and Kinetic Friction
   Goal: To investigate friction and measure the coefficients of friction
   Time: 20 minutes
   Type of Lab: Teacher led demonstration

PHYSICS

Chapter 5: Circular Motion and Newton's Law of Universal Gravitation

A. General aim: To understand circular motion, Kepler's laws of planetary motion, and the Newton's law of universal gravitation.

B. Content

1. Uniform circular motion
2. Kepler's laws
3. Newton's law of universal gravitation

C. <u>Objectives</u>

After reading and participating in the classroom activities, you should be able to:

1. Understand circular motion of a particle and be able to relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.
2. Describe the direction of the particle's velocity and acceleration at any instant during the motion.
3. Determine the magnitude and direction of the net force.
4. State Kepler's three laws of planetary motion.
5. Be able to use Kepler's third law to compare the distances and periods of the planets about the sun.
6. Know Newton's Law of Universal Gravitation and be able to determine the force that one spherically symmetrical mass exerts on another.
7. Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass.
8. Recognize that the motion of a body in circular orbit under the influence of gravitational forces does not depend on the body's mass. Describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radius of the orbit, and derive expressions for the velocity and period of revolution in such an orbit.
9. Calculate the escape velocity from the gravitational force of the Earth.

D. <u>Laboratory</u>

1. Circular Motion

   Goal: To discover the relationships among the variables (speed, mass, force, and radius) in circular motion

   Time: 95 minutes

   Type of Lab: Student conducted (hands on)
2. Kepler's Laws

   Goal: Plot planetary orbit and apply Kepler's laws

   Time: 55 minutes

   Type of Lab: Student conducted (pencil/paper activity)

PHYSICS

Chapter 6: Work, Energy, and Power

A. General aim**:** To study the very important concept of conservation of energy, and the closely related concepts of work and power.

B. Content

1. Work and the Work-Energy Theorem
2. Potential Energy
3. Conservation of Energy
4. Power

D. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Define work and identify the force that does the work.
2. Calculate the work done by a specified constant force on a body that undergoes a specified displacement.
3. Relate the work done by a force to the area under a graph of force as a function of position, and calculate this work in the case where the force is a linear function of position.
4. Calculate the work performed by a specified constant force at an angle to the object that undergoes a displacement along a horizontal plane.
5. Define energy and differentiate between kinetic and potential energy.
6. State the work-energy theorem.
7. Calculate the change in kinetic energy or speed that results from performing a specified amount of work on a body.
8. Calculate the work performed by the net force, or by each of the forces that makes up the net force, on a body that undergoes a specified change in speed or kinetic energy.
9. Calculate the potential energy of a single body in a uniform gravitational field.
10. Write an expression for the force exerted by an ideal spring and for the potential energy stored in a stretched or compressed spring. Apply conservation of energy in

analyzing the motion of bodies that move under the influence of springs.

11. State the law of conservation of energy.
12. Identify situations in which mechanical energy is or is not conserved.
13. Apply conservation of energy in analyzing the motion of bodies that are moving in a gravitational field and are subject to constraints imposed by strings or surfaces.
14. Apply conservation of energy in analyzing the motion of bodies that move under the influence of springs.
15. Define power.
16. Calculate the power required to maintain the motion of a body with constant acceleration (to move a body along a level surface, to raise a body at a constant rate, or to overcome friction for a body that is moving at a constant speed)
17. Calculate the work performed by a force that supplies constant power, or the average power supplied by a force that performs a specified amount of work.

D. Laboratory

1. Ball Toss Using a Motion Detector
   Goal: To examine the changes in kinetic and potential energy
   Time: 35 minutes
   Type of Lab: Teacher led demonstration
2. Hooke's Law
   Goal: To determine the relationship between the extension to an elastic spring and the applied force
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
3. Conservation of Mechanical Energy
   Goal: To determine whether mechanical energy is conserved in an oscillating spring.
   Time: 55 minutes
   Type of Lab: Teacher led demonstration

PHYSICS
Chapter 7: Linear Momentum

A. General aim**:** To understand the law of conservation of linear momentum

B. Content
1. Impact Forces and Momentum Changes
2. Law of Conservation of Linear Momentum
3. Elastic and Inelastic Collisions
4. Motion in the Center of Mass Frame of Reference

C. Objectives
After reading and participating in the classroom activities, you should be able to:
1. Define momentum.
2. Relate mass, velocity, and linear momentum for a moving body, and calculate the total linear momentum of a system of bodies.
3. Define impulse. Understand the relation between average force and time interval for a fixed impulse.
4. Relate impulse to the change in linear momentum and average force acting on a body.
5. State the law of conservation of momentum and recognize the connection between Newton's third law and conservation of momentum.
6. Identify situations in which linear momentum, or a component of the linear momentum vector, is conserved.
7. Apply linear momentum conservation to determine the final velocity when two bodies that are moving along the same line, or at right angles, collide and stick together, and calculate how much kinetic energy is lost in such a situation.
8. Analyze collisions of particles in one or two dimensions to determine unknown masses or velocities, and calculate how much kinetic energy is lost in a collision.

D. Laboratory
1. Momentum
   Goal: To investigate the law of conservation of momentum by analyzing one-dimensional elastic and inelastic collisions
   Time: 55 minutes

Type of Lab: Teacher led demonstration

2. Collisions and Impacts

   Goal: To investigate the law of conservation of momentum by analyzing two-dimensional collisions

   Time: 55 minutes

   Type of Lab: Student conducted (hands on)

PHYSICS

Chapters 8 and 9: Rotational Motion and Static Equilibrium

A. General aim**:** To study the rotational motion of a rigid body and the forces acting on a body at equilibrium.

B. Content

1. Torque and rotational statics
2. Angular momentum and its conservation
3. Bodies in equilibrium

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Define torque and calculate the magnitude of the torque associated with a given force.
2. Calculate the torque on a rigid body due to gravity.
3. Define translational and rotational motion and state the conditions for translational and rotational equilibrium of a rigid body.
4. Analyze the equilibrium of a rigid body under the combined influence of a number of coplanar forces applied at different locations.
5. Define angular momentum and recognize the conditions under which the law of conservation of angular momentum is applicable and relate this law to one-and two-particle systems such as satellite orbits or the Bohr atom.

D. Laboratory

1. Torque

   Goal: To study the factors necessary to produce equilibrium on a balance

   Time: 55 minutes

   Type of Lab: Student conducted (hands on)

PHYSICS
Chapter 10: Fluids

A. <u>General aim:</u> To examine fluids both at rest (fluid statics) and in motion (fluid dynamics)

B. <u>Content</u>

1. Density and specific gravity
2. Pressure in fluids
3. Pascal's Principle
4. Buoyancy and Archimedes' Principle
5. Bernoulli's Principle

C. <u>Objectives</u>

After reading and participating in the classroom activities, you should be able to:

1. Demonstrate an understanding of the concept of pressure and calculate the pressure.
2. Understand the origin of Pascal's and Archimedes' principles and their applications.
3. Draw a diagram showing the three forces acting on the submerged object.
4. Explain Bernoulli's principle and its applications in producing lift.

D. <u>Laboratory</u>

1. Archimedes' Principle

   Goal: To calculate the buoyant force on a submerged object

   Time: 55 minutes

   Type of Lab: Student conducted (hands on)

PHYSICS

Chapter 11: Vibrations and Waves

A. General Aim: To understand simple harmonic motion and the characteristics and motion of waves.

B. Content

1. Simple harmonic motion of a mass on a spring
2. Simple harmonic motion of a pendulum
3. Kinematics of simple harmonic motion
4. Characteristics and measurements of waves
5. Wave interference
6. Reflection, refraction and diffraction of waves

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Identify the conditions of simple harmonic motion.
2. Explain how force, velocity, and acceleration change as an object vibrates with simple harmonic motion.
3. Calculate the spring force using Hooke's law. $F = -k\,x$
4. Apply the expression for the period of oscillation of a mass on a spring. $T = 2\pi\sqrt{m/k}$

2. State how the total energy of an oscillating system depends on the amplitude of the motion, sketch or identify a graph of kinetic or potential energy as a function of time, and identify points in the motion where the energy is all potential or all kinetic.
3. Calculate the kinetic and potential energies of an oscillating system as functions of time, sketch or identify graphs of these functions, and state that the sum of kinetic and potential energy is constant. $E = ½\,mv^2 + ½\,k\,x^2$
4. Apply the expression for the period of a simple pendulum. $T = 2\pi\sqrt{L/g}$
5. State and apply the relation between frequency and period. $f = 1/T$
6. Identify points in the motion where the velocity is zero or achieves its maximum positive or negative value. $v = \pm\, v_{max}\sqrt{1 - x^2/A^2}$

7. State qualitatively the relation between acceleration and displacement.
8. Identify points in the motion where the acceleration is zero or achieves its greatest positive or negative value.
9. Use sinusoidal nature of SHM as a function of time to find displacement, velocity, and acceleration.
   $x = A\cos(2\pi t/T)$; $v = v_{max}\sin(2\pi t/T)$; $a = -(kA/m)\cos(2\pi t/T)$
10. Differentiate between a transverse and a longitudinal wave. Give (or identify) examples of each.

11. Explain the difference between the method of propagation of longitudinal and transverse waves.
12. Sketch or identify graphs that represent traveling waves and determine the amplitude, wavelength, period, and frequency of a wave from such a graph.
13. State and apply the relation among wavelength, frequency, and velocity. $v = \lambda f$
14. Define and sketch a diagram of each of the following: angle of incidence, law of reflection, refraction, and diffraction.

D. Laboratory

1. Waves on Springs
   Goal: Investigate the characteristics of waves on coil springs
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
2. Water Waves
   Goal: Investigate the characteristics of water waves
   Time: 55 minutes
   Type of Lab: Teacher led demonstration
3. Pendulum Periods
   Goal: To design an experiments to determine the factors that may affect the period of a pendulum.
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)

PHYSICS

Chapter 12: Sound

A. <u>General aim:</u> To examine the characteristics of sound, the decibel scale of sound level, sound wave interference, and the Doppler effect

B. Content

1. Characteristics of sound
2. Intensity of sound
3. Vibrating strings and air columns
4. Interference of sound waves
5. Doppler effect

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Know what factors determine the speed of sound.
2. Calculate the speed of sound at a given temperature. V = 331 m/s + 0.61m/s°C(T)
3. Use the equation relating speed of propagation to wavelength and frequency to find any of the variables. ($v = \lambda f$)
4. Identify the range of frequency audible to the human ear, 20 – 20,000 Hz.
5. State that intensity of a wave is the energy per unit time carried across unit area (in watts/m^2).
6. Understand how the intensity of sound is measured using the decibel.
   $\beta = 10 \log \frac{I}{I_o}$ $I_o = 1 \times 10^{-12}$ W/m^2
7. State the superposition principle and explain the concept of resonance.
8. Sketch possible standing wave modes for a stretched string that is fixed at both ends, and determine the amplitude, wavelength, and frequency of such standing waves.
9. Determine how mass per length or tension affects the pitch of a string.
   $V = \sqrt{F_T /(m/L)}$
10. State that the frequencies of a vibrating string are $f = n\frac{v}{2L}$ where n = 1, 2, 3 …
11. Describe possible standing sound waves in a pipe with open ends, and determine the wavelength and frequency of such standing waves.

λ = 2L and f = n$\frac{v}{2L}$ where n = 1, 2, 3 …

12. Describe possible standing sound waves in a pipe with one closed end, and determine the wavelength and frequency of such standing waves.

    λ = 2L and f = n$\frac{v}{2L}$ where only the odd harmonics are present n = 1, 3, 5 …

13. Predict the direction of the shift in wavelength or frequency if a sound source is moving away from the receiver or toward the receiver. (Doppler shift)

    $$f' = f\left(\frac{v_{snd} \pm v_{obs}}{v_{snd} \mp v_{source}}\right)$$

    The upper signs apply if source and observer move toward each other.

D. <u>Laboratory</u>

1. Microphone
   Goal: To determine the period and frequency of a tuning fork.
   Time: 15 minutes
   Type of Lab: Student conducted (hands on)
2. Speed of Sound
   Goal: To determine the speed of sound using a closed pipe
   Time: 35 minutes
   Type of Lab: Student conducted (hands on)

PHYSICS

Chapter 13: Temperature and Kinetic Theory

A. <u>General aim</u>**:** To understand temperature and its effects on matter

B. <u>Content</u>

1. Temperature and thermometers
2. Thermal expansion
3. The gas laws and absolute temperature
4. The ideal gas law

C. <u>Objectives</u>

After reading and participating in the classroom activities, you should be able to:

1. Relate temperature to the kinetic energy of atoms and molecules.
2. Define temperature and distinguish it from internal energy.
3. Convert temperatures between the Fahrenheit, Celsius and Kelvin temperature scales. $^{o}C = (^{o}F - 32) \div 1.8$ $^{o}F = 1.8(^{o}C) + 32$
4. Calculate the change in volume of a solid when its temperature is changed. $\Delta V = \beta V_o \Delta T$
5. Calculate the change in length of a solid when its temperature is changed by ΔT. $\Delta L = \alpha L_o \Delta T$
6. Explain heat as the energy transferred between substances that are at different temperatures.
7. Define the joule as the unit of heat.
8. Understand the "mechanical equivalent of heat" and calculate how much a substance will be heated by the performance of a specified quantity of mechanical work.
9. State the assumptions of the kinetic theory model of an ideal gas.
10. State the connection between temperature and mean translational kinetic energy, and apply it to determine mean speed of gas molecules as a function of their mass and the temperature of the gas. $V_{rms} = \sqrt{3kt/m}$
11. Apply the ideal gas law to find pressure, temperature, volume, number of moles or number of molecules of a gas. $PV = nRT$ where n = # moles and R = 8.31 J/mole K

PV = NkT where N = # molecules and k = 1.38 x 10^{-23} J/K

12. State the relationship among Avogadro's number, Boltzmann's constant, and the gas constant R, and express the energy of a mole of a monatomic ideal gas as a function of temperature. KE = 3/2kT
13. Explain qualitatively how the model explains the pressure of a gas in terms of collisions with the container walls, and explain how the model predicts that, for fixed volume, pressure must be proportional to temperature.

D. Laboratory

1. Thermal Expansion

   Goal: To observe and measure the thermal expansion of a wire as it is heated

   Time: 25 minutes

   Type of Lab: Teacher led demonstration

2. Gas Laws

   Goal: To observe the relationship among temperature, pressure and volume of a gas

   Time: 25 minutes

   Type of Lab: Teacher led demonstration

PHYSICS

Chapters 14 and 15: Heat and Thermodynamics

A. General aim**:** To study of processes in which energy is transferred as heat and as work.

B. Content
1. Transfer of heat energy
2. Specific heat and calorimetry
3. Latent heat
4. Laws of thermodynamics
5. Heat engines

C. Objectives

After reading and participating in the classroom activities, you should be able to:
1. Explain by definition and example the three methods of heat transfer.
2. Define the joule as the unit of heat.
3. Define specific heat and be able to calculate heat transfer or temperature changes due to heat transfers. $Q = cm\,\Delta T$
4. Given a graph relating the quantity of heat added to a substance and its temperature, identify the melting point, boiling point and determine the heats of fusion and vaporization and the specific heat of each phase.
5. Given the heat of fusion, heat of crystallization, heat of vaporization, or heat of condensation, calculate the amount of heat required to cause a phase change in a certain mass of water. $Q = mL$
6. Graph the temperature changes of 1 kg of water initially at -10^{o}C as heat is added, changing it to steam at 110^{o}C.
7. Use the phase diagram below to determine the changes in state given the pressure and the change in temperature or given the temperature and the change in pressure.
8. Determine the final temperature achieved when substances, all at different temperatures, are mixed and allowed to come to thermal equilibrium.
9. State the first law of thermodynamics.
10. State the second law of thermodynamics and define entropy.
11. Label a schematic diagram of a heat engine.

D. Laboratory

1. Specific Heat of a Metal

   Goal: To use calorimetric techniques to determine the specific heat of a metal.

   Time: 50 minutes

   Type of Lab: Student conducted

PHYSICS

Chapters 16 and 17: Electric Charge, Electric Field, and Electric Potential

A. General aim**:** To introduce electricity including Coulomb's law, the electric field, voltage, as well as electric energy storage.

B. Content

1. Electric charge
2. Induced charge and the electroscope
3. Coulomb's law
4. The electric field
5. Electric potential energy and potential difference
6. Relation between electric potential and electric field
7. Electric potential due to point charges
8. Capacitance

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Describe the basic particles in the atom as the protons, electrons and neutrons.
2. State that like electrical charges repel and unlike electrical charges attract.
3. State that the magnitude of the charge on an electron is -1.6×10^{-19} coulombs.
4. Calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field using Coulomb's law, $F = (kQ_1Q_2)/r^2$, $k = 9.0 \times 10^9\ Nm^2/C^2$
5. Define electric field as a region of space in which electric forces can be detected.
6. Differentiate between insulators and conductors.
7. Given a diagram on which an electric field is represented by flux lines, determine the direction of the field at a given point, identify locations where the field is strong and where it is weak, and identify where positive or negative charges must be present.
8. Given a sketch of equipotentials for a charge configuration determine the direction and approximate magnitude of the electric field at various positions.
9. Define electric field as the force per unit charge that would act on a test charge q placed at that point: $E = F/q = kQ/r^2$. Determine the electric field of a single point charge or use vector addition to determine the electric field produced by two or more point charges.

10. Analyze the motion of a particle of specified charge and mass in a uniform electric field.
11. Calculate the potential difference between two points in a uniform electric field and state which is at the higher potential. $V = Ed = kQ/r$
12. Calculate the electrical work done on a positive or negative charge that moves through a specified potential difference. Work $= \Delta PE$ or $\Delta KE = qV_{ba}$
13. Apply conservation of energy to determine the speed of a charged particle that has been accelerated through a specified potential difference.

14. Define a capacitor as a device used to store charge and consists of two nontouching conductors. $C = Q/V$ (1 farad = 1C/V) $C = \varepsilon_o A/d$
 $\varepsilon_o = 8.85 \times 10^{-12}\ C^2/Nm^2$ A charged capacitor stores an amount of electric energy give by $U = ½QV = ½CV^2$
15. Explain the nature of electric fields in and around conductors.

D. <u>Laboratory</u>
1. Electrostatics
   Goal: To understand the nature of electric charge
   Time: 20 minutes
   Type of Lab: Teacher led demonstration
2. Electric Fields
   Goal: To examine certain electric fields; in particular to map the equipotential lines of an electric field and hence determine the electric lines of force.
   Time: 40 minutes
   Type of Lab: Student conducted (pencil/paper)

PHYSICS

Chapters 18 and 19: Electric Circuits

A. General aim**:** To understand the relationships of current, voltage, resistance, and capacitance in circuits.

B. Content

1. Current, Resistance, Power
2. Direct Current Circuits with Batteries and Resistors
3. Capacitors in Circuits

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Define an electric current as the quantity of charge moving through a wire divided by the time required for the charge to move. $I = Q/t$
2. Identify the unit for measuring electric current as the ampere, I = coulomb/second = 1A
3. Define voltage as the difference in potential energy between two points, divided by the magnitude of the charge. 1 volt = 1 joule/coulomb
4. State that electric power is equal to current times the voltage and is measured in watts.
5. Calculate electric power. $P = IV$
6. Define a resistor as a device that hinders the motion of charge through a circuit.
7. Relate current and voltage for a resistor. State and apply Ohm's Law. $V = IR$
8. Describe how the resistance of a resistor depends upon its length and cross-sectional area. $R = \rho L/A$
9. Apply the relationships for the rate of heat production in a resistor. $R = R_o(1 + \alpha T)$ α = temperature coefficient of resistivity
10. Identify the characteristics of series and parallel circuits. Identify on a circuit diagram resistors that are in series or in parallel.
11. Determine the ratio of the voltages across resistors connected in series or the ratio of the currents through resistors connected in parallel.
12. Calculate the equivalent resistance of two or more resistors connected in series or parallel, or of a network of resistors that can be broken down into series and parallel combinations.

13. Calculate the voltage, current, and power dissipation for any resistor in such a network of resistors connected to a single battery.
    P = energy transformed/time = $IV = QV/t = I^2R = V^2/R$ 1 watt = 1J/s
14. Calculate electrical energy and find the percentage of electrical energy that is converted to thermal or mechanical energy.
15. Calculate the terminal voltage of a battery of specified emf and internal resistance from which a known current is flowing.
16. Apply Ohm's Law and Kirchhoff's rules to determine a single unknown current, voltage, or resistance.

17. Understand the properties of voltmeters and ammeters and state whether the resistance of each is high or low.
18. Diagram the correct methods of connecting meters into circuits in order to measure voltage or current.
19. Describe how charge is stored when two capacitors are connected in parallel or when two capacitors are connected in series.
20. Calculate the equivalent capacitance of a series or parallel combination.
21. Determine the ratio of voltages for two capacitors connected in series.
    Hint: The charge on each of the capacitors is the same. $C_1V_1 = C_2V_2$
22. Calculate the voltage or stored charge, under steady-state conditions, for a capacitor connected to a circuit consisting of a battery and resistors.
23. Develop skill in analyzing the behavior of circuits containing several capacitors and resistors and determine voltages and currents immediately after a switch has been closed and also after steady-state conditions have been established.

D. <u>Laboratory</u>

1. Circuits and Currents
   Goal: To introduce the basic structure of series and parallel circuits
   Time: 100 minutes
   Type of Lab: Student conducted (hands on)
2. Ohm’s Law
   Goal: To measure voltage and current and discover Ohm’s law
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
3. Electrical Equivalent of Heat

Goal: To observe the conservation of energy in a conversion of electrical energy to thermal energy.
Time: 40 minutes
Type of Lab: Student conducted (hands on)

PHYSICS

Chapters 20 and 21: Magnetism

A. General aim**:** To understand the concepts of magnetism and electromagnetic induction.

B. Content

1. Magnets and magnetic fields
2. Interaction between magnetic fields and electric currents and moving electric charges
3. Solenoids and electromagnets
4. Electromagnetic induction
5. Faraday's law of induction; Lenz's law
6. Electric motors and generators

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. State that like magnetic poles repel and unlike poles attract.
2. Define magnetic domains as a group of cooperating atoms. Permanent magnets are created when these domains are aligned.
3. Calculate the magnitude and direction of the force in terms of q, v, and B, and explain why the magnetic force can perform no work. $F = Bqv \sin\theta$
4. Deduce the direction of a magnetic field from information about the forces experienced by charged particles moving through that field.
5. Describe the most general path possible for a charged particle moving in a uniform magnetic field, and describe the motion of a particle that enters a uniform magnetic field moving with specified initial velocity.
6. State and apply the formula for the radius of the circular path of a charge that moves perpendicular to a uniform magnetic field, and derive this formula from Newton's Second Law and the magnetic force law.
7. Describe quantitatively under what conditions particles will move with constant velocity through crossed electric and magnetic fields.
8. Calculate the magnitude and direction of the force on a straight segment of current-carrying wire in a uniform magnetic field. $F = BIL\sin\theta$
9. Calculate the force of attraction or repulsion between two long current-carrying wires. $F = \mu_0 I_1 I_2 L/(2\pi r)$

10. Calculate the magnitude and direction of the magnetic field using Ampere's Law,
    (a) at a point in the vicinity of a long straight current-carrying wire, $B = \mu I/2\pi r$
    (b) inside a solenoid, $B = \mu IN/L$
    (c) inside of a loop of current- carrying wire, $B = \mu IN/2r$
11. Use superposition to determine the magnetic field produced by two long current-carrying wires.
12. Indicate the direction of magnetic forces on a current-carrying loop of wire in a magnetic field, and determine how the loop will tend to rotate as a consequence of these forces.

13. Explain how to construct an electromagnet.
14. Define electromagnetic induction as the production of an electric current in a wire when a magnetic field changes near the wire or when the wire moves across a magnetic field.
15. Calculate the flux of a uniform magnetic field through a loop of arbitrary orientation. $\Phi_B = BA\cos\theta$
16. Understand Faraday's Law and Lenz's Law and recognize situations in which changing flux through a loop will cause an induced emf or current in the loop. Faraday's Law: $E = -N\Delta\Phi_B/\Delta t$
17. Calculate the magnitude and direction of the induced emf and current in a square loop of wire pulled at a constant velocity into or out of a uniform magnetic field.
18. Calculate the magnitude and direction of the induced emf and current in a loop of wire placed in a spatially uniform magnetic field whose magnitude is changing at a constant rate.
19. Calculate the magnitude and direction of the induced emf and current in a conducting bar moving perpendicular to a uniform magnetic field. $E = Blv$
20. State that an electric motor changes electrical energy into mechanical energy by moving a current-carrying wire through a magnetic field. Explain how an electric generator works.
21. Explain that transformers can be used to alter the voltage and current (but not the energy) in an alternating current circuit.
22. Differentiate between step-up and step-down transformers.
23. Make calculations using the voltage-turn relationship for a transformer. $(V/N)_{primary} = (V/N)_{secondary}$
24. Make calculations using the power relationship for a transformer. $(IV)_{secondary} = (IV)_{primary}$

D. Laboratory

1. Principles of Electromagnetism

   Goal: To investigate the basic principles of electromagnetism

   Time: 55 minutes

   Type of Lab: Teacher led demonstration

2. Electromagnetic Induction

   Goal: To observe the generation of an electric current when a wire cuts through a magnetic field.

   Time: 40 minutes

   Type of Lab: Student conducted (hands on)

PHYSICS

Chapters 22-25: Electromagnetic Radiation and Optics

A. General aim**:** To understand the principles of physical and geometrical optics.

B. Content

1. Light as an electromagnetic wave

2. Geometrical optics
   A. Reflection and refraction
   B. Image formation by mirrors
   C. Image formation by lenses
   D. Thin lens equation; magnification
3. Physical optics
   A. Interference and diffraction of light
   B. Dispersion and the electromagnetic spectrum
   C. Polarization
   D. Light intensity

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. Describe the electromagnetic wave as oscillating electric and magnetic fields that are perpendicular to each other and to the direction of propagation.
2. Define visible light as an electromagnetic wave and compare the frequency and wavelength of visible light with other types of waves in the electromagnetic spectrum.
3. List the colors of the rainbow in order of increasing frequency.
4. State the law of reflection.
5. Distinguish a real image and virtual image.
6. You should understand image formation by plane or spherical mirrors.
7. Given the distance of the object from the mirror and the focal length of the mirror, use the mirror equation to predict the location of the image.
8. Given the distance of the object and the image from the mirror and the height of the object, find the height of the image.
9. Define refraction.
10. Determine how the speed and wavelength of light change when light passes from

one medium into another.

11. You should understand image formation by converging or diverging lenses.
12. Use the thin lens equation to relate the object distance, image distance, and focal length for a lens, and determine the image size in terms of the object size.
13. Determine whether the focal length of a lens is increased or decreased as a result of a change in the curvature of its surfaces or in the index of refraction of the material of which the lens is made or the medium in which it is immersed.
14. Analyze simple situations in which the image formed by one lens serves as the object for another lens.
15. Define coherent light:
16. Explain how Polaroid lenses work.

17. Use the principle of superposition to describe the conditions under which coherent waves reaching an observation point from two or more sources will all interfere constructively, or under which the waves from two sources will interfere destructively. Relate the amplitude and intensity produced by two or more sources that interfere constructively to the amplitude and intensity produced by a single source.
18. Define dispersion.
19. Apply the principles of interference to light reflected by thin films.
20. As you get farther from the source of the light, the intensity of the light decreases.

$$\frac{I_2}{I_1} = \frac{(d_1)^2}{(d_2)^2}$$

D. <u>Laboratory</u>

1. Mirror Optics
   Goal: To observe images formed by plane, concave, and convex mirrors.
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
2. Refraction of Light
   Goal: To determine the index of refraction of glass using Snell's law
   Time: 55 minutes
   Type of Lab: Student conducted (hands on)
3. Lens Optics
   Goal: To determine the focal length of a converging lens
   Time: 55 minutes

Type of Lab: Student conducted (hands on)

4. Diffraction of Light

   Goal: To determine the wavelengths of red, yellow, green, blue, and violet light

   Time: 55 minutes

   Type of Lab: Student conducted (hands on)

PHYSICS

Chapters 27 and 30: Modern Physics

A. General aim**:** To understand the principles of atomic physics and quantum effects.

B. Content

1. History of the Atomic Theory
2. Photoelectric Effect
3. Energy Levels in Atoms
4. Davisson-Germer Experiment and Compton's Experiment
5. Isotopes and Radioactive Decay

C. Objectives

After reading and participating in the classroom activities, you should be able to:

1. State the postulates of the atomic theory.
2. State the contribution of each scientist to the development of the modern atomic theory: Dalton, Thomson, Millikan, Rutherford, and Bohr.
3. Describe the Rutherford scattering experiment and explain how it provides evidence for the existence of the atomic nucleus.
4. Relate the energy of a photon in joules or electron-volts to its wavelength or frequency.
5. Relate the linear momentum of a photon to its energy or wavelength, and apply linear momentum conservation.
6. Describe the Davisson-Germer experiment, and explain how it provides evidence for the wave nature of electrons.
7. Describe Comptons' experiment, and state what results were observed.
8. Describe the nuclear atom, including the name, location, mass (in amu), and electrical charge of the three primary particles in the atom.
9. Given the symbol for a specified isotope, determine the atomic number and the mass number of the isotope.
10. Write nuclear symbols for protons, neutrons, electrons (beta particles), helium nuclei (alpha particles), and gamma rays.
11. Explain how the band spectrum produced by an atom of an element illustrates the existence of energy levels within an atom.
12. Draw Bohr diagrams of atoms.
13. Complete and balance nuclear equations, having been given all but one of the

particles involved.

14. Use the half-life of a substance to predict the amount of radioisotope present after a given period of time.
15. Graph the amount of a radioactive isotope remaining vs. time. Use the graph to determine the half-life of the isotope.
16. State that radioisotopes can be used in dating objects and as radiotracers.
17. Use Einstein's equation, $E = mc^2$, to calculate the energy change or mass change of a reaction.
18. Differentiate between fission and fusion.

D. <u>Laboratory</u>

1. Photoelectric Effect
   Goal: To describe how the number of photoelectrons and their maximum kinetic energy depend on the wavelength and intensity of the light striking the surface, and account for this dependence in terms of a photon model of light.
   Time: 55 minutes
   Type of Lab: Teacher led demonstration (virtual lab)
2. The Atomic Spectrum of Hydrogen
   Goal: Draw the energy levels of hydrogen and explain how the diagram accounts for the hydrogen spectrum
   Time: 55 minutes
   Type of Lab: Student conducted (pencil/paper lab)
3. Half-life of a Radioisotope
   Goal: To determine the half-life of a radioisotope
   Time: 55 minutes
   Type of Lab: Student conducted (simulated lab)

Laboratory Activities

Chapter	Title and Goal	Time in minutes	Type of Lab
1	Title: Graphing Lengths of Wires Goal: Measurement and usage of graphing calculators	55	Student conducted
2	Title: Uniform Motion Goal: Use graphical methods to analyze the motion of a vehicle	55	Student conducted
2	Title: Motion of Ball on Ramp Goal: Measure and graph the acceleration of a ball moving on an inclined plane	55	Student conducted
2	Title: Match the Graph Using a Motion Detector Goal: Demonstration of displacement, velocity and acceleration	35	Student conducted
3	Title: The Paper River Goal: To investigate the independence of vector quantities	55	Student conducted
3	Title: The Football Throw Goal: To investigate projectile motion	55	Student conducted
4	Title: The Old Tablecloth Trick Goal: Introduction to inertia and Newton's first law.	5	Teacher demo
4	Title: Newton's Second Law Goal: Examine the relationships between mass, force, acceleration, and Newton's laws of motion	55	Student conducted
4	Title: Static and Kinetic Friction Goal: To investigate friction and measure the coefficients of friction	20	Teacher demo
5	Title: Circular Motion Goal: To discover the relationships among the variables (speed, mass, force, and radius) in circular motion	95	Student conducted
5	Title: Kepler's Laws Goal: Plot planetary orbit and apply Kepler's laws	55	Student conducted
6	Title: Ball Toss Using a Motion Detector Goal: To examine the changes in kinetic and potential energy	35	Teacher demo
6	Title: Hooke's Law Goal: To determine the relationship between the extension to an elastic spring and the applied force	55	Student conducted
6	Title: Conservation of Mechanical Energy Goal: To determine whether mechanical energy is conserved in an oscillating spring.	55	Teacher demo
	Title: Momentum		Teacher

7	Goal: To investigate the law of conservation of momentum by analyzing one-dimensional elastic and inelastic collisions	55	demo
7	Title: Collisions and Impacts Goal: To investigate the law of conservation of momentum by analyzing two-dimensional collisions	55	Student conducted
8 and 9	Title: Torque Goal: To study the factors necessary to produce equilibrium on a balance	55	Student conducted
10	Title: Archimedes' Principle Goal: To calculate the buoyant force on a submerged object	55	Student conducted
11	Title: Waves on Springs Goal: Investigate the characteristics of waves on coil springs	55	Student conducted
11	Title: Water Waves Goal: Investigate the characteristics of water waves	55	Teacher demo
11	Title: Pendulum Periods Goal: To design an experiments to determine the factors that may affect the period of a pendulum.	55	Student conducted
12	Title: Microphone Sound Waves Goal: To determine the period and frequency of sound waves	15	Student conducted
12	Title: Speed of Sound Goal: To determine the speed of sound using a closed pipe	35	Student conducted
13	Title: Thermal Expansion Goal: To observe and measure the thermal expansion of a wire as it is heated	25	Teacher demo
13	Title: Gas Laws Goal: To observe the relationship among temperature, pressure and volume of a gas	25	Teacher demo
14 and 15	Title: Specific Heat of a Metal Goal: To use calorimetric techniques to determine the specific heat of a metal	50	Student conducted
16 and 17	Title: Electrostatics Goal: To understand the nature of electric charge	20	Teacher demo
16 and 17	Title: Electric Fields Goal: To examine certain electric fields; in particular to map the equipotential lines of an electric field and hence determine the electric lines of force.	40	Student conducted
18 and 19	Title: Circuits and Currents Goal: To introduce the basic structure of series and parallel	100	Student conducted

	circuits		
18 and 19	Title: Ohm's Law Goal: To measure voltage and current and discover Ohm's law	55	Student conducted
18 and 19	Title: Electrical Equivalent of Heat Goal: To observe the conservation of energy in a conversion of electrical energy to thermal energy.	40	Student conducted
20 and 21	Title: Principles of Electromagnetism Goal: To investigate the basic principles of electromagnetism	55	Teacher demo
20 and 21	Title: Electromagnetic Induction Goal: To observe the generation of an electric current when a wire cuts through a magnetic field.	40	Student conducted
22-25	Title: Mirror Optics Goal: To observe images formed by plane, concave, and convex mirrors.	55	Student conducted
22-25	Title: Refraction of Light Goal: To determine the index of refraction of glass using Snell's law	55	Student conducted
22-25	Title: Lens Optics Goal: To determine the focal length of a converging lens	55	Student conducted
22-25	Title: Diffraction of Light Goal: To determine the wavelengths of red, yellow, green, blue, and violet light	55	Student conducted
27 and 30	Title: Photoelectric Effect Goal: To describe how the number of photoelectrons and their maximum kinetic energy depend on the wavelength and intensity of the light striking the surface, and account for this dependence in terms of a photon model of light.	55	Virtual lab
27 and 30	Title: The Atomic Spectrum of Hydrogen Goal: Draw the energy levels of hydrogen and explain how the diagram accounts for the hydrogen spectrum	55	Student conducted
27 and 30	Title: Half-life of a Radioisotope Goal: To determine the half-life of a radioisotope	55	Student conducted

Each of the above laboratory investigations will be presented to the students as a problem. Some of the laboratories listed lead to the collection of data which can be analyzed through graphical methods. Many of the laboratories listed, require the students to design their own procedure, and methods of data gathering and data analysis. This guided inquiry allows students to develop critical thinking skills. Students work in pairs, but each student must submit a lab report. Each report should include:

- a statement of the problem,
- an hypothesis,
- a discussion or outline of how the procedure will be carried out,
- the data recorded,
- a discussion or outline of how the data was analyzed, and
- a conclusion including error analysis and topics for further study.

Students are required to keep the reports in a notebook for documentation which may be required for college credit for physics.

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