The Seismometer

A Freshman Engineering Design Project

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Overview:

In this project, students design, construct and use a seismometer to examine mechanical vibrations transmitted through the earth. They will look at early models of amateur seismometers and research those models for design ideas. The project integrates the physics and calculus that the students are currently learning with engineering modeling and design components.

Learning Objectives or Student Outcomes:

By the end of this lesson or activity, students will be able to

1. work as a team to design and construct a sensitive seismometer that will be capable of examining mechanical vibrations transmitted through the earth; and
2. complete a team written report detailing the design process.

Length of Lesson:

This project is generally one of two or three in the semester. The length of the lesson will depend on a few factors: the amount of in-class time devoted to the project, the out-of-class time deemed necessary by the instructor, and what other activities will be taking place during the duration of the project.

Assignment(s) to Ensure Student Preparation:

Although there are no specific assignments required to ensure student preparation, this project will integrate knowledge being obtained concurrently by the students in physics and calculus courses.

Team Size:

Teams of 4 work best; if necessary, teams of 3 or 5 people may be formed.

How is *positive interdependence* ensured?

Each student team is working together to create one seismometer and one written report. They must rely on one another for successful completion of the project.

How is *individual accountability* ensured?

Individual accountability is ensured through peer assessments such as the salary allocation activity, where each team member divides a given "salary" amongst all team members and provides a brief explanation for each decision.

Assessment:

Project deliverables and design constraints and guidelines will be provided to teams before they begin work on the projects. Sample amateur seismometers will also be shown to the students. Assessment will be based on the successful completion of both the team design project and the written project report.

Team Skills Needed for Success:
Team members need the ability to cooperate, communicate and collaborate in a structured manner so that all team members feel they are able to contribute ideas and constructively provide feedback.
Materials Needed by Students: • frames and moving parts from Erector sets • op-amp circuits • additional parts as each team sees fit

Instructions to Students:

1	**Project Overview** In the Fall semester, the engineering projects involved the construction of models that helped to integrate the various portions of the Foundation Coalition course. The Catapults were useful for the demonstration of kinematics; the Bungee Omelet reinforced the value of Newton's Laws. The projects also asked the students to combine mathematical principles and English composition skills with engineering design concepts. But the models themselves were really just toys—sophisticated toys—but toys just the same. This semester, the students have already produced something more significant—instruments that can measure some physical phenomenon. Scientists and engineers, of course, design and build structures, systems, products, and countless other items, but they also build and use tools and instruments. And this project involves the construction and use of another interesting instrument—a **seismometer**. This project will once again integrate the physics and calculus that you are currently learning with engineering modeling and design components. The seismometer, in essence, employs mechanical oscillatory motion (a pendulum) to measure other wave phenomena (seismic waves traveling through the earth) and electromagnetics to convert the mechanical motion to electrical energy that can be amplified and examined on the classroom PCs.
2	**Project Goal** The goal of this project is to design and construct a sensitive seismometer that will allow you to examine mechanical vibrations transmitted through the earth. These vibrations are produced both by natural and man-made processes. A seismometer should be able to detect minute ripples in the earth produced by someone walking across a room as well as the substantial motion of the earth's crust caused by earthquakes.
3	**Background Information on the Seismometer** The word seismometer is derived from two Greek words—*seismos* for earthquake and *metros* for measure—and was first invented in 1841 by J.D.Forbes for "measuring earthquake shocks and other concussions." The essential feature of any seismometer to examine the motion of the "ringing earth" is that some point or line within it remains at rest during the complicated movements of the ground. Various methods of obtaining such steady points

	have been proposed, but instruments in general use various forms of **pendulums**. The motion of the pendulum can be observed and recorded with mechanical means (such as a pen tracing the movement on smooth paper), optical means (such as a beam of light reflecting from a mirror attached to the pendulum, then striking photographic film), or electromagnetic means (to be explained later).
4	**Early Seismometers and Your Team's Design** You are probably somewhat familiar with the operation of a geologist's seismometer—perhaps you've seen the strip chart seismograph traces shown on TV news reports whenever California shakes substantially. You probably also think that a seismometer is a formidable piece of instrumentation. It is true that the world's best seismometers have massive frames anchored to piers sunk in bedrock and moving arms pivoting on sapphire bushings and sophisticated motors turning precision drums of paper for recording the pen movements. However, your team can build a sensitive seismometer using: • Frames and moving parts from the Erector Sets • Amplification of the electrical signals with op-amp circuits • Investigation of the measured vibrations with the MPLI equipment But you will have to add some additional parts to complete the construction. Several issues of *Scientific American* from the 50's and 60's had articles in the Amateur Scientist section describing the construction of seismometers suitable for measurement of earthquakes, distant storms, volcanoes on the verge of erupting, etc. These articles showed figures of the amateur seismometers that will be distributed in class. We suggest that your seismometer observe the construction details shown in these figures. According to one of these articles, most earth vibrations range in frequency from 10 Hz to 0.0001Hz. This range is substantially below the minimum frequency detectable by the human ear. The small amplitude tremors are called *microseisms*, and they are caused by "tornados, hurricanes, collapse of small caves, rock slides, and the impact of meteors." Earthquakes, which occur globally on the average of 10 times per day, have fascinating vibration spectra because they consist of so many kinds of waves: • Pressure waves (P waves), which are longitudinal • Shake waves (S waves), which are transverse in nature • Surface waves (L waves), which undulate like a water wave and travel around the surface of the earth
5	**Model and Design Deliverables** • The structure • The detector • The amplifier • The predicted operation • The observed operation
6	**Project Deliverables**

	• Your team seismometer • The team written project report

Handouts:

- Report Format—Seismometer

Report Format—Seismometer

In brief, the report should be in *Lab Format*, not an essay. The following sections should be included—and each section title should be highlighted:

- Introduction
  - Purpose of project
  - Goals
  - Motivation
- Design Process
  - Preliminary Designs (Use sketches or CAD drawings here)
  - Modifications
  - Brainstorming (if carried out)
  - The electronics
- The Seismometer Performance
  - Capturing the data—using the data logger pro
  - Presenting and analyzing the data
- Discussion and Analysis

The report should be descriptive and must use proper grammar, spelling, sentence structure, and so on. It should also be illustrative and use graphs, sketches, figures, and so on as necessary. You want the report to be clear and concise, so that you could pick it up ten years from now and be able to understand what your team has done.