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The Stupendous Seismogram Study

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New York State Standards

STANDARD 1—Analysis, Inquiry, and Design
Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Mathematical Analysis

Key Idea 2:

Deductive and inductive reasoning are used to reach mathematical conclusions.

Scientific Inquiry

Key Idea 1:

The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

- develop extended visual models and mathematical formulations to represent an understanding of natural phenomena

STANDARD 2
Students will access, generate, process, and transfer information, using appropriate technologies.

Key Idea 1:

Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

1.1 Understand and use the more advanced features of word processing, spreadsheets, and database software.

1.3 Access, select, collate, and analyze information obtained from a wide range of sources such as research databases, foundations, organizations, national libraries, and electronic communication networks, including the Internet.

STANDARD 6—Interconnectedness: Common Themes
Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Systems Thinking

Key Idea 1:

Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

Models

Key Idea 2:

Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Patterns of Change

Key Idea 5:

Identifying patterns of change is necessary for making predictions about future behavior and conditions.

5.1 Use sophisticated mathematical models, such as graphs and equations of various algebraic or trigonometric functions.

- predict the behavior of physical systems, using mathematical models such as graphs and equations

5.2 Search for multiple trends when analyzing data for patterns, and identify data that do not fit the trends.

- deduce patterns from the organization and presentation of data
- identify and develop models, using patterns in data

STANDARD 7—Interdisciplinary Problem Solving

Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Earth Science

STANDARD 4 – The Physical Setting

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 2:

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Performance Indicator 2.1: Use the concepts of density and heat energy to explain observations of weather patterns, seasonal changes, and the movements of Earth's plates.

2.1j Properties of Earth's internal structure (crust, mantle, inner core, and outer core) can be inferred from the analysis of the behavior of seismic waves (including velocity and refraction).

- Analysis of seismic waves allows the determination of the location of earthquake epicenters, and the measurement of earthquake magnitude; this analysis leads to the inference that Earth's interior is composed of layers that differ in composition and states of matter.

Physics

Key Idea 4: Energy exists in many forms, and when these forms change energy is conserved.

Performance Indicator 4.3: Students can explain variations in wavelength and frequency in terms of the source of the vibrations that produce them, e.g. molecules, electrons, nuclear particles.

- 4.3d Mechanical waves require a material medium through which to travel
- 4.3h When a wave strikes a boundary between two media, reflection, transmission and absorption occur. A transmitted wave may be refracted.
- 4.3i When a wave moves from one medium into another, the wave may refract due to a change in speed. The angle of refraction (measured with

respect to the normal) depends on the angle of incidence and the properties of the media (indices of refraction).*

Next Generation Science Standards

ESS2.B: Plate Tectonics and Large-Scale System Interactions
PS4.A: Wave Properties
PS3.B: Conservation of Energy and Energy Transfer

The Stupendous Seismogram Study

Gaining an understanding of the relationships between distance from the epicenter and arrival time of seismic waves using "real" data.

Summary:
Earthquakes can be a challenging concept for students to visualize, especially here in NYS. Through the use of computer models, the variables important to the study of earthquakes can be easily revealed and relationships between them can be highlighted. In this lesson, two computer models are used to represent how the seismic waves move through the Earth. They focus on variables such as density and wave velocity and their importance in the study of earthquakes.

Academic Context:
Earth Science Plate Tectonics Unit (could work well in Middle School with some modifications): Lesson would be taught after Seismograms are introduced as well as P and S waves, before discussion of the Richter Scale and how it is measured as well as how epicenter location is triangulated.

Could also work for Physics in a….

Motion Unit:
Lesson would be taught after discussing distance vs. time graphs. It also can be used to look at different types of relationships, e.g. linear, quadratic, as well as different geometries.

Waves Unit:
Lesson can make a great connection to students' prior knowledge from earth science to highlight how waves refract when moving through media of different densities. Then move on to Snell's law and a simplified mathematical treatment of this phenomenon.

Vocabulary: Seismogram/graph, P-wave, S-wave, epicenter, seismic, density, medium

Objectives:

- Students will measure distance and arrival time for p- and s-waves so that they can graph it and interpret the graph.
- Student will graph distance and arrival time for p- and s-waves so that they can use and interpret the "Earthquake P and S wave Travel Time" graph in the ESRT.

Lesson Outline:

Engage students with a cartoon, video clip or **simulation** of an earthquake. Try this: http://www.youtube.com/watch?feature=player_embedded&v=4nS10xNBfVE

Fill in this chart with student answers:

What do we observe during an earthquake?	What can we measure?	What relationships can we study?

Goal: Have students recognize the relationship between distance of a location from the epicenter and the time it takes for the p- and s- waves to arrive at that location.

Investigation of data from an Earthquake – see worksheet

With questioning get students to a point where they can:

- Describe the relationship between distance and arrival time of p- and s-waves
  - Compare this to the relationship between distance and arrival time of surface waves
- Explain how the path of the wave changes due to changes in the density of the earth.

Next Day: Look at P- and S-wave arrival time Graph in ESRT. Compare to graphs made by students in Excel. Use ESRT Graph to practice triangulating the epicenter of an earthquake.

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<u>Procedure:</u>

1. Measure and record the distance to each site from the epicenter.
2. Determine the start time of the earthquake and record in Excel.
3. Determine the arrival time of the p- and s- waves at each site and record in Excel.
4. Plot Arrival time vs. Distance using Excel.

<u>Analysis:</u>

Part A.

1. Describe the *relationship* between distance and arrival time of **p-** and **s-waves**.
2. In your Excel document there is also data for the arrival time of the **surface** waves at each site. Plot this data along with your **p-** and **s-wave** data.
3. Describe the *relationship* between distance and arrival time of the **surface** waves.
4. Compare the *relationships* between distance and arrival time for **each** of these seismic waves. Are they the same? Different? Why might this be?

Part B.

5. Go to http://aspire.cosmic-ray.org/labs/seismic/index.htm :
   a. When did we use this tool before?

b. Draw the motion of the seismic waves in the boxes below:

P-wave	**S-wave**	**Surface**

c. On this animation, there is a slider to adjust the density of the **medium** (or the stuff) the wave travels through. Predict what will happen if the wave moves from a medium with high density to a medium with low density.

d. Now, test your prediction by adjusting the slider. What do you *observe* about the wave?

6. Return to the animation we saw at the beginning of class, http://www.youtube.com/watch?v=4nS10xNBfVE :

a. What do you *observe* about the s-wave on the path to station D?

b. What are two things you *observe* about the p-wave which arrives at station D?

c. What characteristic of the earth alters the path of the p-wave?