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Seeing Mathematics in the Forces of Nature

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Introduction

The Rationale of the unit

The unit is written with the intent of integrating the concepts of waves and its physical interpretation and the mathematics which is used to explain the phenomenon. The concept of waves will be explained from the physical perspective, and the unit will attempt to use simple experiments to demonstrate to students how waves are propagated.

The unit will be written in three sections Section I will discuss the characteristics of waves, and the mathematics involved. Section II will explain sound waves and section III will consist of lesson plans and simple experiments that are designed to accompany the concepts developed in the lesson plans.

The objectives of the unit

1. The unit is designed to provide a series of lessons that can be used to enhance mathematics application in the area of the physical sciences.
2. The unit will aim to provide applications of mathematics for students after completing their AP calculus examination. Students will be expected to do a research on any of the concepts discussed in the unit.
3. The unit is written to provide background knowledge for students in a trigonometry class when working on a unit the application of sine curve.
4. The unit will also satisfy both the State and school district’s comprehensive school goals of providing connections between subject areas. This unit will embed mathematics in the physical sciences and provide real world applications.
5. The unit seeks to satisfy the reading for information objectives, which states that students will read for information to complete a task.

Section I

An Introduction to Waves

What are Waves?

Intuitively a wave is a motion or a disturbance, which causes a movement of particles from place to place. The most common example of wave movement is when a pebble is tossed in water. Water waves are formed by the disturbance that takes place on the surface of the water. On the other hand sound waves are formed when a disturbance is caused by a change in air pressure. Examples of sound waves are caused by a vibrating string. Earthquake waves are waves, which are formed by disturbances that occur in the Earth's surface.

Another description of waves is as a disturbance that moves particles through space and time. Waves travel and displace energy from one point to another. In general waves are formed when there are sustained disturbances of the particle in a medium. This medium can be either a gravitational field or a disturbance in a solid or liquid. In waves the energy vibrations are moving away from the source. The particles in the medium move, but the medium itself does not change location. This movement creates a wave pattern that begins to travel along the medium from one particle to another.

The frequency at which each particle vibrates is the same as the frequency at which the source vibrates. The period of vibration of each individual particle in the medium is equal to the vibration of the source.

All waves exhibits similar characteristics. The amplitude which gives the height of the wave; the period which defines the time for one up and down motion of the waves; and the frequency, which tells how often there is a up and down motion. The wave velocity is defined as the speed at which the disturbance moves. Wave velocity is also referred to as the speed of the wave as it moves from one location to the other. The wavelength is defined as the length of the wave.

Types of Waves

Mechanical Waves: water waves, sound waves, and the waves that are formed when a string or rope is disturbed are known as mechanical waves. The energy is carried through mediums such as water, air, the spring or rope. Mechanical waves are classified in three categories and each type disturbs the medium differently.

> i.) Transverse Waves are formed when the particles of the medium vibrates perpendicular to the direction of motion. The waves move along the string, but the spring is displaced up and down.
> ii.) Longitudinal waves: The wave motion is in the same direction as the disturbance. The displacement of the spring is in the same direction as the motion of the waves.
> iii.) Pulse wave: Pulse waves are formed by a single bump that travels through a medium. For example a pulse wave is formed by the toss of a rope. A particular point of the rope was at rest before the pulse reaches it. It then returns to rest after the pulse passes.

Wave Interference

Waves encounter boundaries or obstacles in their travels through the medium in which they travel. Some waves reflect back in the medium if they meet a very rigid obstacle, other waves will pass through the medium into another medium, sometimes changing direction at the boundary. Wave interference can either be constructive or destructive. The connection of waves with equal but opposite amplitude causes destructive interferences. Constructive interference occurs when the wave displacements are in the same direction. The result of constructive interference is a wave with a higher amplitude is larger than either of the two waves.

The following gives examples of wave interference.

i.) Superposition of waves: When two or more waves move through the same space they will produce a combined effect. Each wave will maintain their own integrity when they over lap and will co-exist in the same medium with themselves being permanently changed.
ii) Standing Waves. Standing waves are formed when a train of waves are generated or when a flexible material for example a rope is attached to a more rigid form such as a wall. Since the wall is too rigid to vibrate, by shaking the rope incident and reflected waves are formed. Standing waves are the result of interference. When two sets of waves of equal amplitude and wavelength pass through each other in opposite directions, the waves passes in and out of phase with each other. The waves will reflect on each other forming regions of constructive and destructive interference.
iii.) Continuous waves: Continuous waves are waves that are capable of moving from one region to another. Continuous waves will move from a region of higher speed to a region of lower speed. The amplitude of the wave will change as a result of the change in speed and also because the wave has less energy.
iv.) Traveling Waves: A traveling wave will move along the medium. Each point in the medium will vibrate regularly by the effect of the traveling waves.

The General Characteristics of Waves:

i.) Refraction: When a wave that moves in two or three dimensions comes to a region where its speed changes, its direction of travel may change. If the wave enters a region head on then the direction does not change, but if the wave enters at a different angle then the direction of travel changes. This change of direction is called refraction
ii.) Reflection: When a wave is returned after it hits a rigid object, this is referred to as reflection. The returning or reflected wave loose some of it energy on the return journey. Some of the energy travel into the medium that carried it. If the medium (example the rope) is anchored to

something rigid, then the returning wave is upside down. If the rope is flipped, then a train of waves travels down the rope. The initial part of the wave reflects from the end, the rope carries both of the waves at the same time, one traveling from the end and the other from the reflecting end. When the two waves merge, the particles on the rope get a push from each wave and move according to the net force they receive.
iii.) Diffraction: When a wave meets a barrier in its path, the waves bend around the edges of the barrier forming circular waves that radiate out the waves that spread out around the barriers. The spread of the waves around the barrier is called diffraction.

The Mathematics of Waves

The Vocabulary of waves :

Frequency: The frequency of a wave refers to how often the particles in the medium vibrate when a wave passes through the medium. The frequency of vibration is the number of to and fro vibrations the wave makes in a given time period. If the complete vibration occurs in one second, the frequency is one vibration per second. The unit of frequency is called the hertz (HZ). One vibration per second is 1 hertz. Higher frequencies are measured in kilohertz, (KHZ). The highest frequency is measured in gigahertz (GHZ,) in billions of hertz.

Period refers to the time which it takes for a particle on a medium to make one complete cycle. The period is measured in units of time such as seconds, hours, days or years. Frequency and period are different but related quantities. Frequency shows how often and period tells the time it takes for the wave to complete its cycle.

Period (P) = 1/ frequency. frequency = 1/ period.

The amplitude of the wave refers to the maximum amount of displacement of a particle on the medium from its rest position. The amplitude is measured from crest to rest. The crest of a wave is the point on the medium that is the maximum amount of upward movement. The trough of the wave is the point on the medium which shows the maximum downward displacement from rest.

Speed refers to how fast an object is moving and is expressed as distance per time. The speed of a wave is the distance traveled by a given point on the wave in a given period of time. The distance traveled by a wave is measured using the units meters traveled per second. The speed of periodic wave motion is related to the frequency and wave length of the waves. The wavelength is measured by how much time passes between the arrival of one crest and the other. The equation used to measure distance is also applicable to wave length: distance = speed / time. Wave speed is given as:

wave speed = wavelength × frequency

wavelength = wave speed / frequency

These relationships relate to all types of waves.

The wave Equation : The equation speed = wavelength × frequency is called the wave equation. It gives the mathematical relationship between the speed of the wave denoted by (v) and its wavelength (Λ) and the frequency (f). Using the symbols:

$V = f \times \Lambda$

The wavelength is the distance from the top of one crest to the top of the next, the unit of measure for wavelength is either meters for waves such as ocean waves; centimeters for pond waves; and nanometers for light waves. The frequency of vibration is the number of to and fro vibrations the wave makes in a given time period. If the complete vibration occurs in one second, the frequency is one vibration per second. The unit of frequency is called the hertz (HZ). One vibration per second is 1 hertz. Higher frequencies are measured in kilohertz, (KHZ). The highest frequency is measured in gigahertz (GHZ,) in billion of hertz.

Frequency = 1/ period

Period = 1/ frequency

2. The sine curve is the mathematical model used to represent the movement of waves.

Section II

Sound Waves

Sound is a longitudinal wave that travels through a material medium. Sound waves are used to discuss those waves that have frequency to produce hearing in humans. Humans are able to hear sound between the frequencies of 20 to 20,000 Hz. This is called the audible region. Sound below the audible region is called infrasonic and those above the audible region are called ultrasonic.

Sound can travel through any material, but the sound we hear travels through the air. The speed of a sound wave depends on the density of the medium, and the ease with which the medium can be compressed. The speed of sound in air is 332 meters per second at zero degrees Celsius, and increases by about 0.6 m/s for each degree increase in air temperature. Sound can travel through liquids as well as solids. The speed of sound is greater in solids and liquid than in gasses. Sound cannot travel through a vacuum, because there are no particles to vibrate.

Sound waves share the properties of other waves. They reflect off hard surfaces. These reflected sound waves are called echoes. Sound waves can also be diffracted, spreading outwards when passing through narrow places. Two or more sound waves can also interfere with each other causing dead spots.

Sound as Mechanical waves

Since sound waves are disturbances which are transported through a medium by the mechanism of particle to particle interaction, they are therefore called mechanical waves. Mechanical waves are waves which require a medium in order to transport their energy from one location to another. There are three processes that are involved in the creation of sound waves. First, there exist a medium which carries the disturbance from one location to another. Because mechanical waves rely on particle interaction in order to transport their energy, they cannot travel through regions of space that do not have particles. This medium could be the air or any other material. The medium is a series of interconnected and interacting particles. Secondly there must be a source of disturbance. This is usually a vibrating object that disturbs the first particle of the medium. Thirdly the sound wave is transported from one location to another by means of particle to particle interaction. If the medium is air then one air particle is displaced from its resting position, it then exerts a push or pull on its nearest neighbor causing them react to the force by moving from their original position. Mechanical waves cannot travel through a vacuum.

Newton's Laws of motion and conservation of energy principles are also applied to the motion of waves. Waves including waves such as sound waves, water waves and waves that are formed on a spring transmit energy are classified as mechanical waves. Mechanical waves serve as models for studying waves such as electronic waves and other waves that cannot be observed.

Sound as Longitudinal waves

Sound waves in the air are longitudinal waves because particles of the medium, air, water, or string through which they travel vibrates parallel to the direction which the sound moves. When the air in the medium is disturbed it pushes on the surrounding air molecules forward. This causes the air to compress into a small region of space. When the medium moves in the reverse direction it causes the air pressure to be lowered, causing the air molecules to move back. This back and forth movement is imparted to other air molecules in the medium.

The recognition that sound wave is a longitudinal wave arose from the fact that it propagates in air. An essential characteristic of a longitudinal wave which makes it different from other waves is that the particles of the medium move in a direction parallel to the direction of the source of energy.

Because of the longitudinal motion of the air particles, there are regions in the air where the air particles are compressed together and in other regions the air is spread apart. The compression regions are regions of high pressure, while the regions of low pressure are called rarefactions.

Sound as pressure waves

Since a sound wave consists of repeating pattern of high and low pressure regions moving through a medium, it is sometimes referred to as pressure waves. A sound detector can differentiate between regions of high pressure; this corresponds to the arrival of compressed air, low pressure region corresponding to rarefaction and region of normal pressure. The plot of the fluctuations in air pressure versus time will produce a sine curve. The peak points of the sine curve represent the compression periods, the low points represent the rarefactions, and the zero points correspond to the normal periods

The Properties of Sound and how it is measured

Sound, like other waves travels at a certain speed and has the same properties of frequency and wavelength. Sound travels at a definite speed and travels slower than light.

Pitch and Frequency

Pitch is a human perception resulting from the sensing of acoustic energy. It is the brain's response to the frequency of sound. The pitch is a pure sound a sinusoidal wave with a single fixed wavelength. The higher the frequency the higher the pitch.

Intensity and the decibel

The intensity of sound is defined as the power transmitted by the sound through a unit of area. This is the rate at which the energy being transported by the wave flows through a unit area perpendicular to the direction of travel of the wave.

Intensity is given as:

Intensity = power/ area.

Intensity is measured in units of watts/ meter squared. The human ear responds to intensities covering the range from 10^{-12} W/m ^{2} to more than 1 W/m ^{2}. Intensities are scaled by factors of ten. 10^{-12} called 0 bel is the reference point, is barely audible and was named after Alexander Graham Bell. A sound ten times as intense has an intensity of 1 bel or 10^{-11} W/m ^{2}. This is 10 decibels. The threshold of hearing is given as $I_0 = 1.0 \times 10^{-12}$ The sound --level is defined as:

$$\beta = 10 \log \left(\frac{I}{I_0} \right).$$

How Sound travels (The speed of sound)

Sound like all waves travels at a certain speed and therefore has the properties of frequency and wavelength. The relationship of speed and wavelength is given by

v = f Λ where v is the speed of sound, f is the frequency and Λ is the wave length. The wave length of sound is the distance between adjacent identical parts of a wave. The frequency is the same as that at the source and is the number of waves that passes a point per unit of time. The speed of sound is independent of the frequency.

The speed of sound is dependent on the medium through which it travels. The speed of sound in a medium is determined by a combination of its rigidity and its density. The more rigid the medium the faster the sound travels. The greater the density of the medium, the slower the speed of sound. The speed of sound in air is low because air is compressed. The speed of sound is greater in liquids and solids than it is in gases. This is because liquids and solids are more compressed.

The speed of sound is affected by temperature in a given medium. The speed of sound in the air at sea level is given as $\mathrm{v} = 331\mathrm{m/s}\sqrt{\frac{T(K)}{273K}}$ The speed of sound in gases is related to the average speed of molecules in the gas $\mathrm{v} = \sqrt{\frac{3kT}{m}}$.

Using Waves Speed to determine Distance

At normal pressure and a temperature of 20 degrees Celsius a sound wave will travel at approximately 343 m/s or 750 miles / hour. The speed of sound waves is much slower than light waves. Light waves travel at a speed of 300,000,000 m/s or 900,000 times the speed of sound. This difference explains why a light wave is seen before the sound wave (the thunder) is heard. The time delay between the arrival of the light wave and the arrival of the sound wave can be used to calculate distance of a storm. The model distance = v (velocity) (time) can be used to determine the distance that the sound wave has traveled.

The time delay between the production of sound and its reflection of the sound off a barrier can be used to calculate the speed at which sound travels. The time delay between the shout in a canyon and the return of the echo represents the time the shout travels the round trip distance. This time increment can be used to calculate the distance to the canyon wall.

Earthquakes

Earthquakes occur as a result of a sudden release of energy in the Earth's crust that creates seismic waves. These waves are caused by slippage along faults in the Earth's interior. These faults can be as deep as 400 miles in the interior. Some of the tremors loose their energy before they reach the Earth's surface. Where there is a major shift in an area where there are faults, a great deal of pressure is released. The rocks move into a new position. When the movement stops, the waves carry the energy in all direction throughout the Earth. The point at which the initial movement of the rock occurs is called the focus or the hypocenter.

Seismic energy travels through the crust in the form of waves. There are two basic kinds of seismic waves. Body waves and surface waves. Body waves travel outward in all directions, including downward, from the quake focus. Surface waves are confined to the upper crust. They travel parallel to the surface like ripples on the surface of a pond, and are usually slower than body waves.

As the earthquake waves move outward from the focus, the energy follows. Therefore the earthquake is strongest at the focus. Earthquake waves are of two types, longitudinal and transverse waves. Transverse waves are referred to as S waves move the Earth from side to side. Longitudinal waves, called P waves push and pull the Earth.

During an earthquake the body waves are the first to arrive. The fastest are the P waves. These P waves moves as an acoustic wave in the air. The S- waves are the second waves to arrive. The S- waves arrive with a sudden jolt. The last waves to arrive are the surface waves. These waves occur with the up and down and back and forth and side to side movements. These movements make the ground appear to roll.

Seismic waves weaken the farther away from the source. The strongest quakes will occur at the epicenter, the point above the focus of the earthquake. The focus can be either a few miles below the ground or can be as deep as 435 miles below. Earthquakes not only present themselves as ground shaking. They can trigger landslides that can cause vast areas to be covered by the sea blocks of the earth's crust can shift along fault lines either horizontally or vertically. Loose soil or sand can be shaken so hard that individual grains separate, turning the earth into a soft liquid. This situation is referred to as liquefaction.

Since earthquakes are sound waves in the earth it demonstrates how the speed is dependent on the rigidity of the medium. The P waves of an earthquake travel faster in granite than the speed of the S- waves. Both the P waves and S waves travel slower in less rigid material. P waves have speeds of between 4.00 to 7.00 km /s, and s waves have speeds of between 2.00 to 5 km/s. The P waves travel ahead of the S waves as they traveled through the earth. The time between the P-waves and the S --waves is used to determine the distance of the epicenter of the earthquake.

The Doppler Effect

The Doppler effect is an alteration of the observed frequency of a sound due to motion of either the source or the observer. The actual change in frequency is called the Doppler shift. For a stationary observer and a moving source, the observed frequency f is

$$f_{obs} = f_s \left\langle \frac{v_w}{v_w + v_s} \right\rangle$$

where f_s is the frequency of the source, v_s is the speed of the source, and v_w is the speed of sound. The minus sign is used for motion toward the observer and the plus sign for motion away. For a stationary source and a moving observer the observed frequency is given as:

$$f_{obs.} = f_s \left\langle \frac{v_w + v_{obs}}{v_w} \right\rangle$$

where v is the speed of the observer.

In general a Doppler effect is experienced when there is motion between the source of the sound and the observer. If the source of the sound and the observer is moving towards each other in opposite directions the frequency heard by the observer is higher than the frequency of the sound. When the source of the sound and the observer are moving away from each other the frequency heard by the observer is lower than the source frequency.

What causes the Doppler Effect or Shift?

The sound waves emitted by the point of source sound spread out spherically. If the source is stationary, then all the spheres are centered on the same point. Observers on either side of the source will experience the same frequency and the wave length between them are the same. If the source is moving, then each disturbance moves out in the sphere from the point of the source, but the point of the source moves. This movement causes the wavelength to be closer together on one side and farther apart on the other side. The wavelengths are closer together in the direction which the source is moving and farther apart in the opposite direction. If the observer is moving, then the frequency at which they hear the sound changes. If the observer is moving towards the source then the frequency is higher. If the observer is moving away from the source then the frequency is lower.

SECTION III - Lesson Plans

Lesson Plan I

Topic: Properties of Waves: Speed and Amplitude

Objectives : Students will be able to

a. Identify the parts of a wave
b. Calculate the speed of a wave

c. Calculate wavelength
d. Calculate the period of a wave.

Content:

How fast does a wave travel? The speed of a wave can be computed by using the same method that is used to determine the speed of a moving car by applying the formula speed (velocity v) = distance / time.

Strategy:

a. discuss properties of waves
b. demonstrate the experiment on the formation of waves
c. Discuss different types of waves.
d. Identify the parts of a wave
e. Review the formula for distance speed and time
f. Show the connection between the speed of waves and the speed of a car
g. Worked examples on CB.

Problems for Application :

Connect the sine curve as a model for wave. Draw and the parts of the wave draw the parallel to the sine curve (amplitude, crest, troughs, wavelength)

Lesson Plan II

Topic: The Doppler Shift

The Essential Questions : Why does the siren of the police seem to fade in the distance?

Objectives: Students will be able to

· Use a diagram to explain the Doppler shift
· Solve problems involving the Doppler shift.

Background Information:

The sudden change in the police siren as the car passes by is defined as the source of motion. The Doppler Effect is the shift in the frequency and wavelength of the sound waves generated from the source moving with respect to the medium. Sound waves are produced at a constant frequency, and the wave-fronts radiate symmetrically away from the source at a constant speed, which is the speed of sound in the medium. The distance between wave-fronts is the wavelength. All observers will hear the same frequency, which will be equal to the actual frequency of the source.

Activities :

i.) Introduction of the Doppler shift formula
ii.) Worked examples
iii.) Reading / research for students
iv.) Research paper on the uses of Doppler shift in medicine, metrology, and shipping.

Significant task : A police cars travels down a highway at a speed of 33.5 m/s or 75miles / hour. Its siren emits sound at a frequency of 400 Hz. If you are a passenger in a car traveling at 24.6 m/ s going in the opposite direction as the car approaches the police car moves and as the car moves away from the police car, calculate the frequency for each. Draw a picture the represent the situation.

Lesson III

Topic : Sound Levels

Objectives :

The students will be able to

a.) Compare different sound levels
b.) Calculate sound levels
c.) Apply the properties of logarithms to calculating the intensity of sound.

The Essential Questions: What is the decibel level of the faintest sound that we can hear? What is the effect of the intensity of sound on the decibel level? Can the MP player damage your hearing?

Background Information :

The faintest sound that the human ear can detect at a frequency of 1000Hz correspond to an intensity of 1.00 $\times 10^{-12}$ This is called the threshold of hearing. The loudest sound that the ear can tolerate correspond to an intensity of 1.00 W/ m^2 . Sound intensity varies by a factor of ten. The table lists noise levels and their effect on hearing

Sound Levels (dB)	Intensity (W/m^2)	Effect / Examples
0	1×10^{-12}	Threshold of hearing at 1000 Hz
10	1×10^{-11}	Rustle of leaves
20	1×10^{-10}	Whisper 1 m away
30	1×10^{-9}	Quiet home
40	1×10^{-8}	Average home
50	11×10^{-7}	Average office, soft music
60	1×10^{-6}	Normal conversation
70	1×10^{-5}	Noisy office, busy traffic
80	1×10^{-4}	Loud radio, classroom lecture
90	1×10^{-3}	Inside a subway train
100	1×10^{-2}	Noisy factory, siren from 30m
110	1×10^{-1}	Damage from 30 minutes exposure
120	1×10^{0}	Loud rock music, threshold of pain damage in seconds
140	1×10^{-2}	Jet plane at 30 meters, severe pain
160	1×10^{-3}	Bursting of eardrum

The sound level in B in decibels of a sound having an intensity of 1 in W/m^2 is defined as

$$\beta\ (\text{dB}) = 10 \log_{10} \left(\frac{I}{I_0} \right) \text{ where } I_0 = 10^{-12}\ \text{W/ m}^2$$

Sound level is not the same as intensity. Sound level B is defined is a ratio, and is therefore a unit- less quantity used to compare sound level to a fixed standard 10^{-12} W/m^2

Classroom problems

Calculate the sound level in decibel for a sound having an intensity of 5.00×10^{-4} W/m^2

Lesson Plan IV

Topic: Sonic Boom

Objectives : Students will

a.) Describe what happens when the source of sound travels faster than the speed of sound.
b.) Geometrically describe sonic boom.

Essential Questions : What happens when a moving source approaches or exceeds the speed of sound?

Background:

Sounds from a source that moves faster than the speed of sound spread out spherically from the point where they are emitted. When the source exceeds the speed of sound no sound is received by the observer until the source is passed. Both the approaching sound and the receding are mixed. This is situation creates a sonic boom. A sonic boom is a constructive interference of sound created by an object moving faster than sound. This can be represented geometrically by a cone in three dimensions with overlapping circles. Inside the cone the interference is mostly destructive, and the sound intensity is less than on the shock wave.

In Class Activity :

a.) discuss sonic boom
b.) Explore movie from the internet that demonstrate sonic Boom

The task: Students will research and make a presentation on Sonic Boom.

Lesson Plan V

Topic: Earthquakes

Objectives : Students will be able to:

a.) Describe the causes of Earthquakes
b.) Identify regions most prone to earthquakes
c.) Apply the study logarithm to the forces of earthquakes.

Essential Questions :

a.) How are Earthquakes formed.
b.) Can we predict when an earthquake will arrive?
c.) How are Earthquake magnitudes measured?

Background Information :

The magnitude of earthquakes is measured on the Richter scale. The Richter magnitudes are based on a logarithmic scale. Each successive unit is ten times more powerful than the one before.

A seismometer is an instrument that senses the earth's motion. The seismograph combines a seismometer with recording equipment to obtain a record of the motions of the earth. From this graph scientists can calculate how much energy is released in an earthquake. Seismograms are placed at different positions, some close to the earthquake and some at greater distances. The readings from all these positions are used to calculate the magnitude of the earthquake. Usually all the seismograph stations will give the same magnitude for an earthquake.

The Richter scale is open- ended. There is no limit to how small or how large an earthquake might be. Since logarithms are used to compute the size of earthquakes it is possible to have earthquakes with negative magnitudes. These earthquakes might be too small to be detected. Alternately the scale can record very powerful earthquakes. The most powerful earthquake recorded was a magnitude of 9.5 recorded in Chile in 1960.

Activities / Problems

Select problems that give practice in the properties of logarithms, but are applied to earthquakes.

1. The energy E (in ergs) released during an earthquake of magnitude R may be approximated by using the formula

$\text{Log } E = 11.4 + (1.5) R.$

- a.) Solve for E in terms of R
- b.) Find the energy released during the Alaskan quake of 1964. The earthquake measured 8.4 on the Richter scale.

Lesson Plan VI

Topic: Earthquakes: How are Earthquakes located?

Objectives : Students will be able to:

- a.) Find the intersection of circles
- b.) Measure distances
- c.) Apply the data generated from a seismograph to locate an earthquake.

Essential Questions :

How do scientists locate the epicenter of an earthquake?
How far away from the epicenter can the waves from an earthquake be felt?

Background Information

Finding the Epicenter of the earthquake

Scientists use the seismograph a sensitive measuring devise to detect the vibrations of distant earthquakes. These seismographs are located in various places across the earth. These seismographs are located in China, in the pacific coast of the United States, the region called the ring of fire, in Australia and other places in the Southern hemisphere.

When an earthquake occurs, the shock waves spread out in all directions. Some of these waves compress the rock layers inside the earth. These compression waves called ‘P’ waves travel through the earth. The movements of these waves are recorded by the seismograph. These P waves are the first to be felt and to be recorded. Other waves, the S waves travel on the surface of the earth. These S waves move up and down and back and forth. These waves have similar behavior as the traverse waves.

Since S waves travels much slower than the P waves, the arrival of their movements are detected and recorded after the P waves. The farther away from the epicenter of the earthquake the instruments are located the longer it will take to record the movements of the P and S waves. Scientists know the speed at which both types of waves travel through their respective medium. The time lag between the arrival of the P waves and the S waves is then used to calculate the distance of the earthquake’s epicenter from the location of the instrument.

How the Location of the Epicenter is done.

Seismographs located at different parts of the world receive the movements of the waves that occur from the earthquake. Let A, B, and C represent seismographs that are located at three different centers through out the world. . The devise at center A record the earthquake waves and a distance of 500 km was estimated to be the distance from the epicenter of the earthquake. A circle of radius 500 km was drawn. It is known that the earthquakes epicenter could be any where on that circle. The center at B also receives the waves and a distance of 400 km was calculated to be the possible distance from the epicenter. A circle of radius 400 km was drawn. The possible location of the epicenter could be at the intersections of both circles. These two circles intersect in two places. To find the exact location the distance from the third center location C is needed. Location C produced a distance of 200 km. The circle of radius 200 km is drawn and at the point of intersection of the three circles will indicate the location of the epicenter of the earthquake. Scientists use the triangulation of the three data sources to locate the precise location of the epicenter of the earthquake.

Activities/ Problems

a) For geometry students can use graph paper and a compass to (using a scale) locate the epicenter of a earthquake.
b) Students can research the seismograph its origin and how it works and their locations.

c) Apply distance time problems

Bibliography

1. Bolemon, J., (1989). Physics: An Introduction, Second Edition, Prentice Hall. Englewood, New Jersey.

A college physics textbook. It provides a good treatment of waves and sound waves. Excellent diagrams are used to represent the concepts.

2. Hecht, E., (2000). Physics: Calculus. Brooks/ Cole. Pacific Grove. CA.

This textbook is a calculus based physics book. It provides mathematical applications to the content covered. It is an excellent source for discussion questions, open ended problems and multiple choice questions.

3. Hewitt, P. G. (2002). Conceptual Physics, 9 th Edition. Pearson Education Inc., Addison Wesley, San Francisco, Ca.

This textbook is written for the high school student. It provides a conceptual approach to the concepts covered It also provides a good collection of project ideas.

4. Karplus, R., (1969). Introductory Physics: A model Approach. W. A Benjamin Inc. New York, New York.

This text will be a good source for teaching a unit on sound.

5. Long, D. (1980). The Physics around You. Wadsworth Publishing Company, Belmont, California.

The chapter that is devoted to sound waves provide excellent problems that are useful in evaluating a unit on sound waves.

6. Serway, R.A. (1982). Physics for Scientists and Engineers. Saunders College publishing, Chicago.

This book is recommended as a teacher source. Provides excellent problems for application.

7. Urone, P. (2001). College Physics. Brooks/ Cole. Pacific Grove. California.

This is a college textbook. Chapter 16 discusses sound waves. It focuses on the mathematical applications of sound waves. Sample problems are given for each concept. Problems in the unit were modeled from this text. The book could be used by the teacher as resource.

8. Zitewitz, P. W.; Neff, R. F.; Davis, M. (1995). Physics: Principles and Problem Glenco/ McGraw- Hill. Ohio.

This is a high school textbook. It is easy to read and will provide good samples of simple labs that can be used to explain sound waves. There are multiple choice and open ended problems that are written so that high school students be provided with practice

WEBSITES

http:// www.glenbrook.K-12il.usgbssci/phys/class/sound/uii2b.html

Provides a series of lessons plans for teaching a physics lesson on waves. Also includes assessments to check for student's understanding.

http://en.wikipedia.org/wiki/wave

A good description of waves is given. Includes mathematical applications

http://en.//wikipedia.org/wiki/Earthquake

This web site provides an extensive discussion on earthquakes. Includes a list of the most famous earthquakes is included.

http:www.glenbrok.k-12.il.us/gbssci/phys/class/waves/u1012c.html

The website provides a series of lesson on sound waves.

http://www.kettering.edu/~drussell/Demos/doppler/doppler.html

The website explains the Doppler effects. It includes a movie of how circular waves are created. It also discusses sonic boom and provides pictures showing shock waves generated by super jets.

http://en.wikipedia.org/wiki/Sonic_boom

The causes and characteristics of sonic boom is discussed.

http://ww2010.atmos.uiuc.edu/(Gh)guides/rs/rad/ptrn/ptrn1.rxml

The causes of earthquakes is discussed. A list of the most disastrous earthquakes is included.

http://www.geo.mtu.edu/UPSeis/intensity.html

This web site gives a history of the Richter scale and explains how the magnitude of earthquakes is calculated.

http://library.thinkquest.org/10136/earthquk/earttq.htm

The topics included in this website are plate tectonics, where earthquakes occur and how earthquakes are measured.

http//www.Worsleyschool.net/science/files/earthquake/epicenter.html.

This website gives an excellent step by step process of how the epicenter of earthquakes is located. Pictures and diagrams that explain the concept are included. This is an excellent resource for teachers.

Appendix: Connecting the unit to the mathematics Standards

The NCTM standards suggest that the mathematics curriculum should make mathematics more relevant and accessible to students. The skills and concepts developed should be integrated across subject areas.

The following standards are covered by this unit:

Standard 8: Communication.

The communication standard states that students should be given the opportunity to

a) Organize and consolidate their understanding of mathematics through communication
b) Communicate their mathematical thinking coherently and clearly
c) Analyze and evaluate their mathematical thinking and strategies to others
d) Use the language of mathematics to express mathematical ideas.

Standard 9: Connections.

This standard states that:

a) Students should be given the opportunity to recognize and use connections among mathematical ideas.
b) Recognize and use mathematics in contexts outside mathematics