Unit 13: Waves and Optics – Wave Motion and Sound

OBJECTIVES:

Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

Enduring Understanding 6.A: A wave is a traveling disturbance that transfers energy and momentum.

Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal.

a. Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves.

b. Electromagnetic waves are transverse waves.

c. Transverse waves may be polarized.

Learning Objective 6.A.1.1: The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave.

Learning Objective 6.A.1.2: The student is able to describe representations of transverse and longitudinal waves.

Learning Objective 6.A.1.3: The student is able to analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation.

Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.

Learning Objective 6.A.2.1: The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.

Learning Objective 6.A.2.2: The student is able to contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation.

Essential Knowledge 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.

Learning Objective 6.A.3.1: The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.

Essential Knowledge 6.A.4: Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves.

Learning Objective 6.A.4.1: The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.

Enduring Understanding 6.B: A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed and energy.

Essential Knowledge 6.B.1: For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.

Learning Objective 6.B.1.1: The student is able to use a graphical representation of a periodic mechanical wave (position vs. time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.

Essential Knowledge 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave.

Learning Objective 6.B.2.1: The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.

Essential Knowledge 6.B.3: A simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave.

Learning Objective 6.B.3.1: The student is able to construct an equation relating the wavelength and amplitude of a wave from a graphical representation of the electric or magnetic field value as a function of position at a given time instant and vice versa, or construct an equation relating the frequency or period and amplitude of a wave from a graphical representation of the electric or magnetic field value at a given position as a function of time and vice versa. [1]

Essential Knowledge 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency.

Learning Objective 6.B.4.1: The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.

Essential Knowledge 6.B.5: The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.

Learning Objective 6.B.5.1: The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.

Enduring Understanding 6.C: Only waves exhibit interference and diffraction.

Essential Knowledge 6.C.1: When two waves cross, they travel through each other; they do not bounce off each other. Where the waves overlap, the resulting displacement can be determined by adding the displacements of the two waves. This is called superposition.

Learning Objective 6.C.1.1: The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves.

Learning Objective 6.C.1.2: The student is able to construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition.

Enduring Understanding 6.D: Interference and superposition lead to standing waves and beats.

Essential Knowledge 6.D.1: Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition.

[1] We will deal with this conceptually here and relate it to the electric and magnetic fields of electromagnetic radiation in the next unit.

Learning Objective 6.D.1.1: The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.

Learning Objective 6.D.1.2: The student is able to design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves).

Learning Objective 6.D.1.3: The student is able to design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium.

Essential Knowledge 6.D.2: Two or more traveling waves can interact in such a way as to produce amplitude variations in the resultant wave.

Learning Objective 6.D.2.1: The student is able to analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes.

Essential Knowledge 6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string and sound waves in both closed and open tubes.

Learning Objective 6.D.3.1: The student is able to refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively.

Learning Objective 6.D.3.2: The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.

Learning Objective 6.D.3.3: The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air.

Learning Objective 6.D.3.4: The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.

Essential Knowledge 6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.

a. A standing wave with zero amplitude at both ends can only have certain wavelengths. Examples should include fundamental frequencies and harmonics.

b. Other boundary conditions or other region sizes will result in different sets of possible wavelengths.

Learning Objective 6.D.4.1: The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.

Learning Objective 6.D.4.2: The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.

Essential Knowledge 6.D.5: Beats arise from the addition of waves of slightly different frequency.
a. Because of the different frequencies, the two waves are sometimes in phase and sometimes out of phase. The resulting regularly spaced amplitude changes are called beats. Examples should include the tuning of an instrument.
b. The beat frequency is the difference in frequency between the two waves.
Learning Objective 6.D.5.1: The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.

PROCEDURE

I. Lesson 1: Wave Motion Introduction

- Notes: Roman numeral I up to IE
- Homework 1: Chapter 16 Conceptual Questions 1 – 12 and Problems 1 – 5

II. Lesson 2: Wave Propagation and other Miscellaneous Stuffs

- Notes: Finish roman numeral I
- Homework 2: Chapter 16 Conceptual Questions 14, 16, 18 – 20 and Problems 48, 53 and Chapter 24 Conceptual Questions 1, 6, 11

III. Lesson 3: Superposition and Standing Waves on Strings

- Notes: Roman numeral II through II.C.3 (stopping at longitudinal waves)
- Homework 3: Chapter 17 Conceptual Questions 1, 2, 8 – 10 and Problems 1 – 3, 24, 25, 59

IV. Lesson 4: Standing Longitudinal Waves in Pipes

- Notes: Finish
- Homework 4: Chapter 17 Conceptual Questions 12 – 15 and Problems 34 – 37, 39, 61