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| **Lesson Title** | Resonate frequency and earthquakes |
| **Length of Lesson** | 1 Day |
| **Created By** | Henry Stauffenberg IV, Matthew Lee |
| **Subject** | Physics |
| **Grade Level** | 9-12 (Physics) |
| **State Standards** | Physics: 1 a, b, c, d, e, f; 2 a, b, c ; 4 a |
| **DOK Level** | Physics: 3 |
| **DOK Application** | Hypothesize, simulate, collect, interpret, investigate, connect, explain, prove, draw conclusions, graph, predict, inquire |
| **National Standards** | 9 – 12 A: Inquiry; B: Physical Science |
| **Graduate Research Element** | Experimental design, excel analysis, inquiry based from hypothesis, real world problem solving |

**Student Learning Goal:**
The purpose of this lesson is to investigate the relationship between natural frequency of objects and height, along with other variables such as mass and geometry. The goal is to take lectured knowledge about waves and frequency and apply it in an earthquake simulation lab providing visual and quantitative results. Students will learn the devastation of earthquakes through wave amplification which occurs when the natural frequency of objects equals that of occurring wave frequency (form of s-wave). Students will inquire about and learn the differences between s and p waves generated in earthquakes. They will learn that all objects vibrate at a particular natural frequency and engineers, through design and testing, must account for this when earthquake proofing buildings.

Mississippi State Standards
Physics: 1: (a) Use current technologies such as CD-ROM, DVD, Internet, and on-line data search to explore current research related to a specific topic; (b) Clarify research questions and design laboratory investigations; (c) Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations; (d) Organize data to construct graphs to draw conclusions and make inferences; (e) Evaluate procedures, data, and conclusions to critique the scientific validity of research; (f) Formulate and revise scientific explanations and models using logic and evidence; 2: (a) Use inquiry to investigate and develop an understanding of the kinematics and dynamics of physical bodies; (b) Analyze, describe, and solve problems by creating and utilizing graphs; (c) Analyze real-world applications to draw conclusions about Newton's law of inertia; 4: (a) Describe and model the characteristics and properties of mechanical waves.

National Science Education Standards of Content 9 – 12
A: Inquiry: identify questions and concepts that guide scientific investigations

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding the hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.

B: Physical Science: motion, forces, and the conservation of energy

- The total energy in the universe is constant. Energy can be transferred in collisions, light waves, and many other ways. Energy can never be destroyed. As these transfers occur, the matter involved steadily becomes less ordered.
- All energy can be considered kinetic, the energy of motion; potential, energy that depends on relative position, or energy contained in a field such as electromagnetic waves.
- Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.

**Materials Needed (supplies, hand-outs, resources):**

Earthquake worksheet handout, earthquake and wave supplemental handout, 2 platform shaker tables (normally used to stir sediment flask or mix chemicals), two 2ft by 2ft boards than can be attached to platform tables (increase surface area for larger groups), 3 by 4 feet step flashing aluminum (or thin flexible sheet metal that can be cut), angle flash galvanized will work as well but is limited for height variation, one pair thick gloves per group as well as; safety glasses, and metal cutting shears.

**Lesson Performance Task/Assessment:**

- Completion of worksheet handout
- Creation of graphs that show the relationship between natural frequency vs. height vs. mass
- Ability to explain and prove results using graphs and applied knowledge from lab experimentation
- Showing inquiry that goes beyond the parameters set by handout
- Ability to answer questions asked at end of activity such as: how does inertia affect natural frequency?

**Lesson Relevance to Performance Task and Students:**

- Practice in hypothesis creation and testing through constructive experimental design
- Real world scenarios investigated through testing, inquiry, and applied knowledge
- Insight into engineering and model design for real world
- Understanding natural frequency and wave interactions through visual activity
- Applying physics into other disciplines such as geology (introduction into geophysics and seismology)

**Anticipatory Set/Capture Interest:**
Talk about destructive power of earthquakes and show demo (see guided practice) of objects swaying back and forth on a shaker table. Show parts of sin waves in oscillating objects that achieve natural frequency or exceed, ex: 400 Hertz, 50cm tall and 2cm wide sheet metal, will show three quarters of a sin wave when rapidly swaying back and forth (can count 2 nodes and one antinode. Tell students that skyscrapers continual sway a few feet back and forth but can only be felt on top floors. All objects continually resonate even stone structures, earth, and more that seem still to naked eye.

**Guided Practice:**
From sheet metal cut out 4 or 5 rectangles all equal width no greater than 2.5cm. Have all vary in height from big to small and tape down in a linear line (row) across shaker table. Should have that descending look of bars, like on a cell phone with signal strength. Add other sheets of rectangles linear fashion (another row) taped behind your first row, make sure enough distance between rows to allow sway that wont clash with other swaying objects. Three rows can fit on shaker platform which will create a metropolis visual with rectangular skyscrapers at varying heights and placement. Start table at lowest rpm setting and step it up slowly until the tallest structure(s) begin to sway back and forth, the sway will increase with increasing rpm up until a certain point. At the point where the sway reduces you have exceeded the maximum natural frequency, the rpm that yields the greatest back and forth motion of object is the natural frequency of object. When rpm increase the larger object will sway less and the next tallest objects will begin to sway greatly. A pattern can be noticed that smaller objects will sway at high frequencies where taller objects sway the most at lower.

Provide both handouts (stated in materials) and let students investigate by building own structures and applying masses (in the form of magnets) to observe changes in natural frequency. Have all groups build structures first and then tape all down in rows on shaker tables. That way when rpm is increased at set intervals all the groups can finish at once instead of waiting for turn using shaker table(s). Each group will observe and record data from their row of buildings. After handout is complete allow students to "go crazy" building structures of different geometry and mass. Let them explore to inquire more about understanding waves and natural frequency with respect to changing multiple variables.

**Independent Practice:**
Analysis of graphical data and writing of a report. Answering extra credit questions that will involve use of resources because the extra credit is college level questions.

**Remediation and/or Enrichment:**
Remediation: individual IEP, partner with helpful student, make lesson more walk through intensive.

Enrichment: The extra credit that asks more specifics about s and p waves generated by earthquakes. Introduce higher level questions such as; what other variables effect natural frequency that was not accounted for in this exercise?

**Check(s) for Understanding:**

- Completion of handout and graphs
- Ability to use graphs to explain and prove hypothesis's
- Ability to explain the purpose of lesson and relationship between natural frequency and described variables
- Further inquiry into earthquakes and natural frequency that is not covered in handout
- Ability to apply what they learned in class and lab to answer follow up questions and creation of good lab report

**Closure:**
Sum up that what they did is similar to what engineers work with. Explain the importance of what they learned and how we have used it to understand earthquakes and how to survive them.

**Possible Alternate Subject Integrations:**

Earth Science: Introduction to earthquakes and seismology
Geometry: Natural frequency is largely dependent on geometry

**Teacher notes:**
1) Make sure students read directions and really tape down models securely
2) Make sure there is enough metal to cut and don't go beyond 50cm in building height for models
3) Building widths wider than 1 inch will take greater frequencies to get results. Have class start with thin structures and then let them increase widths after they get concept.