ELEMENTS OF ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 614

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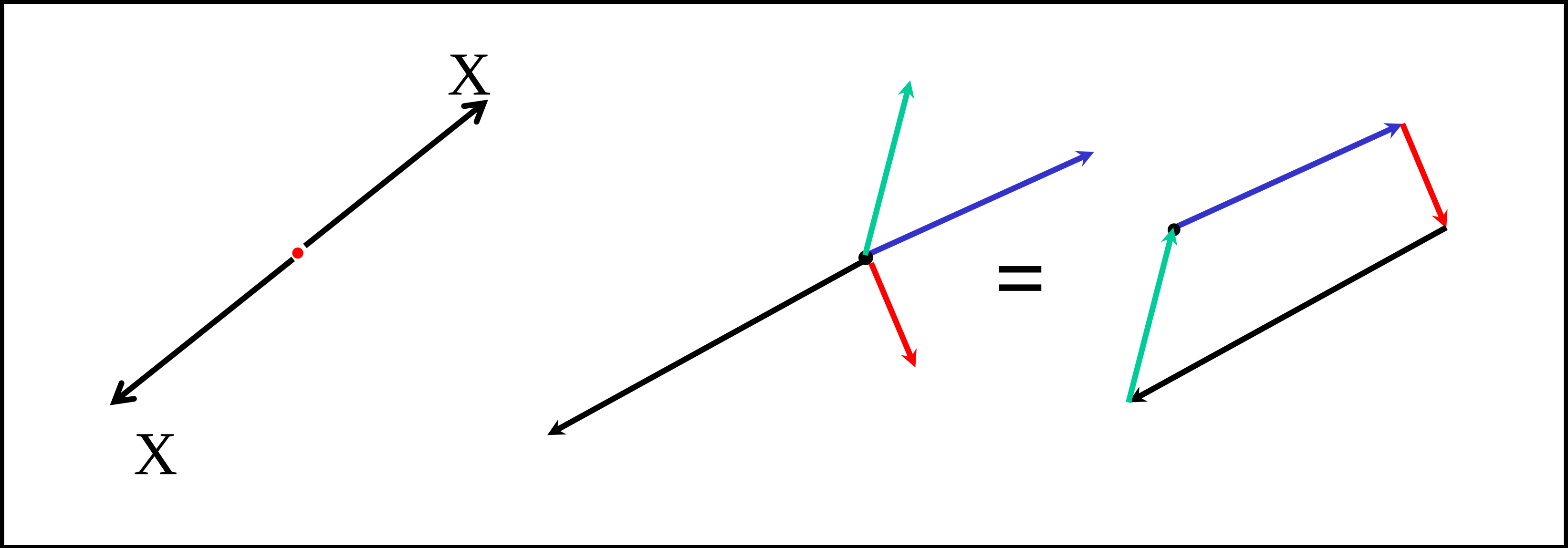
SPRING 2014

lecture
three

equilibrium and planar trusses

Equilibrium

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

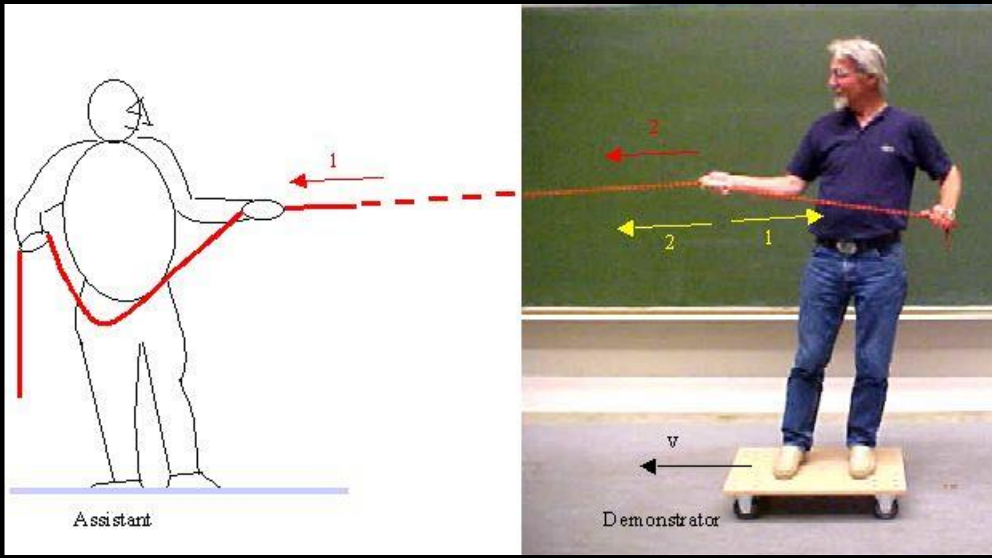


Equilibrium on a Point

- *analytically*

$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$



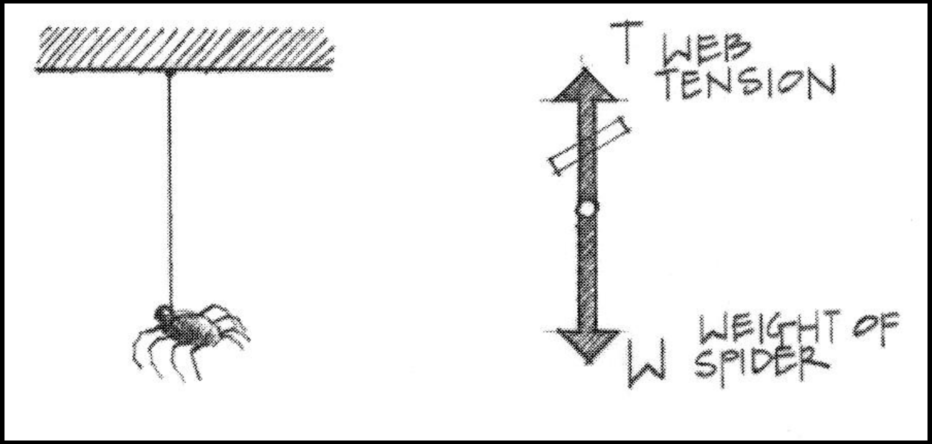
http://www.physics.umd.edu

- *Newton convinces us it will stay at rest*

Equilibrium on a Point

- collinear force system
  - ex: cables

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



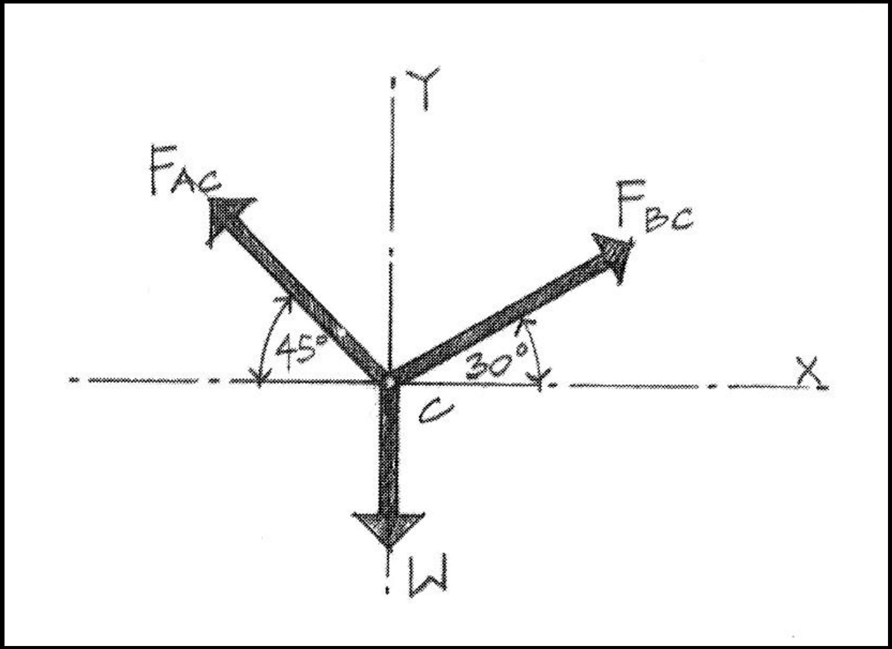
$$\left(R_x = \sum F_x = 0 \qquad R_y = \sum F_y = 0 \right)$$

Equilibrium on a Point

- concurrent force system
  - ex: cables

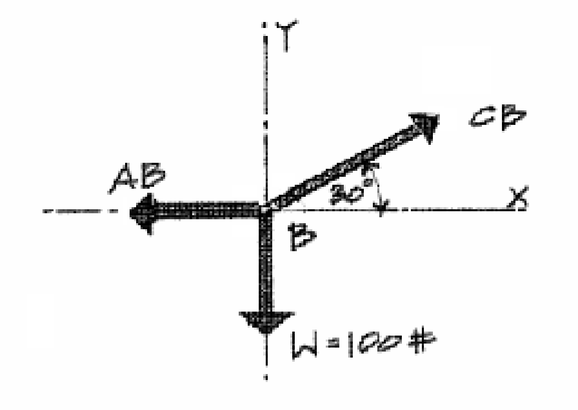
$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$



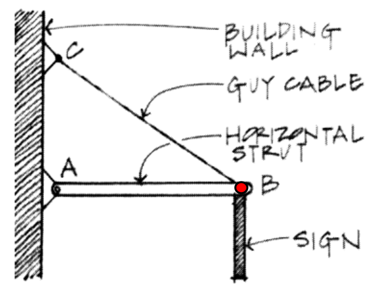
Free Body Diagram

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

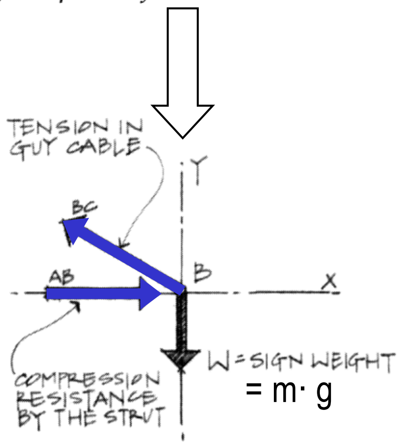


Free Body Diagram

- 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 <u>angles</u> – name them*
  - *known & unknown <u>forces</u> – 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*

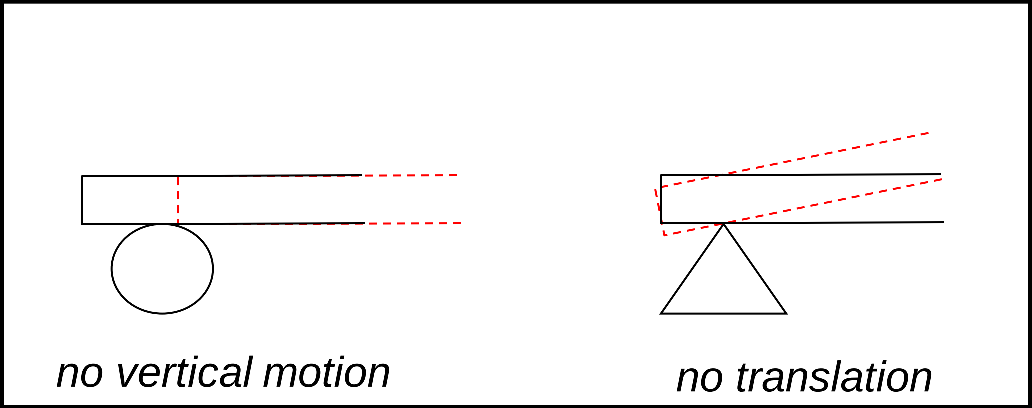
Free Body Diagram

- *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*

$$F = \mu N$$

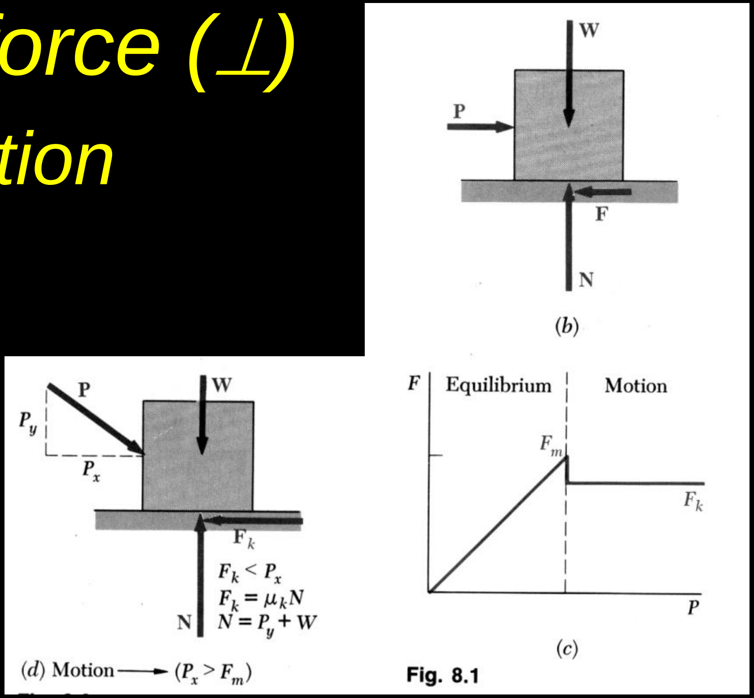
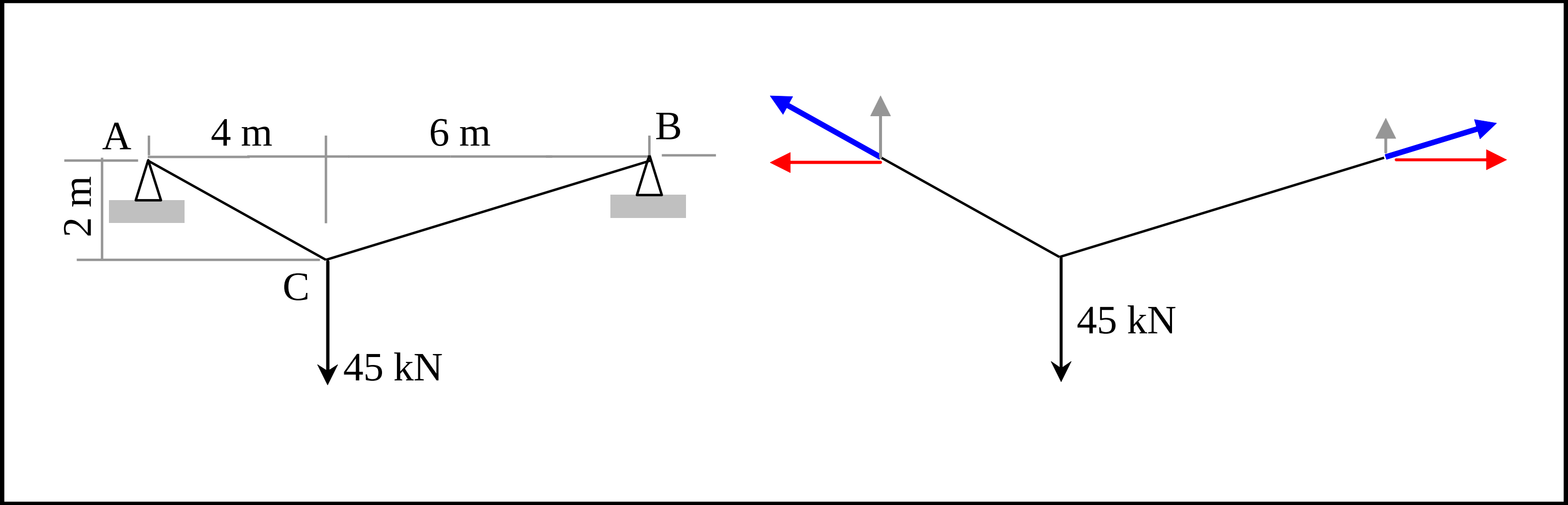


Fig. 8.1

Cable Reactions

- equilibrium:
  - more reactions (4) than equations
  - <u>but</u>, we have <u>slope relationships</u>
  - x component the same everywhere

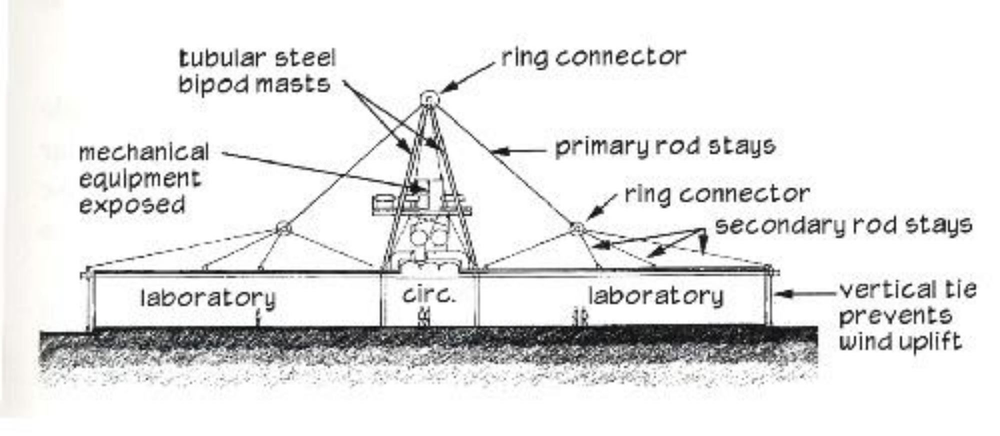


Cable-Stayed Structures

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

Patcenter, Rogers 1986

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



Patcenter, Rogers 1986

- *dashes – cables pulling*

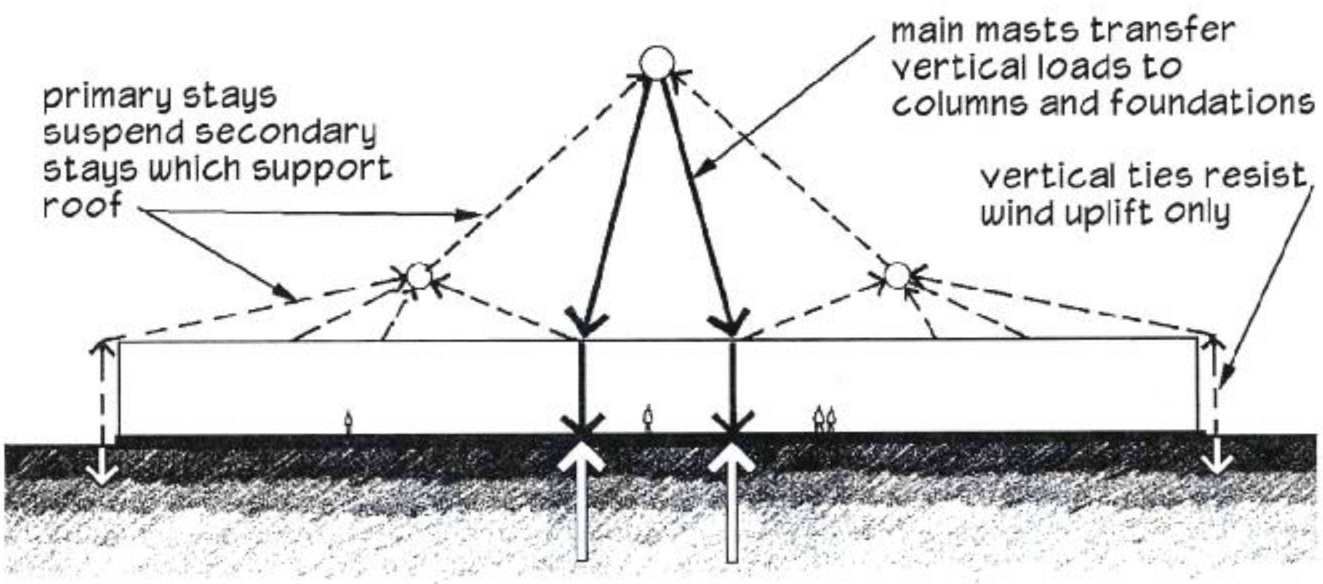
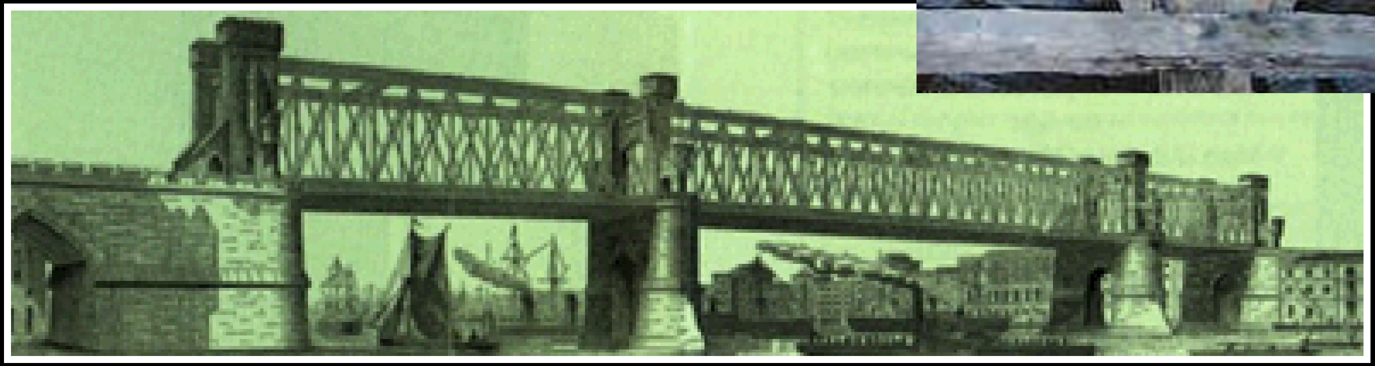


Figure 3.5: Patcenter, load path diagram.

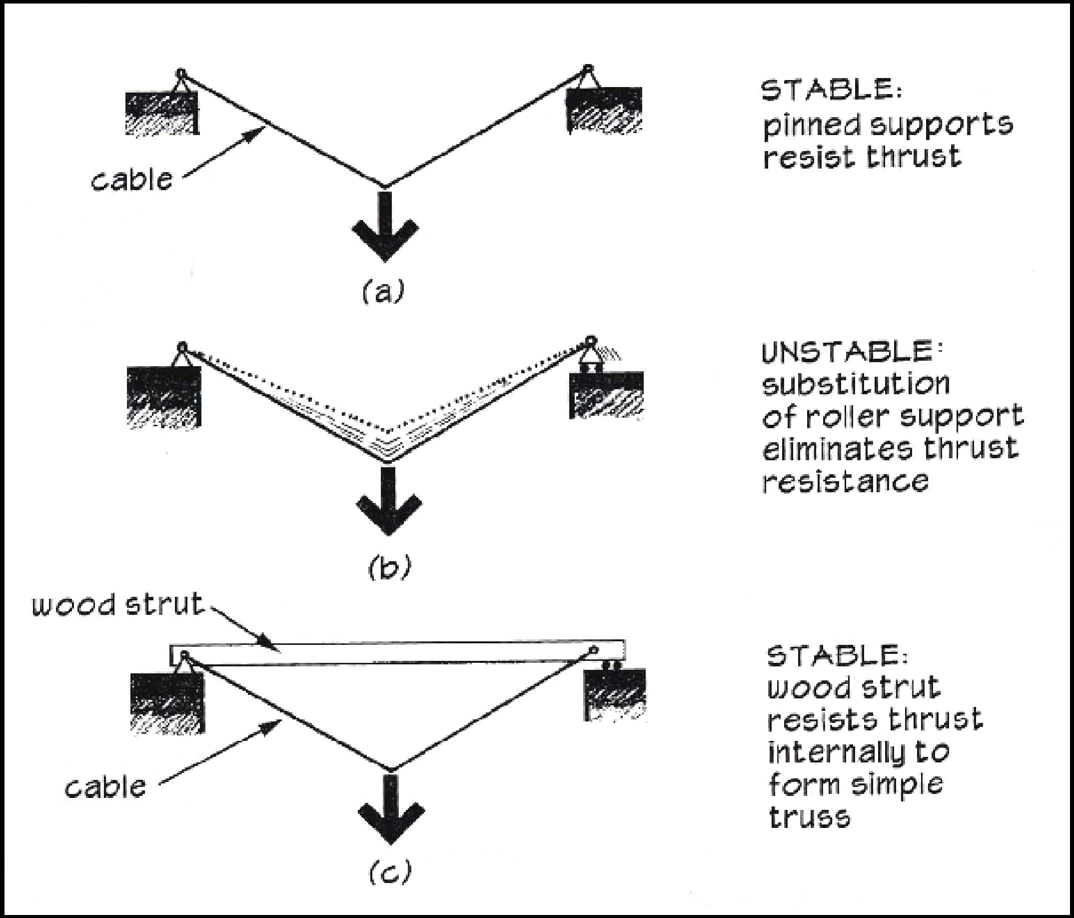
Truss Structures

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



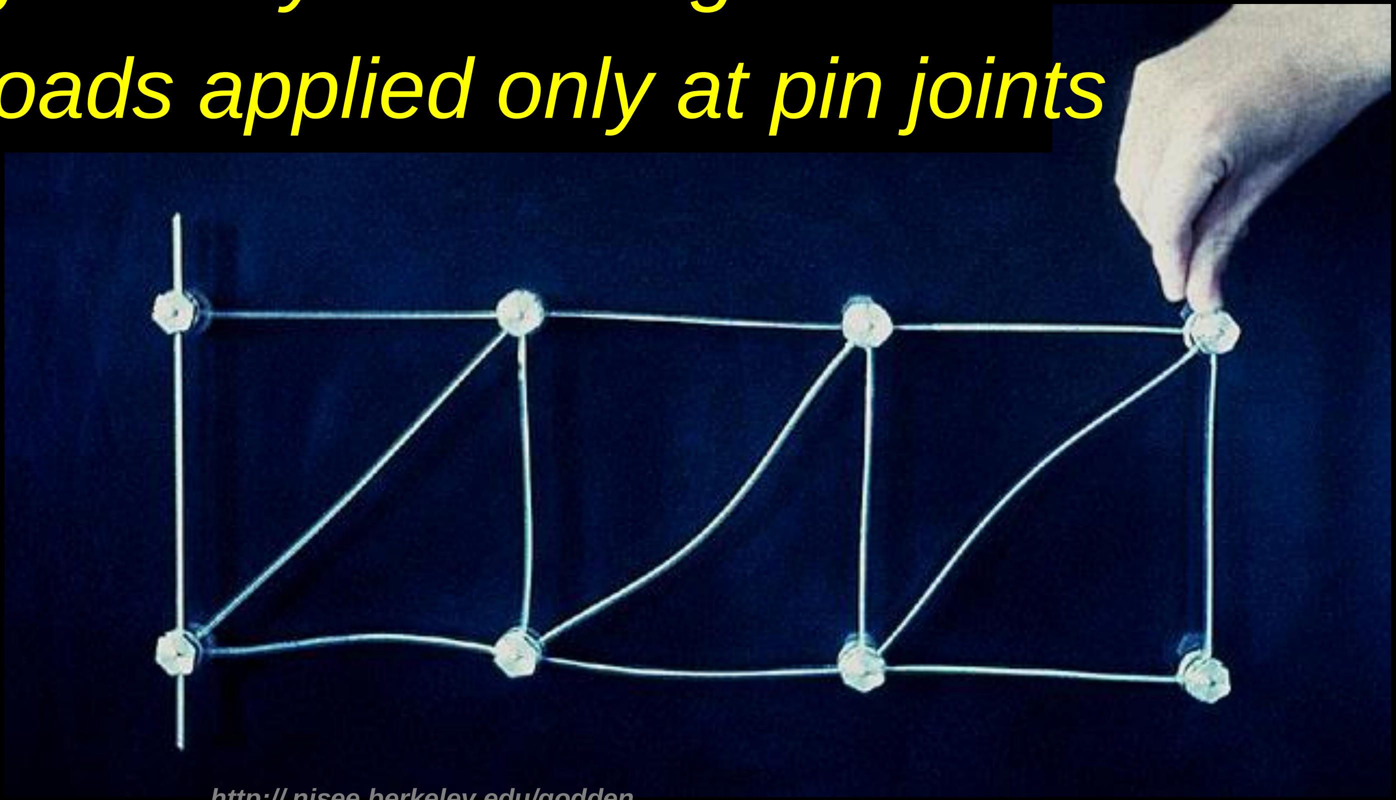
Truss Structures

– *analogous to cables and struts*



Truss Structures

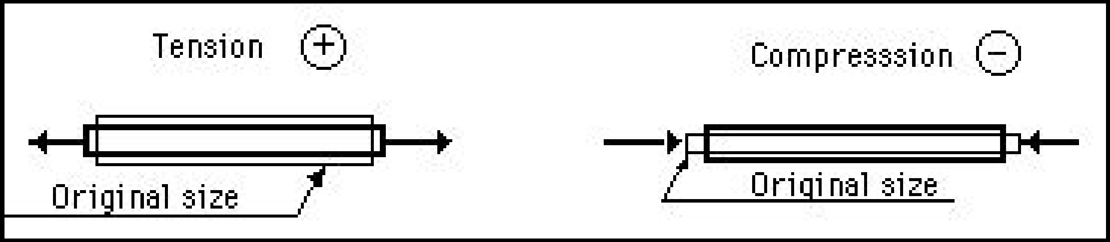
- comprised of straight members
- geometry with triangles is stable
- loads applied only at pin joints



http:// nisee.berkeley.edu/godden

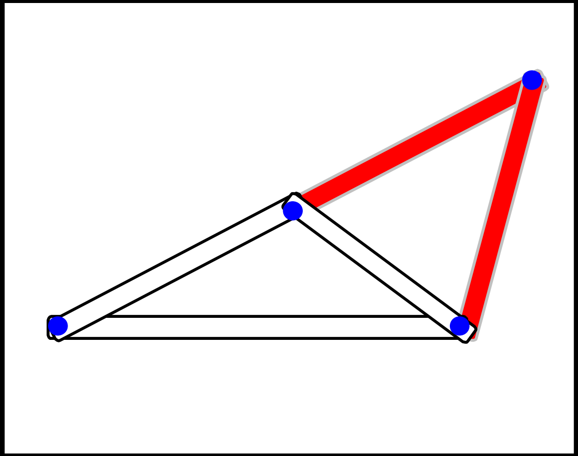
Truss Structures

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



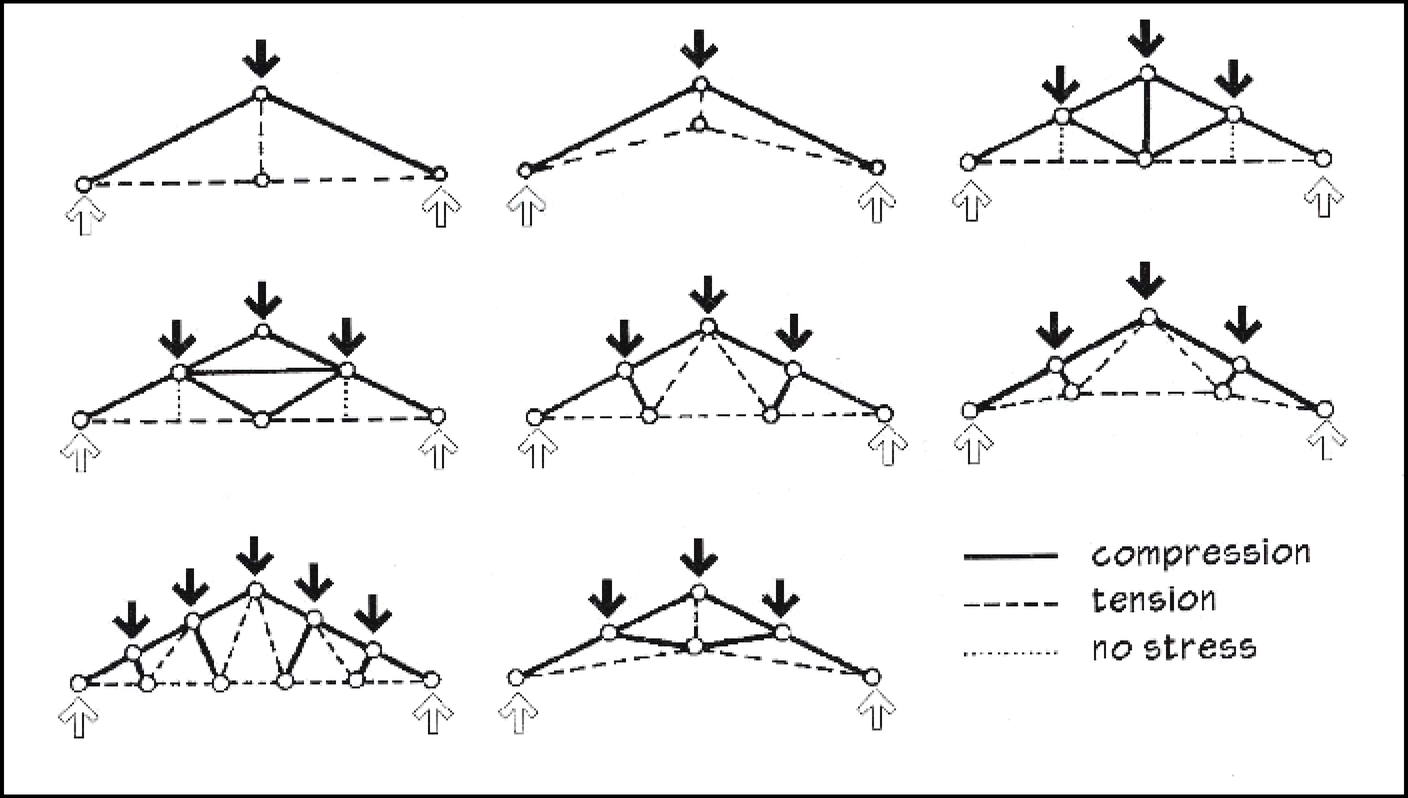
- 3 members connected by 3 joints
- 2 more members need 1 more joint

$$b = 2n - 3$$



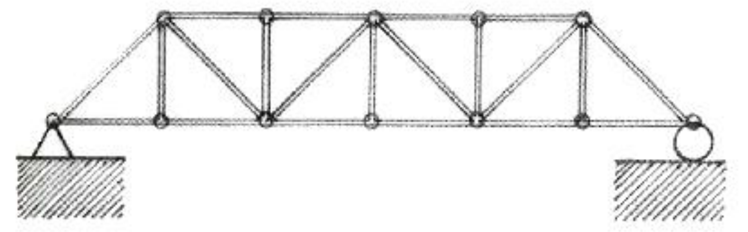
Truss Structures

- *compression and tension*



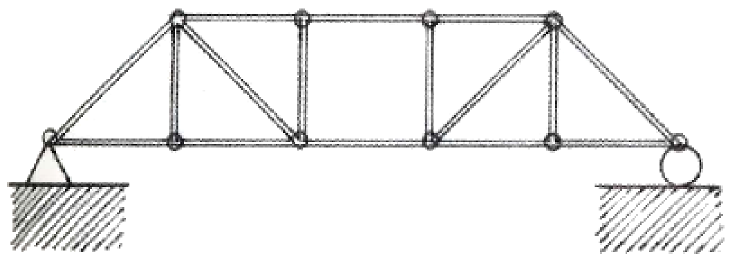
Truss Structures

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



b = 21 n = 12 2(n) – 3 = 2(12) – 3 = 21

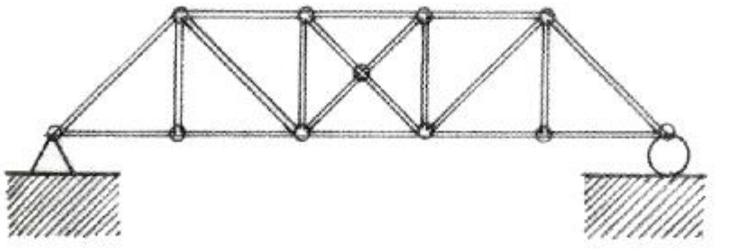
(a) Determinate.



b = 16 n = 10 b = 16 < 2(10) – 3 = 17

(Too few members—square panel is unstable)

(c) Unstable.



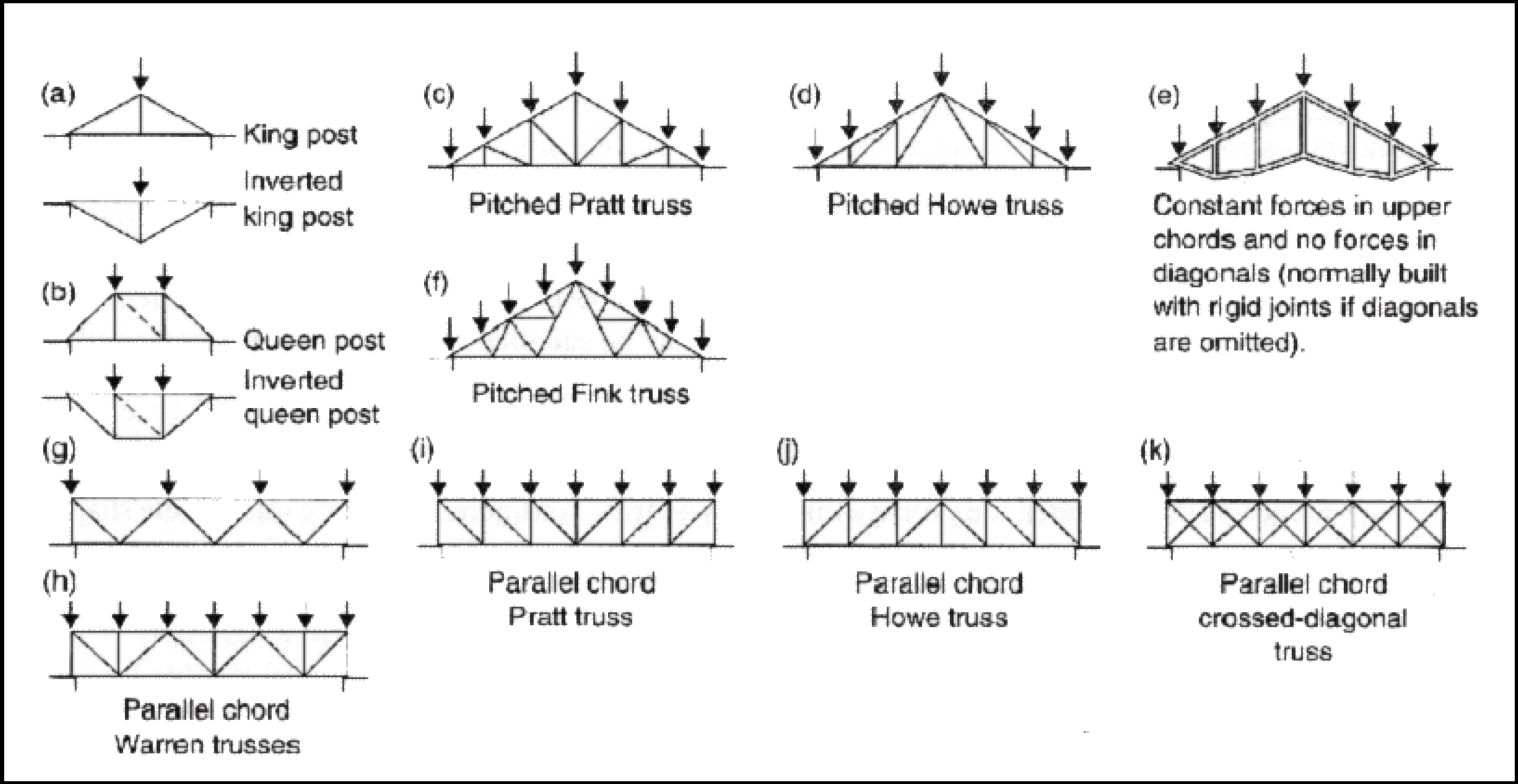
b = 18 n = 10 b = 18 > 2(10) – 3 = 17

(Too many members)

(b) Indeterminate.

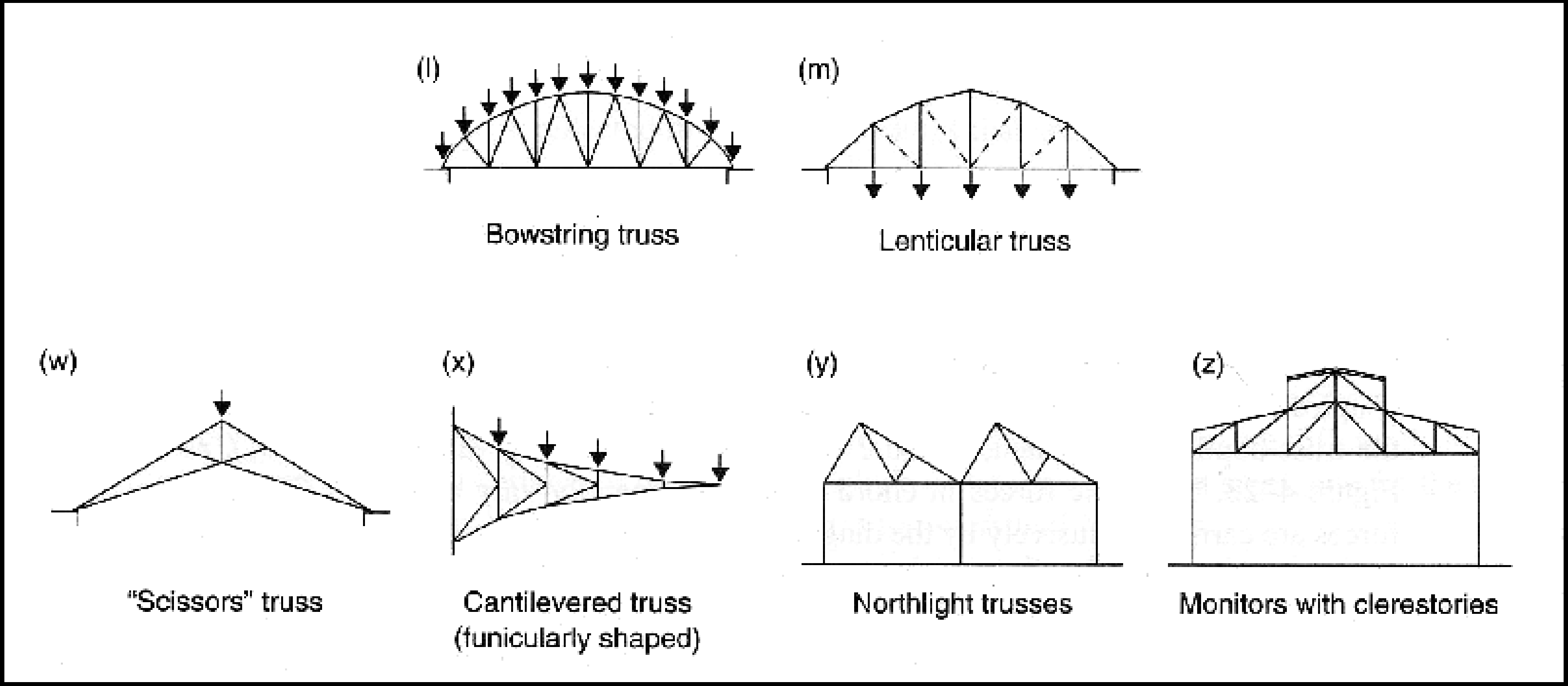
Trusses

- *common designs*



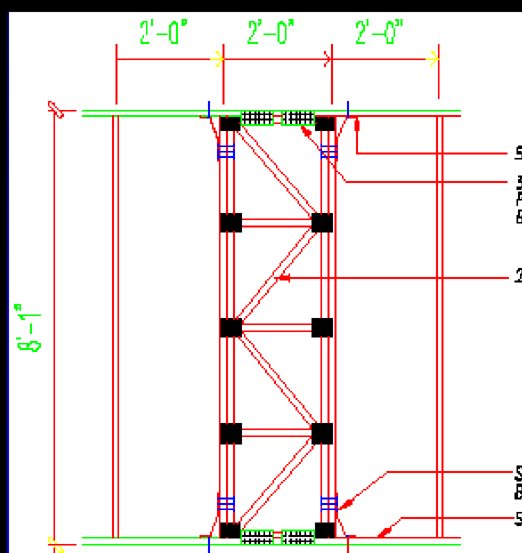
Trusses

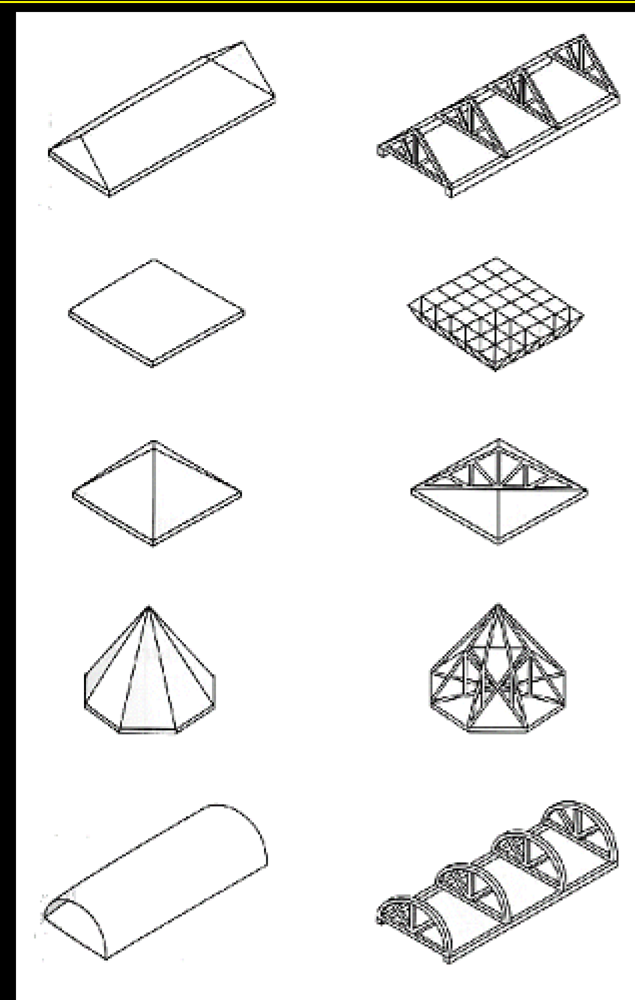
- *common designs*



Trusses

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





Truss Connections

- *"pins"*

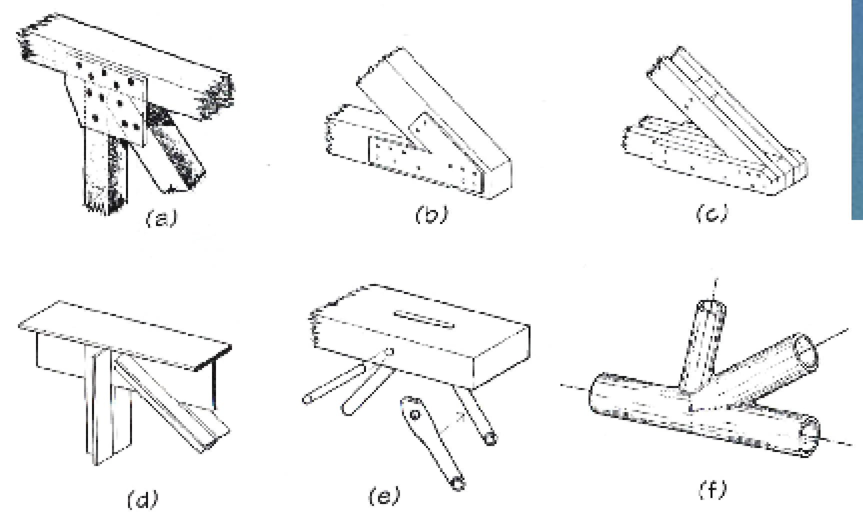
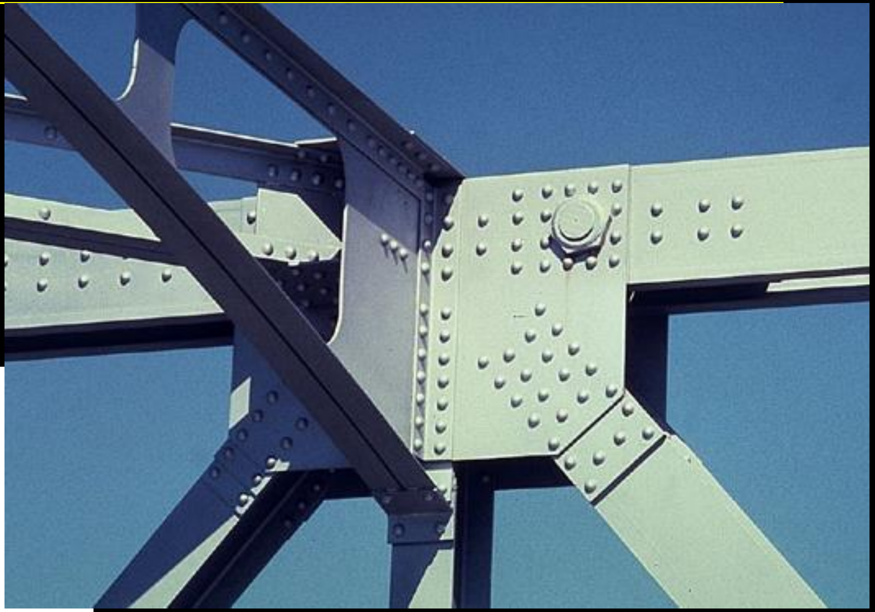


Figure 4.8: Truss joints.



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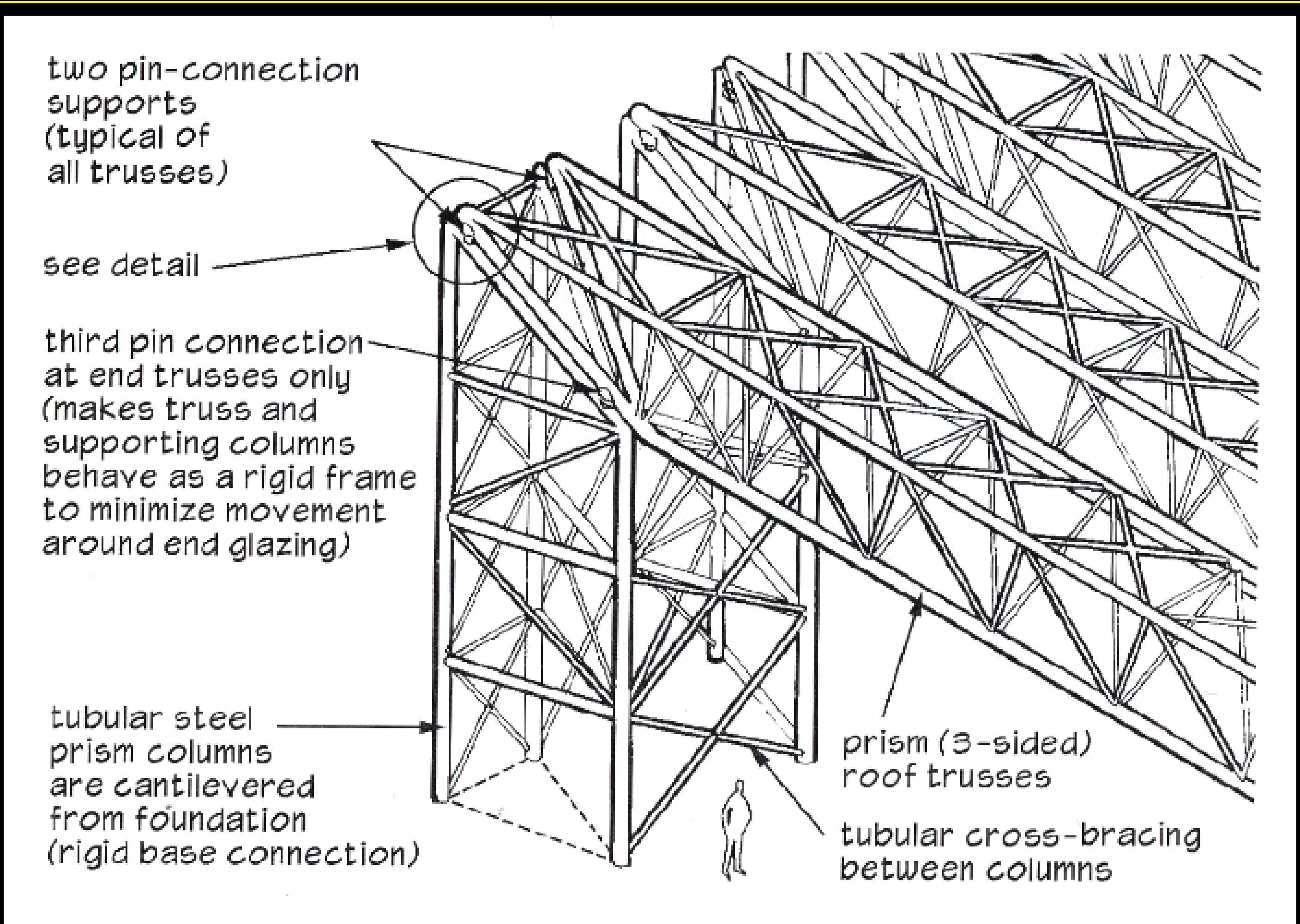
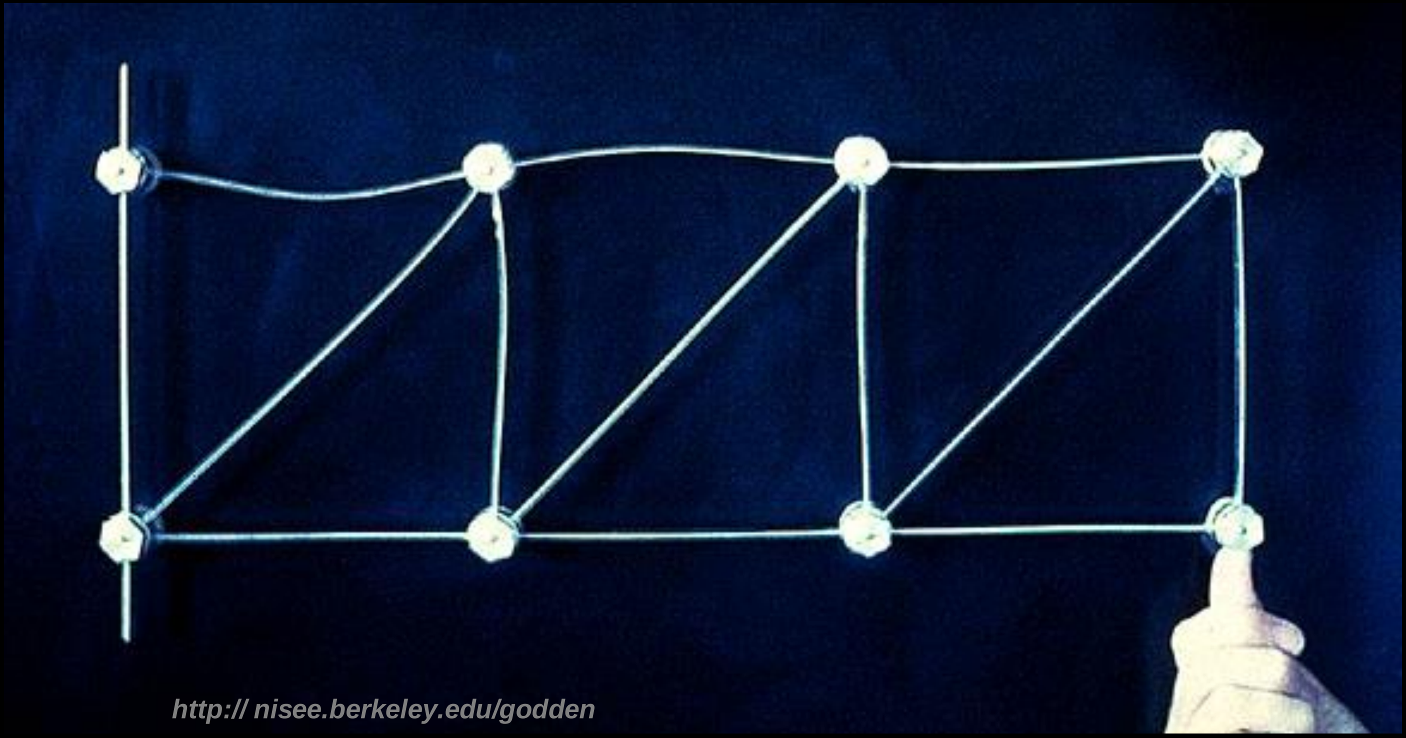
Sainsbury Center, Foster 1978

Sainsbury Center, Foster 1978



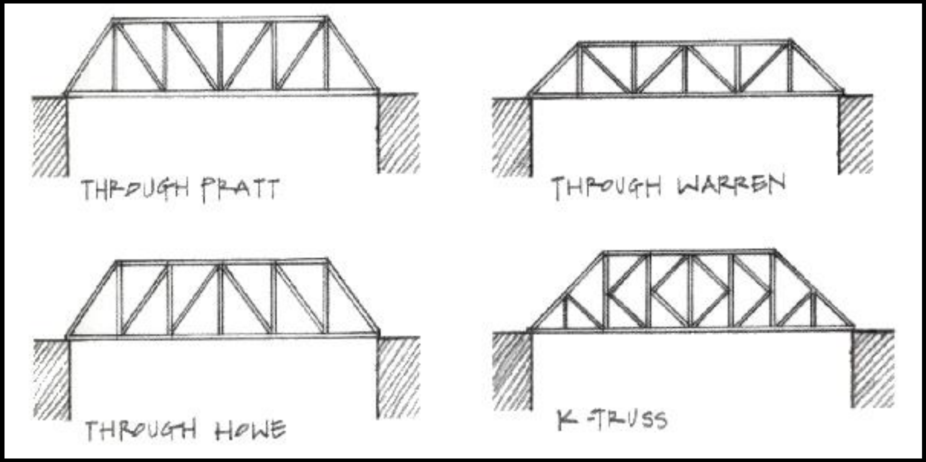
Truss Analysis

- visualize compression and tension from deformed shape

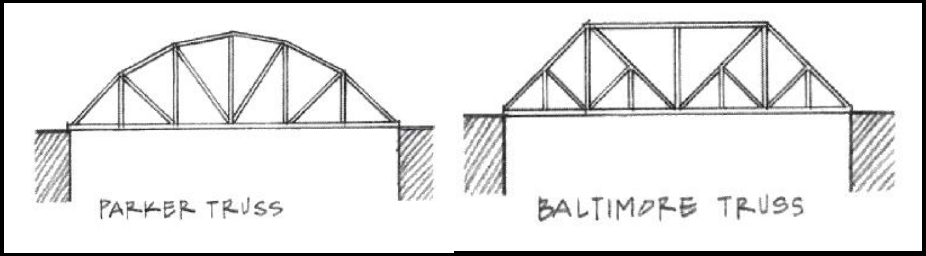


Truss Analysis

- *Method of Joints*
- *Graphical Methods*
- *Method of Sections*

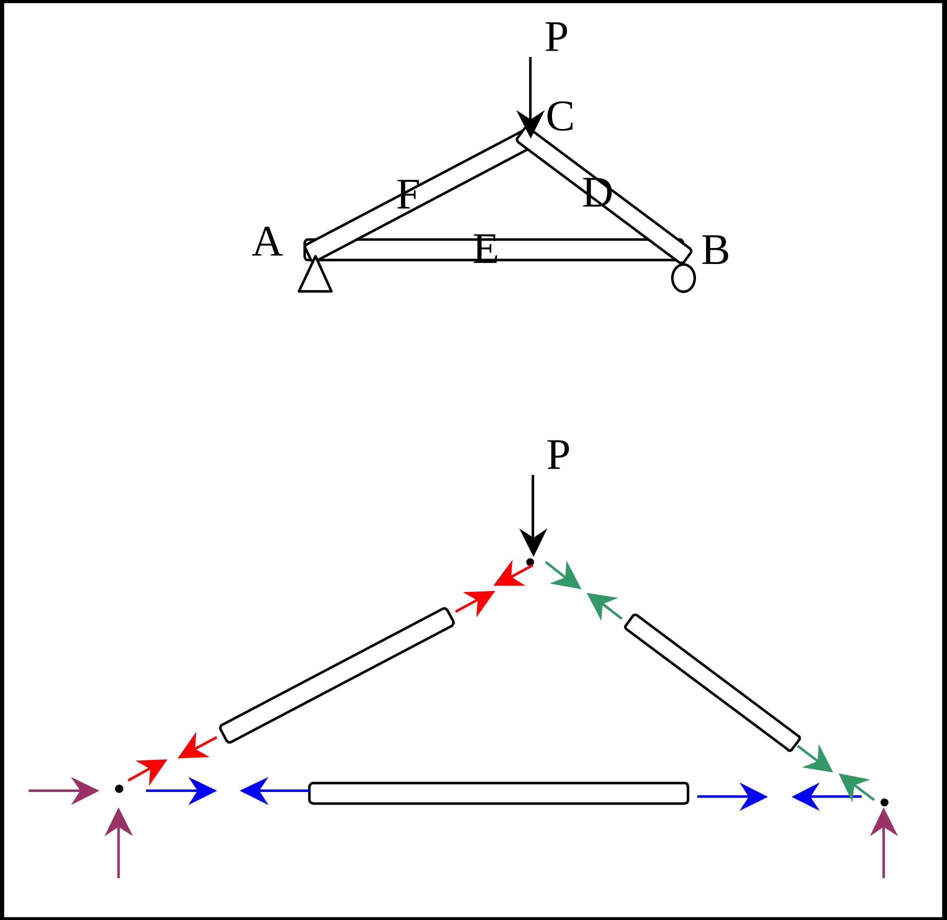


- *all rely on equilibrium*
  - *of bodies*
  - *internal equilibrium*



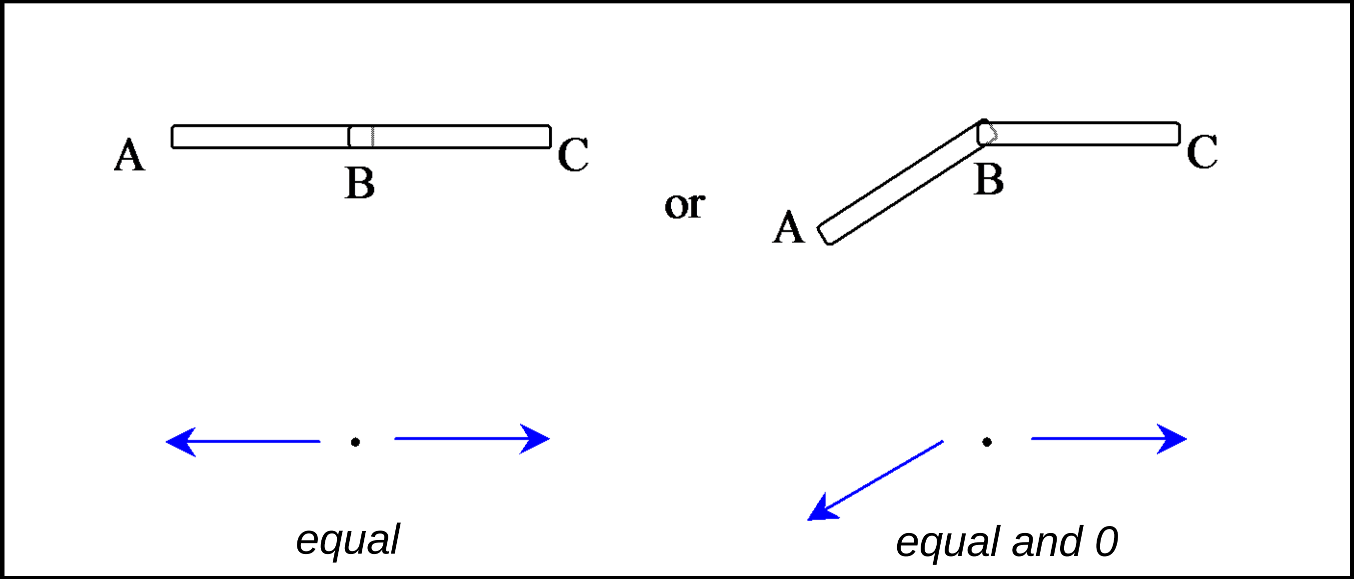
Method of Joints

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



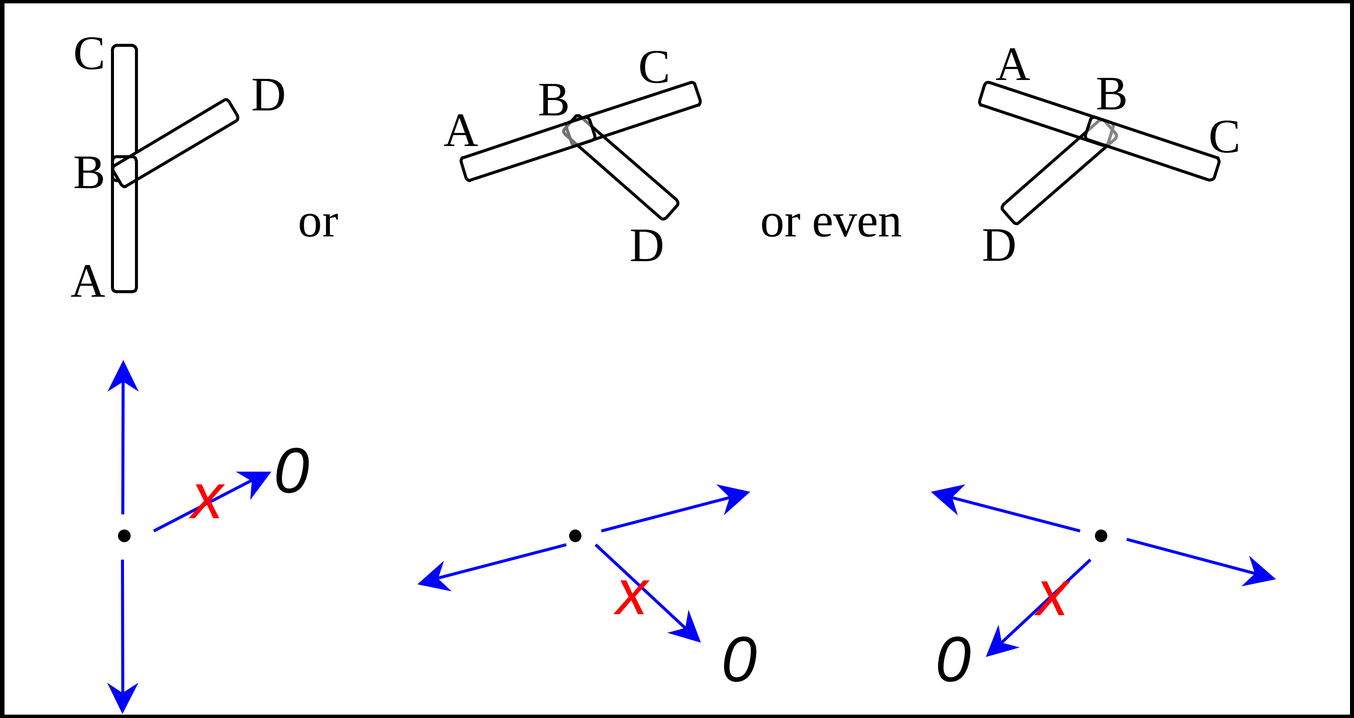
Joint Cases

- *two bodies connected*



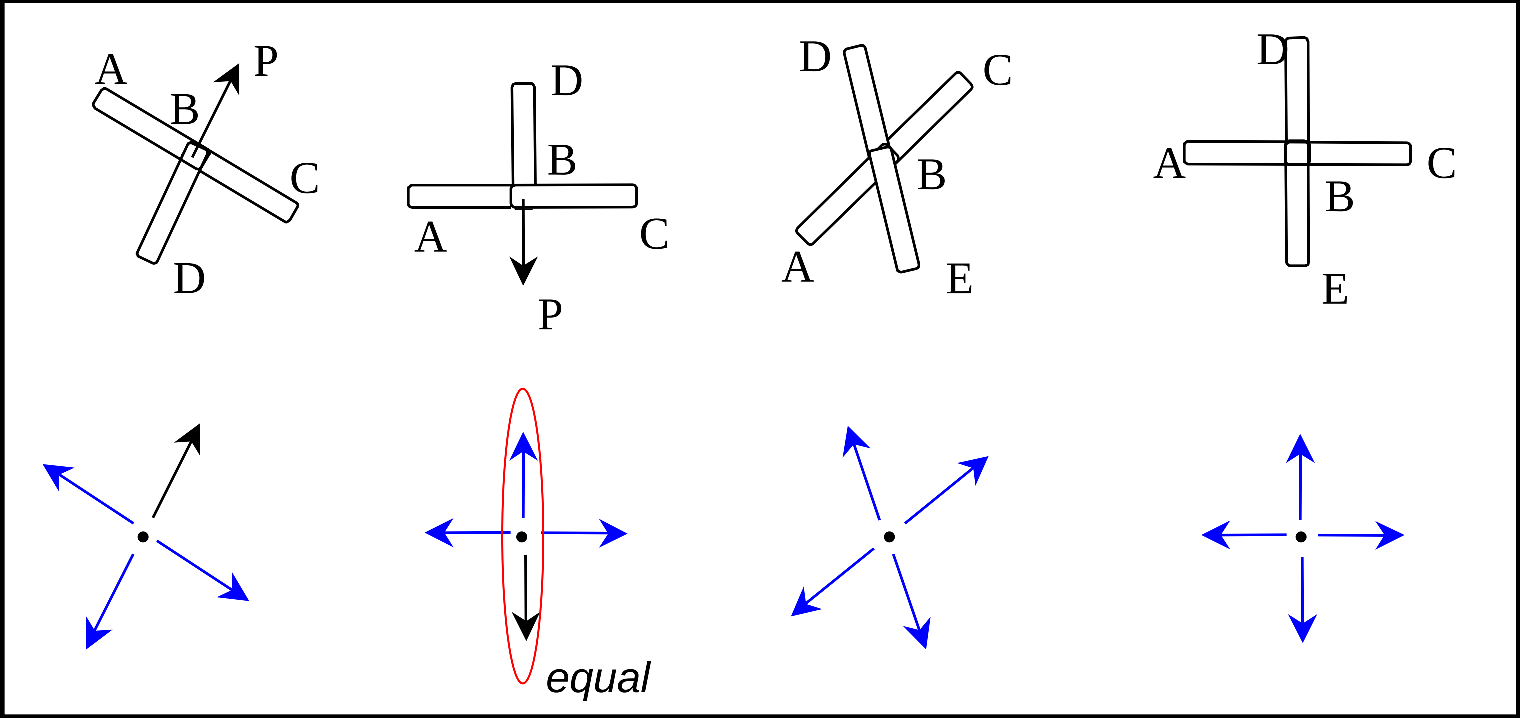
Joint Cases

- *three bodies with two in line*



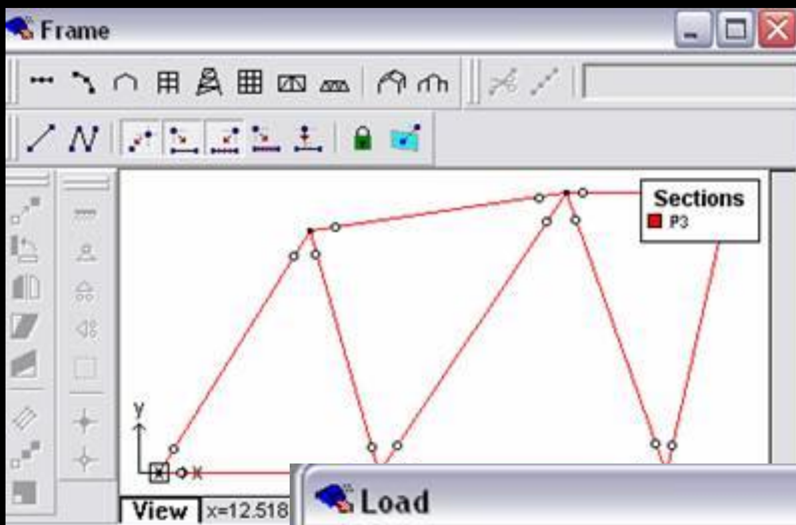
Joint Cases

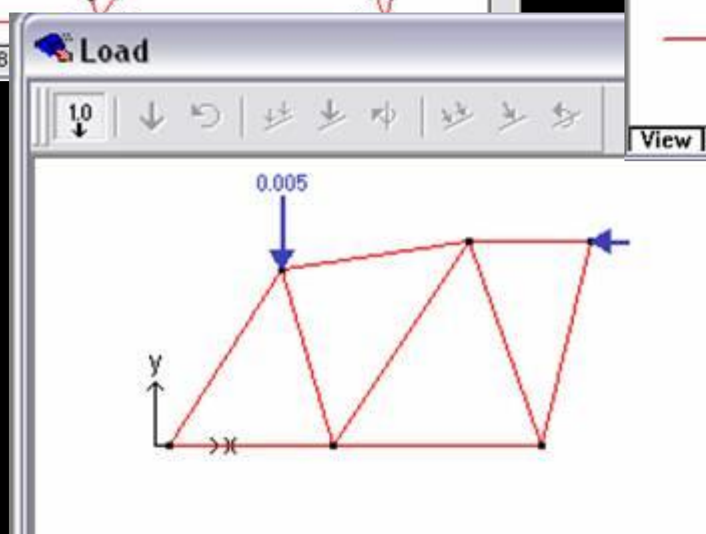
- *crossed*

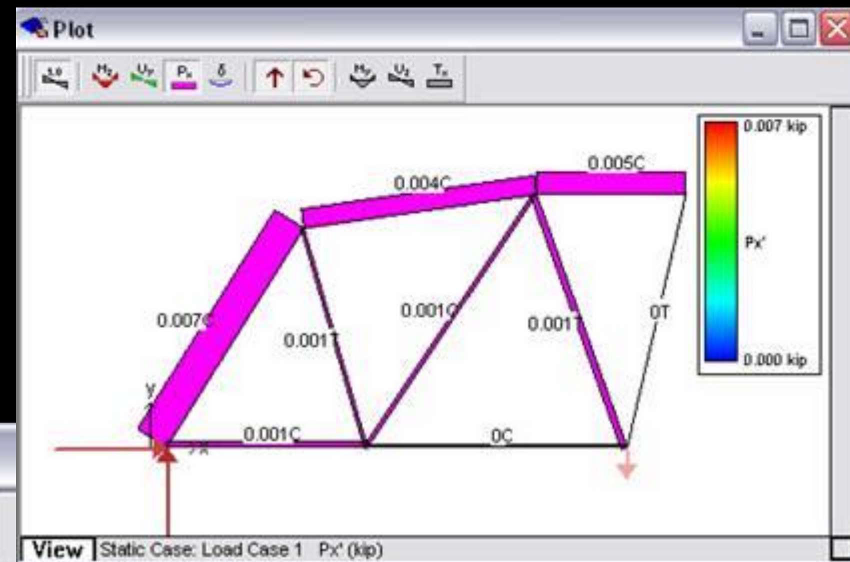


Tools – Multiframe

- *in computer lab*

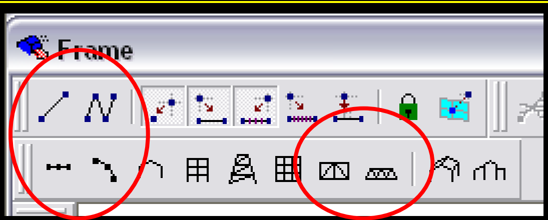




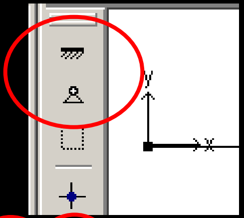


Tools – Multiframe

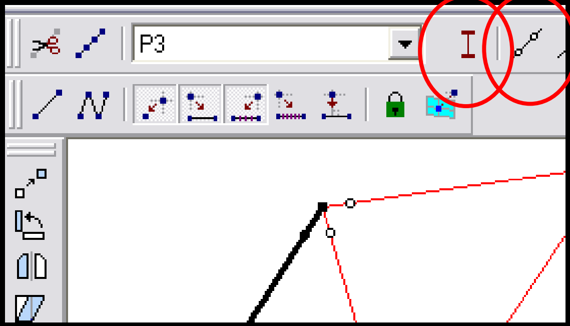
- *frame window*



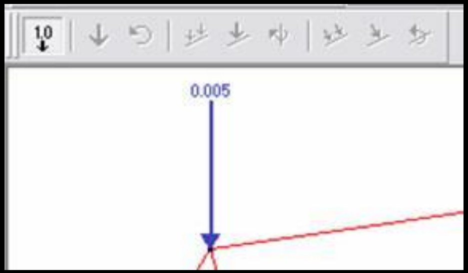
  - *define truss members*
    - *or pre-defined truss*



  - *select points, assign supports*
  - *select members, assign <u>section</u> & assign <u>pin ends</u>*

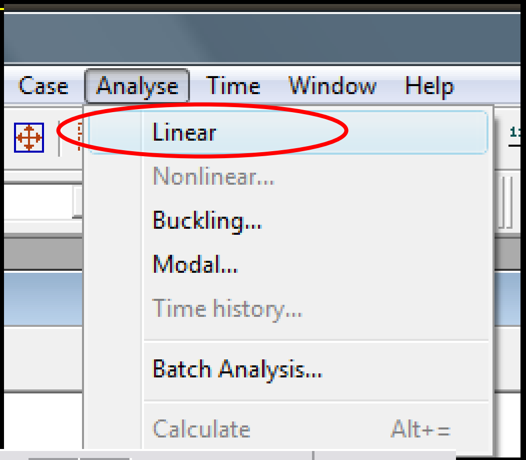


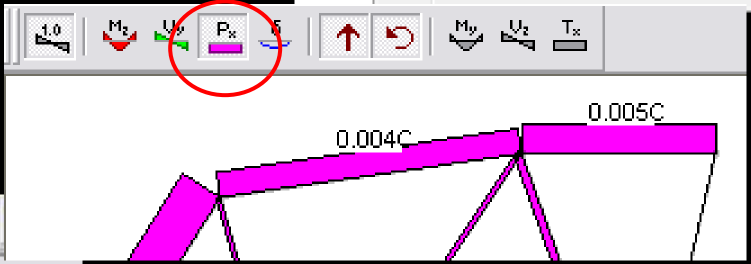
- *load window*
  - *select points, add point load*

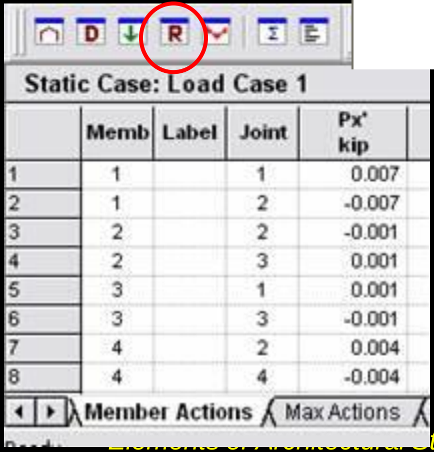


Tools – Multiframe

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







Static Case: Load Case 1

	Memb	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