An Interactive Computer Tutorial for Strength of Materials

George H. Staab
Associate Professor
Aerospace Engineering, Applied Mechanics, and Aviation
The Ohio State University
155 W. Woodruff Ave.
Columbus, Ohio 43210

Fundamental mechanics concepts of statics, dynamics and strength of materials are central to the professional development of most engineering disciplines. The concepts taught in introductory mechanics courses are often difficult for students to visualize and fully grasp. Using interactive software, students are able to reinforce lecture and text topics in a self-paced manner. Software packaged with many texts has evolved to a level where sophisticated simulations of complex mechanisms can be used to illustrate motion and provide real time values for position, velocity, and acceleration of moving components. Although beneficial to those familiar with the topic, this type of presentation can be frustrating for someone attempting to learn the fundamental concepts of the subject. In the opinion of the author, software for introductory mechanics concepts should focus on illustrating theory, presenting relevant examples, and supply quizzes for users to work, while developing problem solving skills. Combining theory, examples, and quizzes allows students a wide range of options which can be used to repeatedly reinforce lecture and text topics. Exploration based education is beneficial if the explorer has a basic idea of what to look for and where it is located. Many students first encountering mechanics have problems identifying what is wanted, how to decompose the problem into simpler segments, and what information they need to solve the problem. For these students, a directed learning procedure similar to that presented as examples in most mechanics texts is an appropriate procedure. Software using an exploration based shell supported by a directed education base can benefit both the self-confident and unsure beginning student.

Establishing confidence and competence with a topic is sometimes complicated by missed or incomplete information obtained either from a text or lecture. The feeling of being judged by those teaching the material fuels the frustration common in students first encountering a mechanics topic. A computer is non judgmental, repeats information as often as requested, and is less intimidating than a teacher when a student is first learning a topic. Screen sizes are limited and the amount of text, figures, and equations contained on each screen is small compared to that of a book. Students who have difficulty assimilating text material are likely to spend more time interacting with a computer program where information can be repeatedly presented in smaller segments. This provides an easier, more relaxed environment when attempting to master a concept. While interacting with a computer, a student can gain knowledge and confidence without fear of judgment. Using interactive computer software, a student can review missed or confusing material, explore examples, and work quizzes as often as needed to master a topic.

A software package is currently being developed for strength of materials using Authorwarwe Professional (a Macromedia product). The package contains four primary modules representing major topical areas. Within each primary module are a series of related topics, as delineated in Table 1. The related topics contain sub-topics which include theoretical developments and examples. A series of quizzes accompanies each related topic. Quizzes are generally structured according to sub-topics within the related topics. There are generally eight quizzes from which to select. Examples and quizzes prepared for the package use randomly generated dimensions and forces so numerical answers are different with each use.

Table 1 Strength of materials modules and related topics

Primary Module	Related Topics
Stress, Strain, and Displacement	Concepts of Stress General Stresses Axial Stress and Strain
Load-Stress Relationships	Torsion Pure Bending Transverse Loading Stress Analysis
Transformations of Stress and Strain	Plane Stress Plane Strain Stress-Strain Analysis

	Beam Analysis
Beams and Columns	Beam Deflections
	Energy Methods
	Columns

Users can selectively navigate to a topic, explore sub-topics, work quizzes (with solutions checked by the computer), or simply view the solution. Depending on the structure of the package, students can reinforce concepts through directed exploration in which a general problem is defined with various aspects of the solution investigated at the users discretion.

Presentations can be structured so that each step in the solution procedure can either be viewed or skipped. For example, the Load-Stress Relations module contains pure bending as a related topic. Within the pure bending topic is the sub-topic of eccentric loading. An option of this sub-topic is an example. Figure 1 represents an initial screen for the example of eccentric loading. The user has the option of selecting from three different eccentric loads, each producing a different result. In addition, the user can reinforce their understanding of area moments of inertia by clicking on the cross section showing dimensions. If this option is exercised, the computation of I with respect to both axis is presented. After demonstrating how to determine I, the user is returned to the screen shown in Figure 1, at which time they can select the loading condition of interest to them.
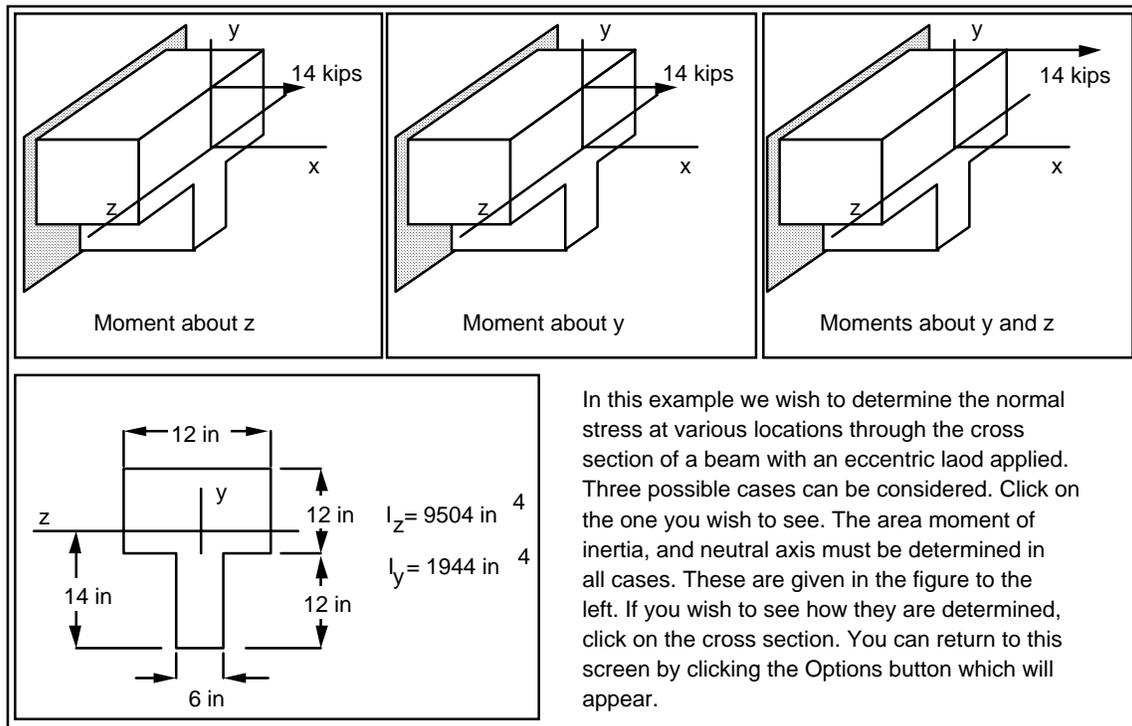
In this example we wish to determine the normal stress at various locations through the cross section of a beam with an eccentric laod applied. Three possible cases can be considered. Click on the one you wish to see. The area moment of inertia, and neutral axis must be determined in all cases. These are given in the figure to the left. If you wish to see how they are determined, click on the cross section. You can return to this screen by clicking the Options button which will appear.

Figure 1 Introduction screen for an example of eccentric loading

Assume the user selects the option of exploring moments about the y and z axes. The next screen demonstrates the computation of moments and shows a section of the beam with all applied loads and moments along with points (represented as material elements) which the user can randomly select for evaluation. In addition, an equation showing the normal stress as a function of y and z is given. If the user selects, for example, point H, an element representing that point is displayed along with the computation of the stress, as illustrated in Figure 2. All points identified on the section can be accessed with similar computations and elements presented for each. In addition, the user may select the Stress Distribution option, which provides a tabulated summary of the computations for defining the normal stress at each point, and a visual display of the stress distribution through the cross section. The user is directed through the example by having the basic framework (geometry, dimensions, loads, etc.) defined for them, while being afforded the opportunity to explore different aspects of an extended problem.

$I_y = 1944\ \text{in}^4 \qquad I_z = 9504\ \text{in}^4$

$A = 216\ \text{in}^2$

84 kip-in

140 kip-in

A B C

D E F G

8 in   3 in   14 kip

H I

J K

The eccentric 14 kip load produces the bending moments shown. The normal stress at any point in the cross section is given by

$$\sigma_x = -\frac{P}{A} + \frac{M_z y}{I_z} - \frac{M_y z}{I_y}$$

$$= \frac{14\ \text{kip}}{216\ \text{in}^2} + \frac{(140\ \text{kip} - \text{in})y}{9504\ \text{in}^4} - \frac{(84\ \text{kip} - \text{in})z}{1944\ \text{in}^4}$$

The normal stress on nine elements can be examined. Click the element (A, B, C, etc.) on the cross section for which you wish to see the stress computation. Click the Stress Distribution button to see the stress distribution over the entire cross section.

Stress Distribution

182.66 psi

182.66 psi

Element H

The coordinates of point H are y = -8 in and z = 3 in

$$\sigma_x = \frac{14\ \text{kip}}{216\ \text{in}^2} + \frac{(140\ \text{kip} - \text{in})(-8\ \text{in})}{9504\ \text{in}^4}$$

$$- \frac{(84\ \text{kip} - \text{in})(3\ \text{in})}{1944\ \text{in}^4} = 64.81 - 117.85 - 129.63$$

$$\sigma_x = -182.66\ \text{psi}$$

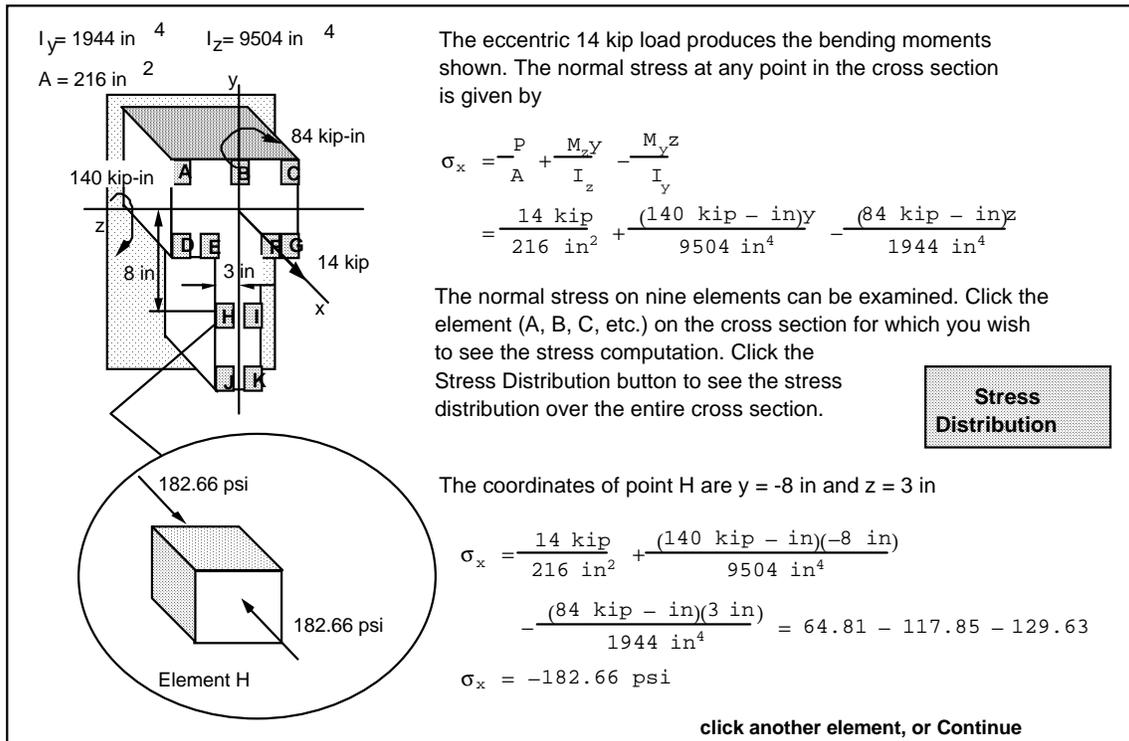**click another element, or Continue**

Figure 2 Computation of stresses at point *H*

Exploration is only one of the many options which a developer can use to demonstrate and reinforce concepts. An effective measure of a students depth of understanding is their ability to identify a state of stress given only a loaded structure. For example, Figure 3 illustrates a screen in which the user is asked to identify the state of stress at a point in a component, given the loads and dimensions. With each incorrect selection a comment such as "... will a force in the direction shown result is a shear stress?" appears on the screen.

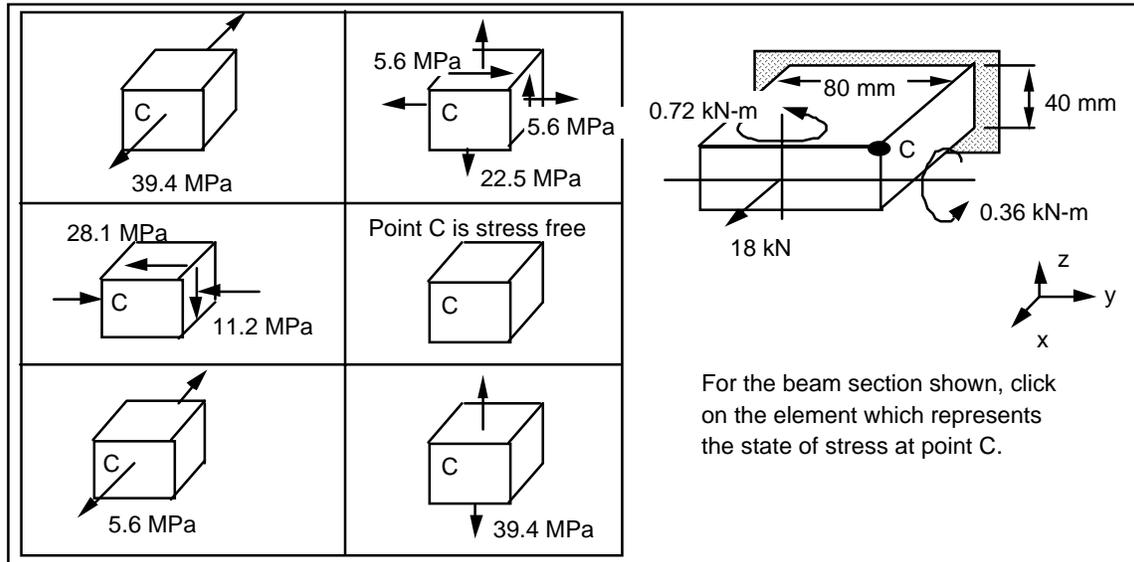When a correct answer is selected, a computation of the state of stress is presented.

Figure 3 Screen for identification of a state of stress

Students enrolled in one of two appropriate mechanics courses at The Ohio State University have access to the software. The software is available at a computing region in the college of engineering. Students are not allowed to copy the program (currently 7.5 MB) since it is still in the developmental phase. Students are informed of the existence of the program, its location, and accessibility by their professors. Although no records of usage are kept, there are students who use the program, but in a limited manner. Student comments regarding the location and accessibility of the program have been forwarded to the author and range from "I didn't know there was such a program" to "I don't have time to use it", or " its not convenient for me to go to the lab". If the program were available for students to use at home, one assumes it would have greater appeal. As its availability is currently structured, the effectiveness of the package as a teaching aid can only be measured through user comments received by the author. Some users claim that they derive no benefit from the program, which is expected from more talented students. At the other end of the comment spectrum, one user claimed that he relied entirely on the software and would have sold the text if their class didn't have homework assigned from it, and if the program were completed. There is mixed appeal for such a program, but generally speaking, those who have used it find it helpful.

Based on student feedback it is obvious that a broad educational strategy needs to be developed for defining topics and presentation styles for educational software. Some students benefit from the current program, which is structured according to observations made by the author regarding topics considered traditionally difficult for students, and a personal opinion as to how the problem can be corrected. Learning styles play a major role in student success with the use of software. To effectively impact a wider range of students, diverse presentation styles should be used. One of these styles should be that of the instructor who has observed the problems and formulated strategies regarding their solution. Another style should be developed based on student input, since they are the intended user and are best equipped to identify the problem areas and suggest possible solutions. The traditional methods of presenting mechanics to undergraduates is changing. There are numerous views and opinions as to why the traditional methods must change and how they should change. One obvious change is the growing use of computers for in-class demonstrations, supplements to complex numerical computations on homework and projects, and as a supplement to text books. Traditional texts will continue to be supplemented with computer software. A fundamental question which must be answered is the type of software. Should it be exploration based, directed, or a combination of the two. For undergraduates initially learning the concepts it seem as if a combination of directed and exploration is appropriate. The software described herein represents this type of directed exploration approach. The best test for the effectiveness of such a program is student evaluation coupled with student suggestions, and faculty evaluation of performances.

GEORGE H. STAAB received his Ph.D. from Purdue University in 1979. He is currently an Associate Professor of mechanics in the department of Aerospace Engineering, Applied Mechanics, and Aviation at The Ohio State University. He has recently completed a set of supplemental software packaged with Vector Mechanics for Engineers: Statics and Vector Mechanics for Engineers: Dynamics by Beer and Johnston.

A prelab tutoring system for the Strength of Materials experiment is prototyped from desired outcomes. The tutoring system utilizes a game-like environment to engage students in learning. Consisting of highly interactive contents made by scalable vector graphics (SVGs), the system helps students to get acquainted with laboratory instruments as well as experimental procedures. Industries are tending toward computer-based simulation, monitoring, and control of processes. This trend suggests an opportunity to modernize engineering laboratory pedagogy to include computer experiments as well as tactile experiments. However, few studies report the impact of simulations upon student learning in engineering laboratories. Strength of Materials and Structures Fourth edition JOHN CASE M.A., F.R.Ae.S. Formerly Head strength of material by s.s rattan. 127 Pages·2012·14.24 MB·7,476 Downloads. Designed for a first course in strength of materials, Applied Strength of Materials has long Schaum's Outlines Strength of Materials. 201 Pages·2011·4.12 MB·5,042 Downloads. Using interactive computer software, a student can review missed or confusing material, explore examples, and work quizzes as often as needed to master a topic. A software package is currently being developed for strength of materials using Authorwarwe Professional (a Macromedia product). The package contains four primary modules representing major topical areas. Within each primary module are a series of related topics, as delineated in Table 1. The related topics contain sub-topics which include theoretical developments and examples.