Course: *Physics* **Unit #5:** Waves	**Year of Implementation:** 2023-2024

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Stage One - Desired Results

Link(s) to New Jersey Student Learning Standards for this course:
https://www.state.nj.us/education/cccs/2020/
https://www.state.nj.us/education/cccs/2020/2020%20NJSLS-CLKS.pdf
https://www.nj.gov/education/standards/ela/Docs/2016NJSLS-ELA_Companion9-10.pdf
https://www.nj.gov/education/standards/ela/Docs/2016NJSLS-ELA_Companion11-12.pdf

- **Unit Standards:**
  - ***Content Standards***
    - 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.
    - HW-PS4-3 - Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or 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.
  - ***21st Century Life & Career Standards***
    - 9.4.12.CI.1 - Demonstrate the ability to reflect, analyze and use creative skills and ideas
    - 9.4.12.IML.3 - Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions.

- ***English Companion Standards***
  - 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.
  - WHST.9-10.2 - Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
  - 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
  - WHST.9-10.9 - Draw evidence from informational texts to support analysis, reflection, and research

- ***Interdisciplinary Content Standards***
  - MP.2 - Reason abstractly and quantitatively.
  - MP.4 - Model with mathematics.
  - 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.
  - HSN-Q.A.2 - Define appropriate quantities for the purpose of descriptive modeling.
  - HSN-Q.A.3 - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
  - HSA-SSE.A.1 - Interpret expressions that represent a quantity in terms of its context.
  - 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.
  - HSA-SSE.A.4 - Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

- ***NJ Statutes:*** NJ State law mandates the inclusion of the following topics in lesson design and instruction as aligned to elementary and secondary curriculum.

Amistad Law: N.J.S.A. 18A 52:16A-88 Every board of education shall incorporate the information regarding the contributions of African-Americans to our country in an appropriate place in the curriculum of elementary and secondary school students.

Holocaust Law: N.J.S.A. 18A:35-28 Every board of education shall include instruction on the Holocaust and genocides in an appropriate place in the curriculum of all elementary and secondary school pupils. The instruction shall further emphasize the personal responsibility that each citizen bears to fight racism and hatred whenever and wherever it happens.

LGBT and Disabilities Law: N.J.S.A. 18A:35-4.35 A board of education shall include instruction on the political, economic, and social contributions of persons with disabilities and lesbian, gay, bisexual, and transgender people, in an appropriate place in the curriculum of middle school and high school students as part of the district's implementation of the New Jersey Student Learning Standards (N.J.S.A.18A:35-4.36) A board of education shall have policies and procedures in place pertaining to the selection of instructional materials to implement the requirements of N.J.S.A. 18A:35-4.35.

Diversity and Inclusion (N.J.S.A. 18A:35-4.36a) A board of education shall incorporate instruction on diversity and inclusion in an appropriate place in the curriculum of students in grades kindergarten through 12 as part of the district's implementation of the New Jersey Student Learning Standards.

Asian American and Pacific Islanders (AAPI) P.L.2021, c.410 Ensures that the contributions, history, and heritage of Asian Americans and Pacific Islanders (AAPI) are included in the New Jersey Student Learning Standards (NJSLS) for Social Studies in kindergarten through Grade 12 (P.L.2021, c.416)

For additional information, see

NJ Amistad Curriculum: http://www.njamistadcurriculum.net/

Diversity and Inclusion: https://www.nj.gov/education/standards/dei/index.shtml

- *(Sample Activities/ Lessons): https://www.nj.gov/education/standards/dei/samples/index.shtml*

Asian American and Pacific Islanders:

- *Asian American and Pacific Islander Heritage and History in the U.S.*
  A Teacher's Guide from EDSITEment offering a collection of lessons and resources for K-12 social studies, literature and arts classrooms that center around the experiences, achievements and perspectives of Asian Americans and Pacific Islanders across U.S. history.

Transfer Goal: Students will be able to independently use their learning to construct, evaluate, and communicate detailed scientific explanations to describe the production, distribution and uses of mechanical and electromagnetic wave energy.

As aligned with LRHSD Long Term Learning Goal(s):

Students will be better able to:

- design, critique, and carry out experiments in order to investigate scientific questions and/or propose solutions.
- collect, interpret, and analyze data in order to solve a defined problem.
- apply mathematics to express relationships efficiently and accurately.
- draw evidence-based conclusions from data in order to make informed decisions.
- construct, interpret, and refine models (scientific and mathematical) to explain the physical and natural world.
- effectively communicate scientific ideas and evidence-based arguments to an appropriate audience through written and oral means.

Enduring Understandings Students will understand that. . . *EU 1* a wave transports energy, and the behavior of that wave is dictated by the medium through which it passes. EU 2 an electromagnetic wave can behave as both a wave and a particle. *EU 3* waves' interaction with matter can be used for information transfer and other applied technologies.	*Essential Questions* *EU 1* ● Where do waves come from? ● What evidence is there to support the idea that waves carry energy? ● How do we describe the behavior of a wave? ● What is the best medium through which mechanical waves can travel? *EU 2* ● What exactly IS light? ● What is the best medium through which electromagnetic waves can travel? ● How can the speed of a wave be most effectively changed? ● How is it possible that an electromagnetic wave can behave as both a wave and particle? *EU 3* ● Is radiation good or bad for living things? ● How does technology use waves? ● Why are waves omnipresent?
Knowledge *Students will know . . .* *EU 1* ● a medium is a physical environment through which a disturbance can travel. (PS4.A)	*Skills* *Students will be able to. . .* *EU 1* ● carry out an investigation that confirms and evaluates the mathematical relationship between the frequency, wavelength and speed of a wave. (SEP3)

● mechanical waves require a medium through which to travel. (PS4.A) ● the vibrations of a transverse wave are perpendicular to the wave motion. ● the vibrations of a longitudinal wave are parallel to the wave motion ● standing waves form from the interference of two identical waves traveling in opposite directions. (PS4.A) ● sound is an example of a longitudinal wave. ● the range of human hearing is from 0 dB to 130 dB. ● moving wave sources or receivers cause an apparent change in frequency which is known as the Doppler effect. ● the speed of a mechanical wave depends on the medium through which it travels and the temperature of that medium. (PS4.A) ● the normal range of human hearing is from 20 Hz to 20,000 Hz.	● construct and communicate an explanation that distinguishes between particle vibration and overall wave motion. (SEP6) ● utilize a graphical model to interpret and describe the differences between transverse and longitudinal waves. (SEP2) ● obtain and evaluate claims that waves transfer energy without transferring matter. (SEP8) ● develop an explanation that communicates the difference between transverse and longitudinal waves. (SEP6) ● obtain, evaluate and communicate evidence that relates the physical properties of sound waves to perceived pitch and loudness. (SEP8) ● model the various parts of a standing wave then develop an explanation of how they are produced. (SEP2) ● describe how engineers continually modify systems by applying scientific knowledge and engineering design practices. ● utilize mathematical and computational thinking to demonstrate an understanding of resonance. (SEP5) ● design an investigation that demonstrates the Doppler effect then obtain and communicate several applications of this principle. (SEP3) ● demonstrate the principle of superposition and construct a model that provides an explanation of wave interference. (SEP2) ● construct an explanation of how beats occur and communicate the result when two slightly different frequencies interfere. (SEP6)

EU 2 ● electromagnetic radiation can be modeled as a wave of changing electric and magnetic fields, or as particles called photons (PS4.B). ● light is a part of a larger family of radiation known as the electromagnetic spectrum. (PS4.B) ● the properties of electromagnetic waves determine their uses. (PS4.B) ● the speed of light in a vacuum is 3.0 x10^8 m/s and this value approximates the speed of light in air. (PS4.A) ● the index of refraction for a particular transparent material is the ratio of light's speed in a vacuum compared to its speed in that medium. ● light can refract when it enters a medium and there is a change in speed. ● total internal reflection occurs when light strikes an interface beyond the critical angle. *EU 3* ● when longer wavelength electromagnetic radiation is absorbed by matter, it is generally converted into thermal energy (PS4.B)	*EU 2* ● construct a graphical model that can be utilized to communicate the difference between crest, trough, amplitude, and wavelength. (SEP2) ● develop a mathematical model to relate wave speed to wavelength and frequency. (SEP2) ● apply the wave speed equation to predict the frequency and wavelength of a wave in a particular medium. ● use mathematical and computational thinking to relate a wave's speed to the medium through which it passes. (SEP5) ● design and evaluate an investigation that describes how waves are reflected and refracted at boundaries between media. (SEP3) ● use a graphical model to demonstrate how the law of reflection can be used to predict where a mirror will produce an image. (SEP2) ● use Snell's Law to model the refraction of light as it passes from one medium to another. (SEP2) ● construct an explanation of how total internal reflection occurs then identify and communicate some important applications of the principle. (SEP6) ● analyze conceptually the double-slit experiment to describe why light has the behavior of both a wave and particle. *EU 3* ● evaluate the validity of scientific claims regarding the effect that various parts of the electromagnetic spectrum have when they interact with matter. (SEP7)

● shorter wavelength electromagnetic radiation can ionize atoms and cause damage to living cells (PS4.B) ● information can be digitized, stored in computer memory, and sent over long distances as a series of wave pulses. (PS4.A). ● multiple technologies that use waves and interact with matter are part of everyday experiences in the modern world (PS4.C)	● obtain evidence to support an argument concerning the dangers and hazards associated with particular types of electromagnetic waves. (SEP8) ● analyze digital photographs and evaluate which one takes more data to store. ● compare types of computer disc drives and evaluate which type is best in certain situations. ● develop an explanation about how certain technology uses waves. (SEP6)
Stage Two - Assessment	
Stage Three - Instruction	

Learning Plan: **Suggested Learning Activities to Include Differentiated Instruction and Interdisciplinary Connections: Each learning activity listed must be accompanied by a learning goal of A= Acquiring basic knowledge and skills, M= Making meaning and/or a T= Transfer.** *The following color codes are used to notate activities that correspond with interdisciplinary connections and 21st Century Life & Career Connections (which involves Technology Literacy): Red = Interdisciplinary Connection; Purple = 21st Century Life & Career Connection*

PHENOMENON 1: Tacoma Narrows Bridge https://youtu.be/esfpcnQW6qs (M/T, EU1)
Goal: Students will analyze the destruction of a bridge and discover how its destruction relates to mechanical, standing waves, and resonance.

1. Show video of the Tacoma Narrows Bridge oscillating and breaking.
    - Suggested questions that will guide thinking and discussion (A/M, EU 1):
        - Describe how the bridge is moving.
        - What happened to the bridge?
        - How can wind cause the bridge to oscillate?
        - What is the relationship to the motion of the bridge to waves?
2. Teacher led instruction on the topic of waves including, but not limited to, types of waves, and associated vocab such as frequency, wavelength, amplitude. (A, EU1)
3. Demo: Reflection of a wave as it encounters a boundary between media. (A/M, EU1)
4. Discussion: What is a medium? What type of waves need a medium? (A, EU1)
5. Small Group Discussion: How might frequency and period relate to the speed of a wave? (A/M, EU1)
6. Students will complete practice problems by calculating quantities such as speed, frequency and wavelength of a wave. (M, EU1,2)
7. Teacher-Student Demo: Standing waves on a slinky spring (A/M, EU1)
8. Simulation: PhET - wave on a string activity (M, EU1)
9. Lab: Speed of a mechanical wave on a Slinky. (M/T, EU1)

PHENOMENON 2: Sound generated by a musical instrument (M/T, EU 1)
Goal: Students will be able to describe and explain how musical instruments work based on waves and their behavior.

1. Demo: Pluck a guitar string (or show a video of one being plucked)
    - Ask the students some questions to guide their thinking and discussion: (A/M, EU1)
        - What is oscillating/vibrating to make the sound?
        - Why and how do you hear something after the string is plucked?
        - How can the pitch of the sound produced be changed?
2. Teacher led instruction on wave behavior such as Reflection, Refraction, Interference, & Diffraction. (A, EU1)
3. Demo: Intensity and Frequency Range of the human ear. Speaker, Frequency Generator Software (A, EU1)

4. Teacher led discussion: Resonance- musical instruments, “marching over a bridge”, earthquakes and building heights. (A/M, EU1)
    - Be sure to refer back to resonance and Phenomenon 1 - Tacoma Narrows Bridge
5. Video: Mechanical Universe - Resonance (A, EU1)
6. Lab: Speed of sound in a closed end tube. (M, EU1)
7. Demo: Tuning Forks (w/ resonance boxes) to demonstrate concept of beats (A, EU1)
8. Students will solve problems, both conceptual and computational, on topics such as wave behavior. (M, EU1)
9. Discussion: Doppler Effect - Ambulance passing you,” Redshift”, Radar guns, Weather Radar (A/M, EU1)
10. Have students complete one or both of the following discovery labs:
    - Lab: How do you make the best “2 cups and a wire phone”. (T, EU1)
    - Lab: Build a musical instrument that can play three (3) notes. (T, EU1)

PHENOMENON 3: Rainbows (M/T, EU2,3)
Goal: Students will be able to describe and explain how light refracts when traveling through different mediums and determine whether light in a rainbow is demonstrated by the wave or particle nature of light.

1. Demo: Show a picture of a rainbow (or use a prism show the refraction of white light)
    - Suggested questions that will guide thinking and discussion: (A/M, EU2)
        - Under what conditions do rainbows occur?
        - Why is a rainbow composed of different colors?
        - Are rainbows always the same?
2. Small Group Discussion: How are mechanical waves and light waves similar/different? (A/M, EU1,2)
3. Teacher led instruction: light, speed of light and direction changes at boundaries, and Index of Refraction (A, EU2)
4. Activity: Geometric Optics (T, EU2)
    - Students will use key points to analyze the path of light before and after it interacts with a mirror or lens.
5. Teacher led discussion: Snell’s Law, Why is spear fishing difficult? (Movie-Castaway), Pencil in a cup of water. (A, EU2)
6. Discussion: TIR (Total Internal Reflection) Diamond Cutting, Fiber Optics and High Speed Telecommunications. (M, EU2)
7. Simulation: PhET simulation activity on “Bending Light” https://phet.colorado.edu/en/simulations/bending-light (A/M, EU2)
8. Students will practice solving problems and calculating related quantities by using Snell’s Law (M, EU2)
9. Lab: Find the angle change of a light as it travels through a clear material using pins. (M, EU2)
10. Lab: Build an optical device using more than one lens, mirror or optical device. (microscope, telescope, binoculars, projector, camera) (T, EU2)
11. Teacher led discussion and notes: Light can act as both a wave and particle, a concept which is referred to as particle-wave duality. Review concept of photoelectric effect - students should have this knowledge from chemistry. (A, EU2,3)
12. Teacher led online demo and discussion: PhET simulation “Molecules and Light” (https://phet.colorado.edu/en/simulations/molecules-and-light)
    - ask students to explain what is occurring in the simulation. (A/M, EU2,3)

- ask students “If light interacts with matter, is it possible that it can be harmful to humans?” (A/M, EU3)

13. Writing assignment: Have students write a paragraph after they complete research to answer the question: “How does sunlight cause sunburn?” .(M/T, EU3)
14. Computer lab simulation: https://phet.colorado.edu/en/simulations/wave-interference double slit experiment and wave interference. Students should complete the demo and be able to describe the particle nature of light, in addition to the wave nature (A/M, EU2,3).
15. Refer back to Phenomenon (M/T, EU2,3):
    - Ask the students to discuss - Are rainbows best described by the wave or the particle model of light? Why?

PHENOMENON 4: A cellular phone can capture, encode, retrieve, transmit, and receive information.(EU 1,2,3)
Goal: Students will be able to recognize and evaluate the advantages of using digital transmission and storage of energy, as well as communicate how some technological devices use waves to interact with matter to transmit and capture information and energy.

1. Demo: Teacher should show a cell phone and say, “We use these not only every day, but multiple times a day” and then ask some following discussion questions (A, EU3):
    - What makes cellular phones so useful?
    - What are some functions that cell phones accomplish?
    - How does your cell phone take and store pictures?
    - How does your cell phone send and receive information to other phones?
    - Is cell phone radiation harmful to human health?
2. Demo/Discussion: Show students two images: one that looks pixelated and one that is not pixelated. Ask: (A, EU3)
    - What makes one image better than the other?
    - Make a prediction about which one takes more memory to store.
3. Notes and Teacher-Led Discussion: Information- analog vs. digital, computer memory (A, EU3)
4. Student independent research: Students should read the websites https://computer.howstuffworks.com/hard-disk.htm and https://computer.howstuffworks.com/solid-state-drive.htm?utm_source=howstuffworks&utm_medium=recirc to acquire information and write a paragraph summarizing how hard drives work and whether they would choose a HDD or SSD if they were purchasing a new computer (A/M, EU3).
5. Cooperative learning research and presentations: Assign partners and groups. Each group will be assigned a different topic to research and present in front of the class, utilizing Google Slides regarding technology and how information is transmitted (A/M, EU1,2,3). Some suggested topics are as follows:
    - Develop an explanation about how microphones transmit energy and the events that lead a speaker to transfer that energy.
    - Describe how antennas can relay information by capturing signals and transferring energy.
6. Refer back to cellular phone phenomenon - (M/T, EU1,2,3)
    - Re-ask all the original discussion questions to be sure they are answered, now that students have learned additional information.

○ Ask the students to answer an open-ended follow-up question, based on their new knowledge: “How can a cell phone be improved without causing damage to living tissue?”

Pacing Guide

Unit #	*Title of Unit*	*Approximate # of teaching days*
1	Kinematics	40
2	Newton’s Laws & Forces	40
3	Energy	30
4	Electricity and Magnetism	40
5	Waves	30

Instructional Materials

A fully equipped physics lab including but not limited to the following:

Blackboard Optics Kit
Slinky Springs

Accommodations

Special Education: The curriculum will be modified as per the Individualized Education Plan (IEP). Students will be accommodated based on specific accommodations listed in the IEP.
Students with 504 Plans: Students will be accommodated based on specific accommodations listed in the 504 Plan.
English Language Learners: Students will be accommodated based on individual need and in consultation with the ELL teacher.
Students at Risk of School Failure: Students will be accommodated based on individual need and provided various structural supports through their school.
Gifted and Talented Students: Students will be challenged to enhance their knowledge and skills through acceleration and additional independent research on the subject matter.