

**AP<sup>®</sup> Physics B**  
**Clayton High School**  
**Instructor: Rex P. Rice**

**Overview:**

AP<sup>®</sup> Physics B is a two-semester course, designed to replicate an algebra/trigonometry based course of the type traditionally known as “college physics.” The course includes topics in classical and modern physics, including Newtonian mechanics, fluid mechanics, thermal physics, electricity and magnetism, waves and optics, and atomic and nuclear physics.

The design of the course is based on a teaching methodology known as modeling, in which students learn physics by constructing scientific models which underlie each unit specifically and physics in general. Where possible, each unit begins with an experiment in which students begin to flesh out one or more physical relationships which serve as a basis for a scientific model. After analyzing one or more experiments, student lab groups present their findings to the class, leading to class discussion to begin formal development of the model. These models are often expressed verbally, graphically, mathematically, or diagrammatically.

Most students enter the course with this methodology well understood, having practiced it through the Freshman Physics or Honors Freshman Physics course developed during the 9<sup>th</sup> grade. In this preliminary course students have already developed models to represent uniform motion, uniformly accelerated motion, forces, energy, and electric circuits, and have developed a laboratory portfolio which documents the initial development of each model. During the summer prior to the AP<sup>®</sup> Physics course, students are given review assignments in which they revisit what they learned in the 9<sup>th</sup> grade course. The fall semester of AP<sup>®</sup> Physics makes liberal use of the foundation built during the previous course.

Each of the content areas described in the “Content Outline for Physics B” section of the College Board course description for Physics, 2006-07, is included in the course, with a time allotment per topic that roughly approximates the percentage goals for the Physics B exam. Each content area is developed through laboratory experimentation and concept development consistent with the modeling method initially developed at Arizona State University.

The course meets daily for 46 minutes or 96 minutes alternating daily, giving a total in class time which averages 355 minutes per week. Most experiments and examinations take place on the longer class periods.

**Textbook:**

*Physics: Principles with Applications*  
Fifth Edition by Douglas C. Giancoli  
ISBN 0-13-611971-9  
Prentice Hall, ©1998

### ***Evaluation:***

Quarter grades are assigned based on the following breakdown

Exams-40%

Laboratory-30%

Quizzes-20%

Homework-10%

These percentages are sometimes altered slightly based on relative emphasis in a given quarter.

Semester grades are assigned based on

1<sup>st</sup>/3<sup>rd</sup> Quarter-40%

2<sup>nd</sup>/4<sup>th</sup> Quarter-40%

Final Exam-20%

### ***Exams:***

Each major unit will be followed by a 90-minute exam. The exams are broken into two parts, approximately half multiple choice and half free response, to simulate the structure of the AP<sup>®</sup> Physics B Exam that will be taken at the end of the course. The AP<sup>®</sup> Physics B Exam has two sections, multiple-choice and free-response, which are weighted equally. The multiple-choice section contains 70 questions for which 90 minutes are allowed. The free-response section has from 6 to 8 questions for which an additional 90 minutes are allowed.

Each unit test for the course will therefore typically contain approximately 35 multiple-choice questions, and 3 to 4 free-response questions to be completed in a 90-minute session. The nature of the multiple-choice and free-response questions is intended to replicate the style and difficulty of the questions that appear on the AP<sup>®</sup> Physics B Exam. Since calculators and equations are not allowed for the multiple-choice section, and are allowed on the free-response section of the AP<sup>®</sup> Physics B Exam, those rules are applied to the corresponding sections of class exams. Students are supplied with a reproduction of the Advanced Placement Physics B Equations, and the Table of Information, each printed on card stock for appropriate use on the respective portions of each exam.

Toward the end of the course, but prior to the scheduled date of the AP<sup>®</sup> Physics B Exam, students meet on a Saturday to take a Final Examination which is a facsimile of a complete AP Physics Exam. This exam has two parts, 90 minutes for a 70-question multiple choice section, and 90 minutes for a 6 to 8 question free-response section. The exam is scored consistent with AP standards as published in the released exams.

### ***Laboratory:***

Where possible, each major unit begins with one or more laboratory investigations, designed to build a physical foundation for the scientific model building process. These investigations are open-ended, with no hint as to expected outcomes. They typically begin with a class discussion about a particular system, leading to an experimental design and specification of which variables and relationships should be investigated. Formal experimental procedure handouts are avoided, although, in the interest of time, parameters for variables are typically suggested. Each investigation includes a session in which students prepare a whiteboard to present and discuss their results with the class. A whole class discussion follows in which we flesh out the model and various ways that it might be represented. Limitations to the model are also discussed during this lab post-mortem session.

In addition to such investigations, experiments are often performed with the primary purpose of applying concepts or “deploying models” that have been developed in the unit. These can take the form of small group experiments, or individual, small group, or whole class lab practica. In such experiments, nature is the judge as to student success in the application of models.

A high percentage of both types of laboratory activities make use of computer based data collection technology including photogates, motion detectors, force probes, force plates, temperature probes, pressure sensors, computer-connected balances, magnetic field sensors, microphones, light sensors, and spectrometers, most connected to the computer through an appropriate computer interface. Other standard physics laboratory equipment is also used throughout the course, with experience with ‘low-tech’ techniques provided where appropriate.

Students who start the class having completed the 9<sup>th</sup> grade Honors Freshman Physics course enter with a bound lab portfolio containing their writeups of over 2 dozen investigations in motion, forces, electric circuits and waves, performed during that course in addition to over 2-dozen activities performed while studying models of electric circuits using the first six units of the CASTLE (Capacitor Aided System for Teaching and Learning Electricity) program. Very little new experimentation is done in the AP<sup>®</sup> Physics units on kinematics, Newton’s Laws, and energy because of the robust laboratory experience in these areas that students experienced during the 9<sup>th</sup> grade course.

The specific laboratory activities that are part of each unit are specified in the part of this document that more outlines those units in more detail.

### ***Quizzes:***

In most units one or more quizzes of varying types are given. Quizzes are sometimes given after a reading assignment. They are also used to assess student progress in applying concepts and quantitative problem solving at various stages of a unit. The lab practicum, and specifically the quality of the documentation of the solution to the practicum is used to assess student understanding of the model being developed in a unit, and often counts as a quiz grade.

### ***Homework:***

Beyond the work done outside of class in preparing lab reports and reading assignments, students are frequently engaged in homework assignments that require conceptual explanation and/or quantitative problem solving. This work comes from a variety of sources including worksheet from the Modeling Program at Arizona State University, selected problems from the Giancoli textbook, old free response questions with particular emphasis on the current unit of study, teacher produced worksheets and problem sets, and a variety of other possible sources.

## ***Course Outline and Objectives:***

The remainder of this document focuses on more specific aspects of each unit, including specific content in each unit and the corresponding laboratory work. Laboratory descriptions that are preceded by an (\*) indicate investigations that were performed during the freshman physics course. Students review the documentation for that experiment from their freshman physics lab portfolios. Investigations without the (\*) are performed as part of the AP Physics course. Those results will be compiled into a bound AP Physics laboratory portfolio to be submitted at the end of the course. Laboratory components labeled LI are designed as laboratory investigations for the development of physical models. Laboratory components labeled LA are designed to allow students to apply/deploy the models developed through laboratory investigations and class discussion. Laboratory components labeled as LP are lab practica, designed to assess the ability of individuals, small groups, or the whole class to apply models to make correct predictions of the behaviors of physical systems.

The times indicated are approximate and will vary dependent on a variety of potential factors.

### ***Unit 1: Introduction (1 week)***

This unit is largely a review of basic scientific skills that were initially developed during the freshman physics class, that have been further practiced in subsequent science courses.

- Systems of measurement and scientific conventions
- Scientific notation
- Significant Figures
- Unit Conversion and Dimensional Analysis
- Experimental Design
- Graphical and Mathematical Analysis of Data (including hand and computer generated graphs)

### **Additional Resources:**

*Student Guide to Graphical Analysis* by Rex and Deborah Rice

Article: *Guide to Metric Practice*, *Physics Today*, August 1997

Problem Solving Format guide

### **Laboratory work:**

- \*LI - Significant Figures Stick Lab

## ***Unit 2: Kinematics Review (1 week)***

This is also a review unit. Students review the results of several motion experiments from freshman year.

- Development of position and time as variables required to describe motion
- Graphical analysis of position vs. time graphs with development of the physical significance of the slope of the graph as velocity.
- Graphical analysis of velocity vs. time graphs with development of the physical significance of the slope of the graph as acceleration.
- Graphical analysis of velocity vs. time graphs with development of the physical significance of the area under the graph as displacement.
- Development of mathematical models for kinematics including uniform and uniformly accelerated motion based on graphs and algebraic manipulation.
- Apply the general model of uniformly accelerated motion to the specific case of free fall.

### **Laboratory work:**

- \*LI – BB in the Tube (uniform motion investigation using metronome for timing)
- \*LI – Glider on a Level Air Track (uniform motion investigation using video analysis of student produced movie)
- \*LI/LA – Uniform Motion with Motion Detector (analysis of motion of student relative to motion detector)
- \*LI – Toy Car Experiment (uniform motion investigation using tiles and flashing light)
- \*LP – Lab practicum in which students predict the meeting point of two toy cars moving in opposite directions at different speeds from predetermined positions.
- \*LI – Speeding Up/Slowing Down (motion of cart on inclined dynamics track using motion detector)
- \*LI – Wheel and Axle Experiment (uniformly accelerated motion using metronome)
- \*LI – Glider on Inclined Air Track (uniformly accelerated motion using video analysis of student produced movie)
- \*LI /LA – Freely Falling Golf Ball (uniformly accelerated motion of student produced stroboscopic photo of falling golf ball)

### ***Unit 3: Vectors and Projectiles (3 weeks)***

This unit builds on the work done during freshman year dealing with vectors in one dimension and the small amount done with vectors in two dimensions. It also give students the opportunity to deploy the one-dimensional models developed for uniform motion and uniformly accelerated motion together to describe the two-dimensional motion of projectiles

- Add and subtract displacement vectors in one, two, or three dimensions
- Add and subtract velocity vectors in one or two dimensions and apply to relative motion
- Add and subtract force vectors to determine the resultant force on a system or the equilibrant for a set of forces.
- Describe the horizontal and vertical components of the motion of a projectile.
- Understand the independence of those motions in order to determine the position or velocity components of the object at any point in its flight.

#### **Laboratory work:**

- \*LI – Development of equations for sine, cosine and tangent by measuring and graphing opposite side, adjacent side, and hypotenuse of sets of similar right triangles.
- LA – Dot to Dot Displacement Vector Lab (finding the displacement between 2 known points in the school building by taking different trips between the points)
- LI/LA – Relative Motion (developing a model for velocity vector addition by describing the motion of a toy car on a moving platform from different frames of reference)
- LA – Forces on a Force Table (using vector addition to predict the equilibrant for a set of known forces on a force table)
- LI – Video Analysis of Horizontally Launched Projectile (comparing the motion of three projectiles, launched horizontally with different speeds, and analyzing and comparing the position vs. time and velocity vs. time relationships for each projectile both horizontally and vertically)
- LA – Hit my Face (By measuring motion of ball prior to becoming a projectile, and other required parameters, predict the landing spot of a horizontally launched ball and place a target with the instructor's face at that spot)
- LA – Projectiles Launched at an Angle (After launching a ball horizontally from a specific height at a specific speed, predict the landing position of the ball when launched from the same height at the same speed but from a different angle)
- LP – Individual assessment of ability to correctly predict the landing position of a horizontally launched projectile.
- LP – Individual assessment of ability to correctly predict the landing position of a projectile launched at an angle.

#### ***Unit 4: Newton's Laws of Motion Review/Extension (1 week)***

This unit is primarily a review of the two forces units from freshman physics in which the force concept was developed with emphasis on the connection between the net force acting on a system and the motion of that system. Additional review of forces as interactions and Newton's 3<sup>rd</sup> Law. The major additional concept that is added is a quantitative model of static and kinetic friction, as well as an increased emphasis on dealing with systems with more than one body.

- Understanding the concepts of mass and gravitational force (weight) and their difference
- Using force diagrams (free-body diagrams) to represent the forces on a system
- Static systems in equilibrium
- Using force diagrams to develop equations to describe systems from a force perspective
- Describing the motion of systems experiencing no net force
- Describing the motion of systems experiencing a constant net force
- Understanding the effect of changing the net force on the motion of a system
- Understanding the effect of changing the mass of a system on its motion
- Formal development of Newton's 2<sup>nd</sup> Law, and understanding of Newton's 1<sup>st</sup> Law as a special case of it.
- Understanding the nature of force as an interaction and the concept of "force pairs"
- Formal development of Newton's 3<sup>rd</sup> Law
- Static friction, qualitative and quantitative models
- Kinetic friction, qualitative and quantitative models

#### **Laboratory work:**

- \*LI – The relationship between mass and gravitational force
- \*Lab Demo – Analyzing forces and motions of objects on an air table
- \*LI – Interactions between Objects (Using force sensors to measure the forces exerted on pairs of objects by each other during a wide variety of interactions—Newton's Third Law)
- \*LI – Motion of System of Constant Mass Experiencing Constant Net Force (Analysis of the motion of a cart on a horizontal track pulled by a mass hanging over the edge of a table. Smart pulley generated position vs. time graph. Students produce corresponding velocity vs. time graph)
- \*LI – Effect of Changing Net Force on a System of Constant Mass (Analysis of smart pulley generated velocity vs. time graphs to determine relationship between acceleration and net force for a system of constant mass—Newton's 2<sup>nd</sup> Law)
- \*LI – Effect of Changing Mass on a System experiencing Constant Net Force (Analysis of smart pulley generated velocity vs. time graphs to determine relationship between acceleration and mass for a system experiencing a constant net force—Newton's 2<sup>nd</sup> Law)
- LI – Static and Kinetic Friction (Use force probes to measure pulling force, and thus the value of the frictional force as an object at rest is pulled until it starts to move, and then pulled so that it moves at a constant speed. Analyze graphs of frictional force vs. normal force as objects as the mass of the object being pulled is increased for both static and kinetic friction. Compare results with groups using different surfaces.)
- LP – Individual lab practicum where students are given an air track and a glider of known mass and are expected to produce a falling mass that will cause an acceleration of some predetermined amount.

### **Unit 5: Energy Review/Extension (1 week)**

This unit is primarily a review of the energy unit from freshman physics. The various ways in which energy can be stored in a system and transferred into or out of a system are explored. Introduction to concept of efficiency.

- Conservation of energy
- Modes of energy storage including kinetic energy, elastic energy, gravitational energy, internal energy, chemical energy
- Modes of energy transfer including working, heating, and radiating
- Development of energy representational tools including pie charts and bar graphs
- Understanding the significance of the area under a force vs. position graph as work or some other means of changing how energy is stored in a system
- Calculating work in specific cases of a constant force on an object undergoing a specific displacement
- Using analysis of systems and representational tools to develop and solve energy equations for systems
- Power
- Efficiency
- Understanding the effect of changing the mass of a system on its motion
- Formal development of Newton's 2<sup>nd</sup> Law, and understanding of Newton's 1<sup>st</sup> Law as a special case of it.
- Understanding the nature of force as an interaction and the concept of "force pairs"
- Formal development of Newton's 3<sup>rd</sup> Law
- Static friction, qualitative and quantitative models
- Kinetic friction, qualitative and quantitative models

#### **Laboratory work:**

- \*LI – The Relationship between Force and Stretch for a "Hookean" Spring (Plot graph of force vs. stretch for two different springs. Develop concept of slope as spring constant and area under graph as elastic energy. Develop mathematical model relating elastic energy and spring compression or stretch)
- \*LI – The Relationship between Kinetic Energy and Speed (Having measured the spring constant use a spring compressed a known amount to launch a dynamics cart on a level track through a photogate. Plot kinetic energy vs. speed. Develop mathematical model relating kinetic energy and speed.)
- \*LI – The Relationship between Gravitational Energy and Height (Use known spring compressed a known amount to launch a dynamics cart on an inclined track. Measure/calculate change in vertical position. Plot gravitational energy vs. height. Develop mathematical model relating gravitational energy and height.)
- LP – Humpty Dumpty Practicum (Given a spring and a mass, determine the height above a raw egg that the mass, attached to the spring must be released in order to touch but not break the egg.)
- \*LA – Human Power Lab (Determine the rate at which energy is expended in climbing three flights of stairs as quickly as possible. Investigate multiple energy and power units and relate personal energy and power to other real world uses of energy and the rate at which it is "used.")

### ***Unit 6: Circular Motion and Gravitation (2 weeks)***

Using student understanding of the effects of a net force on a system of constant mass developed during the Newton's Laws unit, students extend the model to deal with systems that are centrally bound and exhibit circular motion. Introduce Newton's Law of Universal Gravitation with application of the circular motion model to motions of satellites and planets.

- Determine the effect of changing mass, radius, or speed on the net radial force required to keep an object in uniform circular motion.
- Develop concept of centripetal acceleration as radial component of the acceleration of an object moving in a circular path, and corresponding mathematical model.
- Use force diagrams (free-body diagrams) to determine unknown forces on objects moving in circular paths
- Apply centrally bound force model to systems moving in horizontal circles
- Apply centrally bound force model to systems moving in vertical circles
- Newton's Law of Universal Gravitation
- Using Newton's Law of Universal Gravitation along with circular motion to predict behavior of satellite/planetary systems
- Kepler's Laws

#### **Laboratory work:**

- LI – Uniform Circular Motion (Use wireless force probes and photogates to determine relationship between net radial force and speed, net radial force and mass, and net radial force and radius for a system undergoing uniform circular motion)
- LP – Flying Helicopter/Cow/Pig Lab Practicum (Given a flying toy attached to a string, flying at a measurable height, predict the reading on a stopwatch that times the toy for 30 revolutions)
- LP – Washers on Rotating Turntable Practicum (After performing experiment to determine coefficient of static friction between washers and rotating surface, predict at what distance from the center of rotation washers will stay on turntable or leave turntable rotating at specified angular velocity.)

### ***Unit 7: Impulse, Momentum and Center of Mass (2 weeks)***

Introduce concepts of center of mass, impulse and momentum, and develop relationship between impulse and momentum via Newton's 2<sup>nd</sup> Law. Apply Law of Conservation of Linear Momentum in one and two dimensions.

- Develop concept of center of mass and how it is determined.
- Develop concept of momentum and its vector nature
- Develop concept of impulse and its vector nature
- Explore quantitative relationship between impulse and momentum
- Understand impulse as the area under a force vs. time graph
- Conservation of linear momentum
- Application of conservation of linear momentum in one dimension
- Application of conservation of linear momentum in two dimensions
- Energy considerations during sticking and bouncing collisions and explosions

#### **Laboratory work:**

- LI – Collisions and Explosions (Use photogates and gliders with flags on a level air track to explore effect on total linear momentum and kinetic energy of systems of objects with varying masses and velocities undergoing sticking and bouncing collisions and explosions. Develop concept of Conservation of Linear Momentum, and elastic and inelastic collisions in one dimension)
- LA – Collisions in 2 dimensions (Use projectile launcher to collide two steel balls at an angle. Note landing positions of both balls and use conservation of momentum in 2 dimensions to predict landing position of ball in launcher if collision doesn't occur.)
- LP – Ballistic Pendulum (Determine the launch velocity of a steel ball that is "caught" by a pendulum by measuring swing height and applying conservation of momentum.)
- LP – Exploding Soda Cans (Predict the landing position of a soda can after measuring the landing position of a second soda can after an explosion between the two cans from a level platform a measurable distance above the floor.)
- LA – Bouncing vs. Sticking Darts (Predict/explain the behavior of a wooden block when struck by identical darts, one of which sticks to and the other of which bounces from the block.)
- LP – Exploding Carts/Frame Practicum (Given two dynamics carts with in a rectangular frame, predict how far the frame will move after an explosion between the two carts.)

### ***Unit 8: Rotational Motion and Statics (1 week)***

Using what students know about translational systems, develop rotational analogs to each of the kinematic, dynamic, and energy quantities of translation. Use concept of torque to develop the second condition for equilibrium, and analyze rigid body systems accordingly. Develop concept of centripetal acceleration as radial component of the acceleration of an object moving in a circular path, and corresponding mathematical model.

- Develop rotational analogs to position, velocity, acceleration, mass, force, kinetic energy and linear momentum—angular position, angular velocity, angular acceleration, moment of inertia, torque, rotational kinetic energy, and angular momentum
- Use concepts of force torque to analyze systems in static equilibrium

#### **Laboratory work:**

- No laboratory equipment is available at school for lab work in this abbreviated unit.

### ***Unit 9: Fluid Mechanics (2 weeks)***

Develop concepts of hydrostatic pressure, density, buoyancy and fluid flow and the relationships among them.

- Hydrostatic Pressure and its relationship to density, gravitational field strength, and depth.
- Pascal's Principle
- Buoyancy and Archimede's Principle
- Fluid flow continuity
- Energy considerations in Fluids and Bernoulli's Equation

#### **Laboratory work:**

- LI – Buoyancy (Use force probes, cylinders of various densities, and liquids of various densities to determine how each factor affects the buoyant force on a partially immersed object. Develop a mathematical model from the experiment which describes the dependence (or lack thereof) of buoyant force on those factors.

### ***Unit 10: Temperature and Heat (4 weeks)***

Develop concepts relating temperature, heat, kinetic theory, and thermodynamics

- Mechanical Equivalent of Heat
- Heat Transfer and Thermal Expansion
- Kinetic Theory
- Ideal Gases
- Understanding pressure vs. volume graphs
- Isothermal, Adiabatic, Isobaric and Isochoric processes in thermodynamic systems
- The First Law of Thermodynamics
- Energy transfers (heating and working) during expansion and compression of thermodynamic systems
- Understanding meaning of area under sections of pressure vs. volume graphs and sections enclosed by pressure vs. volume graphs.
- Efficiency of heat engines
- The Carnot Cycle
- The Second Law of Thermodynamics

#### **Laboratory work:**

- LI – Gas Laws (Investigating the effects of changing volume on pressure when temperature is held constant, changing temperature on volume when pressure is held constant, and changing temperature on pressure when volume is held constant.)
- LI – Heat and Temperature, A suite of experiments in which students investigate:
  - Effects on temperature of mixing water samples.
  - Relationship between change in temperature and mass when a fixed amount of energy is added.
  - Relationship between temperature and energy added for materials with different specific heats
  - Relationship between temperature and energy added for water as it is heated from ice to steam.
  - Relationship between mass of water sample and energy added for boiling water heated at a constant rate (Heat of vaporization)
  - Heat of Fusion for Water by melting ice.
  - Specific Heats of Metals
  - Mechanical Equivalent of Heat (100 inversions of 1 meter long, metal shot filled tube, temperature measured before and after, and change in temperature related to the change in gravitational energy of the shot as it falls)

### ***Unit 11: Electrostatics (3 weeks)***

Develop major concepts in electrostatics including

- Conductors vs. insulators
- Methods of charging-polarization, conduction, induction
- Coulomb's Law
- Electric fields
- Electric Potential
- Capacitance and capacitors
- Dielectrics

#### **Laboratory work:**

- LI – Qualitative investigation of electrostatics
- LI – Coulombs Law-Investigation of effect of changing charge separation on electrostatic force using charged pith balls.
- LI – Electric Field and Equipotential Mapping
- \*LI – CASTLE electricity units

### ***Unit 12: Electric Circuits (3 weeks)***

Develop major concepts involving direct current electric circuits including

- Current
- Resistance and resistivity
- Electric potential difference
- Steady state direct current in systems with batteries and resistors
- Ohm's Law
- Series and Parallel Circuits
- Equivalent Resistance
- Kirchoff's Laws
- Power dissipation in resistive circuits
- Capacitors in circuits, Steady and transient states

#### **Laboratory work:**

- \*LI – CASTLE units 1-4 (Conductors and insulators, batteries and bulbs, current, resistance, potential difference)
- LI – CASTLE unit 5 (Capacitors in circuits, transient and steady state)
- LI – CASTLE unit 6 (Current, Resistance, and Electric Potential Difference in series and parallel circuits with light bulbs)
- LI – Ohm's Law (Potential difference vs. current for different constant resistors, Current vs. Resistance for variable resistance, constant potential difference)
- LI – Non-ohmic devices (Potential difference vs. current for light bulbs)
- Series and Parallel Circuits (Currents and potential difference for combinations of three resistors in series or parallel—three equal resistors and then three different resistors)

### ***Unit 13: Magnetic Fields and Electromagnetism (3 weeks)***

Develop major concepts in magnetism including

- Permanent Magnets
- Magnetic Fields around long current-carrying wires
- Magnetic Fields inside current-carrying loops
- Forces on charges in magnetic fields
- Forces on current-carrying wires in magnetic fields
- Electromagnetic Induction
- Faraday's Law
- Lenz's Law

#### **Laboratory work:**

- LI: Magnetic Forces and Fields-A suite of experiments in which students investigate
  - Relationship between magnetic field strength and distance for a bar magnet.
  - Relationship between magnetic field strength and distance from a wire with constant current.
  - Relationship between magnetic field strength and current a constant distance from a current carrying wire.
  - Relationship between magnetic field strength inside a coil and number of turns of wire in the coil.
  - Relationship between magnetic field strength inside a coil and current in the coil
  - Relationship between force on a current carrying wire and current.
  - Relationship between force on a current carrying wire and strength of magnetic field.
  - Relationship between force on a current carrying wire and length of wire.

### ***Unit 14: Simple Harmonic Motion and Mechanical Waves (3 weeks)***

Develop major concepts in simple harmonic motion and simple pendulums including

- Requirements for simple harmonic motion
- Position vs. time, velocity vs. time, and acceleration vs. time relationships for systems undergoing simple harmonic motion
- Kinetic energy vs. time, elastic energy vs. time, total energy vs. time relationships for systems undergoing simple harmonic motion
- Periodic motion concepts including period, frequency, amplitude
- Appropriate expressions for position, velocity, and acceleration as a function of time for systems in simple harmonic motion, expressed in terms of sinusoidal functions
- Recognize points of maximum and minimum position, velocity, and acceleration for systems undergoing simple harmonic motion, and the phase relationship among the graphs of those quantities vs. time
- Factors affecting period of system undergoing simple harmonic motion
- Factors affecting period of a simple pendulum system
- Traveling waves
- Wave propagation
- Fixed and free end reflection
- Wave behavior at boundary between different media
- Superposition of waves
- Interference of waves
- Speed, frequency, wavelength relationship
- Quantities which affect wave speed in a given medium
- Standing waves
- Transverse vs. longitudinal waves
- Polarization
- Sound
- The Doppler Effect
- Beats

#### **Laboratory work:**

- LI – Relationship between period of an oscillating system and amplitude, period and spring constant, period and mass.
- \*LI – Wave Races-What factors affect the speed of mechanical waves.
- \*LI – Reflection of waves at fixed and free-end barriers
- \*LI – Reflection and transmission of waves at boundaries between media with different inertial or elastic properties.
- \*LI – Standing waves on springs-Relationship between frequency and wavelength for a constant medium.
- LI – Standing waves on strings-Relationship between frequency and wavelength
- LI – Standing waves on strings-Relationship between wave speed and tension
- LI – Standing waves on strings-Relationship between wave speed and linear density

### ***Unit 15: Models of Light (3 weeks)***

Develop major concepts in geometric and physical optics including

- Reflection and Plane Mirrors
- Curved Mirrors—converging and diverging
- Refraction
- Dispersion
- Total internal reflection
- Lenses—converging and diverging
- Spherical aberration and Chromatic aberration
- Mathematical models relating image distance, object distance, image height, object height for curved mirrors and lenses
- Ray diagrams for plane mirrors, rays traveling between media, curved mirrors, and lenses
- Focal lengths
- Magnification
- Dispersion
- Nature of images produced by curved mirrors and lenses as determined by position of object relative to optical device and foci.
- Wave diffraction and interference
- Single slits, Double slits, and Multiple slits
- Interference patterns and corresponding intensity vs. position graphs
- Maxima and minima in interference patterns relative to geometry of slits relative to each other and screen
- Young's method for determining wavelength using interference patterns
- Diffraction gratings
- Thin film interference
- Interferometry

#### **Laboratory work:**

- LI – Pinholes - Using a pinhole "camera" with a screen to investigate relationship between object distance and image height, object distance and image distance, image distance and image height.
- LI – Law of Reflection - using plane mirrors to investigate relationship between angle of incidence and angle of reflection, image distance and object distance, and image size and object size.
- LI – Converging Mirrors-Relationship between object distance and image distance for real images in a curved mirror, and relationship between object distance and image distance and object height and image height. LI: Snell's Law: Investigate the relationship between angle of incidence and angle of refraction for an air-plastic and an air-water interface.
- LI – Converging Lenses - Relationship between object distance and image distance for real images in a thin lens, and relationship between object distance and image distance and object height and image height.
- LI – Diffraction and Interference - Investigating the effects of passing a laser through single, double, and multiple slits, and various diffraction gratings on the resulting interference pattern.
- LP – Lab Practicum: Circle of Light (Total internal reflection)
- LP – Lab Practicum: Determining wavelength of unknown lasers.
- LP – Lab Practicum: Determining wavelengths of bright lines in spectra of elements.

### ***Unit 16: Atomic and Nuclear Physics (3 weeks)***

Develop major concepts in modern physics including

- Blackbody radiation and Planck's hypothesis
- The Photoelectric Effect experiment and its implications
- The Photon, its energy and momentum
- Compton scattering
- The Thompson, Rutherford, and Bohr models of the atom
- Atomic energy levels and their relation to Emission and absorption spectra for gases
- Wave-Particle Duality
- The deBroglie wavelength
- The Davisson-Germer Experiment
- Mass-energy equivalence
- Nuclear reactions and conservation of mass and charge
- Alpha, Beta, and Gamma decay
- Nuclear force, its range and relative strength
- Half-life
- Nuclear fission and Nuclear Fusion

#### **Laboratory work:**

- LI – The Photoelectric Effect (Experiment using vacuum phototube, various frequency LEDs, and a spectrometer to determine photoelectric threshold frequency, work function, and Planck's constant)
- LI – Radioactive Decay (Simulation using six-sided dice)