Unit 4
Waves
Suggested Time: 30 Hours

Waves

Introduction

Everyone has seen waves in many forms, such as water waves hitting a beach, standing waves in telephone lines, and travelling waves in a skipping rope. Students should observe, predict, and explain specific wave behaviours, such as reflection, refraction, and diffraction. Students could begin their study of waves with familiar mechanical waves, extend their study to sound waves, and then use wave principles they have developed to explain and predict the behaviour of light and other electromagnetic waves. Students should be encouraged to develop their vocabulary and working definitions of wave terminology from their own experiences and from directed activities in class. Through various investigations, they should recognize that any periodic disturbance creates a wave and that the disturbance transmits energy (and therefore information) from one place to another. Familiar activities with Slinkies™ and ripple tanks would allow students to observe, predict, and explain specific wave behaviours, such as reflection, refraction, and diffraction.

Focus and Context

Problem-solving activities should be linked with STSE connections in various activities. Examples could include resonance and earthquakes or the quest for energy. For example, in considering offshore exploration for oil and gas, students must assess risk and benefit.

Because the study of waves is so broad, students have many opportunities to research and investigate different topics—musical instruments, optics, communications systems, electronics, medical imaging, non-destructive testing, and sound pollution, to suggest just a few. As they move from phenomena that can be observed directly, such as mechanical and water waves, to those less directly observable, such as sound and light waves, students should be challenged to make inferences based on wave phenomena. They should increasingly recognize the power of physics in general, and wave concepts in particular, to convey information and permit exploration where the unaided human senses fail. The range of tools used to make indirect observations is vast—from simple hand lenses to compound microscopes to scanning electron microscopes, from radio telescopes to MRI, CAT, and PET scanning technology. However, in all scientific and technological endeavours, the tools to extend our senses were developed using the concepts and principles of physics.

Science Curriculum Links

In elementary grades, students studied light and sound in relation to their scientific properties, their use in technological devices and their relationship to society. Physics 3204 continues wave theory with the development of quantum physics.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Nature of Science and Technology** **115-5** analyze why and how a particular technology was developed and improved over time **Relationships Between Science and Technology** **116-2** analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology **116-4** analyze and describe examples where technologies were developed based on scientific understanding **116-6** describe and evaluate the design of technological solutions and the way they function using principles of energy and momentum **116-7** analyze natural and technological systems to interpret and explain their structure and dynamics **Social and Environmental Contexts of Science and Technology** **117-2** analyze society's influence on scientific and technological endeavours	*Students will be expected to* **Initiating and Planning** **212-3** design an experiment identifying and controlling major variables **212-8** evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making **Performing and Recording** **213-2** carry out procedures controlling the major variables and adapting or extending procedures where required **213-3** use instruments accurately for collecting data **Analysing and Interpreting** **214-3** compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots **214-5** interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables **214-7** compare theoretical and empirical values and account for discrepancies **214-11** provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion	*Students will be expected to* **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 **327-6** describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted **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

Introduction to Waves

Outcomes

Students will be expected to

- describe the production, characteristics, and behaviors of longitudinal and transverse mechanical waves (212-7, 327-1)
  - define the terms vibration, pulse and wave
  - define the frequency and the period of a wave, and show how they are related
  - given one of the frequency or the period of a wave, calculate the other
  - explain what is meant by the cycle and amplitude of a wave, and give examples
  - explain how a wave's energy depends on its amplitude and frequency
  - explain how waves transfer energy
  - explain what is meant by a transverse pulse, and describe how such pulses are created and transmitted
  - describe what is meant by a transverse wave, recognize its crests and troughs, and define the wavelength, amplitude, and period of a periodic wave
  - explain what is meant by a longitudinal pulse and wave, recognizing its compressions and rarefactions, and describe how such pulses and waves are created and transmitted, giving examples

Elaborations—Strategies for Learning and Teaching

Disturbances in a medium create pulses and waves and these transfer energy. A single disturbance in a medium is a wave **pulse**. A mechanical **wave** is a transfer of energy in the form of one or more disturbances through an elastic medium. The students will use their understanding of energy and its analysis in systems to examine how waves are produced and interact. Through a variety of experiences with waves on springs and ripple tanks, students should develop operational definitions which may be refined or expanded as the study of waves continues. To begin, long helical springs and Slinkies™ are ideal for observing large, slow pulses.

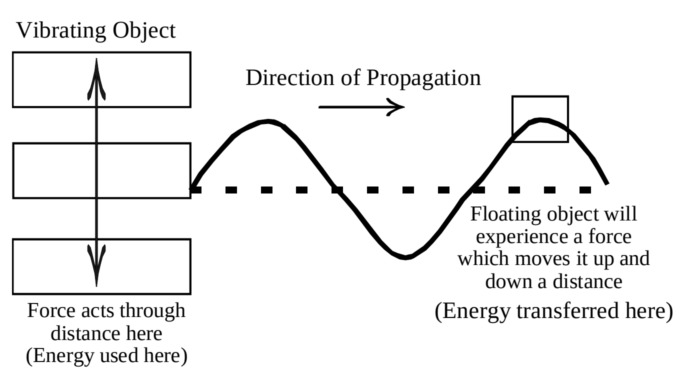
Teachers should be mindful of the treatment of particle and wave theories of light in Physics 3204. It may be wise to reflect on how particles move and make comparisons with wave behaviours as they are explored.

Students should be shown that not all waves are periodic. Many examples of complicated waves could be provided, such as the sound of your voice or sound produced by an orchestra.

Students should realize that we need to narrow our study of waves to periodic waves: waves where the cycle repeats itself over time.

A mechanical wave's energy is proportional to the square of its amplitude in the same way as that of a simple harmonic oscillator. ($E=KA^2$) (See *Physics: C and C,* p 360). It is independent of frequency. Energy of light photons are directly proportional to their frequency. ($E=hf$)

Energy is the ability to exert a force through a distance or do work. In the case of a vibrating object disturbing an elastic medium, a force acts through a distance, or, energy is used as the object displaces the medium. As the wave pattern propagates, one can show energy is transferred to another region. If a block of wood is floating on the surface, the wave will cause it to rise and fall as it passes. Therefore, a force acts through a distance at the block or energy is transferred from the vibrating source to the block.



Introduction to Waves

Suggested Assessment Strategies

Paper and Pencil

- Students could distinguish between the period and frequency of a wave. (327-1, 212-7)
- Students could answer, "Which property of a wave is a measure of the energy in the wave?" They should the work-energy theorem to explain their answer. (327-1, 212-7)
- Students could answer, "How is a longitudinal wave different from a transverse wave? Give a common example of each." (327-1)

Informal Observation

- Teachers could observe students demonstrating and making measurements of the characteristics of waves and experimentally verify the universal wave equation. (327-1, 212-7)

Resources

www.gov.nl.ca/edu/science_ref/main.htm

Physics: C and C, p 387

Physics: C and C, p 388

Physics: C and C, p 387

Physics: C and C, pp 385-387

Physics: C and C, pp 385-388

Physics: C and C, p 385

Physics: C and C, p 386

Introduction to Waves (continued)

Outcomes

Students will be expected to

- describe the production, characteristics, and behaviors of longitudinal and transverse mechanical waves (212-7, 327-1) **Cont'd**
  - identify points in phase and points out of phase on a wave train
  - draw diagrams of two waves (i) in phase (ii) completely out of phase
  - describe and apply the principle of superposition as it applies to transverse pulses and waves
  - describe the constructive interference and destructive interference of pulses or waves, giving an illustration of each
- apply the universal wave equation to explain and predict the behavior of waves (327-2)
  - derive the wave equation
  - calculate the value of any given variable in the wave equation, given the values of the other two variables, or information from which these can first be determined

Elaborations—Strategies for Learning and Teaching

Application of the principle of superposition should be restricted to wave pulses.

Students should be able to solve problems involving period, wavelength, frequency, and speed, using the universal wave equation:

$$v = f \cdot \lambda$$

In deriving the wave equation it should be noted that waves travel with uniform motion. Therefore, we can use the equation $v = \Delta d/\Delta t$.

Introduction to Waves (continued)

Suggested Assessment Strategies

Performance

- Students could demonstrate, using a Slinky™ and diagrams of two waves in phase and two waves completely out of phase. (327-1, 212-7)
- Students could sketch examples of constructive and destructive interference. (327-1, 212-7)

Paper and Pencil

- Students could record observations, both sketches and data, and draw conclusions from a wave activity that they have completed. (327-2, 213-1, 214-8)
- An oscillator vibrates the end of a spring at a frequency of 10.0 Hz. The distance between adjacent crests in the wave pattern formed is 1.50 m. What is the speed of the wave? (327-1)
- Two waves are created from opposite ends of a 10.0 m long spring. The wave from end A has an amplitude of 50.0 cm to the left of the rest position and a frequency of 5.00 Hz. The wave from end B has an amplitude of 30.0 cm on the opposite side of the spring and a frequency of 10.0 Hz.
  - What will the spring look like when the midpoint of the lead pulses meet? Draw a sketch.
  - Can you predict at what point on the spring the two pulses meet? (327-1)

Resources

Physics: C and C, pp 388-389

Physics: C and C, p 389

Physics: C and C, pp 424-427, 486

Physics: C and C, pp 424-427, 486

Physics: C and C, p 390

Physics: C and C, pp 390-391

Light

Outcomes

Students will be expected to

- state a prediction and a hypothesis about wave behavior based on available evidence and background information (212-4)
- describe how light, as a form of energy, is produced and transmitted (327-6)
  - given two of the speed of light, the distance it travels, and the time taken, calculate the third quantity
  - explain the term "rectilinear propagation"
  - differentiate between (i) a beam and (ii) a ray of light
- explain qualitatively and quantitatively, with respect to light, the phenomena of wave interference, diffraction, reflection and refraction, and the Doppler effect (327-5, 327-7, 327-8)
  - describe the reflection of light from a smooth plane surface, such as a mirror
  - state the law of reflection
  - describe the formation of images in plane mirrors
  - use geometry to show how the position of an image in a plane mirror can be located
  - describe what is meant by refraction of light, and explain why it occurs
  - compare the speed of light in air, in water, or in glass, with that in a vacuum

Elaborations—Strategies for Learning and Teaching

Energy is the ability to do work or exert a force through a distance. The fact that light is a form of energy can be shown in the demonstration of the vanes of a radiometer being pushed around when exposed to light **or** when electrons are knocked free in photoelectric cells.

The fact that light can travel through a vacuum may be puzzling to some students. A simplistic explanation could include the description of light as a pattern of strong and weak electric and magnetic forces. Since neither magnetic forces nor electric forces require a medium through which they must pass nor does light. (i.e., A bar magnet will attract a nail through a vacuum and a charged comb will attract pieces of paper in the absence of air.)

The description of images in plane mirrors should be restricted to include the terms virtual and lateral inversion.

Light

Suggested Assessment Strategies

Journal

- Students could combine their observations on the ripple tank with a ray-tracing experiment. What does this mean in terms of waves? Does it make sense logically? Why or why not? Is other information needed? (327-8, 327-7)
- Students could write a short story about the life of a wave. (327-8, 327-7)
- Students could draw a physics cartoon about a ray. They should include information on incident ray, reflected ray, refracted ray, normal, angle of incidence, angle of reflection, and angle of refraction. (327-8, 327-7)

Presentation

- Students could create a display that shows the relationship between a ray diagram and a wave-front diagram for a specific situation, such as circular reflections from a straight barrier. (327-8, 327-7)
- In groups of two to three, students could create a crossword puzzle, a word search, or other puzzle activity of the terms and explanations associated with waves. They should include an answer sheet. They could trade their puzzle(s) with that of another group to see if they can do your puzzle. Some terms to consider include incident ray, reflected ray, refracted ray, normal, angle of incidence, angle of reflection, angle of refraction, and nodes and nodal lines. (327-8, 327-7)

Resources

Physics: C and C, p 391

Physics: C and C, p 394

Physics: C and C, pp 394-395

Physics: C and C, p 395

Physics: C and C, p 397

Physics: C and C, pp 396-399

Physics: C and C, pp 396-399

Physics: C and C, pp 400-401

Physics: C and C, pp 403-407

Light (continued)

Outcomes

Students will be expected to

- explain qualitatively and quantitatively, with respect to light, the phenomena of wave interference, diffraction, reflection and refraction, and the Doppler effect (327-7, 327-8) **Cont'd**
  - define the index of refraction in terms of the speed of light
  - given the index of refraction, draw accurate diagrams for a ray of light passing through a variety of materials
  - given two of the index of refraction, the speed of light in a medium, and the speed of light in a vacuum, calculate the third quantity
  - state Snell's Law of Refraction
  - given two of the angle of incidence, the angle of refraction, and the index of refraction, calculate the third quantity
  - describe the phenomenon of total internal reflection
  - define and calculate the critical angle
  - describe the Doppler effect as it applies to light
  - carry out calculations involving the red and blue shift of light
  - explain the interference of waves as it applies to light
  - calculate the maxima and minima using the interfence (double slit) equations
  - explain the diffraction of waves as it applies to light
  - calculate the maxima and minima using the single slit equations

Elaborations—Strategies for Learning and Teaching

Students should investigate the refraction of light and look for a relation between incident angle and refrcted angle. an investigation using a variety of liquids in semicircular glass containers, could be conducted by paris of sutdetns to develop Snell's Law and the formulae:

This should be followed by the study of total internal reflection and the critical angle.

The Doppler effect will be covered with respect to light and sound. Teachers may wish to cover both topics together or leave sound until later.

Light (continued)

Suggested Assessment Strategies

Presentation

- Students could do a multimedia presentation on waves. They should describe and give examples of reflection, refraction, index of refraction, relative index, critical angle, total internal reflection, diffraction, scattering, interference, and Doppler effect. (327-8, 327-7)

Performance

- Given the index of refraction, students could draw accurate diagrams for a ray of light passing through a variety of materials. (327-8, 327-7)
- Students could conduct Young's experiment, and make a chart of their results. (327-8, 327-7)

Paper and Pencil

- Students could explain the applications of total internal reflection in both telecommunications and medicine. (327-8)
- Students could write a memo on Young's experiment from his point of view. They should explain, with references to their data, how the experiment makes it impossible to dismiss the wave nature of light from Young's time onward. (327-8, 327-7)
- Students could write a short report that summarizes their experiences with light and waves. They could refer to both the particle and wave models in explaining what they have seen and experienced to this point in the unit on waves. (327-8, 327-7)

Resources

Physics: C and C, p 402

Physics: C and C, pp 403-407

Physics: C and C, pp 405-407

Physics: C and C, pp 404-406

Physics: C and C, pp 411-418

Physics: C and C, p 412

Physics: C and C, pp 419-423

Physics: C and C, pp 421-423

Physics: C and C, pp 424-426

Physics: C and C, p 427

Physics: C and C, pp 429-430

Physics: C and C, pp 430-431

Light (continued)

Outcomes

Students will be expected to

- carry out procedures controlling the major variables to investigate Snell's Law (212-3, 213-2)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- use instruments effectively and accurately for collecting data (213-3)
- compile and display evidence and information in a variety of formats (214-3)
- compare theoretical and empirical values and account for discrepancies (214-7)
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables (214-5)
- provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion (214-11)

Elaborations—Strategies for Learning and Teaching

The Laboratory outcomes (212-3, 212-8, 213-2, 213-3, 214-3, 214-5, 214-7, 214-11) and 326-7, 327-8 are addressed by completing Snell's Law CORE LAB #7.

Light (continued)

Suggested Assessment Strategies

Journal

- Students could describe how sound is produced, giving an example of each in nature and technology. They should describe how sound is transmitted and list the factors on which the speed of sound depends. (327-5, 327-6)
- In their journal student could research how red shifts of light from stars is used to help astronomers determine relative distances of these stars from the earth. (327-8)
- In their journal, students could research how x-ray diffraction and interference patterns are used to determine the structure of crystals. (327-8)

Resources

Core Lab #7**: *"Snell's Law"*** *Physics: C and C,* p 442
OR
Computer Interface Alternative:
www.gov.nl.ca/edu/science_ref/main.htm

Sound

Outcomes

Students will be expected to

- describe how sound, as a form of energy, is produced and transmitted (327-5, 327-6, 327-7)
  - describe how sound is produced, giving examples
  - describe how sound is transmitted
  - explain how the transmission of sound is dependent on the medium
  - given two of the speed of sound, the distance travelled, and the time taken, calculate the third quantity
  - given either the air temperature or the speed of sound in air, calculate the value of the other
  - define Mach number and perform appropriate calculations
  - define sound intensity, and describe how it varies with distance from a point source
  - define sound intensity level

Elaborations—Strategies for Learning and Teaching

After listening to a series of common sounds, students should be asked to comment on the cause and nature of the sound. Students should conduct an investigation on the speed of sound. Students should explore the properties that are used to distinguish sounds. Characteristics such as pitch, intensity, tone, and harmonics can be investigated. Tuning forks, sonometers, keyboards, amplifiers, oscilloscopes, and computer software with appropriate probes can be used to investigate the frequency, wavelength, amplitude, and harmonic complexity of waveforms. A simple interference pattern can be created with tuning forks creating a beat frequency. A student could demonstrate how this is used to tune a guitar or violin. Two loudspeakers producing the same pure tone can be used to set up a two point source interference pattern large enough to walk through. For example, two sources producing tones of frequency 256 Hz placed 4.0 m apart will produce a good pattern. On a line parallel to the speaker plane three metres away from the sources, nodes will be spaced about 1 metre apart. It is even possible to make reasonable measurements on the interference pattern and determine the wavelength of the sound source.

Students should begin to ask questions such as “How can the sound of a specific instrument be synthesized?” and “Why are digitally coded signals, such as in CD’s and digital phones, superior to analog systems such as cassette tapes and cellular phones?”

Students should be able to state that doubling the distance from a point source causes the intensity to drop to 1/4 of its original intensity; tripling the distance causes a drop to 1/9, and so on. This is referred to as the inverse square law.

With respect to the decibel system, students would not be required to use the logarithmic formula in calculating decibel level.

Sound

Suggested Assessment Strategies

Performance

- Students could conduct a lab to determine the speed of sound using closed-tube resonance. (327-5, 327-6)
- Using a set of mounted resonance turning forks, students could try to produce beat frequencies of five beats per second and the ten beats per second. They should try to duplicate this effect with small-sized pop bottle filled with water to slightly different heights. (327-5, 327-6)

Journal

- In their journal, students could explain how a particular musical instrument makes use of resonance to produce its characteristic sound. (327-5, 327-6)

Paper and Pencil

- Students could explain the phenomenon of the Doppler effect and give examples. (327-5, 327-6)
- Students could explain the phenomenon of the sonic boom, describe the problems it causes, and how such problems can be minimized. (327-5, 327-6)

Resources

Physics: C and C, pp 450-452

Physics: C and C, p 452

Physics: C and C, p 452

Physics: C and C, pp 453-455

Physics: C and C, pp 458-459

Physics: C and C, pp 459-461

Sound (continued)

Outcomes

Students will be expected to

- describe how sound, as a form of energy, is produced and transmitted (212-7, 327-5, 327-6, 327-7) **Cont'd**
  - explain the phenomenon the Doppler Effect, both qualitatively and quantitatively, and indicate examples
  - explain the phenomenon sonic boom, describe the problems they cause, and how such problems can be minimized
  - indicate an understanding that frequency (as well as intensity) affects the perceived loudness of sounds
  - state the typical frequency range of human hearing, and the effect that aging can have on this range
  - define ultrasonic frequencies, and give examples
- explain with respect to sound, the phenomena of wave interference and reflection (327-5, 327-8)
  - experimentally investigate the behavior of a transverse pulse reflecting from a fixed end and free end of a spring
  - explain how standing waves are produced on a stretched string
  - cause vibrations in a string or rope to observe the fundamental and various overtone frequencies

Elaborations—Strategies for Learning and Teaching

The Laboratory outcomes (212-3, 212-8, 213-2, 213-3, 214-3, 214-5, 214-7, 214-11) and 327-5, 327-6, 327-7 are addressed by completing Speed of Sound CORE LAB #8.

Students will state that the average human ear is most sensitive to sound in a range of frequencies between about 1000 hz and 5000 hz. This means, for example, that a low frequency sound (say 200 hz) must have a higher intensity if we are to perceive it as being as loud as a high frequency sound (say 2000 hz). Put another way: if a tuba and piccolo are emitting the same intensity, the piccolo will sound louder. Our ears are more sensitive to high frequency sounds (within the range set above).

Note: (i) When the end of the string (rubber tubing, slinky) is fixed, the transverse pulse will be reversed on reflection. (ii) A "free-end" may be achieved by attaching one end of a slinky to a fine string, or let the slinky hang down a deep stairwell (2 or 3 flights). The pulse will now be reflected on the same side as the incident pulse.

Using a long piece of tubing (from the chemistry lab?), a slinky or a solid skipping rope, students should be able to produce patterns up to the 3rd overtone and be able to identify the nodes and antinodes or loops of the standing wave patterns.

Sound (continued)

Suggested Assessment Strategies

Paper and Pencil

- Students could explain how standing waves are produced in closed and open pipes. (327-5, 327-6)

Presentation

- Students could compare and contrast properties of electromagnetic radiation and sound. (327-5, 327-6)

Resources

Core Lab #8: "*Speed of Sound*"
Physics: C and C, p 483
OR
Computer Interface Alternative:
www.gov.nl.ca/edu/science_ref/main.htm
Physics: C and C, pp 463-466

Physics: C and C, pp 456-457

Physics: C and C, pp 469-470

Physics: C and C, p 470

Physics: C and C, p 471

Physics: C and C, pp 490-491

Physics: C and C, pp 491-494

Physics: C and C, pp 494-495

Sound (continued)

Outcomes

Students will be expected to

- explain with respect to sound, the phenomena of wave interference and reflection (327-5, 327-8) **Cont'd**
  - given the fundamental frequency and fundamental wavelength of a vibrating string, produce diagrams of various overtones labelled to show the wavelength and frequency of each
  - explain what is meant by resonance, and why it is important for engineers to take account of this phenomenon in designing buildings and bridges for windy areas
  - describe an example of sound resonance involving vibrating strings or tuning forks
  - explain how standing waves are produced in closed and open pipes
  - make use of the phenomenon of resonance in closed pipes to experimentally determine the speed of sound in air
  - produce beats (physically) using two sources of slightly different frequency
  - explain the phenomenon of beats
  - given two of the higher frequency of source A, the lower frequency of source B, and the beat frequency, calculate the third quantity

Elaborations—Strategies for Learning and Teaching

Students could be asked to bring in common instruments which illustrate resonant lengths. A guitar illustrates vibrating strings. A flute or a tin whistle can illustrate open air columns. Many common whistles can be used for illustrating closed air columns.

Students should be asked to predict how destructive resonance causes large structure damage during an earthquake.

Beats can be produced by obtaining two identical tuning forks, placing a small piece of tape on one and striking the two forks.

Sound (continued)

Suggested Assessment Strategies

Paper and Pencil

- Students could explain how a person's voice changes pitch after inhaling helium from a toy balloon. (327-6)

Performance

- Students could take a metre stick and tape recorder to the music room and measure the entire length of a wind instrument. Record the lowest note made on the instrument. Determine the of this note using . Use this estimate of the and the wave equation to detemine the frequency. Determine the frquency of the recorded note using either an oscilloscope or frequency generator. Compare measured readings with your calculated prediction. (327-6)

$L = \frac{\lambda}{2}$

Resources

Physics: C and C, pp 500-501

Physics: C and C, pp 494-496

Physics: C and C, pp 497-502

Physics: C and C, p 499

Physics: C and C, p 521

Physics: C and C, p 509

Physics: C and C, p 509

Physics: C and C, p 510

Sound (continued)

Outcomes

Students will be expected to

- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)
- analyze natural and technological systems to interpret and explain their structure (116-7)
- analyze and describe examples where technological solutions were developed based on scientific understanding (116-4)
- analyze society's influence on scientific and technological endeavours (117-2)
- analyze why and how a particular technology was developed and improved over time (115-5)
- analyze and describe examples where scientific understanding was enhanced as a result of the invention of a technological device (116-2)

Elaborations—Strategies for Learning and Teaching

The CORE STSE component of this unit incorporates a broad range of Physics 2204 outcomes. More specifically it targets (in whole or in part) 115-5, 116-2, 116-4, 116-6, 116-7, 117-2, 327-5, 327-6, 327-8. The STSE component, *The Physics of Guitars*, can be found in Appendix A.

Sound (continued)

Suggested Assessment Strategies

Resources

Core STSE #4: *"The Physics of Guitars"*, Appendix A