Fair Lawn

Public Schools

Fair Lawn, NJ

Advanced Placement Physics C

August

2015

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AP Physics C is a high school science class developed by the Fair Lawn Schools high school science faculty and aligned to the 2009 NJCCCS and correlated to the Common Core State Standards for Literacy & Math.

Science Department

Fair Lawn School District

Committee Credits

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Advanced Placement Physics C

I. Course Synopsis

The Advanced Placement (A.P.) Physics C course is a one-year calculus-based course similar to introductory courses in Calculus-based Physics taught at the university level. The full course is geared toward students who may major in a physical science or engineering in college. The course content is split into two half-year sections: the physics of Mechanics is taught in the first half-year and the physics of Electricity and Magnetism is taught in the second half-year.

In the first half of the course of Mechanics, students will master the concepts of the one-, two-, and three-dimensional applications of the kinematics (e.g., velocity and acceleration) and dynamics (e.g., forces) of various objects. Other topics in Mechanics will include conservation of energy and momentum, circular motion, equilibrium, and the kinematics and dynamics of rigid objects.

In the second half of the course of Electricity and Magnetism students will master the concepts of electric forces and fields, conductors, capacitors and dielectrics, direct-current circuits (including capacitors, resistors, and inductors), magnetic forces and fields, and electromagnetism.

Students who receive a grade of 3 or better on the A.P. Physics C exam, given in mid-May, will be eligible to receive university credit for calculus-based physics, as per the policy of the individual college.

AP Physics is a 7 Credit class.

II. Philosophy & Rationale

To be competitive in a technological society, it is desirable for students to be well-grounded in all aspects of science, regardless of what their future career goals may be. In particular it is important that students have sufficient exposure to the "hard sciences", especially physics, which is considered to be the "most basic of the sciences" or the "science of everything".

The study of physics can enable a student to understand the natural laws that govern the universe. It also helps to improve deductive and inductive reasoning and develop problem-solving skills through the scientific method.

III. Scope & Sequence

Unit 1: Kinematics • Advanced Vector Mathematics • Motion in One Dimension • Motion in Two Dimensions	September	Chapters 1-3
Unit 2: Dynamics • Newton's Three Laws of Motion • Applications of Newton's Laws	October (First 2 Weeks)	Chapters 4-5
Unit 3: Work, Energy, Power • Work & Work-Energy Theorem • Potential Energy & Kinetic Energy • Conservation of Energy • Power	October (Second 2 Weeks)	Chapters 6-7
Unit 4: Linear Momentum • Impulse & Momentum • Conservation of Linear Momentum • Collisions • Center of Mass	November (First 2 Weeks)	Chapter 8
Unit 5: Circular Motion & Rotation • Uniform Circular Motion • Torque & Rotational Statics • Rotational Kinematics & Dynamics • Angular Momentum • Conservation of Angular Momentum	November (Second 2 Weeks)	Chapters 9-10
Unit 6: Gravitation & Oscillations • Newton's Law of Gravitation • Orbits of Planets and Satellites (Circular and Elliptical) • Simple Harmonic Motion (Dynamics and Energy Relationships) • Oscillating Mass on a Spring • The Pendulum and Other Oscillations	December	Chapters 13-14

Unit 7: Electrostatics • Electric Charge • Coulomb's Law of Electrostatics • Electric Fields and Electric Potential (Including Point Charges) • Gauss's Law of Electrostatics • Electric Fields and Potentials of Other Charge Distributions	January	Chapters 21-23
Unit 8: Conductors, Capacitors & Dielectrics • Electrostatics with Conductors • Capacitors Capacitance Parallel-plate Capacitors Spherical and Cylindrical • Capacitor Dielectrics	February (First 2 Weeks)	Chapter 24
Unit 9: Electric Circuits • Current, Resistance, Electric Power • Steady-state Direct Current Circuits with Batteries and Resistors Only • Capacitors in Circuits Steady-state Transients in RC Circuits	February (Second 2 Weeks)	Chapters 25-26
Unit 10: Magnetic Fields • Forces on Moving Charges in Magnetic Fields • Forces on Current-carrying Wires in Magnetic Fields • Magnetic Fields of Long Current-carrying Wires • Biot-Savart Law • Ampere's Law	March	Chapters 27-28

Unit 11: Electromagnetism
• Electromagnetic Induction
  Faraday's Law
  Lenz's Law
• Inductance
  LR Circuits
  LC Circuits
• Maxwell's Equations
	April	Chapters 29,30,32

Unit 12: AP Exam Review	May (First 2 Weeks)	

IV. Unit Descriptions

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Unit 1: Kinematics

Enduring Understanding

1. Kinematics is the study of the "how" things work, governed by natural laws.
2. Both direct and indirect relationships exist in nature.
3. There is a relationship between displacement, velocity, and acceleration.

Essential Question(s)

- In which ways can we describe "how" objects move in nature?

Learning Objectives

1. Apply the concept of unit vectors to the study of dot and cross product.
2. Apply knowledge of differential and integral calculus to the solution of problems utilizing the kinematic equations.
3. Given a graph of one of the kinematic quantities, position, velocity, or acceleration, as a function of time, recognize in what time intervals the other two are positive, negative, or zero and identify or sketch a graph of each as a function of time.
4. Given an expression for one of the kinematic quantities, position, velocity or acceleration, as a function of time, determine the other two as a function of time, and find when these quantities are zero or achieve their maximum and minimum values.
5. Write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities.
6. Apply knowledge of kinematics to projectile motion problems.

Suggested Activities

1. Students will be able to use Microsoft EXCEL and other software to plot graphs for lab reports.
2. Applying Advanced Statistical Analysis to the Measurement of the Length of Objects Lab
3. Inquiry Lab on Finding the Mass and Diameter of a Battery
4. Inquiry Lab on Relating Diameter and Circumference of a Circle
5. Uniformly Accelerated Motion on an Inclined Track (Galileo's Experiment) Lab
6. Horizontal Projectile Motion Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 2: Dynamics

Enduring Understanding

1. Dynamics is the study of "why" things work, governed by natural laws.
2. Both direct and indirect relationships exist in nature.
3. There is a relationship between acceleration, force, and mass.

Essential Question(s)

- What causes objects to move the way they do in nature?

Learning Objectives

1. Analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.
2. Calculate, for an object moving in one dimension, the velocity change that results when a constant force F acts over a specified time interval.
3. Calculate, for an object moving in one dimension, the velocity change that results when a force $F(t)$ acts over a specified time interval.
4. Determine, for an object moving in a plane whose velocity vector undergoes a specified change over a specified time interval, the average force that acted on the object.
5. Draw a well-labeled, free-body diagram showing all real forces that act on the object.
6. Write down the vector equation that results from applying Newton's Second Law to the object, and take components of this equation along appropriate axes.
7. Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, such as motion up or down with constant acceleration.
8. Write down the relationship between the normal and frictional forces on a surface.
9. Analyze situations in which an object moves along a rough inclined plane or horizontal surface.
10. Analyze under what circumstances an object will start to slip, or to calculate the magnitude of the force of static friction.
11. Find the terminal velocity of an object moving vertically under the influence of a retarding force dependent on velocity.
12. Describe qualitatively, with the aid of graphs, the acceleration, velocity, and displacement of such a particle when it is released from rest or is projected vertically with specified initial velocity.
13. Use Newton's Second Law to write a differential equation for the velocity of the object as a function of time.
14. Use the method of separation of variables to derive the equation for the velocity as a function of time from the differential equation that follows from Newton's Second Law.
15. Derive an expression for the acceleration as a function of time for an object falling under the influence of drag forces.
16. Understand Newton's Third Law so that, for a given system, one can identify the force pairs and the objects on which they act, and state the magnitude and direction of each

force.

17. Apply Newton's Third Law in analyzing the force of contact between two objects that accelerate together along a horizontal or vertical line, or between two surfaces that slide across one another.
18. Know that the tension is constant in a light string that passes over a massless pulley and be able to use this fact in analyzing the motion of a system of two objects joined by a string.
19. Solve problems in which application of Newton's laws leads to two or three simultaneous linear equations involving unknown forces or accelerations.

Suggested Activities

1. The Addition and Resolution of Vectors: The Force Table Lab
2. Newton's Second Law Lab with PASCO Tracks and Carts
3. Newton's Second Law: The Atwood machine Lab
4. Finding the Coefficient of Friction Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 3: Work and Energy

Enduring Understanding

- Energy is conserved in nature.

Essential Question(s)

- What is the relationship between work, energy, and power?

Learning Objectives

1. Calculate the work done by a specified constant force on an object that undergoes a specified displacement.
2. 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.
3. Use integration to calculate the work performed by a force $F(x)$ on an object that undergoes a specified displacement in one dimension.
4. Use the scalar product operation to calculate the work performed by a specified constant force F on an object that undergoes a displacement in a plane.
5. Calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object.
6. Calculate the work performed by the net force, or by each of the forces that make up the net force, on an object that undergoes a specified change in speed or kinetic energy.

7. Apply the theorem to determine the change in an object's kinetic energy and speed that result from the application of specified forces, or to determine the force that is required in order to bring an object to rest in a specified distance.
8. State alternative definitions of "conservative force" and explain why these definitions are equivalent.
9. Describe examples of conservative forces and non-conservative forces. □
10. State the general relation between force and potential energy, and explain why potential energy can be associated only with conservative forces.
11. Calculate a potential energy function associated with a specified one-dimensional force $F(x)$.
12. Calculate the magnitude and direction of a one-dimensional force when given the potential energy function $U(x)$ for the force.
13. Write an expression for the force exerted by an ideal spring and for the potential energy of a stretched or compressed spring.
14. Calculate the potential energy of one or more objects in a uniform gravitational field.
15. State and apply the relation between the work performed on an object by nonconservative forces and the change in an object's mechanical energy.
16. Describe and identify situations in which mechanical energy is converted to other forms of energy.
17. Analyze situations in which an object's mechanical energy is changed by friction or by a specified externally applied force.
18. Identify situations in which mechanical energy is or is not conserved.
19. Apply conservation of energy in analyzing the motion of systems of connected objects, such as an Atwood's machine.
20. Apply conservation of energy in analyzing the motion of objects that move under the influence of springs.
21. Apply conservation of energy in analyzing the motion of objects that move under the influence of other non-constant one-dimensional forces.
22. Recognize and solve problems that call for application both of conservation of energy and Newton's Laws.
23. Calculate the power required to maintain the motion of an object with constant acceleration (e.g., to move an object along a level surface, to raise an object at a constant rate, or to overcome friction for an object that is moving at a constant speed).
24. 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.

Suggested Activities

1. Work and Energy on an Inclined Plane Lab
2. Conservation of Spring Energy and Gravitational Potential Energy Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 4: Linear Momentum

Enduring Understanding

- Momentum is conserved in various types of collisions in nature.

Essential Question(s)

- How do perfectly elastic collisions, inelastic collisions, and perfectly inelastic collisions differ as far as conservation of energy and momentum are concerned?

Learning Objectives

1. Relate mass, velocity, and linear momentum for a moving object, and calculate the total linear momentum of a system of objects.
2. Relate impulse to the change in linear momentum and the average force acting on an object.
3. State and apply the relations between linear momentum and center-of-mass motion for a system of particles.
4. Calculate the area under a force versus time graph and relate it to the change in momentum of an object.
5. Calculate the change in momentum of an object given a function $F(t)$ for the net force acting on the object.
6. Explain how linear momentum conservation follows as a consequence of Newton's Third Law for an isolated system.
7. Identify situations in which linear momentum, or a component of the linear momentum vector, is conserved.
8. Apply linear momentum conservation to one-dimensional elastic and inelastic collisions and two-dimensional completely inelastic collisions.
9. Apply linear momentum conservation to two-dimensional elastic and inelastic collisions.
10. Analyze situations in which two or more objects are pushed apart by a spring or other agency, and calculate how much energy is released in such a process.
11. Analyze the uniform motion of an object relative to a moving medium such as a flowing stream.
12. Analyze the motion of particles relative to a frame of reference that is accelerating horizontally or vertically at a uniform rate.
13. Identify by inspection the center-of-mass of a symmetrical object.
14. Locate the center-of-mass of a system consisting of two such objects.
15. Use integration to find the center-of-mass of a thin rod of non-uniform density.
16. Understand and apply the relation between center-of-mass, velocity, and linear momentum, and between center-of-mass, acceleration, and net external force for a system of particles.
17. Define center-of-gravity and to use this concept to express the gravitational potential energy of a rigid object in terms of the position of its center-of-mass.

Suggested Activities

1. Conservation of Momentum in One-Dimensional Collisions Lab
2. Conservation of Momentum in Two-Dimensional Collisions Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 5: Circular Motion and Rotation

Enduring Understanding

1. A centripetal force will cause an object to move in uniform circular motion.
2. A perpendicular or angled force applied at a certain distance from an object's pivot point can cause a system to torque.
3. Angular momentum is conserved in rotating systems in nature, in the absence of external torques.

Essential Question(s)

1. Can a centripetal force and torque-causing force co-exist on the same object?
2. How does the angular momentum of a rotating system change as the mass-distribution or angular velocity of a rotating system changes?

Learning Objectives

1. 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 components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities.
4. Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, in situations such as the following:
    a. Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve).
    b. Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel).
5. Calculate the magnitude and direction of the torque associated with a given force.
6. Calculate the torque on a rigid object due to gravity.
7. State the conditions for translational and rotational equilibrium of a rigid object.

8. Apply the above conditions in analyzing the equilibrium of a rigid object under the combined influence of a number of coplanar forces applied at different locations.
9. Determine by inspection which of a set of symmetrical objects of equal mass has the greatest rotational inertia.
10. Determine by what factor an object's rotational inertia changes if all its dimensions are increased by the same factor.
11. Develop skill in computing rotational inertia so one can find the rotational inertia of:
    a. A collection of point masses lying in a plane about an axis perpendicular to the plane.
    b. A thin rod of uniform density, about an arbitrary axis perpendicular to the rod.
    c. A thin cylindrical shell about its axis, or an object that may be viewed as being
    d. made up of coaxial shells.
    e. State and apply the parallel-axis theorem.

Suggested Activities

1. Conical Pendulum Lab
2. Objects in Static Equilibrium (Ladder Problem) Lab
3. Rotational Motion and Moment of Inertia Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 6: Gravitation and Oscillations

Enduring Understanding

1. Based on Newton's Law of Gravitation, the force of gravity can be calculated for regularly and irregularly-shaped objects.
2. The sum of potential energy and kinetic energy is constant in oscillating systems.

Essential Question(s)

1. How can the Law of Gravitation be applied to circular and elliptical orbits of planets?
2. How can the period of an oscillating pendulum and the period of an oscillating spring-mass system be determined?

Learning Objectives

1. Determine the force that one spherically symmetrical mass exerts on another.
2. Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass.
3. Describe the gravitational force inside and outside a uniform sphere, and calculate how the field at the surface depends on the radius and density of the sphere.

4. Recognize that the motion does not depend on the object'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.
5. Derive Kepler's Third Law for the case of circular orbits.
6. Derive and apply the relations among kinetic energy, potential energy, and total energy for such an orbit.
7. State Kepler's three laws of planetary motion and use them to describe in qualitative terms the motion of an object in an elliptical orbit.
8. Apply conservation of angular momentum to determine the velocity and radial distance at any point in the orbit.
9. Apply angular momentum conservation and energy conservation to relate the speeds of an object at the two extremes of an elliptical orbit.
10. Apply energy conservation in analyzing the motion of an object that is projected straight up from a planet's surface or that is projected directly toward the planet from far above the surface.
11. Understand the concepts of simple harmonic motion so that one may sketch or identify a graph of displacement as a function of time, and determine from such a graph the amplitude, period and frequency of the motion.
12. Write down an appropriate expression for displacement of the form $A \sin \omega t$ or $A \cos \omega t$ to describe the motion.
13. Find an expression for velocity as a function of time.
14. State the relations between acceleration, velocity and displacement, and identify points in the motion where these quantities are zero or achieve their greatest positive and negative values.
15. State and apply the relation between frequency and period.
16. Recognize that a system that obeys a differential equation of the form $d^2x/dt^2 = -\omega^2 x$ must execute simple harmonic motion, and determine the frequency and period of such motion.
17. 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 this energy is all potential or all kinetic.
18. Calculate the kinetic and potential energies of an oscillating system as functions of time, sketch or identify graphs of these functions, and prove that the sum of kinetic and potential energy is constant.
19. Calculate the maximum displacement or velocity of a particle that moves in simple harmonic motion with specified initial position and velocity.
20. Develop a qualitative understanding of resonance so they can identify situations in which a system will resonate in response to a sinusoidal external force.
21. Derive the expression for the period of oscillation of a mass on a spring.
22. Apply the expression for the period of oscillation of a mass on a spring.
23. Analyze problems in which a mass hangs from a spring and oscillates vertically.
24. Analyze problems in which a mass attached to a spring oscillates horizontally.
25. Determine the period of oscillation for systems involving series or parallel combinations of identical springs, or springs of differing lengths.
26. Derive the expression for the period of a simple pendulum.
27. Apply the expression for the period of a simple pendulum.
28. State what approximation must be made in deriving the period.

29. Analyze the motion of a torsional pendulum or physical pendulum in order to determine the period of small oscillations.

Suggested Activities

1. Finding the Mass of Jupiter Lab (Using AAPT's "Physics: Cinema Classics" disk or online software)
2. Hooke's Law for Series and Parallel Springs Lab
3. Physical Pendulum Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 7: Electrostatics

Enduring Understanding

1. Electric charge is conserved in nature.
2. Electric forces and fields exist between charges.

Essential Question(s)

- How can the electric field, electric potential, and electric flux be calculated outside and inside charged regularly-shaped geometric conducting objects?

Learning Objectives

1. Describe the types of charge and the attraction and repulsion of charges.
2. Describe polarization and induced charges.
3. Calculate the magnitude and direction of the force on a positive or negative charge due to other specified point charges.
4. Analyze the motion of a particle of specified charge and mass under the influence of an electrostatic force.
5. Define electric field in terms of the force on a test charge.
6. Describe and calculate the electric field of a single point charge.
7. Calculate the magnitude and direction of the electric field produced by two or more point charges.
8. Calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field.
9. Interpret an electric field diagram.
10. Analyze the motion of a particle of specified charge and mass in a uniform electric field.
11. Determine the electric potential in the vicinity of one or more point charges.
12. Calculate the electrical work done on a charge or use conservation of energy to determine the speed of a charge that moves through a specified potential difference.
13. Determine the direction and approximate magnitude of the electric field at various positions given a sketch of equipotentials.

14. Calculate the potential difference between two points in a uniform electric field, and state which point is at the higher potential.
15. Calculate how much work is required to move a test charge from one location to another in the field of fixed point charges.
16. Calculate the electrostatic potential energy of a system of two or more point charges, and calculate how much work is required to establish the charge system.
17. Use integration to determine electric potential difference between two points on a line, given electric field strength as a function of position along that line.
18. State the general relationship between field and potential, and define and apply the concept of a conservative electric field.
19. Calculate the flux of an electric field through an arbitrary surface or of a field uniform in magnitude over a Gaussian surface and perpendicular to it.
20. Calculate the flux of the electric field through a rectangle when the field is perpendicular to the rectangle and a function of one coordinate only.
21. State and apply the relationship between electric flux and lines of force.
22. State Gauss's Law in integral form, and apply it qualitatively to relate flux and electric charge for a specified surface.
23. Apply Gauss's Law, along with symmetry arguments, to determine the electric field for a planar, spherical, or cylindrically symmetric charge distribution.
24. Apply Gauss's Law to determine the charge density or total charge on a surface in terms of the electric field near the surface.
25. Use the principle of superposition to calculate by integration the electric field of a straight, uniformly charged wire.
26. Use the principle of superposition to calculate by integration the electric field and potential on the axis of a thin ring of charge, or at the center of a circular arc of charge.
27. Use the principle of superposition to calculate by integration the electric potential on the axis of a uniformly charged disk.
28. Identify situations in which the direction of the electric field produced by a charge distribution can be deduced from symmetry considerations.
29. Describe qualitatively the patterns and variation with distance of the electric field of:
    (a) Oppositely-charged parallel plates.
    (b) A long, uniformly-charged wire, or thin cylindrical or spherical shell.
30. Use superposition to determine the fields of parallel charged planes, coaxial cylinders, or concentric spheres.
31. Derive expressions for electric potential as a function of position in the above cases.

Suggested Activities

- Equipotentials and Electric Fields Mapping Lab (with hands-on equipment and computer simulations)

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 8: Conductors, Capacitors, and Dielectrics

Enduring Understanding

1. Electric charge is conserved in nature.
2. Electric energy can be temporarily stored in a capacitor.

Essential Question(s)

- How are voltage across a capacitor and charge on that capacitor related?

Learning Objectives

1. Explain the mechanics responsible for the absence of electric field inside a conductor, and know that all excess charge must reside on the surface of the conductor.
2. Explain why a conductor must be an equipotential, and apply this principle in analyzing what happens when conductors are connected by wires.
3. Show that all excess charge on a conductor must reside on its surface and that the field outside the conductor must be perpendicular to the surface.
4. Describe the process of charging by induction.
5. Explain why a neutral conductor is attracted to a charged object.
6. Explain why there can be no electric field in a charge-free region completely surrounded by a single conductor, and recognize consequences of this result.
7. Explain why the electric field outside a closed conducting surface cannot depend on the precise location of charge in the space enclosed by the conductor, and identify consequences of this result.
8. Relate stored charge and voltage for a capacitor.
9. Relate voltage, charge, and stored energy for a capacitor.
10. Recognize situations in which energy stored in a capacitor is converted to other forms.
11. Describe the electric field inside the capacitor, and relate the strength of this field to the potential difference between the plates and the plate separation.
12. Relate the electric field to the density of the charge on the plates.
13. Derive an expression for the capacitance of a parallel-plate capacitor.
14. Determine how changes in dimension will affect the value of the capacitance.
15. Derive and apply expressions for the energy stored in a parallel-plate capacitor and for the energy density in the field between the plates.
16. Analyze situations in which capacitor plates are moved apart or moved closer together, or in which a conducting slab is inserted between capacitor plates, either with a battery connected between the plates or with the charge on the plates held fixed.
17. Understand cylindrical and spherical capacitors, so one can:
    (a) Describe the electric field inside each.
    (b) Derive an expression for the capacitance of each.
18. Describe how the insertion of a dielectric between the plates of a charged parallel-plate
19. capacitor affects its capacitance and the field strength and voltage between the plates.
20. Analyze situations in which a dielectric slab is inserted between the plates of a capacitor.

Suggested Activities

- Capacitor Circuits Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 9: Electric Circuits

Enduring Understanding

- In electric circuits, voltage and electric current are directly related for a given electric resistance.

Essential Question(s)

- How can voltage and current be measured in series circuits, parallel circuits, series-parallel circuits, and complex circuits?

Learning Objectives

1. Relate the magnitude and direction of the current to the rate of flow of positive and negative charge.
2. Understand conductivity, resistivity, and resistance, so that one can:
   (a) Relate current and voltage for a resistor.
   (b) Write the relationship between electric field strength and current density in a conductor, and describe, in terms of the drift velocity of electrons, why such a relationship is plausible.
3. Describe how the resistance of a resistor depends upon its length and cross-sectional area, and apply this result in comparing current flow in resistors of different material or different geometry.
4. Derive an expression for the resistance of a resistor of uniform cross-section in terms of its dimensions and the resistivity of the material from which it is constructed.
5. Derive expressions that relate the current, voltage and resistance to the rate at which heat is produced when current passes through a resistor.
6. Apply the relationships for the rate of heat production in a resistor.
7. Identify on a circuit diagram whether resistors are in series or in parallel.
8. Determine the ratio of the voltages across resistors connected in series or the ratio of the currents through resistors connected in parallel.
9. Calculate the equivalent resistance of a network of resistors that can be broken down into series and parallel combinations.
10. Calculate the voltage, current, and power dissipation for any resistor in such a network of resistors connected to a single power supply.
11. Design a simple series-parallel circuit that produces a given current through and potential difference across one specified component, and draw a diagram for the

circuit using conventional symbols.

12. Calculate the terminal voltage of a battery of specified emf and internal resistance from which a known current is flowing.
13. Calculate the rate at which a battery is supplying energy to a circuit or is being charged up by a circuit.
14. Be able to apply Ohm's law and Kirchhoff's rules to direct-current circuits, in order to:
    (a) Determine a single unknown current, voltage, or resistance.
    (b) Set up and solve simultaneous equations to determine two unknown currents.

15. Understand the properties of voltmeters and ammeters, so one can:
    (a) State whether the resistance of each is high or low.
    (b) Identify or show correct methods of connecting meters into circuits in order to measure voltage or current.
    (c) Assess qualitatively the effect of finite meter resistance on a circuit into which these meters are connected.
16. Understand the $t = 0$ and steady-state behavior of capacitors connected in series or in parallel, so one can:
    (a) Calculate the equivalent capacitance of a series or parallel combination.
    (b) Describe how stored charge is divided between capacitors connected in parallel.
    (c) Determine the ratio of voltages for capacitors connected in series.
    (d) Calculate the voltage or stored charge, under steady-state conditions, for a capacitor connected to a circuit consisting of a battery and resistors.
17. Understand the discharging or charging of a capacitor through a resistor, so one can:
    (a) Calculate and interpret the time constant of the circuit.
    (b) Sketch or identify graphs of stored charge or voltage for the capacitor, or of current or voltage for the resistor, and indicate on the graph the significance of the time constant.
    (c) Write expressions to describe the time dependence of the stored charge or voltage for the capacitor, or of the current or voltage for the resistor.
    (d) Analyze the behavior of circuits containing several capacitors and resistors, including analyzing or sketching graphs that correctly indicate how voltages and currents vary with time.

Suggested Activities

1. Finding Resistivity of Wires Lab
2. Ammeter-Voltmeter Method of Finding Resistance Using Ohm's Law Lab
3. Wheatstone Bridge Method of Finding Resistance Lab
4. Analysis of Resistors in Series-Parallel Circuits Lab
5. Finding the RC Time Constant Using an Oscilloscope

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 10: Magnetic Fields

Enduring Understanding

- Moving electric charge and magnetism are manifestations of each other.

Essential Question(s)

1. How are moving electric charge and magnetism related?
2. How do the properties of magnetism and electricity differ?

Learning Objectives

1. 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.
2. Deduce the direction of a magnetic field from information about the forces experienced by charged particles moving through that field.
3. Describe the paths of charged particles moving in uniform magnetic fields.
4. Derive and apply the formula for the radius of the circular path of a charge that moves perpendicular to a uniform magnetic field.
5. Describe under what conditions particles will move with constant velocity through crossed electric and magnetic fields.
6. Calculate the magnitude and direction of the force on a straight segment of current-carrying wire in a uniform magnetic field.
7. 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.
8. Calculate the magnitude and direction of the torque experienced by a rectangular loop of wire carrying a current in a magnetic field.
9. Calculate the magnitude and direction of the field at a point in the vicinity of such a wire.
10. Use superposition to determine the magnetic field produced by two long wires.
11. Calculate the force of attraction or repulsion between two long current-carrying wires.
12. Understand the Biot-Savart Law, so one can:
    (a) Deduce the magnitude and direction of the contribution to the magnetic field made by a short straight segment of current-carrying wire.
    (b) Derive and apply the expression for the magnitude of **B** on the axis of a circular loop of current.
13. Understand the statement and application of Ampere’s Law in integral form, so one can:
    (a) State the law precisely.
    (b) Use Ampere’s law, plus symmetry arguments and the right-hand rule, to relate magnetic field strength to current for planar or cylindrical symmetries.
14. Apply the superposition principle so one can determine the magnetic field produced by combinations of the configurations listed above.

Suggested Activities

1. Magnetic Force on a Current-Carrying Wire Lab
2. Measurement of Magnetic Field in a Solenoid Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

Unit 11: Electromagnetism

Enduring Understanding

- Voltages and electric currents can be produced from moving magnetic fields.

Essential Question(s)

1. How are moving electric charge and magnetism related?
2. How do the properties of magnetism and electricity differ?

Learning Objectives

1. Calculate the magnetic flux of a uniform magnetic field through a loop of arbitrary orientation.
2. Use integration to calculate the flux of a non-uniform magnetic field, whose magnitude is a function of one coordinate, through a rectangular loop perpendicular to the field.
3. Understand Faraday's law and Lenz's law, so one can:
    (a) Recognize situations in which changing flux through a loop will cause an induced emf or current in the loop.
    (b) Calculate the magnitude and direction of the induced emf and current in a loop of wire or a conducting bar under the following conditions:
        i. The magnitude of a related quantity such as magnetic field or area of the loop is changing at a constant rate.
        ii. The magnitude of a related quantity such as magnetic field or area of the loop is a specified non-linear function of time.
4. Analyze the forces that act on induced currents so one can determine the mechanical consequences of those forces.
5. Calculate the magnitude and sense of the emf in an inductor through which a specified changing current is flowing.
6. Derive and apply the expression for the self-inductance of a long solenoid.
7. Apply Kirchhoff's rules to a simple *LR* series circuit to obtain a differential equation for the current as a function of time.
8. Solve the differential equation obtained in # 7 above for the current as a function of time through the battery, using separation of variables.
9. Calculate the initial transient currents and final steady state currents through any part of a simple series and parallel circuit containing an inductor and one or more resistors.
10. Sketch graphs of the current through or voltage across the resistors or inductor in a simple series and parallel circuit.
11. Calculate the rate of change of current in the inductor as a function of time.

12. Calculate the energy stored in an inductor that has a steady current flowing through it.
13. Be familiar with Maxwell’s equations so one can associate each equation with its implications.

Suggested Activities

1. Faraday's Law of Induction Lab
2. Phase Measurements and Resonance in AC Circuits (RL, LC, and RLC circuits) with Oscilloscope Lab

New Jersey Core Curriculum Content Standards

5.1.12A1, B1-2, C; 5.3.12A-; 9.2.12A1, F1,4-5, C2, C3; 3.2; 8.2B3; 9.2A3

V. Course Materials

Textbook: University Physics with Modern Physics (13th Ed.) by Young, Hugh D. & Freedman, Roger A., Pearson Education Inc. publishing as Addison-Wesley (2012).
Adopted by the FLBOE during school year 2011-2012.

Additional material: "Mastering Physics" online program that comes with above text for self-study, self-quizzing, homework, etc.

Chapter Correlations & Time Frames

Unit	AP Physics C Time Frame	"College Physics", 9th Ed
1 Kinematics	September	1-3
2 Dynamics	October (first 2 weeks)	4-5
3 Work, Energy, & Power	October (second 2 weeks)	6-7
4 Linear Momentum	November (first 2 weeks)	8
5 Circular Motion & Rotation	November (second 2 weeks)	9-10
6 Gravitation & Oscillations	December	13-14
7 Electrostatics	January	21-23
8 Conductors, Capacitors, Dielectrics	February(first 2 weeks)	24
9 Electric Currents	February (second 2 weeks)	25-26
10 Magnetics Fields	March	27-28
11 Electromagnetism	April	29, 30, 32
12 Review for AP Exam	May	All Previous Chapters

Suggested Activities & Suggested Modifications for Special Education Students, ELL Students, Students at Risk, and Gifted Students:

1. Students with special needs and ELL learners may be provided with key vocabulary terms prior to the unit beginning. In particular, the amount of key vocabulary terms should be reduced for ELL students.
2. ELL students may be provided with additional visual aids. For additional modifications, refer to Classroom Instruction that Works for ELL Learners *or the* SIOP protocol.
3. Gifted students may be challenged by asking them to form additional connections between biology, chemistry, and physics.

VI. Assessments

All students in A.P. Physics C will take a midterm exam, covering Units 1 – 6 inclusive, which will contain a "common aspect" among all students. There is no final exam as per FLBOE policy towards A.P. courses; however, there will be a 5th marking period project related to Units 7 – 11 inclusive. In addition, regular tests, quizzes, lab reports, homework assignments, class participation, etc. will be required throughout marking periods 1 – 4.

VII. Cross Curricular Aspects

The study of A.P. Physics C requires an understanding of Chemistry, Advanced Algebra, Advanced Trigonometry, Advanced Statistics, and certainly Calculus (at least at the level of FLHS's A.P. AB Calculus course). In addition, students in A.P. Physics C will be able to apply their knowledge to FLHS's Multivariable Calculus course. Familiarity with computers is required as well. There are also overlaps between content covered in the technology education program at FLHS.

CCCS Literacy: Click on the link to the High School Evidence Statements to see expectations related to literacy for this unit. In addition, a focus of the course will be on the development of the LAL standards for science & technical subjects.

CCCS Math: Students will be expected to perform measurement, modeling, apply algebra, and geometry and statistics.

Interdisciplinary Connections and Alignment to Technology standards

Science classes in the Fair Lawn Public schools promote career-readiness skills related to Personal Financial Literacy (9.1) and Career Awareness, Exploration, and Presentation (9.2). Some course concepts from the Career and Technical Education Standards (9.3), but these are not directly correlated since our district is not a CTE program.

The Fair Lawn Public Schools District fosters an environment that promotes career-readiness skills in all content areas. Whereas Career Ready Practices are explored consistently, specific alignment to Personal Finance Literacy (9.1) and Career Awareness, Exploration, and Presentation Standards (9.2) are included in the district level document (below). When appropriate, the Career and Technical Education Standards (9.3) have been reviewed and aligned as well.

Examples: 9.2B: Career exploration in each unit of study.

In addition, every effort is made to integrate technology and engineering into our science classes. Educational Technology (8.1) and Technology Education, Engineering, Design, and Computational Thinking – Programming (8.2) standards are cross connected throughout our science programs.

Examples:

- 8.1A: Use spreadsheets to analyze & interpret data from laboratories, 6-12.
  Use the internet to increase productivity and efficiency, 9-12.
- 8.1B,C: Use data to solve real-world problems, 6-12.
  Use online platforms to collaborate & address global issues, 9-12.
- 8.1F: Collect and analyze data using internet and data simulations, 6-12.
- 8.2A: Become aware of the invention process, 3-5.
- 8.2B: Become aware of the global impacts on technology, 6-12.
- 8.2C: Apply the design process to pushes & pulls, K-2.
- 8.2D: Use tools to reduce work, K-2.

For additional detail on how these standards are integrated throughout the Fair Lawn Schools curriculum, review the Fair Lawn Public Schools District Alignment to Technology & Career Readiness & 21st Century Skills Standards Curriculum Appendix.