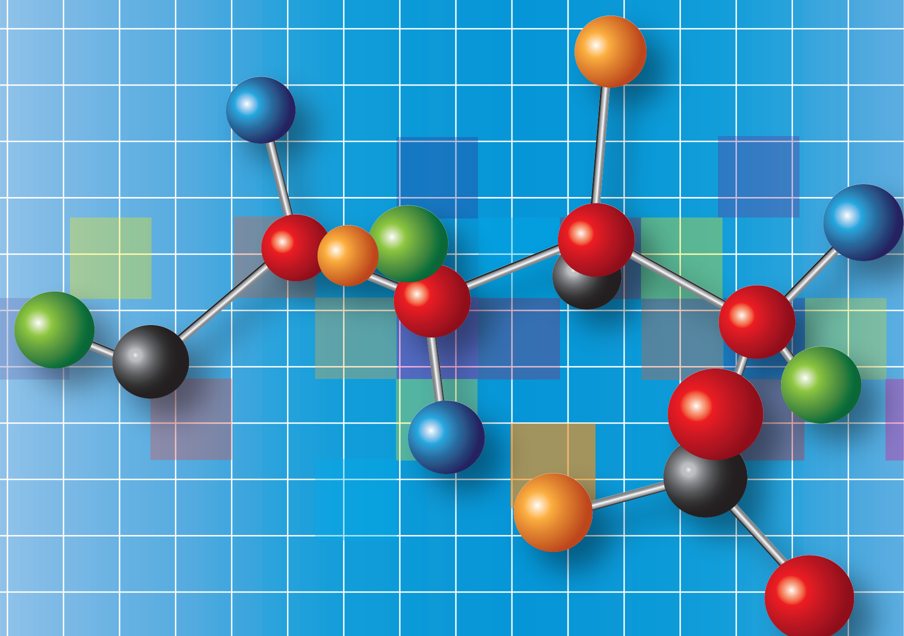
High School Level

Physical Science • Life Science • Earth Science

Real Science

Pathways to Next Generation Science Standards

Teacher Edition



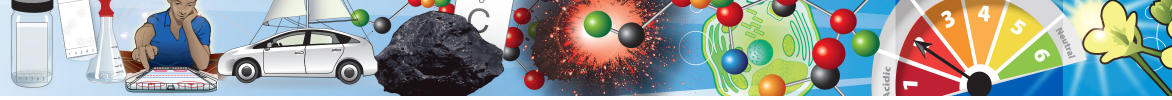
Real Science in Real Situations

CENTER FOR MATHEMATICS, SCIENCE, AND TECHNOLOGY

Illinois State University

STEM

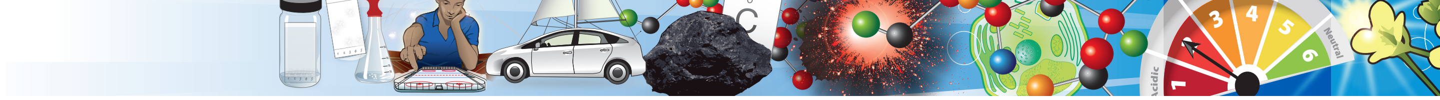
science, technology, engineering, mathematics



Content and Context of Each Learning Cycle

Learning Cycle	Content	Context
Physical Science	**Next Generation Science Standard**	
Chapter 1 **The Burning Question**	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a reaction.	Byron Nuclear Plant Byron, IL Science, Technology, Engineering & Mathematics
Chapter 1 **Sports Toxicologist**	HS-PS1-3: Plan and Conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	Rockford IceHogs Rockford, IL Health Sciences
Chapter 1 **Organizing Elements**	HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	Byron Nuclear Plant Byron, IL Science, Technology, Engineering, & Mathematics
Chapter 1 **Building Your Own Ice Rink**	HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	Rockford IceHogs Rockford, IL Hospitality & Tourism
Chapter 1 **Minimizing Crash Damage**	HS-PS2-3: Apply scientific and engineering ideas to design, evaluate and refine a device that minimizes the force on a macroscopic object during a collision. HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants	Hopperstad Customs Hot Rod Shop Belvidere, IL Manufacturing
Chapter 1 **Measuring From a Distance**	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.* HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	WinGis Rockford, IL TS (National Technical Systems) Rockford, IL Science, Technology, Engineering, and Mathematics

Learning Cycle	Content	Context
Life Science	**Next Generation Science Standard**	
Chapter 2 **Cells: *The Foundation of Life***	HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	Rock River Valley Blood Center Belvidere, IL Health Sciences
Chapter 2 **Contamination: *Save the Plants***	HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environmental and biodiversity. HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.	U of I Extension Office (Agriculture) Dekalb, IL Agriculture, Food, & Natural Resources
Chapter 2 **DNA Structure and Function**	HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.	Rockford Memorial Hospital Cytogenetics Department Rockford, IL and Rock River Valley Blood Center Belvidere, IL Health Sciences and Science, Technology, Engineering, & Mathematics
Chapter 2 **Bacteria at Work**	HS-LS2-3: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.	Rock River Water Reclamation District Rockford, IL Agriculture, Food, and Natural Resources
Chapter 2 **Change by Chance**	HS-LS2-8: Evaluate the evidence for the role of group behavior on individual species' chances to survive and reproduce HS-LS4-4: Construct an explanation based on evidence for how natural selection leads to adaptation of populations. HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increased in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.	Burpee Museum Rockford, IL Agriculture, Food, and Natural Resources



Learning Cycle	Content	Context
Earth Science	**Next Generation Science Standard**	
Chapter 3 **Red Shift**	HS-ESS1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	Astro-Physics Loves Park, IL Science, Technology, Engineering, and Mathematics
Chapter 3 **Earth Puzzle**	HS-ESS1-5: Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. HS-ESS2-1: Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.	Northern Illinois University Department of Geology and Environmental Geosciences DeKalb, IL Agriculture, Food, and Natural Resources
Chapter 3 **Counting Carbon**	HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere	Anderson Gardens Rockford, IL Greenwood Forestry Consulting Winnebago, IL Irene Quarry Wm Charles & Geocon Belvidere, IL Agriculture, Food, and Natural Resources
Chapter 3 **Sunshine On My Soil**	HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth systems result in changes in climate. HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	WTVO Weather, Rockford, IL Agriculture, Food, and Natural Resources, Environmental Service Systems
Chapter 3 **The Green of Going Green**	HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. 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.	Green Circuit Solar Farm, Rockford, IL Finance, and Science, Technology, Engineering, Mathematics

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Science Technology Engineering Mathematics

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Acknowledgements

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Real Science in Real Situations

Center for Mathematics, Science, and Technology
Illinois State University

Welcome!

Welcome to ***Real Science: Pathways to Next Generation Science Standards***, a curriculum that provides unique and engaging science learning experiences. Using constructivist learning cycles, students will learn science concepts through authentic, real-world applications.

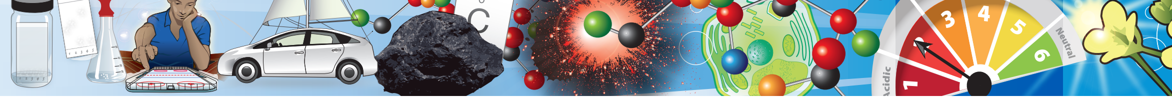
At the beginning of each unit in this book, you will see a "big-picture" context for those applications anchored in U.S. Department of Education ***Career Clusters and Pathways*** (www.careerclusters.org). Each unit is also aligned with ***Next Generation Science Standards*** (www.nextgenscience.org). These units were created by science educators based on visits to businesses in the community during which they explored ways in which science concepts are used in the real world.

The three chapters of ***Real Science*** address the breadth of the content recommended by the ***Next Generation Science Standards*** for high school courses. The chapter titles of **Physical Science, Life Science,** and **Earth Science** are the Domains of the NGSS. There is at least one lesson for each Topic identified by the NGSS. All lessons address at least one of the Performance Expectations and the corresponding Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

The ***Next Generation Science Standards*** identify a fourth Domain, "Engineering, Technology and Applications of Science." This Domain, however, is not addresses separately in "Real Science." Nearly every lesson in this book includes some experience with engineering, technology, and/or the applications of science. It was redundant and counterproductive to separate them.

It should be noted that ***Real Science*** does not simply use the context provided by the Career Cluster as the basis of a series of vignettes or stories of applications. Instead, this curriculum teaches the content through its application. For example, students learn about growth, development, and reproduction of organisms by modeling and analyzing the spread of diseases. This educational process is made possible through the use of ***Learning Cycles***.

Section	Description	Student Role	Teacher Role
Try It *Remember and begin to understand*	Students engage the content through an activity. They are required to build, gather data, look for patterns, etc. Students are prompted to remember previous learning and connect it to new concepts as their understanding grows.	Work in groups or individually, follow the written directions to accomplish the task, collect and record data, make predictions	Facilitate the learning activity. Provide necessary materials and tools. Ask questions, but do not answer them. Assure safe practices.
Discuss It *Understand and begin to apply*	A series of questions designed to clarify concepts and identify misconceptions. Assesses understanding and probes applications.	Complete the questions as assigned. This could be orally as a large group, written individually, or written as a group. Students compare data, form generalizations, write in journals.	Monitor student responses and ask clarifying questions. Assess understanding. Corrects misconceptions.
Apply It *Apply and begin to analyze*	Usually a continuation of an activity that requires the application of the concepts learned in the previous two sections. Requires analysis and evaluation of concepts.	Complete the assigned task, utilizing knowledge gained from the previous sections of the learning cycle.	Facilitate the activity. Provide necessary tools and materials. Monitor progress. Inject leading questions as appropriate. Assure safe practices. Corrects lingering misconceptions.
Expand It *Analyze and begin to evaluate and create*	A few ideas for taking the concept further, possibly a different, but related, application. These tasks require analysis, evaluation, and creation of new applications and connections.	Use the ideas in this section as a foundation for further research.	These ideas provide opportunity for further study. Allow students to explore these concepts on their own. Many will be so interested in the topic that independent learning will occur without prompting.



About the Learning Cycle

Every lesson in this book is organized into a learning cycle. A learning cycle consists of four parts; **Try It, Discuss It, Apply It,** and **Expand It.** In some cases, there may be multiple **Try It** sections, each followed by a **Discuss It** section. There is always one **Apply It** and **Expand It** section in each learning cycle.

Assessment

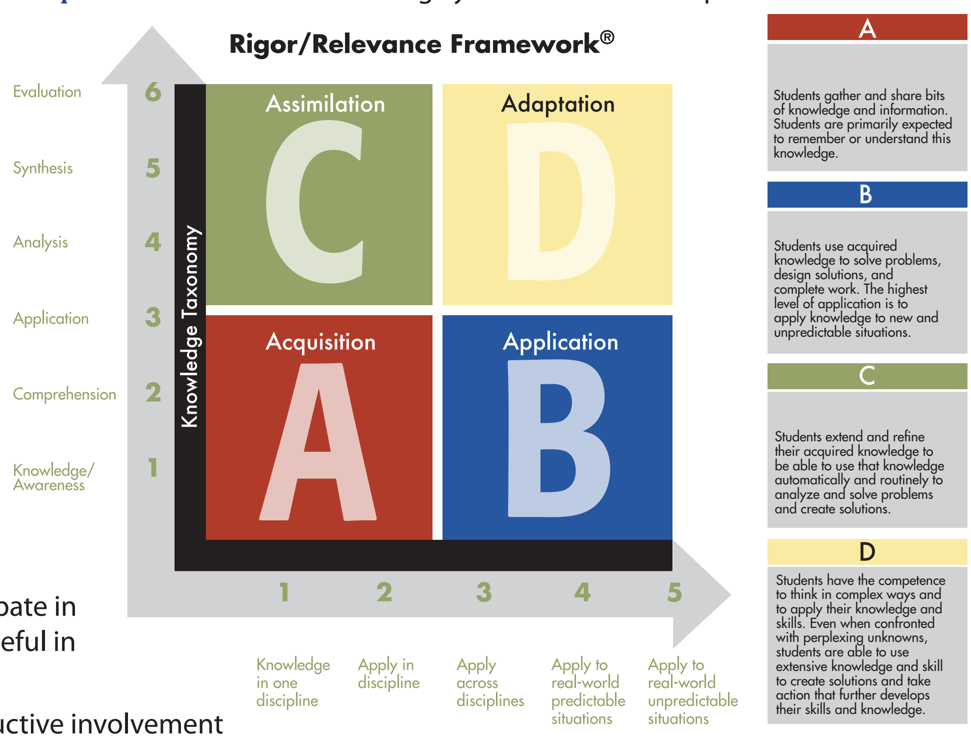
There are several ways to view assessment of student learning in science. Some school districts have a very specific and rigid system of assessment utilizing regularly scheduled standardized tests consistent with state assessment strategies. Other districts are a bit more flexible utilizing teacher-written tests throughout the year culminating with state-mandated standardized testing for certain grades. Regardless of the local process, the lessons in the ***Real Science: Pathways to Next Generation Science Standards*** can be quite useful.

1. All assessments are designed to indicate the level of understanding of a particular topic. When it is clear that a particular topic is not mastered, it makes little sense to teach it again using the same strategies. The lessons in this book provide an alternative.
2. The lessons in this book can be used as a pre-test. Perhaps when first addressing a topic, students are given a lesson from this text. As they progress through the learning cycle, misunderstandings become apparent. The teacher then knows what to cover in more depth. This could occur during the learning cycle or after it has been completed.
3. The lessons in this book can be used as a post-test. After receiving instruction on a particular topic, the corresponding learning cycle could be assigned. Successful completion of the activities could be used to determine mastery.
4. The teacher may decide to write assessments consistent with local policies that measure important objectives aligned with the philosophy of the learning cycle.
5. The teacher may decide to use the learning cycle as a means to teach important objectives that will be assessed using district or state standardized assessment tools.
6. The activities from the **Apply It** or the **Expand It** sections of the learning cycle could be developed into an assessment. A rubric could be created to describe and quantify the quality of work.

Importance of Real-World Connections

Engaging students in experiences that are connected to the real world is critically important to learning. In her publication, "How Children Learn," Stella Vosniadou discusses research that identifies key factors in effective teaching and learning, including:

- Learning becomes more meaningful when the lessons are applied to real-life situations.
- People learn best when they participate in activities that are perceived to be useful in real life and are culturally relevant.
- Learning requires the active, constructive involvement of the learner. [1]



International Center for Leadership in Education, http://www.leadered.com/rrr.html

Dr. Bill Daggett has provided strong leadership for relevance in education. His Rigor and Relevance Framework offers a compelling visual argument for authentic connections and rigorous curriculum.

[1] Vosniadou, Stella. How Children Learn. International Academy of Education. 2001. <http://tinyurl.com/6m82jvk>.

PATHWAYS TO COLLEGE & CAREER READINESS

CareerClusters™

One of the keys to improving student achievement is providing students with relevant contexts for studying and learning. Career Clusters™ do exactly this by linking school-based learning with the knowledge and skills required for success in the workplace. The National Career Clusters™ Framework is comprised of 16 Career Clusters™ and related Career Pathways to help students of all ages explore different career options and better prepare for college and career.

Each Career Cluster™ represents a distinct grouping of occupations and industries based on the knowledge and skills they require. The 16 Career Clusters™ and related Career Pathways provide an important organizing tool for schools to develop more effective programs of study (POS) and curriculum.

Quoted from: http://www.careertech.org/career-clusters/glance/careerclusters.html

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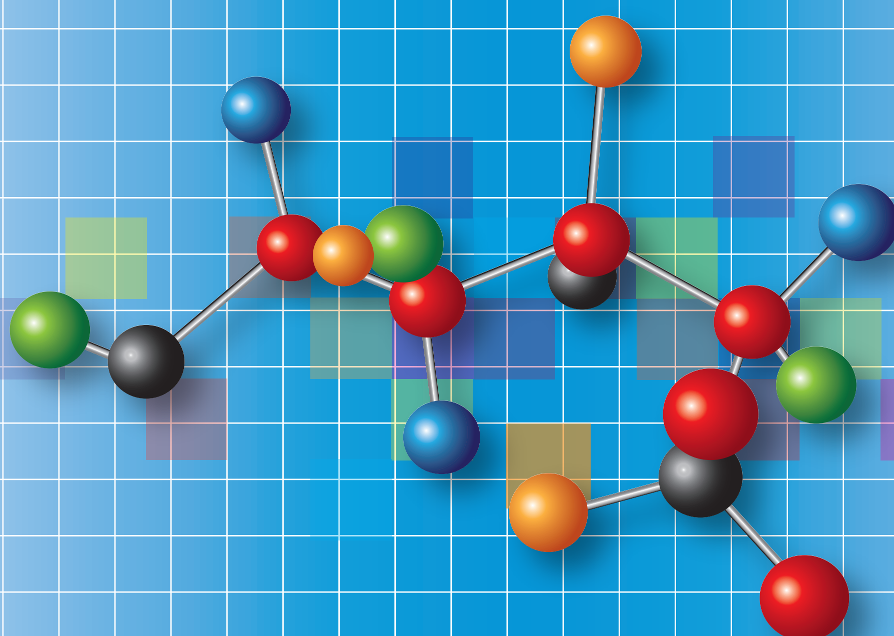

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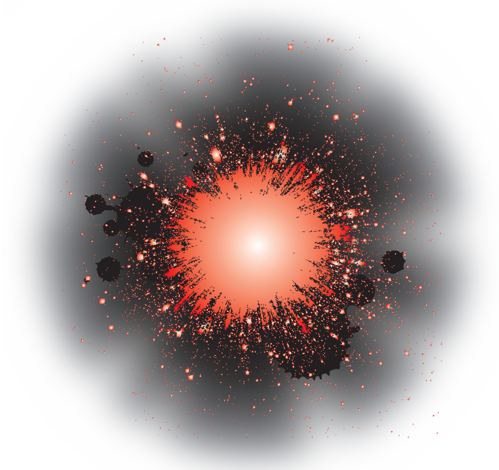
Red Shift

Teacher Edition



Illinois Pathway: Science, Technology, Engineering, and Mathematics

Site Visit: Astro-Physics, Loves Park, IL

Objectives: You will be able to:

- Model and explain the Doppler Effect
- Apply the Doppler Effect to theories of the origins and movement of the galaxies

Introduction: As you know, sound travels in waves. Waves have a wave length, amplitude, and frequency. The wavelength is fairly long on low notes and short on high notes, but it is the frequency that determines the pitch that we hear. Frequency is measured in hertz. One hertz is one cycle per second. As the wave strikes your ear, one trough and one peak per second would be a frequency of 1 hertz. The average human can hear sounds between 20 hertz and 20,000 hertz. Amplitude is the height of the wave and is directly related to volume. Very soft sounds have low amplitude, loud sounds have high amplitude.

In this lesson you will be using wavelength, amplitude, and frequency to learn about our universe.

Your students probably already know that sound travels in waves. They may not be familiar with the terminology or some of the phenomena associated with wave movement.

In this lesson they will be using wavelength, amplitude, and frequency to learn about our universe.

Materials: Each pair of students will need:

- 3 meters of adding machine paper or similar
- Pencil
- Stopwatch
- Meter stick

NEXT GENERATION SCIENCE STANDARDS

Performance Expectations ***Students who demonstrate understanding can:***

HS-ESS1-2. Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

TRY IT

Data you may need:

- **Velocity of sound is about 342 meters per second**
  (about 766 miles per hour depending on temperature, humidity, and air pressure)
- **Frequency = Velocity of wave/wavelength**
- **Velocity of wave= frequency x wavelength**
- **Wavelength = Velocity of wave / frequency**
- **The frequency (hertz) of each higher note is 1.06 times the hertz of the next lower note.**

Part 1

1 Get a piece of paper that is about 1 meter long.

2 Sit on one side of the desk with your partner on the other side.
A narrow desk works well for the first trial, but a wider surface is best for Parts II and III.

3 Have most of the paper on your side, but your partner should be holding on to the end and will pull it his/her direction in step **7**. Don't pull it yet.
They should not start pulling immediately, but be set up to do so.

4 Start moving a pencil at a regular rate back and forth on the paper strip. Your pencil should come close to each side if the paper, but not go off either edge. Don't move the paper yet.
They will probably move back and forth about 3 cm at a rate of about 4-6 stokes per second or so. They should not go too fast. Slower is better than faster.

5 The line you are drawing back and forth represents vibration that causes sound. Half the width of your line is the amplitude of the wave (*from the middle to one edge*).
It will certainly not look like a wave at this point, only a very dark strip that is getting darker.

6 The rate you are going back and forth is the frequency (*measured in hertz*). What is your frequency? Count your back and forth movements and time them to calculate the hertz.

- a If you are at 27.5 hertz, you are producing a sound similar to the lowest note on a piano.
- b If you are at 4186 hertz, you are producing a sound similar to the highest note on the piano keyboard.
  Moving from one edge of the paper and back again is one cycle.

7 But waves move. As you continue to move you pencil back and forth, your partner should pull the paper under your pencil at a regular rate.

The partner should pull the paper so that the wavelength is about 3-5 cm in length. Here again, too fast is not good. Slower is better (to a point).

8 What did you just draw?

Now it looks like a wave.

9 Measure the wavelength.
The wavelength is measured from top of one crest to the top of the next. There is probably some variation due to changes in frequency and pulling speed.

10 The speed of sound equals the frequency (hertz) multiplied by the wavelength. What is your speed of sound?
Your students calculated their frequency in step 6 and now know their wavelength. Multiply the two together to get the velocity.

- a The actual speed of sound is about 342 meters per second. Yes, you would have to pull the paper very fast.
- b The wavelength of the lowest note on the piano is 12.5 meters
- c The wavelength of "Middle C" is 1.31 meters
  You may wish to conduct additional research to share with students concerning the mathematical relationships between musical notes.

11 You just modeled the production of a wave. You just made some noise.
Well, it could be noise, or light, or anything else that produces waves.

Part 2

1 Get another piece of paper.
The additional pieces are also about 1 meter long.

2 What happens if the object making the noise moves toward the receiver?
This activity will model a vehicle moving toward a listener.

3 For this trial, try to keep the amplitude, frequency, and velocity of the paper the same.
This is one reason why going slower is better that going faster. Slower is easier to duplicate.

4 Instead of staying stationary, however, move toward your partner, drawing on the paper closer and closer to your partner's side of the desk as he/she pulls the paper.
This will require a wider desk. The student with the pencil should start on their own side of the desk and end up near the partner's side.

Part 3

1 Get another piece of paper.
Using separate pieces for each trial allows easy comparison.

2 What happens if the object making the noise moves away from the receiver?
This activity will simulate the sound change when the race car suddenly goes from moving toward the listener to going away. All race fans have heard it, but maybe did not understand it.

3 For this trial, try to keep the amplitude, frequency, and velocity of the paper the same.
Perfect uniformity is impossible given the methodology. "Close" is close enough.

4 Instead of staying stationary, however, move away from your partner, drawing on the paper further and further from your partner's side of the desk as he/she pulls the paper.
The student with the pencil should start on the far side of the desk by the partner and move toward their own side.

Lay the three strips of paper side by side and analyze the differences. What you are seeing was first studied by Christian J. Doppler in the 1840s. Any idea what it is called?
The first trial illustrates sound (or any wave) at a standard speed. The second trial will have a shortened wavelength and increased frequency because the object making the wave moved toward the previous wave while creating another wave, thus shortening the distance between them. The third trial illustrates what happens when the object making the wave moved away from the wave while creating another wave, thus lengthening the distance between them. The speed of the wave and the amplitude did not change. This is known as the Doppler Effect.

Discuss It

1 As the frequency increases, what happens to the pitch of the musical note?
Pitch increases

2 If the velocity of the wave stays the same but the frequency increases, what must happen to the wavelength?
According to the mathematical formula describing the relationship between frequency, speed, and wavelength, the wavelength must decrease.

3 Your first trial modeled sound at a regular velocity with the producer and receiver stationary. What happened to frequency when the producer was moving toward the receiver? What would you hear?
The frequency increased so the pitch will be higher.

4 What happened to the wavelength when the producer was moving toward the receiver?
The wavelength decreased.

5 Your third trial modeled the producer moving away from the receiver. What happened to the frequency when the producer was moving away from the receiver? What would you hear?
The frequency decreased so the pitch will be lower.

6 What happened to the wavelength when the producer was moving away from the receiver?
The wavelength increased.

Apply It

1 The phenomena that you just explored works with all types of waves.
In this section it will be applied to light waves. It may be helpful if students look at the color spectrum something like the notes on a piano. The low notes (long wavelength) are red and the high notes (short wavelengths) are blue.

2 Scientists have discovered that light coming from more distant stars is more reddish in color than that coming from nearer stars. In fact, it appears that the further away a star is, the more reddish the color.
You may wish to share some research with your students concerning this discovery. Hint: the Hubble Space Telescope is named after one if the key scientists.

3 Make a list of the possible causes of a reddish shift.
The most obvious is that the universe is expanding. The galaxies further away seem to be going faster than the ones that are closer. It may also be caused somehow by the distance or perhaps the further galaxies are emitting a different light than expected. Perhaps the spinning of the galaxies cause the aparent movement away from earth now, but toward earth later (on the other side of the "lap"). Remember that the earth is also moving. There are many unknowns when dealing with galaxies that are hundreds or even millions of light years away.

4 What are the ramifications or theories that can be made about the universe due to this observation?
If the universe is expanding, then rewinding the process means that in the past all parts were closer together. This theory is strengthened by more distant galaxies moving faster than nearer galaxies. In the very long distant past, they were very, very close together. Perhaps in one big, very dense clump, being dispersed by a "big bang" (an obvious understatement).

Expand It

1 If you knew the frequency of the sound of an engine, could you calculate the speed of the vehicle? How?

2 What other devices use the Doppler Effect of wave motion?

References:

www.curiosity.discovery.com

http://www.school-for-champions.com/science/sound_frequencies.htm#.VCWVtfldVik