Wave Model Applications

Curriculum Connections

ALBERTA, NORTHWEST TERRITORIES, NUNAVUT—Physics 20: Oscillatory Motion and Mechanical Waves

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics Curriculum Connections (Physics 20)
(2007, updated 2014)

Activity 1: Wave Interference

Unit D: Oscillatory Motion and Mechanical Waves

Specific Outcomes for Knowledge

20–D2.1k describe mechanical waves as particles of a medium that are moving in simple harmonic motion

20–D2.3k define longitudinal and transverse waves in terms of the direction of motion of the medium particles in relation to the direction of propagation of the wave

20–D2.4k define the terms wavelength, wave velocity, period, frequency, amplitude, wave front and ray as they apply to describing transverse and longitudinal waves

20-D2.8k explain, qualitatively, the conditions for constructive and destructive interference of waves and for acoustic resonance

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

20–D2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- *predict the conditions required for constructive and destructive interference to occur* **(IP–NS3)**

Performing and Recording

20–D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- draw wave-front and ray diagrams **(PR–NS4)**
- draw a wave-front diagram of a two-point source interference pattern **(PR–NS4)**
- perform an experiment to illustrate the phenomenon of acoustic resonance **(PR–NS3)**

Analyzing and Interpreting

20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Communication and Teamwork

20–D2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *use scientific vocabulary and principles in everyday discussions*
- *recognize that many careers require science- and technology-related knowledge and skills*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*
- *be attentive when others speak, seek the point of view of others, and consider a multitude of perspectives*
- *use appropriate communication technology to elicit feedback from others*

Activity 2: Applications of Sound Waves

Unit D: Oscillatory Motion and Mechanical Waves

Specific Outcomes for Knowledge

20–D1.1k describe oscillatory motion in terms of period and frequency

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

20–D1.1sts explain that the goal of science is knowledge about the natural world **(NS1)**

- *analyze, qualitatively, the forces in real-life examples of simple harmonic motion:*
  - *action of springs in vehicle suspensions*
  - *mechanical resonance in cars, bridges and buildings*
  - *seismic waves in Earth's crust*

Specific Outcomes for Skills (Nature of Science Emphasis)

Analyzing and Interpreting

20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Communication and Teamwork

20–D1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Specific Outcomes for Knowledge

20–D2.1k describe mechanical waves as particles of a medium that are moving in simple harmonic motion

20–D2.3k define longitudinal and transverse waves in terms of the direction of motion of the medium particles in relation to the direction of propagation of the wave

20–D2.4k define the terms wavelength, wave velocity, period, frequency, amplitude, wave front and ray as they apply to describing transverse and longitudinal waves

20-D2.6k predict, quantitatively, and verify the effects of changing one or a combination of variables in the universal wave equation ($v = f\lambda$)

20-D2.7k explain, qualitatively, the phenomenon of reflection as exhibited by mechanical waves

20-D2.8k explain, qualitatively, the conditions for constructive and destructive interference of waves and for acoustic resonance

Specific Outcomes for Science, Technology and Society (STS) (Science and Technology Emphasis)

20–D2.1sts explain that the goal of technology is to provide solutions to practical problems **(ST1) [ICT F2–4.4, F2–4.8]**

- *investigate the application of acoustic phenomena in recreation, medicine, industry and technology (sonography, ultrasound, sonar, pipe organs, wind and brass instruments, noise-reduction devices, noise-measurement devices)*
- *describe the properties of waves that can be used to manipulate direction and speed when travelling (surfing, canoeing or kayaking) in rivers or oceans*

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

20–D2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

Performing and Recording

20–D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

Analyzing and Interpreting

20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- determine the speed of a mechanical wave; e.g., *water waves and sound waves* **(PR–NS2)**
- *relate apparent changes in wavelength and frequency to the speed of the source relative to the observer* **(AI–NS2) [ICT C7–4.2]**

Communication and Teamwork

20–D2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions (CT–NS2)

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields

- *research the answers to questions they generate*
- *use scientific vocabulary and principles in everyday discussions*
- *recognize that many careers require science- and technology-related knowledge and skills*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas

- *provide the same attention and energy to the group's product as they would to a personal assignment*
- *be attentive when others speak, seek the point of view of others, and consider a multitude of perspectives*
- *use appropriate communication technology to elicit feedback from others*

Activity 3: Investigating Earthquakes

Unit D: Oscillatory Motion and Mechanical Waves

Specific Outcomes for Knowledge

20–D1.1k describe oscillatory motion in terms of period and frequency

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

20–D1.1sts explain that the goal of science is knowledge about the natural world **(NS1)**

- *analyze, qualitatively, the forces in real-life examples of simple harmonic motion:*
  - *action of springs in vehicle suspensions*
  - *mechanical resonance in cars, bridges and buildings*
  - *seismic waves in Earth's crust*

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

20–D1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- predict the conditions required for mechanical resonance **(IP–NS3)**

Performing and Recording

20–D1.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

Analyzing and Interpreting

20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Communication and Teamwork

20–D1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Specific Outcomes for Knowledge

20–D2.1k describe mechanical waves as particles of a medium that are moving in simple harmonic motion

20–D2.3k define longitudinal and transverse waves in terms of the direction of motion of the medium particles in relation to the direction of propagation of the wave

20–D2.4k define the terms wavelength, wave velocity, period, frequency, amplitude, wave front and ray as they apply to describing transverse and longitudinal waves

20-D2.6k predict, quantitatively, and verify the effects of changing one or a combination of variables in the universal wave equation ($v = f\lambda$)

20–D2.8k explain, qualitatively, the conditions for constructive and destructive interference of waves and for acoustic resonance

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

20–D2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- *predict the conditions required for constructive and destructive interference to occur* **(IP–NS3)**

Analyzing and Interpreting

20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- determine the speed of a mechanical wave; e.g., *water waves and sound waves* **(PR–NS2)**

Communication and Teamwork

20–D2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields

- *research the answers to questions they generate*
- *use scientific vocabulary and principles in everyday discussions*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *explore where further science- and technology-related studies and careers can be pursued*
- *recognize that many careers require science- and technology-related knowledge and skills*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *recognize the contribution of science and technology to the progress of civilizations*
- *show support for the development of technologies and science as they relate to human needs*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*
- *be attentive when others speak, seek the point of view of others, and consider a multitude of perspectives*

Stewardship

demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment; *e.g.,*

- *discuss both the positive and negative effects of environmental changes caused by nature and by humans on human beings and society*

Activity 4: How Do We Hear?

Unit D: Oscillatory Motion and Mechanical Waves

Specific Outcomes for Knowledge

20–D1.1k describe oscillatory motion in terms of period and frequency

20-1.5k define mechanical resonance

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

20–D1.1sts explain that the goal of science is knowledge about the natural world **(NS1)**

- *analyze, qualitatively, the forces in real-life examples of simple harmonic motion:*
  - *action of springs in vehicle suspensions*
  - *mechanical resonance in cars, bridges and buildings*
  - *seismic waves in Earth's crust*
- *relate the fundamental frequency and amplitude of a vibrating drum membrane to its properties*

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

20–D1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- design an experiment to demonstrate that simple harmonic motion can be observed within certain limits, relating the frequency and period of the motion to the physical characteristics of the system; *e.g., a frictionless horizontal mass-spring system or a pendulum* **(IP–NS2)**

Performing and Recording

20–D1.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

Analyzing and Interpreting

20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Communication and Teamwork

20–D1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Specific Outcomes for Knowledge

20-D2.3k define longitudinal and transverse waves in terms of the direction of motion of the medium particles in relation to the direction of propagation of the wave

20–D2.4k define the terms wavelength, wave velocity, period, frequency, amplitude, wave front and ray as they apply to describing transverse and longitudinal waves

20–D2.6k predict, quantitatively, and verify the effects of changing one or a combination of variables in the universal wave equation ($v = f\lambda$)

20-D2.7k explain, qualitatively, the phenomenon of reflection as exhibited by mechanical waves

20–D2.8k explain, qualitatively, the conditions for constructive and destructive interference of waves and for acoustic resonance

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

20–D2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- *predict the conditions required for constructive and destructive interference to occur* **(IP–NS3)**

Performing and Recording

20–D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- perform an experiment to illustrate the phenomenon of acoustic resonance **(PR–NS3)**

Analyzing and Interpreting

20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- determine the speed of a mechanical wave; e.g., *water waves and sound waves* **(PR–NS2)**

Communication and Teamwork

20–D2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *use scientific vocabulary and principles in everyday discussions*
- *be interested in science and technology topics not directly related to their formal studies*
- *recognize the importance of making connections among various science disciplines*

- *explore where further science- and technology-related studies and careers can be pursued*
- *recognize that many careers require science- and technology-related knowledge and skills*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *recognize the contribution of science and technology to the progress of civilizations*
- *show support for the development of technologies and science as they relate to human needs*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *appreciate how scientific problem solving and the development of new technologies are related*
- *assess, critically, their opinion of the value of science and its applications*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*
- *be attentive when others speak, seek the point of view of others, and consider a multitude of perspectives*

Safety

show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information*; e.g.,*

- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials according to safety guidelines*
- *seek assistance immediately for any first-aid concerns, such as cuts, burns or unusual reactions*

Activity 5: Exploring Gravitational Waves

Unit D: Oscillatory Motion and Mechanical Waves

Specific Outcomes for Knowledge

20–D1.1k describe oscillatory motion in terms of period and frequency

Specific Outcomes for Skills (Nature of Science Emphasis)

Analyzing and Interpreting

20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Specific Outcomes for Knowledge

20–D2.3k define longitudinal and transverse waves in terms of the direction of motion of the medium particles in relation to the direction of propagation of the wave

20–D2.4k define the terms wavelength, wave velocity, period, frequency, amplitude, wave front and ray as they apply to describing transverse and longitudinal waves

20–D2.6k predict, quantitatively, and verify the effects of changing one or a combination of variables in the universal wave equation ($v = f\lambda$)

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

20–D2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

Analyzing and Interpreting

20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *use scientific vocabulary and principles in everyday discussions*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *be interested in science and technology topics not directly related to their formal studies*
- *explore where further science- and technology-related studies and careers can be pursued*
- *recognize that many careers require science- and technology-related knowledge and skills*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*

Safety

show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information*; e.g.,*

- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *seek assistance immediately for any first-aid concerns, such as cuts, burns or unusual reactions*

Design Challenge: Resisting Earthquakes with Engineering

Unit D: Oscillatory Motion and Mechanical Waves

Specific Outcomes for Knowledge

20–D1.4k determine, quantitatively, the relationships among kinetic, gravitational potential and total mechanical energies of a mass executing simple harmonic motion

20–D1.5k define mechanical resonance

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

20–D1.1sts explain that the goal of science is knowledge about the natural world **(NS1)**

- *analyze, qualitatively, the forces in real-life examples of simple harmonic motion:*
  - *action of springs in vehicle suspensions*
  - *mechanical resonance in cars, bridges and buildings*
  - *seismic waves in Earth's crust*

Specific Outcomes for Skills (Nature of Science Emphasis)

Communication and Teamwork

20–D1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Specific Outcomes for Knowledge

20–D2.1k describe mechanical waves as particles of a medium that are moving in simple harmonic motion

20–D2.3k define longitudinal and transverse waves in terms of the direction of motion of the medium particles in relation to the direction of propagation of the wave

20–D2.4k define the terms wavelength, wave velocity, period, frequency, amplitude, wave front and ray as they apply to describing transverse and longitudinal waves

20–D2.8k explain, qualitatively, the conditions for constructive and destructive interference of waves and for acoustic resonance

Specific Outcomes for Science, Technology and Society (STS) (Science and Technology Emphasis)

20–D2.1sts explain that the goal of technology is to provide solutions to practical problems **(ST1) [ICT F2–4.4, F2–4.8]**

Specific Outcomes for Skills (Nature of Science Emphasis)

Performing and Recording

20–D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

Analyzing and Interpreting

20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Communication and Teamwork

20–D2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *use scientific vocabulary and principles in everyday discussions*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *be interested in science and technology topics not directly related to their formal studies*

- *recognize the importance of making connections among various science disciplines*
- *maintain interest in pursuing further studies in science*
- *explore where further science- and technology-related studies and careers can be pursued*
- *recognize that many careers require science- and technology-related knowledge and skills*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *recognize the contribution of science and technology to the progress of civilizations*
- *show support for the development of technologies and science as they relate to human needs*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *appreciate how scientific problem solving and the development of new technologies are related*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*
- *seek new models, explanations and theories when confronted with discrepant events*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*
- *be attentive when others speak, seek the point of view of others, and consider a multitude of perspectives*

Safety

show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information*; e.g.,*

- *consider safety a positive limiting factor in scientific and technological endeavours*
- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials according to safety guidelines*
- *seek assistance immediately for any first-aid concerns, such as cuts, burns or unusual reactions*
- *keep the work station uncluttered, ensuring that only appropriate laboratory materials are present*
- *criticize a procedure, a design or materials that are not safe or that could have a negative impact on the environment*

Wave Model Applications

Curriculum Connections

BRITISH COLUMBIA AND YUKON—Physics 11 and Earth Sciences 11

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Physics 11 and Earth Sciences 11 Curriculum Connections
(June 2018)

Activity 1: Wave Interference

Curricular Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies

Construct, analyze, and interpret graphs, models, and/or diagrams

- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Connect scientific explorations to careers in science

Applying and innovating

- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon

Big Ideas—Elaborations

- **waves:**
  - What are the factors that affect wave behaviours?
  - How would you investigate the relationships between the properties of a wave and properties of the medium?

Curriculum Competencies—Elaborations

- **Communicating:**
  - Create a model that demonstrates constructive and destructive interference of waves

Physics 11 Content

- generation and **propagation of waves**
- **properties and behaviours** of waves

Activity 2: Applications of Sound Waves

Curricular Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)
- Assess risks and address ethical, cultural, and/or environmental issues associated with their proposed methods
- Use appropriate SI units and appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Describe specific ways to improve their investigation methods and the quality of their data
- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Consider the changes in knowledge over time as tools and technologies have developed
- Connect scientific explorations to careers in science
- Consider social, ethical, and environmental implications of the findings from their own and others' investigations
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

Big Ideas—Elaborations

- **waves:**
  - Sample questions to support inquiry with students:
  - What are the factors that affect wave behaviours?
  - How would you investigate the relationships between the properties of a wave and properties of the medium?

Curriculum Competencies—Elaborations

- **Questioning and predicting:**
  - Observe waves in natural settings (e.g., lakes, oceans, rivers)
- **Evaluating:**
  - Consider the social and environmental implications of noise pollution generated by sources such as ear buds, cell phones, or sporting events
- **Processing and analyzing data and information:**
  - Identify wave behaviour patterns in mediums with different properties (e.g., material, fixed/open-end, densities)

Physics 11—Content

- generation and **propagation of waves**
- **properties and behaviours** of waves
- **characteristics** of sound
- resonance and **frequency** of sound
- **graphical methods** in physics

Earth Science 11—Content

- **properties of the ocean and the ocean floor**

Activity 3: Investigating Earthquakes

Curricular Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world
- Formulate multiple hypothesises and predict multiple outcomes

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)
- Use appropriate SI units and appropriate equipment, including digital technologies, to systematically and accurately collect and record data
- Apply the concepts of accuracy and precision to experimental procedures and data:
  - significant figures

Processing and analyzing data and information

- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information
- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Describe specific ways to improve their investigation methods and the quality of their data
- Consider the changes in knowledge over time as tools and technologies have developed
- Consider social, ethical, and environmental implications of the findings from their own and others' investigations
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Contribute to finding solutions to problems at a local and/or global level through inquiry
- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

Big Ideas—Elaborations

- **waves:**
  - What are the factors that affect wave behaviours?
  - How would you investigate the relationships between the properties of a wave and properties of the medium?

Curriculum Competencies—Elaborations

- **Processing and analyzing data and information:**
  - Identify wave behaviour patterns in mediums with different properties (e.g., material, fixed/open-end, densities)

- **Evaluating:**
  - Consider the social and environmental implications of noise pollution generated by sources such as ear buds, cell phones, or sporting events

Physics 11—Content

- generation and **propagation of waves**
- **properties and behaviours** of waves
- **graphical methods** in physics

Activity 4: How Do We Hear?

Curricular Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world
- Formulate multiple hypotheses and predict multiple outcomes

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)
- Assess risks and address ethical, cultural, and/or environmental issues associated with their proposed methods

Processing and analyzing data and information

- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

Big Ideas—Elaborations

- **waves:**
  - What are the factors that affect wave behaviours?
  - How can you determine which harmonics are audible in different musical instruments?

Curriculum Competencies—Elaborations

- **Planning and conducting:**
  - What data are needed to determine the speed of sound in air?
- **Processing and analyzing data and information:**
  - Identify wave behaviour patterns in mediums with different properties (e.g., material, fixed/open-end, densities)
- **Evaluating:**
  - Consider the social and environmental implications of noise pollution generated by sources such as ear buds, cell phones, or sporting events

Physics 11—Content

- generation and **propagation of waves**
- **properties and behaviours** of waves
- **characteristics** of sound
- resonance and **frequency** of sound

Activity 5: Exploring Gravitational Waves

Curricular Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world
- Formulate multiple hypotheses and predict multiple outcomes

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Connect scientific explorations to careers in science

Applying and innovating

- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

Big Ideas—Elaborations

- **waves:**
  Sample questions to support inquiry with students:
  - What are the factors that affect wave behaviours?
  - How would you investigate the relationships between the properties of a wave and properties of the medium?

Curriculum Competencies—Elaborations

- **Processing and analyzing data and information:**
  - Identify wave behaviour patterns in mediums with different properties (e.g., material, fixed/open-end, densities)

Physics 11—Content

- generation and **propagation of waves**
- **properties and behaviours** of waves
- **graphical methods** in physics

Design Challenge: Resisting Earthquakes with Engineering

Curricular Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Formulate multiple hypotheses and predict multiple outcomes

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)
- Assess risks and address ethical, cultural, and/or environmental issues associated with their proposed methods

Processing and analyzing data and information

- Experience and interpret the local environment
- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information
- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies

- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions
- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Co-operatively design projects with local and/or global connections and applications
- Contribute to finding solutions to problems at a local and/or global level through inquiry
- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

Big Ideas—Elaborations

- **waves:**
  Sample questions to support inquiry with students:
  - What are the factors that affect wave behaviours?
  - How would you investigate the relationships between the properties of a wave and properties of the medium?

Curriculum Competencies—Elaborations

- **Communicating:**
  - Create a model that demonstrates constructive and destructive interference of waves

Physics 11—Content

- horizontal **uniform and accelerated motion**
- balanced and unbalanced **forces in systems**
- **properties and behaviours** of waves
- **graphical methods** in physics

Wave Model Applications

Curriculum Connections

MANITOBA—Senior 3 Physics: Waves

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Senior 3 Physics Curriculum Connections
(2003)

Activity 1: Wave Interference

Skills and Attitudes Outcomes

S3P-0-2F Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4c Demonstrate confidence in their ability to carry out investigations in science and to address STSE issues.

S3P-0-4e Demonstrate a continuing and more informed interest in science and science-related issues.

Topic 1.1: Waves in One Dimension

Specific Learning Outcomes

S3P-1-01 Describe a wave as a transfer of energy.
Include: medium, mechanical wave, pulse, periodic wave

S3P-1-02 Describe, demonstrate, and diagram the characteristics of transverse and longitudinal waves.
Include: crest, trough, amplitude, wavelength, compression, rarefaction

S3P-1-03 Compare and contrast the frequency and period of a periodic wave.
Include: $T = 1 / f$

S3P-1-05 Describe, demonstrate, and diagram the transmission and reflection of waves travelling in one dimension.
Include: free and fixed ends, different media

S3P-1-06 Use the principle of superposition to illustrate graphically the result of combining two waves.
Include: constructive and destructive interference, nodes, antinodes, standing waves

Topic 1.3: Sound

Specific Learning Outcomes

S3P-1-17 Investigate to analyze and explain how sounds are produced, transmitted, and detected, using examples from nature and technology.

S3P-1-18 Use the decision-making process to analyze an issue related to noise in the environment.

S3P-1-20 Describe and explain in qualitative terms what happens when sound waves interact (interfere) with one another.
Include: production of beats

Activity 2: Applications of Sound Waves

Skills and Attitudes Outcomes

S3P-0-2F Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-2a Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4e Demonstrate a continuing and more informed interest in science and science-related issues.

Topic 1.1: Waves in One Dimension

Specific Learning Outcomes

S3P-1-01 Describe a wave as a transfer of energy.
Include: medium, mechanical wave, pulse, periodic wave

S3P-1-02 Describe, demonstrate, and diagram the characteristics of transverse and longitudinal waves.
Include: crest, trough, amplitude, wavelength, compression, rarefaction

S3P-1-04 Derive and solve problems, using the wave equation ($v = f\lambda$).

Topic 1.3: Sound

Specific Learning Outcomes

S3P-1-17 Investigate to analyze and explain how sounds are produced, transmitted, and detected, using examples from nature and technology.

S3P-1-18 Use the decision-making process to analyze an issue related to noise in the environment.

S3P-1-26 Describe the diverse applications of sound waves in medical devices, and evaluate the contribution to our health and safety of sound-wave-based technologies.

Activity 3: Investigating Earthquakes

Skills and Attitudes Outcomes

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4e Demonstrate a continuing and more informed interest in science and science-related issues.

Topic 1.1: Waves in One Dimension

Specific Learning Outcomes

S3P-1-01 Describe a wave as a transfer of energy.
Include: medium, mechanical wave, pulse, periodic wave

S3P-1-02 Describe, demonstrate, and diagram the characteristics of transverse and longitudinal waves.
Include: crest, trough, amplitude, wavelength, compression, rarefaction

S3P-1-06 Use the principle of superposition to illustrate graphically the result of combining two waves.
Include: constructive and destructive interference, nodes, antinodes, standing waves

Activity 4: How Do We Hear?

Skills and Attitudes Outcomes

S3P-0-2F Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4e Demonstrate a continuing and more informed interest in science and science-related issues.

Topic 1.1: Waves in One Dimension

Specific Learning Outcomes

S3P-1-01 Describe a wave as a transfer of energy.
Include: medium, mechanical wave, pulse, periodic wave

S3P-1-02 Describe, demonstrate, and diagram the characteristics of transverse and longitudinal waves.
Include: crest, trough, amplitude, wavelength, compression, rarefaction

S3P-1-03 Compare and contrast the frequency and period of a periodic wave.
Include: $T = 1 / f$

S3P-1-04 Derive and solve problems, using the wave equation ($v = f\lambda$).

S3P-1-05 Describe, demonstrate, and diagram the transmission and reflection of waves travelling in one dimension.
Include: free and fixed ends, different media

S3P-1-06 Use the principle of superposition to illustrate graphically the result of combining two waves.
Include: constructive and destructive interference, nodes, antinodes, standing waves

S3P-1-07 Investigate the historical development of a significant application of communications technology that uses waves.

Topic 1.3: Sound

Specific Learning Outcomes

S3P-1-17 Investigate to analyze and explain how sounds are produced, transmitted, and detected, using examples from nature and technology.

S3P-1-20 Describe and explain in qualitative terms what happens when sound waves interact (interfere) with one another.
Include: production of beats

S3P-1-21 Experiment to analyze the principle of resonance and identify the conditions required for resonance to occur.
Include: open- and closed-column resonant lengths

Activity 5: Exploring Gravitational Waves

Skills and Attitudes Outcomes

S3P-0-2F Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4c Demonstrate confidence in their ability to carry out investigations in science and to address STSE issues.

S3P-0-4e Demonstrate a continuing and more informed interest in science and science-related issues.

Topic 1.1: Waves in One Dimension

Specific Learning Outcomes

S3P-1-01 Describe a wave as a transfer of energy.
Include: medium, mechanical wave, pulse, periodic wave

S3P-1-02 Describe, demonstrate, and diagram the characteristics of transverse and longitudinal waves.
Include: crest, trough, amplitude, wavelength, compression, rarefaction

S3P-1-04 Derive and solve problems, using the wave equation ($v = f\lambda$).

S3P-1-07 Investigate the historical development of a significant application of communications technology that uses waves.

Topic 1.2: Waves in Two Dimensions

S3P-1-08 Describe and give examples of two-dimensional waves.

Design Challenge: Resisting Earthquakes with Engineering

Skills and Attitudes Outcomes

S3P-0-2F Record, organize, and display data, using an appropriate format.
Include: labelled diagrams, tables, graphs

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4c Demonstrate confidence in their ability to carry out investigations in science and to address STSE issues.

S3P-0-4e Demonstrate a continuing and more informed interest in science and science-related issues.

S3P-0-2i Select and integrate information obtained from a variety of sources.
Include: print, electronic, and/or specialist sources, resource people

Topic 1.1: Waves in One Dimension

Specific Learning Outcomes

S3P-1-01 Describe a wave as a transfer of energy.
Include: medium, mechanical wave, pulse, periodic wave

S3P-1-02 Describe, demonstrate, and diagram the characteristics of transverse and longitudinal waves.
Include: crest, trough, amplitude, wavelength, compression, rarefaction

S3P-1-06 Use the principle of superposition to illustrate graphically the result of combining two waves.
Include: constructive and destructive interference, nodes, antinodes, standing waves

Wave Model Applications

Curriculum Connections

NEW BRUNSWICK—Physics 11: Waves

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

* Further curriculum connections can be made to Introduction to Physical Geography 110 and Physics 12 but that is beyond the scope of this particular chart.

Physics 11 Curriculum Connections
(Atlantic Canada Science Curriculum, 2003)

Activity 1: Wave Interference

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Social and Environmental Contexts of Science and Technology

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Analysing and Interpreting

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler effect

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Attitude Outcome Statements

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

438 value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds

Interest in Science

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 2: Applications of Sound Waves

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Social and Environmental Contexts of Science and Technology

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler effect

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Attitude Outcome Statements

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Interest in Science

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

446 have a sense of personal and shared responsibility for maintaining a sustainable environment

Activity 3: Investigating Earthquakes

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships Between Science and Technology

116-7 analyse natural and technological systems to interpret and explain their structure and dynamics

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

Attitude Outcome Statements

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

437 appreciate that the applications of science and technology can raise ethical dilemmas

Interest in Science

439 show a continuing and more informed curiosity and interest in science and science-related issues

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

447 project the personal, social, and environmental consequences of proposed action

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 4: How Do We Hear?

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Analysing and Interpreting

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler effect

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Attitude Outcome Statements

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

438 value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds

Interest in Science

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 5: Exploring Gravitational Waves

STSE

Relationships Between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Analysing and Interpreting

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-5 compare and describe the properties of electromagnetic radiation and sound

Attitude Outcome Statements

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Interest in Science

439 show a continuing and more informed curiosity and interest in science and science-related issues

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Design Challenge: Resisting Earthquakes with Engineering

STSE

Relationships Between Science and Technology

116-7 analyse natural and technological systems to interpret and explain their structure and dynamics

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Performing and Recording

213-7 select and integrate information from various print and electronic sources or from several parts of the same source

Analysing and Interpreting

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

Attitude Outcome Statements

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

437 appreciate that the applications of science and technology can raise ethical dilemmas

438 value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds

Interest in Science

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

447 project the personal, social, and environmental consequences of proposed action

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Wave Model Applications

Curriculum Connections

NEWFOUNDLAND AND LABRADOR—Physics 2204: Waves

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

* This compilation could be used to support outcomes in Earth Systems (ES3209), Unit 4.

Physics 2204 Curriculum Connections
(2018)

Activity 1: Wave Interference

Initiating and Planning

1.0 identify questions to investigate that arise from practical problems and issues [GCO 2]

Performing and Recording

6.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

Analyzing and Interpreting

17.0 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion [GCO 2]

Communication and Teamwork

22.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

25.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise [GCO 2]

Unit 4: Waves

Longitudinal and Transverse Waves

63.0 describe the characteristics of longitudinal and transverse waves [GCO 3]

Universal Wave Equation

64.0 apply the wave equation to explain and predict the behaviour of waves [GCO 3]

65.0 describe how sound, as a form of energy, is produced and transmitted [GCO 3]

Applications of Sound Waves

66.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

68.0 explain qualitatively and quantitatively the phenomena of wave interference, reflection, and diffraction [GCO 3]

68.1 explain qualitatively and quantitatively the phenomena of wave interference and reflection of sound

Activity 2: Applications of Sound Waves

Initiating and Planning

1.0 identify questions to investigate that arise from practical problems and issues [GCO 2]

4.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making [GCO 2]

Performing and Recording

6.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

7.0 use instruments effectively and accurately for collecting data [GCO 2]

8.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]

Analyzing and Interpreting

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]

17.0 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion [GCO 2]

Communication and Teamwork

22.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

24.0 develop, present, and defend a position or course of action, based on findings [GCO 2]

25.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise [GCO 2]

Unit 4: Waves

Longitudinal and Transverse Waves

63.0 describe the characteristics of longitudinal and transverse waves [GCO 3]

Universal Wave Equation

64.0 apply the wave equation to explain and predict the behaviour of waves [GCO 3]

65.0 describe how sound, as a form of energy, is produced and transmitted [GCO 3]

Applications of Sound Waves

66.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

68.0 explain qualitatively and quantitatively the phenomena of wave interference, reflection, and diffraction [GCO 3]

68.1 explain qualitatively and quantitatively the phenomena of wave interference and reflection of sound

Doppler Effect

70.0 explain qualitatively and quantitatively the Doppler-Fizeau effect [GCO 3]

Activity 3: Investigating Earthquakes

Initiating and Planning

1.0 identify questions to investigate that arise from practical problems and issues [GCO 2]

Performing and Recording

6.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

8.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]

Analyzing and Interpreting

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]

12.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]

17.0 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion [GCO 2]

Communication and Teamwork

22.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

Unit 4: Waves

Longitudinal and Transverse Waves

63.0 describe the characteristics of longitudinal and transverse waves [GCO 3]

Universal Wave Equation

64.0 apply the wave equation to explain and predict the behaviour of waves [GCO 3]

Applications of Sound Waves

66.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

Wave Refraction and Snell's Law

72.0 apply the laws of reflection and the laws of refraction to predict wave behaviour [GCO 3]

Activity 4: How Do We Hear?

Initiating and Planning

1.0 identify questions to investigate that arise from practical problems and issues [GCO 2]

4.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making [GCO 2]

Performing and Recording

6.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

7.0 use instruments effectively and accurately for collecting data [GCO 2]

8.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]

Analyzing and Interpreting

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]

17.0 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion [GCO 2]

18.0 construct and test a prototype of a device or system and troubleshoot problems as they arise [GCO 2]

Communication and Teamwork

22.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

25.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise [GCO 2]

Unit 4: Waves

Longitudinal and Transverse Waves

63.0 describe the characteristics of longitudinal and transverse waves [GCO 3]

Universal Wave Equation

64.0 apply the wave equation to explain and predict the behaviour of waves [GCO 3]

Applications of Sound Waves

66.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

Activity 5: Exploring Gravitational Waves

Initiating and Planning

1.0 identify questions to investigate that arise from practical problems and issues [GCO 2]

Performing and Recording

6.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

8.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]

Analyzing and Interpreting

17.0 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion [GCO 2]

Communication and Teamwork

22.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

Unit 4: Waves

Longitudinal and Transverse Waves

63.0 describe the characteristics of longitudinal and transverse waves [GCO 3]

Universal Wave Equation

64.0 apply the wave equation to explain and predict the behaviour of waves [GCO 3]

Applications of Sound Waves

66.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

Design Challenge: Resisting Earthquakes with Engineering

Initiating and Planning

1.0 identify questions to investigate that arise from practical problems and issues [GCO 2]

2.0 design an experiment identifying and controlling major variables [GCO 2]

3.0 identify the theoretical basis of an investigation and develop a prediction and a hypothesis that are consistent with the theoretical basis [GCO 2]

4.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making [GCO 2]

Performing and Recording

6.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

7.0 use instruments effectively and accurately for collecting data [GCO 2]

8.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]

9.0 use library and electronic research tools to collect information on a given topic [GCO 2]

Analyzing and Interpreting

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]

17.0 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion [GCO 2]

18.0 construct and test a prototype of a device or system and troubleshoot problems as they arise [GCO 2]

Communication and Teamwork

22.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

25.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise [GCO 2]

Unit 4: Waves

Longitudinal and Transverse Waves

63.0 describe the characteristics of longitudinal and transverse waves [GCO 3]

Universal Wave Equation

64.0 apply the wave equation to explain and predict the behaviour of waves [GCO 3]

Applications of Sound Waves

66.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

68.0 explain qualitatively and quantitatively the phenomena of wave interference, reflection, and diffraction [GCO 3]

Wave Model Applications

Curriculum Connections

NOVA SCOTIA—Physics 11: Waves

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics 11 Curriculum Connections
(2002)

Activity 1: Wave Interference

STSE

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Initiating and Planning

212-7 formulate operational definitions of major variables

Knowledge

327-1 describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves

327-2 apply the universal wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy transfer, are produced and transmitted

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

438 value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds

Interest in Science

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 2: Applications of Sound Waves

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Skills

Initiating and Planning

212-7 formulate operational definitions of major variables

Analysing and Interpreting

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves

327-2 apply the universal wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

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443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

446 have a sense of personal and shared responsibility for maintaining a sustainable environment

Activity 3: Investigating Earthquakes

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Initiating and Planning

212-4 design an experiment identifying and controlling major variables

212-7 formulate operational definitions of major variables

Performing and Recording

213-1 implement appropriate sampling procedures

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves

327-2 apply the universal wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

437 appreciate that the applications of science and technology can raise ethical dilemmas

Interest in Science

439 show a continuing and more informed curiosity and interest in science and science-related issues

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

447 project the personal, social, and environmental consequences of proposed action

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 4: How Do We Hear?

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Initiating and Planning

212-4 design an experiment identifying and controlling major variables

212-7 formulate operational definitions of major variables

Performing and Recording

213-1 implement appropriate sampling procedures

213-7 select and integrate information from various print and electronic sources or from several parts of the same source

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

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327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy transfer, are produced and transmitted

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Activity 5: Exploring Gravitational Waves

STSE

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Initiating and Planning

212-4 design an experiment identifying and controlling major variables

212-7 formulate operational definitions of major variables

Analysing and Interpreting

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Knowledge

327-1 describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves

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327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

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Collaboration

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Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Design Challenge: Resisting Earthquakes with Engineering

STSE

Social and Environmental Contexts of Science and Technology

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Initiating and Planning

212-4 design an experiment identifying and controlling major variables

212-7 formulate operational definitions of major variables

Performing and Recording

213-7 select and integrate information from various print and electronic sources or from several parts of the same source

Analysing and Interpreting

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327-1 describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves

327-2 apply the universal wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

437 appreciate that the applications of science and technology can raise ethical dilemmas

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444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

447 project the personal, social, and environmental consequences of proposed action

Safety in Science

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450 be aware of the direct and indirect consequences of their actions

Grade 11: Wave Model Applications

Curriculum Connections

ONTARIO - Waves and Sound

IP = Initiating and Planning, PR = Performing and Recording, AI = Analysing and Interpreting, C = Communicating

Physics Curriculum Connections (SPH3U)
Activity 1: Wave Interference
Scientific Investigation Skills and Career Exploration
– **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
– **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
– **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
– **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., zoologist, botanist, geneticist, ecologist, pharmacologist, farmer, forester, horticulturalist) and the education and training necessary for these careers
Waves and Sound
– **E1.1** analyse how properties of mechanical waves and sound influence the design of structures and technological devices (e.g., the acoustical design of a concert hall; the design of headphones, hearing aids, musical instruments, wave pools) [AI, C]
– **E1.2** analyse the negative impact that mechanical waves and/or sound can have on society and the environment, and assess the effectiveness of a technology intended to reduce this impact [AI, C]
– **E2.1** use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave*, *transverse wave*, *frequency*, *period*, *cycle*, *amplitude*, *phase*, *wavelength*, *velocity*, *superposition*, *constructive interference*, *destructive interference*, *standing waves*, and *resonance* [C]
– **E2.2** conduct laboratory inquiries or computer simulations involving mechanical waves and their interference (e.g., using a mass oscillating on a spring, a mass oscillating on a pendulum, the oscillation in a string instrument) [PR]
– **E3.3** explain and graphically illustrate the principle of superposition with respect to standing waves and beat frequencies
– **E3.6** explain selected natural phenomena (e.g., echo location, or organisms that produce or receive infrasonic, audible, or ultrasonic sound) with reference to the characteristics and properties of waves

Physics Curriculum Connections (SPH3U)

Activity 2: Applications of Sound Waves

Scientific Investigation Skills and Career Exploration

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.2** select appropriate instruments (e.g., sampling instruments, a microscope, a stethoscope, dissection instruments) and materials (e.g., dichotomous keys, computer simulations, plant cuttings), and identify appropriate methods, techniques, and procedures, for each inquiry [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.6** compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.11** communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models) [C]
- **A1.12** use appropriate numeric, symbolic, and graphic modes of representation (e.g., biological diagrams, Punnett squares), and appropriate units of measurement (e.g., SI and imperial units) [C]
- **A1.13** express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures [C]
- **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., zoologist, botanist, geneticist, ecologist, pharmacologist, farmer, forester, horticulturalist) and the education and training necessary for these careers

Waves and Sound

- **E1.2** analyse the negative impact that mechanical waves and/or sound can have on society and the environment, and assess the effectiveness of a technology intended to reduce this impact [AI, C]
- **E2.1** use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave*, *transverse wave*, *frequency*, *period*, *cycle*, *amplitude*, *phase*, *wavelength*, *velocity*, *superposition*, *constructive interference*, *destructive interference*, *standing waves*, and *resonance* [C]
- **E2.4** investigate the relationship between the wavelength, frequency, and speed of a wave, and solve related problems [PR, AI]
- **E2.5** analyse the relationship between a moving source of sound and the change in frequency perceived by a stationary observer (i.e., the Doppler effect) [AI]
- **E3.6** explain selected natural phenomena (e.g., echo location, or organisms that produce or receive infrasonic, audible, or ultrasonic sound) with reference to the characteristics and properties of waves

Physics Curriculum Connections (SPH3U)

Activity 3: Investigating Earthquakes

Scientific Investigation Skills and Career Exploration

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.6** compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams [PR]
- **A1.7** select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.12** use appropriate numeric, symbolic, and graphic modes of representation (e.g., biological diagrams, Punnett squares), and appropriate units of measurement (e.g., SI and imperial units) [C]
- **A1.13** express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures [C]

Waves and Sound

- **E1.1** analyse how properties of mechanical waves and sound influence the design of structures and technological devices (e.g., the acoustical design of a concert hall; the design of headphones, hearing aids, musical instruments, wave pools) [AI, C]
- **E1.2** analyse the negative impact that mechanical waves and/or sound can have on society and the environment, and assess the effectiveness of a technology intended to reduce this impact [AI, C]
- **E2.1** use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave*, *transverse wave*, *frequency*, *period*, *cycle*, *amplitude*, *phase*, *wavelength*, *velocity*, *superposition*, *constructive interference*, *destructive interference*, *standing waves*, and *resonance* [C]
- **E2.3** plan and conduct inquiries to determine the speed of waves in a medium (e.g., a vibrating air column, an oscillating string of a musical instrument), compare theoretical and empirical values, and account for discrepancies [IP, PR, AI, C]
- **E3.1** distinguish between longitudinal and transverse waves in different media, and provide examples of both types of waves
- **E3.5** explain the relationship between the speed of sound in various media and the particle nature of the media (e.g., the speed of sound in solids, liquids, and gases; the speed of sound in warm and cold air
- **E3.6** explain selected natural phenomena (e.g., echo location, or organisms that produce or receive infrasonic, audible, or ultrasonic sound) with reference to the characteristics and properties of waves

Physics Curriculum Connections (SPH3U)

Activity 4: How Do We Hear?

Scientific Investigation Skills and Career Exploration

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.2** select appropriate instruments (e.g., sampling instruments, a microscope, a stethoscope, dissection instruments) and materials (e.g., dichotomous keys, computer simulations, plant cuttings), and identify appropriate methods, techniques, and procedures, for each inquiry [IP]
- **A1.4** apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory and biological materials (e.g., preserved specimens); and by using appropriate personal protection [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.6** compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.12** use appropriate numeric, symbolic, and graphic modes of representation (e.g., biological diagrams, Punnett squares), and appropriate units of measurement (e.g., SI and imperial units) [C]
- **A1.13** express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures [C]
- **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., zoologist, botanist, geneticist, ecologist, pharmacologist, farmer, forester, horticulturalist) and the education and training necessary for these careers

Waves and Sound

- **E1.1** analyse how properties of mechanical waves and sound influence the design of structures and technological devices (e.g., the acoustical design of a concert hall; the design of headphones, hearing aids, musical instruments, wave pools) [AI, C]
- **E1.2** analyse the negative impact that mechanical waves and/or sound can have on society and the environment, and assess the effectiveness of a technology intended to reduce this impact [AI, C]
- **E2.1** use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave*, *transverse wave*, *frequency*, *period*, *cycle*, *amplitude*, *phase*, *wavelength*, *velocity*, *superposition*, *constructive interference*, *destructive interference*, *standing waves*, and *resonance* [C]
- **E2.2** conduct laboratory inquiries or computer simulations involving mechanical waves and their interference (e.g., using a mass oscillating on a spring, a mass oscillating on a pendulum, the oscillation in a string instrument) [PR]
- **E2.3** plan and conduct inquiries to determine the speed of waves in a medium (e.g., a vibrating air column, an oscillating string of a musical instrument), compare theoretical and empirical values, and account for discrepancies [IP, PR, AI, C]
- **E2.4** investigate the relationship between the wavelength, frequency, and speed of a wave, and solve related problems [PR, AI]
- **E2.6** predict the conditions needed to produce resonance in vibrating objects or air columns (e.g., in a wind instrument, a string instrument, a tuning fork), and test their predictions through inquiry [IP, PR, AI]
- **E2.7** analyse the conditions required to produce resonance in vibrating objects and/or in air columns (e.g., in a string instrument, a tuning fork, a wind instrument), and explain how resonance is used in a variety of situations (e.g., to produce different notes in musical instruments; to limit undesirable vibrations in suspension bridges; to design buildings so that they do not resonate at the frequencies produced by earthquakes) [AI, C]
- **E3.2** explain the components of resonance, and identify the conditions required for resonance to occur in vibrating objects and in various media (e.g., with reference to a musical instrument, a child on a swing, the Tacoma Narrows Bridge)
- **E3.3** explain and graphically illustrate the principle of superposition with respect to standing waves and beat frequencies
- **E3.4** identify the properties of standing waves, and, for both mechanical and sound waves, explain the conditions required for standing waves to occur
- **E3.6** explain selected natural phenomena (e.g., echo location, or organisms that produce or receive infrasonic, audible, or ultrasonic sound) with reference to the characteristics and properties of waves

Physics Curriculum Connections (SPH3U)

Activity 5: Exploring Gravitational Waves

Scientific Investigation Skills and Career Exploration

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.13** express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures [C]
- **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., zoologist, botanist, geneticist, ecologist, pharmacologist, farmer, forester, horticulturalist) and the education and training necessary for these careers

Waves and Sound

- **E2.1** use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave*, *transverse wave*, *frequency*, *period*, *cycle*, *amplitude*, *phase*, *wavelength*, *velocity*, *superposition*, *constructive interference*, *destructive interference*, *standing waves*, and *resonance* [C]
- **E2.4** investigate the relationship between the wavelength, frequency, and speed of a wave, and solve related problems [PR, AI]
- **E3.1** distinguish between longitudinal and transverse waves in different media, and provide examples of both types of waves
- **E3.6** explain selected natural phenomena (e.g., echo location, or organisms that produce or receive infrasonic, audible, or ultrasonic sound) with reference to the characteristics and properties of waves

Physics Curriculum Connections (SPH3U)

Design Challenge: Resisting Earthquakes with Engineering

Scientific Investigation Skills and Career Exploration

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.2** select appropriate instruments (e.g., sampling instruments, a microscope, a stethoscope, dissection instruments) and materials (e.g., dichotomous keys, computer simulations, plant cuttings), and identify appropriate methods, techniques, and procedures, for each inquiry [IP]
- **A1.3** identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately [IP]
- **A1.4** apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory and biological materials (e.g., preserved specimens); and by using appropriate personal protection [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.7** select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.11** communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models) [C]
- **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., zoologist, botanist, geneticist, ecologist, pharmacologist, farmer, forester, horticulturalist) and the education and training necessary for these careers

Waves and Sound

- **E1.1** analyse how properties of mechanical waves and sound influence the design of structures and technological devices (e.g., the acoustical design of a concert hall; the design of headphones, hearing aids, musical instruments, wave pools) [AI, C]
- **E2.1** use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave*, *transverse wave*, *frequency*, *period*, *cycle*, *amplitude*, *phase*, *wavelength*, *velocity*, *superposition*, *constructive interference*, *destructive interference*, *standing waves*, and *resonance* [C]
- **E2.2** conduct laboratory inquiries or computer simulations involving mechanical waves and their interference (e.g., using a mass oscillating on a spring, a mass oscillating on a pendulum, the oscillation in a string instrument) [PR]
- **E2.6** predict the conditions needed to produce resonance in vibrating objects or air columns (e.g., in a wind instrument, a string instrument, a tuning fork), and test their predictions through inquiry [IP, PR, AI]
- **E2.7** analyse the conditions required to produce resonance in vibrating objects and/or in air columns (e.g., in a string instrument, a tuning fork, a wind instrument), and explain how resonance is used in a variety of situations (e.g., to produce different notes in musical instruments; to limit undesirable vibrations in suspension bridges; to design buildings so that they do not resonate at the frequencies produced by earthquakes) [AI, C]
- **E3.2** explain the components of resonance, and identify the conditions required for resonance to occur in vibrating objects and in various media (e.g., with reference to a musical instrument, a child on a swing, the Tacoma Narrows Bridge)
- **E3.4** identify the properties of standing waves, and, for both mechanical and sound waves, explain the conditions required for standing waves to occur

Wave Model Applications

Curriculum Connections

PRINCE EDWARD ISLAND—Physics 11: Waves

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics 11 Curriculum Connections (521A)
(2009)

Activity 1: Wave Interference

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

438 value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds

Interest in Science

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 2: Applications of Sound Waves

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Performing and Recording

213-1 implement appropriate sampling procedures

213-7 select and integrate information from various print and electronic sources or from several parts of the same source

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Interest in Science

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Scientific Inquiry

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444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

446 have a sense of personal and shared responsibility for maintaining a sustainable environment

Activity 3: Investigating Earthquakes

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Social and Environmental Contexts of Science and Technology

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Performing and Recording

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213-7 select and integrate information from various print and electronic sources or from several parts of the same source

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

437 appreciate that the applications of science and technology can raise ethical dilemmas

Interest in Science

439 show a continuing and more informed curiosity and interest in science and science-related issues

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

447 project the personal, social, and environmental consequences of proposed action

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 4: How Do We Hear?

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Performing and Recording

213-1 implement appropriate sampling procedures

213-7 select and integrate information from various print and electronic sources or from several parts of the same source

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

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327-1 describe the characteristics of longitudinal and transverse waves

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327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Attitudes

Appreciation of Science

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Interest in Science

441 consider further studies and careers in science- and technology-related fields

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

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444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 5: Exploring Gravitational Waves

STSE

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

327-5 compare and describe the properties of electromagnetic radiation and sound

Attitudes

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Scientific Inquiry

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444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Design Challenge: Resisting Earthquakes with Engineering

STSE

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

Knowledge

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

Attitudes

Appreciation of Science

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444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Stewardship

447 project the personal, social, and environmental consequences of proposed action

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Wave Model Applications

Curriculum Connections

SASKATCHEWAN—Physical Science 20: Properties of Waves

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physical Science 20 Curriculum Connections (March 2017)	**Earth Science 30 Curriculum Connections / Health Science 20 Curriculum Connections** (February 2018 version; March 2017 version, respectively)
Activity 1: Wave Interference	
Properties of Waves **PS20-PW1** Investigate the properties and characteristics of one-, two- and three- dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI] a. Pose questions about the nature and prevalence of waves in the world around us (e.g., What are waves? Where do we find waves in the world around us? Do all waves exhibit the same properties and behaviours? Why are waves important to study?). (S, STSE, A) c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K) d. Communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. (S, K) e. Rephrase questions about waves (e.g., What controls the frequency of a wave? What controls the speed of a wave? What happens when two or more waves meet?) into experimentally testable formats. (S, A) f. Identify characteristics of transverse and longitudinal waves including crests (positive pulse), troughs (negative pulse), compressions, rarefactions and the relationship between direction of vibration and energy transfer. (K)	

j. Illustrate constructive and destructive interference in one-, two- and three-dimensional waves, including the principle of superposition and standing waves, using point-source and straight-source waves. (S, K) **Foundation 4: Attitudes** **Appreciation of Science** Students will be encouraged to critically and contextually appreciate the role and contributions of science and technology in their lives and to their community's culture; and to be aware of the limits of science and technology as well as their impact on economic, political, environmental, cultural and ethical events. **Interest in Science** Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community. **Inquiry in Science** Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge. **Collaboration** Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.	
Activity 2: Applications of Sound Waves	
Career Exploration **PS20-CE1** Analyze and explore physical science related occupations in Saskatchewan, Canada and the world. [CP, DM] ***Properties of Waves*** **PS20-PW1** Investigate the properties and characteristics of one-, two- and three- dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI] a. Pose questions about the nature and prevalence of waves in the world around us (e.g., What are waves? Where do we find waves in the world around us? Do all waves exhibit the same properties and behaviours? Why are waves important to study?). (S, STSE, A) c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K)	***Health Science 20 Curriculum Connections*** ***Diagnostics and Treatment*** **HS20-DT1** Explore the tools and procedures used to diagnose and monitor medical conditions. [CP, SI, TPS] **HS20-DT2** Assess the importance of interpreting diagnostic findings to support treatment options for specific pathologies. [DM, SI, CP]

d. Communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. (S, K) e. Rephrase questions about waves (e.g., What controls the frequency of a wave? What controls the speed of a wave? What happens when two or more waves meet?) into experimentally testable formats. (S, A) h. Trace the historical developments of technologies used to measure the speed of light and/or sound. (STSE) i. Solve problems related to speed, period, frequency and wavelength using the universal wave equation ($v = \lambda f$), the period-frequency relationship ($T = 1/f$) and the correct number of significant figures. (S, K) l. Provide examples of applications of the properties and characteristics of waves or electromagnetic radiation in various technologies (e.g., ultrasound, sonar, Doppler Effect, sonic booms, satellite dishes, microwaves, mobile phones, wireless routers, Bluetooth, radio waves, X-rays, radar and remote controls). (STSE, K) **PS20-PW2** Examine, using physical materials, ray diagrams and mathematical equations, how waves reflect from a variety of barriers. [DM, SI] d. Provide examples of wave and particle reflection in everyday situations such as echoes, reverberation, room acoustics, radar, sonar, parabolic microphones, ultrasound, water waves, satellite dishes, billiard balls and ball-based sports. (STSE, K, A) h. Describe the implications of wave-based technologies in furthering scientific understanding of phenomena such as Earth's internal structure, the topography of the ocean floor and the rock cycle. (STSE, K) **Foundation 4: Attitudes** **Appreciation of Science** Students will be encouraged to critically and contextually appreciate the role and contributions of science and technology in their lives and to their community's culture; and to be aware of the limits of science and technology as well as their impact on economic, political, environmental, cultural and ethical events.	

Interest in Science Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community. **Inquiry in Science** Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge. **Collaboration** Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.	
Activity 3: Investigating Earthquakes	
Properties of Waves **PS20-PW1** Investigate the properties and characteristics of one-, two- and three- dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI] a. Pose questions about the nature and prevalence of waves in the world around us (e.g., What are waves? Where do we find waves in the world around us? Do all waves exhibit the same properties and behaviours? Why are waves important to study?). (S, STSE, A) c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K) d. Communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. (S, K) f. Identify characteristics of transverse and longitudinal waves including crests (positive pulse), troughs (negative pulse), compressions, rarefactions and the relationship between direction of vibration and energy transfer. (K) g. Describe the characteristics of the transmission of waves, including rectilinear propagation and the nature of the medium and its relationship to the speed of the wave. (S, K) h. Trace the historical developments of technologies used to measure the speed of light and/or sound. (STSE)	***Earth Science 30 Curriculum Connections*** ***Foundations of Earth Science*** **ES30-FO1** Examine the multi-disciplinary nature of earth science. [SI, DM] f. Provide examples of how earth scientists collect evidence using analytical, field, theoretical, experimental and/or modeling studies. (STSE) g. Identify how earth scientists draw upon principles and processes from scientific fields such as biology, chemistry, computer science, geology, mathematics, and physics in order to address their questions. (STSE)

i. Solve problems related to speed, period, frequency and wavelength using the universal wave equation ($v = \lambda f$), the period-frequency relationship ($T = 1/f$) and the correct number of significant figures. (S, K)

PS20-PW2 Examine, using physical materials, ray diagrams and mathematical equations, how waves reflect from a variety of barriers. [DM, SI]

h. Describe the implications of wave-based technologies in furthering scientific understanding of phenomena such as Earth's internal structure, the topography of the ocean floor and the rock cycle. (STSE, K)

Foundation 4: Attitudes

Appreciation of Science

Students will be encouraged to critically and contextually appreciate the role and contributions of science and technology in their lives and to their community's culture; and to be aware of the limits of science and technology as well as their impact on economic, political, environmental, cultural and ethical events.

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.

Stewardship

Students will be encouraged to develop responsibility in the application of science and technology in relation to society and the natural environment.

Safety

Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.

Activity 4: How Do We Hear?	
Career Exploration **PS20-CE1** Analyze and explore physical science related occupations in Saskatchewan, Canada and the world. [CP, DM] ***Properties of Waves*** **PS20-PW1** Investigate the properties and characteristics of one-, two- and three- dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI] a. Pose questions about the nature and prevalence of waves in the world around us (e.g., What are waves? Where do we find waves in the world around us? Do all waves exhibit the same properties and behaviours? Why are waves important to study?). (S, STSE, A) b. Examine First Nations and Metis perspectives on waves, including waves as carriers of energy. (STSE, K) c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K) d. Communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. (S, K) f. Identify characteristics of transverse and longitudinal waves including crests (positive pulse), troughs (negative pulse), compressions, rarefactions and the relationship between direction of vibration and energy transfer. (K) i. Solve problems related to speed, period, frequency and wavelength using the universal wave equation ($v = \lambda f$), the period-frequency relationship ($T = 1/f$) and the correct number of significant figures. (S, K) j. Illustrate constructive and destructive interference in one-, two- and three-dimensional waves, including the principle of superposition and standing waves, using point-source and straight-source waves. (S, K) m. Explore wave-related phenomena such as natural vibrations, forced vibrations, resonance and harmonics in the context of musical instruments and human hearing. (STSE, S, K)	***Health Science 20 Curriculum Connections*** **HS20-CE1** Analyse and explore health-science related occupations in Saskatchewan, Canada and the world. [CP, DM] ***Human Body*** **HS20-HB1** Analyze the anatomy and physiology of a healthy human. [CP, SI]

PS20-PW2 Examine, using physical materials, ray diagrams and mathematical equations, how waves reflect from a variety of barriers. [DM, SI] h. Describe the implications of wave-based technologies in furthering scientific understanding of phenomena such as Earth's internal structure, the topography of the ocean floor and the rock cycle. (STSE, K) **Foundation 4: Attitudes** **Appreciation of Science** Students will be encouraged to critically and contextually appreciate the role and contributions of science and technology in their lives and to their community's culture; and to be aware of the limits of science and technology as well as their impact on economic, political, environmental, cultural and ethical events. **Interest in Science** Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community. **Inquiry in Science** Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge. **Collaboration** Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school. **Safety** Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.	
Activity 5: Exploring Gravitational Waves	
Properties of Waves **PS20-PW1** Investigate the properties and characteristics of one-, two- and three- dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI] a. Pose questions about the nature and prevalence of waves in the world around us (e.g., What are waves? Where do we find waves in the world around us? Do all waves exhibit the same properties and behaviours? Why are waves important to study?). (S, STSE, A)	

c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K)

d. Communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. (S, K)

f. Identify characteristics of transverse and longitudinal waves including crests (positive pulse), troughs (negative pulse), compressions, rarefactions and the relationship between direction of vibration and energy transfer. (K)

i. Solve problems related to speed, period, frequency and wavelength using the universal wave equation ($v = \lambda f$), the period-frequency relationship ($T = 1/f$) and the correct number of significant figures. (S, K)

Foundation 4: Attitudes

Appreciation of Science

Students will be encouraged to critically and contextually appreciate the role and contributions of science and technology in their lives and to their community's culture; and to be aware of the limits of science and technology as well as their impact on economic, political, environmental, cultural and ethical events.

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.

Safety

Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.

Design Challenge: Resisting Earthquakes with Engineering	
Career Exploration **PS20-CE1** Analyze and explore physical science related occupations in Saskatchewan, Canada and the world. [CP, DM] ***Student-Directed Study*** **PS20-SDS1** Create and carry out a plan to explore one or more topics of personal interest relevant to Physical Science 20 in depth. [DM, SI, TPS] ***Properties of Waves*** **PS20-PW1** Investigate the properties and characteristics of one-, two- and three- dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI] a. Pose questions about the nature and prevalence of waves in the world around us (e.g., What are waves? Where do we find waves in the world around us? Do all waves exhibit the same properties and behaviours? Why are waves important to study?). (S, STSE, A) c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K) d. Communicate information about the properties and characteristics of waves using appropriate terminology, including medium, pulse, vibration, cycle, periodic motion, frequency, period, amplitude, phase and wavelength. (S, K) f. Identify characteristics of transverse and longitudinal waves including crests (positive pulse), troughs (negative pulse), compressions, rarefactions and the relationship between direction of vibration and energy transfer. (K) j. Illustrate constructive and destructive interference in one-, two- and three-dimensional waves, including the principle of superposition and standing waves, using point-source and straight-source waves. (S, K) **PS20-PW3** Analyze, using physical materials, ray diagrams and mathematical equations, how waves refract at boundaries between different media. [DM, SI] a. Pose scientific questions about how waves behave when they travel from one medium to another. (S)	***Earth Science 30 Curriculum Connections*** ***Career Exploration*** **ES30-CE1** Analyze and explore earth-science related career paths in Saskatchewan, Canada and the world. ES30-FO1 Examine the multi-disciplinary nature of earth science. [SI, DM] ***Student-Directed Study*** **ES30-SDS1** Create and carry out a plan to explore a topic covered in Earth Science 30 in depth.

Foundation 4: Attitudes **Appreciation of Science** Students will be encouraged to critically and contextually appreciate the role and contributions of science and technology in their lives and to their community's culture; and to be aware of the limits of science and technology as well as their impact on economic, political, environmental, cultural and ethical events. **Interest in Science** Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community. **Inquiry in Science** Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge. **Collaboration** Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school. **Stewardship** Students will be encouraged to develop responsibility in the application of science and technology in relation to society and the natural environment. **Safety** Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.	

Wave Model Applications

Curriculum Connections

Next Generation Science Standards (NGSS): Grades 9–12

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Physics Curriculum Connections
(April 2013)

Activity 1: Wave Interference

Physical Science

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

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.* [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]

Activity 2: Applications of Sound Waves

Physical Science

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

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Activity 3: Investigating Earthquakes

Physical Science

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

Earth and Space Science

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

Activity 4: How Do We Hear?

Physical Science

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

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.* [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]

Activity 5: Exploring Gravitational Waves

Physical Science

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

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.* [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]

Design Challenge: Resisting Earthquakes with Engineering

Physical Science

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

Earth and Space Science

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

Engineering Design

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.