

### Learning Statics with Multimedia and Other Tools

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Although we started out to develop a multimedia program for statics, our learning environment has evolved to include physical models, interactive multimedia, traditional pencil-and-paper activities, and cooperative learning. Multimedia is just one of several tools to facilitate learning. Our objective is to create an effective learning environment that helps to "produce learning" (Barr and Tagg, 1995). In this paper we describe some elements of the learning environment and illustrate the use of multimedia learning models in the subject area of trusses.

#### Learning Environment

*I see more clearly than before that the path to motivating students is the joy of creation, exploration, and discovery. I see also that these processes are social in nature and that shared experiences in class and through teamwork projects are vital.* **Shneiderman** (1993)

The principal elements of our learning environment are cooperative and experiential learning. Team work tends to provide students with a variety of benefits which include active involvement, enhanced performance, learning skills, interpersonal skills, and self-esteem, and it creates a learning community (Gardiner, 1996). Moreover, "Team learning is vital because teams, not individuals, are the fundamental learning unit in modern organizations" (Senge, 1990). Experiential learning has its roots in the works of Dewey, Lewin, and Piaget [Kolb, 1984]. It focuses on the central role that experience plays in the learning process, where "concepts are derived and continuously modified by experience. No two thoughts are ever the same, since experience always intervenes" (Kolb, 1984, p. 26). Kolb (1984, p. 21) defines experiential learning as "a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior." This interconnectedness is central to holistic learning (Miller, 1993).

**Cooperative Learning.** Cooperative learning is a structured learning strategy in which small groups of students work toward a common goal (Cooper, et al., 1994). Cooperative learning is an old concept [Ercolano, 1994]. Extensive research, initiated in the late 1800s, has demonstrated significant advantages of cooperative learning over competitive and individualistic learning in various learning characteristics; these include [Johnson et al., 1991]: high-level reasoning; generation of new ideas and solutions; motivation for learning; personal responsibility; and student retention.

Cooperative learning provides structures [Kagan, 1990] to engage students in meaningful activities that can be shared with others [Papert and Harel, 1991]. Meaningful activities include authentic activities that represent future tasks and problems and are rich in learning resources

[Beichner, 1993]. Kagan [1990] encourages teachers to use a range of cooperative structures to student learning.

We have been experimenting with some structures and have found **think-pair-share (TPS)** [Lyman, 1987; Habel, 1996] and variations of pair activities effective in the classroom: Students **think** about a problem individually to organize their thoughts; they form **pairs** to share and discuss their solutions; they **share** and discuss their findings with another pair or a larger group. Another pair activity, specifically designed for problem solving, is called **thinking aloud pair problem solving (TAPPS)** (Lochhead, 1987). Each pair is divided into a problem solver and a listener, each with specific instructions. Their roles are reversed after every problem but not during a problem. Aside from being an effective cooperative learning tool, **TAPPS** facilitates the development of communication, listening, and team learning skills. If a team struggles, try **TAPPS**. The students' active involvement is essential in developing problem solving skills (Woods, et al., 1997).

**Experiential Learning.** "Learning is a process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). The two fundamental activities of learning are grasping and transforming experience (Fig. 1).

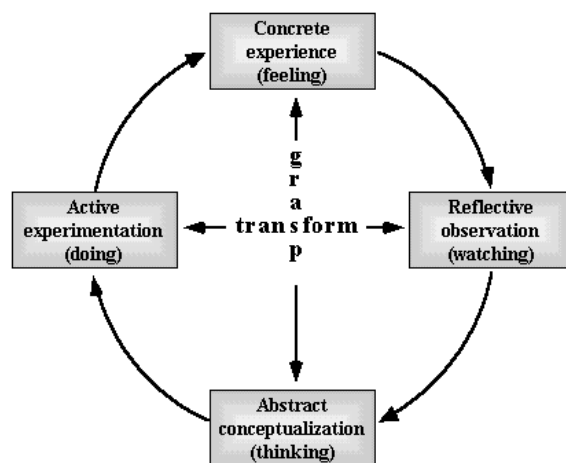


Figure 1. Experiential Learning Model (Kolb, 1984, p. 42)

There are two opposite modes of grasping, directly through the senses (concrete experience) or indirectly in symbolic form (abstract conceptualization). Similarly there are two distinct ways of transforming experience, by reflection or action. The complete process is a four-stage cycle (Fig. 1) of four adaptive learning modes. The active involvement of students through all four learning modes helps develop higher-order skills (Kolb, 1984; Wankat and Oreovicz, 1993). A detailed description of these learning modes (type of learners) with suggestions for writing activities, "a means to think and learn," is presented by Sharp, et al. (1997).

**Computer Lab.** Our class meets in a computer lab where two students share one computer. A session is generally divided into three parts: (1) we start with short group activities, a warm-up

problem, to focus on problems or questions that surfaced in homework, weekly quizzes, or minute papers; (2) this is followed by mini-lectures (10-15 minutes long) interspersed with cooperative activities; (3) at the end of a session, students are asked to reflect and answer questions about the day's lesson and activities in minute papers (Cross, 1991). Light (1991, p. 36) states: "This extraordinarily simple idea [the one-minute paper] is catching on throughout Harvard. Some experienced professors comment that it is the best example of high payoff for a tiny investment they have ever seen." It provides real-time feedback of student learning and problems and the opportunity to make incremental improvements in the learning environment.

## Trusses

We start learning about trusses by exploring images of existing truss structures (Fig. 2). The objective is to identify their common characteristics (Fig. 3)<sup>1</sup>. Next we discuss the transformation of a truss into a model (Fig. 4) to predict the behavior of the truss in its actual environment, the function of analysis.

The analysis of trusses (Fig. 5) is divided into **member forces**, to develop the concepts of two- and three-force members; **methods of analysis**, their development (inductive) and summary (deductive); and **problems** for analysis. Here we illustrate some learning modules from member forces.

**Member Forces.** We use the 3-step analysis process (Free-Body Diagrams (FBD), Equilibrium, Final FBD) to guide teams of students in the development of two- and three-force members. A summary of the results facilitates a quick review of the properties of two- and three-force members (Fig. 6).

Students draw the FBD of the straight member on paper and compare it with the representation on screen (Fig. 7); the question about the assumed sense of a force encourages reflection. They are asked to enter values of reactions (Fig. 8): The first incorrect value provides a clue ( $\Sigma M_a = 0$ ), the second (e.g.,  $B_x = 4$ ) results in the solution (see **Note** in Fig. 8). These interactive activities are continued and lead to the property of two-force members (Figs. 9 and 10).

A similar guided, inductive approach is used to develop properties of curved members (Fig. 11) and three-force members (Fig. 12). If the member load is moved to joint b, the three-force member (Fig. 13) becomes a two-force member. Investigating straight and curved, two-force and three-force members in context reveals what they have in common and how they differ. It provides connections that facilitate the construction of knowledge. "In order to understand what something is, one must also understand what it is not." (Arons, 1990, p.92)

## Learning Environment and Student Reactions

Experiential learning (Kolb, 1984) provides the framework for our learning environment, and it guides the design of the multimedia program. Cooperative learning is our engine to achieve the learning objectives, which include mastery of statics in the solution of engineering problems,

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<sup>1</sup> We want to expand our library of trusses and include Quick Time<sup>TM</sup> movies of engineering processes including conception, design, and construction. Please contact us if you have any material to share ([Holzer@vt.edu](mailto:Holzer@vt.edu)).

improvement in teamwork, communication, and learning skills, and development of a positive attitude.

The multimedia program provides the learning content and activities to engage students through fundamental learning modes (Kolb, 1984). The multimedia program is used in various ways: (1) to present mini-lectures; (2) to guide student teams in the development of concepts, the solution of problems, and discussions; (3) to provide connections to the students' background and engineering structures; (4) to integrate traditional pencil-and-paper activities; and (5) to preview and review lessons (each student should have a personal copy of the program; not all students did).

The most challenging part in this active learning environment is to achieve a good balance among the various activities, to make sure that the students are in phase and some are not lost, and to know when and how to shift smoothly from one activity to another.

The following student responses to a questionnaire provide a window to their views:

*I did download the program to my PC and it was very helpful to use at home.*

*...the inductive examples [in the multimedia program] were extremely helpful to visualize the problem. However the answers to the problem were too accessible. The students (as a general rule) therefore did not really work through them.*

*I used it [the multimedia program] a lot out of class and found it very helpful.*

*...the visual aids [in the multimedia program] helped with concepts.*

*I found it [the multimedia program] somewhat helpful—but most of what I learned was from...lectures.*

*It [the multimedia program] gave you the opportunity to look ahead and go back. This I feel is helpful in the learning process.*

*It [the multimedia program] was time consuming to use, and the ideas were easier explained on the chalkboard.*

*Yes [the multimedia program facilitated learning]. Because with a computer you are able to read about concepts, see realistic examples of their application, and work out problems all during class. You can get the whole picture while interacting with the computer, the professor, and class mates all at once. Everything is there—you can't tell yourself "I don't understand—I'll read it in the book later." If you do need to spend extra time with the computer, the problems look the same as they did in class—no confusion.*

*I didn't use the computer outside of class, and I found the computer not very helpful in understanding concepts in class. I prefer to study handouts, homework, etc...*

*Yes [the multimedia program] helped me a lot. It was really good to see examples and how they worked.*

*I did have a copy in my home and I did review the sessions and it helped with learning.*

*Yes [the multimedia program facilitated learning]. It is an excellent connection between ones mind and the material at hand.*

*Yes [the multimedia program facilitated learning]. It worked very well in class time and with a partner.*

*[The multimedia program] was helpful in the classroom, but it would have been even more helpful to have a copy at home.*

*I would have used it much more if I had a personal copy at home.*

*Yes [the multimedia program facilitated learning]. The examples illustrated concepts sometimes better than an oral discussion could.*

*Yes, the [multimedia program] did facilitate learning by providing an interactive learning procedure where principles were developed and expanded upon active involvement with concrete and abstract example problems.*

*Forget the computer.*

*His system with the computer, "think-pair-share" learning teams, and in-class problem solving is the most effective way to learn such subject matter that I have encountered in 16 years of schooling.*

## **Acknowledgment**

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## Biographical Information

Siegfried M. Holzer, Alumni Distinguished Professor of Civil Engineering, is involved in developing effective learning communities.

Raul H. Andruet, an engineering graduate student, has been developing multimedia software for five years. He is completing his dissertation on "2-D and 3-D special finite elements for analysis of adhesively bonded joints."

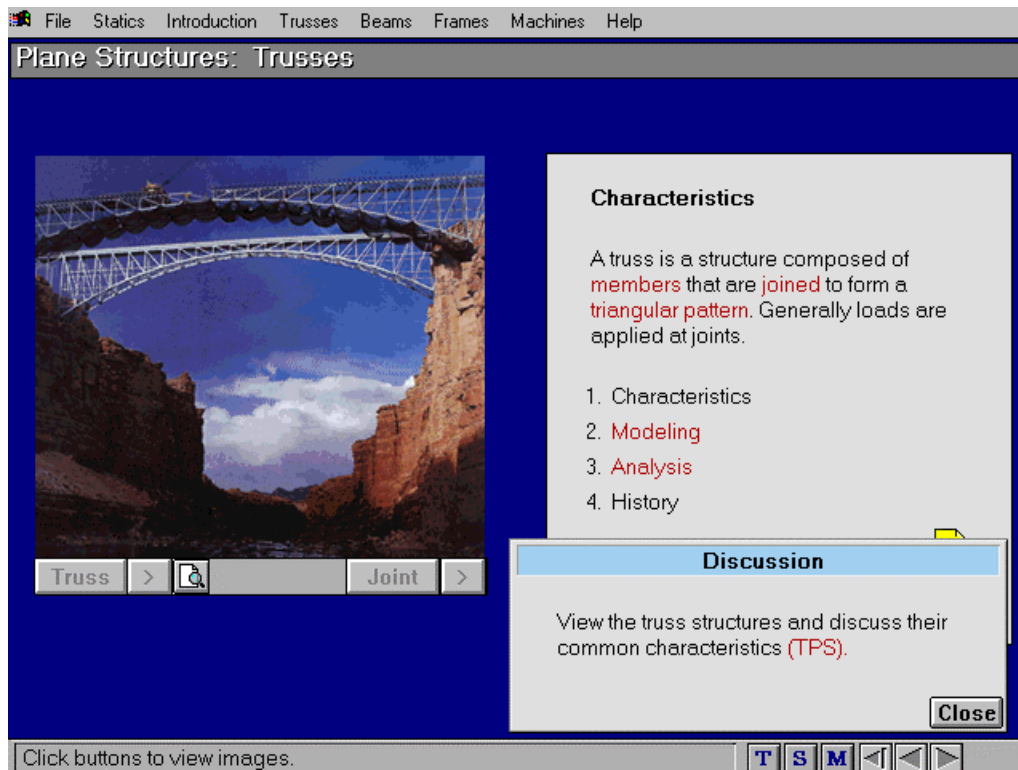


Figure 2. Characteristics of Trusses

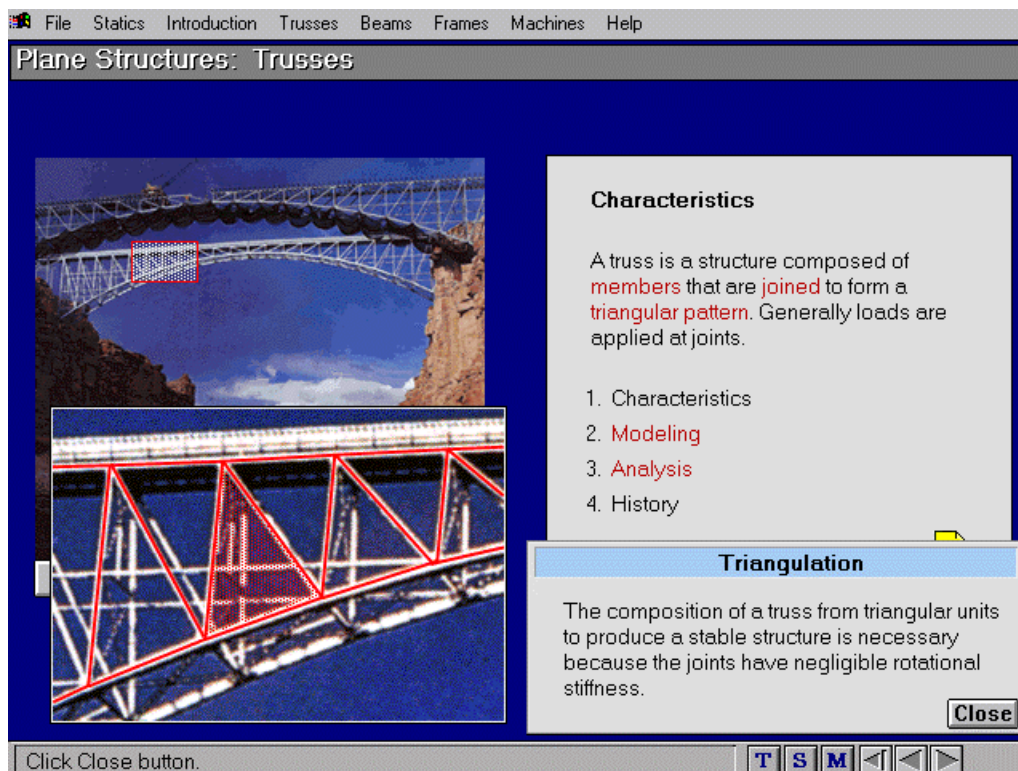


Figure 3. Triangulation of Trusses

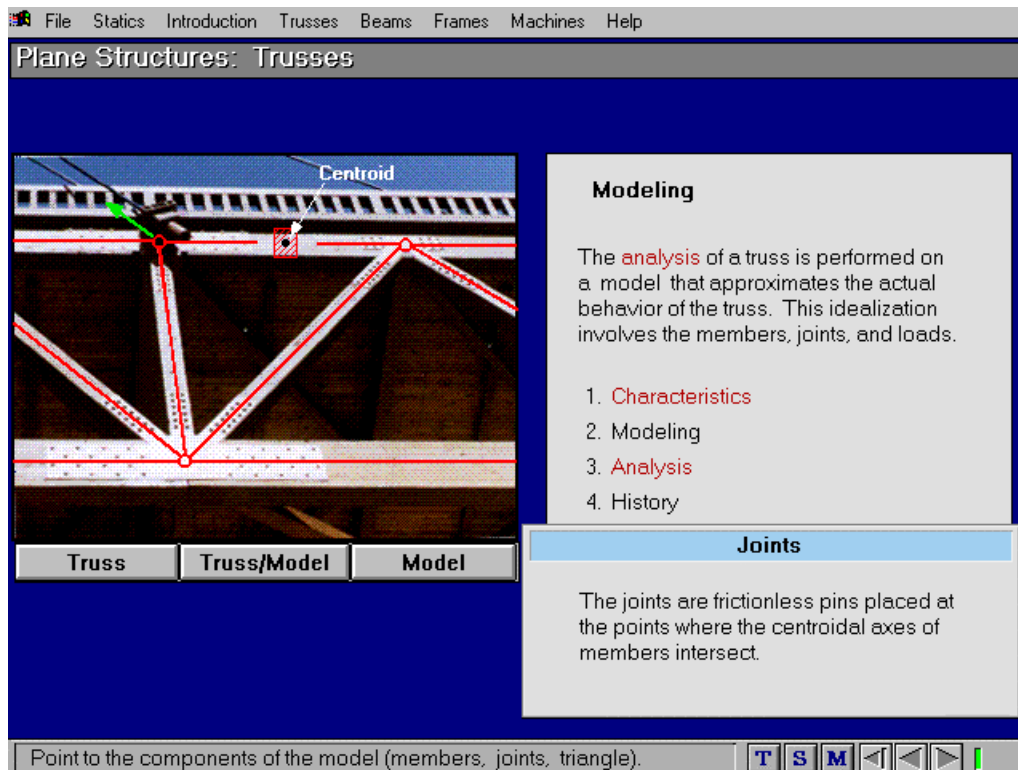


Figure 4. Modeling of Trusses

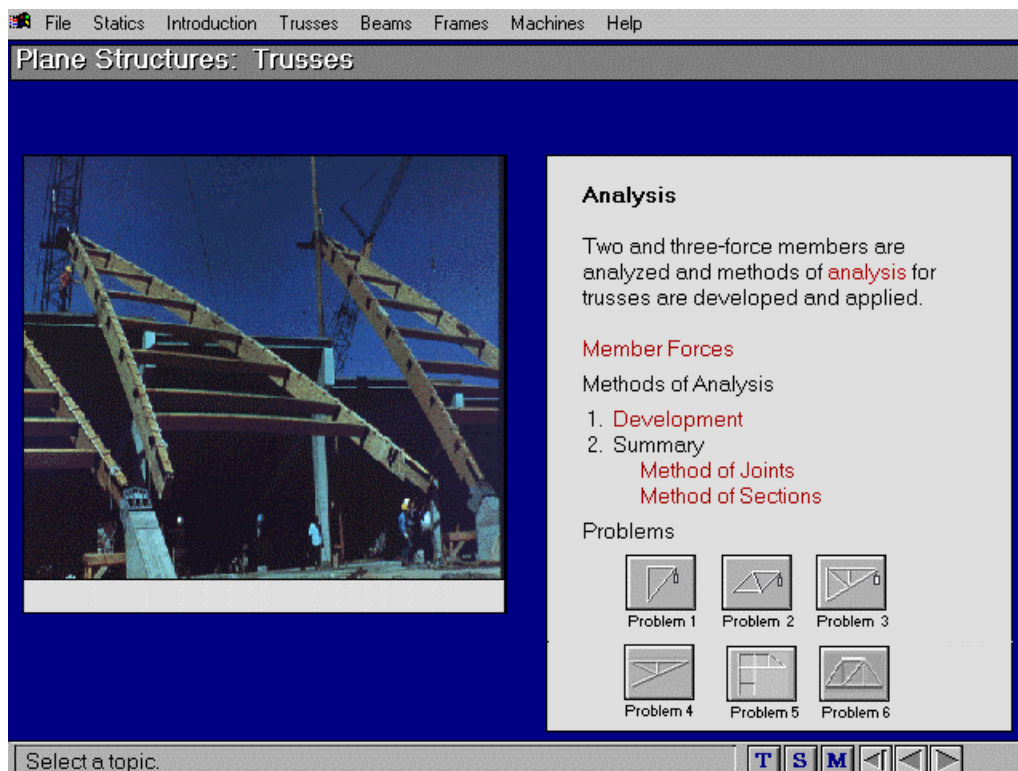


Figure 5. Analysis of Trusses



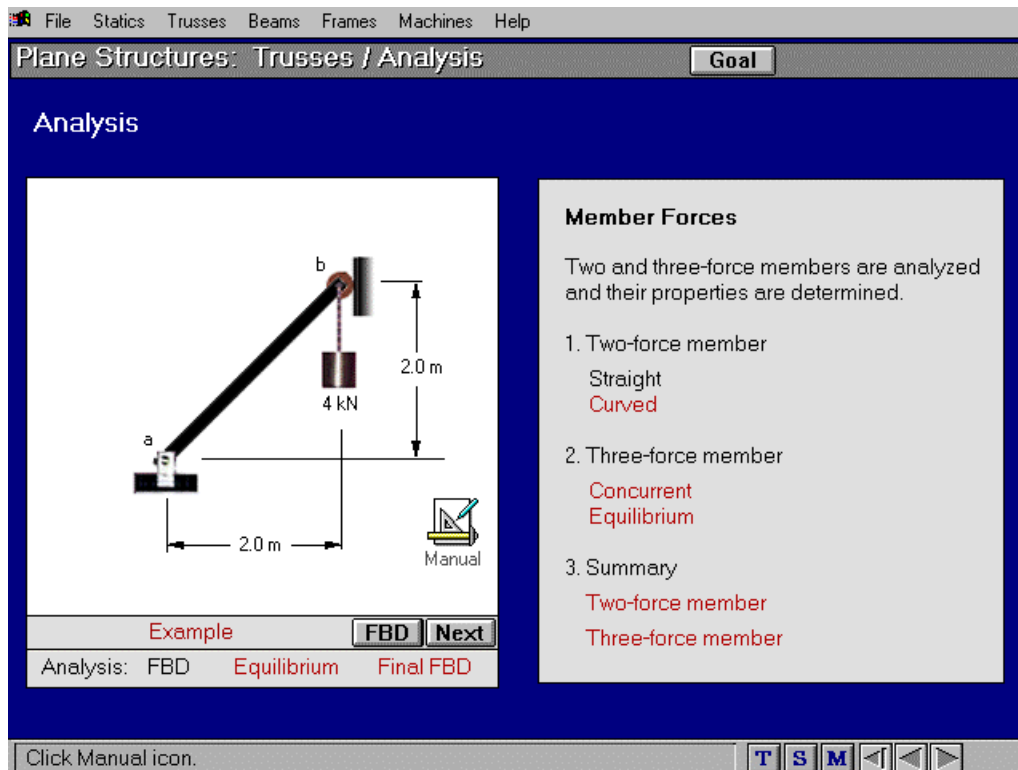


Figure 6. Member Forces

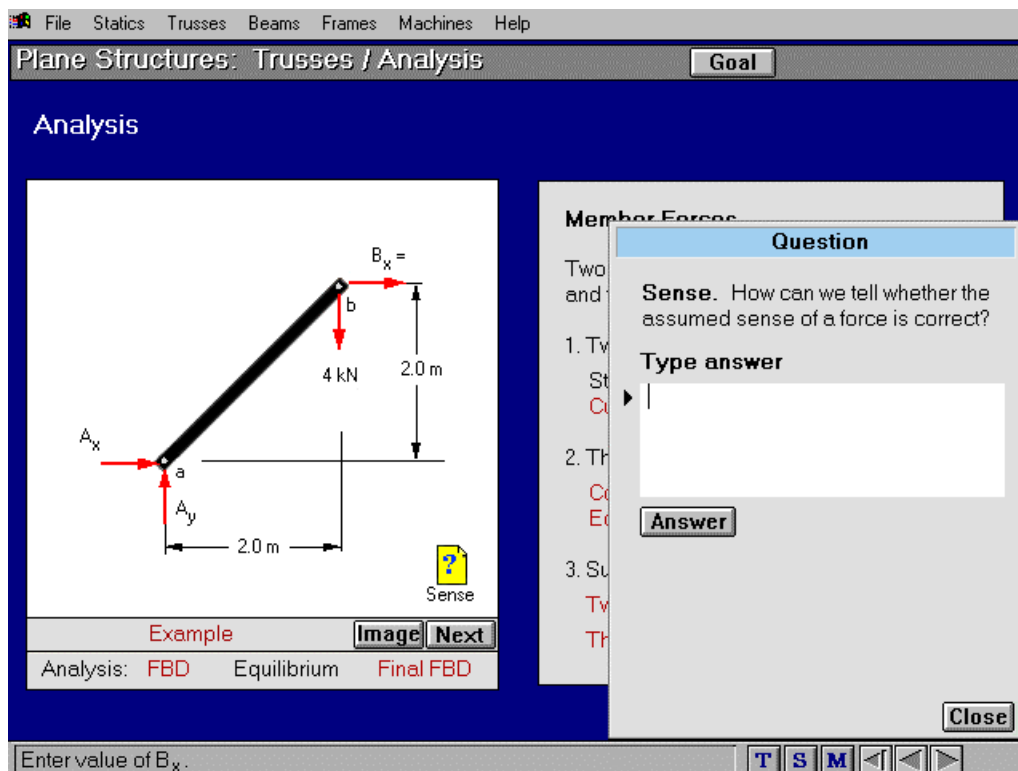
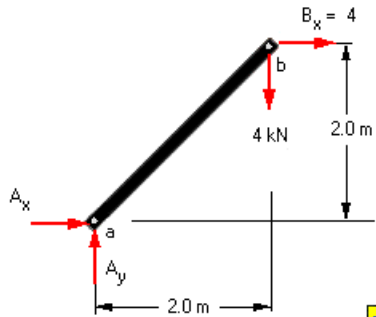


Figure 7. FBD of Member

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis Goal

### Analysis



Example Image Next

Analysis: FBD Equilibrium Final FBD

Enter value of  $B_x$ . T S M ◀ ▶

#### Member Forces

Two and three-force members are analyzed and their properties are determined.

- Two-force member
  - Straight
  - Curved
- Three-force member
  - Concurrent

#### Note

$$\Sigma M_a = -B_x(2.0) - 4(2.0) = 0$$

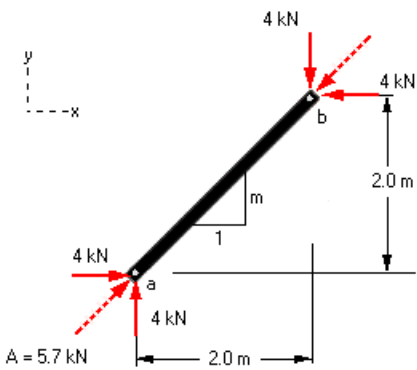
$$B_x = -4 \text{ kN} = 4 \text{ kN} \leftarrow$$
OK

Figure 8. Computation of Reactions

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis Goal

### Analysis



Example Image Next

Analysis: FBD Equilibrium Final FBD

Slopes of resultants and member are? ▶

Enter same or different. T S M ◀ ▶

#### Member Forces

Two and three-force members are analyzed and their properties are determined.

- Two-force member
  - Straight
  - Curved
- Three-force member
  - Concurrent
  - Equilibrium
- Summary
  - Two-force member
  - Three-force member

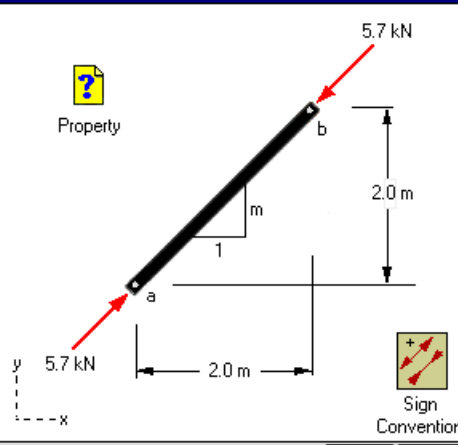
Figure 9. Slopes of Resultant and Member

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Goal

### Analysis



Property

Example

Image Next

Analysis: FBD Equilibrium Final FBD

Click Next button.

T S M

**Question**

**Property.** What is the property of two-force members in equilibrium?

**Type answer.**

Answer

The forces of two-force members in equilibrium are equal in magnitude, opposite in sense, and collinear.

Close

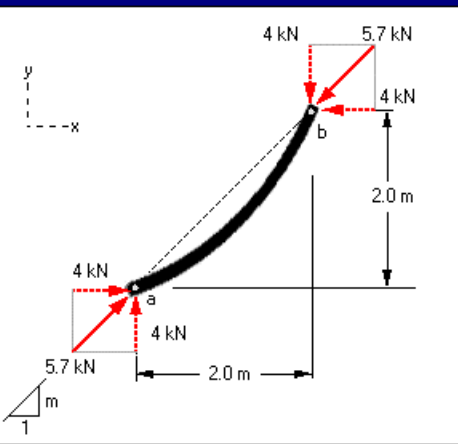
Figure 10. Property of Two-Force Member

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Goal

### Analysis



Member:

Image Next

Analysis: Equilibrium Final FBD

Slopes of resultants and member chord are? d

Member Forces

Two and three-force members are analyzed and their properties are determined.

1. Two-force member

Note

For member chord

$$m = \frac{2.0}{2.0} = 1$$

For resultants

$$m = \frac{4}{4} = 1$$

OK

T S M

Figure 11. Curved Member

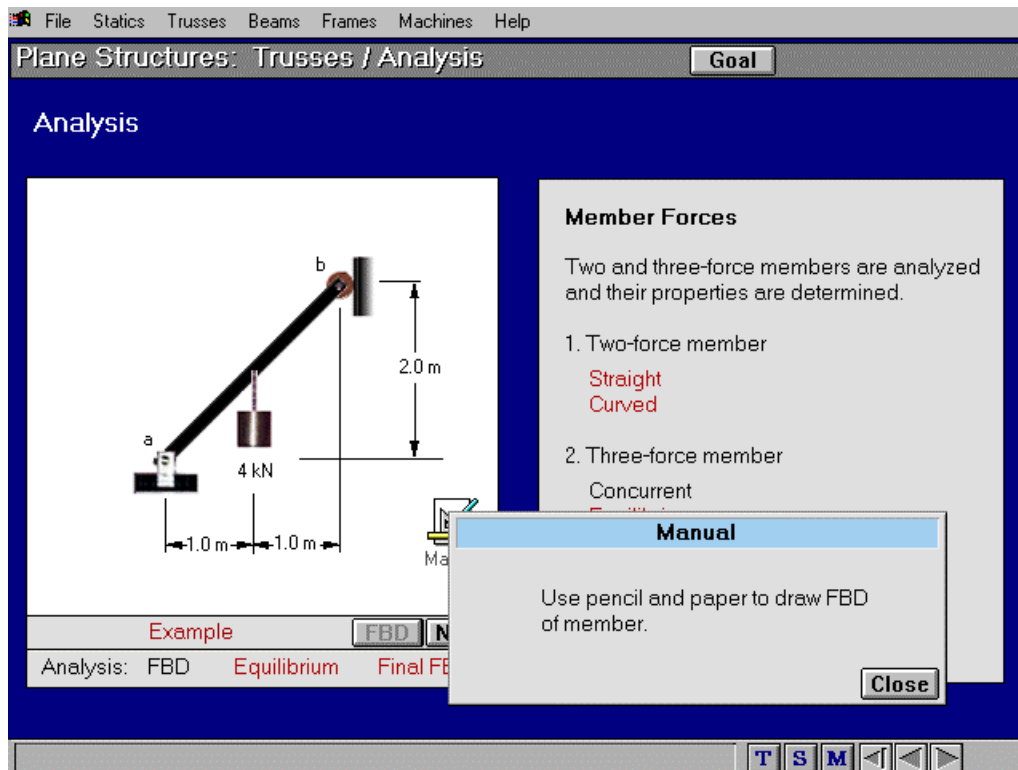


Figure 12. Member Load

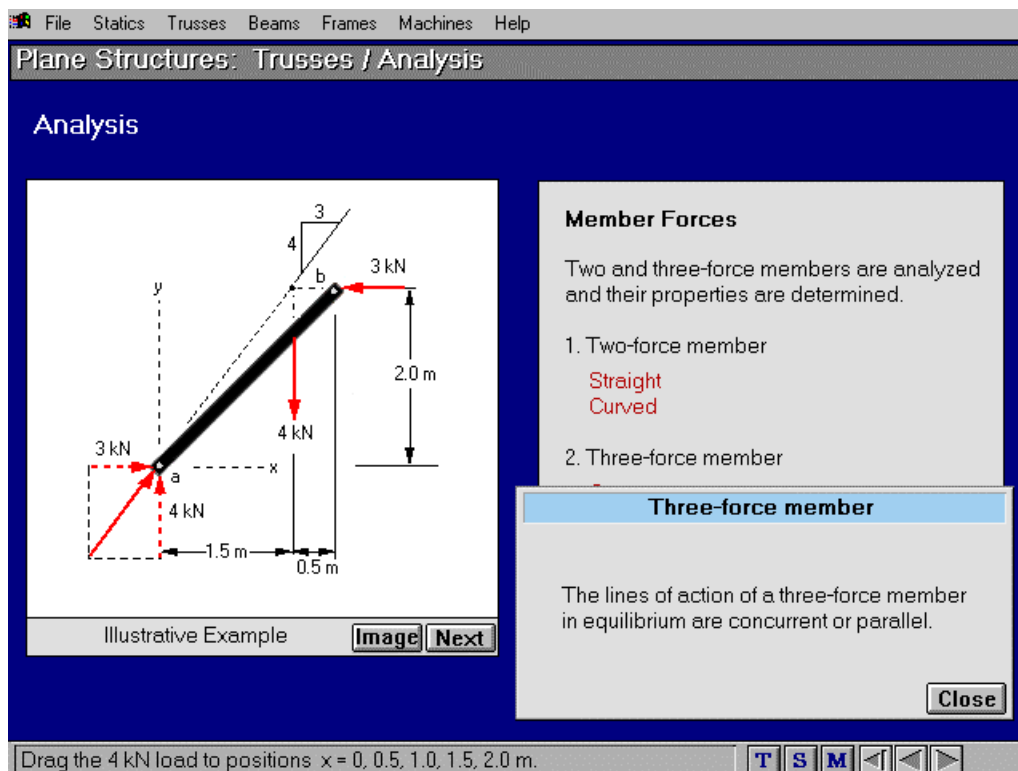


Figure 13. Three-Force Member