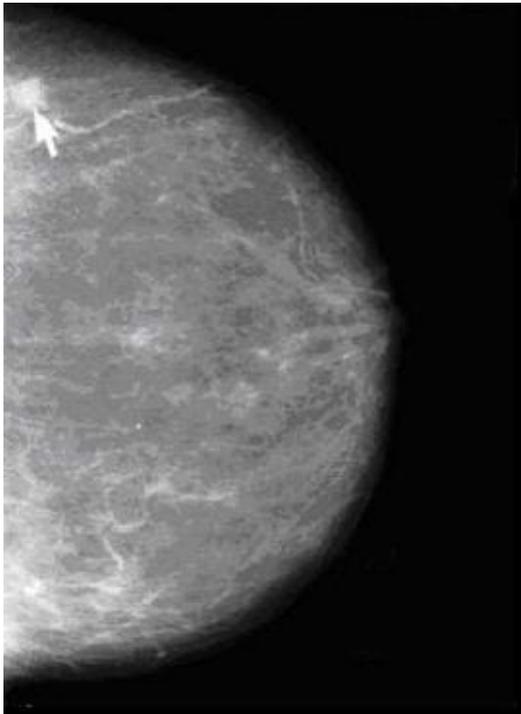


Curricular Unit: Using Stress and Strain to Detect Cancer!

Contributed by: VU Bioengineering RET Program, School of Engineering, Vanderbilt University

Quick Look

Grade Level: 11 (10-12)
Time Required: 300 minutes
(six 50-minute class periods)



A mammogram shows a tumor.

Summary

Students are presented with a biomedical engineering challenge: Breast cancer is the second-leading cause of cancer-related death among women and the American Cancer Society says mammography is the best early-detection tool available. Despite this, many women choose not to have them; of all American women at or over age 40, only 54.9% have had a mammogram within the past year. One reason women skip annual mammograms is pain, with 90% reporting discomfort. Is there a way to detect the presence of tumors that is not as painful as mammography but more reliable and quantifiable than breast self-exams or clinical breast exams? This three lesson/three activity unit is designed for first-year accelerated or AP physics classes. It provides hands-on activities to teach the concepts of stress, strain and Hooke's law, which students apply to solve the challenge problem.

This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Today, medical imaging is generally accepted as a safe, noninvasive means of generating internal images of the body. More than 100 years ago, such beneficial uses of harmful radiation would have been dismissed as outrageous and impossible. Decades of work by doctors, radiologists, scientists and engineers has provided safer use of x-rays for imaging of the skeletal system and some soft tissue, computer axial tomography, CT scans, to obtain three dimensional x-ray based imaging, magnetic resonance imaging, MRI, for depicting high contrast in soft tissues, and ultrasound imaging using high-frequency sound waves to depict moving structures and tissues in real time. Unfortunately, challenges remain in medical imaging today; one of which is presented in this unit. With nearly 45% of women avoiding annual mammograms due to pain and discomfort, students are challenged to think like engineers to develop a painless means of breast cancer detection that is reliable, cost effective and noninvasive.

Unit Overview

The unit's design uses a contextually based "Challenge" followed by a sequence of instruction in which students first offer initial predictions ("Generate Ideas") and then gather information from multiple sources ("Multiple Perspectives"). This is followed by "Research and Revise" as students integrate and extend their knowledge through a variety of learning activities. The cycle concludes with formative ("Test Your Mettle") and summative ("Go Public") assessments that lead the student towards answering the Challenge question. See the unit overview below for the progression of the legacy cycle through the unit. Research and ideas behind this way of learning may be found in *How People Learn*, (Bransford, Brown & Cocking, National Academy Press, 2000); see the entire text at <http://www.nap.edu/html/howpeople1/>.

The legacy cycle has similarities to the engineering design process; they both involve identifying needs existing in society, combining science and math to develop solutions, and applying the research conclusions to design clear conceived solutions to the challenges. Though the engineering design process and the legacy cycle depend on a correct and accurate solution, each focuses particularly on how the solution is devised and presented. See an overview of the engineering design process at http://en.wikipedia.org/wiki/Engineering_design_process.

In lesson 1, students are presented with the following *Grand Challenge*: "Breast cancer is the second-leading cause of cancer death among women (Papas, 253) and the American Cancer Society has indicated that mammography is the best early-detection tool available. Despite the fact that mammograms are the most effective early-detector of breast cancer, many women choose not to have them. Of all American women at or over the age of 40, only 54.9% have had a mammogram within the past year (ACS, 15). One reason women attribute skipping their annual mammogram is pain with 90% report experiencing discomfort (Papas, 254). *Is there a way to detect the presence of tumors that isn't as painful as mammography but more reliable and quantifiable than a breast-self exam and clinical breast-exams?*"

Students begin by *Generating Ideas* in lesson 1's associated activity, answering questions such as, "What are your initial thoughts about how this question can be answered?" and "What do you know about breast cancer and tumor detection already?" Students then enter the *Multiple Perspectives* phase of the legacy cycle as they read an expert interview from a professor of biomedical imaging. To extend the *Multiple Perspectives* phase, it is suggested that a local specialist make a guest presentation on medical imaging to the class.

In lesson 2, students enter the *Research and Revise* phase focusing on the concepts of Hooke's law and stress-strain relationships. The lesson includes a problem set to complete individually or as a class. The practice problems give students experience manipulating the new equations. Students extend their understanding of these concepts in the associated activity. In the first portion of the activity, students explore Hooke's law by experimentally solving for an unknown spring constant. In the second portion of the activity, students apply this understanding to study breast tissue with respect to cancer detection. After completing the lesson and the associated activities, students enter the *Test Your Mettle* phase by completing a quiz on stress, strain and Hooke's law.

Finally, lesson 3 and its associated activity constitute the *Go Public* phase of the legacy cycle. First, in the associated activity, students create a graph in Excel® depicting the location of a cancerous tumor amidst healthy breast tissue. This in-class assignment constitutes one-half of the grade while the other half results from a take-home assignment. In the take-home assignment, students are create informative brochures presenting their innovative, painless form of breast cancer detection to patients and physicians.

Unit Schedule

- Day 1: Your Biomedical Challenge: Painlessly Detecting Disease lesson
- Day 2: Learning Imaging Techniques! activity
- Day 3: Stress, Strain and Hooke's Law lesson
- Day 4-5: Applying Hooke's Law to Cancer Detection activity
- Day 6: Making Brochures: Presenting Painless Cancer Detection! lesson and You Be the Radiologist! Strain Graphs That Reveal Tumors activity

Assessment

Lesson 3 and its associated activity constitute the final *Go Public* phase of the legacy cycle during which students apply the concepts they have learned to answer the *Grand Challenge* question. They relate the learned concepts of Hooke's law, stress and strain to medical imaging. This summative assessment covers the previous two lessons and their associated activities.

Contributors

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Last modified: March 17, 2018

Lesson: Your Biomedical Challenge: Painlessly Detecting Disease

Contributed by: VU Bioengineering RET Program, School of Engineering, Vanderbilt University

Quick Look

Grade Level: 11 (10-12)
Time Required: 30 minutes
Lesson Dependency : None



Learn the potentials of ultrasound.

Summary

Students are introduced to the unit challenge: To develop a painless means of identifying cancerous tumors. Solving the challenge depends on an understanding of the properties of stress and strain. After learning the challenge question, students generate ideas and consider the knowledge required to solve the challenge. Then they read an expert's opinion on ultrasound imaging and the potentials for detecting cancerous tumors. This interview helps to direct student research and learning towards finding a solution.

This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Through years of developing medical imaging, engineers and scientists have gained the ability to control and manipulate potentially lethal radiation in order to produce meaningful, lifesaving images. As students are presented with the challenge of designing a means of painlessly detecting breast cancer, they consider the potential hazards of the imaging techniques. In light of this consideration, students must think not just as biomedical engineers, but even further, like safety engineers as well. In the post lesson assessment questions 2-6, students consider the potential advantages and hazards of ultrasound imaging as suggested in the expert interview.

Learning Objectives

After this lesson, students should be able to:

- Explain the challenge problem.
- List information that might be needed to answer the problem.
- Group together similar areas of knowledge needed to address the challenge.

Introduction/Motivation

Exactly what is an x-ray? Have you ever heard of a CT scan? Or how about an ultrasound? What about a mammogram? Today we have been assigned an engineering challenge and it is our task to devise a plan of attack, identify what we need to know to solve the challenge and begin solving the challenge. So let's get started.

Breast cancer is the second-leading cause of cancer death among women (Papap, 253). The American Cancer Society states that mammography is the best early-detection tool available. It is able to detect cancer before – sometimes years before – physical symptoms are present (American Cancer Society, 13). It is recommended that women at or older than 40 have a mammogram annually (ACS, 13). Despite the fact that mammograms are the most effective early-detector of breast cancer, many women choose not to have them. Of all American women at or over the age of 40, only 54.9% have had a mammogram within the past year (ACS, 15).

One reason that women may not get an annual mammogram is pain. Mammography is quite painful for some women. In a summary of studies, between 0.2% and 62% of women reported some pain related to mammography. If the qualifier was changed from "pain" to "discomfort," 90% of women answered that they had experienced this (Papap, 254). Other forms of early-detection exist—breast-self exam (BSE) and clinical breast-exams (CBE)—but these are not as effective as mammography.

Is there a way to detect the presence of tumors that is not as painful as mammography but more reliable and quantifiable than a BSE or CBE?

Over the next week or so of classes, we will work through solving this engineering challenge. This type of challenge-based learning may be new to us but it will be exciting and very fun. We begin our learning by *Generating Ideas*, considering what we already know and what we need to learn in order to solve the challenge. Then we hear *Multiple Perspectives* from professionals specializing in medical imaging. Hearing the thoughts of professionals helps us adapt our initial thoughts! Then, we begin the *Research and Revise* phase in which we learn the fundamental concepts of Hooke's law and stress and strain, which are essential to our solution. We will have a short quiz to assess our learning, constituting the *Test your Mettle* step of this learning cycle. Finally, instead of a unit test we will *Go Public* with our engineering solution by creating an informational brochure! Now that we know what lies ahead, let's get started!

Lesson Background and Concepts for Teachers

Legacy Cycle Information

This lesson covers the *Challenge, Generates Ideas and Multiple Perspectives* phases of the legacy cycle. After being introduced to the challenge question, have students begin to brainstorm ideas and organize the information they deem necessary to solve the challenge. This constitutes the *Generate Ideas* phase of the cycle. After which, students are introduced to the input of a professional in order to help guide their learning, also known as the *Multiple Perspectives* phase. An extension to this phase might be a biomedical imaging presentation by a local professor of biomedical engineering. In the next lesson, students begin the *Research and Revise* phase in which they acquire an understanding of stress and strain, as needed to solve the challenge question.

Lecture Information

Begin by introducing students briefly to the legacy cycle and the way in which they will learn the concepts of stress and strain as described in the introduction. This helps students understand why they are going through each phase of the cycle.

Next, complete the associated activity. Read the challenge question aloud to the class. Begin with students working alone to record their personal thoughts and ideas by answering the generate ideas question on the handout. After an adequate amount of time, generate a class list on the board of concepts that must be considered in order to solve the challenge question. Next ask students to generate a list of knowledge areas and categorize the concepts they have listed into these knowledge areas. Work with students until they begin discussing various imaging techniques such as x-ray, MRI, CT, ultrasound, etc. Lead students toward discussing the fundamental functions of these imaging techniques; for example, x-ray images depict tissue density and PET scans depict cellular metabolism.

After ideas have been generated, pass out to each student an Ask the Expert Handout—a five question/answer interview with Dr. Michael Miga, professor of biomedical engineering. Read the handout aloud as a class. Afterwards, permit students to alter the ideas on the board, adding to the concepts they expect to learn in order to solve the challenge.

Attachments

Ask the Expert Handout (doc)

Ask the Expert Handout (pdf)

Assessment

Post-Lesson Assessment:

Journal Questions: As a writing assignment, ask students to answer the following questions.

- What do you know about stress and strain? What do these terms refer to? Do you know of a relationship between the two concepts?
- What do you know about ultrasound imaging? What are other uses for this technology, besides prenatal ultrasound?
- How does ultrasound imaging produce images?
- What exactly is being depicted in an ultrasound?
- What are other ways to depict what an ultrasound shows in its images?
- What are safety concerns related to using an ultrasound?

References

Dictionary.com. Lexico Publishing Group,LLC. Accessed December 28, 2008. (Source of vocabulary definitions, with some adaptation) <http://www.dictionary.com>

American Cancer Society. (2005) Breast Cancer Facts and Figures 2005-2006. Atlanta: American Cancer Society, Inc.

Papas, Mia A., Klassen Ann C. (2005) Pain and Discomfort Associated with Mammography Among Urban Low-Income African-American Women [Electronic version]. *Journal of Community Health*, 30, 253 – 267.

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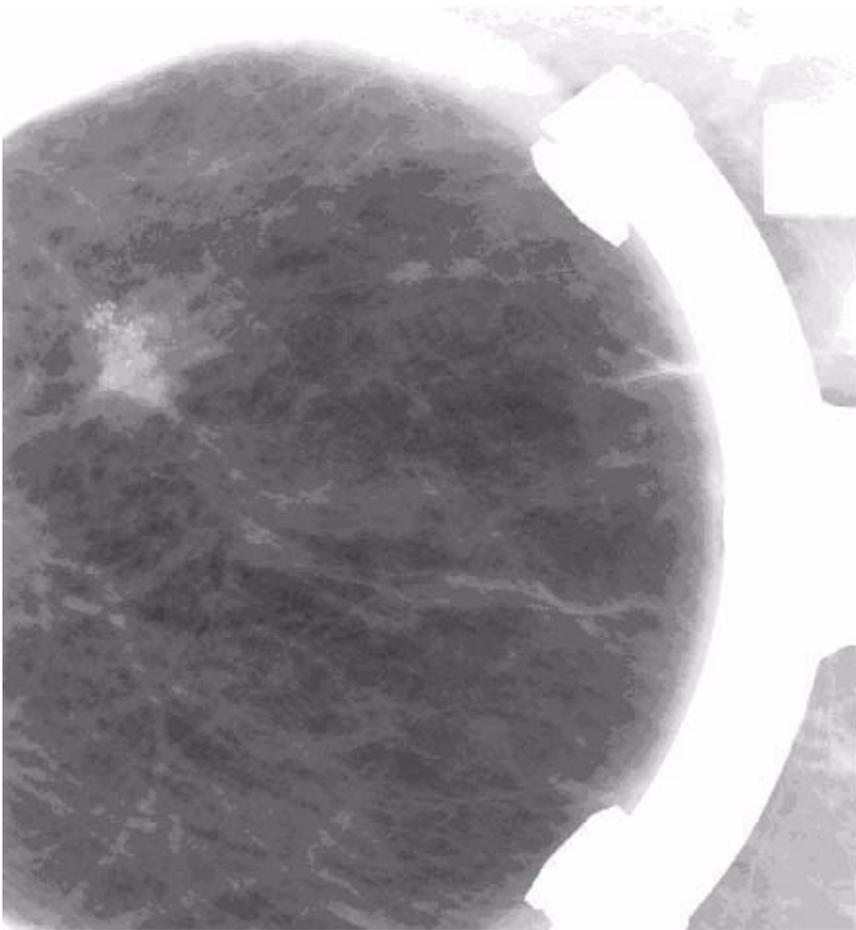
Last modified: March 17, 2018

Hands-on Activity: Learning Imaging Techniques!

Contributed by: VU Bioengineering RET Program, School of Engineering, Vanderbilt University

Quick Look

| | |
|------------------------------|---|
| Grade Level: | 11 (10-12) |
| Time Required: | 30 minutes |
| Expendable Cost/Grp : | US \$0.00 |
| Group Size: | 3 |
| Activity Dependency : | Your Biomedical Challenge: Painlessly Detecting Disease |



Mammogram image depicting a tumor.

Summary

During this activity, students are introduced to the concepts of the unit's "grand challenge." They generate ideas for solving the problem, first independently, then in small groups. Finally, as a class, students compile their ideas with a visual as a learning supplement.

This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

This activity presents students with a need in society and asks them to consider a method for finding a solution, also known as the engineering design process. As engineers, students must first identify the need for a painless, yet reliable method for detecting cancerous tumors; then, students will define the challenges which must be considered in the

design. In the next phase, research will begin but before researching, students must identify the information they will need to acquire through their research. Engineers of all types constantly follow the engineering design process, with the first and most crucial steps being identifying the need in society. Like engineers, students must learn to apply their peripheral knowledge to solve the identified need. In questions 1-4 of the Generate Ideas section of the handout, students must identify a need in society and consider how it can be fulfilled.

Pre-Req Knowledge

A basic understanding of biomedical imaging techniques.

Learning Objectives

After this activity, students should be able to:

1. Apply their background knowledge to begin solving the challenge.
2. Identify gaps in their knowledge needed to solve the challenge.

Materials List

Each student needs a copy of the Grand Challenge: Detecting Breast Cancer Handout.

Introduction/Motivation

Do you know any engineers? Do you know what exactly engineers do? Do engineers invent things? Or do they adapt things? Today, we are going to think like engineers and we will grow familiar with the engineering design process. We have already been presented with our challenge question, and now it is time to be the engineers we know we can be. I will pass out a handout which will be your guide to thinking like a biomedical engineer. Please answer the questions first on your own. Soon, we will reconvene in small groups to share our thoughts. Then as a class, we will generate a few lists on the board. Please keep your mind open and do your best to consider anything and everything that may apply to the engineering challenge. You may add to your initial notes once we begin working in groups!

Vocabulary/Definitions

cancer: A malignant and invasive growth or tumor tending to recur after removal and to metastasize to other sites.

ultrasound Imaging: The application of ultrasonic waves to therapy or diagnostics, as in deep-heat treatment of a joint or imaging of internal structures.

Procedure

Background

This activity introduces students to the material they will soon learn in an exciting, unique manner. Students begin generating ideas on the challenge question and contribute to class discussion in an engaging manner.

Before the Activity

Make copies of the Grand Challenge: Detecting Breast Cancer Handout, one per student.

With the Students

1. Describe the challenge to the students.
2. Ask students to take notes on their handout individually for a few minutes.
3. Then assign small groups and have students share their thoughts with each other.
4. Finally ask students from each group to volunteer their thoughts.
5. Compile their suggestions on the board to provide a visual.
6. Generate a list of a few knowledge areas on which the students should focus. Categorize the concepts they have suggested into the knowledge areas.

Attachments

Grand Challenge: Detecting Breast Cancer Handout (doc)

Grand Challenge: Detecting Breast Cancer Handout (pdf)

Investigating Questions

- What types of imaging would be a candidate for detecting breast cancer?
- What do you know about cancerous tissue and how it differs from healthy tissue?
- Can you think of any other means of graphing or depicting the data that an ultrasound captures?
- What will you need to learn in order to devise a painless technique for identifying malignant tumors?

Assessment

Activity Embedded Assessment: Formulate students' daily participation grade considering their individual contributions while the class compiles its ideas and thoughts.

Activity Extensions

If students show an interest in the various imaging techniques, ask a professor of biomedical engineering from a local university to deliver a presentation on biomedical imaging to the class.

Activity Scaling

- For lower grades, provide more time for group discussions.
- For upper grades, ask further investigating questions with respect to other means of graphing the data received from the ultrasound.

References

Dictionary.com. Lexico Publishing Group,LLC. Accessed December 28, 2008. (Source of vocabulary definitions, with some adaptation)

American Cancer Society. (2005) Breast Cancer Facts and Figures 2005-2006. Atlanta: American Cancer Society, Inc.

Papas, Mia A., Klassen Ann C. (2005) *Pain and Discomfort Associated with Mammography among Urban Low-Income African-American Women* [Electronic version]. Journal of Community Health, 30, 253 – 267.

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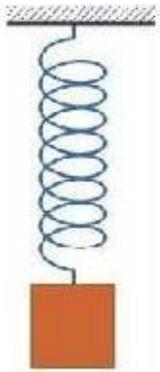
Last modified: March 17, 2018

Lesson: Stress, Strain and Hooke's Law

Contributed by: VU Bioengineering RET Program, School of Engineering, Vanderbilt University

Quick Look

Grade Level: 11 (10-12)
Time Required: 75 minutes
Lesson Dependency : Detecting Breast Cancer



Summary

Students are introduced to Hooke's law as well as stress-strain relationships. First they learn the governing equations, then they work through several example problems, first individually, then as a class. Through the lesson's two-part associated activity, students 1) explore Hooke's law by experimentally determining an unknown spring constant, and then 2) apply what they've learned to create a strain graph depicting a tumor using Microsoft Excel®. After the activities, the lesson concludes with a stress-strain quiz to assess each student's comprehension of the concepts.

This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Students explore
Hooke's Law

More than 300 years ago, Robert Hooke identified a proportionality that has remained a fundamental concept to physicists and engineers to this day. Though his "law" was established for the case of springs alone, it has since been related to all materials of known surface area. The relationship used most readily today is the direct proportionality between stress and strain. Together, civil engineers, mechanical engineers and material scientists, carefully select structural materials that are able to safely endure everyday stress while remaining in the elastic region of the stress-strain curve, otherwise permanent deformation occurs. Architects who once chose stone for its aesthetic appeal now choose steel for its long-term endurance. For biomedical engineers, titanium is often the material of choice for its biocompatibility and more importantly, its capability to withstand the tensile and compressive stress of the body's weight. In the provided problem set, students explore applications of Hooke's law and stress-strain relationships. In problem 7 specifically, students apply these relationships to the case of body tissue, as biomedical engineers would.

Pre-Req Knowledge

A basic understanding of algebra and the ability to solve simple algebraic expressions. In addition, an understanding of the cancer detection challenge, as introduced in the previous lesson.

Learning Objectives

After this lesson, students should be able to:

- Explain the stress and strain concepts and the relationship between them.
- Explain Hooke's law and apply it to analyze springs.
- Use Microsoft Excel® to make a simple strain plot.
- Relate stress and strain to the unit's engineering challenge.

Introduction/Motivation

In today's lesson, we will begin to learn about Hooke's law and then we learn how to apply this proportionality to body tissue. We will learn exactly what the terms stress and strain describe as well as the relationship between them. After going through the lesson's material, I will pass out a handout with example problems. Work these to the best of your abilities independently first; then we will review the problems as a class.

After becoming familiar with using the new equations, we will explore Hooke's law in an associated activity (Applying Hooke's Law to Cancer Detection) by experimentally determining an unknown proportionality constant. After exploring Hooke's law, in the second portion of the activity, we will begin to apply what we've learned to develop a means of imaging body tissues and we will soon be able to detect malignant tumors!

You will also practice graphing prepared data to depict cancerous tissue. After we have mastered this material, we will have a quiz on stress, strain and Hooke's law. Please take careful notes and be sure to ask any questions you have about the example problems we will be working through.

Referring back to the legacy cycle which we discussed in the previous lesson, today's lesson constitutes the research and revise phase. Refer back to your initial thoughts notes and record any new information that applies to solving the challenge. Your goal today is to review, revise and expand your current knowledge! Now, let's learn how to detect cancer.

Lesson Background and Concepts for Teachers

Legacy Cycle Information

This lesson falls into the *Research and Revise* phase of the legacy cycle. Students begin to learn the basic concepts required for creating a strain graph to depict cancerous tissue. Following this lesson, have students revise their initial thoughts and at the conclusion of the associated activity, students should have the skills necessary to *Go Public* with a solution. But before *Going Public*, have students complete the Stress, Strain and Hooke's Law Quiz as part of the *Test Your Mettle* phase of the legacy cycle. The quiz serves as a formative assessment while the next lesson's *Go Public* phase provides a summative assessment.

Lecture Information

In the late 1600s, Robert Hooke stated that "The power of any springy body is in the same proportion with the extension." Though Hooke's law has remained valid today, the wording has been corrected, replacing power with force. The law is explained by a direct proportionality between a spring's compression or expansion and the restoring force which ensues. The relationship is given by $F = -k \cdot \Delta x$ where Δx is the distance a spring has been stretch, F is the restoring force exerted by the spring and k is the spring constant which characterizes elastic properties of the spring's material. This law is valid within the elastic limit of a linear spring, when acting along a frictionless surface.

Extending Hooke's exploration of springs, it becomes apparent that most materials act like springs with force being directly proportional to displacement. But as compared to springs, other materials possess an area which must be accounted for. Replacing force with a measure of stress and displacement with a measure of strain, the following expression may be obtained, $\sigma = E \cdot \epsilon$. We will now explore the measures of stress and strain.

Stress is a measure of average force per unit area, given by $\sigma = F/A$ where average stress, σ , equals force, F , acting over area, A . The SI unit for stress is pascals (Pa) which is equal to 1 Newton per square meter. The Psi is an alternative unit which expresses pounds per square inch. The units of stress are equal to the units of pressure which is also a measure of force per unit area.

Stress cannot be measured directly and is therefore inferred from a measure of strain and a constant known as Young's modulus of elasticity. The relationship is given by $\sigma = E \cdot \epsilon$, where σ represents stress, ϵ represents strain and E represents Young's modulus of elasticity. Using this means of inferring stress, strain is a geometrical measure of deformation and Young's modulus is a measure used to characterize the stiffness of an elastic material. Strain does not carry a unit but the units of Young's modulus are Pa.

Strain is characterized by the ratio of total deformation or change in length to the initial length. This relationship is given by $\epsilon = \Delta l/l_0$ where strain, ϵ , is change in l divided by initial length, l_0 .

The following problems may be worked independently and reviewed as a class, encouraging students to become more familiar with using the equations given above. Give each student a copy of the Stress, Strain and Hooke's Law Problem Set.

You are required to SHOW ALL WORK. Useful constants that are provided in a table below. (assume given constants have three significant figures (SF). Please also note that the relationships we have just discussed are given below.

Material

- steel

- Young's module: 200×10^9 E(Pa)
- 2. cast iron
- Young's module: 100×10^9 E(Pa)
- 3. concrete
- Young's module: 20.0×10^9 E(Pa)

$$F = m \cdot a \quad \sigma = F/A \quad \epsilon = \Delta l/l_0 \quad \sigma = E \cdot \epsilon \quad F = -k \cdot \Delta x$$

1. A 3340 N ball is supported vertically by a 1.90 cm diameter steel cable. Assuming the cable has a length of 10.3 m, determine the stress and the strain in the cable.
2. Consider an iron rod with a cross-sectional area of 3.81 cm² that has a force of 66,700 N applied to it. Find the stress in the rod.
3. A concrete post with a 50.8 cm diameter is supporting a compressive load of 8910 Newtons. Determine the stress the post is bearing.
4. The concrete post in the previous problem has an initial height of 0.55 m. How much shorter is the post once the load is applied (in mm)?
5. A construction crane with a 1.90 cm diameter cable has a maximum functioning stress of 138 MPa. Find the maximum load that the crane can endure.
6. Consider Hooke's law as a simple proportionality where F is directly proportional to Δx . Therefore, we know the force stretching a spring is directly proportional to the distance the spring stretches. If 223 N stretches a spring 12.7 cm, how much stretch can we expect to result from a of 534 N?
7. Figure 1 shows a column of fatty tissue, determine the strain in each of the three regions.

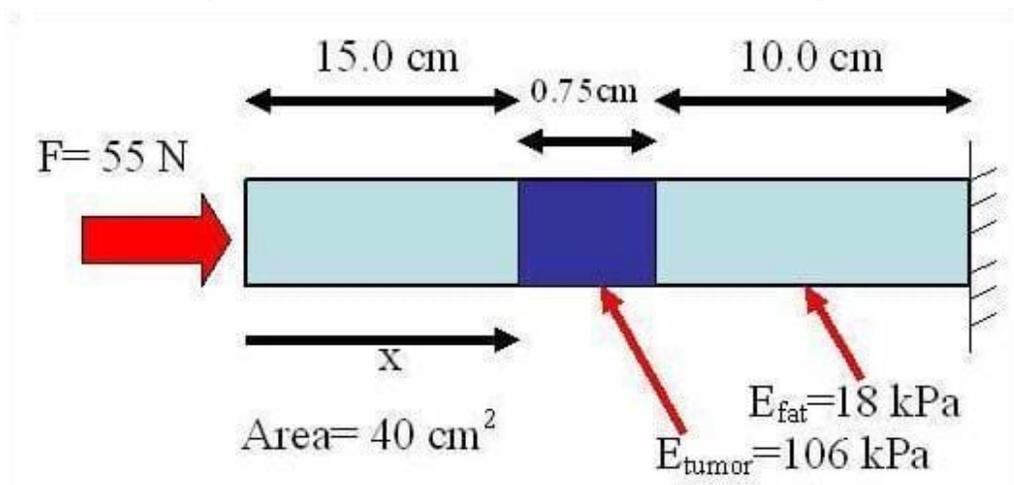


Figure 1. A column of fatty tissue.

Vocabulary/Definitions

radiologist: A medical specialist who examines photographs of tissues, organs, bones for use in the treatment of disease.

strain: Deformation of a body or structure as a result of an applied force. Stretch beyond the proper point or limit.

stress: The physical pressure, pull or other force exerted on a system by another. A load, force, or system of forces producing a strain. The ratio of force to area.

Attachments

Stress, Strain and Hooke's Law Problem Set (pdf)

Stress, Strain and Hooke's Law Problem Set Solutions (pdf)

Stress, Strain and Hooke's Law Quiz (pdf)

Assessment

Post-Introduction Assessment:

Problem Set: Have students complete the Stress, Strain and Hooke's Law Problem Set in class to gauge their comprehension. The final question of the problem set and the application questions from the associated activity serve as an assessment of students' understanding of the challenge. Use these questions as a means of testing whether students are applying their acquired knowledge toward solving the engineering challenge.

Post-Lesson Assessment:

Quiz: Administer the Stress, Strain and Hooke's Law Quiz as a formative post-lesson assessment, serving as part of the *Test your Mettle* phase of the legacy cycle.

References

Dictionary.com. Lexico Publishing Group,LLC. Accessed December 28, 2008. (Source of vocabulary definitions, with some adaptation) <http://www.dictionary.com>

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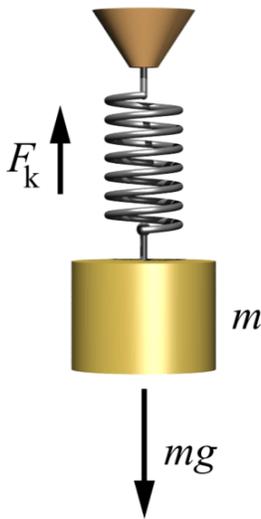
Last modified: March 9, 2018

Hands-on Activity: Applying Hooke's Law to Cancer Detection

Contributed by: VU Bioengineering RET Program, School of Engineering, Vanderbilt University

Quick Look

| | |
|------------------------------|---|
| Grade Level: | 11 (10-12) |
| Time Required: | 90 minutes |
| Expendable Cost/Grp : | US \$0.00 |
| | The activity requires some non-expendable (reusable) computers and lab equipment; see the Materials List for details. |
| Group Size: | 3 |
| Activity Dependency : | Lesson 2: Stress, Strain and Hooke's Law |



Students investigate Hooke's Law

Summary

Students explore Hooke's law while working in small groups at their lab benches. They collect displacement data for springs with unknown spring constants, k , by adding various masses of known weight. After exploring Hooke's law and answering a series of application questions, students apply their new understanding to explore a tissue of known surface area. Students then use the necessary relationships to depict a cancerous tumor amidst normal tissue by creating a graph in Microsoft Excel.

This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

Hooke's law defines the direct proportionality between a spring's deformation and the restoring force that results. Most commonly, a derivative of Hooke's law is used in engineering applications—a relationship that directly relates stress and strain. For example, the stress-strain curve is commonly used by material scientists and engineers while selecting materials for structures. Within the linear region, the slope is defined by the Young's modulus of elasticity. Civil engineers often study the stress-strain curve when using strain hardening and other methods to increase the yield strength of a material. In this activity, particularly in the investigating questions 6 and 7, students explore the relationship between Hooke's law and the stress-strain equation. In addition, students must apply their understanding of Hooke's law to create a strain plot.

Pre-Req Knowledge

A basic understanding of the concepts of Hooke's law, stress and strain, as presented in Lesson 2.

Learning Objectives

After this activity, students should be able to:

- Describe what is meant by Hooke's law.
- Apply Hooke's law relationships to analyzing tissue of a known surface area.
- Depict a cancerous tumor using graphing methods in Microsoft Excel.

Materials List

Part 1:

Each lab group needs:

- physics lab stand
- meter stick
- spring (with hooks)
- pendulum clamp
- slotted mass set
- computer with Microsoft Excel (or other spreadsheet application)
- Hooke's Law Worksheet, one per student

Part 2:

Each group needs a computer with Microsoft Excel and the Generating a 1-D Strain Plot Handout. The handout has instructions specifically for Excel, but if you adjust the instructions, another spreadsheet program could be used.

Introduction/Motivation

Have you ever wondered how the value of the gas constant was measured/discovered, or the charge on an electron, or the Young's modulus of elasticity values we used in the problem set yesterday? Ever wondered where all these values come from? Well today we are going to solve for one ourselves.

In groups of three, we are going to experimentally find the spring constant, k , for a few springs. After collecting data, we will use the relationship given by Hooke's law to solve for an approximation of the constant.

After exploring Hooke's law and answering a few application questions, we will apply what we've learned to study a body tissue with known surface area. Because Hooke's law applies to springs, we must make a few adaptations to the expression $F = -k \Delta x$, to account for area. By the end of the activity, you will be able to apply what you know about Hooke's law, stress and strain to depict a tumor amidst normal tissue using a graph in Microsoft Excel.

Vocabulary/Definitions

cancer: A malignant and invasive growth or tumor tending to recur after removal and to metastasize to other sites.

force: An influence on a body or system, producing a change in movement or in shape or other effects.

spring: An elastic body such as a wire of steel coiled spirally that recovers its shape after being compressed, bent or stretched.

strain: Deformation of a body or structure as a result of an applied force beyond limit.

stress: The physical pressure, pull or other force exerted on a system by another, producing a strain. Measured by the ratio of force to area.

ultrasound imaging: The application of ultrasonic waves to therapy or diagnostics, as in deep-heat treatment of a joint or imaging of internal structures.

Young's modulus of elasticity: A mathematical constant that represents how difficult a material is to stretch

Procedure

Background

This activity constitutes the *Research and Revise* phase of the legacy cycle. Students explore Hooke's law in a hands-on, laboratory situation. They experimentally solve for the spring constant, k , of a given spring by measuring the spring's displacement when a mass of known weight is added. After answering some application questions on Hooke's law, students relate Hooke's law to a body tissue of known surface area. Continuing their research and revising their initial thoughts for solving the engineering challenge, students follow step-by-step instructions to depict a cancerous tissue in a graph generated in Microsoft Excel. Though students work in groups, it is expected that they complete their own activity worksheets. Students may discuss the questions but should answer the questions individually.

Before the Activity

- Provide each lab station with the necessary materials.
- Assign groups of three for the activity.
- Make copies of the Hooke's Law Worksheet and Generating a 1-D Strain Plot Handout.



Example lab setup.

With the Students

1. Pass out the two handouts. Use the Hooke's Law Worksheet as an instructional guide when creating strain plots. Use the Generating a 1-D Strain Plot Handout as an instructional guide to the lab; each student is responsible for completing and submitting the analysis and application questions by the end of the class period.
2. Have students move into their assigned groups and go to their lab benches.
3. Direct students to follow the worksheet and handout instructions. Remind them that they may work together, but each student is responsible for completing and turning in their own answers and solutions.
4. When students are ready to move on to the strain plot, have them remain in their groups; only one graph needs to be turned in per group. Remind them to return to their initial thoughts notes and add any new notes that may help them solve the challenge.

Attachments

Hooke's Law Worksheet (doc)

Hooke's Law Worksheet (pdf)

Generating a 1-D Strain Plot Handout (doc)

Generating a 1-D Strain Plot Handout (pdf)

Investigating Questions

- How does Hooke's law and the stress-strain relationship relate? Which variables correspond?
- What do we know about cancerous tissue that allows us to use these concepts to depict it?
- What types of software would be appropriate for our imaging?
- Using these methods, will our imaging method be painless? Will it be effective and reliable? How about cost effective?

Assessment

Activity Embedded Assessment: The Hooke's law application questions and the 1-D strain plot both function as means of assessment. Students must first develop an understanding of Hooke's law. Then they must relate this concept to a tissue with known cross-sectional area. This concept may be used to detect a cancerous tumor where the tumor's elastic properties differ from that of normal tissue.

Activity Extensions

To extend the hands-on aspect of exploring the tissue, consider obtaining ballistic gel (such as https://en.wikipedia.org/wiki/Ballistic_gelatin or <http://www.myscienceproject.org/gelatin.html>) of differing stiffness. This may be used to mimic the differing tissue structure of cancerous and normal tissue as represented by varying Young's modulus of elasticity.

Activity Scaling

- For upper-level students, remove the step-by-step instructions for generating the 1-D strain plot.
- For lower-level students, take the time to relate Hooke's law to the stress-strain relationship as a class. Make this connection with the students, using a visual representation on the board.

References

Dictionary.com. Lexico Publishing Group, LLC. Accessed December 28, 2008. (source of vocabulary definitions, with some adaptation)

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Lesson: Making Brochures: Presenting Painless Cancer Detection!

Contributed by: VU Bioengineering RET Program, School of Engineering, Vanderbilt University

Quick Look

Grade Level: 11 (10-12)
Time Required: 10 minutes
Lesson Dependency : Stress, Strain and Hooke's Law



Students learn about breast cancer detection

Summary

This lesson culminates the unit with the Go Public phase of the legacy cycle. In the associated activity, students depict a tumor amidst healthy body tissue using a Microsoft Excel® graph. In addition, students design a brochure for both patients and doctors advertising a new form of painless yet reliable breast cancer detection. Together, the in-class activity and the take-home assignment function as an assessment of what students have learned throughout the unit.

This engineering curriculum meets Next Generation Science Standards (NGSS).

Engineering Connection

As part of the engineering design process, when a need in society is established as an engineering challenge, in order for the challenge to be solved, the solution must be well tested, found to be reliable and then presented to the demographic in need, through evidential explanations. For example, in the case of biomedical engineering, a need for painless, reliable breast cancer detection has been presented to researchers at the university level. Following the engineering design process, once a well-tested, consistent and accurate solution has been established in ultrasound technology, it must be presented to radiologists in hopes of implementation on a clinical level. Similarly, in the associated activity, students must demonstrate the accuracy of their solution; while in the lesson's assessment, students must present the solution to doctors and patients with an informative brochure.

Pre-Req Knowledge

A complete understanding of Hooke's law and stress-strain relationships.

Learning Objectives

After this lesson, students should be able to:

- Present a painless means of detecting breast cancer.
- Explain how knowing the different properties of a material can lead to a useful solution.
- Describe the role of tissue properties in detecting a tumor.
- Produce an image depicting the location of a tumor.

Introduction/Motivation

Today is the big day! Today we will design a painless yet reliable method for detecting breast cancer. This is the time to *Go Public* with what you've learned! First you will complete the in-class portion in which you create a graph depicting the location of a tumor given certain conditions. Then you have three nights to complete the take-home portion in which you create a brochure advertising the new form of breast cancer detection to patients and doctors. Your brochure should explain how it works and the advantages and disadvantages of your design. It should also explain how you disseminated the problem and found a manageable solution to a complex issue. Please use the grading rubric to guide your brochure design.

Lesson Background and Concepts for Teachers

Legacy Cycle Information

This lesson includes the final step of the legacy cycle, the Go Public step. In the associated activity (You Be the Radiologist! Strain Graphs That Reveal Tumors), students create a graph depicting the location of a tumor amidst fatty tissue, given certain conditions. In the take-home portion of the Go Public phase, students are given three to design a brochure advertising the new form of breast cancer detection to patients and doctors. The brochure should explain how the detection works, its advantages and its disadvantages.

Informative Brochure

Distribute the attached grading rubric to the class. Have each student prepare his/her own brochure and use the grading rubric as a guide in assessing student designs.

Vocabulary/Definitions

cancer: A malignant and invasive growth or tumor tending to recur after removal and to metastasize to other sites.

force: An influence on a body or system, producing a change in movement or in shape or other effects.

spring: An elastic body such as a wire of steel coiled spirally that recovers its shape after being compressed, bent or stretched.

strain: Deformation of a body or structure as a result of an applied force beyond limit.

stress: The physical pressure, pull or other force exerted on a system by another, producing a strain. Measured by the ratio of force to area.

Attachments

Now Presenting Painless Breast Cancer Detection! Grading Rubric (doc)

Now Presenting Painless Breast Cancer Detection! Grading Rubric (pdf)

Assessment

Embedded Assessment:

Give each student a composite grade based on the graph generated in the associated activity as well as the informative brochure.

References

Dictionary.com. Lexico Publishing Group,LLC. Accessed December 28, 2008. (Source of vocabulary definitions, with some adaptation) <http://www.dictionary.com>

Contributors

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Hands-on Activity: You Be the Radiologist! Strain Graphs That Reveal Tumors

Contributed by: VU Bioengineering RET Program, School of Engineering, Vanderbilt University

Quick Look

| | |
|------------------------------|---|
| Grade Level: | 11 (10-12) |
| Time Required: | 40 minutes |
| Expendable Cost/Grp : | US \$0.00 |
| Group Size: | 3 |
| Activity Dependency : | Making Brochures: Presenting Painless Cancer Detection! |



Students act as radiologists

Summary

In addition to the associated lesson, this activity functions as a summative assessment for the Using Stress and Strain to Detect Cancer unit. In this activity, students create 1-D strain plots in Microsoft Excel® depicting the location of a breast tumor amidst healthy tissue. The results of this activity function as proof of the accuracy and reliability of students' breast cancer detection designs. *This engineering curriculum meets Next Generation Science Standards (NGSS).*

Engineering Connection

Biomedical engineers conducting cancer research have shifted their attention toward tumor classification since finding characteristics common to all types of malignant breast cancer increases the validity in cancer diagnosis. One characteristic that distinguishes breast cysts from cancerous tumors is a dense fibrous area surrounding the lesion. This occurs as the body attempts to ward off the malignant tumor. Benign tumors are found to be much softer. On a very basic level, in this activity, students apply this concept to Young's modulus of elasticity. In generating the strain graph, the malignant region is depicted with a much higher modulus of elasticity indicating a stiffer region with less deformation. This understanding is applied in the generation of the strain graph as well as the brochures generated as part of the associated lesson's assessment.

Pre-Req Knowledge

A complete understanding of Hooke's law, stress, strain and the associated relationships.

Learning Objectives

After this activity, students should be able to:

- Model a tumor in normal tissue using a stress strain relationship.
- Depict a tumor using a graph in excel.
- Describe the advantages and disadvantages of this imaging technique.
- Explain how breaking down the problem can lead to an achievable solution.

Materials List

Each student needs a copy of the attached handout (doc).

Introduction/Motivation

Today we will finally complete our unit and it will be your task to create an image depicting a tumor amidst healthy breast tissue. You will each receive a handout with an image which, after making the appropriate calculations, should be depicted in a graph generated in Microsoft Excel®. Please read the instructions on your assignment and ask any me any questions you may have. Today's assignment is worth 50 points, like your brochure. Together the two assignments are worth 100 points, equal to a test grade. Not to worry though! You all are more than prepared to create your challenge solution. Please clear everything from your desks and remember this is an individual assessment so please only look at your computer screen.

Vocabulary/Definitions

cancer: A malignant and invasive growth or tumor tending to recur after removal and to metastasize to other sites.

force: An influence on a body or system, producing a change in movement or in shape or other effects.

spring: An elastic body such as a wire of steel coiled spirally that recovers its shape after being compressed, bent, or stretched.

strain: Deformation of a body or structure as a result of an applied force beyond limit.

stress: The physical pressure, pull, or other force exerted on a system by another, producing a strain. Measured by the ratio of force to area.

Procedure

Background

This activity provides students with the first portion of the Go Public phase of the legacy cycle. Students create strain plots without any aids. They are graded on their solutions. This activity tests students on their comprehension of the material presented thus far, which includes the concepts of Hooke's law, stress, strain and biomedical imaging techniques.

With the Students

Hand out tp students the Show Me the Tumor! Handout. Explain that they may not use their notes or any other aids. This is an individual assessment, which along with the take-home portion, will count as a test grade.

Attachments

Show Me the Tumor! Handout (doc)

Show Me the Tumor! Handout (pdf)

Show Me The Tumor Handout Answer (xls)

Investigating Questions

- What fundamental concepts does this method of cancer detection rely upon?
- Is this method reliable?
- Is this method of tumor detection cost effective?
- Is this method reasonable for clinical use?
- Are there any other methods to detect tumors in tissue? If so compare to the method used in this activity.

Assessment

Activity Embedded Assessment: Grade on the accuracy of their graphs as well as their supporting calculations.

References

Dictionary.com. Lexico Publishing Group,LLC. Accessed December 28, 2008. (Source of vocabulary definitions, with some adaptation)

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