PLTW Science Frameworks

PLTW Course: Principles of Engineering

Science Strand being addressed: The Nature of Science and Engineering
Science Sub-strand being addressed: Interactions Among Science, Technology, Engineering, Mathematics, and Society

Science Standard being addressed: 9.1.3.4

Overview:

Science Standard and Benchmarks: 9.1.3.4.3, 9.1.3.4.4

Standard 9.1.3.4: Science, technology, engineering and mathematics rely on each other to enhance knowledge and understanding.

Benchmark 9.1.3.4.3: Select and use appropriate numeric, symbolic, pictorial, or graphical representation to communicate scientific ideas, procedures and experimental results.

Benchmark 9.1.2.4.4: Relate the reliability of data to consistency of results, identify sources of error, and suggest ways to improve data collection and analysis.

For example: Use statistical analysis or error analysis to make judgments about the validity of results.

Correlation to AAAS Atlas:
MN 9.1
11B/H1a, 11B/H2

National Science Education Standards
Unifying Concepts and Processes Standard K-12:

As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change and measurement
- Evolution and equilibrium
- Form and function

Science As Inquiry Standard B:
As a result of activities in grades 9-12, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Essential Understandings/Big Ideas:

Scientists, Engineers and Mathematicians must use appropriate systems to relate information so it can be understood and verified. The use of an appropriate numeric, symbolic, pictorial or graphical representation in communicating ideas, procedures and results is necessary for others to understand, recreate and verify results. Material testing will be used as an example of process used that demonstrates benchmark 9.1.3.4.3 and 9.1.2.4.4

Material Testing is a critical process that determines whether a product is reliable, safe and predictable in function. Material testing is basically divided into two major categories: destructive testing and nondestructive testing. Destructive testing is defined as a process where a material is subjected to a load in a manner that will ultimately cause the material to fail. Machines have been developed specifically to conduct destructive testing. These machines exert force on the sample and record information such as resulting deformation, the amount of stress that builds up inside the sample, elastic behavior, strength, etc. When non-destructive testing is performed on a material, the part is not permanently affected by the test. The part is usually still serviceable. The purpose of non-destructive testing is to determine whether the material contains imperfections.

Over many years, tests have been developed for measuring the common properties of engineering materials, including acoustical, electrical, magnetic, physical, optical, and thermal properties.

What should students know and be able to do [at a mastery level] related to these benchmarks?

- Utilize a five-step technique to solve word problems.
- Obtain measurements of material samples.
- Tensile test a material test sample and express the results in numeric, symbolic and graphical representation.
- Express results in numeric, symbolic and/or graphical representation
- Identify and calculate test sample material properties using a stress strain curve.

Misconceptions:

Student Misconceptions

- Students often believe it is not important to show their work. It is difficult to assist students in determining where mistakes are made without seeing all the steps taken.

- Students must be persuaded to show work in all calculations and label answers with proper units.
- Students will want to get a "right answer".
- In this exercise the main purpose is to demonstrate how a destructive test is performed while attempting to collect data.
- The focus should be on correctly performing the experiment and gathering good data that will usable to determine a number of attributes about the material.

Teacher Resources:

Teacher Notes

In this unit students will explore and gain an understanding of:

- Forces acting on a body in static equilibrium
- Calculating internal and external forces of a system
- Basic categories and properties of materials
- Material testing
- Design problems related to materials and structures

The instructor should practice material testing procedures. It is important that the materials are tested in the same way to give students similar results to one another as well as to established standards.

The instructor should provide a graph of the data in digital form so students can import into their own document and manipulate. The graph is used for all calculations and thus important to be of an adequate size to be read and understood.

In a student's attempt to get any answer they often overlook what would seem obvious to the instructor therefore the instructor should perform a practice destructive test using some other material than brass or aluminum. Students should perform calculations with the instructor to understand the process and how to use the graphical data to make calculations.

New Vocabulary

Axial Stress	A force with its resultant passing through the centroid of a particular section and being perpendicular to the plane of the section. A force in a direction parallel to the long axis of the structure.
Breaking Stress	The stress required to fracture a material by compression, tension or shear.
Compression	When a material is reduced in volume by the application of pressure; the reciprocal of the bulk modulus.

Deformation	Any alteration of shape or dimensions of a body caused by stresses, thermal expansion or contraction, chemical or metallurgical transformations, or shrinkage and expansions due to moisture change.
Destructive Testing	Test methods used to examine an object, material or system causing permanent damage to its usefulness.
Elastic Limit	Maximum stress that a material will withstand without permanent deformation.
Elongation	The fractional increase in a material's length due to stress in tension or thermal expansion.
Factor of Safety	The ratio of actual strength to required strength.
Failure Point	Condition caused by collapse, break, or bending, so that a structure or structural element can no longer fulfill its purpose.
Fatigue	The loss of the load-bearing ability of a material under repeated load application, as opposed to a single load.
Hooke's Law	The law stating that the stress of a solid is directly proportional to the strain applied to it.
Modulus of Elasticity	The ratio of the increment of some specified form of stress to the increment of some specified form of strain, such as Young's modulus, the bulk modulus, or the shear modulus. Also known as coefficient of elasticity, elasticity modulus, elastic modulus.
Nondestructive Testing	Test methods used to examine an object, material, or system without impairing its' future usefulness.
Proportional Limit	Point at which the deformation is no longer directly proportional to the applied force. Hooke's Law no longer applies.

Reliability	The probability that a component part, equipment, or system will satisfactorily perform its' intended function under given circumstances, such as environmental conditions, limitations as to operating time, and frequency and thoroughness of maintenance for a specified period of time.
Resilience	A mechanical property of a material that shows how effective the material is absorbing mechanical energy without sustaining any permanent damage.
Rupture Strength	Nominal stress developed in a material at rupture. Not necessarily equal to ultimate strength. Since necking is not taken into account in determining rupture strength, seldom indicates true stress at rupture.
Shear Stress	A measure of how easily a material can be twisted.
Strain	Change in the length of an object in some direction per unit.
Stress	The force acting across a unit area in a solid material resisting the separation, compacting or sliding that tends to be induced by external forces.
Stress-Strain Curve	Graphical representation of a material's mechanical properties.
Tension	The condition of a string, wire or rod that is stretched between two points.
Toughness	Mechanical property of a material that indicates the ability of the material to handle overloading before it fractures.
Ultimate Stress	Sometimes referred to as tensile strength; determined by measuring the maximum load a material specimen can carry when in the shape of a rectangular bar or cylindrical can.
Variance	The average of the squared differences from the mean.

Vignette:

- **Activity 2.3.2 Tensile Testing.** The teacher will demonstrate how to test a "dogbone" of aluminum material and a second of brass. All of the proper software settings will be demonstrated and students will take notes for reference during the activity. The instructor will also demonstrate safety procedures in using the testing apparatus.
- Several measurements of the original "dogbone" must be made prior to its testing including the original length of the narrow region (L0), the diameter of the narrow region (D0) and calculate the area of the narrow region (A0).

  Students may ask, "Does it matter if we measure the actual one we test, or can we just measure any one of the "dogbones" in the container?"

  The instructor should respond, "In order to have reliable results that are consistent from the data of one experimenter to another we must minimize sources of error. Measuring one item but testing another completely different item will give us inaccurate results, and may prove a problem later when trying to verify the attained results. In other words, if you forget to take measurements before you destroy your sample, your results will inaccurate. You must measure your dogbone before you test it."

- After the successful destructive test of aluminum a stress/strain graph will be produced from the results. The instructor will make the data available to all students for their own calculations on either computer or by hand.
- The instructor should demonstrate where on the graph the information can be found, how to calculate using the appropriate formulas and what the implication from the results are.
- The instructor will demonstrate how to calculate the test samples total Strain/Deformation – The total amount of elongation of a sample to rupture normalized (divided) by the initial length. The formula **etotal = dtotal/L0** will be used where dtotal is the total elongation, taken from the stress/strain graph divided by the length of the original narrow section of the "dogbone."
- Calculate the test samples reduction in area using the formula **Reduction in area = (A original – A final)/A original*100**

- The instructor will demonstrate on the graph where the following points are found:

  - Proportional limit stress
  - Yield Point stress

    - Ultimate/Tensile stress
    - Breaking/Rupture Point stress.
- Each of the stress points use the formula s = P/A.
- The instructor should go through each calculation with the students to verify their understanding.

  Students may ask,” Isn’t ultimate/Tensile stress, and Breaking/Rupture Point stress the same?”

  The instructor may respond, “That is a good question and looking at the graph will help answer that. The maximum amount of stress a sample can hold is at the very peak of the graph. As we continue following the stress/strain curve on the graph you will see that the material continues to elongate, but the amount of stress (what the sample can hold) is decreasing. The material is actually stretching in the narrow region and getting weaker. The breaking point is actually less than the ultimate stress.”

  (Here is also where the connection between the standard and this activity occurs. A graphical representation is used to communicate the results of an experiment.)

- Students will fill in Activity 2.3.2 Tensile Testing with classroom demo data. Students can then use demo data as a guide in calculating their own data.

Additional Instructional Resources

The Physics Classroom,
http://www.physicsclassroom.com/morehelp/graphpra/graphs.cfm.

Principles of Engineering, 1st Edition, Brett Handley - Wheatfield-Chili Middle School/High School, New York, Craig Coon, David M. Marshal, SBN-10: 1435428366 ISBN13: 9781435428362.

Assessment:

Assessment Methods

Explanation

* Students will explain the importance of material testing as a verification process.

Application

- Students will tensile test a material sample and identify and calculate material properties.

Interpretation

- Students will write journal entries reflecting on their learning and experiences.
- An example writing prompt: What is something you learned today about material testing, manufacturing processes, or engineering problem solving that you did not understand or know before?

Self-Knowledge

- Students will reflect on their work by recording their thoughts and ideas in journals.
- They may use self-assessments as a basis for improvement.

Ideas and questions students may pose and respond to in their journals are:

- Today the hardest concept for me to understand was . . .
- When I work in a group, I find that . . .
- When I work by myself, I find that . . .
- What did I accomplish today?
- Now that I have completed this task, what is next?

Differentiation:

Gifted and Talented

Students who understand the concepts can be supplied with a stress-strain curve graph from which they can calculate axial stress, shear stress, total deformation, normal strain, modulus of elasticity and modulus of toughness. Students would use their results to try and determine what the material is composed of.

Special Education

For students on an IEP; all PowerPoints, reading materials and activity sheets can be made available on a school-sponsored, secure web site. Teachers using interactive whiteboards and other enhancements could make lessons available on a website. Students could review work outside of class time to reinforce their understanding.

The text, Principles of Engineering, by Handley, Coon, Marshall could be purchased for use by students both in and out of class as a resource.

As the topic area can be difficult for some learners, the teacher should have examples of previous student work for learners to gather ideas from. The teacher should demonstrate procedures for each activity using a previous student project for better understanding.

English Language Learners

Vocabulary should be an integral part of the unit. The instructor can use several different strategies to introduce terminology such as a word of the day with weekly and unit quizzes to reinforce learning.

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are:	Teachers Are:
Taking notes and completing practice tensile tests calculations	Demonstrating the safe and effective use of tensile testing equipment
Using a lathe to make "dogbones"	Demonstrating and supervising the use of lathes
Testing their "dogbones" with the structural stress analyzer	Providing students the digital data from the SSA to use in performing calculations.
Analyzing data and performing calculations from the graphical information	Assisting students in performing data interpretation and calculations
Comparing data and calculations with "knowns"	Analyzing student work

Professional Learning Communities

Reflection: Critical Questions regarding the teaching and learning of these benchmarks

1. Why is it critical for engineers to document all calculation steps when solving problems?
2. How is material testing data useful?
3. Stress strain curve date points are useful in determining what specific material properties?

Principles of Engineering, 1st Edition, Brett Handley - Wheatfield-Chili Middle School/High School, New York, Craig Coon, David M. Marshal, SBN10: 1435428366, ISBN 13: 9781435428362.

Parent Resources:

Tensile Testing, Wikipedia, http://en.wikipedia.org/wiki/Tensile Testing.Tensile Properties, NDT Education Resource Center, Brian Larson, Editor, 2001-2011.

The Collaboration for NDT Education, Iowa State University, http://www.ndt-ed.org/EducationResources/CommunityCollege/Materials/Mechanical/Tensile.htm..

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