

lecture
three

equilibrium
and planar trusses



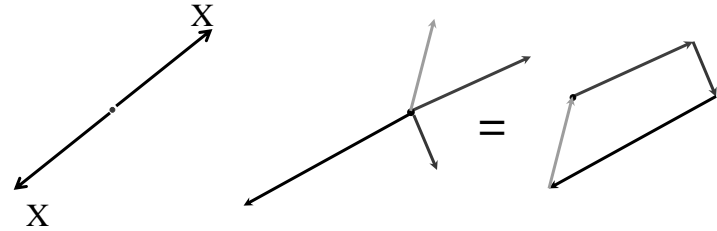
Equilibrium 1
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Equilibrium

- balanced
- steady
- resultant of forces on a particle is 0



Equilibrium 2
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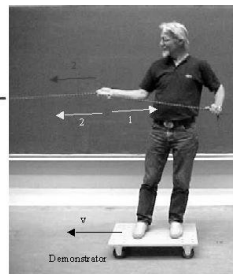
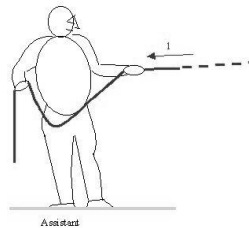
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Equilibrium on a Point

- analytically

$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$



<http://www.physics.umd.edu>

- Newton convinces us it will stay at rest

Equilibrium 6

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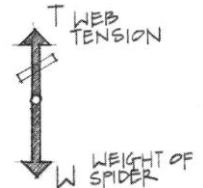
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Equilibrium on a Point

- collinear force system

– ex: cables

$$\sum F_{in-line} = 0$$



$$\left[R_x = \sum F_x = 0 \quad R_y = \sum F_y = 0 \right]$$

Equilibrium 7

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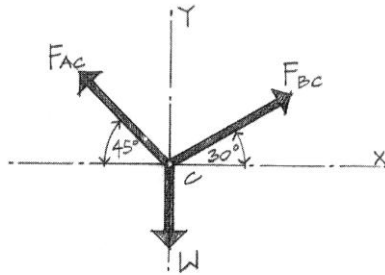
Equilibrium on a Point

- concurrent force system

– ex: cables

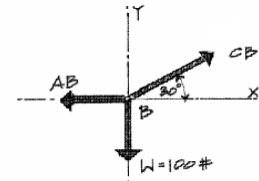
$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$



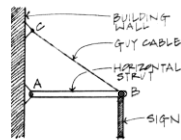
Free Body Diagram

- FBD (sketch)
- tool to see all forces on a body or a point including
 - external forces
 - weights
 - force reactions
 - internal forces

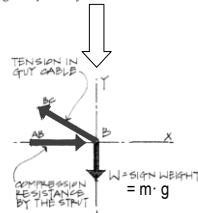


Free Body Diagram

- determine point
- FREE it from:
 - ground
 - supports & connections
- draw all external forces acting ON the body
 - reactions
 - (supporting forces)
 - applied forces
 - gravity



Sign suspended from a strut and cable.



FBD of concurrent point B.

Free Body Diagram

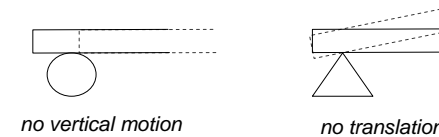
- sketch FBD with relevant geometry
- resolve each force into components
 - known & unknown angles – name them
 - known & unknown forces – name them
- are any forces related to other forces?
- for the unknowns
- write only as many equilibrium equations as needed
- solve up to 2 equations

Free Body Diagram

- solve equations
 - most times 1 unknown easily solved
 - plug into other equation(s)
- common to have unknowns of
 - force magnitudes
 - force angles

Force Reactions

- result of applying force
- unknown size
- connection or support type
 - known direction
 - related to motion prevented



Friction

- resistance to movement
- contact surfaces determine μ
- proportion of normal force (\perp)
 - opposite to slide direction
 - static > kinetic

$$F = \mu N$$

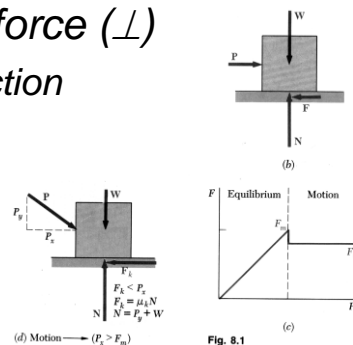
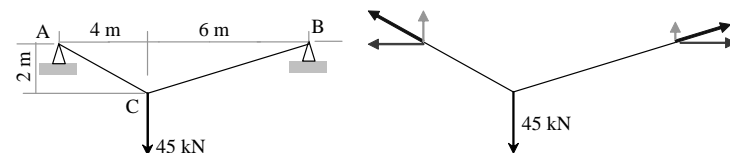


Fig. 8.1

Cable Reactions

- equilibrium:
 - more reactions (4) than equations
 - but, we have slope relationships
 - X component the same everywhere



Cable-Stayed Structures

- diagonal cables support horizontal spans
- typically symmetrical
- Patcenter, Rogers 1986



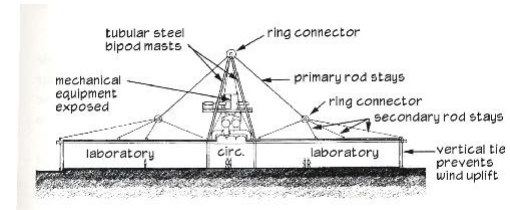
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Patcenter, Rogers 1986

- column free space
- roof suspended
- solid steel ties
- steel frame supports masts



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Patcenter, Rogers 1986

- dashes – cables pulling

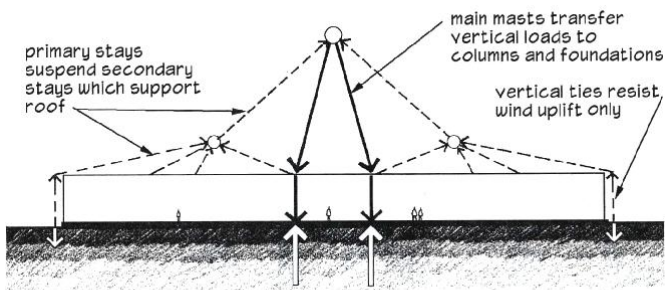


Figure 3.5: Patcenter, load path diagram.

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Truss Structures

- ancient (?) wood
– Romans 500 B.C.
- Renaissance revival
- 1800's analysis
- efficient



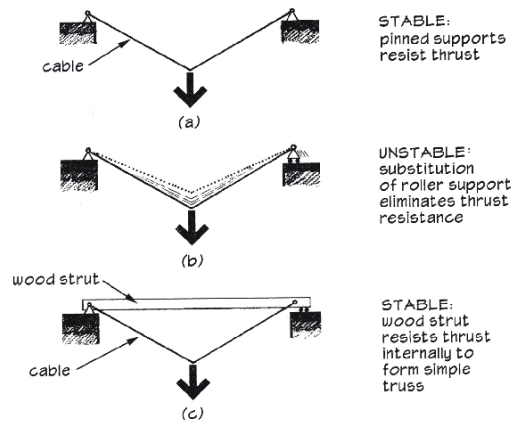
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Truss Structures

– analogous to cables and struts



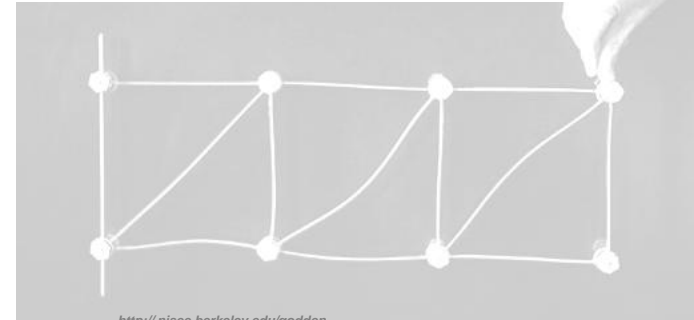
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Truss Structures

- comprised of straight members
- geometry with triangles is stable
- loads applied only at pin joints



<http://nisee.berkeley.edu/godden>

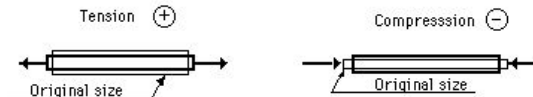
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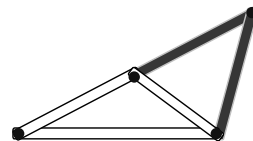
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Truss Structures

- 2 force members
 - forces in line, equal and opposite
 - compression
 - tension



- 3 members connected by 3 joints
- 2 more members need 1 more joint $b = 2n - 3$



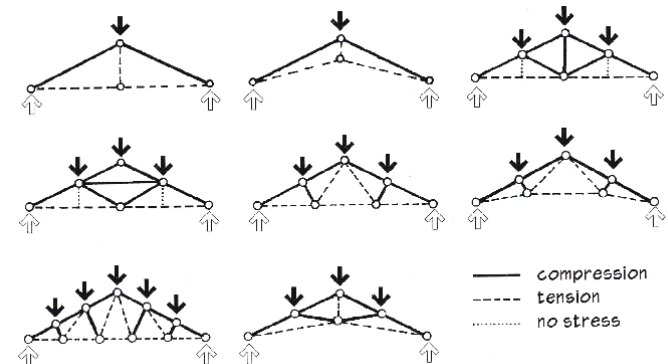
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Truss Structures

- compression and tension



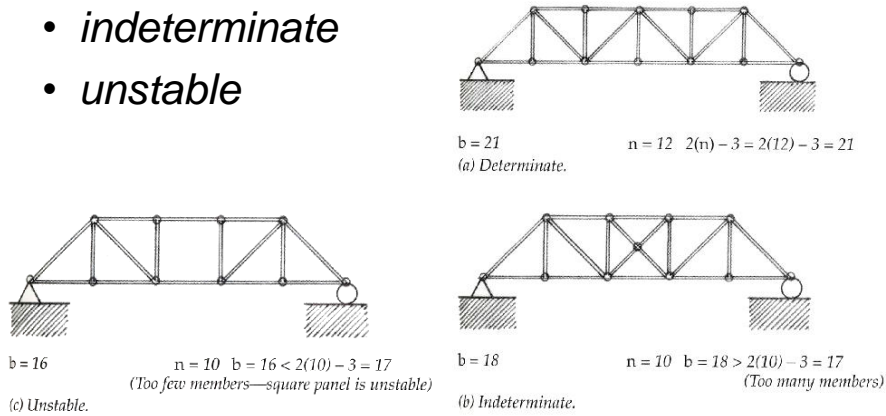
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Truss Structures

- statically determinate
- indeterminate
- unstable



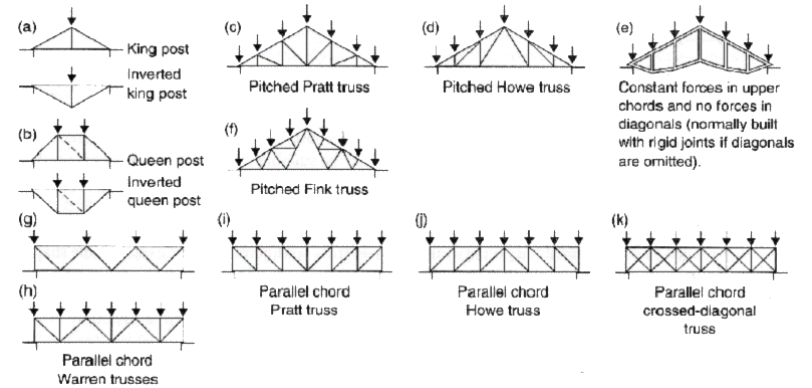
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Trusses

- common designs



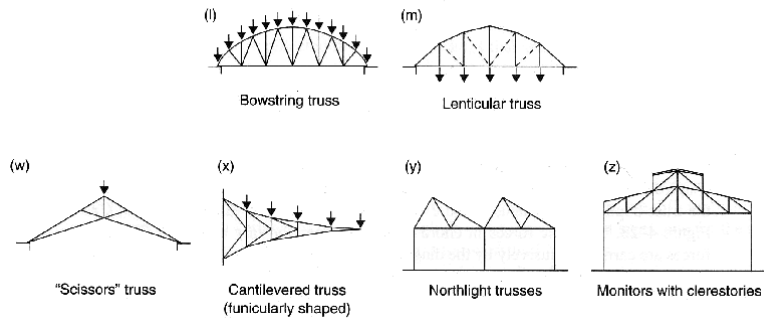
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Trusses

- common designs



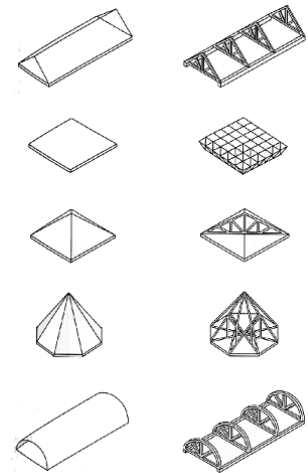
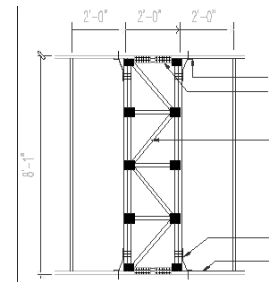
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Trusses

- uses
 - roofs & canopies
 - long spans
 - lateral bracing



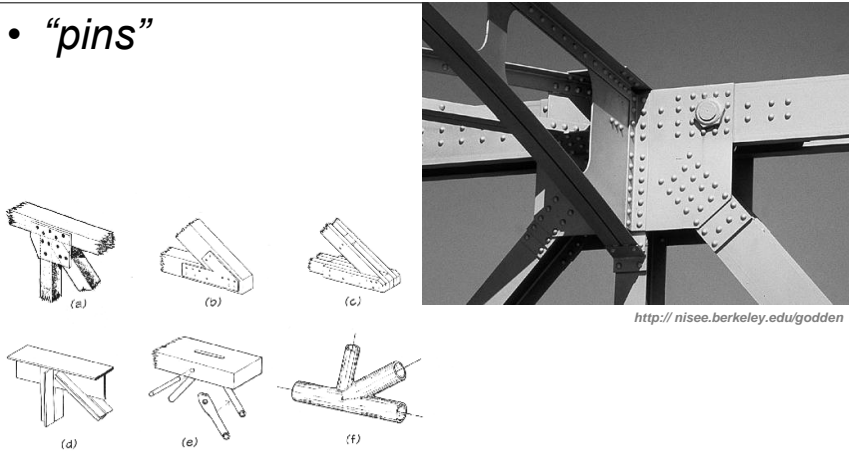
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Truss Connections

- “pins”



<http://nisee.berkeley.edu/godden>

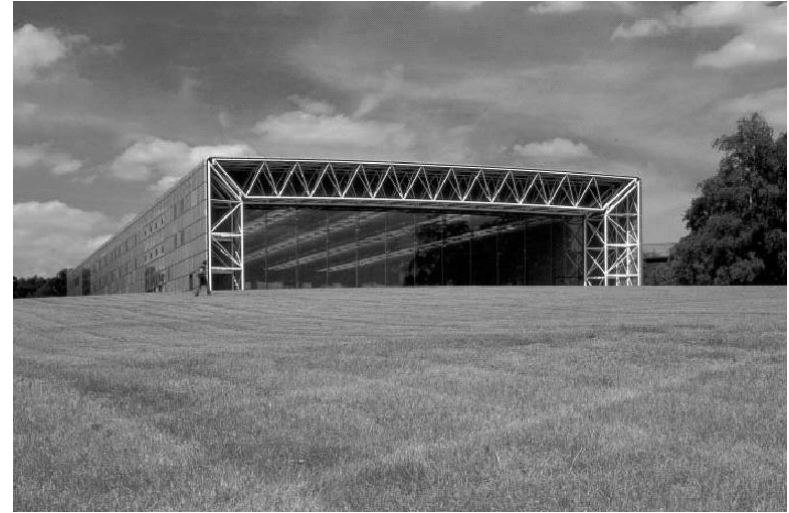
Figure 4.8: Truss joints.

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Sainsbury Center, Foster 1978

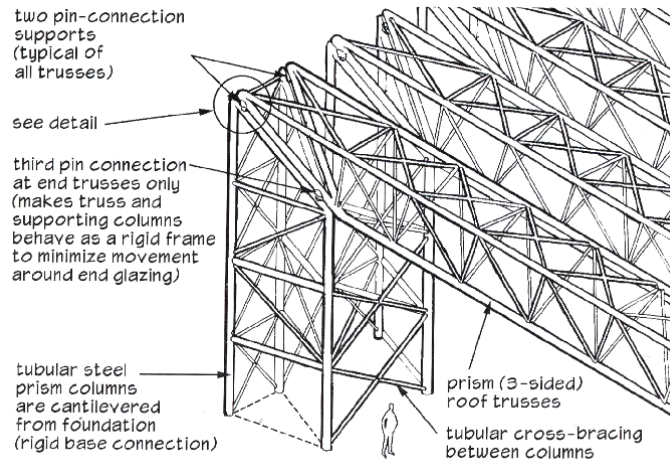


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Sainsbury Center, Foster 1978



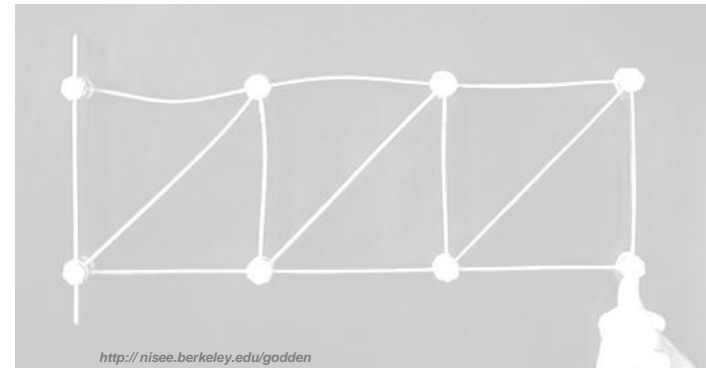
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Truss Analysis

- visualize compression and tension from deformed shape



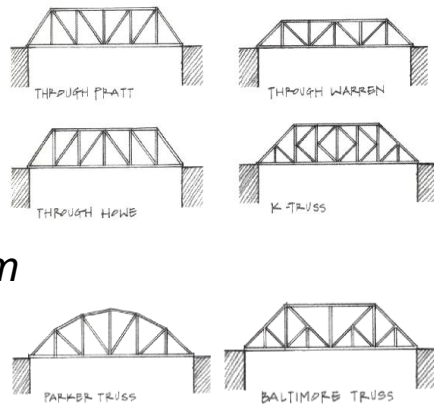
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Truss Analysis

- Method of Joints
- Graphical Methods
- Method of Sections
- all rely on equilibrium
 - of bodies
 - internal equilibrium



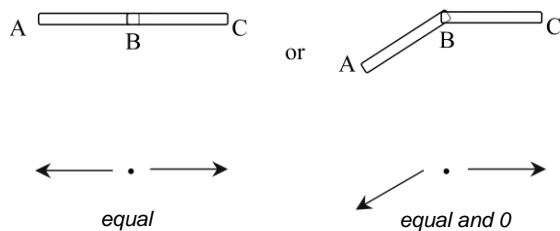
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Joint Cases

- two bodies connected



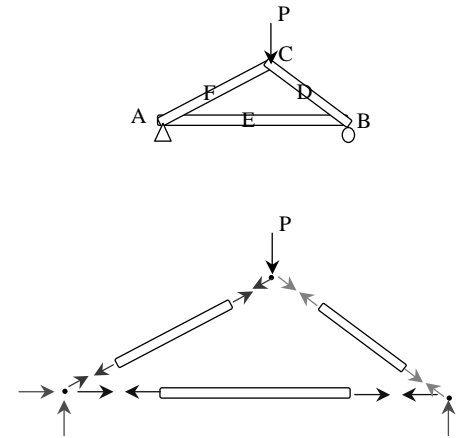
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Method of Joints

- isolate each joint
- enforce equilibrium in F_x and F_y
- can find all forces
- long
- easy to mess up



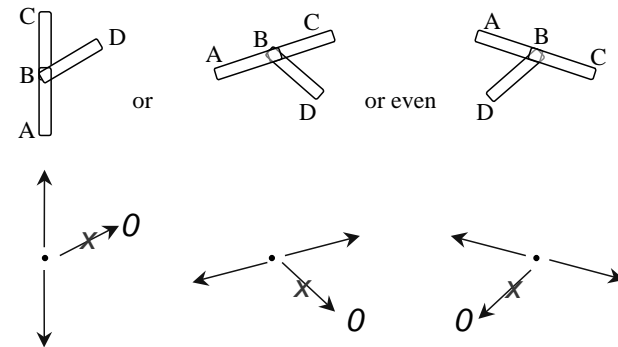
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Joint Cases

- three bodies with two in line



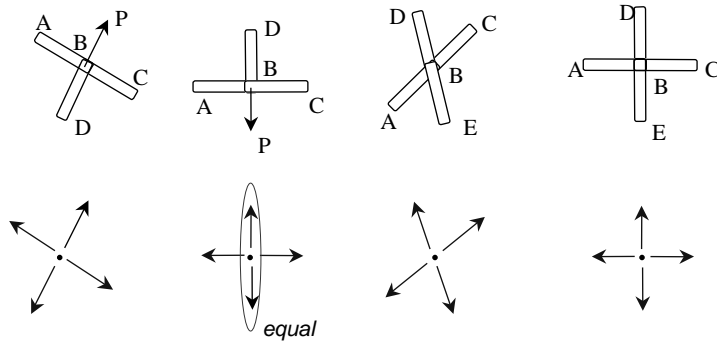
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Joint Cases

- crossed



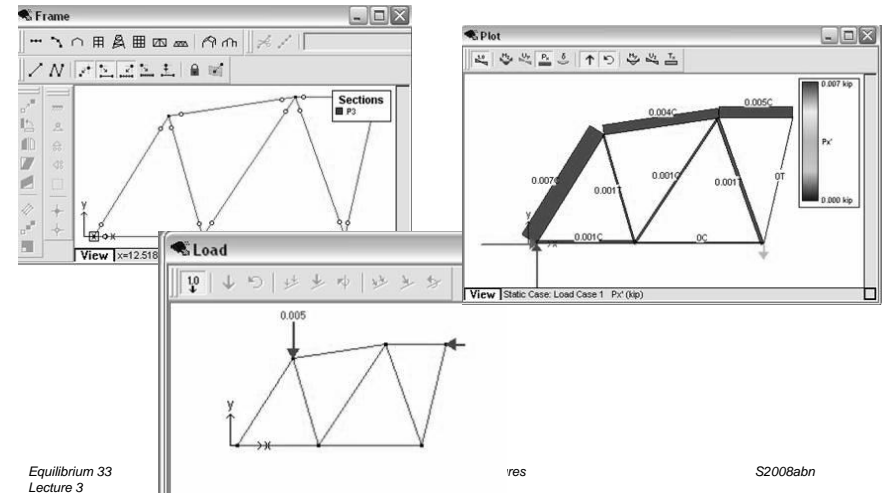
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Tools – Multifram

- in computer lab



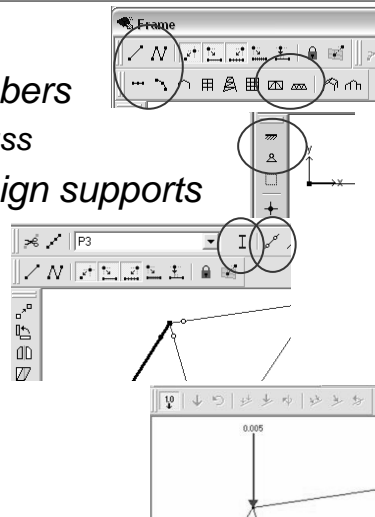
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Lecture 3

yes

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Tools – Multifram

- frame window
 - define truss members
 - or pre-defined truss
 - select points, assign supports
 - select members, assign section & assign pin ends
- load window
 - select points, add point load



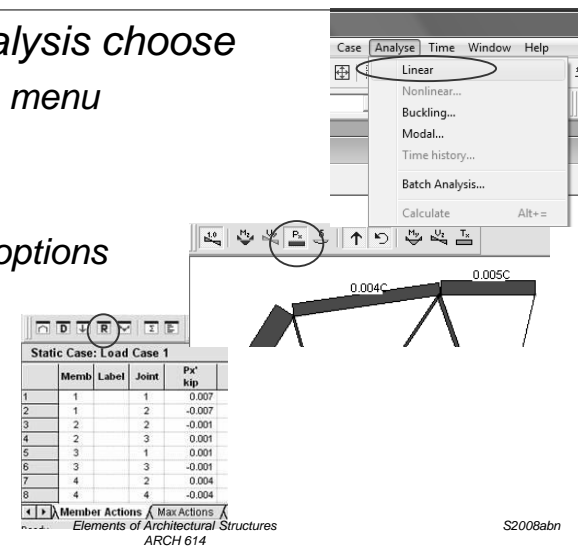
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Tools – Multifram

- to run analysis choose
 - Analysis menu
 - Linear
- plot
 - choose options
- results
 - choose options



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