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ABSTRACT

The researchers are developing a learning environment in the subject area of statics that includes physical models, interactive multimedia, traditional pencil-and-paper activities, and cooperative learning in the framework of experiential learning (Kolb, 1984). They are using Authorware Professional to construct the multimedia program. The researchers taught a section of statics in this format, which now includes topics from mechanics of materials, for the third time in the fall of 1997 to students in architecture. This paper describes briefly the learning environment (Holzer and Andruet, 1998) and illustrates how students are guided to learn about trusses. Twenty-three figures from the multimedia program make up the majority of the document. (Author/SAH)

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Learning about Trusses with Multimedia

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Abstract - We are developing a learning environment in the subject area of statics that includes physical models, interactive multimedia, traditional pencil-and-paper activities, and cooperative learning in the framework of experiential learning (Kolb, 1984). We are using Authorware Professional to construct the multimedia program. We taught a section of statics in this format, which now includes topics from mechanics of materials, for the third time in the fall of 97 to students in architecture. In this paper we describe briefly the learning environment (Holzer and Andruet, 1998) and illustrate how students are guided to learn about trusses.

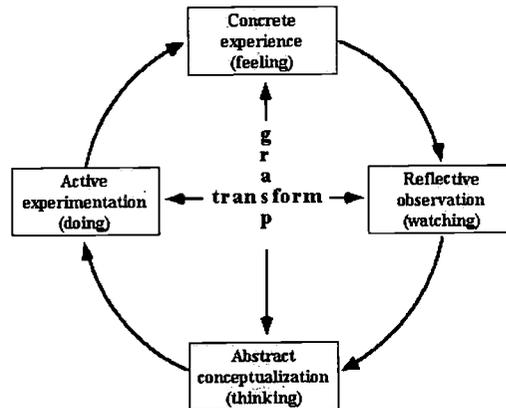


Figure 1. Experiential Learning Model (Kolb, 1984, p. 42)

Learning Environment

Learning is the process whereby knowledge is created through the transformation of experience.
David Kolb (1984)

Experiential learning focuses on the two fundamental activities of learning: grasping and transforming experience (Fig. 1). Each activity involves two opposite but complementary modes of learning. One can grasp an experience directly through the senses (sensory, inductive mode) or indirectly in symbolic form (conceptual, deductive mode). Similarly, there are two distinct ways to transform experience, by reflection or action. At any moment in the learning process, one or a combination of the four fundamental learning modes may be involved. It is significant that their synthesis leads to higher levels of learning (Kolb, 1984). This is confirmed in a study by Stice (1987), which shows that the students' retention of knowledge increases from 20% when only abstract conceptualization is involved to 90% when students are engaged in all four stages of learning.

Our class meets in a computer lab where two students share one computer. This facilitates cooperative learning where the pair is the basic unit.

Examples of cooperative learning structures for pairs include think-pair-share (TPS) (Lyman, 1987) and think-aloud-pair-problem-solving (TAPPS) (Lochhead, 1987). We found that in the classroom environment, teams of two students are more effective than teams of three or more students because the one-on-one interaction of a pair can accommodate students with diverse characteristics. In groups of three or more students, one student is frequently left out. For example in TAPPS, where one student is the problem solver and the other the listener, the roles of the members are so well defined that cooperation is necessary. Once students have become experienced with TAPPS, they may prefer a more flexible version that permits collaboration during the solution process. This was recommended by students experienced in TPS; now we use a modified version which we call MTAPPS.

Learning about Trusses

We learn about trusses by identifying their characteristics, constructing mathematical models, and analyzing models of trusses (Fig. 2). The analysis of trusses (Fig. 3) is divided into member forces, to develop concepts of two- and three-force members (Holzer and Andruet, 1998); methods of analysis, which includes their development (inductive) and summary (deductive); and the solution of problems.

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Method of Sections

Here we illustrate the development of the method of sections and its application in the solution of two truss problems.

Development

The objective is to learn how we can use sections of trusses to compute member forces. A section is an isolated part of a truss containing two or more joints. The development of the method of sections involves the first three stages of experiential learning (Fig. 1). Effective activities for the first stage are hands-on laboratory experiments that engage students directly through concrete experiences. Specifically, students may be asked to guess whether a member is in tension or compression and to measure member forces. It is simple to measure tensile forces with spring scales (Fig. 4), but it is not obvious how to measure compressive forces. This provides the opportunity for posing a puzzler, a very effective way to stimulate interest and involvement: how can we measure a compressive member force with a spring scale that records tension? Students are asked to work cooperatively in pairs to answer the question. The benefit of such experiences is the active involvement in learning and the process of discovering new concepts. The answer to the question is illustrated in Fig. 5. We use such experiments in a hands-on-statics laboratory, a pilot course supported by SUCCEED. Our goal is to promote the integration of elements from this pilot course in the standard engineering statics course.

Figures 4, 6, and 7 are concerned with the **analysis** (reflective observation) of the experiment and the formulation of an analysis **procedure** (abstract conceptualization) based on truss sections. We found that traditional pencil-and-paper activities (Manual in Fig. 4) facilitate learning with multi-media tools. Analysis results are displayed in Fig. 6. It is difficult for some students to realize that the member forces acting on one section represent the effect of the other section, the portion of the truss removed, and that free-body-diagrams are virtual concepts. The product of this development, the method of sections, is summarized and illustrated in Fig. 7.

Analysis of a simple truss

Figures 8-16 illustrate activities in the analysis of a simple truss that are inquiry-based to promote cooperative learning. The objective is to compute each member force directly from a single condition of equilibrium (Fig. 8.). The analysis process includes choices and questions. For example, one can select the member force (Fig. 9), the method of analysis (Fig. 10), and the condition of equilibrium (Fig. 14). Questions

concern the choice of a section (Fig. 12), the assumed sense of a force (Fig. 13), and the equilibrium of the final FBDs of the sections (Fig. 16), which are constructed by the students. Figure 11 shows the integration of pencil-and-paper with multimedia activities. Figures 14 and 15 illustrate constructive feedback: generally, the program provides a clue in response to the first error in a small task and the solution after the second error.

Analysis of a complex truss

One objective of the problem in Fig. 17 is to compute the force in member 4 with the fewest conditions of equilibrium. The solution procedure is first discussed by students in teams (TPS). This is followed by a class discussion based on the solution in Figs. 18 and 19. The FBD for the computation of F_1 and feedback to the second error are displayed in Fig. 20. After the computation of F_4 , students are asked to identify the zero-force members. Feedback in Fig. 21 guides this task. Finally, the students are asked to compute the remaining member forces (Fig. 22) and color code the result (Fig. 23).

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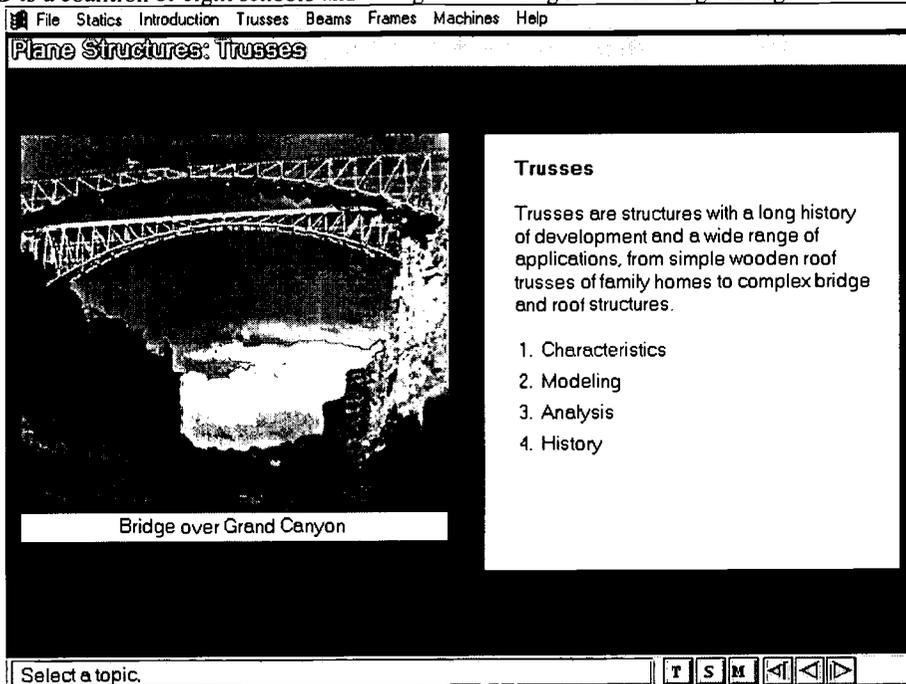


Figure 2. Trusses

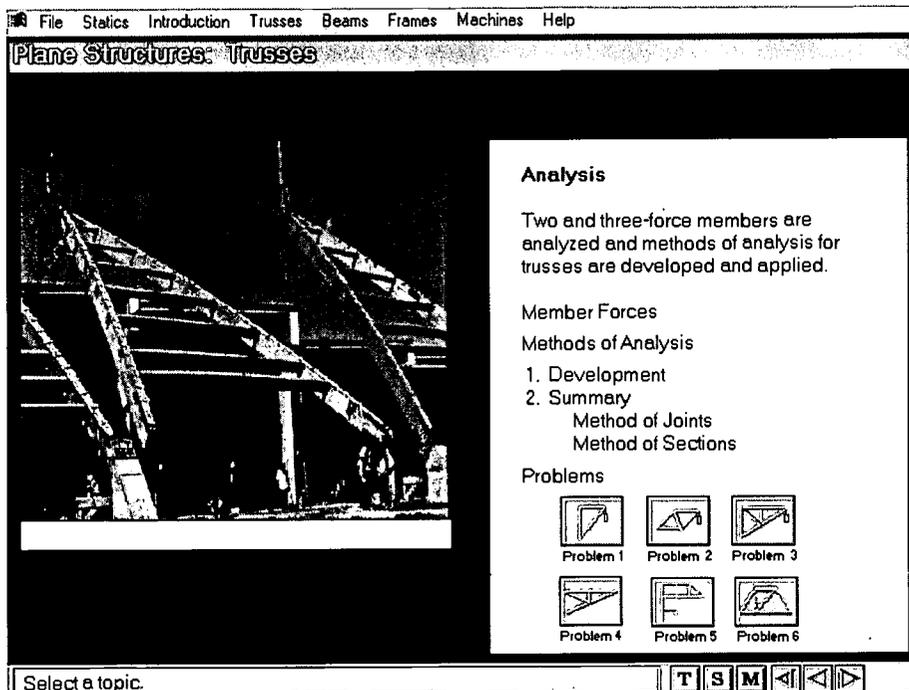


Figure 3. Analysis of Trusses

File Statics Introduction Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis Goal

Development

Truss Image Next

Method of Sections

A procedure is developed to compute member forces from FBDs of sections.

1. Analysis
2. Procedure
3. Final FBD

Manual

Use pencil and paper to draw right-hand section of truss; cut members 1, 2, and 3.

OK

Click Manual icon. T S M < >

Figure 4. Development of Method of Sections

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Plane Structures: Trusses / Analysis Goal

Development

Experiment Image Next

Transmissibility

The indirect measurement of the compressive member force with a spring scale illustrates the principle of transmissibility.

Note

A spring scale is attached to joint c and pulled in line with member 1 until member 1 lifts off from support b. At that moment the spring scale reads 39 oz.

What was the magnitude of the compressive force in member 1?

Close

Click Next button. T S M < >

Figure 5. Measuring Compressive Forces

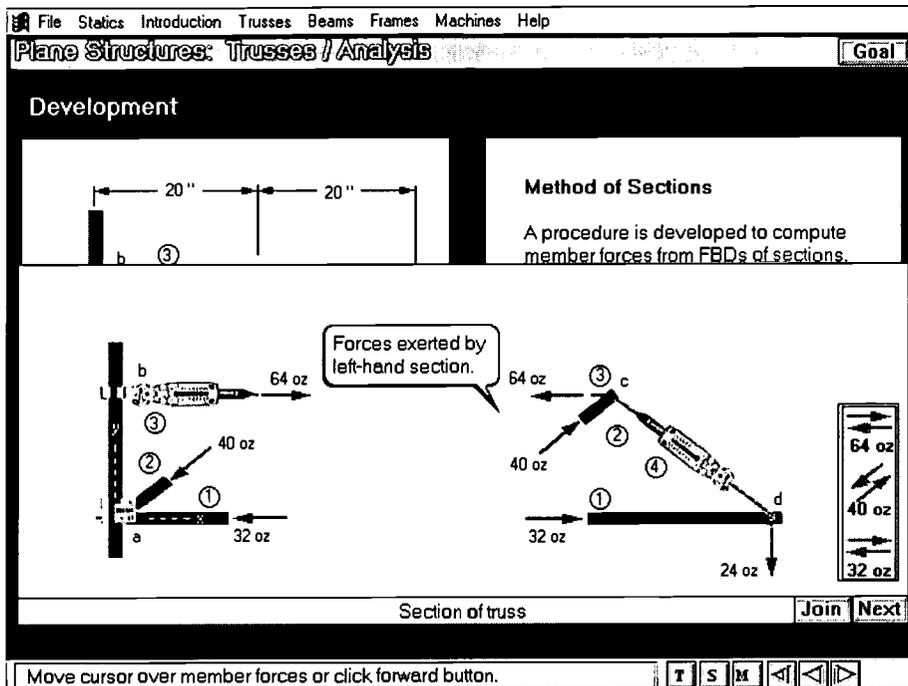


Figure 6. Results of Analysis

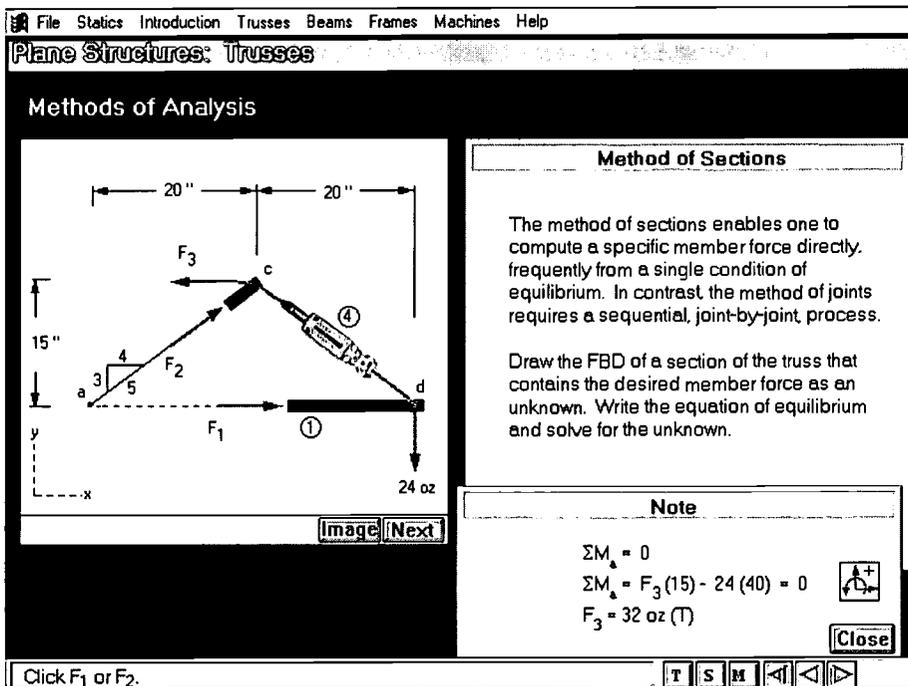


Figure 7. Method of Sections

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Plane Structures: Trusses / Analysis

Problem 2

Analysis

Draw FBDs, formulate equations of equilibrium, and solve them to compute reactions and member forces. Draw final FBDs.

Formulate Equations

Try to write each equation of equilibrium such that it contains only one unknown.

The value of this unknown, which can be computed directly, can be used in subsequent equations.

Analysis: FBD Equilibrium

Select a topic. T S M < < > >

Figure 8. Analysis of Simple Truss

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Problem 2

Analysis

Draw FBDs, formulate equations of equilibrium, and solve them to compute reactions and member forces. Draw final FBDs.

Reactions

Member forces

Final FBDs

Sections

Joints & members

Member force F₁ F₂ F₃ Image Next

Analysis: FBD Equilibrium

Click a member force button. T S M < < > >

Figure 9. Selection of Member Force

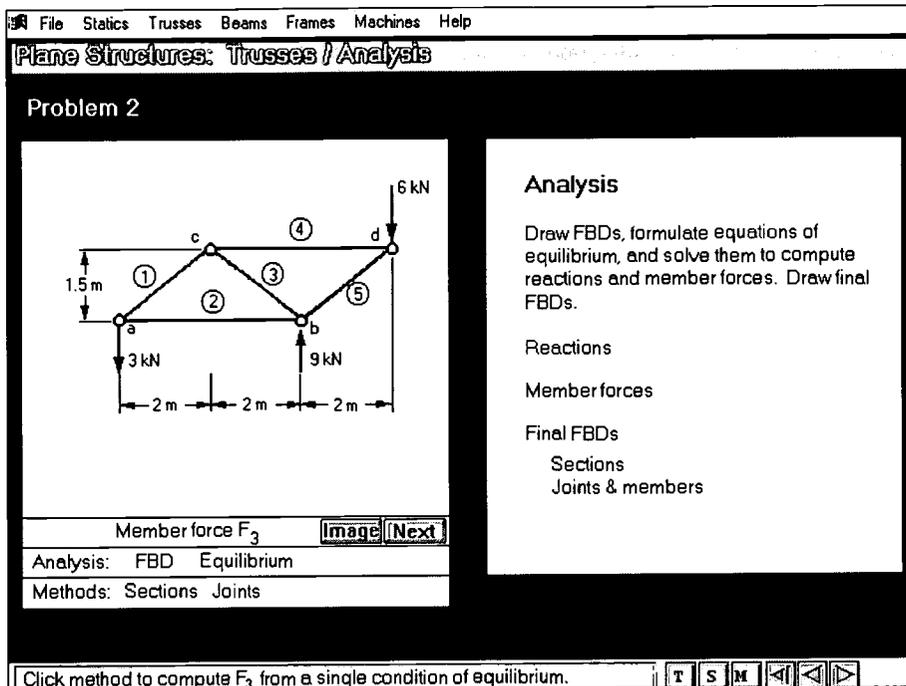


Figure 10. Selection of Analysis Method

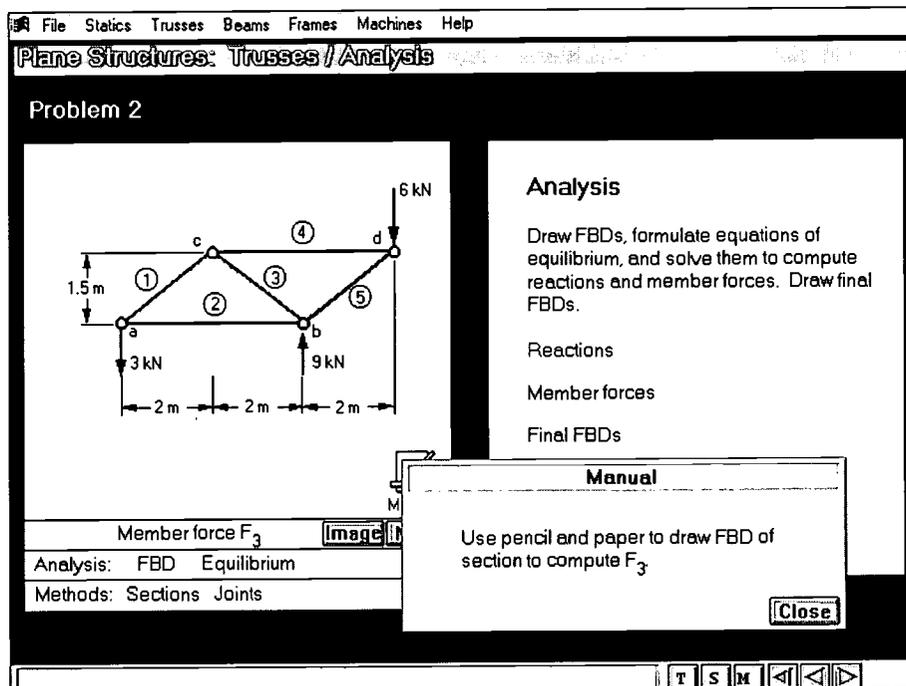


Figure 11. Pencil and Paper Activity

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Problem 2

Member force F_3

Analysis: FBD Equilibrium

Question

FBDs. Why can we use either FBD to compute the member forces (TPS)?

Think, Pair, Share

Cooperative Learning

Think
Think about the solution of the problem individually.

Pair
Form pairs and discuss your thoughts and solutions: rotate roles.

Share
Share your findings with another pair or a larger group.

T S M

Figure 12. Choice of Section

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Plane Structures: Trusses / Analysis

Problem 2

Member force F_3

Analysis: FBD Equilibrium

Conditions of equilibrium: $\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma M = 0$

Question

Sense. How can we tell whether the assumed sense of a force is correct?

Type answer

Answer

If the computed magnitude of a force is positive, the assumed sense is correct otherwise the sense must be reversed.

Click condition of equilibrium that contains only F_3 . T S M

Figure 13. Choice of Sense

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Problem 2

Member force F_3

Analysis: FBD Equilibrium

Conditions of equilibrium: $\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma M = 0$

Analysis

Draw FBDs, formulate equations of equilibrium, and solve them to compute reactions and member forces. Draw final FBDs.

Reactions

Member forces

Final FBDs

Note

$\Sigma M = 0$ contains F_2 or F_4 since they are parallel.

Click condition of equilibrium that contains only F_3 .

Figure 14. Choice of Equilibrium Condition

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Problem 2

Member force F_3

Analysis: FBD Equilibrium

$\Sigma F_y = 0$ contains only F_3 .

Analysis

Draw FBDs, formulate equations of

Note

Resolve F_3 :

Figure 15. Error Message

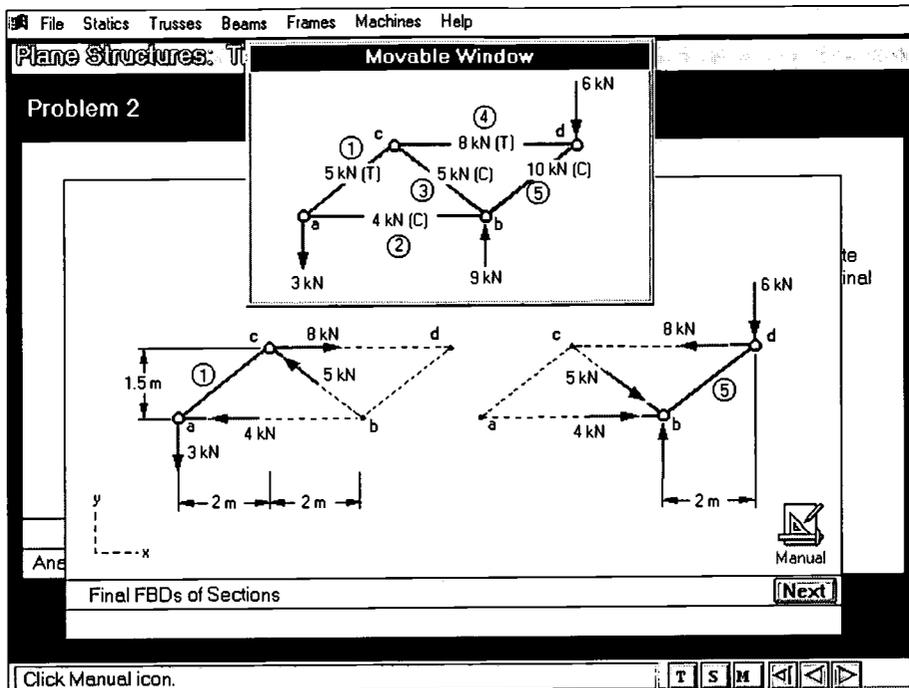


Figure 16. Final Free-Body Diagrams

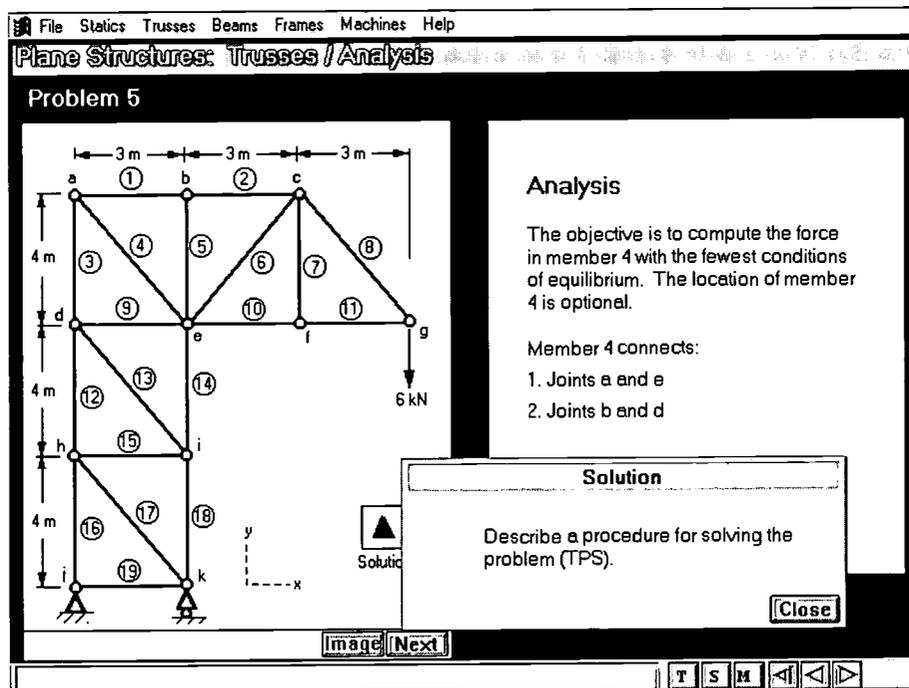


Figure 17. Analysis of Complex Truss

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Problem 5

Analysis

The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional.

Solution

Two-step procedure

1. Isolate section of truss by cutting members 1, 5, 6 and 10 and compute F_1 from a single condition of equilibrium.
2. Isolate joint a and compute F_4 from a single condition of equilibrium.

Can you think of alternative two-step solutions?

Close

Touch step 1 and 2.

Image Next

Figure 18. Procedure for F_1

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Plane Structures: Trusses / Analysis

Problem 5

Analysis

The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional.

Solution

Two-step procedure

1. Isolate section of truss by cutting members 1, 5, 6 and 10 and compute F_1 from a single condition of equilibrium.
2. Isolate joint a and compute F_4 from a single condition of equilibrium.

Can you think of alternative two-step solutions?

Close

Touch step 1 and 2.

Image Next

Figure 19. Procedure for F_4

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Problem 5

Analysis

The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional.

Member 4 connects:

1. Joints a and e
2. Joints b and d

Note

$$\sum M_e = F_1(4) - 6(6) = 0$$

$$F_1 = 9 \text{ kN (T)}$$

Sense

image Next

T S M

Figure 20. Computation of F_1

File Statics Trusses Beams Frames Machines Help

Plane Structures: Trusses / Analysis

Problem 5

Analysis

The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional.

Note

From FBDs of joints b and f, we obtain $F_5 = 0$ and $F_7 = 0$.

Next we cut members 3, 9, and 14 and from condition $\sum F_x = 0$ of section FBD, we obtain $F_9 = 0$.

Finally, FBDs of joints d, i, h, and k yield $F_{13} = 0$, $F_{15} = 0$, $F_{17} = 0$, and $F_{19} = 0$.

The number of zero force members is: 5

Enter number of zero force members.

T S M

Figure 21. Zero-Force Members

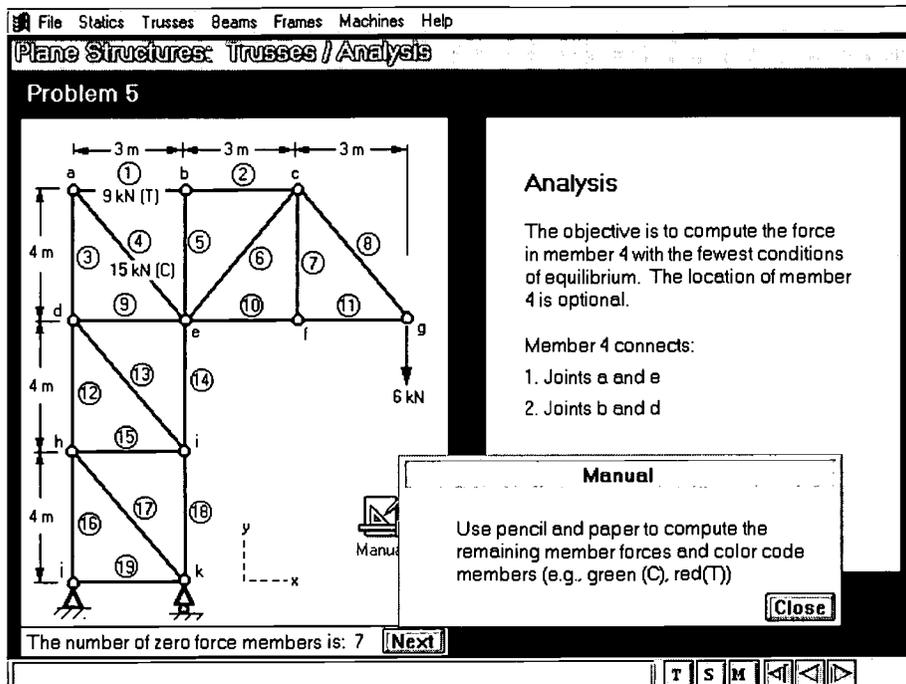


Figure 22. Remaining Member Forces

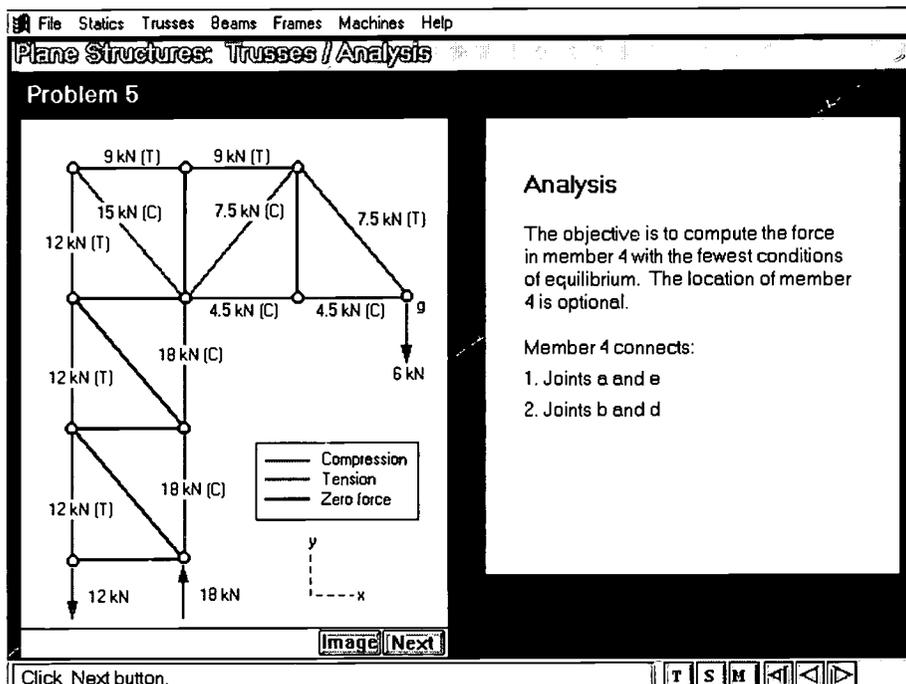


Figure 23. Color-Coded Member Forces

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