Teaching Physics and Earth Science using a Slinky Seismometer Network

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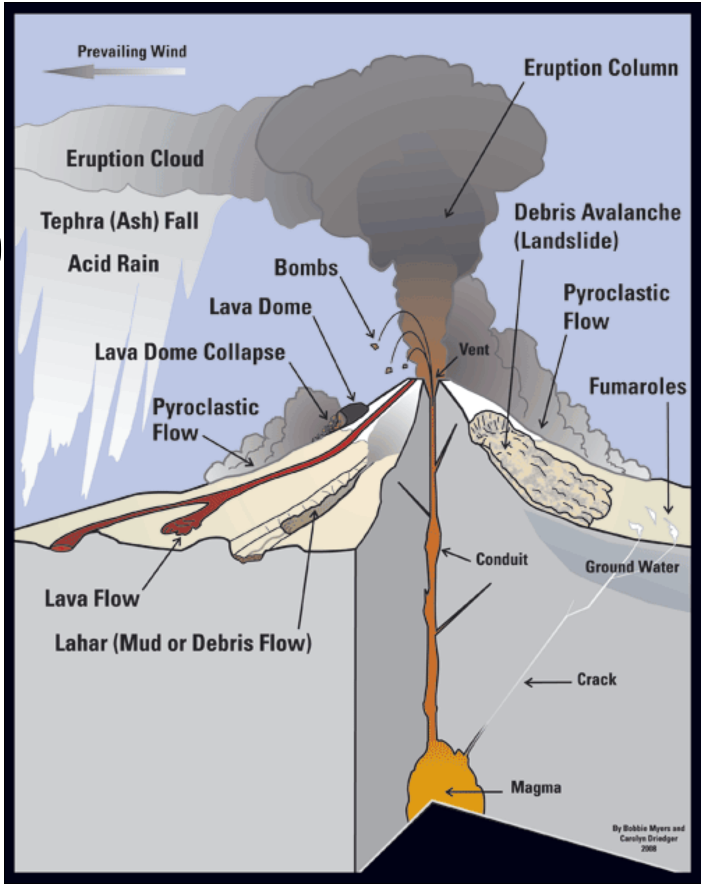
Motivation

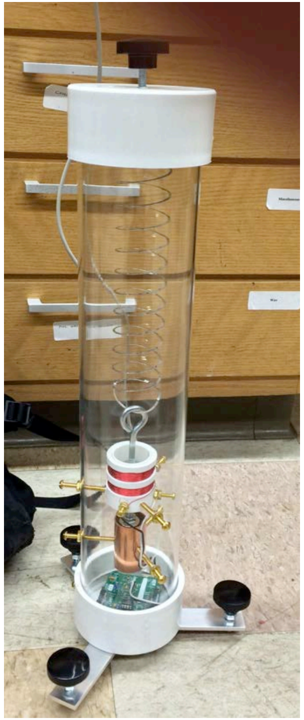
- **Earth Science, often neglected in high school curricula, combines foundational science knowledge (such as physics), *'integrative thinking,'* and direct societal relevance (is prominent in NGSS)**



Motivation

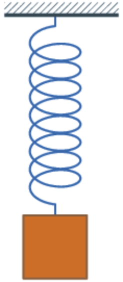
- **Earth Science, often neglected in high school curricula, combines foundational science knowledge (such as physics), *'integrative thinking,'* and direct societal relevance.**

- **Design and use of equipment necessary to collect earth science data typically combines science, engineering and math.**

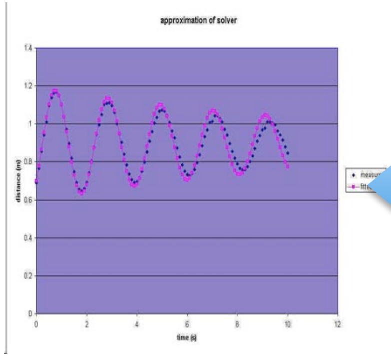


Engineering design questions:

- *what is appropriate frequency (ω)?*
- *what spring stiffness (k) works best?*
- *what is optimal mass (m)?*



record vertical position over time



fit with sine function through experimentation find that

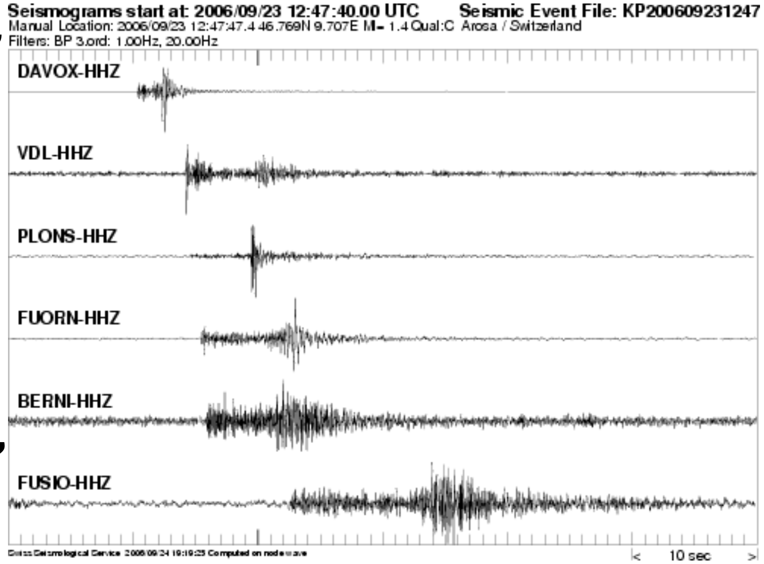
$$\omega = \sqrt{\frac{k}{m}} = \frac{2\pi}{T}.$$

Motivation

Earth Science, often neglected in high school curricula, combines foundational science knowledge (such as physics), *'integrative thinking,'* and direct societal relevance.

Design and use of equipment necessary to collect earth science data typically combines science, engineering and math.

It is straightforward to analyze earth science data using 'big data' constructs (e.g., cross-correlation), which students will undoubtedly encounter in their careers.



time (seconds)

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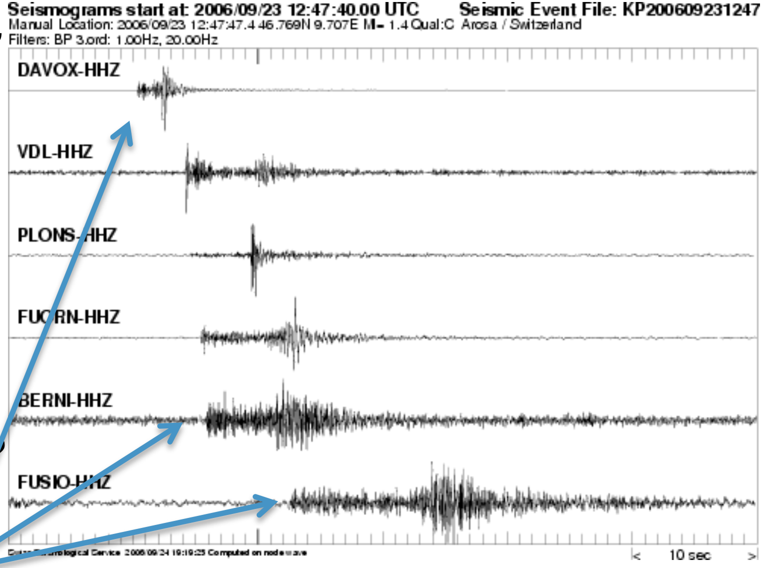
same earthquake recorded at different seismometers worldwide



why do signals start at different times?
what are those patterns for each earthquake?, what do they tell us?

what science + math analysis helps us locate and characterize this earthquake?

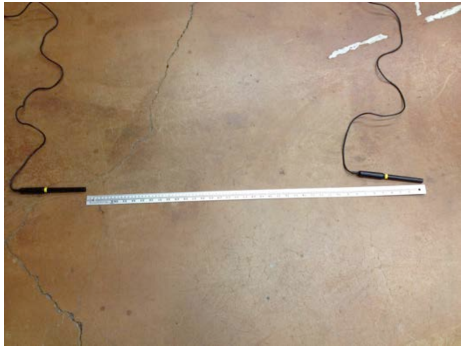
Overview– 5, 2-hour sessions, H1800

- **Session 1: Slinky Seismometers, Stretching Springs**
  S1-A) An introduction to seismology– sound waves in the Earth
  S1-B) Stretched springs with balanced forces, using m to probe for k
- **Session 2: Oscillators**
  S2-A) Physics of simple oscillators, variables for oscillators
  S2-B) Mathematics and variables in oscillators
- **Session 3: Electromagnetism**
  S3-A) Making magnets with electricity and coils [variables exploration]
  S3-B) Making electricity with magnets and coils
- **Session 4: Applications and Tricks with Electromagnetism**
  S4-A) Build a speaker/microphone
  S4-B) Lenz law damping and its uses
- **Session 5: Understanding Seismic Signals**
  S5-A) Return to and build a slinky seismometer
  S5-B) The basic physics & mathematics of seismic signals

Measuring the Speed of Sound

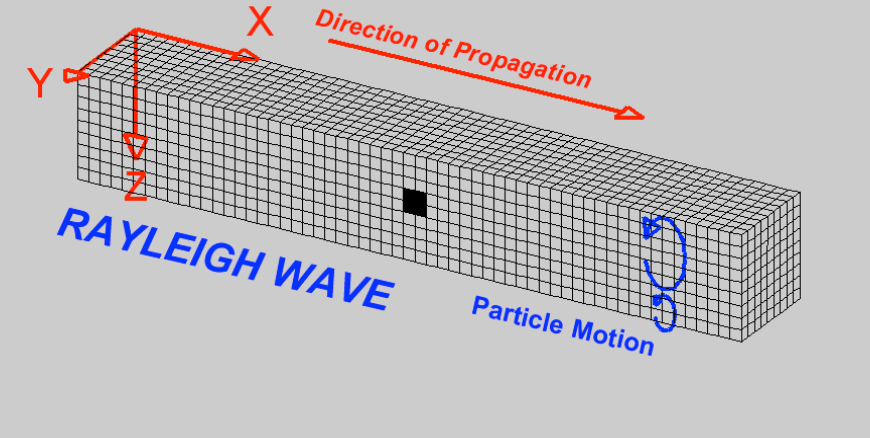
Overview
Speed of sound in air
- 2 Vernier lab microphones, meter sticks, logger pro, and clapping
- Predictions
- Data taking with logger pro
- Analysis

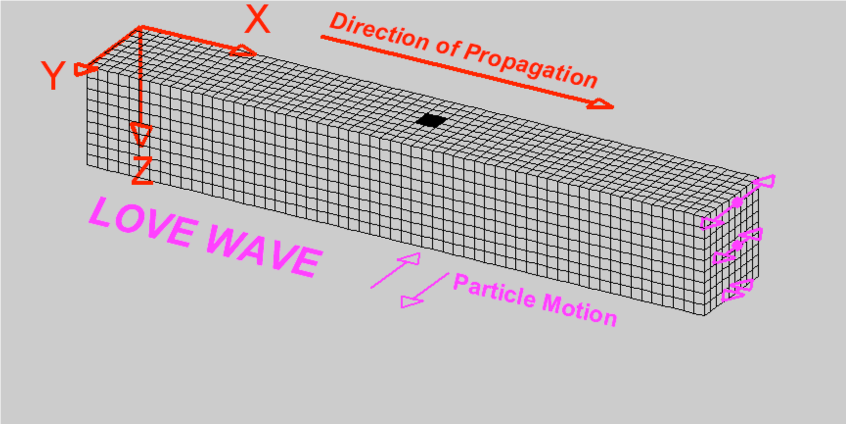
The Speed of Sound in a Solid
- 2 microphones attached to either side of a board with cups, logger pro, tapping
- Predictions
- Data taking
- Analysis



Surface waves .

Both *Rayleigh* and *Love waves* are surface waves. Surface waves, of course, travel only along a surface. Water waves on lakes and oceans, at the interface between water and air, are another type of surface wave. These are slower than both P-waves and S-waves. Surface waves are the most damaging to building situated near an earthquake, as they deform the surface in which buildings are typically embedded (or rest upon).

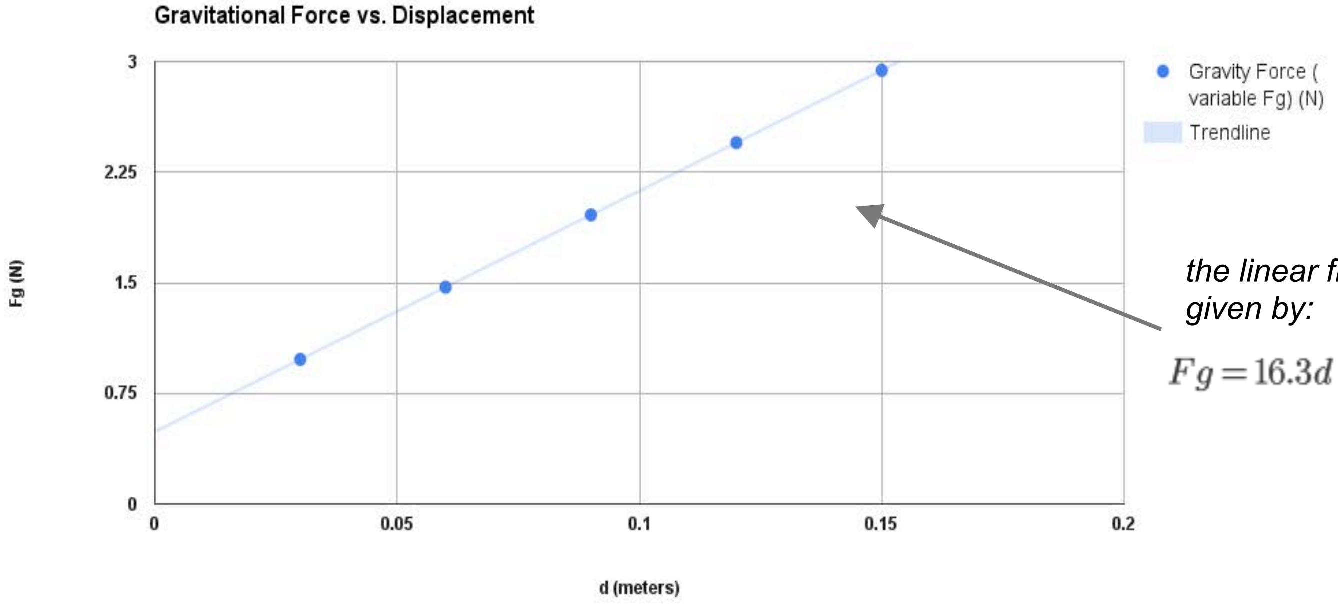




Hanging Masses on Springs

Overview

Data table and plot (from Google Sheets)



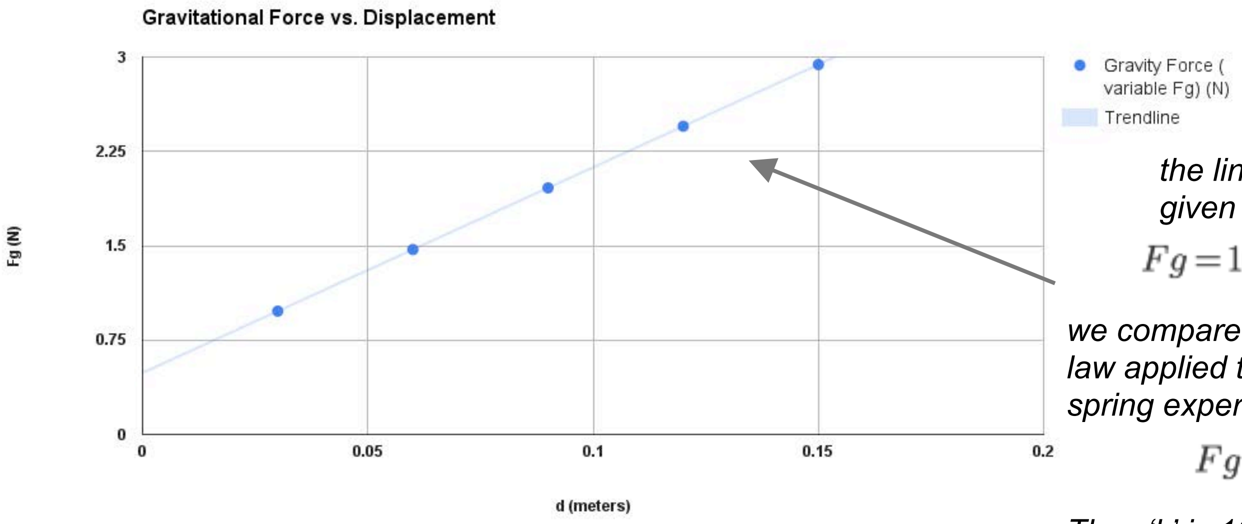
the linear fit is given by:

$$Fg = 16.3d + 0.49$$

Hanging Masses on Springs

Overview

Data table, plot (from Google Sheets) and interpretation



the linear fit is given by:

$$Fg = 16.3d + 0.49$$

we compare this to Hook's law applied to our stretched spring experiment

$$Fg = k\Delta x$$

Thus 'k' is 16.3 (N/kg) (sorry d = Δx, but Google Sheets won't allow Greek chars….)

this number, 'k' characterizes our spring!

Hanging Masses on Springs

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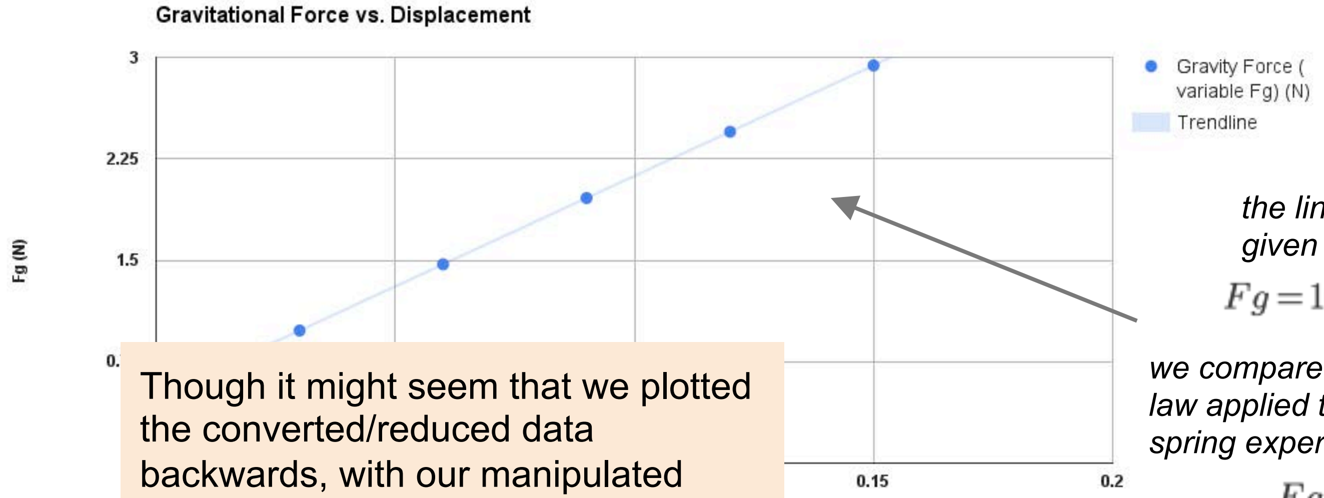
Data table, plot (from Google Sheets) and interpretation



Though it might seem that we plotted the converted/reduced data backwards, with our manipulated variable (mass => Fg) on the vertical axis, we did this for a reason. Plotting as we did lets us read "k" directly as the slope of the linear fit.

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Session 2-A- Harmonic Oscillators

- **S2-A)** Physics of oscillators, variables for oscillators (~70m)

  Three different looks at oscillators and resonance

  1. Using apparatus and Vernier probe (saw this earlier)

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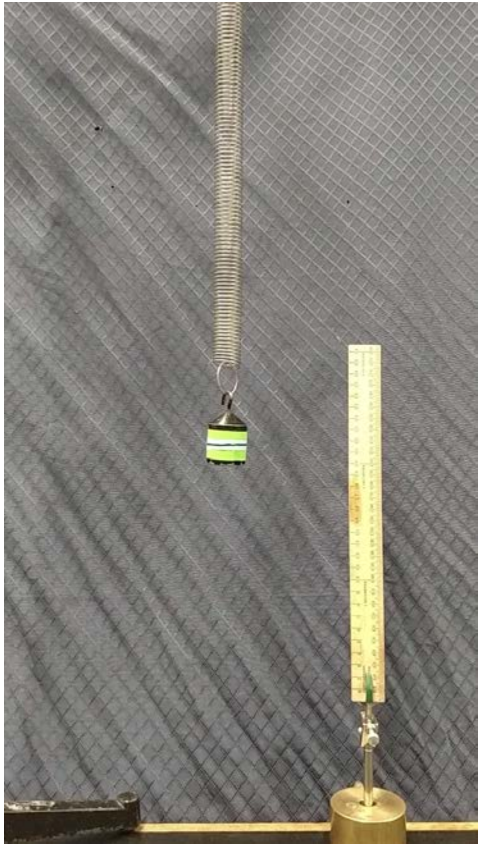
- **S2-A)** Physics of oscillators, variables for oscillators

  Three different looks at oscillators and resonance

  1. Using apparatus and Vernier probe
  2. Videotaping oscillator with cell phone and using free video analysis software (Tracker)



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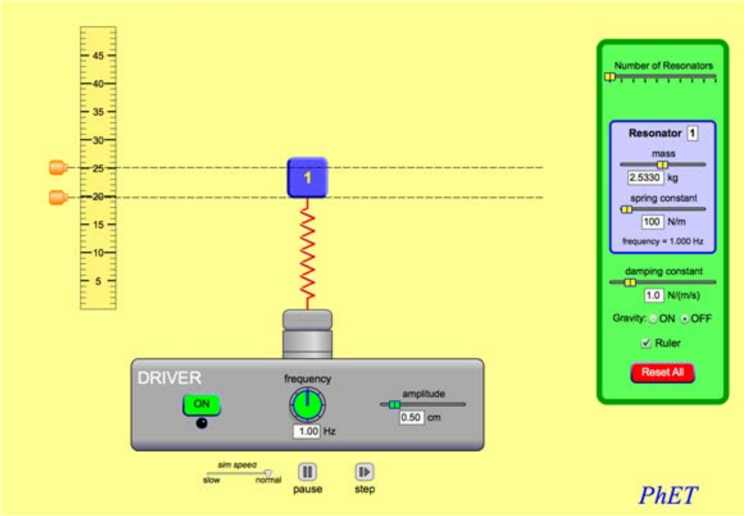
  Three different looks at oscillators and resonance

  1. ....
  2. .....
  3. Using a U. Colorado PhET simulation



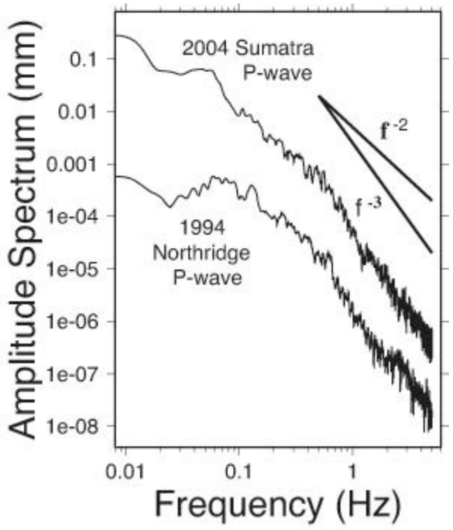
Session 3A- Electricity & Magnetism

- **S3-A)** Making magnets with electricity and coils [variables exploration]
  - Recap of Session 1 by Dr. Dhiti (~10m)
  - Wrapup of oscillators (~5m Dr. Dean)

k determined by spring stiffness

$$f = \frac{1}{2\pi}\sqrt{k/M}$$

M shows how increase in mass affects oscillator



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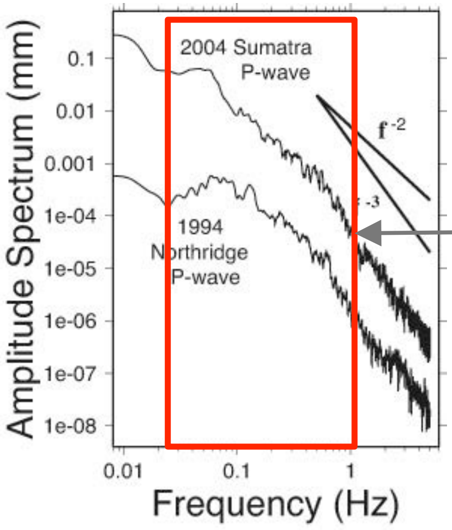


k determined by spring stiffness, I change springs to change this

$$f = \frac{1}{2\pi}\sqrt{k/M}$$

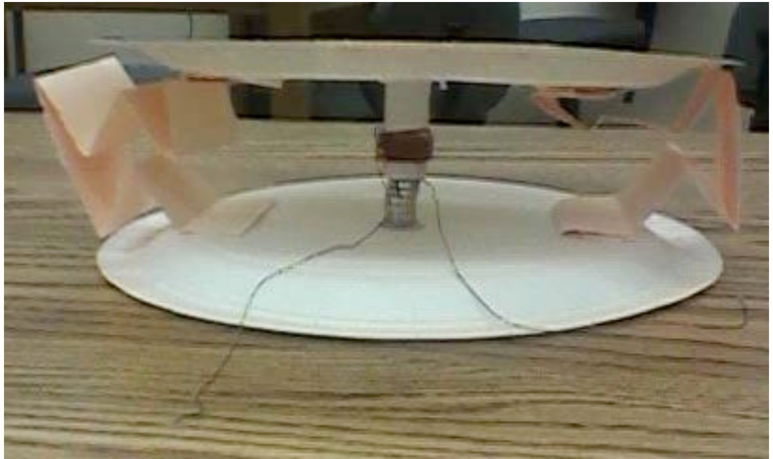
we want to adjust f to sit in the box

M shows how increase in mass affects oscillator

This is engineering design!

Session 4A

- S4-A Build a working loudspeaker
    - **A:** S4-A-a) use principles of electromagnets to build a working loudspeaker (and this link) **(**Blake, Alexa, **Nick & Alex)**



Session 4A

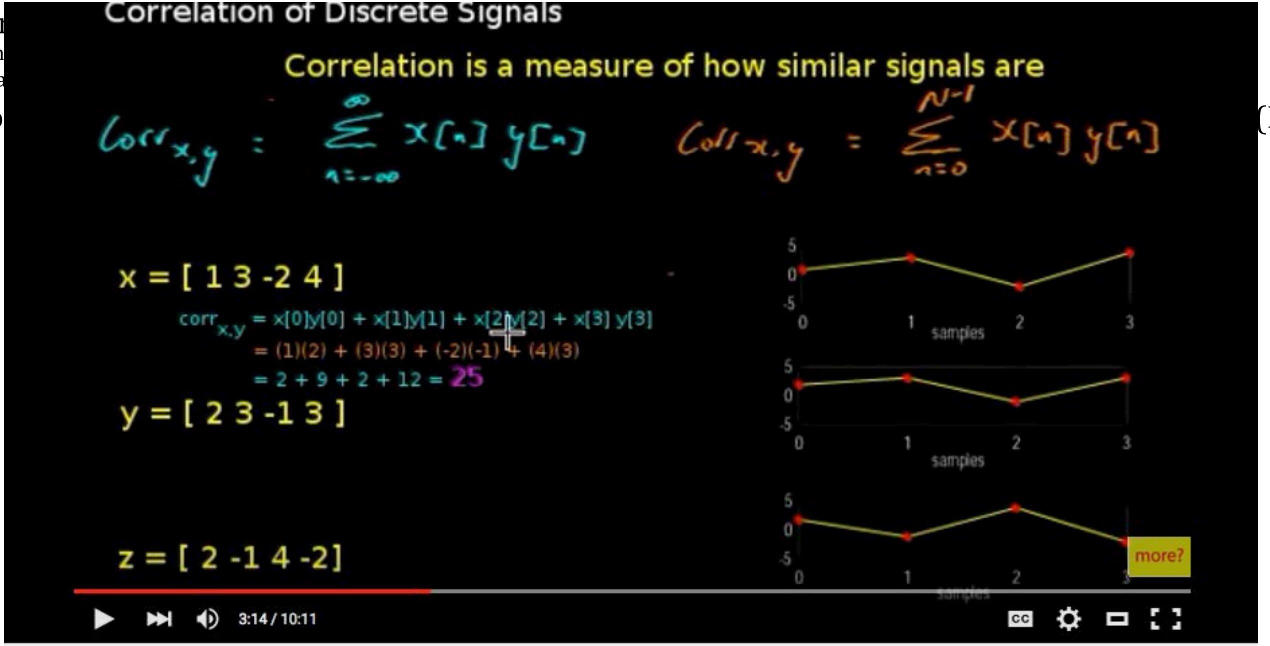
- S4-A Build a working loudspeaker
    - **A:** S4-A-a) use principles of electromagnets to build a working loudspeaker (and this link)
    - **B:** S4-A-b) what about *resistance?*, and how does it affect our experiments and designs?
    - **C:** S4-A-c) modify the loudspeaker for various design goals, e.g., better bass sounds, louder sounds, etc. **(Blake, Alex & Nick)**

Glue the cards to the foam plate. Try to align both business cards. (Parallel)

Session 5

S5-B) Picking ar

- **E:** Earth
- Locate a
- **F:** Ho (Dr. Dean, Max,



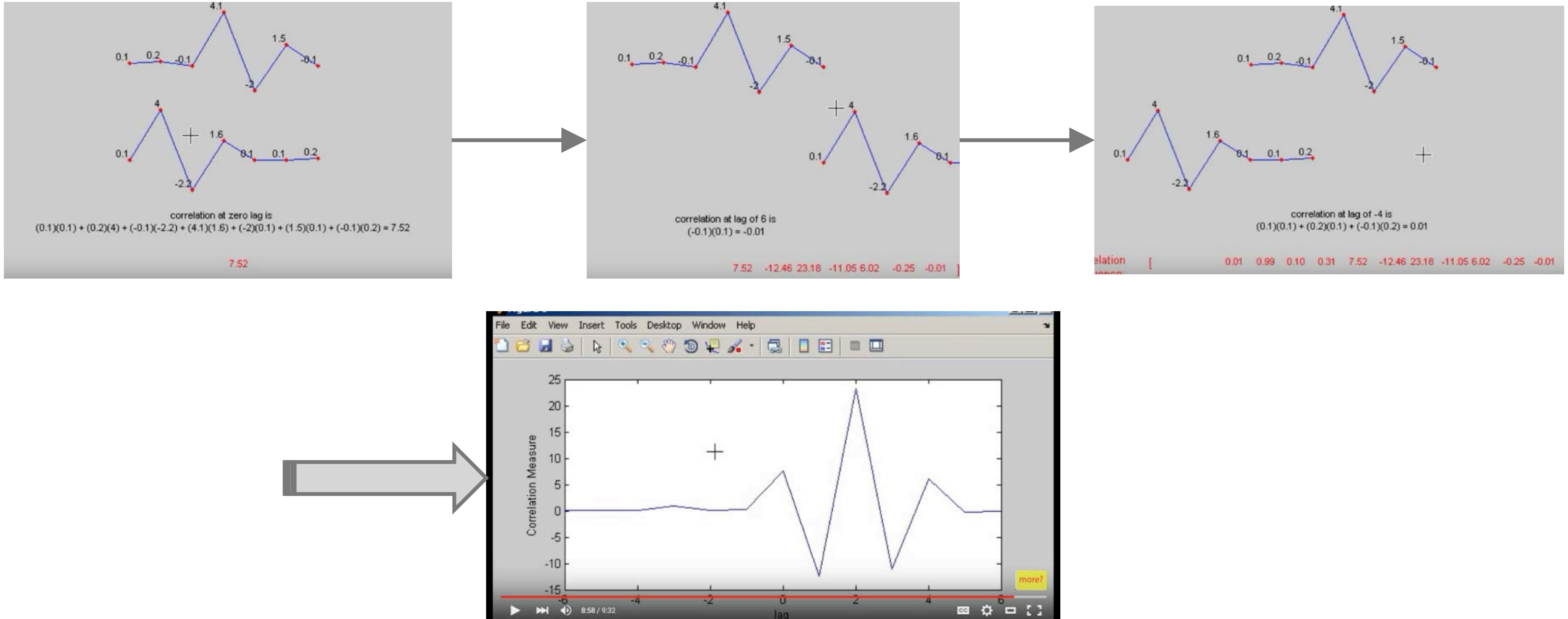
corrx,y= x1*y1+ x2*y2+ x3*y3+x4*y4

corrx,y= 1*2 + 3*3 + -2*-1 + 4*3 = 25

Session 5

S5-B) Picking and locating earthquakes, and what they tell us about the Earth

- **E:** Earthquake signals in the earth, 'pick' an earthquake recorded by a slinky seismometer (Alex & Nick)
- Locate an earthquake using signals on 3 seismometers, followed by questions (Alex & Nick, 20m both)
- **F:** How can we tell if it's an earthquake signal? Correlation as a mathematical signal analysis tool (Dr. Dean, Max, 10m)



The Thai Slinky Seismometer Network

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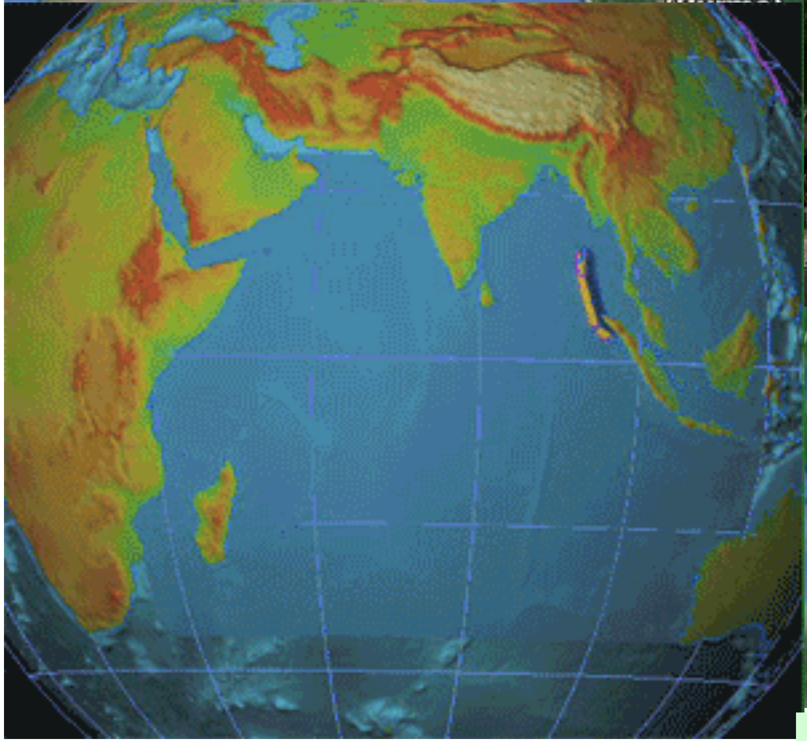
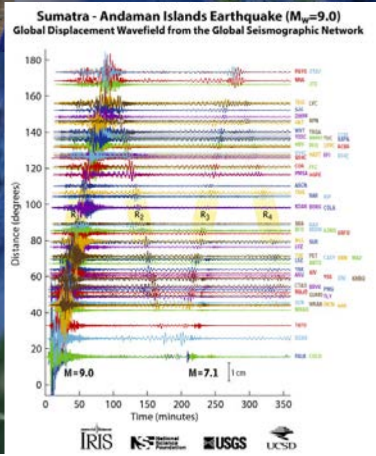
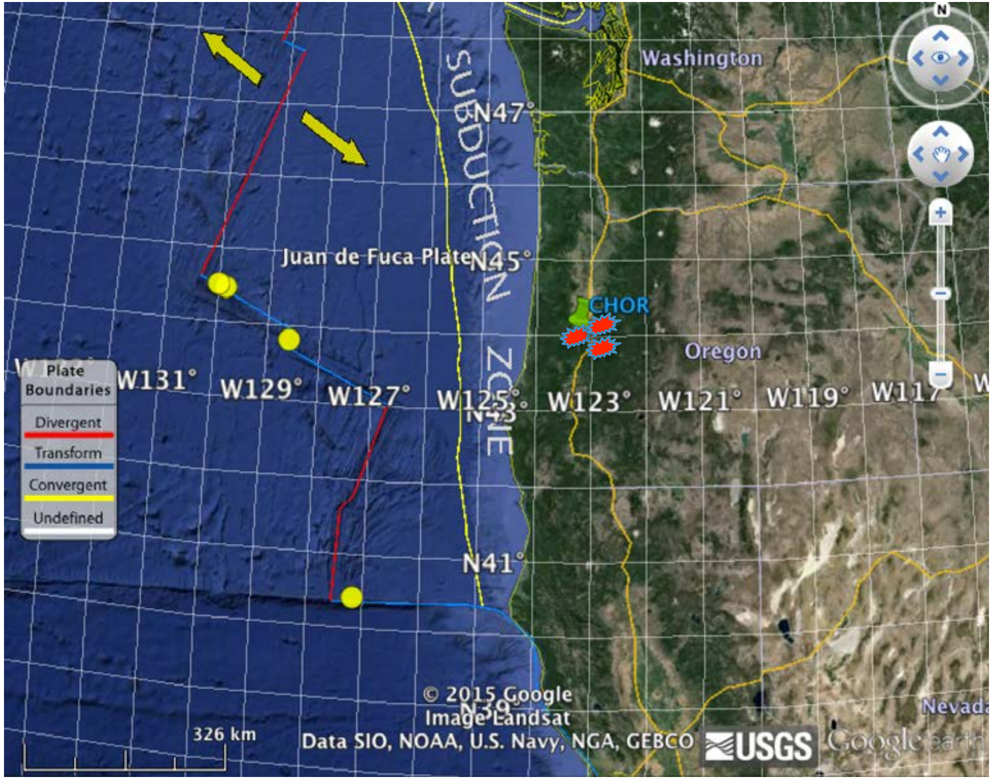


"2004-tsunami" by David Rydevik (email: david.rydevik@gmail.com), Stockholm, Sweden.

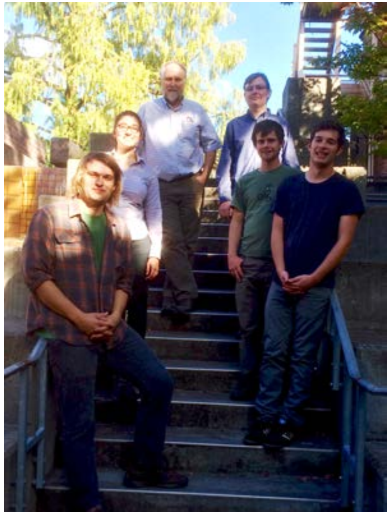


"2004 Indonesia Tsunami Complete" by Animation fournie par Vasily V. Titov,

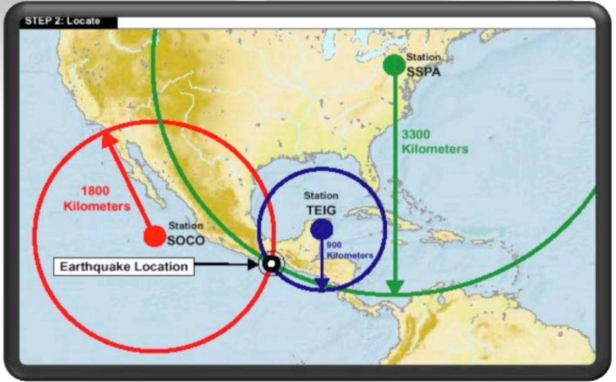
The Lane County, Oregon Slinky Seismometer Network



well…, it's under construction by these folks, and a kiosk looks like this…



Thanks!


STEP 2: Locate
Station
SSPA
3300
Kilometers
1800
Kilometers
Station
SOCO
Station
TEIG
900
Kilometers
Earthquake Location