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| **Grade Level/Subject** | Middle School, Applied Earth Science & and General Earth Science classes |
| **Unit** | Geology: Earthquakes |
| **Enduring Understanding** | By manipulating and evaluating an inquiry lab with which students can evaluate and graph results, they will be able to apply knowledge to seismic wave graphs to interpret them and evaluate relationship of time gap between waves to the epicenter. |
| **SOL Objectives** | ES.1 The student will plan and conduct investigations in which scales, diagrams, charts, graphs, tables, imagery, models, and profiles are constructed and interpreted; current applications are used to reinforce Earth science concepts. |
| **Title** | **P & S Waves Inquiry Graphing Lab** |
| **Lesson Objective** | For students to observe, record, graph, interpret and evaluate the time difference between the P and S seismic waves and the distance from the epicenter by modeling with difference between toy cars of different speeds. |
| **Inquiry Level** | 3 |
| **Materials Required** | Modeling board (large dry-wipe board), 2 stop watches for each student. Clip board with lab data sheets. Pen/Pencils. Students in teams of 3 or 4. Masking or painter tape, markers. 2 toy cars, marked “P” and “S”. |

**P & S Waves Inquiry Graphing Lab** 30 to 45 minutes

**Suitability**: Middle School, Applied Earth Science & and General ES Reinforcement

**Objective:** For students to observe, record, graph, interpret and evaluate the time difference between the P and S seismic waves and the distance from the epicenter by modeling with difference between toy cars of different speeds.

**Overview**: Tack set up with marks at 2, 6, 12, and 20 meters. Two battery operated toy cars, preset with one faster than the other (use new batteries in one car and old in another). Teacher will call “Start” and mark the beginning time cars are released. Students will use 2 stop watches to stop when each car passes their measured mark. After the run, students will meet in teams to fill in data charts, graph data, and evaluate relationship of time gap between cars to the starting point

**Equipment per team**: Modeling board (large dry-wipe board), 2 stop watches for each student. Clip board with lab data sheets. Pen/Pencils. Students in teams of 3 or 4. Masking or painter tape, markers. 2 toy cars, marked “P” and “S”.

**Set Up**: Place tape on floor running 20 meters long. Mark with cross tape or markers

Start 2 6 12 20 meters

**Procedure:**

1. Students will be station at each marking point with 2 stop watches one for the P car and one for the S car.
2. The cars are started at the same time. They might need an occasional tap to keep them heading straight down the center line tape. The starting time is marked by the teacher. Put the starting time on the board as **Starting Clock Time HH:MM:SS**
3. Each student will stop the time when the car touches the cross mark tape. Each student will have a time for each car to get to their distance mark.
4. After making the run, students will regroup in their teams and fill out the data chart for their team’s measurements.
5. Students will graph their data on the modeling boards and answer questions on lab sheet.
6. After all teams are finished, students share with the class their graphs and findings.

**Differentiation**:

1. Practice/review adding time to help students add their time to the start clock time.
2. Have only 2 students at each station one for the P car one for the S car. Share data
3. Fill out the data cart as a class on the smart board
4. Have an example graphs set up on the board to see
5. Have graphs preset so just the data needs to be added

**P & S Waves Inquiry Graphing Lab**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Team partners: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_ Period: \_\_\_

**Equipment per team**: Modeling board (large dry-wipe board), 2 stop watches for each student marked with P or S. Clip board with lab data sheets. Pen/Pencils. Students in teams of 3 or 4.

**Procedure:**

1. One team member at each marking point with 2 stop watches, one for the P car and one for the S car. Mark the timers with P and S
2. Start both stopwatches when the cars start together.
3. Stop the timer when the car touches the cross mark tape. You should have a different time for each car when it got to your mark. Make sure you use the right timer for each car.
4. After the run, regroup in team and fill out the data chart for your team’s time measurements.
5. Use the start time on the board to calculate arrived time for each car.
6. Graph their data on the modeling boards and answer questions on lab sheet. After all teams are finished, share with the class your graphs and findings.

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| --- | --- | --- | --- | --- |
| Data Table | | | | |
| Station | **P** car | **S** car | Difference between  P & S times (lag) |  |
| A | Stopwatch reading | Stopwatch reading |  |  |
| 2 meters | Time it arrived | Time it arrived |  |  |
| B | Stopwatch reading | Stopwatch reading |  |  |
| 6 meters | Time it arrived | Time it arrived |  |  |
| C | Stopwatch reading | Stopwatch reading |  |  |
| 12 meters | Time it arrived | Time it arrived |  |  |
| D | Stopwatch reading | Stopwatch reading |  |  |
| 20 meters | Time it arrived | Time it arrived |  |  |

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**Graphing**

What is the independent variable? The ones you set up for mesaurement: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What is the dependent variable? The data to you took based on the I.V. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Use accuracy in marking graph lines spaces.

I.V. on the X axis

D.V. on the Y axis Use the start clock time as origin for time intervals.

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Graph #1 Graph 2 lines, one for the arrival time for the P car and another line for the S car

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Graph # 2 Graph 1 line using the difference in arrival times, also called the “lag time”.

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1. Which station had the smallest difference between the P and S car? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Which station was the closest to the beginning of the cars run? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. Which station had the largest difference between the P and S car? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Which station was the farthest from the beginning of the cars run? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Is there a connection between the distance from the beginning and the lag time between the arrival of the P car and the arrival of the S car? \_\_\_\_\_\_  
   Explain why? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. What would be a reasonable lag time for a station located at 8 meters? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
7. If the start time was 2:00 PM what would be a reasonable time for   
    the P car to arrive at station B? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
8. Using your graph #2, if you know the gap or lag between the P car and S car arrival could you determine the distance from the start point using your graph? \_\_\_\_\_\_\_\_\_\_\_\_\_\_

Present your graphs and findings to the class when asked.

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