The Physics of Music

Course Information

Grade(s):	11, 12
Discipline/Course:	Science/Physics of Music
Course Title:	Physics of Music
Prerequisite(s):	Algebra 1
Course Description: *Program of Studies*	This course explores the science behind sound and music, from wave generation, to acoustics, to harmonies and instrumentations. As a final project, students will be tasked with creating their own instruments and composing music, then interpreting the sounds heard by an audience due to the acoustics of an area. Digital and analog recording and hearing will also be investigated.
Course Essential Questions:	How are specific sounds created by one or more instruments? How does an environment manipulate the way sounds are heard by an observer? How are sounds recorded and replayed?
Course Enduring Understandings:	Sound is a mechanical wave that occurs due to energy passing through mediums as vibrations, the frequency and amount of energy in the wave determine the pitch and loudness. Waves can interfere or complement one another to create dissonance and harmony, and the acoustics of a space can cause waves to dissipate or reflect. Recordings can be digital or analog, which vary in sound quality.
Duration:	Half year/0.5 credit
Course Materials/ Resources:	N/A

FPS Course Academic Expectation(s):	Creating and Constructing Using Communication (Media) Tools

Unit Number and Title:	Unit 1: *Introduction to Mechanical Waves & Sound*
Duration:	Approximately 5-6 weeks
Resource(s):	N/A
Unit Overview:	This unit will investigate mechanical waves and their properties (wavelength, frequency, speed, pitch and loudness) along with how waves are generated through energy transfer. Wave phenomena in the context of music will also be explored with concepts including doppler effect, reflection, refraction, interference and harmonies.
Learning Goals	
Standard(s):	**Scientific and Engineering Practices: (Highlighted Practices are Priority)** **Asking Questions**, Engaging in Argument from Evidence, Construction Explanations & Designing Solutions, **Developing & Using Models**, Obtaining, Evaluating & Communicating Information, Analyzing & Interpreting Data, **Using Mathematics and Computational Thinking** **Disciplinary Core Ideas:** **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-PS3-2) At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. **HS.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)

	Crosscutting Concepts: Patterns, Cause and Effect, Structure and Function,
Essential Question(s):	How do mechanical waves form and behave? How does our interpretation of sound originate in mechanical waves?
Enduring Understanding(s):	Mechanical waves are energy moving through a medium in the form of vibrations which can be interpreted as sound. Frequency of a wave determines pitch, which is unaffected by medium. Waves can be generated to create different tones and pitches depending on the instrument used to propagate the wave. An instrument is considered in tune when there is an absence of audible beats compared to a known tone.
Learning Goal(s): *Students will be able to use their learning to:*	**During this unit, students will meet the following Performance Expectations:** Develop models using computational thinking to demonstrate the relationship between frequency, wavelength, and speed of a wave, as well as the impacts of two or more sound waves interfering. HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. Utilize concepts of wave behavior to create questions and predict the impact of the environment on a sound wave's generation and transmission. **During this unit, students will be working towards the following NGSS Performance Expectations:** 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 motion of particles (objects) and energy associated with the relative positions of particles (objects).

Unit Number and Title:	Unit 2: *Instrumental Structure*
Duration:	Approximately 5-6 weeks
Resource(s):	N/A
Unit Overview:	This unit will explore how the structure of instruments match their function. Instruments explored will include string instruments, vocal chords, open-ended pipes, and closed-ended pipes. Harmonics, scales, resonance, dissonance, and timbre (why the same note will sound different on different instruments) for each type of instrument will be researched.
Learning Goals	
Standard(s):	**Scientific and Engineering Practices: (Highlighted Practices are Priority)** Asking Questions, **Planning and Carrying Out Investigations**, **Engaging in Argument from Evidence**, Construction Explanations & Designing Solutions, Developing & Using Models, **Obtaining, Evaluating & Communicating Information**, Analyzing & Interpreting Data **Disciplinary Core Ideas:** **HS.PS4.A: Wave Properties** 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.) (HS-PS4-3) **CCCs: Patterns; Structure and Function; Scale, Proportion, and Quantity**
Essential Question(s):	How do instruments make a variety of sounds and how are those sounds described? How do combinations of instruments create harmonies?

Enduring Understanding(s):	Timbre allows instruments playing the same note to be differentiated from one another. Instruments create harmonies by utilizing notes that complement one another's frequencies.
Learning Goal(s): *Students will be able to use their learning to:*	**During this unit, students will meet the following Performance Expectations:** Students will obtain, evaluate, and communicate information analyzing a family of instruments and their specific sound properties.

Unit Number and Title:	Unit 3: *Recording, Hearing, and Acoustics*
Duration:	Approximately 5-6 weeks
Resource(s):	N/A
Unit Overview:	How do we hear music? This unit will cover the physics of hearing, the structure of the ear, and how hearing loss can occur. Recording music will also be covered, including how music is recorded via analog and digital means, how microphones, speakers, and electric instruments operate, and how acoustics can be utilized for a more pleasant recording/listening experience. Physics of hearing ○ Structure of the ear and energy/wave transfer during hearing ○ Hearing loss ○ Analog and Digital Recording ○ Microphones, speakers, electric instruments ○ Acoustics
Learning Goals	
Standard(s):	**Scientific and Engineering Practices: (Highlighted Practices are Priority)** Asking Questions, **Planning and Carrying Out Investigations**, **Engaging in Argument from Evidence**, **Construction Explanations & Designing Solutions**, **Developing & Using Models**, **Obtaining, Evaluating & Communicating Information**, Analyzing & Interpreting Data **Disciplinary Core Ideas:** **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)

	PS4.A 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.) 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 producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5) 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),(HSPS4-5) **CCCs: Patterns; Structure and Function; Scale, Proportion, and Quantity**
Essential Question(s):	How do we hear music? How do we record music? How do acoustics of a space impact sound quality?
Enduring Understanding(s):	The inner ear utilizes the energy in waves to create electrical signals in our brains that we interpret as sounds. Recorded music can be done in either analog or digital, with digital technologies utilizing computational functions that are now close to their smoother analog counterparts. The materials and shape of materials have a direct impact on sound wave behavior, creating beneficial or detrimental results in terms of sound quality.

Learning Goal(s): *Students will be able to use their learning to:*	**During this unit, students will meet the following Performance Expectations:** Students will be able to determine if a space is suitable for recording or performance and construct an explanation as to why utilizing their observations of patterns in acoustical spaces. Students will be able to explain the process of sound entering the ear through its interpretation as sound. Students will compare digital and analog recordings, create their own recordings, and describe each process. **During this unit, students will be working towards the following NGSS Performance Expectations:** **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. **HS-PS4-2**: Evaluate questions about the advantages of using digital transmission and storage of information. **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.

Unit Number and Title:	Unit 4: *Culminating Experience & Final Project*
Duration:	Approximately 2 weeks
Resource(s):	N/A
Unit Overview:	Create an instrument, analyze the sounds it creates, then perform a piece and explain how the acoustics of the location could be improved.
Learning Goals	
Standard(s):	**Scientific and Engineering Practices: (Highlighted Practices are Priority)** Asking Questions, **Planning and Carrying Out Investigations**, Engaging in Argument from Evidence, **Construction Explanations & Designing Solutions**, **Developing & Using Models**, **Obtaining, Evaluating & Communicating Information, Analyzing & Interpreting Data** **Disciplinary Core Ideas:** **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. (HS-ETS1-1) **ETS1.B:** Developing Possible Solutions When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) **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)

	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 **CCCs: Patterns; Structure and Function; Scale, Proportion, and Quantity**
Essential Question(s):	How are instruments created and improved upon?
Enduring Understanding(s):	Sound is a mechanical wave that occurs due to energy passing through mediums as vibrations, the frequency and amount of energy in the wave determine the pitch and loudness. Waves can interfere or complement one another to create dissonance and harmony, and the acoustics of a space can cause waves to dissipate or reflect. Recordings can be digital or analog, which vary in sound quality
Learning Goal(s): *Students will be able to use their learning to:*	**During this unit, students will meet the following NGSS Performance Expectations:** Demonstrate mastery of previous performance expectations through a culminating engineering and analysis task. Students will create an instrument, analyze the sounds it creates, then perform a piece and explain how the acoustics of the location could be improved.