

## WEB-BASED INSTRUCTIONAL UNITS FOR TEACHING MECHANICS

Kamal B. Rojiani<sup>\*</sup>, Rakesh K. Kapania<sup>\*\*</sup>, Yong Y. Kim<sup>\*\*</sup>, and Jing Li<sup>\*\*</sup>

<sup>\*</sup>*Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA 24061, USA*

<sup>\*\*</sup>*Department of Aerospace and Ocean Engineering, Virginia Tech, Blacksburg, VA 24061, USA*

Summary A series of novel web-based instructional units that facilitate the teaching of basic concepts in mechanics have been developed. The instructional units are delivered over the Web as HTML documents containing embedded Java applets. The advantage of providing these instructional units in the form of web documents is that they can be accessed from anywhere. Examples of instructional units developed include Mohr's circle for two- and three-dimensional stress, shear center for open and closed section thin walled tubes, section properties of built-up sections, and shear, moment and deflection analysis of beams. The advantages of using Java applets and the web for teaching are also discussed.

### INTRODUCTION

The World Wide Web is a popular vehicle for publicizing information in text or graphical form. In recent years it has also become a valuable resource for educators. A significant weakness of web pages is that they offer only static access to information. With the advances in technology in the form of the Java programming language the web now offers real opportunities for delivering interactive, dynamic content essential for active learning. Java is an object-oriented programming language with capabilities similar to advanced programming languages. Java is unique in that Java applications can be embedded in web pages (where they are called applets) and can be executed from within the web browser. Java is also platform independent. Thus, web pages containing Java applets can be accessed by anyone with an Internet connection and a Java capable web browser.

### FORMAT OF INSTRUCTIONAL UNITS

Each instructional unit consists of a series of HTML documents which present fundamental concepts and theoretical background, instructions for running the Java applet, example problems, exercises, and a feedback form. Each instructional unit is independent and addresses a single topic. This makes it easy for educators to incorporate the instructional units into existing courses. Instructional units are organized in a format that makes it easy for students to access the applet, learn how to use it, study the theory behind the applet and provide feedback. The first page gives students the option to start the applet, view instructions, or study the theory. The instruction page describes the user interface. The theory page presents the fundamental concepts behind the applet. An examples page provides several example problems for students to solve and compare their answers with those given by the applet. Lastly, there is a survey page which gives students an opportunity to provide feedback for improving the applet and instructional units.

### BRIEF DESCRIPTION OF APPLETS

In this section brief descriptions of some of the applets developed are presented. The reader is encouraged to visit the web site <http://www.engapplets.vt.edu> to access the instructional units and to view detailed descriptions of the applets.

**Mohr's Circle Applet for 2D and 3D Stress:** The Mohr's circle applets for 2D and 3D state of stress assists in the understanding of two of the most important concepts in mechanics - stress and strain. The Mohr's circle applet shown in Figure 1 draws the Mohr's circle for 2D stress analysis. Upon entering the three stress components,  $\sigma_x$ ,  $\sigma_y$ , and  $\tau_{xy}$ , the applet computes the principal stresses,  $\sigma_1$  and  $\sigma_2$ , the maximum shear stress,  $\sigma_{\max}$  and the angle of inclination of the principal planes. The average stress and the radius of the circle are also displayed. This applet is a useful tool in understanding the construction of Mohr's circle and the concepts associated with the use of Mohr's circle since it graphically illustrates the relationships between the various stress components. The Mohr's Circle 3D applet draws Mohr's circles for 3D stress analysis. Input to the applet consists of the six stress components,  $\sigma_x$ ,  $\sigma_y$ ,  $\sigma_z$ ,  $\tau_{xy}$ ,  $\tau_{xz}$ ,  $\tau_{yz}$ . The applet computes the three principal stresses,  $\sigma_1$ ,  $\sigma_2$ , and  $\sigma_3$  and the three maximum stresses,  $\tau_{\max 1}$ ,  $\tau_{\max 2}$ ,  $\tau_{\max 3}$ . The computation procedure involves performing an eigenvalue analysis and solving for the roots of the characteristic polynomial equations. These roots represent the three principal stresses,  $\sigma_1$ ,  $\sigma_2$  and  $\sigma_3$ .

**Section Properties Applet:** An important topic in undergraduate mechanics courses is the computation of section properties of planar areas. These section properties appear frequently in design formulas used in fluid mechanics, solid mechanics and structural design. With the section properties applet (see Figure 2) students can build a section consisting of a combination of various shapes such as polygons, rectangles, ellipses and quarter-ellipses. The applet computes section properties of the built-up section. The properties computed include area, centroid, moments of inertia, and the product of inertia. Principal moments of inertia and the orientation of the principal axes are also computed. A useful feature of the applet is that it lets students experiment with different types of sections and to study the effect of changes in section geometry on the properties of the section.

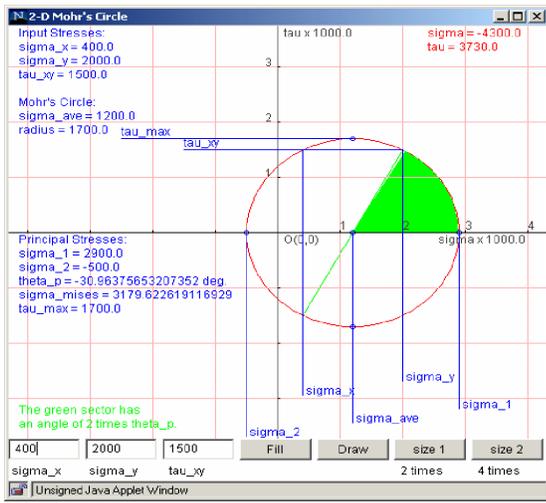


Figure 1. Mohr's Circle Applet for 2D State of Stress.

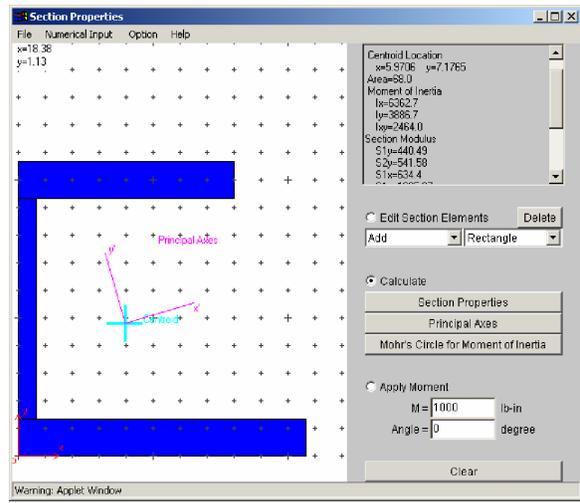


Figure 2. Section Properties Applet.

**Shear Center Applet:** The shear centre applet shown in Figure 3 determines the shear centre of open and closed thin-walled sections having one-axis of symmetry. When entering the geometry of the section in the applet it is only necessary to draw the top half of the symmetric cross-section. The section geometry can also be specified by providing numerical values instead of entering points with the mouse. This applet lets applet students try different cross-sections and obtain a better understanding of the concepts associated in the determination of the shear centre.

**Beam Analysis Applet:** This applet computes the shear, moment and deflection at a number of points along a beam. It also draws the shear, moment and deflection diagrams. The applet is shown in Figure 4. The types of beams that can be analysed include cantilever beams, simply supported beams, propped cantilever beams and beams with both ends fixed. A variety of loads can be applied including uniformly distributed loads, concentrated loads, linearly varying loads, and moments applied at the ends or at intermediate points along the beam. These loads can be applied in any combination. The beam analysis applet allows students to study how the distribution of shear, moment and deflection changes under each load. It also demonstrates graphically the effect of different support conditions and of adding different types of load and thus serves as a very useful tool for studying these concepts without having to perform lengthy and tedious computations by hand.

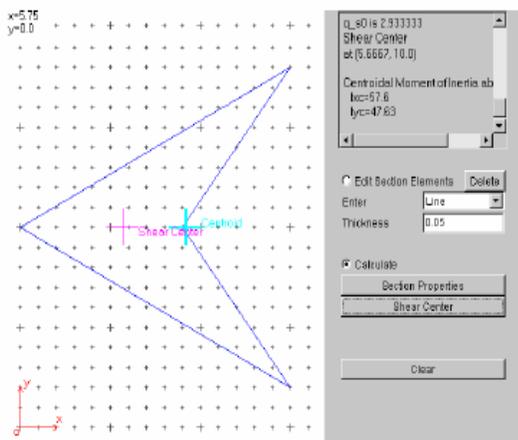


Figure 3. Shear Center Applet.

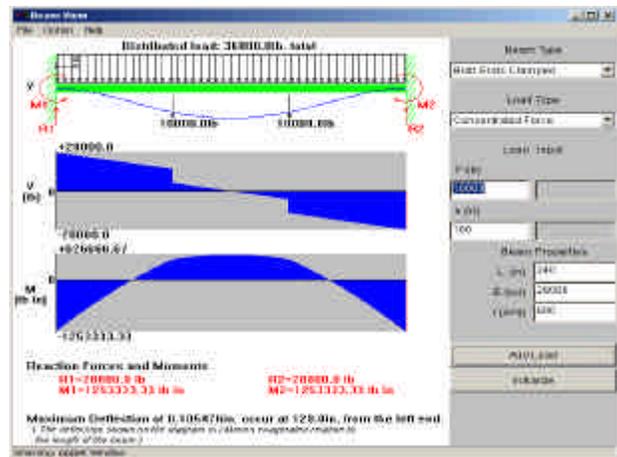


Figure 4. Beam Analysis Applet.

### CONCLUSIONS

Web-based instructional units containing embedded Java applets can provide students with a dynamic interactive learning environment and can significantly increase students' understanding of the subject matter. They also provide many benefits for instructors. Java class files are compact and can be easily distributed over the internet to remote users thereby eliminating many of the difficulties associated with delivering and updating software via other media such as CD-ROM. The latest version of the applet is always available since the files are stored on the server instead of the client machine. Java applets are universally available since they are platform independent. The approach presented in this paper is well suited for educational use especially for topics requiring a dynamic graphical interactive presentation and instant and broad access. It is believed that interactive teaching units delivered via the Web will have a significant impact on enhancing the quality of mechanics education.