Waves and Electromagnetic Spectrum Resource Guide

Curated by the GUHSD OER Physics Team

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Unit Overview

NGSS Performance Expectations	Concepts
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.*	• Wave Structure, Wave Nature • Digital vs Analogue Transmission • Wave-Particle Duality • Electromagnetic Radiation Applications and Hazards • Wave Energy / Wave Nature leading to the capture of information and energy

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	**PS3.D: Energy in Chemical Processes** • Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary) **PS4.A: Wave Properties**	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Asking Questions and Defining Problems

- Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set or the suitability of a design.

Engaging in Argument from Evidence

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

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- 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. 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.

Obtaining, Evaluating, and Communicating Information

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

- 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**.**
- 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.
- [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. (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.)
- 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.

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.
- 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.
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

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, scanners) and in scientific research. They are essential tools for

- 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.
- Systems can be designed to cause a desired effect.

Stability and Change

- Systems can be designed for greater or lesser stability.

Influence of Engineering, Technology, and Science 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.

Systems and System Models

- Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions — including energy, matter and information flows — within and between systems at different scales.

Interdependence of Science, Engineering, and Technology

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

	producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.	**Influence of Engineering, Technology, and Science on Society and the Natural World** ● Modern civilization depends on major technological systems.

Framework Background

The Performance Expectations associated with the topic Waves and Electromagnetic Radiation are critical to understand how many new technologies work. As such, this disciplinary core idea helps students answer the question, “How are waves used to transfer energy and send and store information?” The disciplinary core idea in PS4 is broken down into Wave Properties, Electromagnetic Radiation, and Information Technologies and Instrumentation. Students are able to apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales. Models of electromagnetic radiation as either a wave of changing electric and magnetic fields or as particles are developed and used. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Students also demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. The crosscutting concepts of cause and effect; systems and system models; stability and change; interdependence of science, engineering, and technology; and the influence of engineering, technology, and science on society and the natural world are highlighted as organizing concepts for these disciplinary core ideas. In the PS4 performance expectations, students are expected to demonstrate proficiency in asking questions, using mathematical thinking, engaging in argument from evidence, and obtaining, evaluating and communicating information; and to use these practices to demonstrate understanding of the core ideas. (NGSS Lead States 2013f)

Table of Contents

Section 1: Wave Structure

CK-12 Core Content Reading
YOU DO NOT NEED AN ACCOUNT TO ACCESS READINGS

- Simple Harmonic Motion
- Wavelength
- Wave Frequency
- Wave Speed
- Transverse Wave
- Longitudinal Wave
- Sound Waves
- Speed of Sound

Readings & Articles

- Types of Waves -Reading Log
- Simple Harmonic Motion Reading with Quiz
- Nature of Sound Waves
- Physics - Waves - Introduction

Videos & Animations

- Physics - Waves - Introduction
- What does sound look like?
- Superposition of Waves
- Simple Harmonic Motion:Crash Course Physics #16
- Traveling Physics: Crash Course Physics #17
- Electromagnetic Wave Properties
- Surfing world record
- Oscillation animations
- Waves on a string
- Sound Waves
- Doppler
- Quantifying Sound

Simulations & Interactives

- Wave on a String
- Musical notes frequency and wavelength
- Virtual oscilloscope (Way Cool)
- Piano keyboard and air particles
- Music Lab
- Wave Simulator - Explore Wave Sim
- Wave on a string Sim - Elaborate Wave
- Wave Interference Sim
- Wave addition simulator

Phenomena & Data

- Military wave
- Bowling ball pendulum

Labs

- Pendulum Lab
- Speed of Sound lab
- Speed of Sound in Air Lab
- Waves on a String
- Guided Oscillation Lab
- Waves on a string lab, handout and video direction
- Speed of sound lab, handout and video directions
- Resonance and the Speed of Sound

Project Ideas

- Build a Pendulum to match a song

Other Activities

- Practice Problems
- Practice Problems
- Waves and Technology Unit from The Patterns Approach

Section 2: Wave Behavior

CK-12 Core Content Reading
YOU DO NOT NEED AN ACCOUNT TO ACCESS READINGS

- Wave Interactions
- Wave Interference
- Standing Waves
- Sound in a Tube
- Intensity and Loudness of Sound
- Doppler Effect
- Digital Transmission

Readings & Articles

- Wave Interference
- Behavior of sound waves
- The physics of musical instruments

Videos & Animations

- Wave Properties
- Sound: Crash Course Physics #18
- Bragg's Peaks - Explain wrksht part or 5E
- Explanation of Bragg Peak part of 5E
- Doppler Effect Student Notes Taking
- Sound: Diffraction and Interference + Note Taking
- Light: Polarization
- Light: Diffraction and Interference
- Wave Particle Duality - Dr. Q goes w/ 5E
- Interference
- Standing Waves
- Virtual oscilloscope

Simulations & Interactives

- Doppler Ducks Sim
- Slinky Lab - Explore - Wave Particle Duality
- Standing waves
- Photoelectric Effect - Elaborate Doc
- Photoelectric Effect - Goo Draw it
- Picture of sound transmission
- Wave interference and beats

Phenomena & Data

- Laser Communicator - Engage goes w/ 5

Labs

- The Doppler Effect Lab
- Sound Interference and Diffraction Lab
- Doppler effect lab, handout and video
- Standing Wave lab

Project Ideas

- Guitar Design Project

Other Activities

- Student Practice
- Practice Problems
- Waves and Technology Unit from The Patterns Approach

Assessment Options & Performance Tasks

- Photoelectric Effect - Goo Draw it

Section 3: Electromagnetic Radiation Applications and Hazards

CK-12 Core Content Reading
YOU DO NOT NEED AN ACCOUNT TO ACCESS READINGS

- Electromagnetic Waves
- Electromagnetic Spectrum
- Wave-Particle Theory
- Photoelectric Effect
- Single Slit Diffraction
- Double Slit Diffraction

Readings & Articles

- Webb vs. Hubble Telescope
- Cell Phone Technology Reading
- (*Share your ideas!* *Submission Form*)

Videos & Animations

- Duality of light use CER graphic organizer with video
- Bragg's Peaks - Explain wrksht part or 5E
- Explanation of Bragg Peak part of 5E

Simulations & Interactives

- Black Body Radiation
- Virtual oscilloscope

Phenomena & Data

- Leaves separate from UV

Labs

- EM Spectrum lab

Other Activities

- Explore Particle nature: Materials, Procedure
- Explain: Bragg's Peaks
- Waves and Technology Unit from The Patterns Approach