**NGSS Physics**

**Grades: 10,11,12**

**Length: Full Year**

**Environment: Classroom-based**

**Honors: None**

**Subject: Science (D)**

**Discipline: Physics**

**Institution: San Francisco Unified School District**

**Course Overview**

Using the guidance of the CA Framework’s High School 3-Course Model, NGSS Physics integrates Physical and Earth and Space Science performance expectations in a way that allows students to apply their knowledge of physical science concepts in the context of Earth and Space Science. The storyline of this NGSS Physics course progresses from observable phenomena (motion of objects familiar to students, including freefall and projectile motion, and motion of larger bodies, such as tectonic plates) to the force fields that govern them and concludes with pairing students’ year long learning to outer space and the astronomical objects in it.

The course builds upon students knowledge of mathematical concepts such as unit conversion, scientific notation, significant figure rules, dimensional analysis, and algebraic rules of calculations. It introduces students to new mathematical concepts that they use to demonstrate their understanding of Physical and Earth and Space Science concepts.

The course utilizes a 5E Instructional Model in which teaching and learning proceeds through five different stages: Engage, Explore, Explain, Elaborate, and Evaluate. Using the 5E instructional model allows students the opportunity to ask questions and define problems about the natural and designed world, design investigations in which they collect and analyze trends and patterns in their data, develop models of physical phenomena and to communicate their findings from their investigations. The course emphasizes the use of evidence based reasoning for scientific explanations and engineering solutions in order to communicate recommendations to address real world problems. Students discuss and evaluate a wide variety of scientific texts and data from different sources, which include the analysis and interpretation of data sets used by the scientific community. In each unit, the Disciplinary Core Ideas and Crosscutting Concepts are contextualized by a “storyline” and assessments are designed to measure competency in the 8 Science and Engineering Practices and Disciplinary Core Ideas.

**Unit 0. Science Skills and Engineering Practices**

**Essential Question(s):** What skills are necessary to be a scientist or an engineer?

**Unit Description:**

This brief introductory unit is designed to build upon foundational skills in scientific inquiry and strengthen mathematical skills needed to analyze data, spreadsheet and word-processing skills to present data, and to refine their understanding of engineering principles needed to develop a solution to a problem within given constraints. These skills will be called up and further developed throughout the course. Topics of study and coursework will include engaging in arguments from evidence, systems and system models, accuracy and precision, types of data, mathematical manipulation, recording of results, analyzing raw data, constructing tables, drawing graphs, describing statistics and the spread of data, and engineering principles (define->develop->optimize)

**Performance Expectations:**

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.

**DCI:**

ETS1.A: Defining and Delimiting Engineering Problems

ETS1.B: Developing Possible Solutions

ETS1.C: Optimizing the Design Solution

**SEP(s):**

Asking questions (for science) and defining problems (for engineering)

**CC:**

Scale, Proportion and Quantity

**Assignments:**

Students will start reading some breakthrough scientific news. They will review the steps of scientific methods including, making observations, formulating a hypothesis, testing the hypothesis with new observations. They will also practice writing scientific hypothesis. Students will also practice unit conversion in this unit.

**Lab Activates:**

Students develop the concept of precision and accuracy by measuring the length of their table using different tools. They will learn the difference between systematic error and random error. Students will also learn about the potential uncertainty factors.

**Unit 1: Introduction to Motion**

**Essential Question(s):** How can we measure and explain the motion of objects in the world around us?

**Unit Description:**

In this introductory unit, students explore measurement, precision, accuracy and graphing. Students analyze and investigate the concepts of position, distance, time, speed and acceleration through the use of stop motion animation; and explore their own movement and that of carts and cars with motion detectors. Throughout this unit, students practice generating and interpreting position time graphs with collected and provided data sets.

**Performance Expectations**:

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.

**DCI:**

PS2.A: Forces and Motion

**SEP(s):**

Analyzing and Interpreting Data

**CC:**

Analyzing and Interpreting Data

Patterns

**Assignments**

After analyzing different “clips” to determine what makes the motion of a car realistic, students will investigate the motion of a cart on an incline using a motion detector probe. After trying different kinds of motion (constant or changing speed, constant or changing acceleration) students will graph their data and make connections between the observed motion of the cart and features of the graph. Finally, students will apply what they have learned about distance, time, speed, and velocity to make a stop motion animation that relates their calculations to one of several class scenarios.

**Lab Activities**

Students develop and use models for motion. They use a motion detector to produce distance- time and velocity-time graphs for a cart as it moves down and up an inclined ramp. Before collecting data, they make predictions about the distance-time graphs. While engaging in the laboratory they collect distance-time data. They then generate a graph of their data, compare their predictions to what they observed, and determine what the slope of their graph represents.

Students then run additional trials, changing a variable of their choice, to further investigate motion. Students present their additional investigations to classmates and write up their investigation in a lab report.

**Unit 2: Forces & Motion**

**Essential Question(s):** How can we use force to measure, explain, and predict the motion of objects?

**Unit Description:**

In this unit, students learn that the laws of physics hold true not only within the confines of their lab, but in the outside world. Students investigate Galileo’s law of inertia and Newton’s Laws by focusing on the relationship between force and motion in the context of sports. Students will be prepared to demonstrate their understanding of inertia and mass, speed, acceleration, free fall, projectile motion, and friction through a culminating challenge in which they produce a 2-3 minute voice-over narration of a sporting event in which they explain the physics behind it. Students will acquire an understanding of the different types of forces, such as natural forces (gravity, electricity, magnetism, nuclear), reactive forces (friction, normal force, air drag), applied forces, and conservative forces.

**Performance Expectations:**

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-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

**DCI:**.

PS2.A: Forces and Motion

PS2.B: Types of Interactions

ESS1.B: Earth and the Solar System

ETS1.A: Defining and Delimiting an Engineering Problem

ETS1.C: Optimizing the Design Solution

**SEP(s):**

Analyzing and Interpreting Data

Using Mathematics and Computational Thinking

**CC**

Patterns

Cause and Effect

Scale, Proportion, and Quantity

**Assignments**

Using their learning from this unit, students engage in a culminating project where they create a voice-over for a sports event that educates the audience on the physics behind the action.

Students select sports footage of their choice that includes examples of physics topics from this unit (e.g. inertia, mass, speed, force, acceleration, projectile motion, and friction). Students identify four to five specific instances within the footage where they will detail the physics involved. While watching the identified footage, they gather data that allows them to calculate the magnitude of forces, masses, and accelerations in the sports clip. Students will include calculations for any estimates made, such as estimating speed of an object (equipment or person) based on the mass and how long it took to travel a certain distance.

**Lab Activities**

As part of an exploration of frictional forces, students measure the coefficient of sliding friction between the soles of athletic shoes and a variety of surfaces and calculate the effects of frictional forces on the motion of objects. During this lab investigation, students initially collect numerical data on a shoe (using a spring scale to measure the weight of the shoe in newtons) as well as observational data (brand, tread, materials used). They brainstorm and select a variable that may affect the force required to pull the shoe. Students design and carry-out an experiment to test the selected variable. Students present their design, data, and summary of findings to classmates during class presentations.

**Unit 3: Momentum**

**Essential Question(s):** How can Newton’s laws be applied to conserve momentum?

**Unit Description:**

In this unit, students continue to describe, explain, and apply Newton’s laws of motion, specifically Newton’s second law. Students will be prepared to demonstrate their understanding of force, momentum (p=mv), collisions (elastic & inelastic), impulse (force applied over a period of time), and the Law of Conservation of Momentum. In the key assignment students apply Newton’s laws, the relationship between impulse and momentum, and conservation of momentum to design and build and refine a crash barrier that minimizes the force on an object during a collision.

**Performance Expectations:**

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.\*

**DCI:**

PS2.A: Forces and Motion•

ETS1.A: Defining and Delimiting an Engineering Problem

**SEP(s):**

Developing and Using Models

Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions

**CC:**

Cause and Effect

Systems and System Models

**Assignments**

Through videos, text, class discussion and calculations, students will explain how force affects the time of impulse and the change in momentum. They will use the situation of car crashes and car safety features to design and test a crash barrier that reduces the force on the passenger by 25% during a collision. Using probeware, students will measure the force generated in their collision. In their final evaluation, students present collision data including an F-t graph, error estimates, derivation of speed just prior to the collision, and an analysis of the change of momentum for each case (with and without their prototype safety system).

**Lab Activities**

Students conduct analyses of momentum of pairs of objects (carts) involved in one-dimensional collisions. They stage a head-on collision between two collision carts of equal mass that serves as a model for the elastic collision of vehicles. They then investigate how changing the speed or mass (and therefore momentum) of an object changes the results of the collision. Students write up their findings in a lab report and use them as evidence in a class discussion of different collision scenarios.

**Unit 4: Energy**

**Essential Question(s**): How are forces and energy related? How is energy transferred and converted?

**Unit Description**:

In this unit, students investigate and apply ideas involving vectors, kinematics, gravitational force, Newton’s laws, kinetic and potential energy, conservation of energy, circular motion, work, and power. Students will be prepared to demonstrate their understanding of the relationship between work (W = Fd) and energy, that the energy of a system is conserved (Law of Conservation of Energy), and that energy is transformed from one kind to another. They will demonstrate that energy can be divided into mechanical (kinetic, potential, elastic), and non-mechanical form (heat, electrical, chemical, nuclear), that the total energy of a system is always conserved, and energy ‘loss’ is the transformation of one type of energy into [mainly] heat energy. Students investigate centripetal force and apply it to a roller coaster. They complete the unit with the design of an energy conversion device (roller coaster) in which they diagram the energy changes in a model and calculate potential and kinetic energy.

**Performance Expectations**:

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 positions 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.\*

**DCI:**

PS3.A: Definitions of Energy

PS3.B: Conservation of Energy and Energy Transfer

ETS1.A: Defining and Delimiting an Engineering Problem

**SEP(s):**

Developing and Using Models

Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions

**CC:**

Cause and Effect

Systems and System Models

Energy and Matter

**Assignments**

Upon the completion of their exploration of energy, students present a blueprint for a roller-coaster design that includes a model of their design, calculations of energy required to get the roller coaster started, to travel through a variety of hills and curves, and the energy dissipated to stop the roller coaster at the end of the ride. Additionally, students provide data on the height, speed, and acceleration of the roller coaster at multiple locations in their design.

**Lab Activities**

As part of their exploration of energy, students carry out an investigation and use mathematics to calculate gravitational potential energy and kinetic energy. Students use a steel ball, a track, and velocimeter to determine if a pattern exists between the placement of the ball and its speed at the bottom of the track. After discovering that the speed of the ball increases if the height and/or distance increases, students investigate whether knowledge of one of the variables makes it easier to determine the ball’s speed. They change the angle of the track and conduct the same investigation using curved tracks. Students make predictions and collect data for each height trial, compare predicted speeds with measured speeds, and write a summary comparing the speed at the bottom of a curved track with that of a straight track.

**Unit 6: Electricity and Magnetism**

**Essential Question(s):** How can electricity and magnetism be explained and used to develop technology?

**Unit Description:**

In this unit, students investigate the properties of electric and magnetic fields. They begin by tracing energy transformations, constructing a circuit that lights a bulb, and adjusting the brightness of a bulb with a hand generator. Students continue their exploration of electricity with physical models, comparing series and parallel circuits, calculating resistance, and exploring power and calculating power limits. Additionally, students use mathematical representations of Newton’s law of universal gravitation and Coulomb’s law to describe and predict the gravitational and electrostatic forces between objects. Students explore how these phenomena interact with each other in modern technology.

Students will be prepared to demonstrate separation of charges, understand the relationship between electricity and magnetism, and an understanding that moving charges produce a magnetic field. They gain an understanding that that a changing magnetic field produces an electric potential difference, and vibrating charges will produce electromagnetic waves.

**Performance Expectations**:

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.

**DCI:**

PS3.A: Definitions of Energy

PS3.C: Relationship Between Energy and Forces

**SEP(s):**

Developing and Using Models

Planning and Carrying Out Investigations

**CC:**

Energy and Matter

Cause and Effect

**Assignments**

Students design and build a model of a sustainable home for a family of four. They choose sustainable sources of power and select the home appliances that would improve the quality of life for the family without overloading electrical circuits. Their project consists of a 3D model of the home with completed wiring, working lights, a battery, and resistors representing appliances, a home electrical circuit diagram of the model home, and justification of the selected source of energy and appliances for the family of four.

**Lab Activities**

Students calculate the resistance of an unknown resistor given the voltage drop and current. Students are presented with a scenario of a “box,” a box that you cannot see inside, in which they need to determine the contents of the box electrically by measuring the voltage across and the current through the resistor inside. They set up a simple circuit with a resistor, voltmeter, and an ammeter. By varying the voltage of the battery, they learn how the current of the circuit and the voltage across a resistor change. Students plan an experiment to find out how the voltage and current vary for a 5? 10? and 15? resistor. Students write up their findings in a lab report and use their data to determine the resistor in the “box.”

**Unit 6: Waves**

**Essential Question(s):** How does the nature of waves allow us to communicate and learn about the world?

**Unit Description:**

In this unit, students use the wave equation to understand and explore wavelength, frequency, wave speed, tension, and diffraction in the contexts of sound and light. Additionally, students explore how the properties of EM waves allow them to be transmitted and absorbed by matter. They learn about the wave particle nature of light and demonstrate their understanding of different properties of waves, such as reflection, refraction and polarization. They develop an understanding that waves carry energy, and the source of all waves is vibrating matter. Additionally, students explore how modern technology uses wave behavior to transmit and capture information and energy.

**Performance Expectations:**

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.\*

HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

**DCI:**

PS4.A: Wave Properties

PS4.B: Electromagnetic Radiation

**SEP(s):**

Asking Questions and Defining Problems Analyzing and Interpreting Data

Using Mathematics and Computational Thinking Engaging in Argument From Evidence

Obtaining, Evaluating, and Communicating Information

**CC:**

Cause and Effect

Systems and System Models

Stability and Change

**Assignments**

Student models build from previous learning of wave amplitude and wavelength to include mathematical representations including relationships involving speed and frequency, transmission of energy without transmitting matter, and the role of elastic properties to reverse deformation of the medium. The next step would be to apply these models to earthquakes and plate tectonics and explain the relationship between the Earth’s composition and the rate at which seismic waves travel through the different materials. Students then extend their mathematical representations of amplitude and frequency to electromagnetic waves. They examine experimental evidence that supports the claim that light is a wave phenomenon, and the evidence that supports the claim that light is a particle phenomenon.

As they learn the physics of electromagnetic radiation, they also obtain and communicate information about the variety of applications that improve our quality of life and about health hazards associated with electromagnetic waves. Students focus is on the influence of science, engineering, and technology on society and how scientists and engineers have applied physical principles to achieve technological goals and how the resulting technologies have influenced society and culture. Students now apply their understanding of wave phenomenon to support current theories of the origin and expansion of the universe, citing wave evidence such as the doppler effect, red shift, and microwaves.

**Lab Activities**

Students make sounds by plucking a string and investigate how the length of the string affects the pitch (how high or low the note is) of the sound produced, and then how the tension in the string affects the pitch. The student set up includes a pulley mounted over one end of a table, string, mass, a plastic cup, and a clamp. After investigating a provided scenario, students change the length of the section of the string that is vibrating by sliding the cup. They measure the length of the section, pluck the string, and record changes in pitch. They use their collected data to then investigate how the size of the mass affects the pitch of the sound. Students write up their findings on variables that affect pitch of sound produced in a lab report that includes, their methods and data.

Unit 7: Cosmology

**Essential Question(s):** How can we use starlight to learn about stars and unveil the history of the universe? What led to the formation of the universe and earth as we know it today?

**Unit Description**:

In this unit, students gain an understanding of the evidence astronomers use to model the life cycle of a star and the formation of the Universe. Students apply their prior learning of the electromagnetic spectrum to studying the light from stars, including our Sun. Students will compare the spectra of different stars to detect the pattern of their chemical composition. Students will also be prepared to interpret a model of fusion in stars over a star’s life cycle (stellar birth, activating fusion, mid-life as a balance of nuclear and gravitational forces, growing older, end of stars). Additionally, students develop a scale model of the solar system, explore the Sun-Earth- Moon system, learn about the origin of the universe and solar system, and use mathematics to predict the motion of orbiting objects in the solar system.

**Performance Expectations**:

HS-ESS1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation

HS-ESS1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

HS-ESS1-4: Use mathematical or computational representations to predict the motion of

orbiting objects in the solar system.

HS-ESS1-6: Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history

**DCI:**

PS3.D: Energy in Chemical Processes and Everyday Life

ESS1.A: The Universe and Its Stars

**SEP(s):**

Developing and Using Models

Constructing Explanations and Designing Solutions

Scale, Proportion, and Quantity

**CC:**

Energy and Matter

Stability and Change

**Assignments**

In the design challenge for this unit, students to make a podcast on the possible effects that objects from space can have on Earth and their community. They will decide which topics to cover. Students could discuss how the Sun and the Moon affect Earth through tides, solar winds or sunspots. Or they could discuss how impact events have affected both Earth and its solar system. They could focus on small or large impact events in Earth’s history and how likely they are to occur. They will also need to include possible hazards to their community from outer space and if prevention or mitigation is possible. Students’ final product may be in a variety of formats, including a skit, song, short video or a mock interview.

**Lab Activities**

Students examine the electromagnetic spectrum and how it is used to observe stars, galaxies, and other distant objects in the universe. They use a spectrometer to observe the visible part of the electromagnetic spectrum. They compare what they see when observing sunlight (not direct), fluorescent light, and light from an incandescent bulb. They compare the patterns of the colors they observed and think about the information a spectrometer would provide if they were to look at the light from other stars. Students present a summary of their findings in a lab report.

Unit 5: Plate Tectonics

**Essential Question(s):** How and why is Earth still changing and how do we know?

**Unit Description:**

In this unit, students will apply their knowledge of the physical concepts of energy and motion from units 1-4 to investigate the early history of Earth, Earth’s interior, and the cycling of matter by thermal convection. Students will use a wide variety of data sources, including seismic waves, records of rate change of Earth’s magnetic field and plate movement, and density of Earth’s interior layers.

Students begin by identifying patterns in the location of recent earthquakes in Northern California. They will then look at the patterns of earthquakes and volcanoes on a global scale and again see that they tend to be located in certain locations worldwide. They will make connections between the patterns they saw on the global map to different types of plate boundaries. In order to extend their understanding to the oceans and the idea of seafloor spreading, students will model and interpret magnetometer readings from the seafloor and calculate the average spreading rate over a long period of time for the Mid-Atlantic ridge. Using Google Earth, students will explore different localities, identify features in the landscape and then read about that type of boundary in depth, including analyzing a cross-section model. Finally, students apply their learning to identify a newly discovered plate boundary. They use evidence and reasoning to support their claim.

**Performance Expectations:**

HS-ESS1-5: Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.

HS-ESS1-6: Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history.

HS-ESS2-1: Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. HS-ESS2-3: Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection

**DCI:**

PS1.C: Nuclear Processes

PS3.B: Conservation of Energy and Energy Transfer

PS3.D: Energy in Chemical Processes

ESS2.A: Earth Materials and Systems

ESS2.B: Plate Tectonics and Large-Scale System Interactions

ESS1.C: The History of Planet Earth

**SEP(s):**

Developing and Using Models

Planning and Carrying Out Investigations

Constructing Explanations and Designing Solutions

Engaging in Argument from Evidence

**CC:**

Patterns

Systems and System Models

Energy and Matter

Stability and Change

**Assignments**

After analyzing data from GPS stations to determine what the movement of different tectonic plates would look like when graphed vs. time, students examine 2 sets of data from 2 sites on Iceland that show that the two stations are moving apart from each other (divergent boundary). Students calculate the velocity of the GPS stations in 2 different directions over a period of 10 years and generate vector diagrams to show the sum of the movement. Finally students will calculate how far apart these stations will be in 100, 1000, 1 million and 10 million years.

Students carry out an investigation on the density of various materials and apply evidence from their investigations to provide an explanation for Earth’s layered structure. Students make predictions about the position of water, corn syrup, and vegetable oil if each were poured into a column. They observe what occurs when the three liquids are combined and use their observations to plan an investigation to determine the density of each of the three liquids using a graduated cylinder, 10 mL of each liquid, and a scale. After getting teacher approval and carrying out their investigation, students write up their findings in a lab report that includes the goal of the investigation, methods used, data collected, analysis and calculations. They develop an explanation for their observations using the densities calculated as supporting evidence.

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| Textbooks |  | | | | |
| Title | Authors | Publisher | Edition | Website | Is Primary |
| Active Physics | Eisenkraft | Active Learning | 3rd Edition | https://activatelearning.com/active-physics | No |
| Earth Comm | Carpenter, Hoover et. al. | Activate Learning | 2nd Edition | https://activatelearning.com/earthcomm/content | No |
| CK 12  Physics |  | CK 12 Physics | web  Edition | <https://flexbooks.ck12.org/cbook/ck-12-physics-flexbook-2.0/> | Yes |