

Introduction to FEM

7

FEM Modeling: Introduction

FEM Terminology

degrees of freedom (abbrv: DOF)

state (primary) variables: displacements in mechanics

conjugate variables: forces in mechanics

stiffness matrix

master stiffness equations

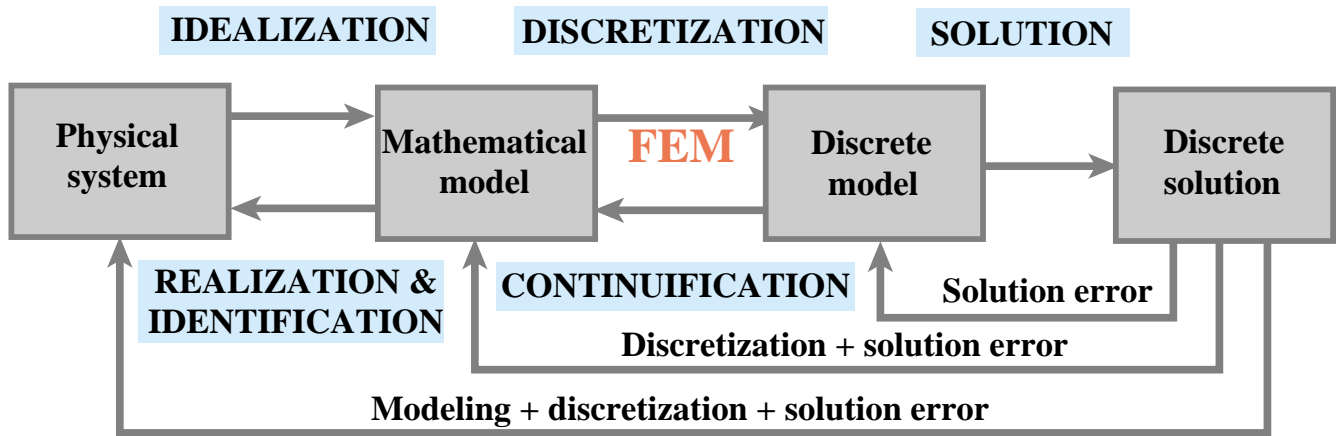
$$\mathbf{K} \mathbf{u} = \mathbf{f}$$

$$\mathbf{K} \mathbf{u} = \mathbf{f}_M + \mathbf{f}_I$$

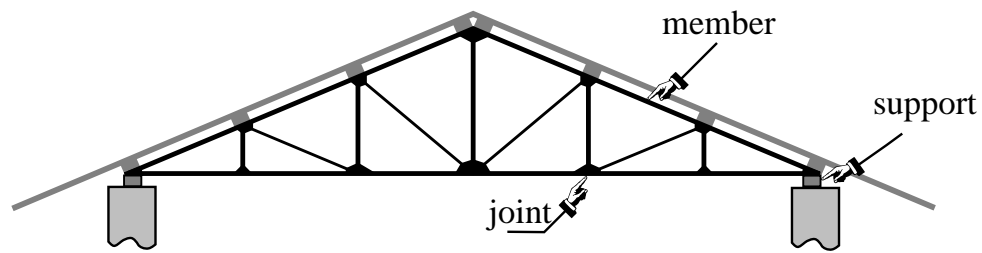
Physical Significance of Vectors \mathbf{u} and \mathbf{f} in Miscellaneous FEM Applications

<i>Application Problem</i>	<i>State (DOF) vector \mathbf{u} represents</i>	<i>Forcing vector \mathbf{f} represents</i>
Structures and solid mechanics	Displacement	Mechanical force
Heat conduction	Temperature	Heat flux
Acoustic fluid	Displacement potential	Particle velocity
Potential flows	Pressure	Particle velocity
General flows	Velocity	Fluxes
Electrostatics	Electric potential	Charge density
Magnetostatics	Magnetic potential	Magnetic intensity

The FEM Simulation Process



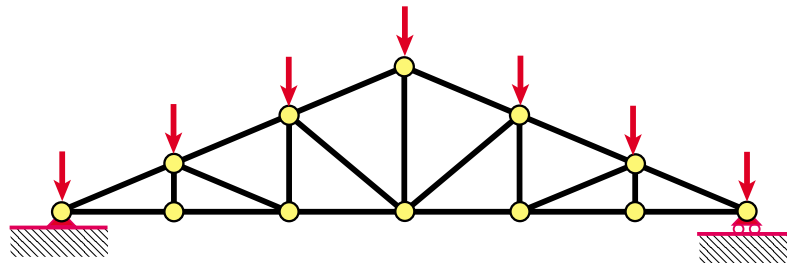
Idealization



Physical System



IDEALIZATION



Mathematical Model

Mathematical Model Definition

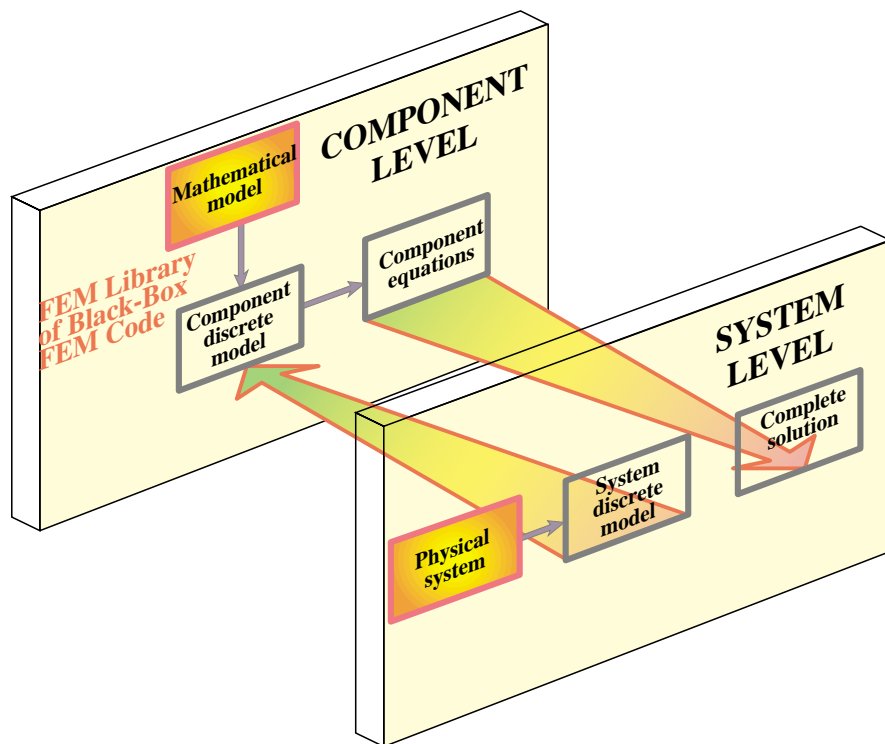
Traditional definition

*Scaled fabricated version of a physical system
(think of a car or train model)*

Simulation oriented definition

*A model is a symbolic device built to simulate
and predict aspects of behavior of a system*

Implicit Modeling



Recall the "Breakdown" DSM Steps

Breakdown { **Disconnection**
Localization
Member (Element) Formation

Let Stop Here and
Study Generic Elements next

... Because Most of the Remaining DSM Steps

Globalization

Merge

Application of BCs

Solution

Recovery of Node Forces

are **Element Independent**

Attributes of Mechanical Finite Elements

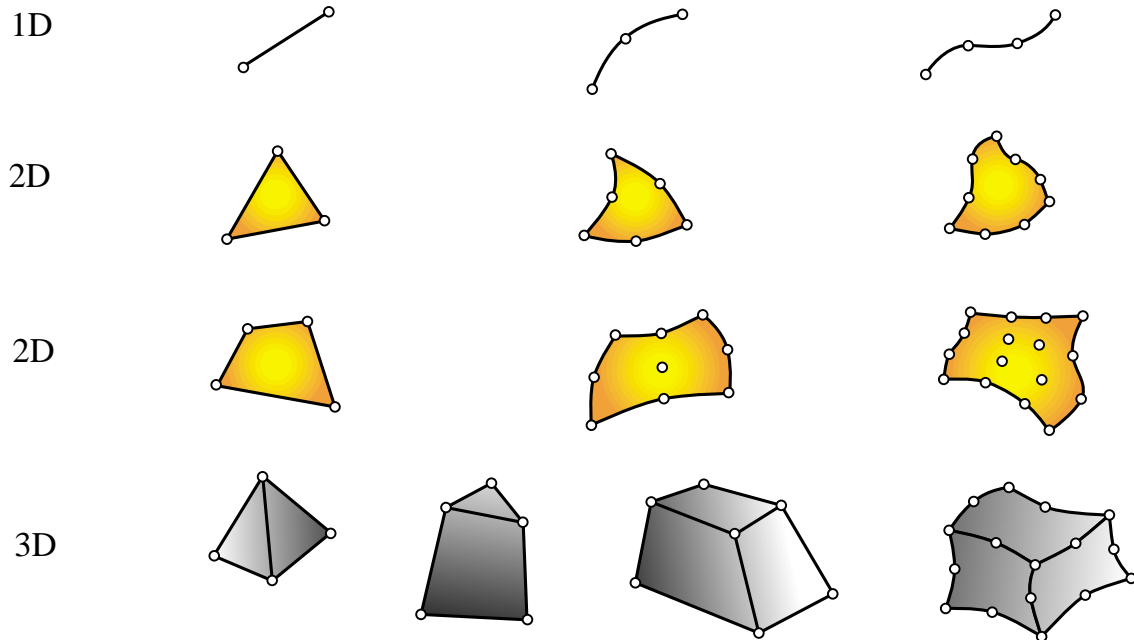
Dimensionality

Nodes serve two purposes
geometric definition
home for DOFs (connectors)

Degrees of freedom (DOFs) or "freedoms"
Conjugate node forces

Material properties
Fabrication properties

Element Geometry Is Defined by Node Locations



Classification of Mechanical Finite Elements

Primitive Structural

Continuum

Special

Macroelements

Substructures

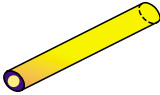

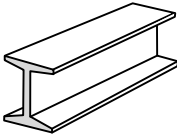

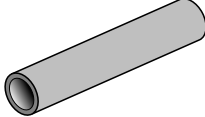

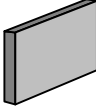

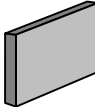
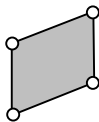


Superelements

Primitive Structural Elements

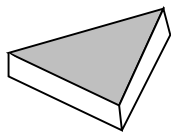
(often built from MoM models)

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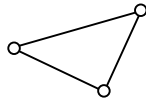
Physical Structural Component	Mathematical Model Name	Finite Element Discretization
	bar	
	beam	
	tube, pipe	
	spar (web)	
	shear panel (2D version of above)	

Continuum Elements

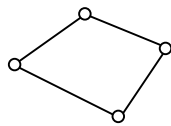
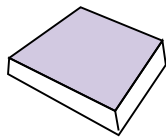
Physical



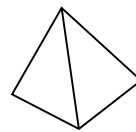
Finite element
idealization



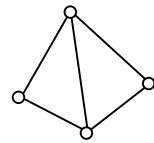
plates



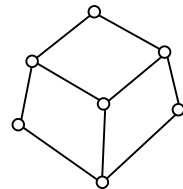
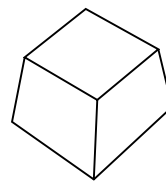
Physical



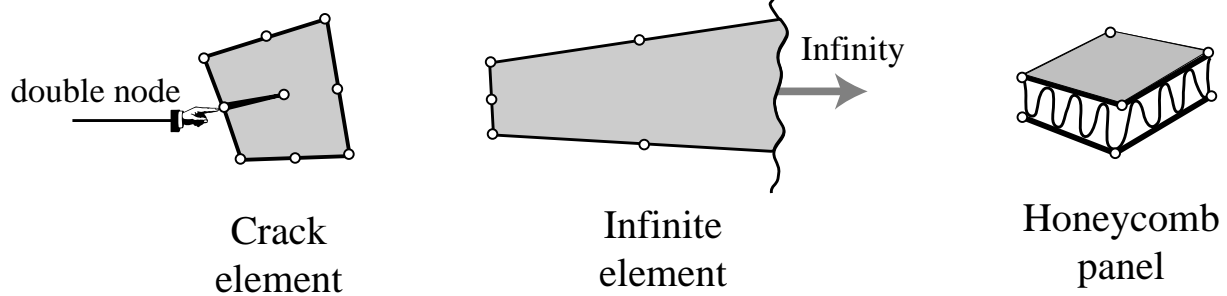
Finite element
idealization



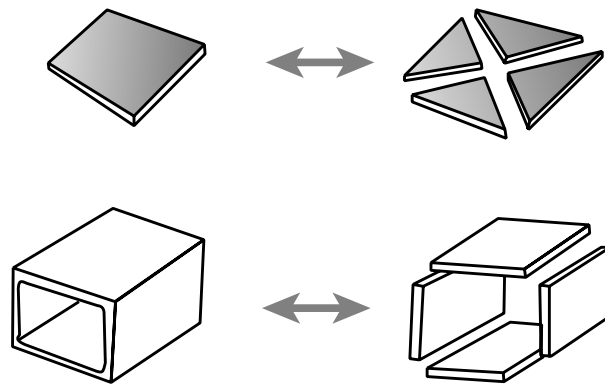
3D solids



Special Elements

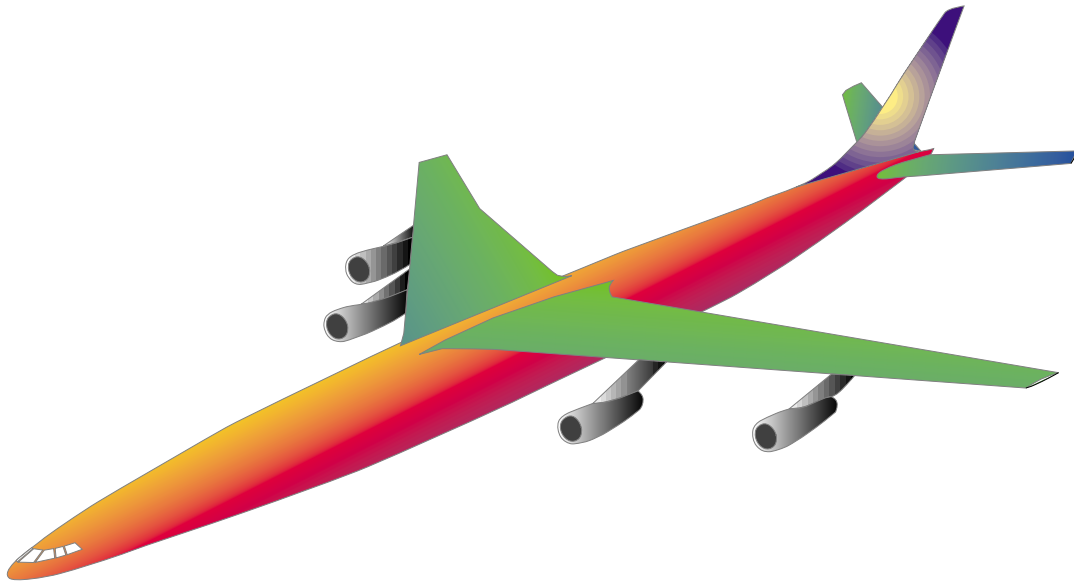


MacroElements

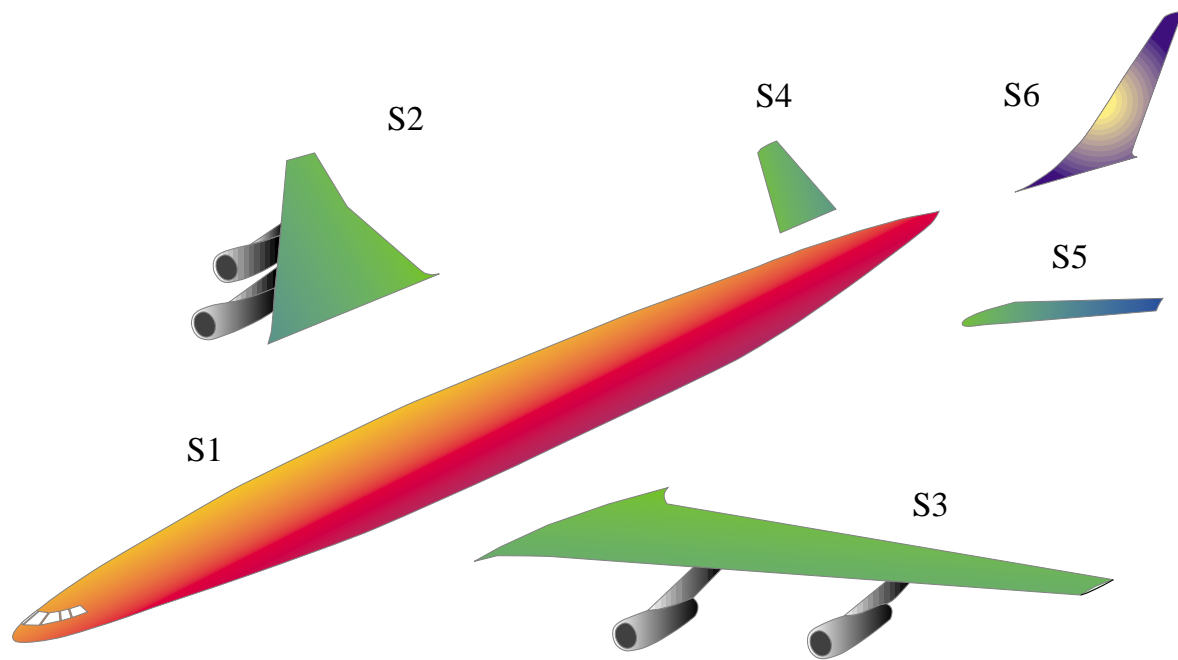


Introduction to FEM

Substructures



Substructures (cont'd)



Boundary Conditions (BCs)

**The most difficult topic for FEM
program users ("the devil hides on
the boundary")**

Two types

Essential
Natural

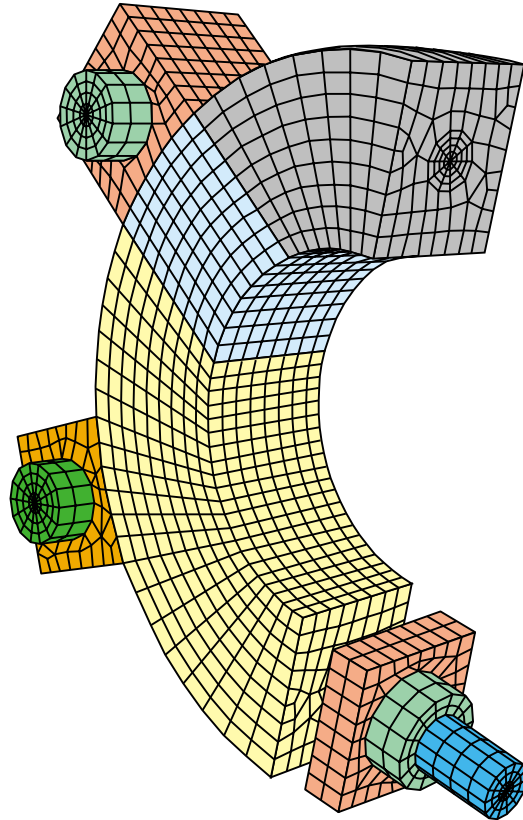
Boundary Conditions

Essential vs. Natural

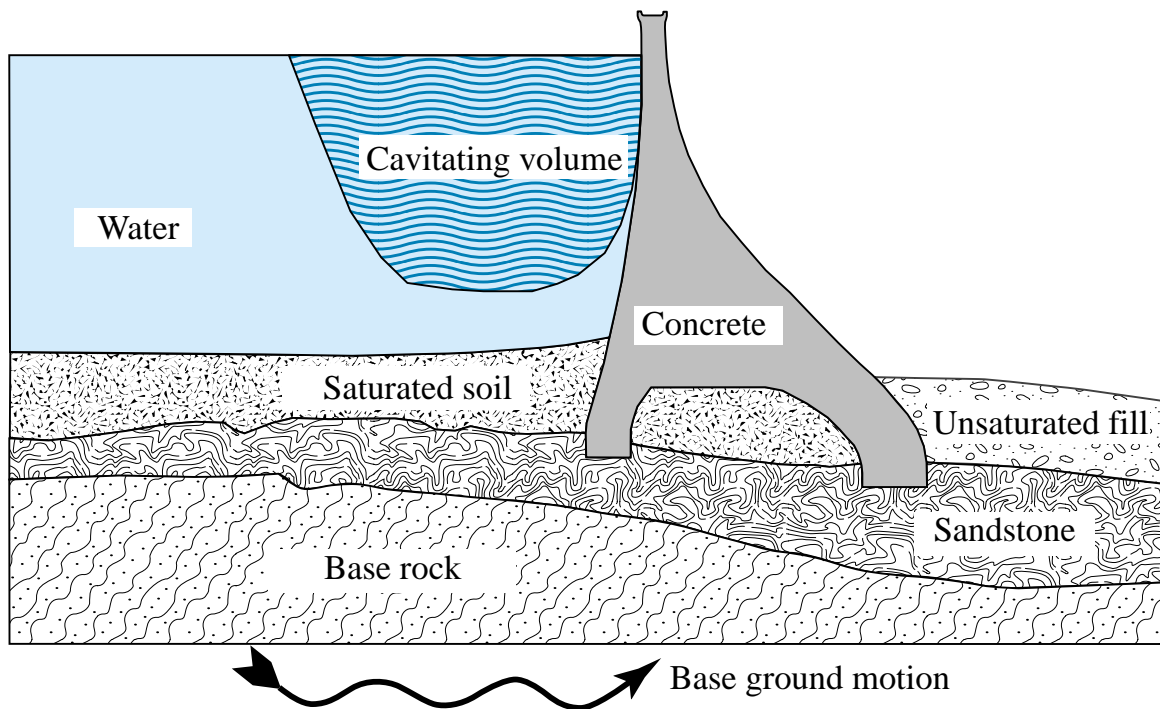
Recipe:

1. If a BC involves one or more DOF in a *direct* way, it is *essential* and goes to the **Left Hand Side (LHS)** of $Ku = f$
2. Otherwise it is *natural* and goes to the **Right Hand Side (RHS)** of $Ku = f$

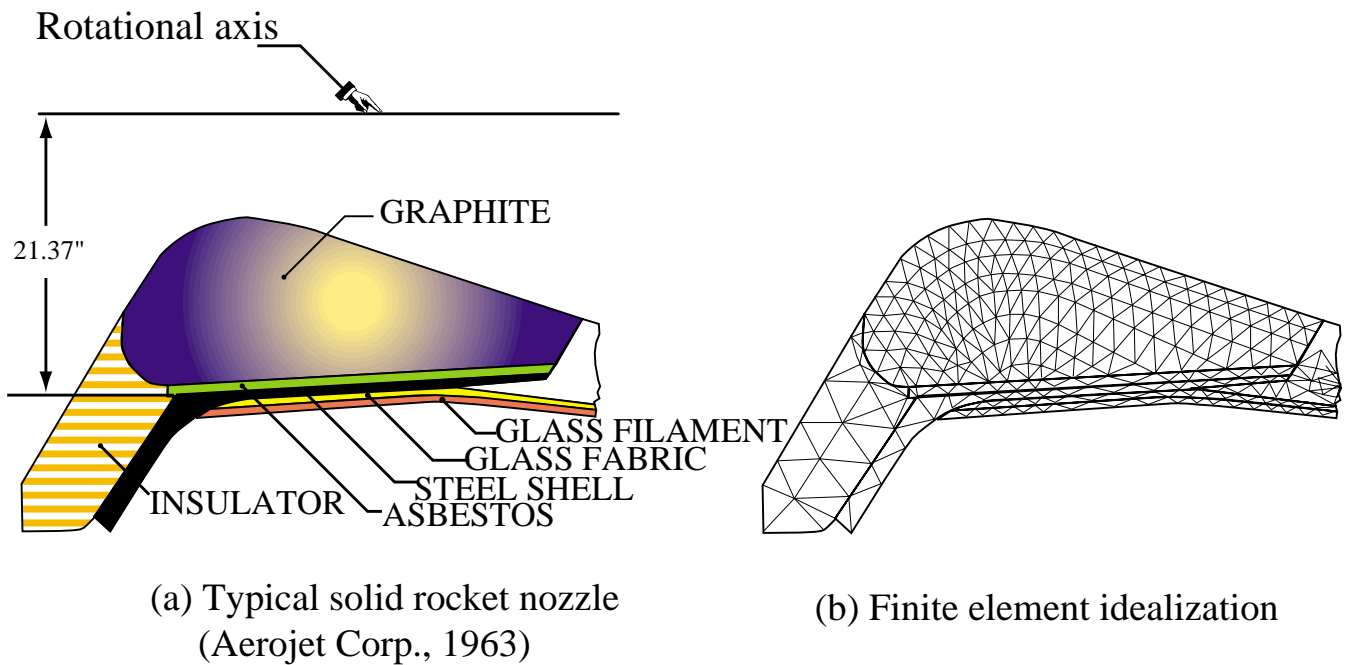
Examples of Structural Models: Machine Component (Mech. Engrg)



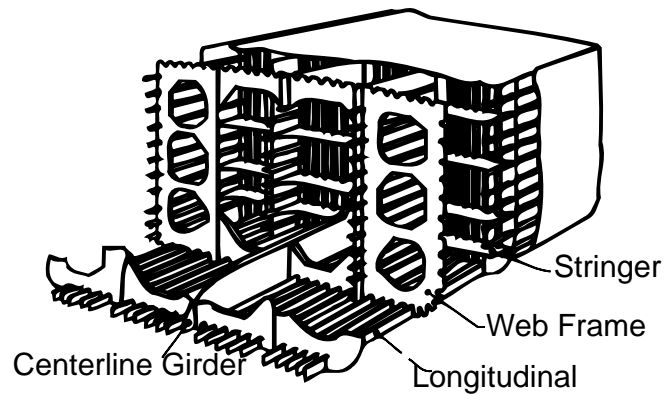
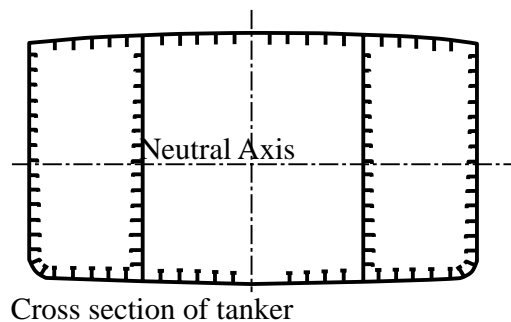
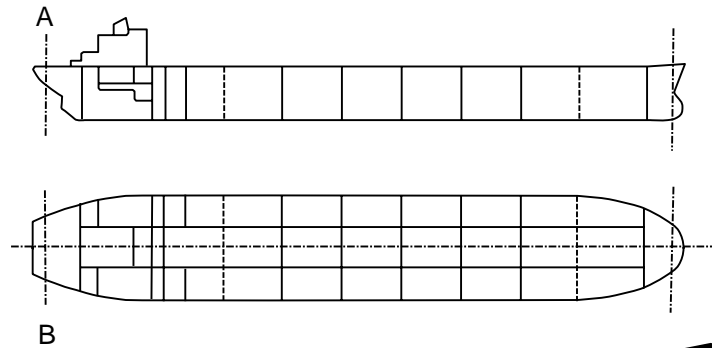
Examples of Structural Models: Dam under Ground Motion (Civil Engrg)



Examples of Structural Models: Rocket Nozzle (Aerospace Engrg)



Examples of Structural Models: SuperTanker (Marine Engrg)



Typical internal structure of tanker

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Examples of Structural Models: F16 External View (Aero)



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Examples of Structural Models: F16 Internal Structure (Aero)

