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EVOLUTION OF A NASTRAN TRAINER

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INTRODUCTION

This paper traces the development of a NASTRAN training system. It encompasses the design and organization of the program, including the static and dynamic modules. A discussion of how user feedback, in the form of questionnaire responses, was used to evaluate and improve the trainer is included.

BACKGROUND

The user-friendly NASTRAN trainer was originally designed as a segment of a larger system (ref. 1). After the static module was developed, used, and evaluated (ref. 2), it became clear that the trainer concept readily lent itself to a wide range of applications.

The NASTRAN trainer (figure 1) was initially conceived as a low-cost, convenient tool for giving engineers who were novices in finite element analysis a few practical applications of the method. Although several very good short courses and classes on NASTRAN are available, most are offered periodically and cost $200 to $800 per person. These classes usually require the engineer to set aside his current work assignment and devote his full time to the class for anywhere from a couple of days to a couple of weeks. When funds are low or schedules are tight, the money or time required for these classes can be insurmountable barriers.

Various researchers have developed computer programs for structural analysis and design applications. Ginsburg (ref. 3) addresses computer literacy, and Woodward and Morris discuss improved productivity through interactive processing (ref. 4). Wilson and Holt (ref. 5) developed a system of computer-assisted learning in structural engineering. Sadd and Rolph (ref. 6) describe the various ways in which design engineers could be trained to use the finite element method. Self-adapting menus for computer-aided design (CAD) software are covered by Ginsburg (ref. 7).

Bykat (ref. 8) is developing a system that will have features for training, analysis control, and interrogation.

STATIC MODULE

The static module was developed to provide the user a variety of different types of problems. The ten problems generally increase in difficulty as their numbers increase. Table I describes each problem, and figures 2 and 3 show the problems. Figure 4 gives the classical solution for static example 6.

The user may work the problems in any order.

DYNAMIC MODULE

The dynamic module contains eight problems (table II) of increasing complexity. The problems are shown in figures 5 and 6. A classical solution for dynamic problem 4 is presented in figure 7. The examples were selected to allow the user to decide on:

1. Grid fineness
2. Mass representation
3. Number of degrees of freedom retained
4. Particular degrees of freedom retained

Each of these decisions can have a significant bearing on the accuracy of the eigensolution.

A complete description of this module is given in ref. 9.

TRAINER ORGANIZATION

The NASTRAN Environment (NE) is written for the IBM computer system running MVS/ESA SP 4.1.0 using TSO/E 2.1.0. It uses the features provided by the dialogue management services under ISPF/PDF to the fullest extent. This includes panels, skeletons, CLISTs, and tutorial services. In addition, the trainer requires VS/FORTRAN and VS/Pascal compilers if the executable code is not directly portable. Newer versions of any of these services should not invalidate the NE if the improvements are upwardly compatible.

The NE has job setups to execute MSC/NASTRAN and COSMIC/NASTRAN on IBM and/or MSC/NASTRAN on the Cray running Unicos 6.1. At least one of these programs must be available for the NE to be used as intended. These codes are not delivered with the NE.

The NE comprises 15 datasets; 14 are partitioned and 1 is sequential. These datasets are listed below with a brief explanation of their contents. Figure 8 illustrates the organization of the NE datasets.

- ALTER—Rigid format alter library for NASTRAN. Must be updated with each release of a new version of NASTRAN. Not a requirement for the trainer and most NASTRAN users.
- CLIST—Procedural commands to invoke the NE, allocate and manage datasets, create and submit batch jobs, invoke the SPF editor and initialize profile variables.
- MSGS—Messages that appear on panels for information, caution, and warning.
- PNLZ (Environment)—Panels that serve as the user interface. All information that the user inputs and the system outputs is through panels. This includes data entry screens, system news, help sections, user manuals, problem descriptions, and classical solutions.
- DOC—Documentation on efforts to develop NASTRAN expert systems.
- FORT—FORTRAN programs and subroutines that compute the classical solutions and extract system jobcard information.

- INP—Input decks that are example solutions to the NASTRAN trainer problems.
- LOAD—Load modules of the compiled and linked FORTRAN and Pascal programs.
- LOG—Log of NASTRAN trainer usage for each NASTRAN trainer job submitted.
- OBJ—Object modules of the compiled FORTRAN and Pascal programs.
- OUT—Output decks that are example solutions to the NASTRAN trainer problems.
- PVS—Pascal program that produces a report of the usage of the NASTRAN trainer.

FUTURE ENHANCEMENTS AND USER FEEDBACK

Modules for elastic stability (buckling) and substructuring are in the planning stage. These additions are planned as self-contained units that can be used by anyone who has completed the static module.

Users of the static module were asked to fill out a questionnaire. The questions and responses are shown in figure 9. Another questionnaire is currently being used to solicit opinions about the dynamic module.

CONCLUSIONS

The NASTRAN trainer has been used by a number of engineers, who found it to be a versatile low-cost tool. It is particularly helpful in bridging the gap from theory to practical application of the finite element method for structural analysis. The program, along with documentation, is available through COSMIC.

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6. Sadd, M.H., and W.D. Rolph III: On Training Programs for Design Engineers in the Use of Finite Element Analysis. Computers and Structures, vol. 26, no. 12, 1987.

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8. Bykat, A.: Design of FEATS, a Finite Element Applications Training System. Prepared for presentation at the 16th NASTRAN Users' Colloquium, Arlington, Virginia, April 1988.

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TABLE I.-STATIC EXAMPLE PROBLEMS

Example	Description	Significant Features
1	Statically determinate plane truss subjected to point load	Bar elements, stability constraints
2	Beam simply supported on one end and fixed at the other subjected to point load	Beam elements
3	Beam fixed at both ends subjected to through-the-depth temperature difference	Temperature input
4	Plane frame subjected to point load	Half-model, symmetric, and antisymmetric loads
5	Simply supported beam subjected to temperature pattern	Half-model, temperature distribution decomposed into symmetric and antisymmetric parts
6	Plate with hole in center subjected to in-plane load	Plane stress, quarter-model, fine grid around hole
7	Simply supported square plate subjected to out-of-plane point load at center	Plate-bending elements, quarter-model
8	Three-dimensional frame subjected to point load	Tapered beams, three-dimensional
9	Cylindrical shell subjected to hydrostatic loading	Three-dimensional simulation of curved surface using flat elements
10	Cylindrical shell with ring frames closed at both ends subjected to internal pressure	Self-equilibrating loading, three-dimensional

TABLE II.-DYNAMIC EXAMPLE PROBLEMS

Example	Description	Significant Features
1	Beam simply supported on both ends with lumped mass in middle	Motion in one plane only, lumped mass only
2	Beam simply supported on both ends with uniformly distributed mass	Motion in one plane only, distributed mass
3	Beam fixed on one end with a lumped mass at the free end	Motion in any direction, lumped mass only
4	Beam fixed on one end with a uniformly distributed mass	Motion in any direction with uniformly distributed mass
5	Rectangular plate clamped on one edge, all other edges free, with a uniformly distributed mass	Plate bending with distributed mass
6	Rectangular plate, free-free with uniformly distributed mass	Free-free (implies six modes with zero frequency)
7	Two beams connected by springs, each with distributed and lumped mass	Multibody problem, free-free
8	Problem 7 with a forcing function added	Forcing function

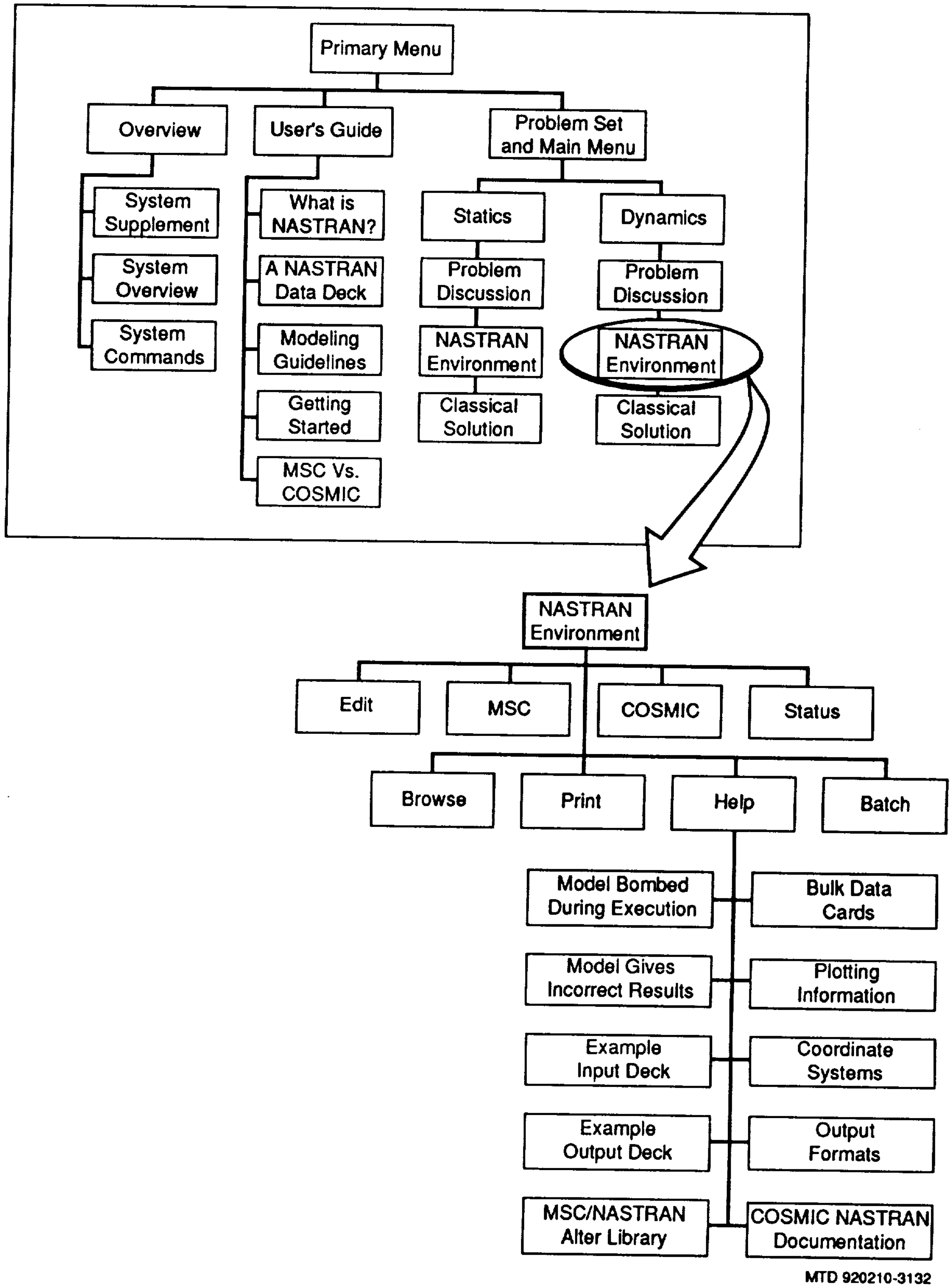
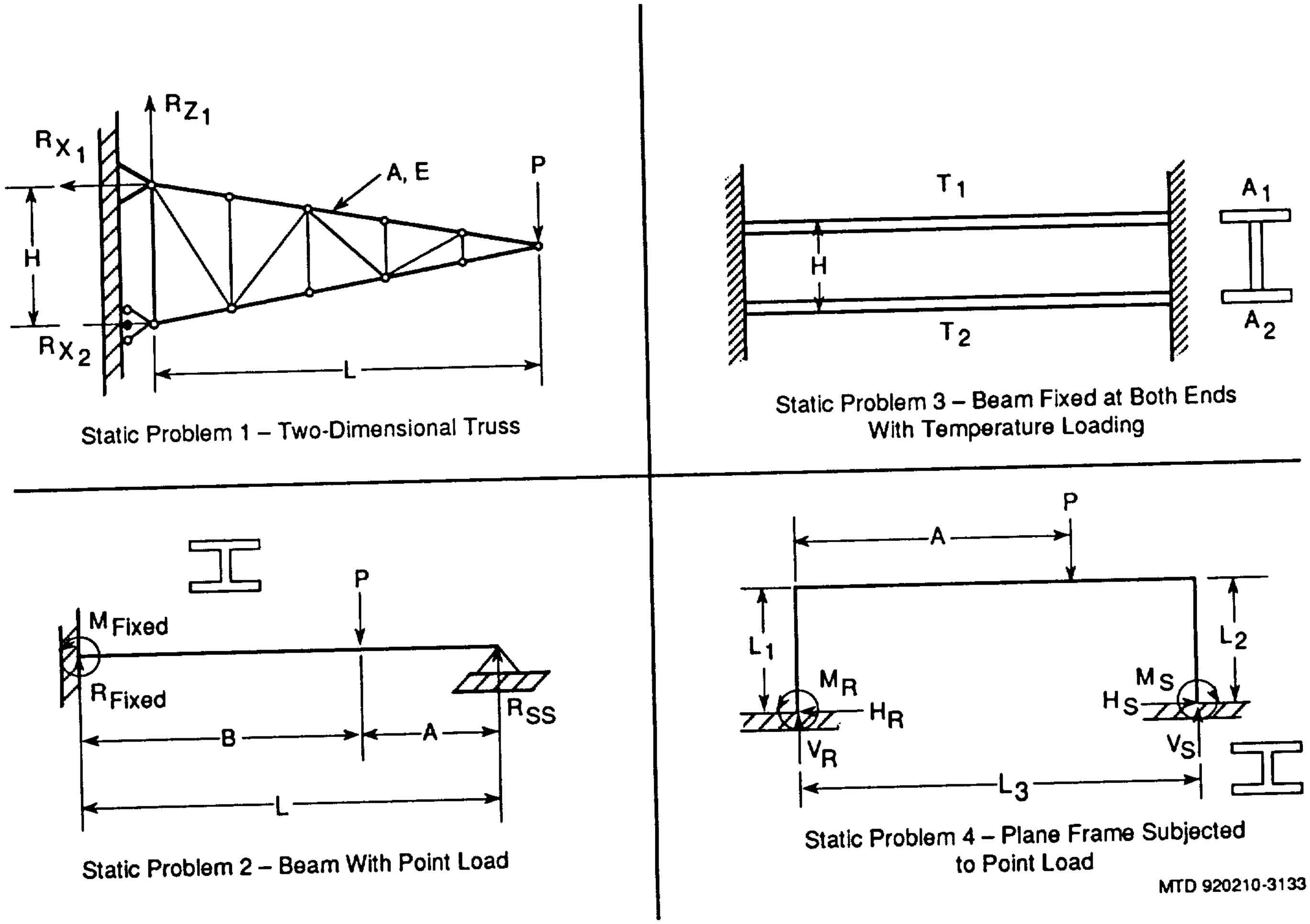


FIGURE 1.–THE STRUCTURE OF THE TRAINER



Static Problem 1 – Two-Dimensional Truss

Static Problem 3 – Beam Fixed at Both Ends With Temperature Loading

Static Problem 2 – Beam With Point Load

Static Problem 4 – Plane Frame Subjected to Point Load

FIGURE 2.–STATIC PROBLEMS 1 TO 4

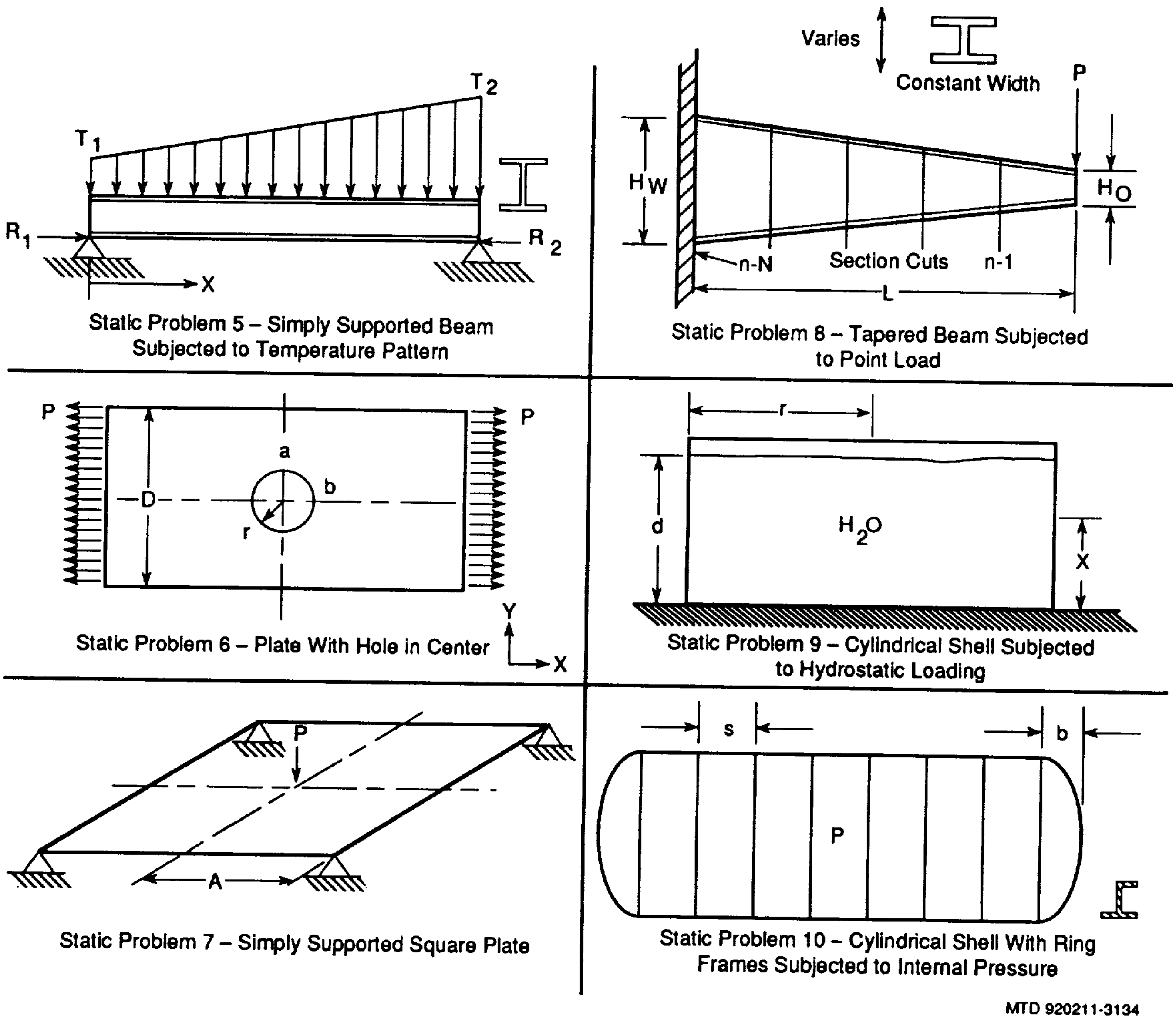
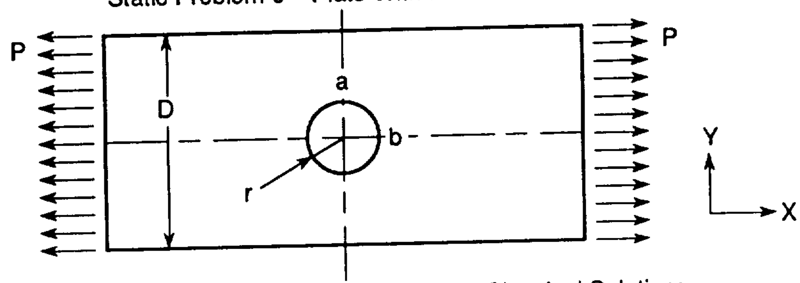


FIGURE 3.–STATIC PROBLEMS 5 TO 10

Static Problem 6 – Plate With Hole in Center



P = Running Load (lb/in.)
D = Width of Plate (in.)
t = Thickness of Plate (in.)
r = Radius of Hole (in.)
σ_T = Stress at Distance From Hole (psi)
σ_X = Stress (X) at Hole (psi)
σ_Y = Stress (Y) at Hole (psi)

Classical Solution:

Calculate σ_X at Point a:

$$\sigma_X = \sigma_{max} = \sigma_a = k\sigma_{nom}$$

Where $\sigma_{nom} = \dfrac{PD}{t(D - 2r)}$

$$k = 3.00 - 3.13\left(\frac{2r}{D}\right) + 3.66\left(\frac{2r}{D}\right)^2 - 1.53\left(\frac{2r}{D}\right)^3$$

Calculate σ_Y at Point b:

σ_T = Stress at Distance From Hole = $\dfrac{P}{t}$

$$\sigma_Y = \sigma_b = -\sigma_T$$

Reference: Roark and Young. Formulas for Stress and Strain, 5th Edition, p. 594.

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FIGURE 4.–CLASSICAL SOLUTION FOR STATIC PROBLEM 6

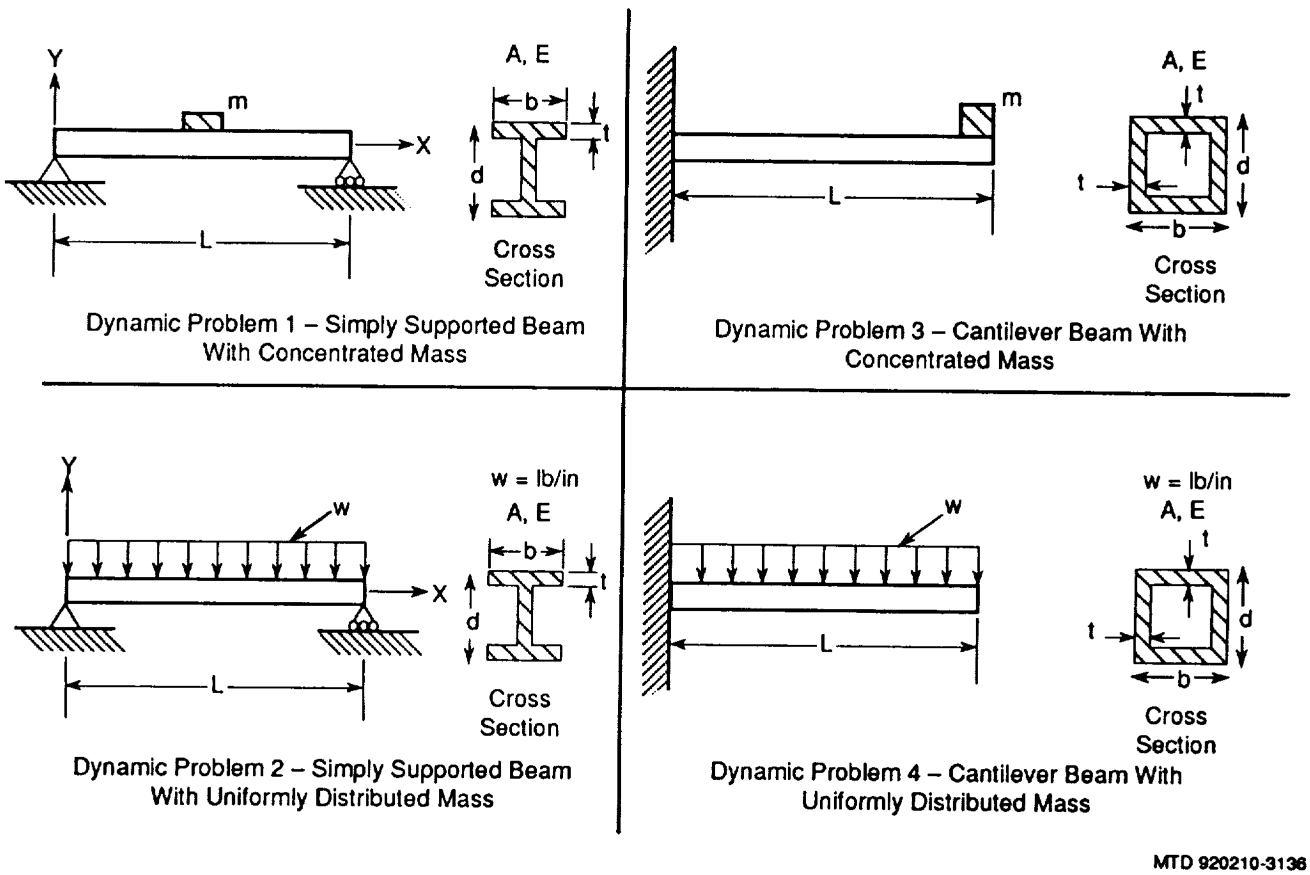
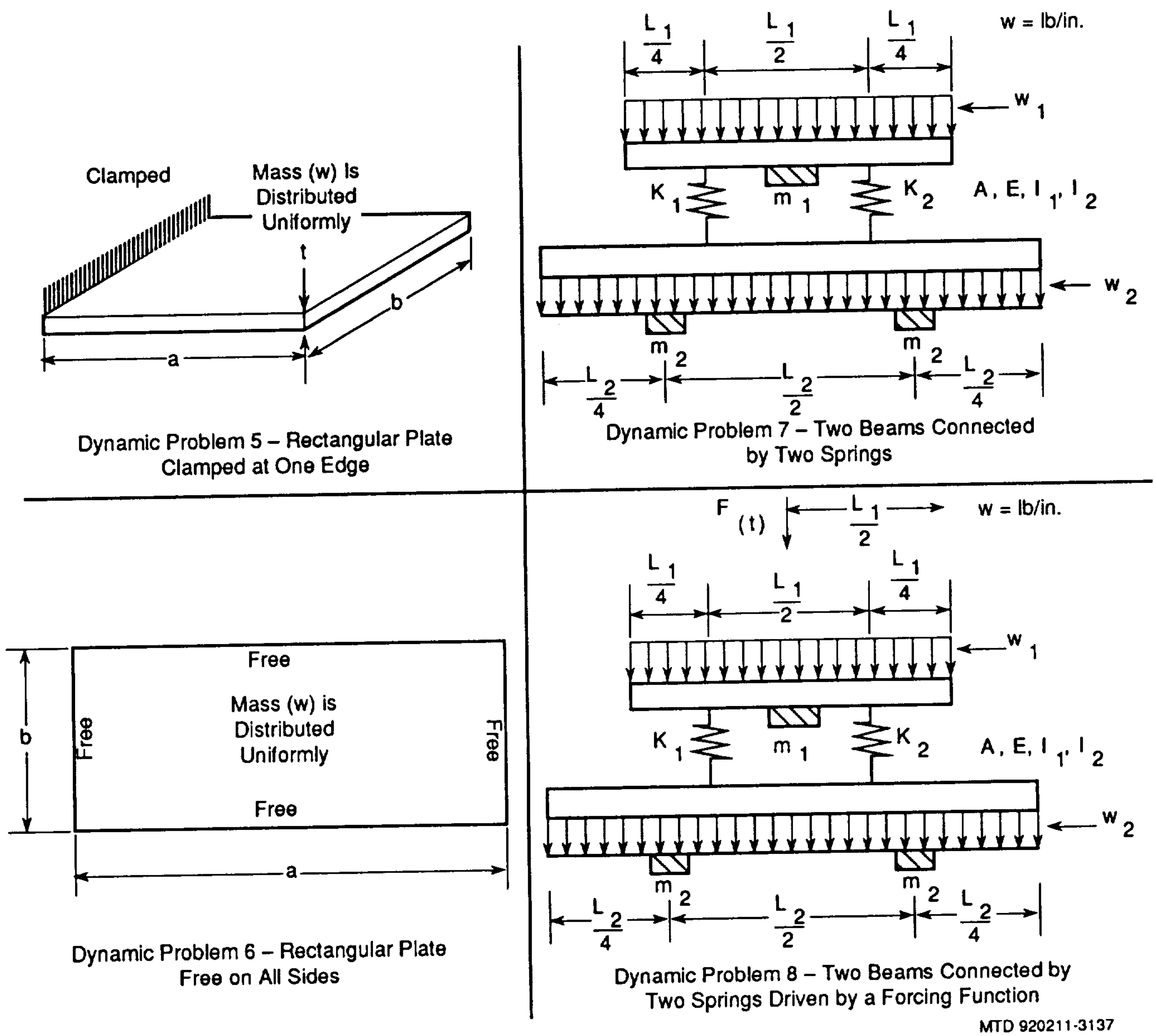


FIGURE 5.–DYNAMIC PROBLEMS 1 TO 4



Dynamic Problem 5 – Rectangular Plate Clamped at One Edge

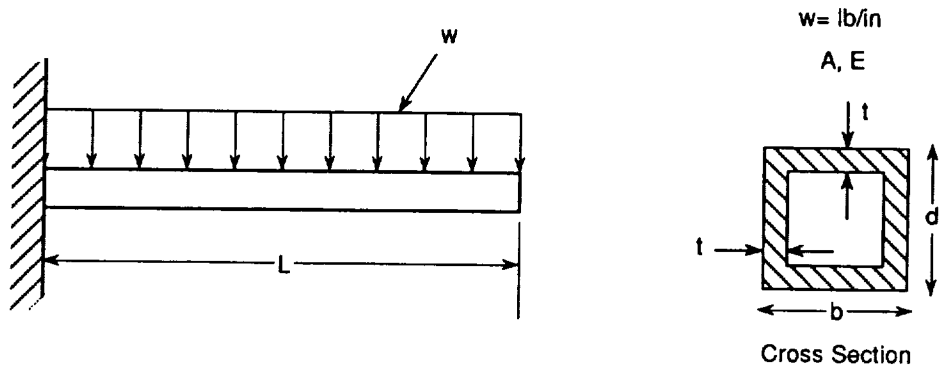
Dynamic Problem 6 – Rectangular Plate Free on All Sides

Dynamic Problem 7 – Two Beams Connected by Two Springs

Dynamic Problem 8 – Two Beams Connected by Two Springs Driven by a Forcing Function

FIGURE 6.–DYNAMIC PROBLEMS 5 TO 8

Dynamic Problem 4 – Cantilever Beam With
Uniformly Distributed Mass



E = Modulus of Elasticity (psi)

I = Moment of Inertia (in.^{4})

μ = Distributed Mass (lb-sec^2/in.^{2})

L = Length of Beam (in.)

ω_n = Natural Frequency - Angular (rad/sec)

f_n = Natural Frequency (cycles/sec or hertz)

Reference: Flügge, W.: Handbook of Engineering Mechanics. McGraw-Hill 1962, pp. 61-8.

Classical Solution:

Calculate Natural Frequencies:

$$\omega_i = \frac{(0.597\,\pi)^2}{L^2}\sqrt{\frac{EI}{\mu}} \qquad \text{(Fundamental Mode)}$$

$$\omega_n = \frac{(n - 1/2)^2\,\pi^2}{L^2}\sqrt{\frac{EI}{\mu}} \qquad \text{(Higher Order Modes)}\ (n > 1)$$

$$f_n = \frac{\omega_n}{2\pi}$$

Where n = 1, 2, ... (the Mode Number)

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FIGURE 7.–CLASSICAL SOLUTION FOR DYNAMIC PROBLEM 4

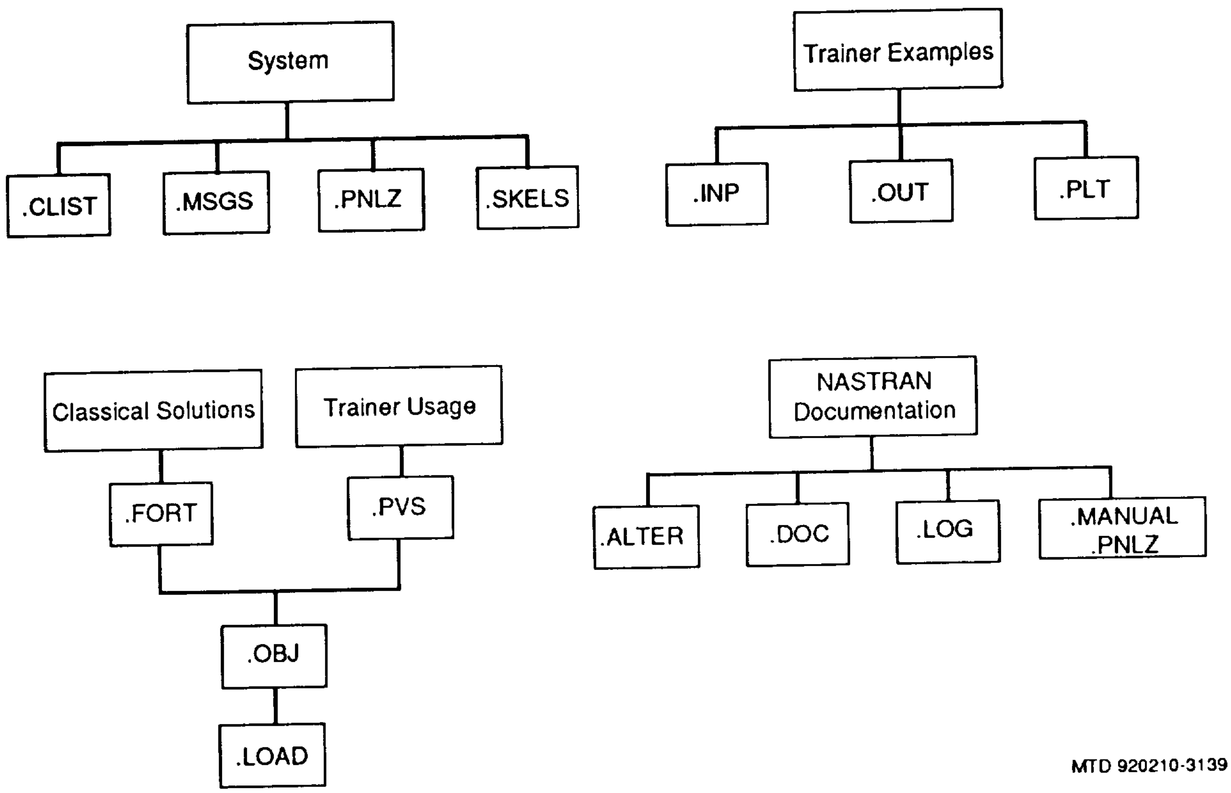

FIGURE 8.–NASTRAN ENVIRONMENT DATASET ORGANIZATION

Critique of NASTRAN Trainer

1 Was using this system a worthwhile expenditure of your time?
- a. Yes (89%)
- b. No (0%)
- c. Undecided (11%)

2 How much total time would you estimate that you spent using the trainer?
60 hours

3 How much total time would you have spent (estimate) to gain this knowledge if the trainer had not been available 135 hours

4 The number of examples was
- a. Too few (17%)
- b. Too many (6%)
- c. About right (77%)

5 The system was
- a. Too simple (17%)
- b. Too complicated (6%)
- c. About right (77%)

6 Could the trainer be improved by adding other topics?
- a. Yes (67%)
- b. No (22%)
- c. Maybe (11%)

7 Which section, if any, should be expanded upon?
(Wide variety of responses.)

8 How often (average) did you invoke the NASTRAN documentation manual section?
- a. Never (44%)
- b. 0-2 times/example (22%)
- c. More than 2 times/example (34%)

9 Was the NASTRAN documentation section useful?
- a. Yes (38%)
- b. No (33%)
- c. Never used it (29%)

10 How often did you use (average) the printed COSMIC or MSC NASTRAN manuals?
- a. Never (6%)
- b. 0-2 times/example (17%)
- c. More than 2 times/example (77%)

11 Please add any additional comments you desire.
(Responses vary from "great" to "give us more advanced problems.")

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FIGURE 9.–QUESTIONNAIRE FOR USER FEEDBACK (STATIC)