Material Science Labs in Algebra II

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Subject: Algebra II, but adaptive to Physics and Algebra I
Level: 9-12
Standards: New York State- Intermediate Science (www.emsc.nysed.gov/ciai/)
Standard 1: Analysis, Inquiry, and Design
Standard 2: Mathematics
Standard 4: Science
Standard 5: Technology
Standard 6: Interconnectedness:
Standard 7: Interdisciplinary Problem Solving
Schedule: One 90 minute block, Two 53-minute periods, and parts of Two 53-minute periods.

Objectives:

Engage students in a lab to observe linearity of variables contained in Hooke's Law for elastic materials, have students appropriately graph the data and write an equation for the line of best fit. Then given data for what students assume would be a non-elastic material, graph stress vs strain, statistically determine the median-median line, and determine Young's Modulus. Explore careers involving material science.

Students will:

- Properly set-up and conduct a lab investigating Hooke's Law or another similar experiment.
- Graph the experimental data, draw a line of best fit, and write an equation for the line.
- Graph prepared data and determine the median-median line and its equation.
- Explore careers concerning material science.

Vocabulary:

Stress
Hooke's Law
Line of Best Fit
Median-Median Line
Slope
Direct Variation
Elasticity
Strain
Young's Modulus
Tensile Strength
Material Science

Materials:

For Each Group:

Graph Paper
Straight Edge
Graphing Calculator
Graph Transparencies
Different colored overhead markers
3 springs of varying spring constants
Varying masses
Force probe
Action figure or doll
100 Identical rubber bands
Meter sticks
Tape measures
Masking tape
Large rubber ball
2 bathroom scales
6-foot 2"X6"
Toy race track
Toy car
Spring cart
Booklets or CDs
2 cardboard tubes

Safety:

Students should wear safety goggles while conducting the experiments.

Science Content for the Teacher:

Hooke's Law - is an approximation that states that the amount by which a material is deformed (the strain) is directly proportionsl to the force causing the deformation (the stress). As in this lab, the extension produced in the rubber band or spring is directly proportional to the load:

$F = -kx$, where

F is the restoring force exerted by the material (usually in newtons),

x is the distance that the spring has been stretched or compressed away from the equilibrium position, (usually in meters), and

k is the **spring constant**. The constant has units of force per unit length (usually in newtons per meter).

There is a negative sign on the right hand side of the equation because the restoring force always acts in the opposite direction of the displacement **x** (when a spring is stretched to the left, it pulls back to the right).

Young's Modulus - is a measure of the stiffness of a material. It is defined as the ratio of stress (force per unit area) over strain (change in length over original length) and can be determined from the slope of a stress-strain curve created during tensile strength tests conducted on a sample of the material.

Material Science - Materials Science and Engineering (MSE) is a field of engineering that encompasses the spectrum of materials types and how to use them in manufacturing. Materials span the range: metals, ceramics, polymers (plastics), semiconductors, and combinations of materials called composites. (used with permission from the Sloan Career Cornerstone Center):
http://www.careercornerstone.org/pdf/matscieng/matscience.pdf

Preparation:

Day 1: The teacher should be prepared to explain each of the 8 labs that will simultaneously occur in, or near, the classroom. It is important to stress that students will be responsible for listening, as no handouts will be given for the labs. A brief explanation of each lab, dependent, and independent variables are listed. Teachers can access more resources for this activity at:
www.yostark.wikispaces.com

Hooke's Law – Students will be given masses and 3 springs of different constants. They will measure the displacement from equilibrium and graph it vs. mass, having each of the three graphs on transparencies using the same scale.

Young's Modulus – Students will be given an apparatus to test tensile strength. It consists of a force probe connected to a bolt and a fastened rubber band. They will lengthen the rubber band at a constant rate by turning the nut once per second. Students will record force vs. displacement.

Bungee Action Dude (Bungee Barbee) – Students will take a small action figure or doll, suspended by varying number of like rubber bands, drop over a banister, and measure distance it falls. They will graph distance vs. number of rubber bands.

Spring Cart – Students will be given a spring cart and numerous objects of similar size, such as CDs or booklets. The objects will be secured in the cart and students will measure distance the cart travels after the spring is released. Students will graph distance vs. number of objects.

View Tube - Students will take two cylindrical tubes of different size, such as paper towel tubes, and determine viewing size on a wall from varying distances away. Students will graph viewing diameter vs. distance away.

Ball Bounce – Students will be given a larger rubber ball (or basketball) and measure drop and rebound height. Students will record and graph two sets of data; rebound height vs. drop height, and rebound height vs. bounce number. (The latter one will be exponential.)

Walk the Plank – Students will be given a 6-foot 2"X6" and two bathroom scales. A student will move on the plank between the scales. Students will record and graph distance weight on a scale vs. distance away from scale.

Race Track – Students will be given lengths of toy race track and a car. Students will measure distance that car travels vs. ramp height. (This one is not linear.)

Day 2: Teacher should have all lab materials available.

Day 3: The teacher should have scoring sheets and a timing system ready before class start. Each group has 5 minutes to present.

Day 4: The teacher should be prepared to answer any group's questions from the presentations and have an example prepared to explain the process for determining the median-median line. He / She should also be ready to present the powerpoint presentation concerning Young's Modulus and physical properties.

Day 5: The teacher should be familiar with the powerpoint presentation covering material science and careers. The teacher may delete or skip over slides as he/she feels fit.

Classroom Procedure:

Day 1:

Engage (Time: 30 min.)

The teacher will introduce the class to the eight labs: Hooke's Law (using 3 springs of different constants), Young's Modulus, Bungee Action Dude, Spring Cart, View Tube, Ball Bounce, Walk the Plank, and Race Track. Students will be placed into groups of 3-4.

Day 2:

Explore (Time: 90 min.)

The students will conduct the labs in groups of 3 or 4. They will tabulate and graph their data, draw a line of best fit, and determine an equation for the line. They will create a poster showing the data, line of best fit, calculations for determining equation, and explanations in real world meaning (including units) of slope and intercepts.

Day 3:

Explain (Time: 53 min.)

The students have 5 minutes per group to present their lab and findings using their poster. Groups must include the units in their presentation and explanations of slope and intercepts.

Day 4:

Explain (Time: 38 min.)

The teacher will explain the process for statistically determining the median-median line. He will also explain Hooke's Law and Young's Modulus using results from the labs and emphasizing the units. The students will take the data from Cornell University to determine the line of best fit and Young's Modulus as part of their homework.

Expand (Time: 15 min.)

The teacher will present the powerpoint on Young's Modulus and determing physical constants of materials.

Day 5:

Explain (Time: 10 min.)

The teacher will review the homework on Median-Median line for the Young's Modulus data.

Expand (Time: 25 min.)

The teacher will present the powerpoint on Material Science and Engineering including information from CCMR and the Sloan Career Cornerstone Center. Students will be directed to explore the sites:
http://www.careercornerstone.org/pdf/matscieng/matscience.pdf and
http://www.careercornerstone.org/

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain	Expand/Synthesis
1	Student listened to introduction of labs, took notes, and prepared his lab group for the activity.	Student worked well with group on lab. The student did his part and helped keep the rest of the group on task. He was a group leader and assisted others.	The student listed to explanations on the median-median line and presentation. The student contributed to the discussions. He helped other students on the assignment.	The student explored the PowerPoints and asked questions. He showed an interest in exploring careers in STEM more.
2	Student listened to introduction of labs and took notes.	Student worked well with group on lab. The student did his part and helped keep the rest of the group on task.	The student listed to explanations on the median-median line and presentation. The student contributed to the discussions.	The student explored the PowerPoints and asked questions.
3	Student listened to introduction of labs, but did not take notes.	Student worked well with group on lab. The student did his part.	The student listed to explanations on the median-median line and presentation.	The student explored the PowerPoints, but did not ask questions.
4	The student did not listen to the introduction of the labs.	The student was not involved with the activity requiring others in his group to do all of the work.	The student did not listen to the explanations or presentations.	The student did not explore the PowerPoints or ask questions.

Extension Activities:

Students can explore the PhET simulation:
http://phet.colorado.edu/sims/mass-spring-lab/mass-spring-lab_en.html

Teachers can find the data from RET, PowerPoints, and other resources for this lesson plan at: www.yostark.wikispaces.com

Supplemental Information:

Adaptation to Physics, Freshman Physical Science, and Algebra I

Physics – All groups do both Hooke's Law and Young's Modulus labs. For Hooke's Law, different groups have different spring constants. Groups bring up transparencies of graphs. Teacher asks why data is different. Most groups should have correctly graphed data as direct variation (going through origin) but hopefully one group didn't by not compensating for displacement from equilibrium. It is recommended that the teacher insert a "dummy" transparency graphs that would show a parallel line, but not through origin for clarification of measurements and direct variation. More time should be spent looking at glass transition, polymers, and aspects in powerpoint. Also, more time should be given exploring careers and colleges for STEM subjects.

Freshman Physics (9 week course) - All groups do 9 labs, Match-It (with motion detectors), Speed (with motion detectors – converting units from m/s to mi/hr), Hooke's Law, Young's Modulus, Ball Bounce (linear restitution), Ball Bounce (exponential decay of height based on bounce number), Spring Cart, Walk the Plank, and calculation of acceleration due to gravity. Students do not look at median-median line.

Algebra I – Students can do the same labs as Algebra II, but do not look at median-median line.

Safety: Students should wear safety goggles while conducting the experiments.

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