Passaic County Technical Institute

Wayne, NJ

AP Physics C: Mechanics Curriculum

Course # 0172

5 Credits

August 2018

AP Physics C: Mechanics Curriculum

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AP Physics C: Mechanics

AP® Physics C is a national calculus-based course in physics. It is examined in two separate exams. The two exams correspond to the physics C course sequence. One exam covers mechanics and the other covers electricity and magnetism. This course will cover the mechanics portion of AP Physics C. The syllabus for this course is designed by the College Board. The mechanics course is equivalent to the pre- engineering introductory physics course for university students. The emphasis is on understanding the concepts and skills and using the concepts and formulae to solve problems. Laboratory work is an integral part of this course. It is especially appropriate for students planning to specialize or major in physical science or engineering. The course explores topics such as kinematics; Newton's laws of motion; work, energy and power; systems of particles and linear momentum; circular motion and rotation; and oscillations and gravitation. Introductory differential and integral calculus is used throughout the course. It will be run as a year-long course and includes an introductory/review section on differential and integral calculus, and vector algebra at the start of the course. At the end of the course, students are expected to take the College Board's exam in May of school year.

Course Objectives/Outline

Content Area:	**AP Physics C: Mechanics**	**Grade(s)**	**11,12**
Unit Plan Title:	**Forces and Motion**		
NJSLS			

HS-PS2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

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. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

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. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]

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.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

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. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two 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. [Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models. 1. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5) **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. 2. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1) **Using Mathematics and Computational**	**PS1.A: Structure and Properties of Matter** • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary to HS-PS2-6) **PS2.A: Forces and Motion** • Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3) **PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) • Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause	**Patterns** ▪ Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) **Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5) ▪ Systems can be designed to cause a desired effect. (HS-PS2-3) **Systems and System Models** ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2) **Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)

Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. 3. Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student- generated sources of evidence consistent with scientific ideas, principles, and theories. 4. Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.	magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5) • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6),*(secondary to HS-PS1-1)*,*(secondary to HS-PS1-3)* **PS3.A: Definitions of Energy** • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. *(secondary to HS-PS2-5)* **ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS2-3)* **ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary to HS-PS2-3)*	

5. Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6) --- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Theories and laws provide explanations in science. (HS-PS2-1),(HS-PS2-4) Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1),(HS-PS2-4)		

Connections to other DCIs in this grade-band: **HS.PS3.A** (HS-PS2-4),(HS-PS2-5); **HS.PS3.C** (HS-PS2-1); **HS.PS4.B** (HS-PS2-5); **HS.ESS1.A** (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); **HS.ESS1.B** (HS-PS2-4); **HS.ESS1.C** (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); **HS.ESS2.A** (HS-PS2-5); **HS.ESS2.C** (HS-PS2-1),(HS-PS2-4); **HS.ESS3.A** (HS-PS2-4),(HS-PS2-5)
Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS2-6); **MS.PS2.A** (HS-PS2-1),(HS-PS2-2),(HS-PS2-3); **MS.PS2.B** (HS-PS2-4),(HS-PS2-5),(HS-PS2-6); **MS.PS3.C** (HS-PS2- 1),(HS-PS2-2),(HS-PS2-3); **MS.ESS1.B** (HS-PS2-4),(HS-PS2-5)
ELA/Literacy amd Mathematics – See Appendix 2

Anchor Text
Title: <u>Fundamentals of Physics</u> **Publisher:** Wiley; 9th Edition, Binder Ready Version edition (March 2010) by **David Halliday**, **Robert Resnick** and **Jearl Walker**: **Language:** English **ISBN-10:** 0470556536 **ISBN-13:** 978-0470556535

Loose Leaf: 1136 pages	
Informational Texts (3-5)	
1. Test Preparation Book: Cracking the AP Physics C Exam, 2018 Edition: Proven Techniques to Help You Score a 5 (College Test Preparation**) csm Edition, Kindle Edition. ISBN-13: 978-1524710132, ISBN-10: 152471013X,** 2. **Physics for Scientists & Engineers with Modern Physics** (4th Edition) by Douglas C. Giancoli (Author); Publication Date: September 4, 2008 **| ISBN-10:** 0131495089 **| ISBN-13:**978-0131495081 **| Edition:** 4 **(Publisher,** Pearson)	
Short Texts (1-3)	
Suggested Formative & Summative Assessments	
AP Physics C: Mechanics exams on paper, Instructor guided laboratory assignments and formal reports, Homework, Student guided laboratory assignments and formal reports, Unit tests, Quizzes and tests on canvas, Laboratory based past exam questions, Projects, General AP Physics C: Mechanics free response questions assignments	
Resources (websites, Blackboard, documents, etc.)	
Canvas Instructure Learning Management System, The College Board Website, pHET Simulations Website, Khan's Academy	
Labs	
Areas, volumes, and densities of given solids and liquids Prediction and reproduction of kinematics graphs with motion detector Determination of acceleration due to gravity Projectile motion — relationship between Θ and range	
Suggested Time Frame:	10 Weeks

Content Area:	**AP Physics C: Mechanics**	**Grade(s)**	**11,12**
Unit Plan Title:	**Forces and Interactions**		
NJSLS			
HS-PS2 Motion and Stability: Forces and Interactions			
Students who demonstrate understanding can:			

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Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.

6. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

7. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)

Using Mathematics and Computational

PS1.A: Structure and Properties of Matter
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary to HS-PS2-6)

PS2.A: Forces and Motion
- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)
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Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5)
- Systems can be designed to cause a desired effect. (HS-PS2-3)

Systems and System Models
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Structure and Function
Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)

Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. 8. Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student- generated sources of evidence consistent with scientific ideas, principles, and theories. 9. Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.	magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5) • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6),*(secondary to HS-PS1-1)*,*(secondary to HS-PS1-3)* **PS3.A: Definitions of Energy** • "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. *(secondary to HS-PS2-5)* **ETS1.A: Defining and Delimiting Engineering Problems** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS2-3)* **ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary to HS-PS2-3)*	

10. Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6) --- *Connections to Nature of Science* **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** - Theories and laws provide explanations in science. (HS-PS2-1),(HS-PS2-4) Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1),(HS-PS2-4)		

Connections to other DCIs in this grade-band: **HS.PS3.A** (HS-PS2-4),(HS-PS2-5); **HS.PS3.C** (HS-PS2-1); **HS.PS4.B** (HS-PS2-5); **HS.ESS1.A** (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); **HS.ESS1.B** (HS-PS2-4); **HS.ESS1.C** (HS-PS2-1),(HS-PS2-2),(HS-PS2-4); **HS.ESS2.A** (HS-PS2-5); **HS.ESS2.C** (HS-PS2-1),(HS-PS2-4); **HS.ESS3.A** (HS-PS2-4),(HS-PS2-5)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS2-6); **MS.PS2.A** (HS-PS2-1),(HS-PS2-2),(HS-PS2-3); **MS.PS2.B** (HS-PS2-4),(HS-PS2-5),(HS-PS2-6); **MS.PS3.C** (HS-PS2- 1),(HS-PS2-2),(HS-PS2-3); **MS.ESS1.B** (HS-PS2-4),(HS-PS2-5)

ELA/Literacy amd Mathematics – See Appendix 2

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Short Texts (1-3)
Suggested Formative & Summative Assessments
AP Physics C: Mechanics exams on paper, Instructor guided laboratory assignments and formal reports, Homework, Student guided laboratory assignments and formal reports, Unit tests, Quizzes and tests on canvas, Laboratory based past exam questions, Projects, General AP Physics C: Mechanics free response questions assignments
Resources (websites, Blackboard, documents, etc.)
Canvas Instructure Learning Management System, The College Board Website, pHET Simulations Website, Khan's Academy, YouTube, CK12 website for
Labs
Areas, volumes, and densities of given solids and liquids Prediction and reproduction of kinematics graphs with motion detector Determination of acceleration due to gravity Projectile motion — relationship between Θ and range

Suggested Time Frame:	10 Weeks

Content Area:	AP Physics C: Mechanics	Grade(s)	11,12
Unit Plan Title:	Energy		

NJSLS

HS-PS3 Energy

Students who demonstrate understanding can:

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. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]

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). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

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.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.]

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). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

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. [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. 1. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS- PS3-5) **Planning and Carrying Out Investigations** Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. 2. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS3-4) **Using Mathematics and Computational**	**PS3.A: Definitions of Energy** • Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS- PS3-1),(HS-PS3-2) • At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS- PS3-2) (HS-PS3-3) • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2) **PS3.B: Conservation of Energy and**	**Cause and Effect** ▪ Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS3-5) **Systems and System Models** ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4) ▪ Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS- PS3-1) **Energy and Matter** ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS- PS3-3) ▪ Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2) --- ***Connections to Engineering, Technology, and***

Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. 3. Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9– 12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS- PS3-3)	**Energy Transfer** • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4) • Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1) • The availability of energy limits what can occur in any system. (HS-PS3-1) • Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4) **PS3.C: Relationship Between Energy and Forces** • When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5) **PS3.D: Energy in Chemical Processes** Although energy cannot be destroyed, it can	*Applications of Science* **Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3) --- *Connections to Nature of Science* **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Science assumes the universe is a vast single system in which basic laws are consistent. (HS- PS3-1)

	be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3),(HS-PS3-4) **ETS1.A: Defining and Delimiting Engineering Problems** - Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS3-3)*	

Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-PS3-2); **HS.PS1.B** (HS-PS3-1),(HS-PS3-2); **HS.PS2.B** (HS-PS3-2),(HS-PS3-5); **HS.LS2.B** (HS-PS3-1); **HS.ESS1.A** (HS- PS3-1),(HS-PS3-4); **HS.ESS2.A** (HS-PS3-1),(HS-PS3-2),(HS-PS3-4); **HS.ESS2.D** (HS-PS3-4); **HS.ESS3.A** (HS-PS3-3)

Articulation to DCIs across grade-bands: **MS.PS1.A** (HS-PS3-2); **MS.PS2.B** (HS-PS3-2),(HS-PS3-5); **MS.PS3.A** (HS-PS3-1),(HS-PS3-2),(HS-PS3-3); **MS.PS3.B** (HS-PS3-1),(HS-PS3- 3),(HS-PS3-4); **MS.PS3.C** (HS-PS3-2),(HS-PS3-5); **MS.ESS2.A** (HS-PS3-1),(HS-PS3-3)

ELA/Literacy amd Mathematics – See Appendix 2

Anchor Text

Title: Fundamentals of Physics
Publisher: Wiley; 10th Edition, Electronic Book, (January 2015) by **David Halliday**, **Robert Resnick** and **Jearl Walker**:
Language: English
ISBN: 978-1-119-04023-1

Informational Texts (3-5)

1. Test Preparation Book: Cracking the AP Physics C Exam, 2018 Edition: Proven Techniques to Help You Score a 5 (College Test Preparation**).** Publisher: Random House Children Books.**ISBN-13: 978-1524710132**
2. Physics for Scientists & Engineers with Modern Physics (4th Edition) **by Douglas C. Giancoli (Author); Publication Date: September 4, 2008** | ISBN-10: **0131495089** | Edition: **4** (Publisher, **Pearson)**

Short Texts (1-3)

Suggested Formative & Summative Assessments

AP Physics C: Mechanics exams on paper, Instructor guided laboratory assignments and formal reports, Homework, Student guided laboratory assignments and formal reports, Unit tests, Quizzes and tests on canvas, Laboratory based past exam questions, Projects, General AP Physics C: Mechanics free response questions assignments

Resources (websites, Blackboard, documents, etc.)
Canvas Instructure Learning Management System, The College Board Website, pHET Simulations Website, Khan's Academy, YouTube, CK12 website for
Labs
Conservation of mechanical energy spring-mass system — air track Conservation of linear momentum — the three kinds of collisions — air track

Suggested Time Frame:	5 Weeks

Content Area:	**AP Physics C: Mechanics**	**Grade(s)**	**11, 12**
Unit Plan Title:	**Oscillations**		
NJSLS			

HS-PS4 Waves and Their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

HS-PS4-2. Evaluate questions about the advantages of using a digital transmission and storage of information. [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]

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. [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.]

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. [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]

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.* [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. 1. Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational	**PS3.D: Energy in Chemical Processes** • Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. *(secondary to HS-PS4-5)* **PS4.A: Wave Properties** • The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1) • Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2),(HS-PS4-5) • [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1) ▪ Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4) ▪ Systems can be designed to cause a desired effect. (HS-PS4-5) **Systems and System Models** ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-PS4-3) **Stability and Change** ▪ Systems can be designed for greater or lesser stability. (HS-PS4-2)

simulations are created and used based on mathematical models of basic assumptions.

2. Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science.

3. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3)

Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

4. Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4)
5. Communicate technical information or

(Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3)

PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

PS4.C: Information Technologies and Instrumentation

Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, and scanners) and in scientific research. They

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Connections to Engineering, Technology and Applications of Science

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). (HS- PS4-5)

Influence of Engineering, Technology, and Science on Society and the Natural World

- Modern civilization depends on major technological systems. (HS-PS4-2),(HS- PS4-5)

Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS- PS4-2)

ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS4-5) -- *Connections to Nature of Science* **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** 6. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)	are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)	

Connections to other DCIs in this grade-band: **HS.PS1.C** (HS-PS4-4); **HS.LS1.C** (HS-PS4-4); **HS.PS3.A** (HS-PS4-4),(HS-PS4-5); **HS.PS3.D** (HS-PS4-3),(HS-PS4-4); **HS.ESS1.A** (HS- PS4-3); **HS.ESS2.A** (HS-PS4-1); **HS.ESS2.D** (HS-PS4-3)

Articulation to DCIs across grade-bands: **MS.PS3.D** (HS-PS4-4); **MS.PS4.A** (HS-PS4-1),(HS-PS4-2),(HS-PS4-5); **MS.PS4.B** (HS-PS4-1),(HS-PS4-2),(HS-PS4-3),(HS-PS4-4),(HS-PS4-5); **MS.PS4.C** (HS-PS4-2),(HS-PS4-5); **MS.LS1.C** (HS-PS4-4); **MS.ESS2.D** (HS-PS4-4)

ELA/Literacy amd Mathematics – See Appendix 2

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Resources (websites, Blackboard, documents, etc.)
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Labs
Simple pendulum — photogate and spring-mass system — force sensor Physical pendulum — relationship between *T* and *d*

Suggested Time Frame:	3 Weeks

III. Methods of Student Evaluation:

Assessment can be divided into two general categories: formal (graded) and informal/classroom-based (both graded and ungraded). The key to effectively assessing a student's mastery of skills is to match the assessment method to the learning objective.

Formal Assessments

- Past AP Physics C: Mechanics exams on paper
- Instructor guided laboratory assignments and formal reports
- Homework
- Student guided laboratory assignments and formal reports
- Unit tests
- Quizzes and tests on canvas
- Laboratory based past exam questions
- Projects
- General AP Physics C: Mechanics free response questions assignments

Informal Assessments

- Instructor's observations of note-taking, and organization of notebooks and assignments
- Cooperative learning activities, including labs
- Creative project assignments
- Laboratory behavior
- Observing citizenship and appropriate social responses
- Instructor's observations of time management skills
- Practice AP Physics C Exams
- Diagnostic AP Physics C Exam
- Benchmark unit diagnostic test

Mechanics Labs

There are to be a double period labs during the course. **[SC15]** The lab report will be graded on the student's participation in the actual experiment and the written report.

Students must save all the graded lab reports. They will be required to present the lab reports as proof of having done these labs when they seek credit for this course in college. [SC16]

At least 10 of the following lab experiments will be performed.

1. Indirect measurement of inaccessible heights and distances
2. Areas, volumes, and densities of given solids and liquids
3. Prediction and reproduction of kinematics graphs with motion detector
4. Determination of acceleration due to gravity
5. Projectile motion — relationship between Θ and range
6. Projectile challenge — shoot the given target suspended from ceiling
7. Hooke's law: springs in series and parallel
8. Elastic force in rubber bands — nonlinear spring
9. Atwood's machine — verification of Newton's first law
10. Relationships between F_c and r for uniform circular motion
11. Rotational dynamics — relationships among rotational variables
12. Conservation of mechanical energy spring-mass system — air track
13. Conservation of linear momentum — the three kinds of collisions — air track
14. Simple pendulum — photogate and spring-mass system — force sensor
15. Physical pendulum — relationship between T and d
16. Center of mass of flat discs of various shapes

Each lab will require:

- The formation of a hypothesis or hypotheses based on in-class discussion of the presented problem or focus of each experiment;
- Design of an experiment or multiple experiments, also based on in-class discussion, to test the hypothesis or hypotheses;
- Collection of data and observations;

- Calculations using the collected data;
- Conclusions about how well the hypothesis or hypotheses held up based on the experiment;
- Class discussion of variance and error analysis; and
- A written report.

IV. Instructional Strategies Based on Instructional Goals:

- Graphs and other visuals
- Engaging in discussions
- Reading silently and aloud
- Listening and speaking activities
- Watching and responding to media
- Brainstorming
- Listening
- Mapping
- Revising and editing
- Participating in small and large groups
- Researching to make connections to texts and classroom discussions
- Collaborative projects
- Answering questions (oral and written)
- Summarizing
- Practicing past AP Physics C questions
- Analyzing texts, discussions, etc.
- Peer teaching
- Note taking and note making
- Writing

V. Text:

<u>Fundamentals of Physics</u> / Jearl Walker, David Halliday, Robert Resnick—10th edition. Publisher, Wiley

ISBN: 978-1-119-04023-1; January 2015; 1232 pages; Printed in the United States of America.

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VI. Scope and Sequence

Key: I – Introduced, D-developed in Depth, R-Reinforced

Skill to be learned

Find the first and second derivatives of simple polynomials, *ln*(x), e^x and trigonometric functions and apply them to extrema and rates of change.	I,D,R	I,D,R
Find the definite integral of simple polynomials, *ln*(x), e^x and trigonometric functions and apply them to areas under a curve.	I,D,R	I,D,R
Generate and solve simple differential equations related to concepts in mechanics.	I,D,R	I,D,R
Understand the unit vector representation of vector quantities and calculate the sum and products of vectors.	I,D,R	I,D,R
Understand the concept of kinematics and solve problems involving motion in one and two dimensions, particularly in projectile motion and relative velocity.	I,D,R	I,D,R
Explain Newton's laws of motion. Solve dynamics problems involving tension, normal force and weight.	I,D,R	I,D,R
Use Newton's Laws to analyze forces and motion involving friction, circular motion and drag forces. Solve problems using free body diagrams that are concerned with friction, inclines, drag and other forces.	I,D,R	I,D,R
Explain the concept of a centripetal force in describing circular motion. Analyze and solve problems involving Newtons laws and circular motion.	I,D,R	I,D,R

Define impulse and linear momentum and relate momentum to force. Describe the conservation of linear momentum and solve problems involving two body collisions 1-D and 2-D.	I,D,R	I,D,R
Analyze the momentum of system of particles. Find or calculate the center of mass of system of particles and/or objects of various shapes.	I,D,R	I,D,R
Describe rotational kinematics and define the angular speed and acceleration. Understand the relationships between linear and angular variables.	I,D,R	I,D,R
Analyze the rotation of rigid bodies about differing rotational axes and define torque and moment of inertia.	I,D,R	I,D,R
Calculate the momentum inertia of certain symmetrical objects about defined rotational axes or points and solve problems in rotational dynamics.	I,D,R	I,D,R
Understand the parallel-axis and perpendicular-axis theorem.	I,D,R	I,D,R
Define angular momentum and its conservation.	I,D,R	I,D,R
Describe the conditions necessary for a system to be in static equilibrium.	I,D,R	I,D,R
Describe conditions and forces involved in rolling motion.	I,D,R	I,D,R
Describe the relationship between kinetic energy and work and the work-kinetic energy theorem.	I,D,R	I,D,R
Calculate the work done by a varying force using calculus and graphically as the area under the force versus displacement graph.	I,D,R	I,D,R
Distinguish between conservative and non-conservative forces and associate the conservation of energy and the definition of potential energy within systems where conservative forces act.	I,D,R	I,D,R
Associate gravity as a conservative force and describe systems such as spring/mass and earth/mass systems as energy conservation systems.	I,D,R	I,D,R
Describe the conservation of mechanical energy and solve problems involving work and energy conservation.	I,D,R	I,D,R

Analyze curves of potential energy as a function of a particle's position *x*, determine the force on the particle, turning points and explain neutral, stable and unstable equilibrium.	I,D,R	I,D,R
Explain the conservation of energy for a system of particles undergoing translation motion.	I,D,R	I,D,R
Understand and be able calculate kinetic and potential energies of objects undergoing rotation or rolling, including motion on inclines with, or without slipping.	I,D,R	I,D,R
Understand the relationship between work, energy and power. Solve problems involving average and instantaneous power.	I,D,R	I,D,R
Explain the principle of superposition as it relates to gravitation forces. Use Newtons universal law of gravitation to solve problems involving particles near to the surface of the earth.	I,D,R	I,D,R
Examine gravitational forces on particles within the shell of the earth and compute problems to determine the gravitational force.	I,D,R	I,D,R
Explain gravitational potential energy and calculate the escape velocity of objects projected from the surface of the earth.	I,D,R	I,D,R
Understand Newton's synthesis of Kepler's laws concerning planetary motion, and the motion of satellites around the earth. Solve problems involving planetary and satellite motion.	I,D,R	I,D,R
Explain the motion of a simple harmonic oscillator using both equations and graphs of position, acceleration, velocity as functions of time.	I,D,R	I,D,R
Understand the concepts of a restoring force and a phase angle.	I,D,R	I,D,R
Analyze changes in kinetic and potential energy in a simple harmonic oscillator such as in a spring/mass system.	I,D,R	I,D,R
Describe the motion of an angular simple harmonic oscillator.	I,D,R	I,D,R
Describe and analyze the motion a simple and a physical pendulum.	I,D,R	I,D,R

Describe and analyze the motion a simple and a physical pendulum.	I,D,R	I,D,R

VII. Pacing Chart:

<u>Unit 1(Forces and Motion)</u>

Math Methods

Week 1: (Commencing 1st week)
Introduction and Math Methods (3 to 4 weeks)

- Differentiation, to include polynomial functions of x, ln$x$, e^x, the chain rule, first and second derivatives
- Applications of derived functions; extrema, rates of change and motion involving position functions.
- Integral calculus to include; polynomial functions of x, ln$x$, e^x, the definite integral and integration using substitution.
- Applications of integration; area under the curve and solid of revolution, and motion involving position functions.
- Solution to simple differential equations
- Vector algebra to include; vector representation using unit vectors in 3D, position vector **r**, sum of vectors, and dot and cross products of vectors.
- 2 quizzes and exam in math methods.

Week 5 (October)
Kinematics (3 weeks)
Kinematics [AP® Physics C Mechanics scoring component, SC1; See appendix 1 for the full list of scoring components]

- Motion in 1-D
- Motion in 2-D
- Projectiles
- Uniform Circular Motion
- Relative Motion

SC1 - The course covers Newtonian mechanics in depth and provides instruction in kinematics

Week 9 (November)
Newton's Laws of Motion and Classical Mechanics [SC2], (3 weeks)

- Force and Mass
- Tension and Normal Reaction
- Uniform Circular Motion
- Friction
- Drag Force

SC2-The course covers Newtonian mechanics in depth and provides instruction in Newton's laws of motion.

Unit 2 (Types of Interactions)

Week 12 (Nov. - Dec.)
Linear Momentum [SC7], (3 weeks)

- Impulse and Linear Momentum
- Law of Conservation of Linear Momentum
- Two-Body Collisions in 1-D and 2-D
- Systems of Particles [SC6]

SC7 - The course covers Newtonian mechanics depth and provides instruction in linear momentum.
SC6 -The course covers Newtonian mechanics in depth and provides instruction in systems of particles.

Week 15, (Dec. – Jan.)
Rotational Kinematics (2 weeks)

- Constant Angular Speed
- Constant Angular Acceleration
- Relationships between Linear and Angular Variables

Week 17(Jan. – Feb.)
Rotational Dynamics [SC8 & SC9], (4 weeks)

- Rigid Bodies
- Moment of Inertia and Torque
- Rotational Variables and Newton's Second Law
- Angular Momentum
- Conservation of Angular Momentum
- Rotational Equilibrium
- Mechanical Equilibrium
- Rolling Motion

SC8 -The course covers Newtonian mechanics in depth and provides instruction in circular motion.
SC9 -The course covers Newtonian mechanics in depth and provides instruction in rotation.

Unit 3 (Energy)

Week 21 (Feb. – Mar.)

Work, Energy, and Power [SC3, SC4 & SC5], (3 weeks)

- Work
- Energy
- Conservation of Energy
- Work Done by Conservative and Non-Conservative Forces
- Work Done by Variable Forces
- Kinetic and Potential Energies
- Conservation of Mechanical Energy
- Translational Motion
- Rotational Motion
- Rolling Motion

- Power

SC3 -The course covers Newtonian mechanics in depth and provides instruction in work.
SC4 -The course covers Newtonian mechanics in depth and provides instruction in energy.
SC5 -The course covers Newtonian mechanics in depth and provides instruction in power.

Week 25 (Mar.)
Gravitation [SC11] (2 weeks)

- Newton's Law of Gravitation
- Gravitational Potential Energy
- Motion of Planets and Satellites
- Kepler's Laws
- Critical and Escape Velocities

SC11 -The course covers Newtonian mechanics in depth and provides instruction in gravitation

Unit 4 (Waves and Their Applications)

Week 27 (April)
Oscillations [SC10], (3 weeks)

- Simple Harmonic Oscillations
- Kinematics
- Dynamics
- Simple Pendulum
- Spring Mass System
- Physical Pendulum

SC10 -The course covers Newtonian mechanics in depth and provides instruction in oscillations.

Week 30 (April - May)
Final Exam Preparation (2 weeks)

- Practice Exams and Exam Questions
- AP-Physics C: Mechanics Mock Exam

Week 32 (2^{nd} Week in May)

- AP-Physics C: Mechanics Exam

Week 34 (May -Jun)

- Students' projects and preparation for PCTI final exams

VIII. Student Handout:

AP Physics C Mechanics

Course Description

AP® Physics C is a national calculus-based course in physics. It is examined in two separate exams. The two exams correspond to the physics C course sequence. One exam covers mechanics and the other covers electricity and magnetism. This course will cover the mechanics portion of AP Physics C. The syllabus for this course is designed by the College Board. The mechanics course is equivalent to the pre- engineering introductory physics course for university students. The emphasis is on understanding the concepts and skills and using the concepts and formulae to solve problems. Laboratory work is an integral part of this course. It is especially appropriate for students planning to specialize or major in physical science or engineering. The course explores topics such as kinematics; Newton's laws of motion; work, energy and power; systems of particles and linear momentum; circular motion and rotation; and oscillations and gravitation. Introductory differential and integral calculus is used throughout the course. It will be run as a year-long course and will include an introductory/review section on differential and integral calculus, and vector algebra at the start of the course. At the end of the course, students are expected to take the College Board’s exam in May of school year.

Proficiencies

1. Logically gather order and interpret data through an appropriate use of measurements and tools.
2. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science. Students will use standard safety practices for all classroom laboratory and field investigations. Students will identify and investigate problems scientifically.
3. Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.
4. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.
5. Students will communicate scientific investigations and information clearly.
6. Students will analyze how scientific knowledge is developed.
7. Students will understand important features of the process of scientific inquiry.
8. Demonstrate an understanding of the nature, types and causes of motion.
9. Demonstrate an understanding of the nature of gravitational fields and forces.
10. Explain the law of conservation of energy and relate it to energy transformations.
11. Demonstrate an understanding of the characteristics of work and energy.
12. Students will analyze the relationships between force, mass, gravity, and the motion of objects. Students will evaluate the significance of energy in understanding the structure of matter and the universe.

13. Students will evaluate the forms and transformations of energy.
14. Students will analyze the properties and applications of waves.
15. Examine contributions of important scientists to the development of physics principles.

APPENDIX 1.

The College Board's AP Physics C: Mechanics Scoring Components

The College Board bases the course and exam on several scoring components shown in the table below;

Scoring Components	Page(s)
SC1 The course covers Newtonian mechanics in depth and provides instruction in kinematics.	
SC2 The course covers Newtonian mechanics in depth and provides instruction in Newton's laws of motion.	
SC3 The course covers Newtonian mechanics in depth and provides instruction in work.	
SC4 The course covers Newtonian mechanics in depth and provides instruction in energy.	
SC5 The course covers Newtonian mechanics in depth and provides instruction in power.	
SC6 The course covers Newtonian mechanics in depth and provides instruction in systems of particles.	
SC7 The course covers Newtonian mechanics in depth and provides instruction in linear momentum.	
SC8 The course covers Newtonian mechanics in depth and provides instruction in circular motion.	
SC9 The course covers Newtonian mechanics in depth and provides instruction in rotation.	
SC10 The course covers Newtonian mechanics in depth and provides instruction in oscillations.	
SC11 The course covers Newtonian mechanics in depth and provides instruction in gravitation.	
SC12 Introductory differential and integral calculus are used throughout the course.	
SC13 The course utilizes guided inquiry and student-centered learning to foster the development of critical thinking skills.	
SC14 Students spend a minimum of 20% of instructional time engaged in laboratory work.	
SC15 A hands-on laboratory component is required.	
SC16 Each student should complete a lab notebook or portfolio of lab reports.	

APPENDIX 2

NJSLS Literacy and Mathematics

ELA/Literacy –

Reading

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2), (HS-PS4-3), (HS-PS4-4)

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)*

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)

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)

Writing

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-PS2-6)*

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), (HS- PS2-5)

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)*

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. *(HS-PS2-*

(HS-PS2-5),

Mathematics –

ELA/Mathematics

MP.2 Reason abstractly and quantitatively. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)

MP.4 Model with mathematics. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)

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-PS2-1), (HS-PS2-2), (HS-PS2-4), *(HS-PS2-5), (HS-PS2-6)*

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-1), (HS-PS2-2), (HS-PS2-4), (HS-PS2-5), (HS-PS2-6)*

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1), (HS-PS2-2), (HS-PS2-4), *(HS-PS2-5),(HS-PS2-6)*

HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1), (HS-PS2-4)

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)

HSA-CED.A.1 Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1), (HS-PS2-2)

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)*

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)*

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)

HSS-ID.A.1 Represent data with plots on the real number line (dot plots, histograms, and box plots). *(HS-PS2-1)*