MOORESTOWN TOWNSHIP PUBLIC SCHOOLS
MOORESTOWN, NEW JERSEY

Moorestown High School
Science Department

AP Physics 2
Grade 12

Date: July 2022
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Supervisor: Gavin Quinn

Contents

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Course Description and Fundamental Concepts

AP Physics 2 is an algebra-based, introductory college-level physics course. Students cultivate their understanding of Physics through inquiry-based investigations as they explore topics such as fluid statics and dynamics; thermodynamics with kinetic theory; PV diagrams and probability; electrostatics; electrical circuits with capacitors; magnetic fields; electromagnetism; physical and geometric optics; and quantum, atomic, and nuclear physics. Through inquiry-based learning, students will develop scientific critical thinking and reasoning skills.

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New Jersey Student Learning Standards (NJSLS)

Subject/Content Standards *Include grade appropriate subject/content standards that will be addressed*

Standard #	Standard Description
HS-PS1	
HS-PS1-1	*Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.*
HS-PS1-2	*Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.*
HS-PS1-3	*Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.*
HS-PS1-4	*Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.*
HS-PS1-5	*Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.*
HS-PS1-6	*Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*
HS-PS1-7	*Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.*
HS-PS1-8	*Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.*
HS-PS2	
HS-PS2-1	*Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.*
HS-PS2-2	*Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.*
HS-PS2-3	*Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

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HS-PS2-4	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
HS-PS2-5	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
HS-PS2-6	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
HS-PS3	
HS-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known..
HS-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
HS-PS3-4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
HS-PS3-5	Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
HS-PS4	
HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-2	Evaluate questions about the advantages of using a digital transmission and storage of information.
HS-PS4-3	Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.
HS-PS4-4	Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
HS-PS4-5	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

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ETS1 Engineering Design	
HS-ETS1-1	*Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.*
HS-ETS1-2	*Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*
HS-ETS1-3	*Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.*
HS-ETS1-4	*Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.*

English Companion Standards

List grade-level appropriate companion standards for History, Social Studies, Science and Technical Subjects (CTE/Arts) 6-12. English Companion Standards are required in these subject/content areas.

Unit Addressed	Standard #	Standard Description
1,2,3,4,5,6,7	*RST.11-12.1*	*Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-1),(HS-PS2-6))*
1,2,3,4,5,6,7	*RST.11-12.7*	*Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1*
1,2,3,4,5,6,7	*RST.11-12.8*	*Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4)*
1,2,3,4,5,6	*WHST.9-12.2*	*Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)*
1,2,5	*WHST.9-12.5*	*Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)*

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1,2,5,7	*WHST.9-12.7*	*Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3),(HSPS2-5)*
1,2,5,7	*WHST.11-12.8*	*Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5)*
1,2,3,4,5,6,7	*WHST.9-12.9*	*Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1),(HS-PS2-5)*
1,2,3,4,5,6,7	*SL.11-12.5*	*Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1),(HS-PS3-2),(HS-PS3-5)*

Career Awareness, Exploration, Preparation, and Training (Standard 9.2)
List appropriate units below for which standards will be addressed

By Grade 12		
Unit Addressed	**Core Idea**	**Standard / Description**
1,2,3,4,5,6,7	There are strategies to improve one's professional value and marketability.	***9.2.12.CAP.1***: *Analyze unemployment rates for workers with different levels of education and how the economic, social, and political conditions of a time period are affected by a recession.* ***9.2.12.CAP.2***: *Develop college and career readiness skills by participating in opportunities such as structured learning experiences, apprenticeships, and dual enrollment programs.* ***9.2.12.CAP.3***: *Investigate how continuing education contributes to one's career and personal growth.*

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1,2,3,4,5,6,7	Career planning requires purposeful planning based on research, self-knowledge, and informed choices.	***9.2.12.CAP.4***: *Evaluate different careers and develop various plans (e.g., costs of public, private, training schools) and timetables for achieving them, including educational/training requirements, costs, loans, and debt repayment.* ***9.2.12.CAP.5***: *Assess and modify a personal plan to support current interests and postsecondary plans.* ***9.2.12.CAP.6***: *Identify transferable skills in career choices and design alternative career plans based on those skills.* ***9.2.12.CAP.7***: *Use online resources to examine licensing, certification, and credentialing requirements at the local, state, and national levels to maintain compliance with industry requirements in areas of career interest.* ***9.2.12.CAP.8***: *Determine job entrance criteria (e.g., education credentials, math/writing/reading comprehension tests, drug tests) used by employers in various industry sectors.* ***9.2.12.CAP.9***: *Locate information on working papers, what is required to obtain them, and who must sign them.* ***9.2.12.CAP.10***: *Identify strategies for reducing overall costs of postsecondary education (e.g., tuition assistance, loans, grants, scholarships, and student loans).* ***9.2.12.CAP.11***: *Demonstrate an understanding of Free Application for Federal Student Aid (FAFSA) requirements to apply for postsecondary education.*
1,2,3,4,5,6,7	An individual's income and benefit needs and financial plan can change over time.	***9.2.12.CAP.12***: *Explain how compulsory government programs (e.g., Social Security, Medicare) provide insurance against some loss of income and benefits to eligible recipients.* ***9.2.12.CAP.13***: *Analyze how the economic, social, and political conditions of a time period can affect the labor market.*
1,2,3,4,5,6,7	Securing an income involves an understanding of the costs and time in preparing for a career field, interview and negotiation skills, job searches, resume development, prior experience, and vesting and retirement plans.	***9.2.12.CAP.14***: *Analyze and critique various sources of income and available resources (e.g., financial assets, property, and transfer payments) and how they may substitute for earned income.*

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	Understanding income involves an analysis of payroll taxes, deductions and earned benefits.	***9.2.12.CAP.15***: *Demonstrate how exemptions, deductions, and deferred income (e.g., retirement or medical) can reduce taxable income.* ***9.2.12.CAP.16***: *Explain why taxes are withheld from income and the relationship of federal, state, and local taxes (e.g., property, income, excise, and sales) and how the money collected is used by local, county, state, and federal governments.* ***9.2.12.CAP.17***: *Analyze the impact of the collective bargaining process on benefits, income, and fair labor practice.* ***9.2.12.CAP.18***: *Differentiate between taxable and nontaxable income from various forms of employment (e.g., cash business, tips, tax filing and withholding).* ***9.2.12.CAP.19***: *Explain the purpose of payroll deductions and why fees for various benefits (e.g., medical benefits) are taken out of pay, including the cost of employee benefits to employers and self-employment income.* ***9.2.12.CAP.20***: *Analyze a Federal and State Income Tax Return.*
	There are ways to assess a business's feasibility and risk and to align it with an individual's financial goals.	***9.2.12.CAP.21***: *Explain low-cost and low-risk ways to start a business.* ***9.2.12.CAP.22***: *Compare risk and reward potential and use the comparison to decide whether starting a business is feasible.* ***9.2.12.CAP.23***: *Identify different ways to obtain capital for starting a business*

Life Literacies and Key Skills (Standard 9.4)
List appropriate units below for which standards will be addressed

By Grade 12		
Unit Addressed	**Core Idea**	**Standard / Description**
1,2,3,4,5,6,7	**Creativity and Innovation**: With a growth mindset, failure is an important part of success.	***9.4.12.CI.1***: *Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).*

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1,2,3,4,5,6,7	**Creativity and Innovation**: Innovative ideas or innovation can lead to career opportunities.	***9.4.12.CI.2:*** *Identify career pathways that highlight personal talents, skills, and abilities (e.g., 1.4.12prof.CR2b, 2.2.12.LF.8).* ***9.4.12.CI.3:*** *Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).*
1,2,3,4,5,6,7	**Critical Thinking and Problem-solving:** Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.	***9.4.12.CT.1:*** *Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).* ***9.4.12.CT.2:*** *Explain the potential benefits of collaborating to enhance critical thinking and problem solving (e.g., 1.3E.12profCR3.a).* ***9.4.12.CT.3:*** *Enlist input from a variety of stakeholders (e.g., community members, experts in the field) to design a service learning activity that addresses a local or global issue (e.g., environmental justice).* ***9.4.12.CT.4:*** *Participate in online strategy and planning sessions for course-based, school-based, or other projects and determine the strategies that contribute to effective outcomes.*
3,4,5,6	**Digital Citizenship:** Laws govern the use of intellectual property and there are legal consequences to utilizing or sharing another's original works without permission or appropriate credit.	***9.4.12.DC.1****: Explain the beneficial and harmful effects that intellectual property laws can have on the creation and sharing of content (e.g., 6.1.12.CivicsPR.16.a).* ***9.4.12.DC.2****: Compare and contrast international differences in copyright laws and ethics*
3,4,5,6	**Digital Citizenship:** Laws govern many aspects of computing, such as privacy, data, property, information, and identity. These laws can have beneficial and harmful effects, such as expediting or delaying advancements in computing and protecting or infringing upon people's rights.	***9.4.12.DC.3****: Evaluate the social and economic implications of privacy in the context of safety, law, or ethics (e.g., 6.3.12.HistoryCA.1).* ***9.4.12.DC.4****: Explain the privacy concerns related to the collection of data (e.g., cookies) and generation of data through automated processes that may not be evident to users (e.g., 8.1.12.NI.3).* ***9.4.12.DC.5****: Debate laws and regulations that impact the development and use of software.*
3,4,5,6	**Digital Citizenship:** Cultivating online reputations for employers and academia requires separating private and professional digital identities.	***9.4.12.DC.6****: Select information to post online that positively impacts personal image and future college and career opportunities.*

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3,4,5,6	**Digital Citizenship:** Digital communities influence many aspects of society, especially the workforce. The increased connectivity between people in different cultures and different career fields have changed the nature, content, and responsibilities of many careers.	***9.4.12.DC.7****: Evaluate the influence of digital communities on the nature, content and responsibilities of careers, and other aspects of society (e.g., 6.1.12.CivicsPD.16.a).*
3,4,5,6	**Digital Citizenship:** Network connectivity and computing capability extended to objects, sensors and everyday items not normally considered computers allows these devices to generate, exchange, and consume data with minimal human intervention. Technologies such as Artificial Intelligence (AI) and blockchain can help minimize the effect of climate change.	***9.4.12.DC.8****: Explain how increased network connectivity and computing capabilities of everyday objects allow for innovative technological approaches to climate protection.*
3,4,5,6	**Global and Cultural Awareness:** Solutions to the problems faced by a global society require the contribution of individuals with different points of view and experiences.	***9.4.12.GCA.1:*** *Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).*
3,4,5,6	**Information and Media Literacy:** Advanced search techniques can be used with digital and media resources to locate information and to check the credibility and the expertise of sources to answer questions, solve problems, and inform the decision-making.	***9.4.12.IML.1:*** *Compare search browsers and recognize features that allow for filtering of information.* ***9.4.12.IML.2:*** *Evaluate digital sources for timeliness, accuracy, perspective, credibility of the source, and relevance of information, in media, data, or other resources (e.g., NJSLSA.W8, Social Studies Practice: Gathering and Evaluating Sources.*

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3,4,5,6	**Information and Media Literacy:** Digital tools such as artificial intelligence, image enhancement and analysis, and sophisticated computer modeling and simulation create new types of information that may have profound effects on society. These new types of information must be evaluated carefully	***9.4.12.IML.3***: *Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions (e.g., S-ID.B.6a., 8.1.12.DA.5, 7.1.IH.IPRET.8)* ***9.4.12.IML.4***: *Assess and critique the appropriateness and impact of existing data visualizations for an intended audience (e.g., S-ID.B.6b, HS-LS2-4).*
3,4,5,6	**Information and Media Literacy:** In order for members of our society to participate productively, information needs to be shared accurately and ethically.	***9.4.12.IML.5***: *Evaluate, synthesize, and apply information on climate change from various sources appropriately (e.g., 2.1.12.CHSS.6, S.IC.B.4, S.IC.B.6, 8.1.12.DA.1, 6.1.12.GeoHE.14.a, 7.1.AL.PRSNT.2).* ***9.4.12.IML.6***: *Use various types of media to produce and store information on climate change for different purposes and audiences with sensitivity to cultural, gender, and age diversity (e.g., NJSLSA.SL5).*
3,4,5,6	**Information and Media Literacy:** Accurate information may help in making valuable and ethical choices.	***9.4.12.IML.7***: *Develop an argument to support a claim regarding a current workplace or societal/ethical issue such as climate change (e.g., NJSLSA.W1, 7.1.AL.PRSNT.4).*
3,4,5,6	**Information and Media Literacy:** Media have embedded values and points of view.	***9.4.12.IML.8***: *Evaluate media sources for point of view, bias, and motivations (e.g., NJSLSA.R6, 7.1.AL.IPRET.6).* ***9.4.12.IML.9***: *Analyze the decisions creators make to reveal explicit and implicit messages within information and media (e.g., 1.5.12acc.C2a, 7.1.IL.IPRET.4).*
3,4,5,6	**Technology Literacy:** Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.	***9.4.12.TL.1***: *Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specific task (e.g., W.11-12.6.).* ***9.4.12.TL.2***: *Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data.*

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3,4,5,6	**Technology Literacy:** Collaborative digital tools can be used to access, record and share different viewpoints and to collect and tabulate the views of groups of people.	***9.4.12.TL.3****: Analyze the effectiveness of the process and quality of collaborative environments.* ***9.4.12.TL.4****: Collaborate in online learning communities or social networks or virtual worlds to analyze and propose a resolution to a real-world problem (e.g., 7.1.AL.IPERS.6).*

Interdisciplinary Connections (2020 NJSLS)
List any other content standards addressed as well as appropriate units. All arts integration connections may be listed within this chart.

Visual & Performing Arts Integration (Standard 1)
List appropriate units below for which standards (1.1 through 1.5) may be addressed

Unit Addressed	Artistic Process	Anchor Standard
1,2,3,4,5,6,7	**Creating**	*Anchor Standard 1: Generating and conceptualizing ideas.* *Anchor Standard 2: Organizing and developing ideas.* *Anchor Standard 3: Refining and completing products.*
1,2,3,4,5,6	**Connecting**	*Anchor Standard 10: Synthesizing and relating knowledge and personal experiences to create products.* *Anchor Standard 11: Relating artistic ideas and works within societal, cultural, and historical contexts to deepen understanding.*
1,2,3,4,5	**Performing/ Presenting/ Producing**	*Anchor Standard 4: Selecting, analyzing, and interpreting work.* *Anchor Standard 5: Developing and refining techniques and models or steps needed to create products.* *Anchor Standard 6: Conveying meaning through art.*
1,2,3,4,5,6,7	**Responding**	*Anchor Standard 7: Perceiving and analyzing products.* *Anchor Standard 8: Applying criteria to evaluate products.* *Anchor Standard 9: Interpreting intent and meaning.*

Other Interdisciplinary Content Standards
List appropriate units below for any other content/standards that may be addressed

Unit Addressed	Content / Standard #	Standard Description

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1,2,3,4,5,6,7	*Math / MP.2*	*Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7)*
1,2,3,4,5,6,7	*Math / MP.4*	*Model with mathematics. (HS-PS1-4),(HS-PS1-8)*
1,2,3,4,5,6,7	*Math / HSN-Q.A.1*	*Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)*
1,2,3,4,5,6,7	*Math / HSN-Q.A.2*	*Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7),(HS-PS1-8)*
1,2,3,4,5,6,7	*Math / HSN-Q.A.3*	*Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)*
1,2,3,4,5,6,7	*Math / HSA-SSE.A.1*	*Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)*
1,2,3,4,5,6,7	*Math / HSA-SSE.B.3*	*Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1),(HS-PS2- 4)*
1,2,3,4,5,6,7	*Math / HSA-CED.A.1*	*Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)*
1,2,3,4,5,6,7	*Math / HSA-CED.A.2*	*Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2- 1),(HS-PS2-2)*
1,2,3,4,5,6,7	*Math / HSA-CED.A.4*	*Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1),(HS-PS2-2)*
2,3,4,5,7	*Math / HSF-IF.C.7*	*Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. (HS-PS2-1)*
1,2,3,4,5,6,7	*Math / HSS-ID.A.1*	*Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)*

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Pacing Guide (All Dates are approximate based on the school calendar)

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<tr><th>Unit/ Topic</th><th>Month
(w/Approx number of Teaching Days)</th></tr>
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(~19 days)</td></tr>
<tr><td rowspan="2">Unit 2. Thermodynamics: Kinetic Theory, Ideal Gases, First Law of Thermo, Thermodynamic Processes and PV Diagrams, Heat Engines, Carnot Cycle, Efficiency, Second Law of Thermo</td><td>October
(~19 days)</td></tr>
<tr><td rowspan="2">November
(~16 days)</td></tr>
<tr><td>Unit 3. Electrostatics: Electric Force, Electric Field, Electric Potential</td></tr>
<tr><td>Unit 4. Electric Circuits: Electric Resistance, Ohm's Law, DC Circuits, Kirchhoff's Laws, Series and Parallel Circuits, Capacitance, DC Circuits with Resistors and Capacitors</td><td>December
(~15 days)</td></tr>
<tr><td rowspan="2">Unit 5. Magnetism and Electromagnetic Induction: Magnetic Field, Magnetic Force on a Charged Particle, Magnetic Force on a Current Carrying Wire, Magnetic Flux, Faraday's Law, Lenz's Law, Motional EMF</td><td>January
(~18 days)</td></tr>
<tr><td rowspan="2">February
(~18 days)</td></tr>
<tr><td>Unit 6. Quantum Physics, Atomic and Nuclear Physics: Atoms, Atomic Mass, Mass Number, Energy Levels, Absorption and Emission Spectra, Wave vs. Particle, Photoelectric Effect, De Broglie Wavelength, Mass-Energy Equivalence, Radioactive Decay (Alpha, Beta, Gamma), Half-Life, Conservation of Nucleon Number (Fission and Fusion)</td></tr>
<tr><td rowspan="2">Unit 7. Geometric and Physical Optics: Reflection, Images Formed by Flat and Curved Mirrors, Refraction and Snell's Law, Images Formed by Thin Lenses, Interference and Diffraction, Double Slit, Single Slit, Diffraction Gratings, Thin Film Interference</td><td>March
(~15-20 days)</td></tr>
<tr><td rowspan="2">April
(~15-20 days)</td></tr>
<tr><td rowspan="2">Review for AP Exam, Projects and Labs</td></tr>
<tr><td>May
(~18 days)</td></tr>
<tr><td>Projects, Labs and Final Exam Project</td><td>June
(~15 days)</td></tr>
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[Units Scope and Sequence](#)

Unit 1: Fluids
Learning Goals: What do I want my students to learn?
Standards
NJSLS - *HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.*   *HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.* *NJSLS - Career Awareness, Exploration, Preparation, and Training* *NJSLS - Life Literacies and Key Skills* *NJSLS - Interdisciplinary Standards*
Fundamental Concepts / Big Ideas
● Objects and systems have properties such as mass and charge. Systems may have internal structure. ● The interactions of an object with other objects can be described by forces. ● Changes that occur as a result of interactions are constrained by conservation laws. ● Pressure is determined by the depth within fluids and the velocity of the fluids.
Learning Objectives
Students will be able to… ● Predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction. ● Select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. ● Make claims about various contact forces between objects based on the microscopic cause of those forces. ● Explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. ● Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. ● Create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. ● Re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. ● Predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. ● Make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation). ● Use Bernoulli's equation and the continuity equation to make calculations related to a moving fluid.

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Unit 2: Thermodynamics

Learning Goals: What do I want my students to learn?

Standards

NJSLS -
HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
NJSLS - Career Awareness, Exploration, Preparation, and Training
NJSLS - Life Literacies and Key Skills
NJSLS - Interdisciplinary Standards

Fundamental Concepts / Big Ideas

- Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.
- The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems.
- Heat is the flow of thermal energy.
- The internal energy of an isolated Ideal Gas system may change due to Heat and Work.

Learning Objectives

Students will be able to…
- Design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables.
- Analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law PV = nRT.

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- Treating a gas molecule as an object, analyze qualitatively the collisions with a container wall and determine the cause of pressure, and at thermal equilibrium, quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables.
- Extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero.
- Make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system.
- Describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation.
- Construct an explanation, based on atomic-scale interactions and probability, of how a system approaches thermal equilibrium when energy is transferred to it or from it in a thermal process.
- Design an experiment and analyze data from it to examine thermal conductivity.
- Qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system.
- Connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and relate this to thermodynamic processes.
- Describe and make predictions about the internal energy of systems.
- Predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles.
- Make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system.
- Predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.
- Design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system.
- Create a plot of pressure versus volume for a thermodynamic process from given data.
- Use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the first law of thermodynamics).
- Connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how it (entropy) behaves in reversible and irreversible processes.

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Unit 3: Electrostatics

Learning Goals: What do I want my students to learn?

Standards

NJSLS -
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects

*HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.**

HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
NJSLS - Career Awareness, Exploration, Preparation, and Training
NJSLS - Life Literacies and Key Skills
NJSLS - Interdisciplinary Standards

Fundamental Concepts / Big Ideas

- Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Fields existing in space can be used to explain interactions.
- The interactions of an object with other objects can be described by forces.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.

Learning Objectives

Students will be able to…
- Predict electric charges on objects within a system by application of the principle of charge conservation within a system.
- Make predictions about the redistribution of charge during charging by friction, conduction, and induction.
- Make claims about natural phenomena based on conservation of electric charge.
- Construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices.
- Design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data.
- Make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes.
- Challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object.
- Construct a representation of the distribution of fixed and mobile charge in insulators and conductors that predicts charge distribution in processes involving induction or conduction.

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- Make predictions about the redistribution of charge caused by the electric field due to other systems, resulting in charged or polarized objects.
- Plan and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure.
- Qualitatively and semi-quantitatively apply the vector relationship between the electric field and the net electric charge creating that field.
- Explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object.
- Predict the direction and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: $F=qE$ a vector relation.
- Challenge a claim that an object can exert a force on itself.
- Describe a force as an interaction between two objects and identify both objects for any force.
- Calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities.
- Make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge.
- Use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges.
- Use mathematics to describe the electric force that results from the interaction of several separated point charges.
- Justify the selection of data relevant to an investigation of the electrical charging of objects and electric charge induction on neutral objects.
- Apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points.
- Determine the structure of isolines of electric potential by constructing them in a given electric field.
- Predict the structure of isolines of electric potential by constructing them in a given electric field and make connections between these isolines and those found in a gravitational field.
- Qualitatively use the concept of isolines to construct isolines of electric potential in an electric field and determine the effect of that field on electrically charged objects.
- Apply the concept of the isoline representation of electric potential for a given electric charge distribution to predict the average value of the electric field in the region.
- Apply mathematical routines to calculate the average value of the magnitude of the electric field in a region from a description of the electric potential in that region using the displacement along the line on which the difference in potential is evaluated.
- Create representations of the magnitude and direction of the electric field at various distances (small compared to plate size) from two electrically charged plates of equal magnitude and opposite signs, and recognize that the assumption of uniform field is not appropriate near edges of plates.
- Calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation.
- Represent the motion of an electrically charged particle in the uniform field between two oppositely charged plates and express the connection of this motion to projectile motion of an object with mass in the Earth's gravitational field.
- Construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential.
- Connect the strength of electromagnetic forces with the spatial scale of the situation, the magnitude of the electric charges, and the motion of the electrically charged objects involved.

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- Calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.
- Connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.
- Connect the strength of the gravitational force between two objects to the spatial scale of the situation and the masses of the objects involved and compare that strength to other types of forces.

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Unit 4: Electric Circuits

Learning Goals: What do I want my students to learn?

Standards

NJSLS -
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).

HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
NJSLS - Career Awareness, Exploration, Preparation, and Training
NJSLS - Life Literacies and Key Skills
NJSLS - Interdisciplinary Standards

Fundamental Concepts / Big Ideas

- Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.
- There exists a relationship between Curren, Resistance and Voltage. This relationship extends to Power as well.
- The behavior of both resistors and capacitors in steady-state direct current circuits.

Learning Objectives

Students will be able to…
- Choose and justify the selection of data needed to determine resistivity for a given material.
- Design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.
- Make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.
- Analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.
- Make predictions about the properties of resistors and/or capacitors when placed in a simple circuit, based on the geometry of the circuit element and supported by scientific theories and mathematical relationships.
- Translate between graphical and symbolic representations of experimental data describing relationships among power, current, and potential difference across a resistor.
- Predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff's junction rule and relate the rule to the law of charge conservation.

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- Determine missing values and direction of electric current in branches of a circuit with resistors and NO capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule.
- Determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other branches of the circuit.
- Analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff's loop rule $\sum \Delta V = 0$
- Use conservation of energy principles (Kirchhoff's loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors.
- Refine and analyze a scientific question for an experiment using Kirchhoff's loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor.
- Mathematically express the changes in electric potential energy of a loop in a multi loop electrical circuit and justify this expression using the principle of the conservation of energy.
- Make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.
- Plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors.

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Unit 5: Magnetism and Electromagnetic Induction

Learning Goals: What do I want my students to learn?

Standards

NJSLS -
HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
NJSLS - Career Awareness, Exploration, Preparation, and Training
NJSLS - Life Literacies and Key Skills
NJSLS - Interdisciplinary Standards

Fundamental Concepts / Big Ideas

- Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Fields existing in space can be used to explain interactions.
- The interactions of an object with other objects can be described by forces.
- Interactions between systems can result in changes in those systems.
- A magnetic force is exerted on moving charges within a magnetic field.
- A magnetic flux may induce a voltage. Within a closed-loop system this may induce a current.

Learning Objectives

Students will be able to…
- Describe the orientation of a magnetic dipole placed in a magnetic field in general and the particular cases of a compass in the magnetic field of the Earth and iron filings surrounding a bar magnet.
- Distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field) and make claims about the spatial behavior of the fields using qualitative or semi-quantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field.
- Create a verbal or visual representation of a magnetic field around a long straight wire or a pair of parallel wires.
- Apply mathematical routines to express the force exerted on a moving charged object by a magnetic field.

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- Use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor.
- Plan a data collection strategy appropriate to an investigation of the direction of the force on a moving electrically charged object caused by a current in a wire in the context of a specific set of equipment and instruments and analyze the resulting data to arrive at a conclusion.
- Reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.
- Predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations.
- Construct an explanation of the function of a simple electromagnetic device in which an induced emf is produced by a changing magnetic flux through an area defined by a current loop (i.e., a simple microphone or generator) or of the effect on behavior of a device in which an induced emf is produced by a constant magnetic field through a changing area.
- Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces.
- Use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.
- Analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces.
- Use the representation of magnetic domains to qualitatively analyze the magnetic behavior of a bar magnet composed of ferromagnetic material.
- Use representations and models to qualitatively describe the magnetic properties of some materials that can be affected by magnetic properties of other objects in the system.

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Unit 6: Quantum Physics, Atomic and Nuclear Physics

Learning Goals: What do I want my students to learn?

Standards

NJSLS -
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).

HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

HS-PS4-2. Evaluate questions about the advantages of using a digital transmission and storage of information.

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

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HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.
NJSLS - Career Awareness, Exploration, Preparation, and Training
NJSLS - Life Literacies and Key Skills
NJSLS - Interdisciplinary Standards

Fundamental Concepts / Big Ideas

- Objects and systems have properties such as mass and charge. Systems may have internal structure.
- The interactions of an object with other objects can be described by forces.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.
- Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.
- The mathematics of probability can be used to describe the behavior of complex systems and to interpret the behavior of quantum mechanical systems.

Learning Objectives

Students will be able to…

- Construct representations of the differences between a fundamental particle and a system composed of fundamental particles and relate this to the properties and scales of the systems being investigated.
- Challenge the claim that an electric charge smaller than the elementary charge has been isolated.
- Use a graphical wave function representation of a particle to predict qualitatively the probability of finding a particle in a specific spatial region.
- Use a standing wave model in which an electron orbit circumference is an integer multiple of the de Broglie wavelength to give a qualitative explanation that accounts for the existence of specific allowed energy states of an electron in an atom.
- Construct representations of the energy-level structure of an electron in an atom and relate this to the properties and scales of the systems being investigated.
- Describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including characterization of the frequency of radiation emitted or absorbed.
- Construct or interpret representations of transitions between atomic energy states involving the emission and absorption of photons.
- Support the photon model of radiant energy with evidence provided by the photoelectric effect.
- Explain why classical mechanics cannot describe all properties of objects by articulating the reasons that classical mechanics must be refined and an alternative explanation developed when classical particles display wave properties.
- Articulate the evidence supporting the claim that a wave model of matter is appropriate to explain the diffraction of matter interacting with a crystal, given conditions where a particle of matter has momentum corresponding to a de Broglie wavelength smaller than the separation between adjacent atoms in the crystal.
- Predict the dependence of major features of a diffraction pattern (e.g., spacing between interference maxima), based upon the particle speed and de Broglie wavelength of electrons in an electron beam interacting with a crystal.
- Make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate.

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- Articulate the reasons that classical mechanics must be replaced by special relativity to describe the experimental results and theoretical predictions that show that the properties of space and time are not absolute.
- Apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale.
- Apply conservation of nucleon number and conservation of electric charge to make predictions about nuclear reactions and decays such as fission, fusion, alpha decay, beta decay, or gamma decay.
- Predict the number of radioactive nuclei remaining in a sample after a certain period of time, and also predict the missing species (alpha, beta, gamma) in a radioactive decay.
- Apply conservation of mass and conservation of energy concepts to a natural phenomenon and use the equation E = mc^2 to make a related calculation.
- Apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.
- Analyze electric charge conservation for nuclear and elementary particle reactions and make predictions related to such reactions based upon conservation of charge.
- Identify the strong force as the force that is responsible for holding the nucleus together.
- Articulate the reasons that the theory of conservation of mass was replaced by the theory of conservation of mass-energy.

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Unit 7: Geometric and Physical Optics

Learning Goals: What do I want my students to learn?

Standards

NJSLS -
HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.
NJSLS - Career Awareness, Exploration, Preparation, and Training
NJSLS - Life Literacies and Key Skills
NJSLS - Interdisciplinary Standards

Fundamental Concepts / Big Ideas

- Photons and particles such as an electron exhibit particle-wave duality characteristics.
- Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

Learning Objectives

Sudents will be able to…
- Describe representations of transverse and longitudinal waves.
- Use a visual representation of a periodic mechanical wave to determine wavelength of the wave.
- Contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation.
- Describe representations and models of electromagnetic waves that explain the transmission of energy when no medium is present.
- Make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves.
- Construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition.
- Make claims about the diffraction pattern produced when a wave passes through a small opening, and qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave.
- Qualitatively apply the wave model to quantities that describe the generation of interference patterns to make predictions about interference patterns that form when waves pass through a set of openings whose spacing and widths are small, but larger than the wavelength.
- Predict and explain, using representations and models, the ability or inability of waves to transfer energy around corners and behind obstacles in terms of the diffraction property of waves in situations involving various kinds of wave phenomena, including sound and light.
- Make qualitative comparisons of the wavelengths of types of electromagnetic radiation.

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- Analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation.
- Construct an equation relating the wavelength and amplitude of a wave from a graphical representation of the electric or magnetic field value as a function of position at a given time instant and vice versa, or construct an equation relating the frequency or period and amplitude of a wave from a graphical representation of the electric or magnetic field value at a given position as a function of time and vice versa.
- Make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed.
- Describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media.
- Plan data collection strategies as well as perform data analysis and evaluation of the evidence for finding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell's law).
- Make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation.
- Make predictions about the locations of object and image relative to the location of a reflecting surface. The prediction should be based on the model of specular reflection with all angles measured relative to the normal to the surface.
- Plan data collection strategies, and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from curved spherical mirrors.
- Use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the reflection of light from surfaces.
- Use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the refraction of light through thin lenses.
- Plan data collection strategies, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses.

Please contact the Content Supervisor for any questions.

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