Schema: Mechanics of Materials

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Schema (Wikipedia)

(a) describes an organized pattern of thought
(b) a system of organizing and perceiving new information
(c) people are more likely to notice things that fit into their schema, while re-interpreting contradictions to the schema as exceptions or distorting them to fit.

Meaning (a)

An important part of success in learning, and consequently, best grades is to develop the habit of organizing what your teachers teach you in class. Experts have well-linked (see the arrows in Figs.-1, 2 below) organized knowledge, novices do not. If you need too much time to finish your homework or you often ask the question, "I do not know where to start solving this problem." your knowledge base is not organized. You must have a "schema!"

Meaning (b)

A schema is like the catalog system at the library, how items are arranged at the grocery store, or how you store your files and folders in your computer. When you acquire new knowledge, you carefully decide where to put it, at the right place in an existing schema or in a new schema. Good schema improves your learning, brings success, and gives you motivation. Learning is fun when you do it the rights way; start now!

Meaning (c)

You first learn schema from your teacher, but eventually you become brave and build your own schema, because you own your schema. You must revisit your schema often to make changes so that new information fits into it and experience improves your schema making ability and removes all contradictions.

Examples of Schema

A schema can cover a single lecture in your course, or a section of a chapter in your textbook, or a chapter in your textbook, or even a complete one-semester long course. Shown in Fig.-1 is the first and most important schema in your Mechanics of Materials class. The schema summarizes and organizes the following knowledge elements:

- Load has three parts – force, moment, and couple/torque. While solving a problem, you must mentally go through this list and ensure that you have included the effect of all three.
- Load and geometry determine the stress in the material at a point. Stress does not depend on what the material is, wood or steel. Geometry enters the stress calculation as cross-sectional area, or area moment of inertia, or certain lengths. The formula for stress calculation is a detail not included in this schema, but you can include it yourself.
- The significance of one-way or two-way arrows is important. Stress is connected with load and geometry by one-way arrows. This signifies that for given load and geometry, you can calculate stress, but for a given stress, you cannot calculate load and geometry.
- You substitute the stress in the material property equations, the Hooke's Law to calculate strain. Following the reversed direction of two-way arrows, you substitute the strain in Hooke's Law to calculate strain. The material property, i.e., whether the material is wood or steel only becomes relevant in strain calculation.

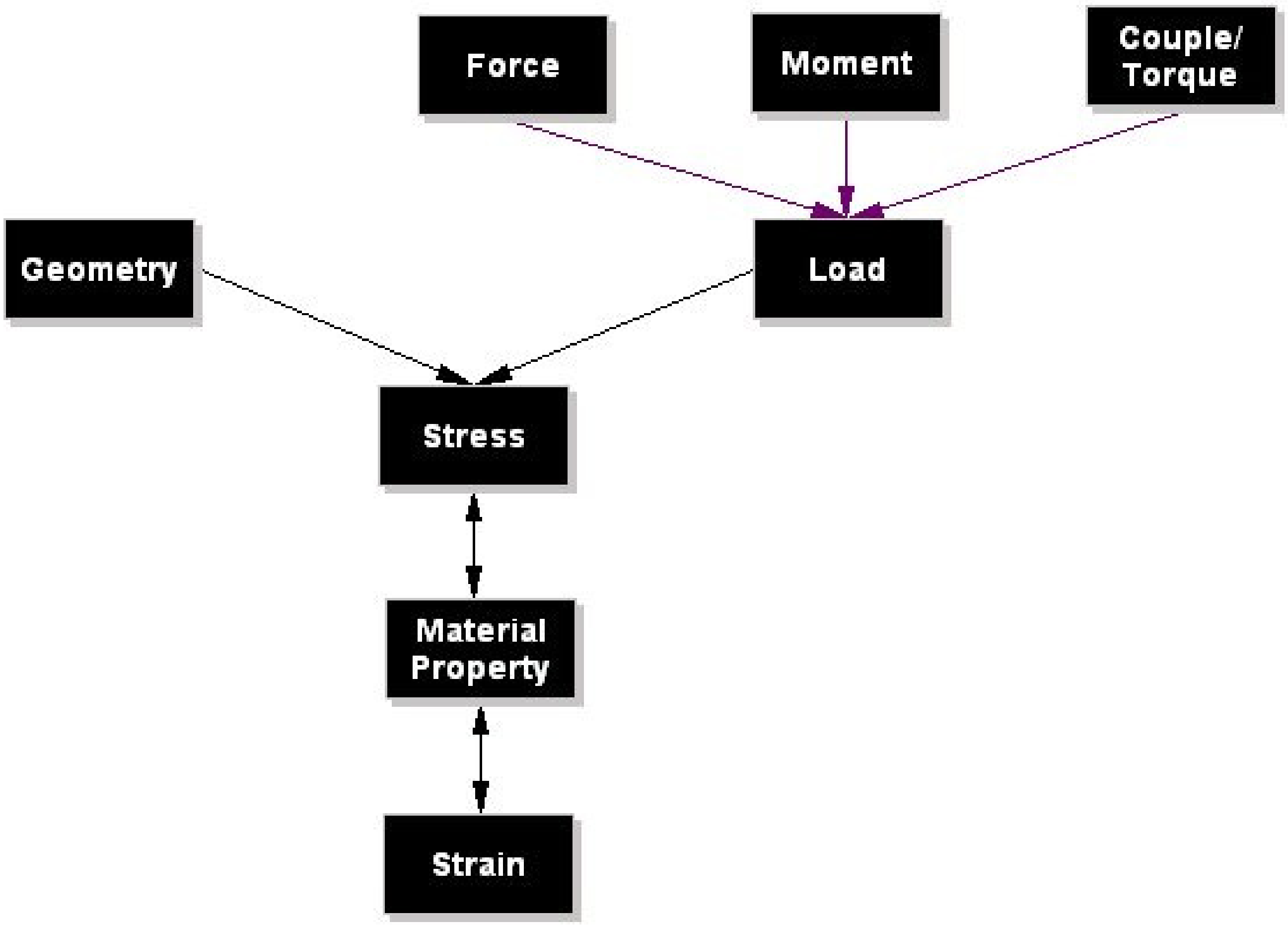

Figure-1: Fundamental Schema

A much broader schema that covers all the topics that are covered in a semester long Mechanics of Materials course is shown in Fig.-2.

Concept Map
A concept map is a schema where all the relevant equations associated with a block in the schema are saved within the block. This software package contains two concept maps: (i) stress transformation and (ii) cylindrical pressure vessel.

My Schema and Your Schema
Constructing, correcting, improving, expanding, using, and remembering schema is the best thing you can do to improve your learning. You begin schema building by following or copying someone. After a while, schema building on your own will become a habit and you will be amazed by your own academic and professional success.

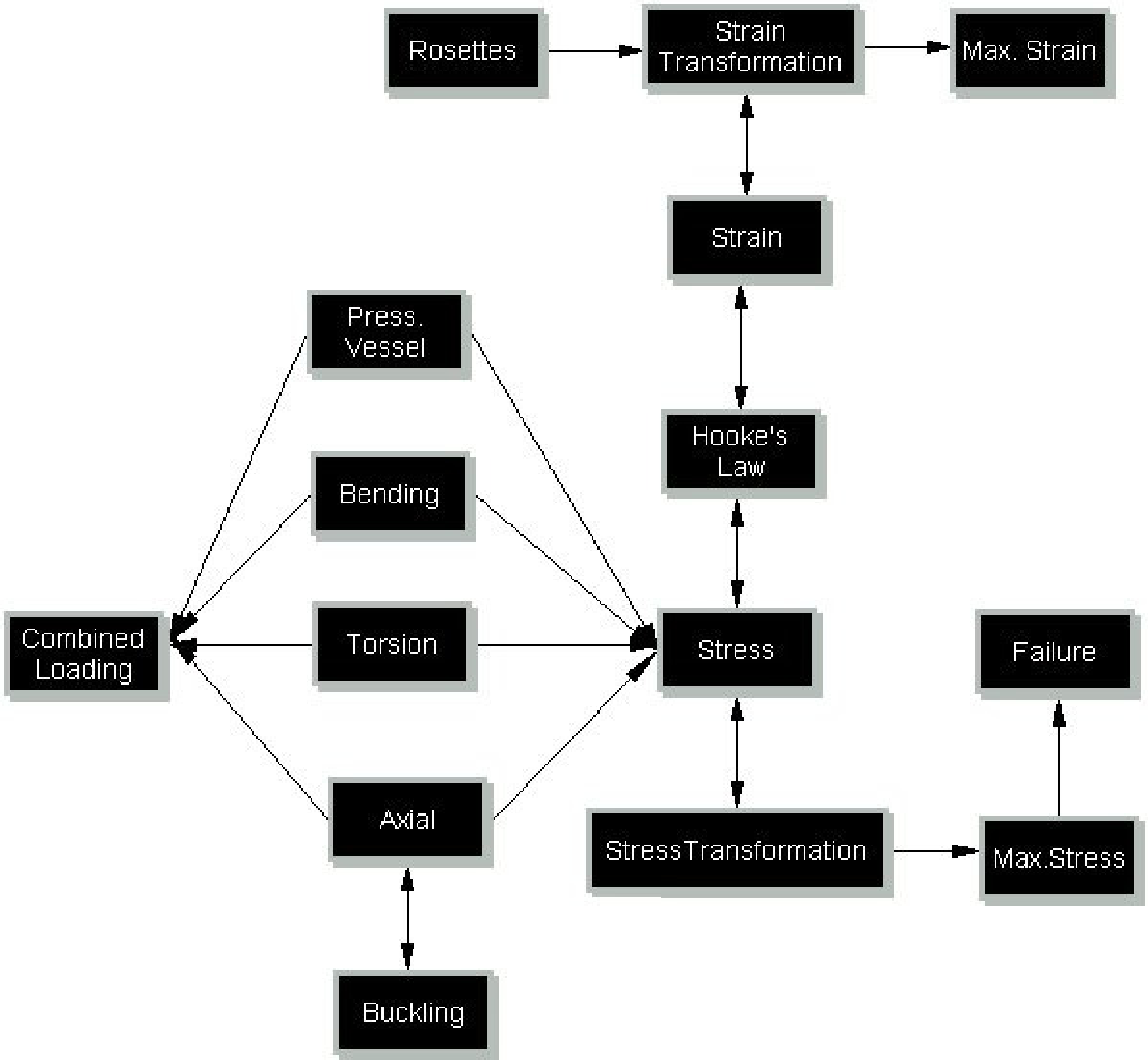

Figure-2: Mechanics of Materials schema.

By comparing Fig.-1 and Fig-2., you will discover that the load and geometry are replaced by the following:

- Pressure Vessels – contains force, diameter of the vessel and thickness of the skin of the vessel.
- Bending – contains force, moment, and certain area properties of the cross section of the beam.
- Torsion – contains torque and certain area properties of the cross section of the shaft.
- Axial Loading and Buckling – contains force, certain area properties of the cross section of the column, and material property of the column.
- Combined Loading – a combination of the four afore-mentioned cases.
- The stress and strain boxes are further extended with transformation equations, maxima calculations and failure.

If you wish, you can insert appropriate equations in each box to build a comprehensive and organized knowledge base for the entire Mechanics of Materials course.

Now we will summarize a few key issues of analysis and application for each kind of loading-geometry combination.

What are Cuts?

To calculate the stress at a point, we take an imaginary cut across the material through that point. This imaginary cut slices through all the molecular bonds and exposes the force-moment-torque that the bonds support. The force-moment-torque supported by the bonds is calculated by enforcing the equilibrium conditions (force balance and moment balance) on the piece to the right of the cut or the piece to the left of the cut.

What are Sections in Axial and Torsional Loading Problems?

For these problems, a shaft or a column first is broken into multiple sections. The section boundaries are determined as follows:

- The left end and the right end of the shaft/column are the two obvious section boundaries.
- From the schema of Fig.-1, stress changes whenever the loading changes or the geometry (namely the diameter of shaft/column) changes. Therefore, any location on the shaft/column with loading or geometry change is a section boundary.
- A section is a piece of the shaft/column between two section boundaries.
- In each section you take a cut, enforce the equilibrium conditions, determine the force-moment-torque supported by the molecular bonds at the cut, and determine the stress at the cut. This stress remains constant within the section.

What are Shear and Bending Moment Diagrams in Bending Problems?

Ideally, you must take infinite number of cuts along the length of a beam and calculate the force-moment supported by the molecular bonds at each of this infinite number of cuts. This task of calculating force-moment at infinite number of cuts is performed by a mathematical analysis. This analysis yields the variation of force-moment along the beam. The force variation is called the shear diagram and the moment variation is called the bending moment diagram. From these diagrams, you can calculate the stress variation along the beam.

Pressure Vessels

For these problems, a cut is taken along a plane through the diameter of a cylindrical or spherical pressure vessel.

Combined Loading

Take a cut across the section where you want to calculate stress. Transfer all forces and couples to the centroid of this section. Couples transfer without any change and forces transfer as a force-couple combination. Add all forces and couples to determine net force and net couple. Examine the components of the net force and identify each component as axial or shear. Examine the components of the net moment and identify each as torsion or bending moment. Consider each component and apply appropriate formula, axial or torsion or bending, to calculate the stresses. Add all stresses up and you have solved a combined loading problem.