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A Sound Education

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Educational Outreach
Baylor College of Medicine



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Biology Teacher Resources from Baylor College of Medicine

A Sound Education

Image Reference

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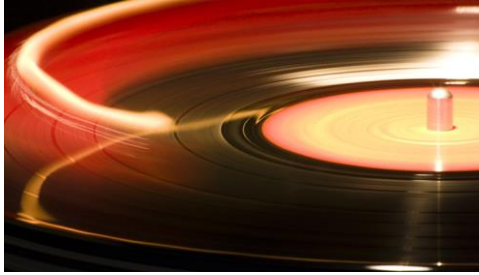
Key Words

amplitude, doppler, energy, frequency, hear, hearing, hertz, Hz, infrasound, sound, sound waves, wavelength, wave crest, wave trough, ultrasound

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What Is Sound?

- Sound is an oscillation of pressure, transmitted as waves through solids, liquids, gases and plasma.



- Sound is a form of energy.

What Is Sound?

Sound moves through matter in the form of waves. Although we typically think of sound as coming through the air, it also moves through solids, liquids and plasma.

Image Reference

Photo © Ivan Zubar. The Sound of Decadence. Used with permission.
<http://www.flickr.com/photos/25922018@N07/2776100984>

Key Words

sound, energy, mechanical energy, pressure, sound wave

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What Is Energy?

- Energy is hard to define because it exists in many forms and can change from one form to another. It causes matter to change states (such as the melting of an ice cube or the burning of a candle). Energy also can produce movement (such as a vibration or a physical relocation).
- Energy is anything that can change the condition of matter, or the ability to do work.
- In a sound wave, energy is manifested as vibrations.



What Is Energy?

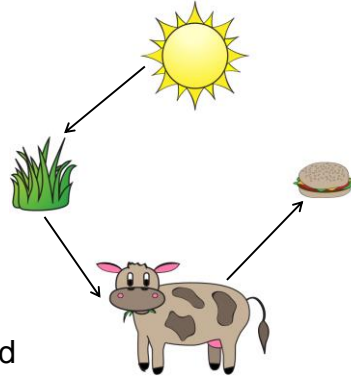
Key Words

sound, energy, matter, mechanical energy, movement, pressure, sound wave, vibration, work

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The Food Chain

- The sun produces that is transferred across space in the form of light and heat.
- When the energy reaches Earth, it is taken in by plants.
- The chemical energy is taken in by the cow when it eats the plant.
- When the cow becomes a food product, the chemical energy is transferred to the food.



The Food Chain

The sun produces energy through a thermonuclear reaction. The energy is transferred across space in the form of light and heat.

When the energy reaches Earth, it is taken in by plants, in chemical form (carbon dioxide and water), through the process of photosynthesis.

The chemical energy is taken in by the cow when it eats the plant.

When the cow becomes a food product, the chemical energy is transferred to the food.

Image Reference

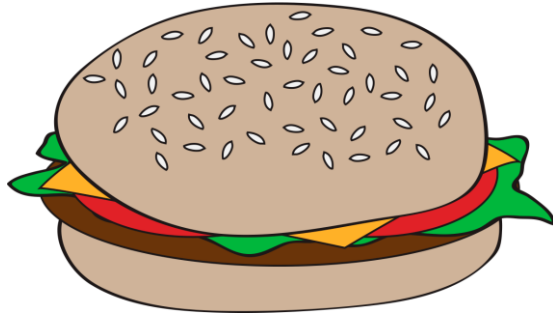
Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

Key Words

sound, energy, animal, chemical energy, cow, electromagnetic radiation, food, food chain, heat, light, matter, mechanical energy, photosynthesis, plant

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Is the Energy Used Up?



Is the Energy Used Up?

Is the energy used up? [No. When the cow becomes a food product, the chemical energy is transferred to the food.]

Image Reference

Illustration by G.L. Vogt, EdD.

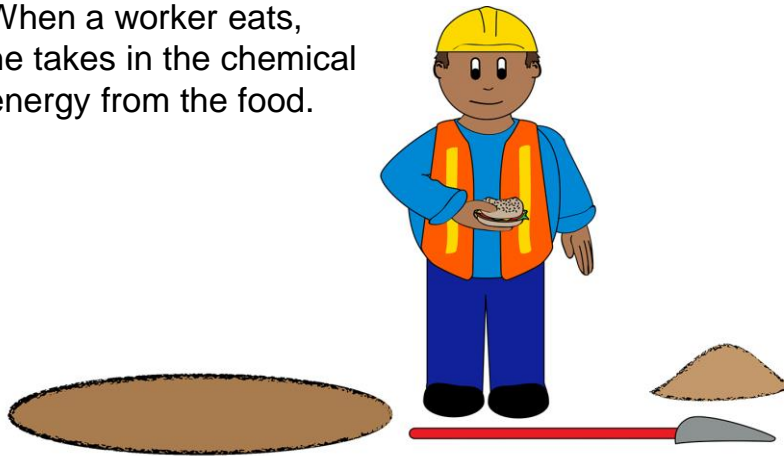
Key Words

sound, energy, animal, chemical energy, electromagnetic radiation, food, food chain, food product, heat, light, matter, mechanical energy

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Food Contains Energy

When a worker eats, he takes in the chemical energy from the food.



Food Contains Energy

When a worker eats, he takes in the chemical energy from the food.

Image Reference

Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

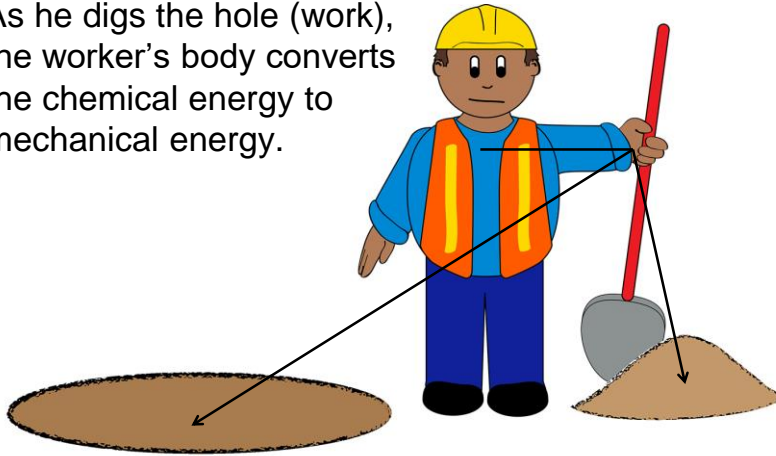
Key Words

sound, energy, chemical energy, food, food chain, food product, human, kinetic energy, matter, mechanical energy, work

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Work Causes Energy to Change Forms

As he digs the hole (work), the worker's body converts the chemical energy to mechanical energy.



Work Causes Energy to Change Form

As he digs the hole (work), the worker's body converts the chemical energy to mechanical energy.

Image Reference

Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

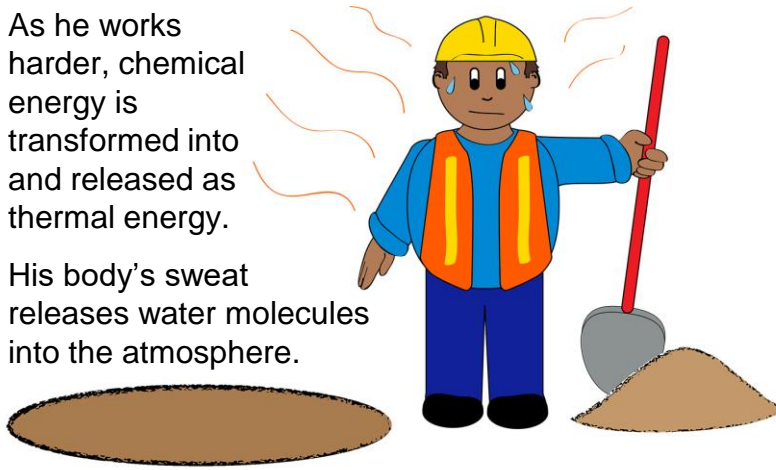
Key Words

sound, energy, chemical energy, food, food chain, food product, kinetic energy, human, matter, mechanical energy, work

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Forms: Thermal and Chemical Energy

- As he works harder, chemical energy is transformed into and released as thermal energy.
- His body's sweat releases water molecules into the atmosphere.



From the Worker to Thermal Energy

As he works harder, chemical energy is transformed into thermal energy. Sweating releases water molecules into the atmosphere.

Image Reference

Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

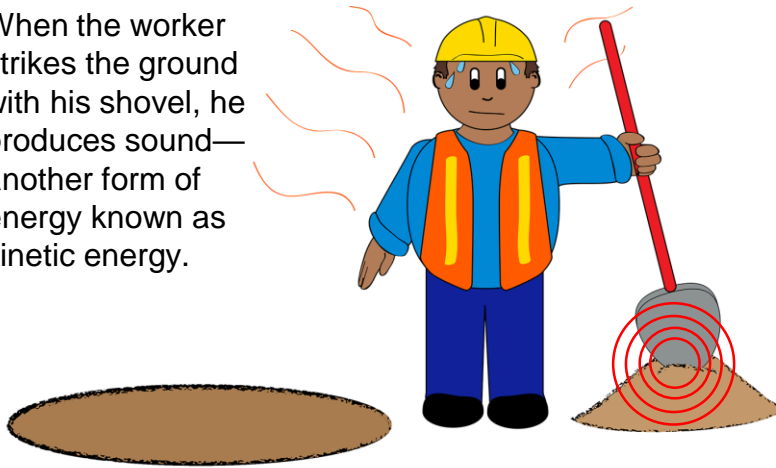
Key Words

sound, energy, chemical energy, food, food chain, food product, heat, human, kinetic energy, matter, mechanical energy, sweating, thermal energy, work

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Energy as Sound

When the worker strikes the ground with his shovel, he produces sound—another form of energy known as kinetic energy.



From the Worker's Shovel to Sound!

When the worker strikes the ground with his shovel, he produces sound—another form of energy known as kinetic energy.

Image Reference

Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

Key Words

sound, energy, atmosphere, chemical energy, food, food chain, heat, human, kinetic energy, matter, mechanical energy, sweating, thermal energy, work

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Conservation of Energy

Energy cannot be created or destroyed. It may be transformed from one form into another, but the total amount of energy never changes.



Stellar nurseries, areas where new stars form in space, are made of dense clouds of dust and gas called nebulae. Nebulae are produced by exploding stars.



Illustration courtesy of NASA.

Conservation of Energy

The first law of thermodynamics expresses that energy can be transformed (changed from one form into another), but cannot be created nor destroyed. In other words, in any process in an isolated system, the total energy remains the same. A closed system transfers energy by the processes of heat and mechanical work.

Image Reference

Pillar and Jets HH 901/02. Hubble Space Telescope WFC3/UVIS, courtesy of NASA. http://www.nasa.gov/images/content/447139main_hubble20th-img.jpg

Key Words

sound, energy, conservation of energy

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How is Sound Related to Energy?

- Energy is anything that can change the condition of matter, or the ability to do work.
 - Change of position (movement)
 - Change of state (ice melts into liquid, water evaporates into vapor, water vapor condenses and falls as rain, liquid water flows to the ocean)
- Sound is a form of energy because it is an oscillation of pressure that is transmitted by waves (vibrations) through solids, liquids, gases and plasma.



How is Sound Related to Energy?

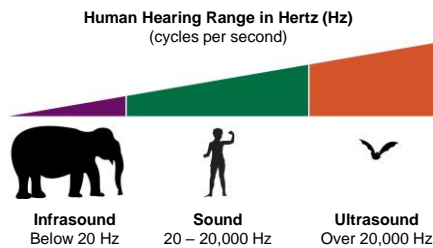
Key Words

sound, energy, change of state, matter, oscillation, pressure, vibration, wave, work

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Are All Sounds Audible?

- Sound is an oscillation of pressure transmitted by mechanical waves through solids, liquids, gases and plasma. We think of sound as composed of frequencies within the range of hearing. But additional sounds are out of our audible range.
- Vibrations too low for us to hear are known as infrasounds.
- Ultrasounds are those sounds that are too high for us to hear.



Are All Sounds Audible?

While we focus on sounds we can hear, there are other sounds beyond our audible range (range that can be detected by our hearing).

Infrasounds are vibrations too low for us to hear.

Ultrasounds are sounds too high for us to hear.

Our ears cannot detect those out-of-range sounds, but technologies allow us to utilize ultrasounds in medicine, geology and many other fields.

Image Reference

Illustration by M.S. Young, BFA from G.L. Vogt, EdD.

Key Words

sound, energy, audible, frequency, hear, hearing, hertz, Hz, infrasound, oscillation, pressure, mechanical wave, sound wave, ultrasound, vibration

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A Few Sound Misconceptions

- Hitting an object harder changes the pitch of the sound produced.
- You can simultaneously see and hear a distinct event.
- Sounds can travel through empty space.
- Sounds cannot travel through liquids and solids.
- In wind instruments, the instrument itself vibrates.
- In actual telephones, sounds are carried through the wires.



A Few Sound Misconceptions

Reference

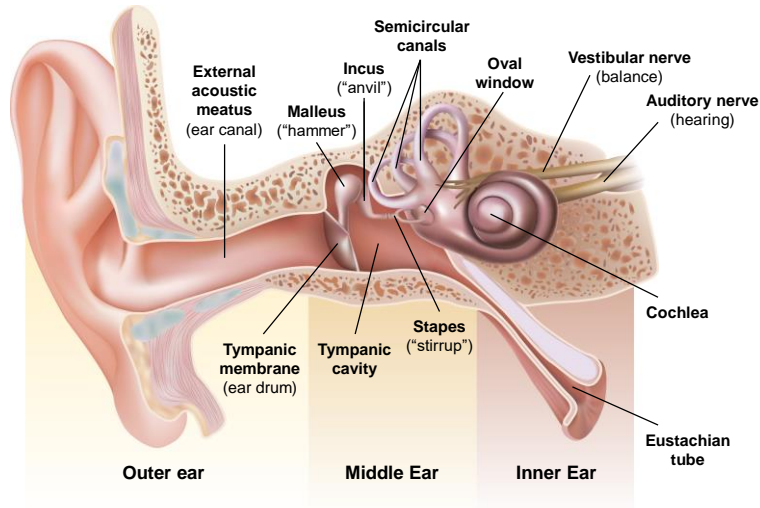
Hapkiewicz, A. (1992). Finding a List of Science Misconceptions. *MSTA Newsletter*, 38 (Winter 92), pp.11-14.

Key Words

sound, energy, telephone, vibrate, vibration

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Anatomy of the Human Ear



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Anatomy of the Human Ear

There are three main components of the human ear: the outer ear, the middle ear and the inner ear.

Image Reference

Modified (re-labeled ear parts) illustration 13699578 © Peter Junaidy. Licensed for use.

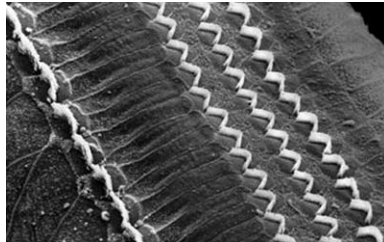
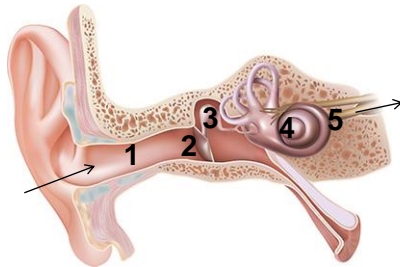
Key Words

sound energy, anatomy, auditory nerve, cochlea, ear, ear canal, ear drum, hear, hearing, incus, inner ear, malleus, middle ear, stapes, outer ear

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How Do We Hear Sound?

Sound waves are channeled into the ear via the outer ear structure. They pass through the ear canal, causing the eardrum to vibrate, and then reach the cochlea, where hair cells detect vibrations and transmit electrical signals through an auditory nerve to the brain.



This SEM shows normal hair cells in the cochlea. On the right are three bands of outer hair cells, which amplify sound waves. On the left are inner ear hair cells, which help transform sound waves into electrical signals.



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SEM courtesy of Andres Groves, PhD. Used with permission.

How Do We Hear Sound?

1-2. Sound waves entering the outer ear pass through the ear canal, causing the ear drum to vibrate.

3. The vibrations of the ear drum focuses waves through the three tiny bones (malleus, incus and stapes) before moving through the oval window into the cochlea.

4. Outer hair cells mechanically amplify low-level sounds that enters the cochlea. Inner hair cells of the cochlea help transform the mechanical sound vibrations into electrical signals.

5. The electrical signals are transmitted via the auditory nerve to the brain. The brain translates the electrical signals into the sound we perceive.

Note: The semicircular canals (oriented along pitch, roll and yaw axes), and vestibular nerve are part of the vestibular system, which contributes to movement and sense of balance. The Eustachian tube helps equalize

pressure between that in the middle ear and atmospheric pressure. It also drains mucus from the inner ear.

References

- 1.Eustachian tube. Wikipedia CC-BY-3.0.
http://en.wikipedia.org/wiki/Eustachian_tube
- 2.Hair Cell. Wikipedia CC-BY-3.0. http://en.wikipedia.org/wiki/Hair_cell
- 3.OpenStax College. Hearing. OpenStax CNX CC-BY-3.0. June 20, 2012.
<http://cnx.org/content/m42297/1.3/>
- 4.Science of Sound and Auditory Injury. Hearing Center of Excellence, U.S. Department of Defense.
<http://hearing.health.mil/HearingLoss101/ScienceofSoundandAuditoryInjury.aspx>

Image Reference

- 1.Modified (re-labeled ear parts) illustration 13699578 © Peter Junaidy. Licensed for use.
- 2.SEM courtesy of Andrew Groves, PhD. Integrative Molecular and Biomedical Sciences, Baylor College of Medicine.
<https://www.bcm.edu/education/programs/imbs/?PMID=9497>

Key Words

sound energy, anatomy, auditory nerve, cochlea, ear, ear canal, ear drum, hair cells, hear, hearing, incus, inner ear, malleus, middle ear, stapes, outer ear

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Sound Transmission Speeds

- The speed of sound depends on the density of the material through which it is passing.
- The greater the density, the faster sound is transmitted. In lower-density materials, sound is transmitted more slowly.

Gas (depends upon the gas)

1 kilometer in ~ 3 sec (1 mile in 5 sec)

Liquids (depends upon the liquid)

Fresh water = 1.497 km/sec
Seawater = 1.560 km/sec

Solids (depends upon the solid)

Granite = ~ 5 km/sec
Steel alloy = ~ 6 km/sec



Sound Transmission Speeds

The key to how fast sound waves travel is the density of the media through which the waves move.

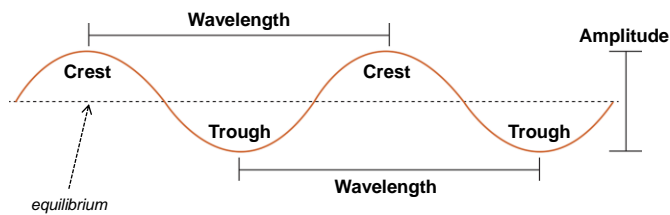
Key Words

sound, energy, density, gas, liquid, solid, sound transmission, sound wave, speed of sound,

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Sound Wavelength and Amplitude

- Sound travels in the form of waves. Wavelength is the distance between consecutive wave crests or wave troughs.
- Amplitude is the magnitude of change from highest crest to lowest trough (oscillations in pressure).



Sound Wavelength and Amplitude

Image Reference

Illustration by G.L. Vogt, EdD.

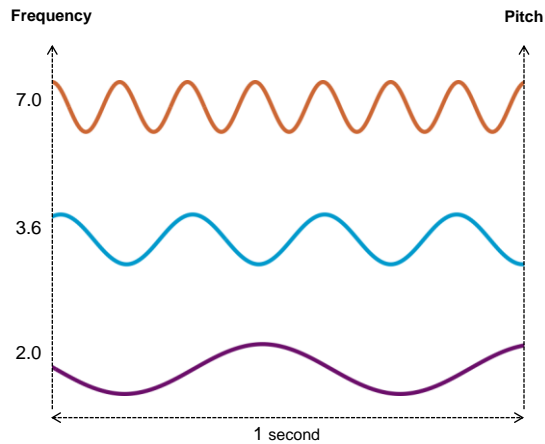
Key Words

sound, amplitude, oscillation, pressure, wave crest, sound wave, waves, wave trough, wavelength,

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Sound Wave Frequency

Sound wave frequency is the number of sound waves passing a fixed point in one second.



Sound Wave Frequency

Image Reference

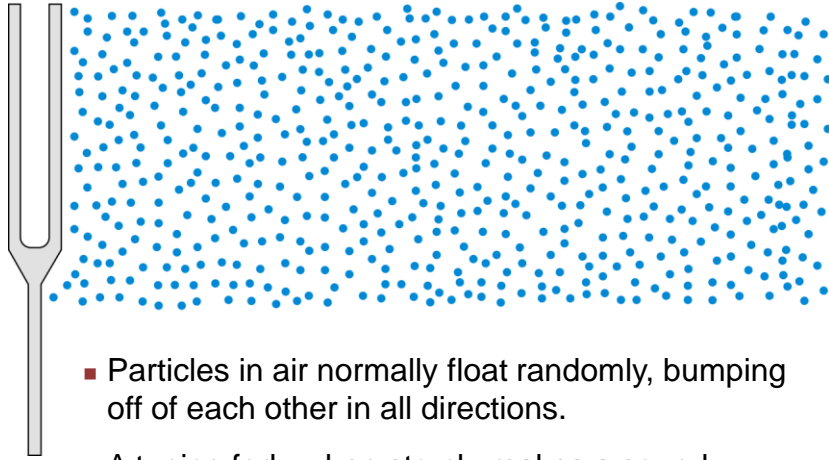
Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

Key Words

sound, frequency, pitch, sound wave, speed of sound, wavelength, waves

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Air Particles and Sound



Air Particles and Sound

Image Reference

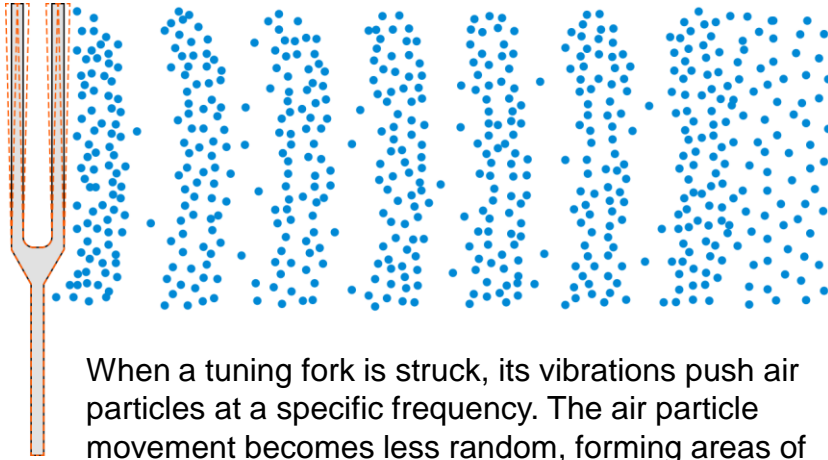
Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

Key Words

sound, air particles, tuning fork

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Sound is Vibration



When a tuning fork is struck, its vibrations push air particles at a specific frequency. The air particle movement becomes less random, forming areas of compressions and rarefactions, or sound waves.



Sound is Vibration

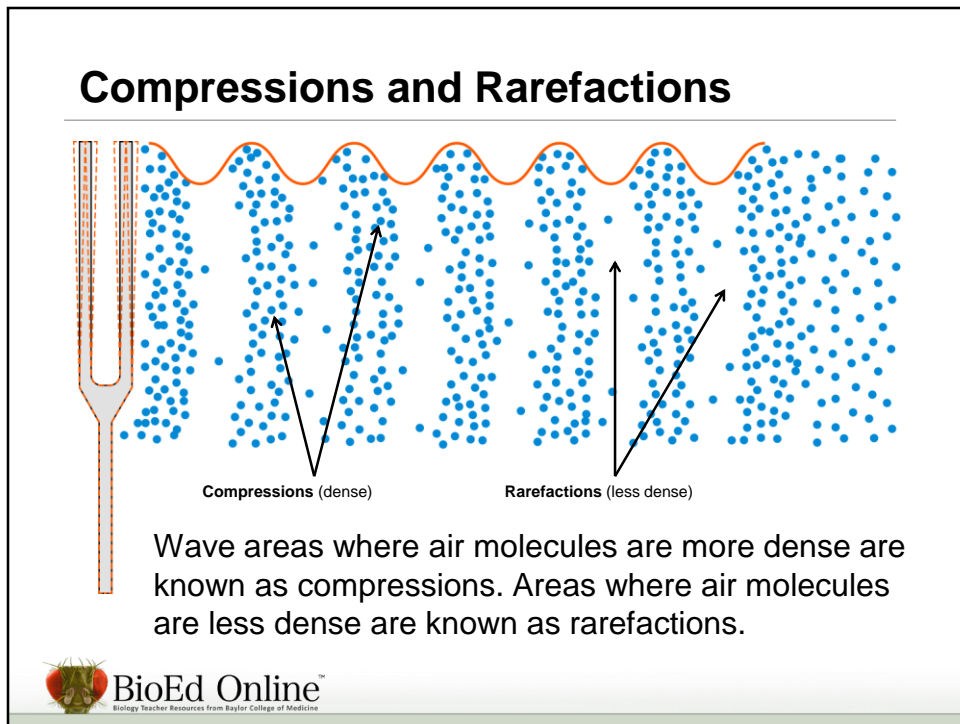
Image Reference

Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

Key Words

sound, air particles, movement, pressure, sound wave, tuning fork, vibration

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Compressions and Rarefactions

The atoms and molecules of gas inside the “tube” become waves that travel the tube’s length. Areas where the air is more dense (crests of the waves) are known as compressions. Areas where air is less dense (troughs of the waves) are known as rarefactions.

Longitudinal sound waves are waves of alternating pressure deviations from the equilibrium pressure, causing compression and rarefaction.

Reference

Sound. Wikipedia CC-BY-3.0.

http://en.wikipedia.org/wiki/Sound_wave#Longitudinal_and_transverse_waves

Image Reference

Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

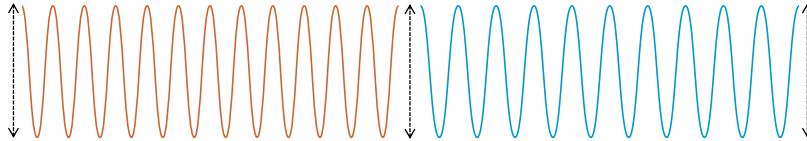
Key Words

sound, air particles, compressions, movement, rarefactions, pressure, sound wave, vibration

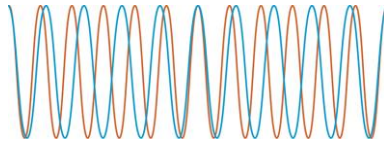
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Unsynchronized Wave Action

The two waves shown below have the same amplitude (magnitude of change between highest point (crests) and lowest points (troughs)).



When the waves are superimposed, it becomes apparent that they have different frequencies (more “orange” waves).



Unsynchronized Wave Action

Reference

Frequency. Wikipedia CC-BY-3.0. <http://en.wikipedia.org/wiki/Frequency>

Image Reference

Illustration by G.L. Vogt, EdD.

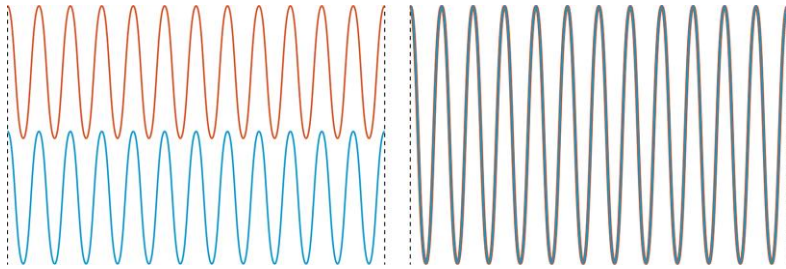
Key Words

sound, amplitude, sound crest, sound trough, sound wave, unsynchronized wave, wave action

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Synchronized Waves: Reinforcement

If two sound waves are synchronized such that their peaks and troughs coincide, the result of combining them is a more intense wave, created through their reinforcement.



Synchronized Waves: Reinforcement

Image Reference

Illustration by M.S. Young, BFA, from G.L. Vogt, EdD.

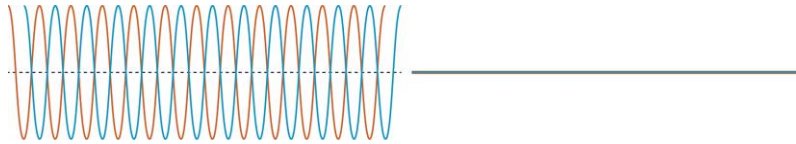
Key Words

sound, amplitude, cancellation, reinforcement, sound crest, sound trough, sound wave, synchronized wave, wave action

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Synchronized Waves: Cancellation

If two equal sound waves are synchronized such that the crests of each one coincides with the troughs of the other, a cancellation effect will produce a result identical to there having been no wave at all.



Synchronized Waves: Cancellation

Image Reference

Illustration by G.L. Vogt, EdD.

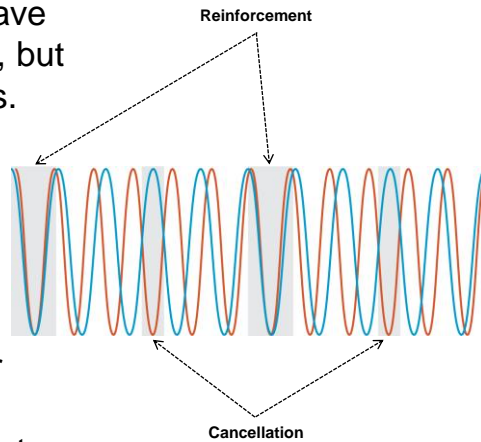
Key Words

sound, amplitude, cancellation, reinforcement, sound crest, sound trough, sound wave, synchronized wave, wave action

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Reinforcement and Cancellation

- These two waves have the same amplitude, but different frequencies.
- Because the waves' crests and troughs are not synchronized, the waves sometimes reinforce each other and sometimes cancel each other out.



Reinforcement and Cancellation

Image Reference

Illustration by G.L. Vogt, EdD.

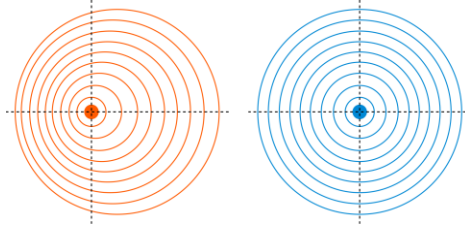
Key Words

sound, amplitude, cancellation, reinforcement, sound crest, sound trough, sound wave, unsynchronized wave, wave action

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Doppler Effect (Doppler Shift)

- When a moving object creates sound, like a police car with its siren on, the space between sound waves is compressed ahead of the car and stretched out behind it (illustration, left). This changes the perceived natural pitch of the siren to bystanders.
- However, inside the car (illustration, right), the police hear just the natural pitch because they are traveling with the sound. The faster the squad car goes, the greater the pitch change.



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Doppler Effect (Doppler Shift)

Image Reference

Illustration by M.S. Young, BFA.

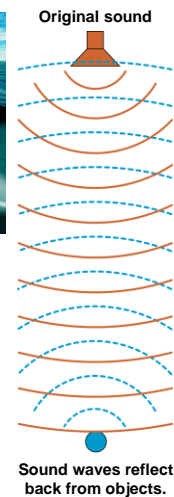
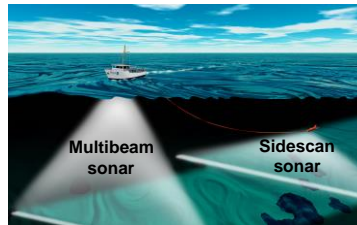
Key Words

sound, compression, doppler, movement, pitch, sound wave, vibration

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Sound Navigation and Ranging (SONAR)

- Sound waves can travel through water and reflect off the objects with which they come into contact. Active sonar works by sending pulses of sound and listening for echoes. The echoes are picked up by special machines and interpreted.
- Sonar is used in seafloor mapping, detecting objects, finding fish, and tracking underwater vessels.



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Multibeam and sidescan sonar illustration courtesy of NOAA.
Sonar diagram image modified from illustration © Georg Wlora CC-BY-SA 3.0.

Sound Navigation and Ranging (SONAR)

Sound waves can travel through water and reflect off the objects with which they come into contact. Passive sonar is simply listening for sounds made by other objects, such as submarines. Active sonar works by sending pulses of sound and listening for echoes. The echoes are picked up by special machines and interpreted. Sonar is used in seafloor mapping, finding fish, detecting objects, and tracking underwater vessels.

Sonar frequencies vary from infrasonic frequencies (very low) to extremely high frequencies.

Reference

Sonar. Wikipedia CC-BY-3.0. <http://en.wikipedia.org/wiki/Sonar>

Image References

1. Multibeam and Sidescan sonar illustration courtesy of NOAA.

http://oceanexplorer.noaa.gov/explorations/04fire/background/mapping/media/multi_sonar.html

2. Illustration modified from Sonar_Principle_DE.svg © Georg Wiora CC-BY-SA 3.0.

http://commons.wikimedia.org/wiki/Sonar#mediaviewer/File:Sonar_Principle_EN.svg

Key Words

sound, sound wave, seafloor mapping, sonar

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Ultrasound

Ultrasound is a sound wave that humans cannot hear. Often used in medicine, ultrasound allows the internal structure of the human body to be seen and imaged. It also is used as a diagnostic tool in veterinary medicine, and in testing of materials to find flaws.



Ultrasound of a normal kidney.



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Photo © Nevit Dilmen CC-BY-SA 3.0.

Ultrasound

Ultrasound is a sound wave that humans cannot hear. Often used in medicine, ultrasound allows the internal structure of the human body to be seen and imaged. It also is used as a diagnostic tool in veterinary medicine and in testing of materials to find flaws.

Reference

Ultrasound. Wikipedia CC-BY-3.0. <http://en.wikipedia.org/wiki/Ultrasound>

Image Reference

Photo © Nevit Dilmen CC-BY-3.0.

http://commons.wikimedia.org/wiki/File:Kidney_ultrasound_110315132820_1329070.jpg

Key Words

sound, sound wave, ultrasound

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