

# ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 331  
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SPRING 2013

## lecture four

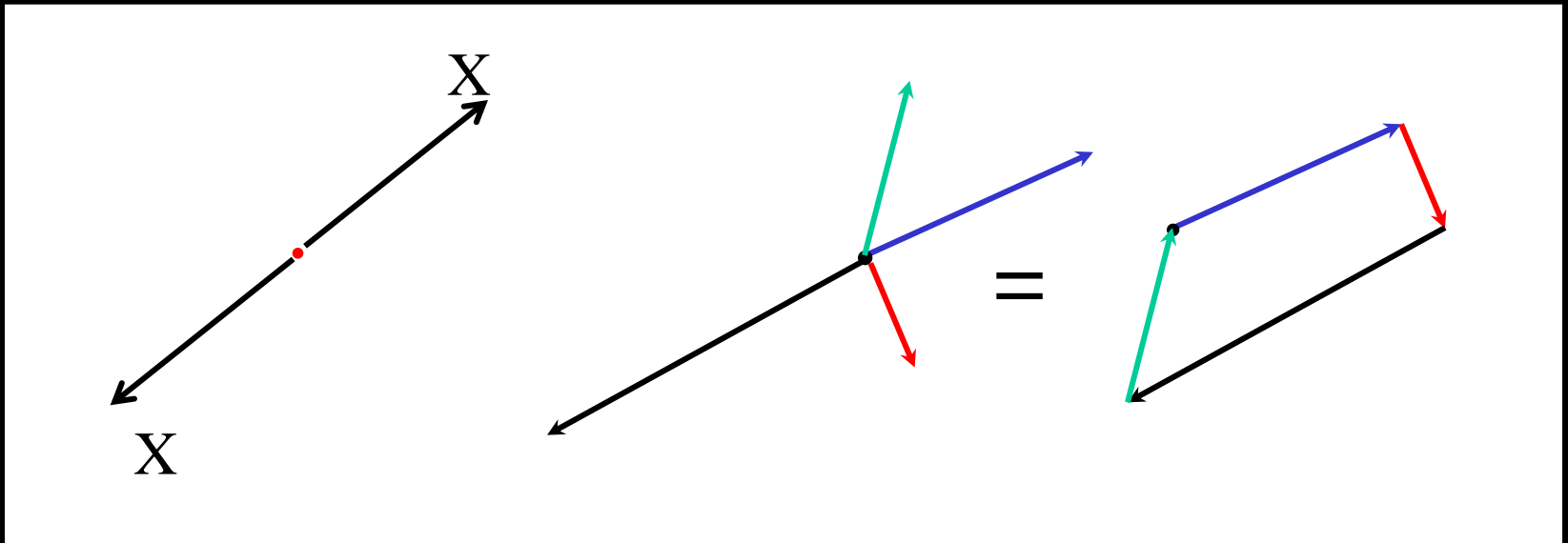


<http://nisee.berkeley.edu/godden>

# point equilibrium and planar trusses

# Equilibrium

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

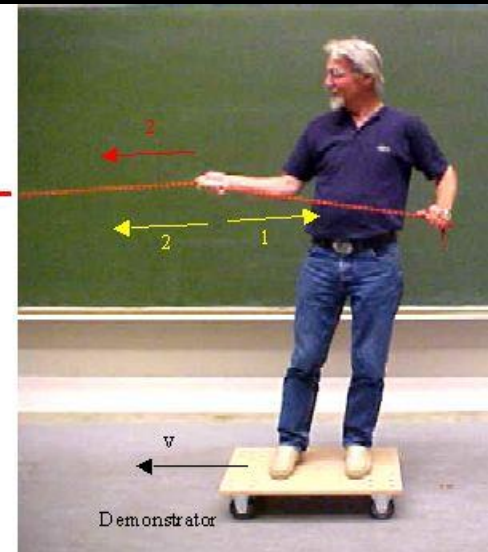
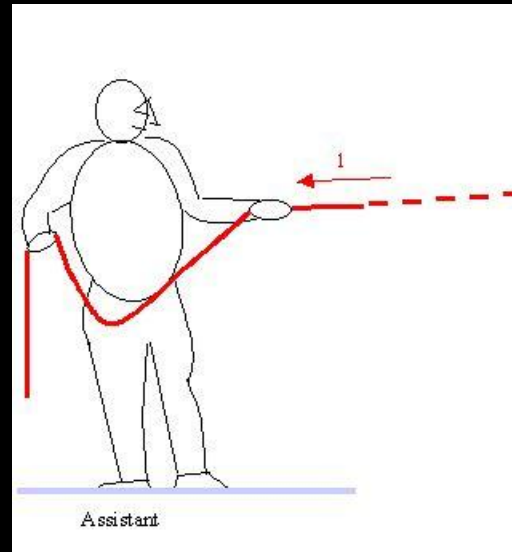


# Equilibrium on a Point

- analytically

$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$



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

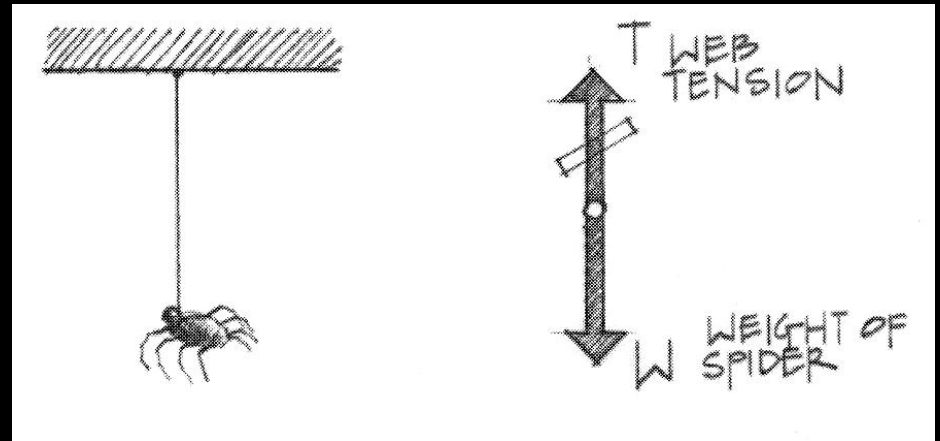
- Newton convinces us it will stay at rest

# Equilibrium on a Point

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- *collinear force system*
  - *ex: cables*

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



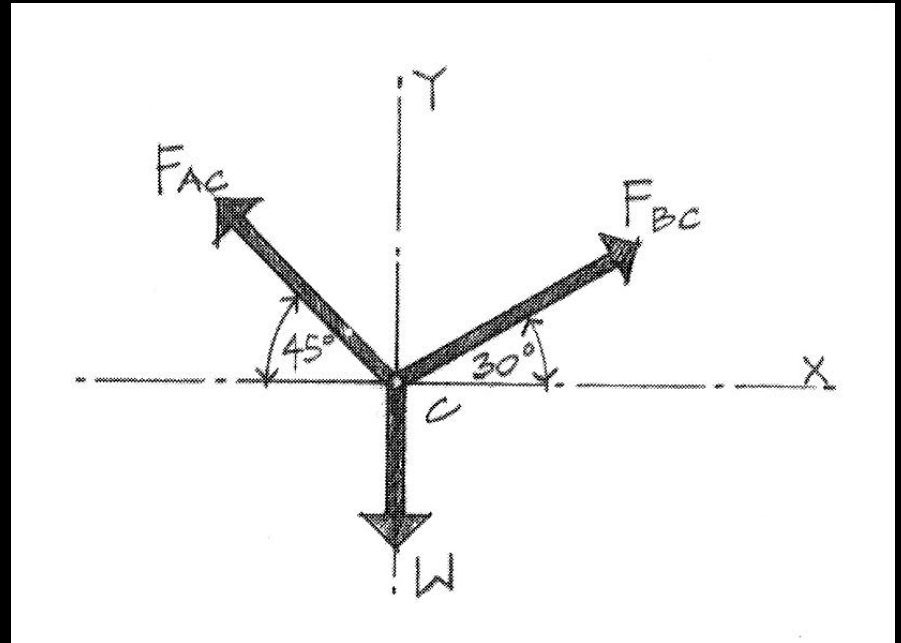
$$\left[ R_x = \sum F_x = 0 \qquad R_y = \sum F_y = 0 \right]$$

# Equilibrium on a Point

- *concurrent force system*
  - *ex: cables*

$$R_x = \sum F_x = 0$$

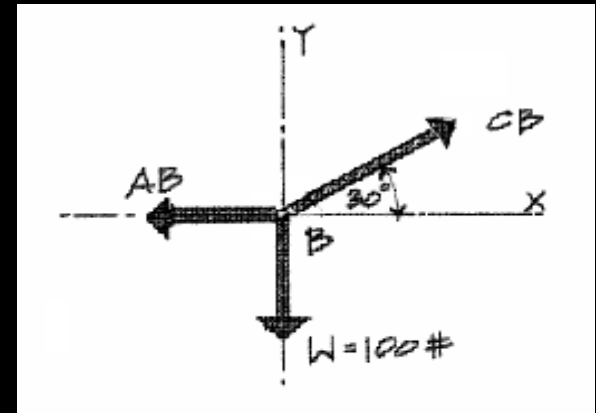
$$R_y = \sum F_y = 0$$



# Free Body Diagram

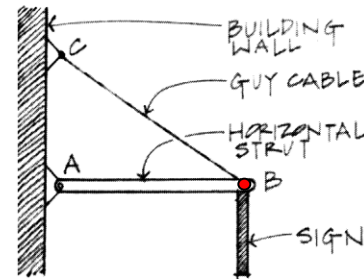
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- *FBD (sketch)*
- *tool to see all forces on a body or a point including*
  - *external forces*
  - *weights*
  - *force reactions*
  - *internal forces*

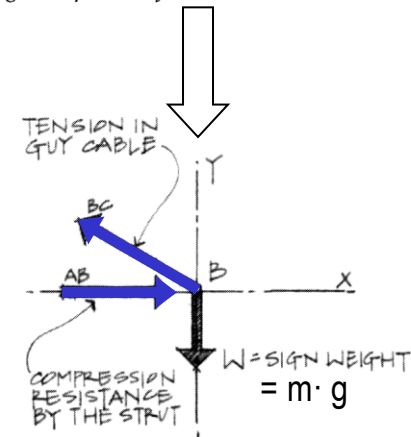


# Free Body Diagram

- *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

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- *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*

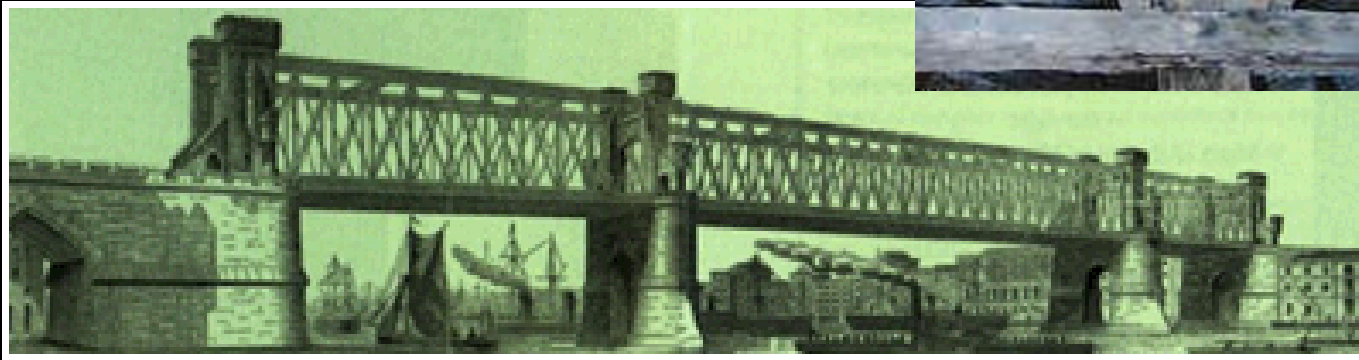
# *Free Body Diagram*

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

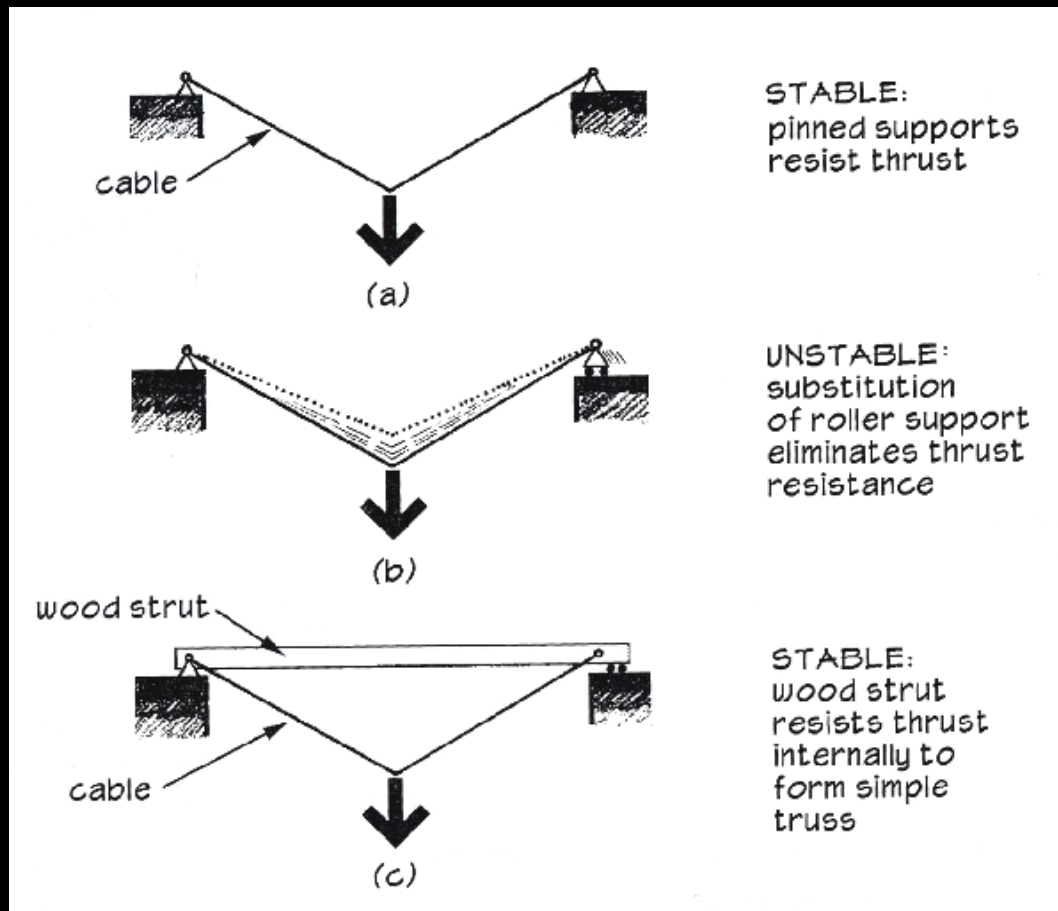
# Truss Structures

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



# Truss Structures

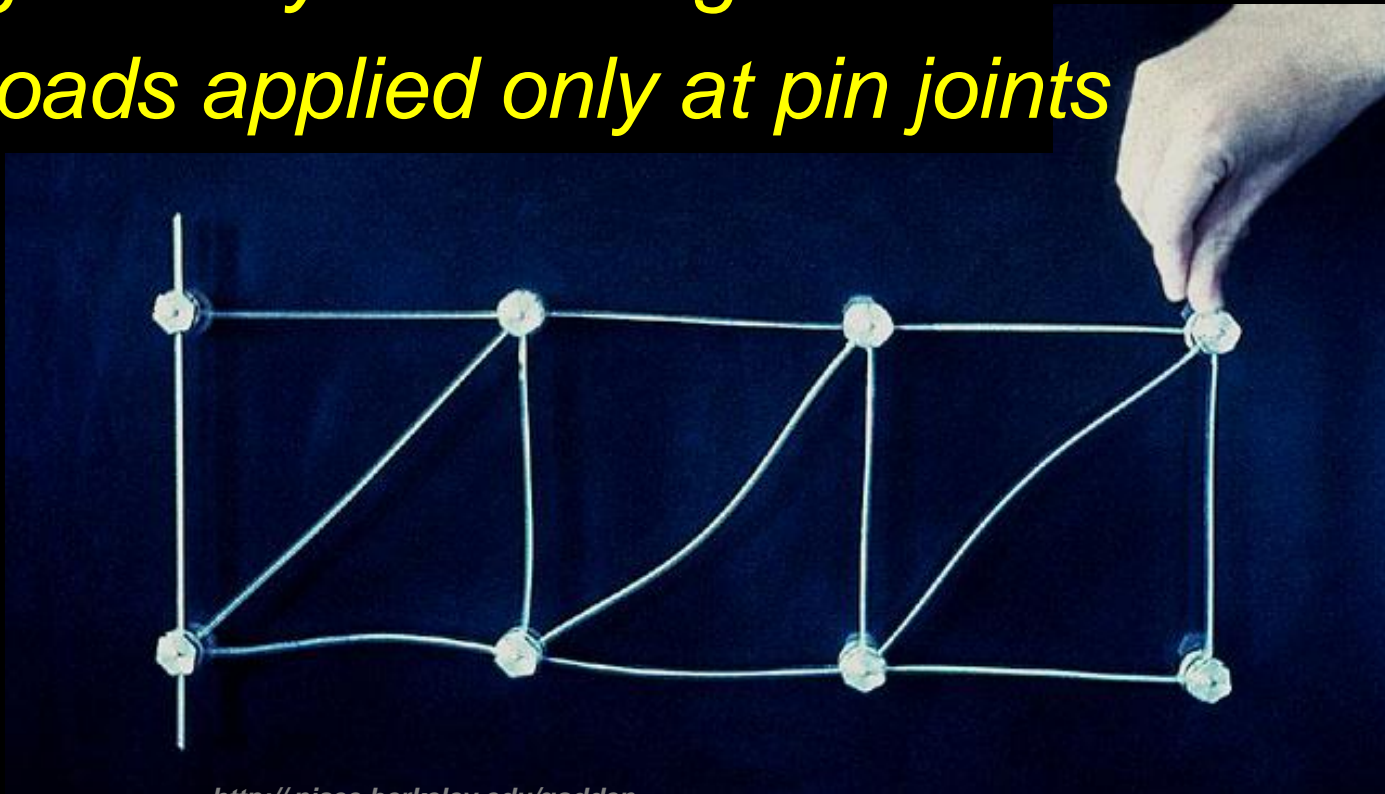
– *analogous to cables and struts*



# Truss Structures

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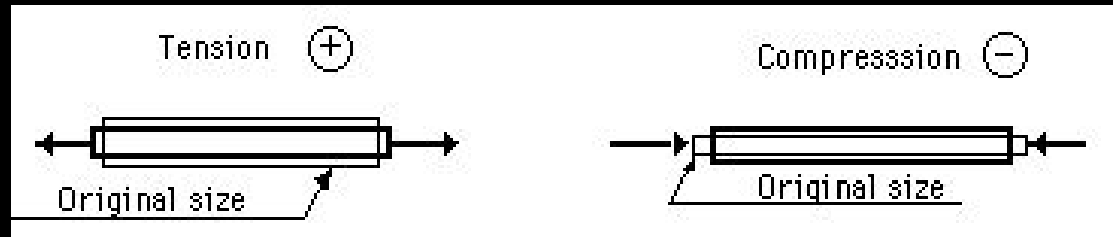
- *comprised of straight members*
- *geometry with triangles is stable*
- *loads applied only at pin joints*



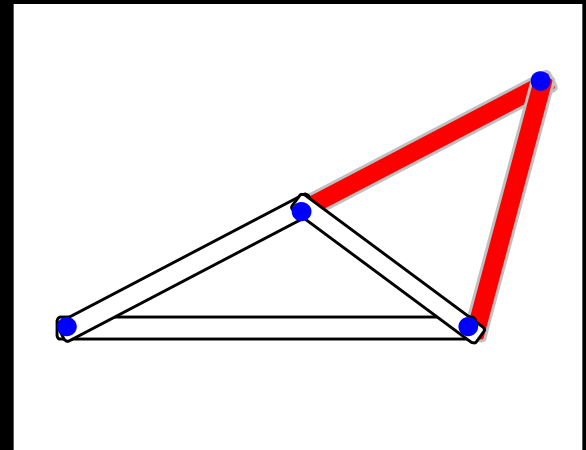
<http://nisee.berkeley.edu/godden>

# Truss Structures

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

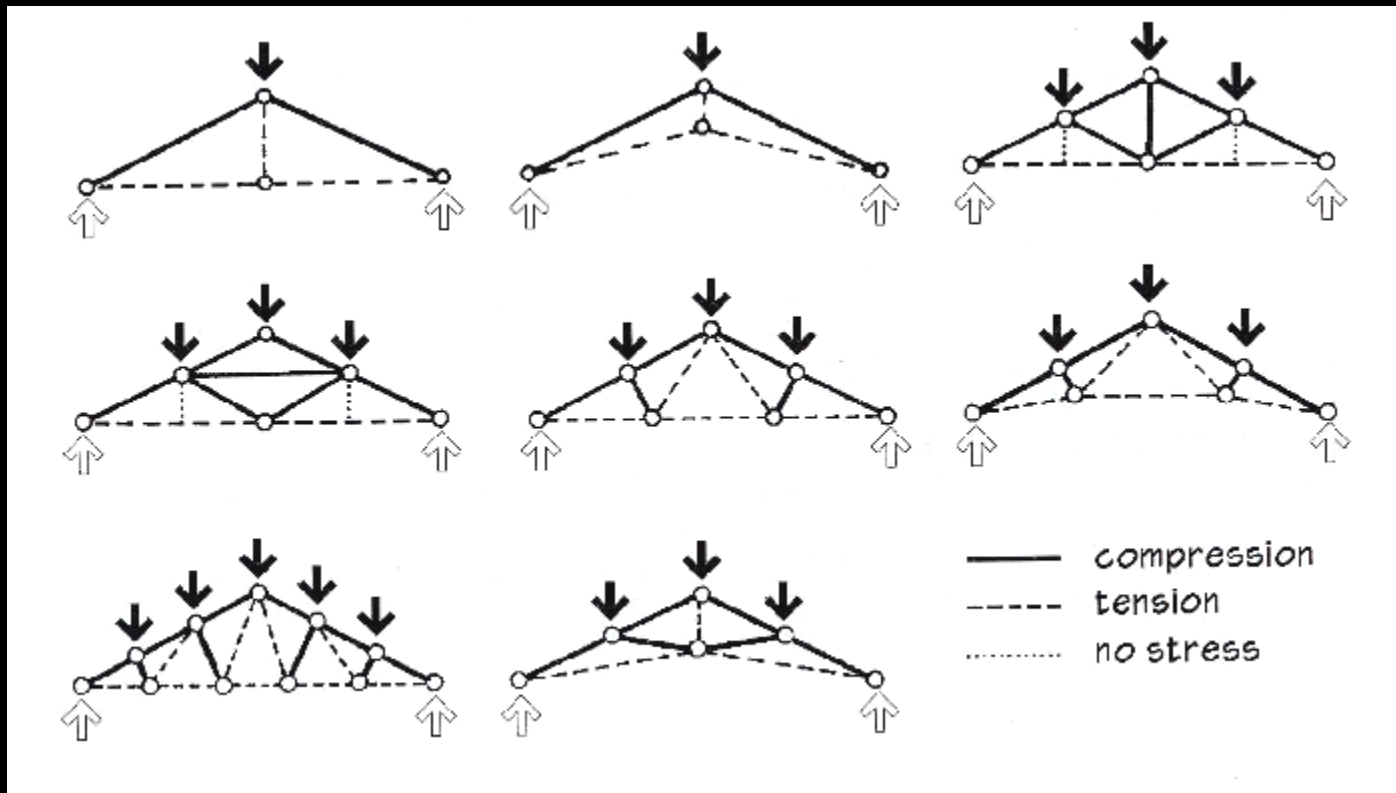


- 3 members connected by 3 joints
- 2 more members need 1 more joint  $b = 2n - 3$



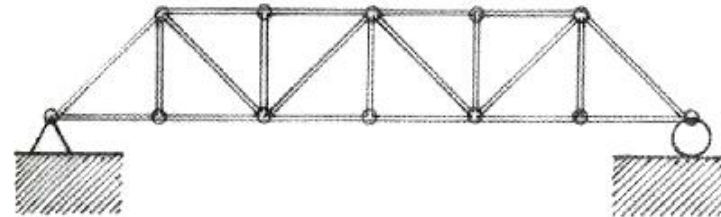
# Truss Structures

- compression and tension*



# Truss Structures

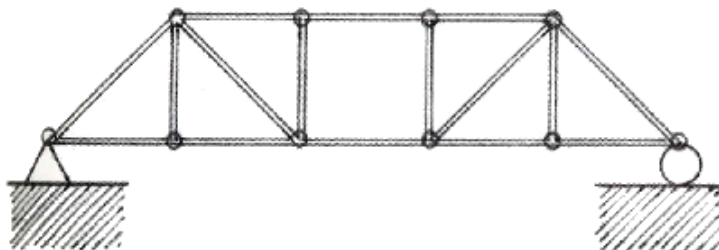
- *statically determinate*
- *indeterminate*
- *unstable*



$$b = 21$$

$$n = 12 \quad 2(n) - 3 = 2(12) - 3 = 21$$

(a) *Determinate.*

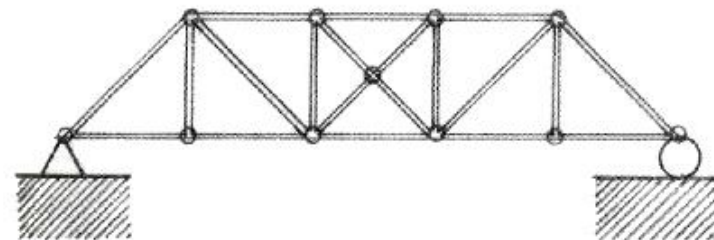


$$b = 16$$

$$n = 10 \quad b = 16 < 2(10) - 3 = 17$$

(Too few members—square panel is unstable)

(c) *Unstable.*



$$b = 18$$

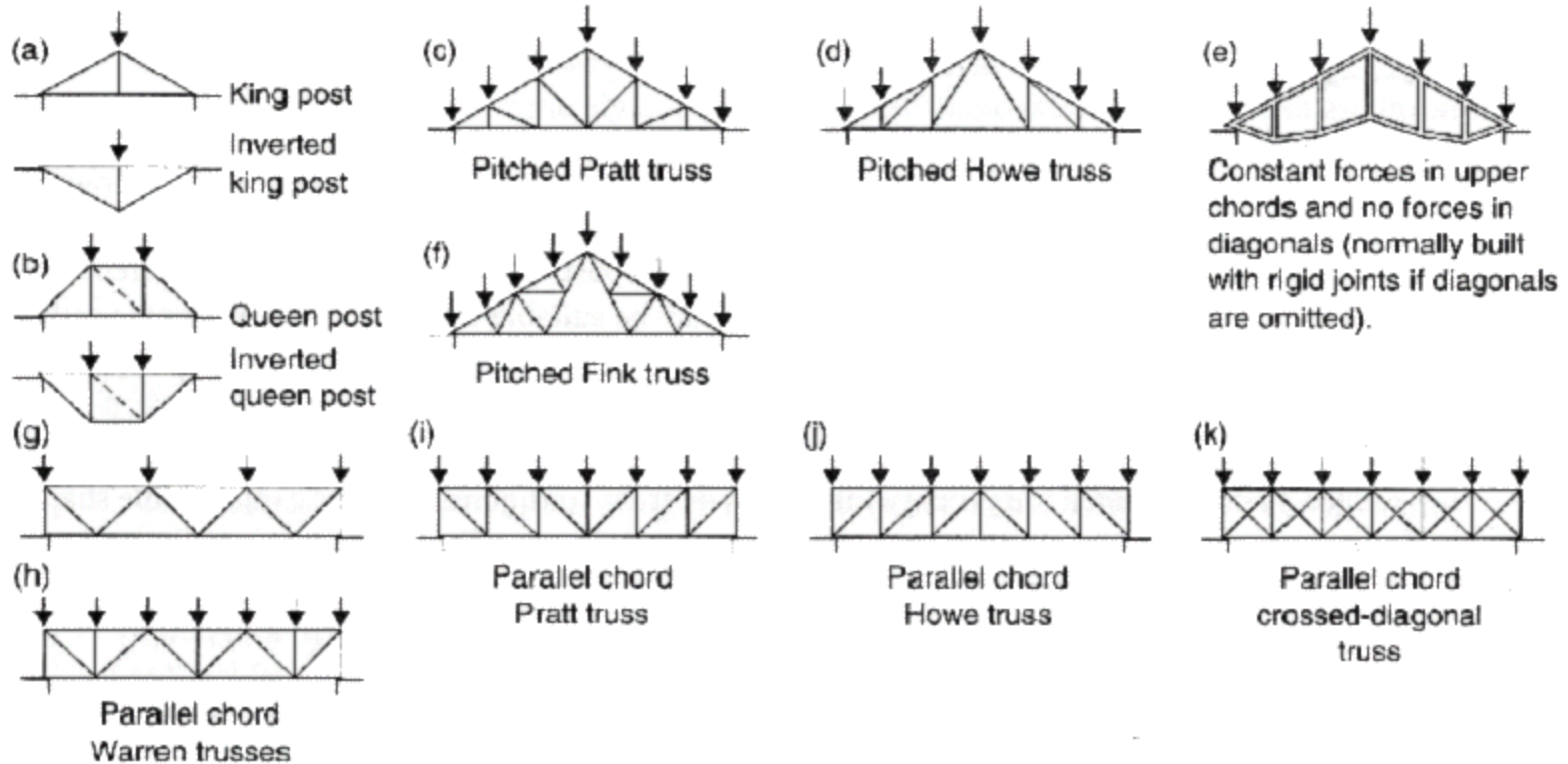
$$n = 10 \quad b = 18 > 2(10) - 3 = 17$$

(Too many members)

(b) *Indeterminate.*

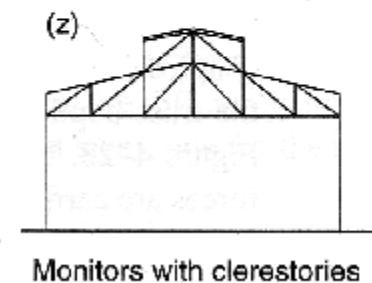
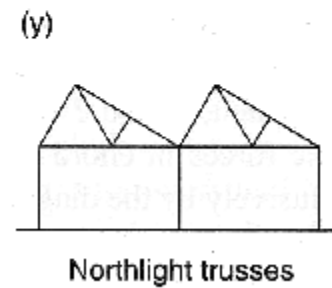
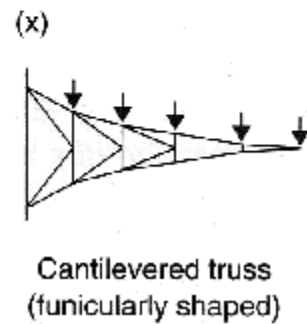
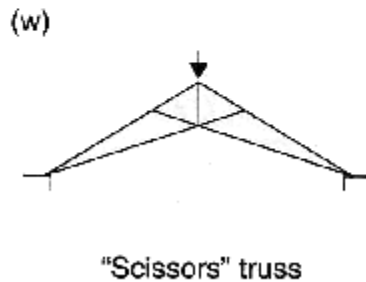
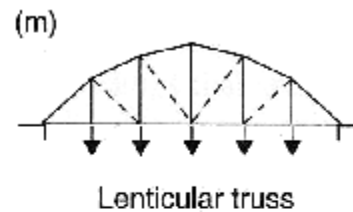
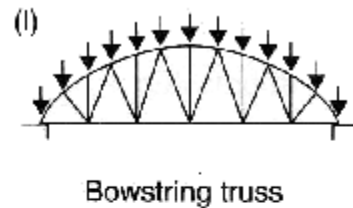
# Trusses

- common designs*



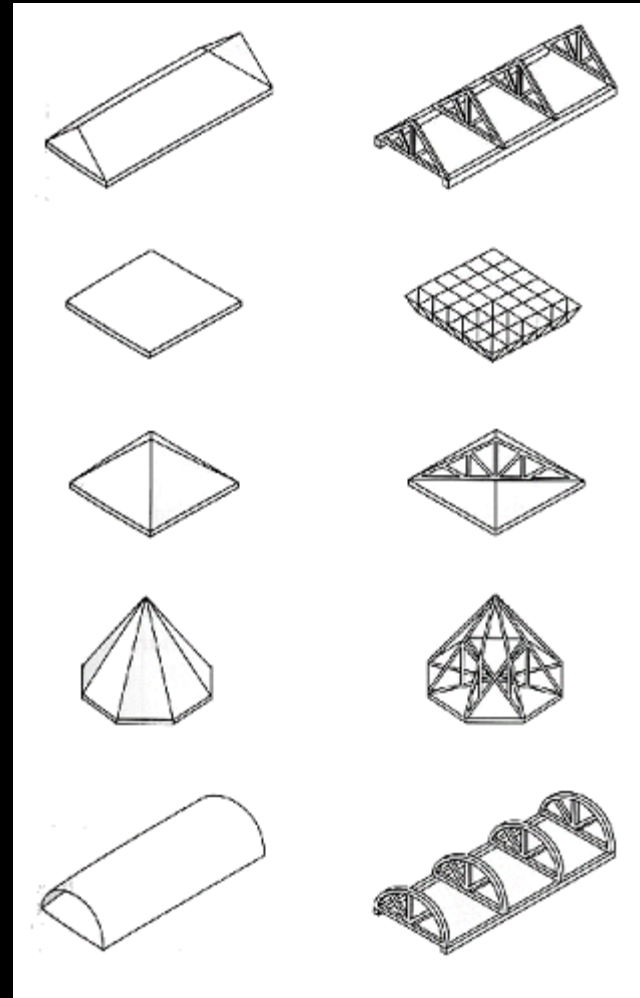
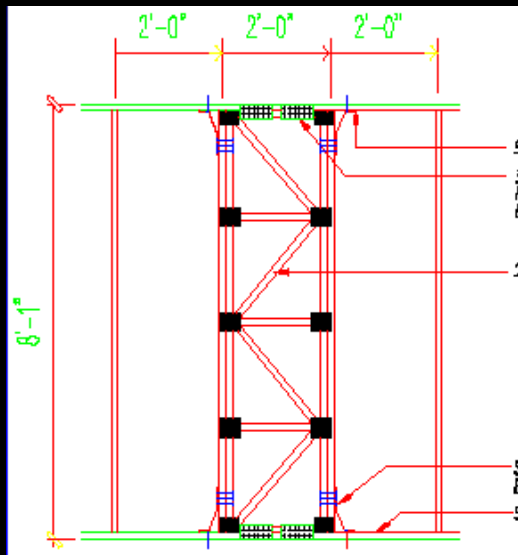
# Trusses

- common designs*



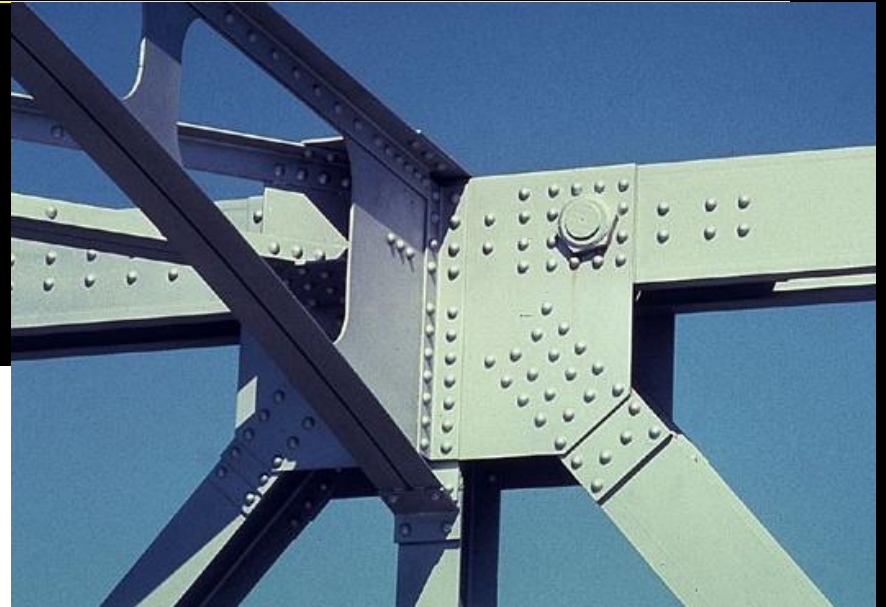
# Trusses

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



# Truss Connections

- “pins”



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

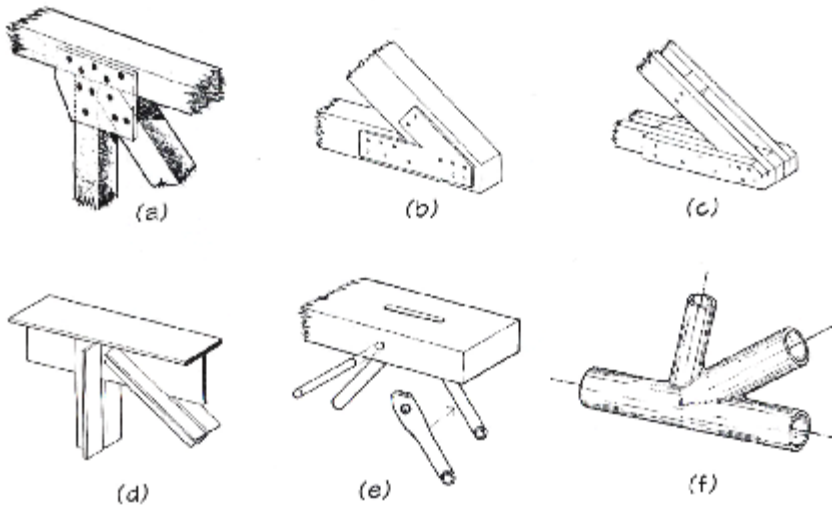


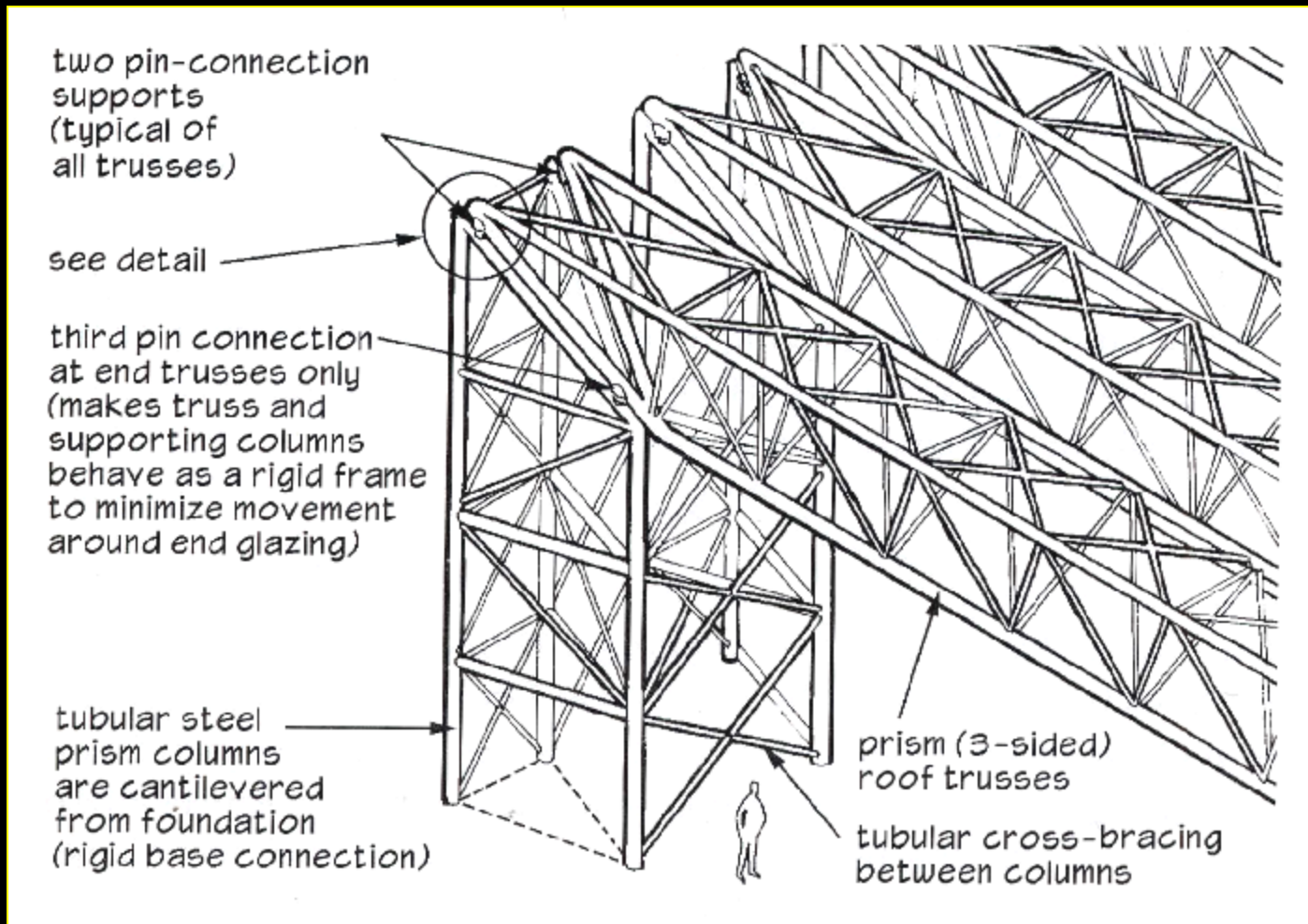
Figure 4.8: Truss joints.

# *Sainsbury Center, Foster 1978*

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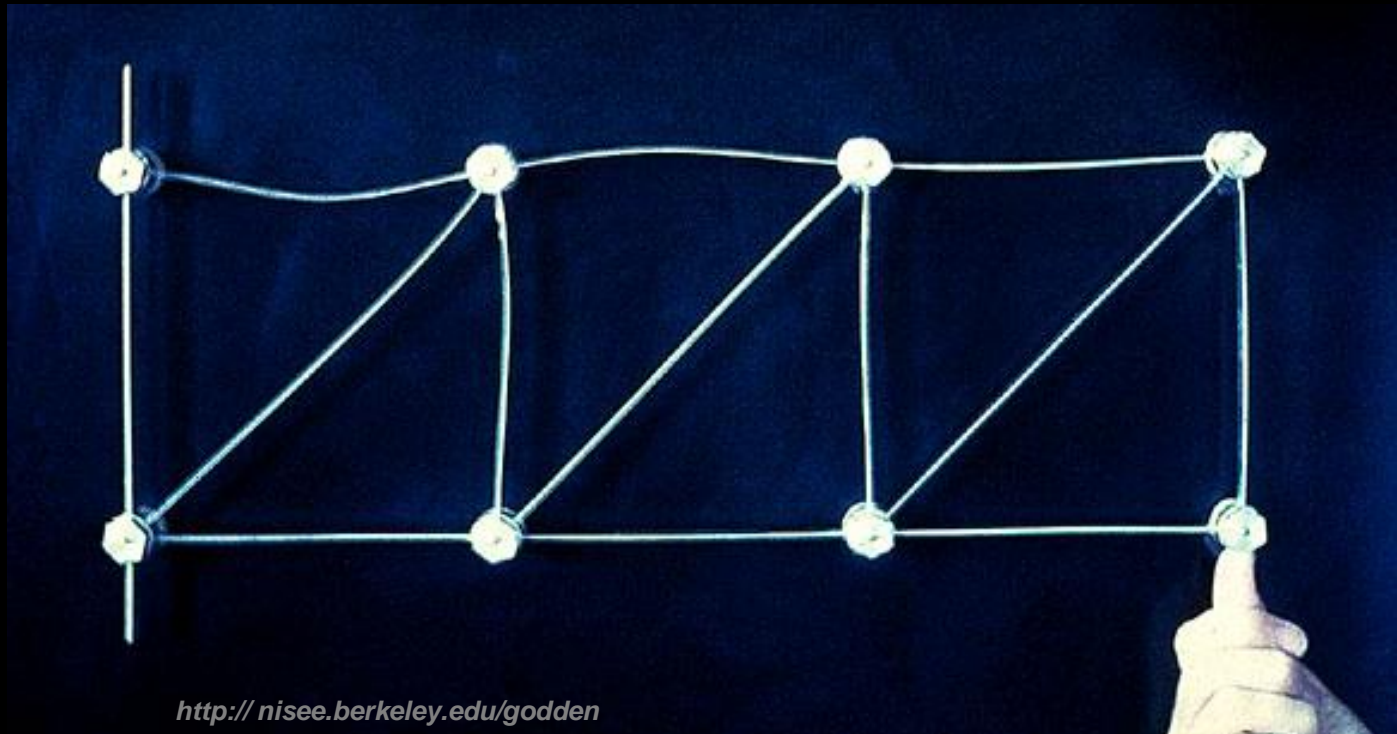
# Sainsbury Center, Foster 1978



# Truss Analysis

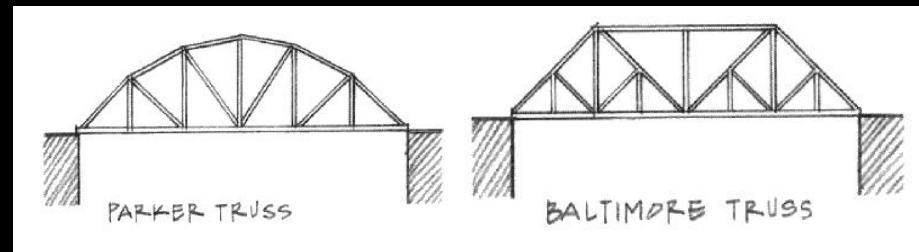
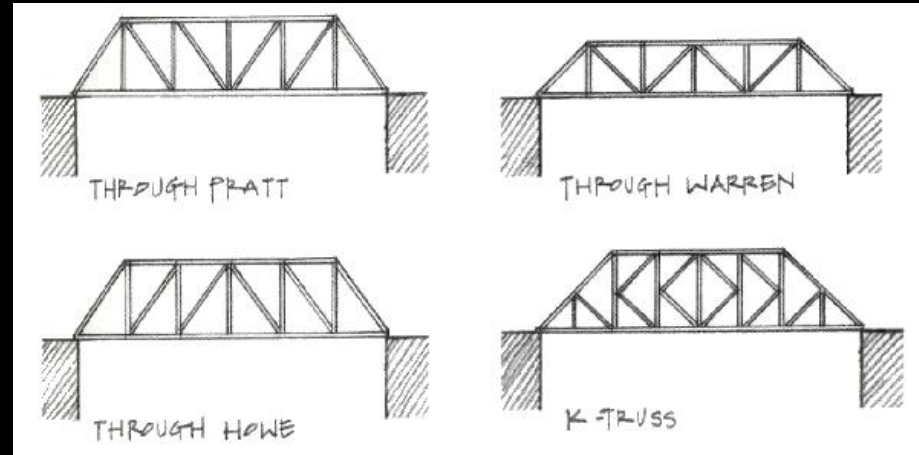
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- *visualize compression and tension from deformed shape*



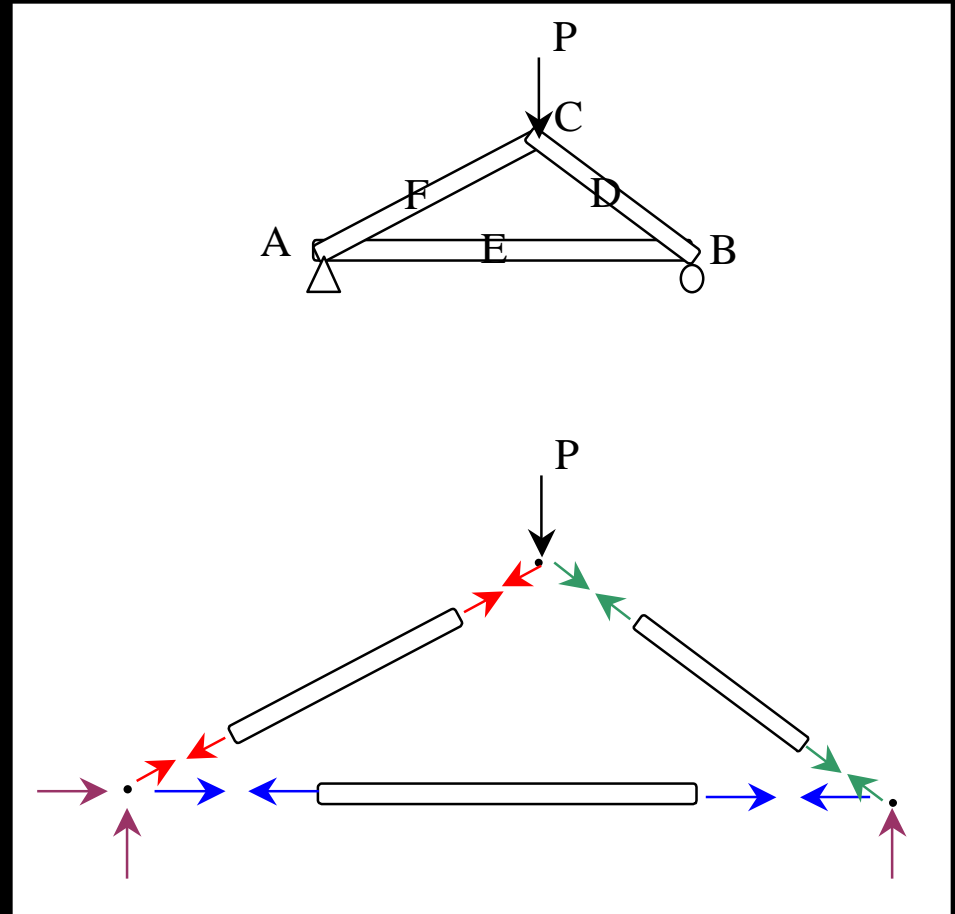
# Truss Analysis

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



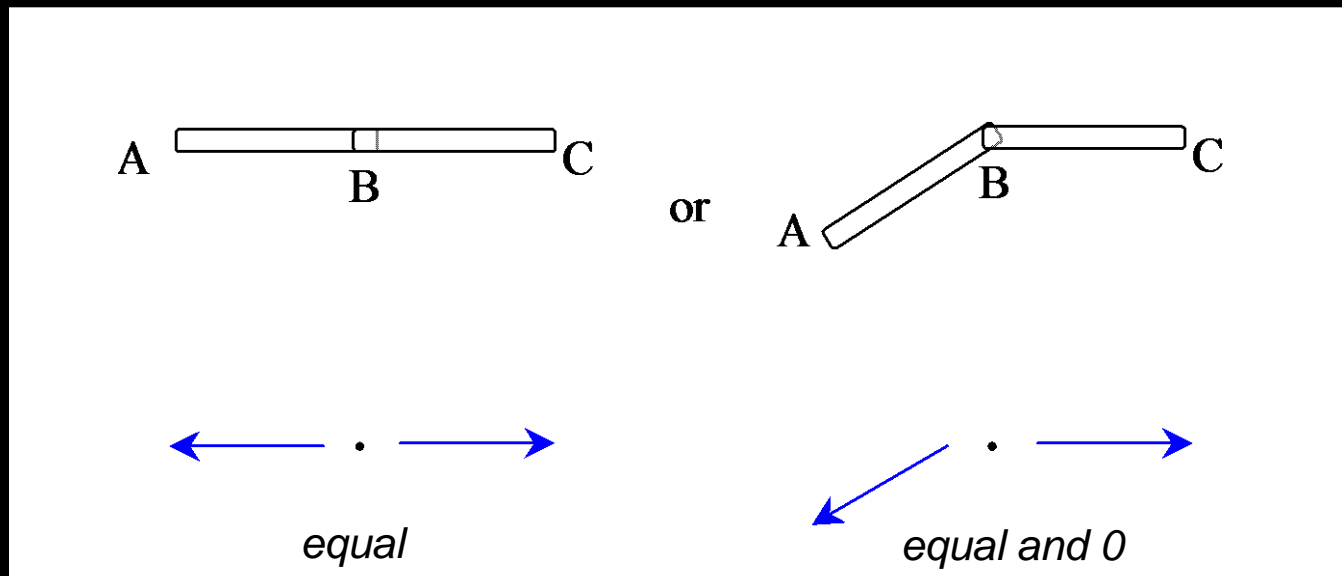
# Method of Joints

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



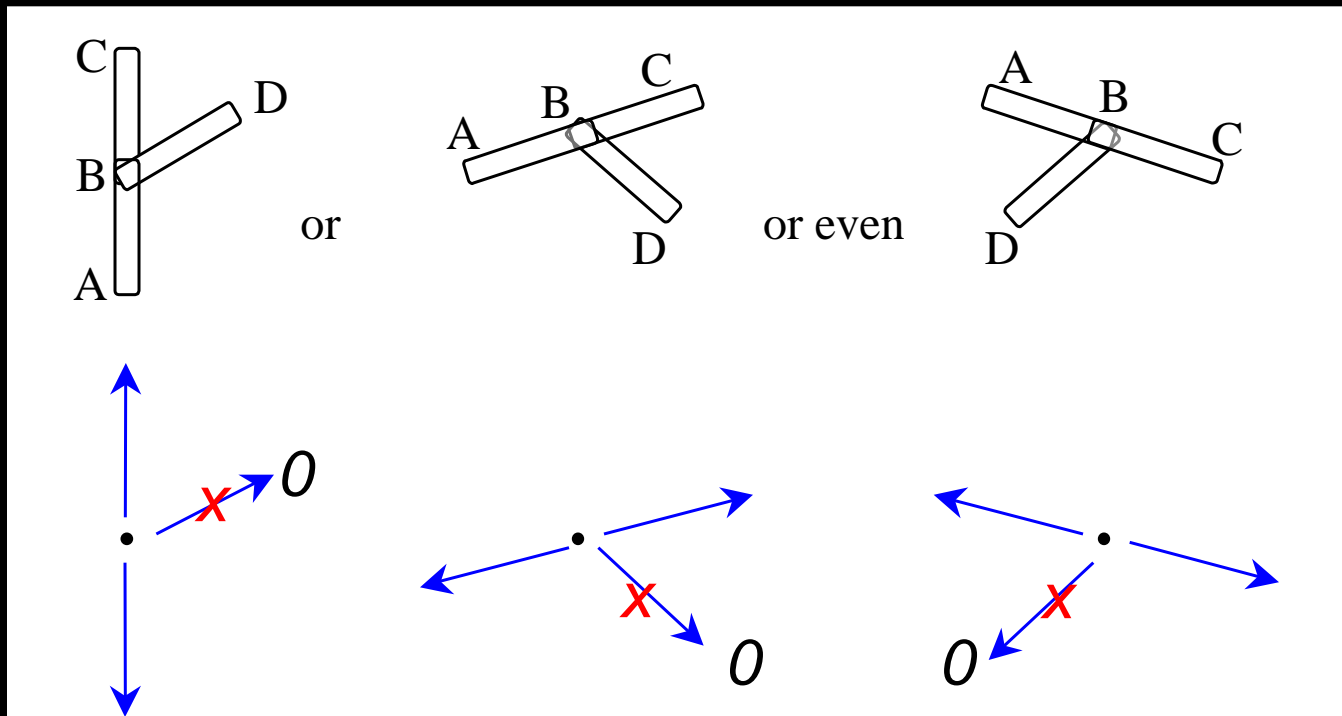
# Joint Cases

- *two bodies connected*



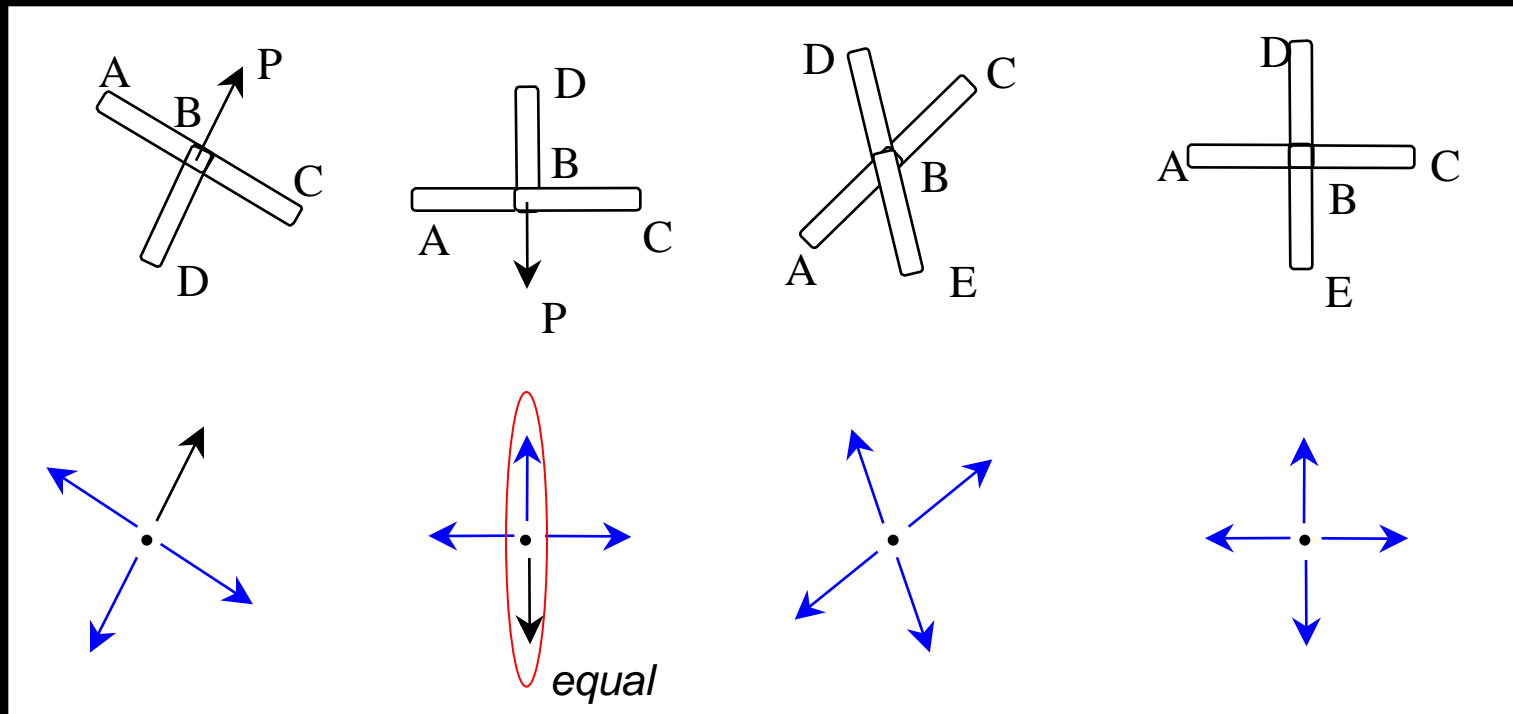
# Joint Cases

- *three bodies with two in line*



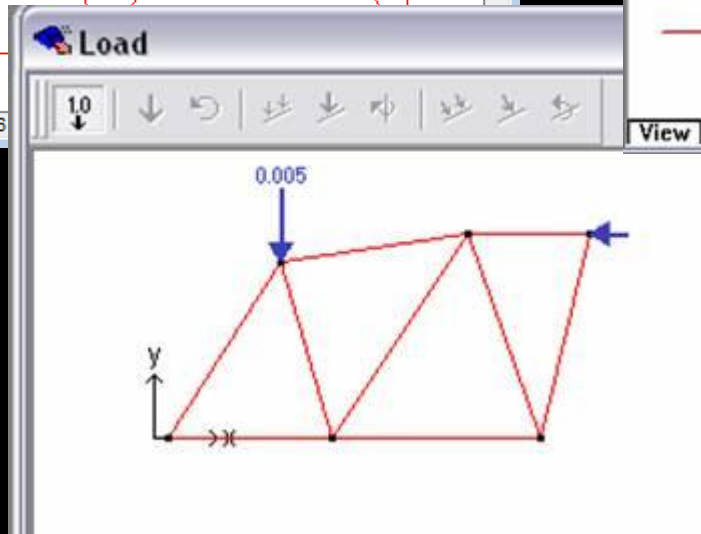
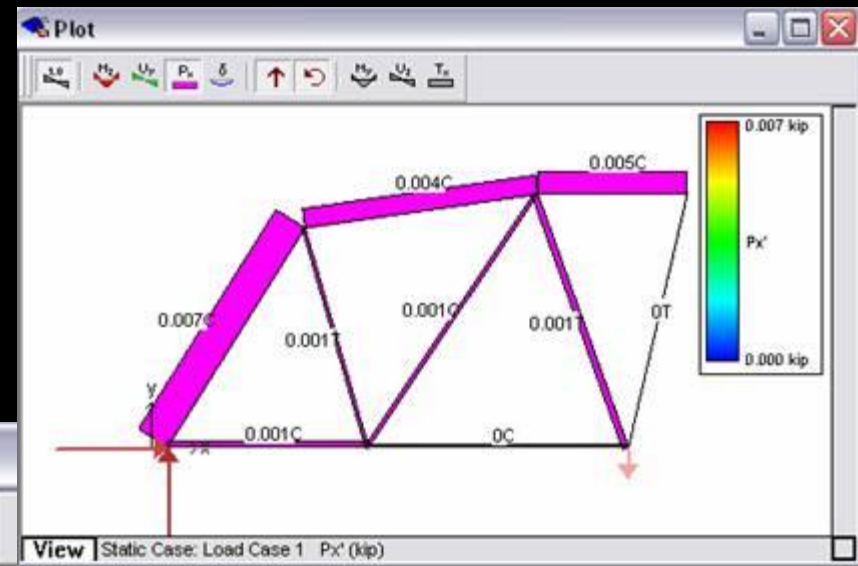
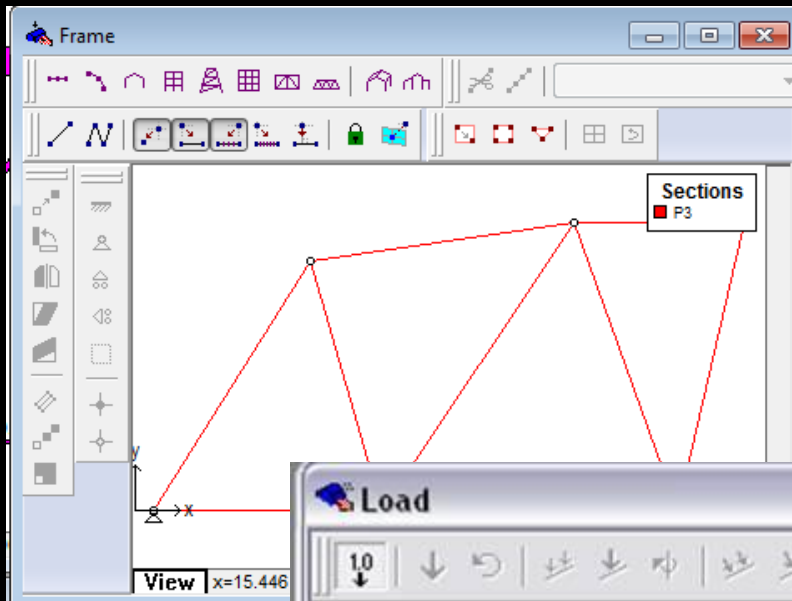
# Joint Cases

- crossed*



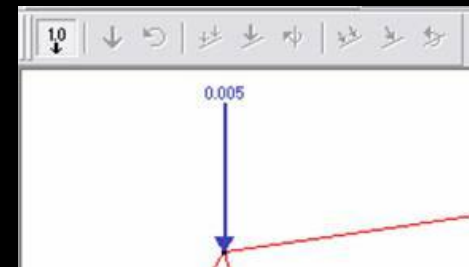
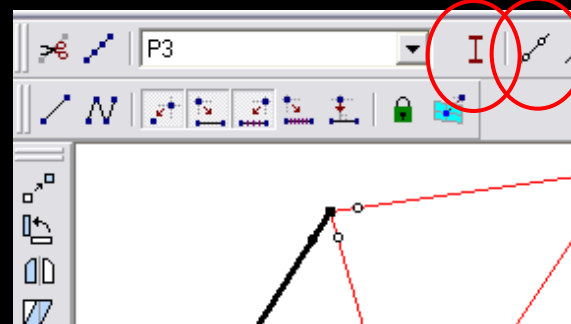
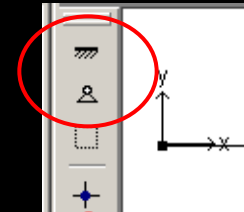
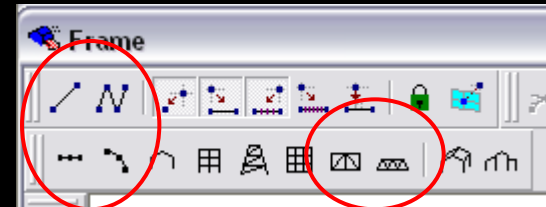
# Tools – Multiframe

- *in computer lab*



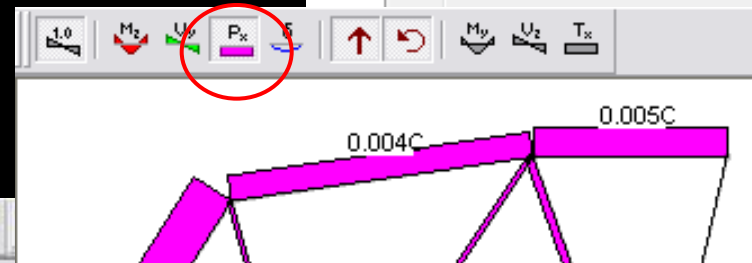
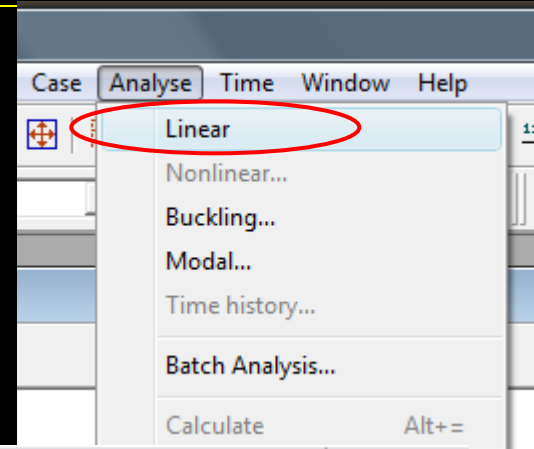
# Tools – Multiframe

- *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*



# Tools – Multiframe

- *to run analysis choose*
  - *Analyze menu*
    - *Linear*
- *plot*
  - *choose options*
- *results*
  - *choose options*



	Membr	Label	Joint	Px' kip
1	1		1	0.007
2	1		2	-0.007
3	2		2	-0.001
4	2		3	0.001
5	3		1	0.001
6	3		3	-0.001
7	4		2	0.004
8	4		4	-0.004

Member Actions Max Actions