Elements of Architectural Structures: Form, Behavior, and Design

ARCH 614

Dr. Anne Nichols

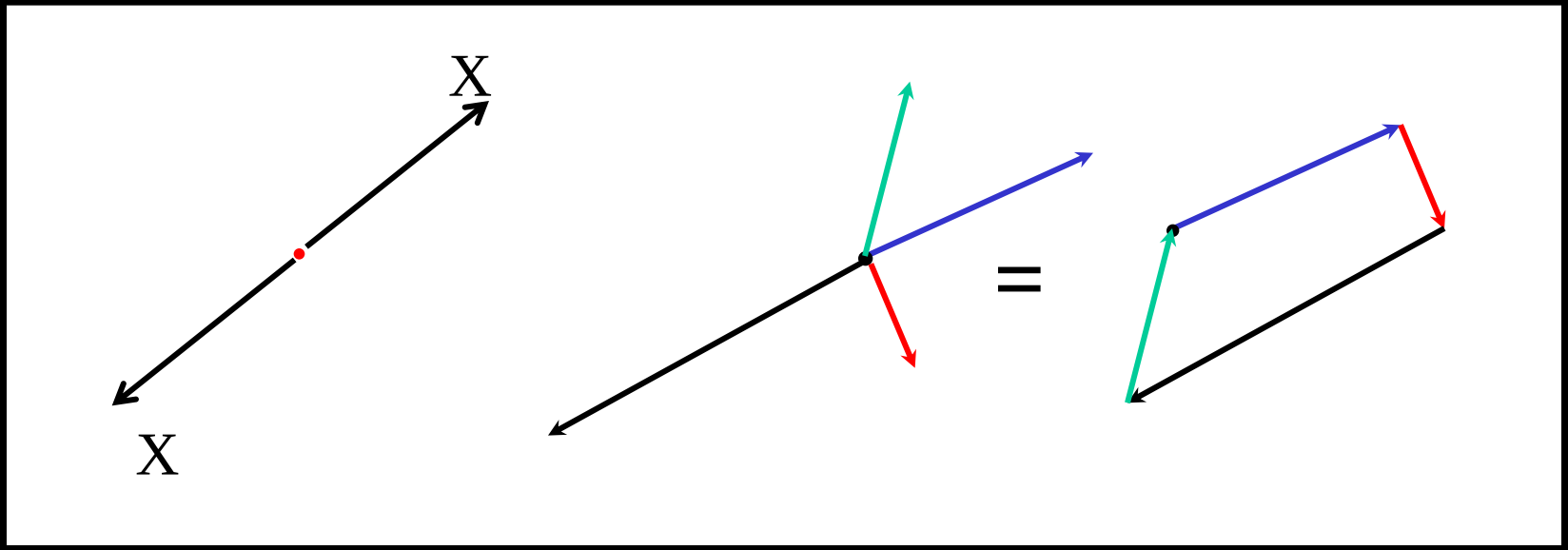
Spring 2013

lecture three

equilibrium and planar trusses

Equilibrium

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

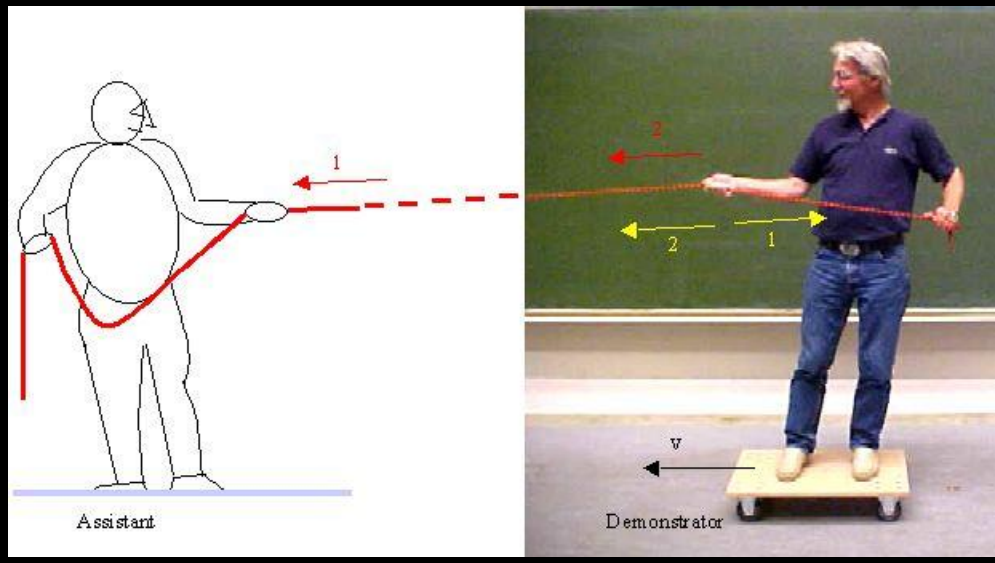


Equilibrium on a Point

- *analytically*

$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$



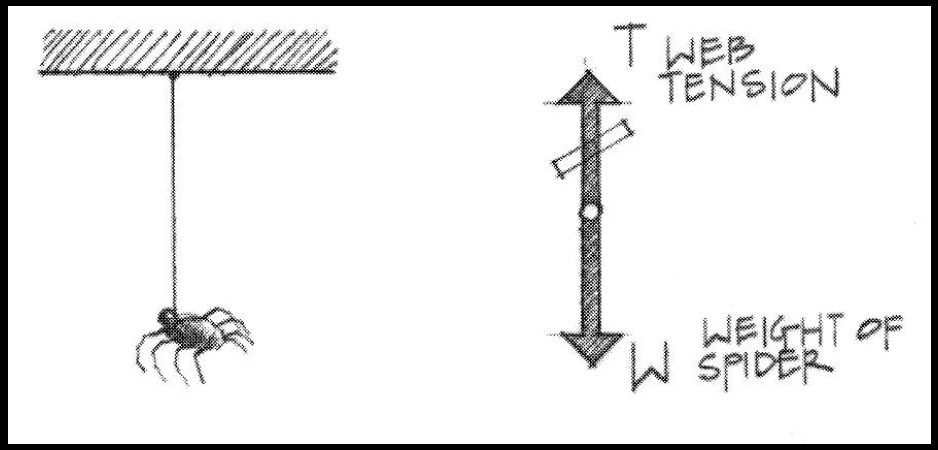
http://www.physics.umd.edu

- *Newton convinces us it will stay at rest*

Equilibrium on a Point

- collinear force system
  - ex: cables

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



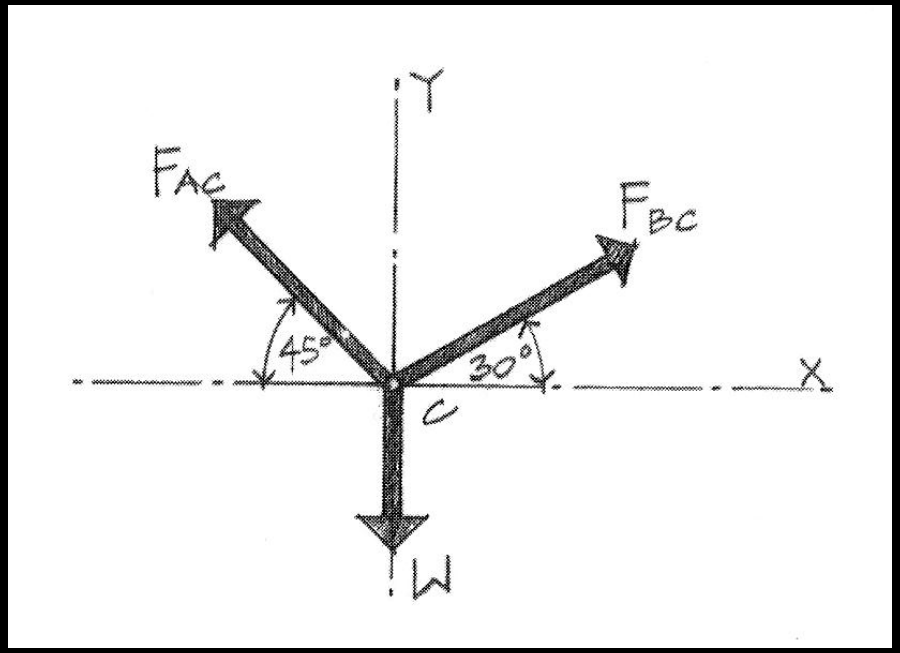
$$\left\{ R_x = \sum F_x = 0 \qquad R_y = \sum F_y = 0 \right\}$$

Equilibrium on a Point

- concurrent force system
  - ex: cables

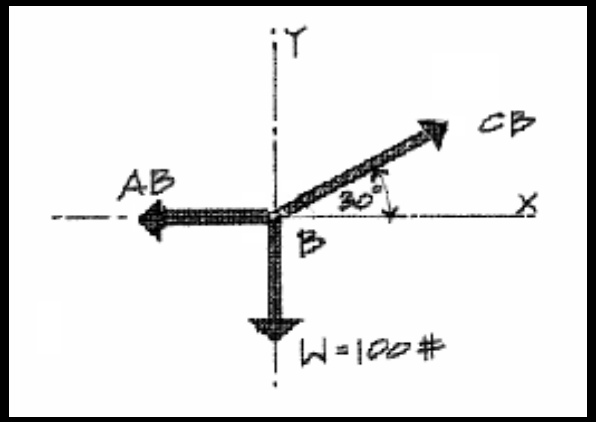
$$R_x = \sum F_x = 0$$

$$R_y = \sum F_y = 0$$



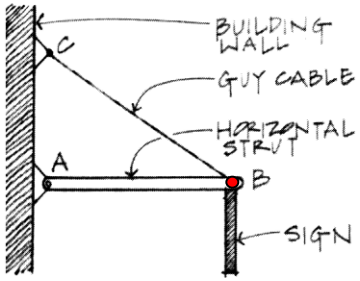
Free Body Diagram

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

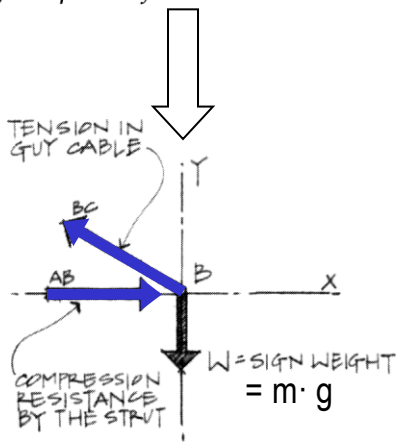


Free Body Diagram

- *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 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*

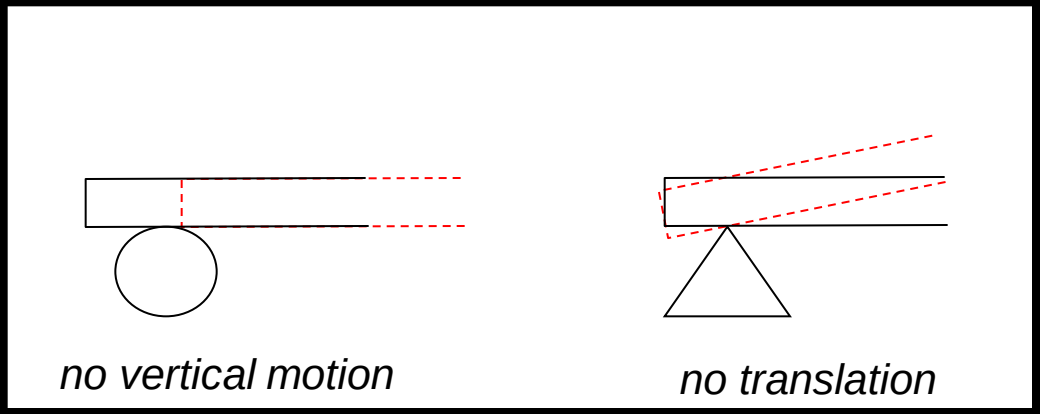
Free Body Diagram

- *solve equations*
  - *most times 1 unknown easily solved*
  - *plug into other equation(s)*

- *common to have unknowns of*
  - *force magnitudes*
  - *force angles*

Force Reactions

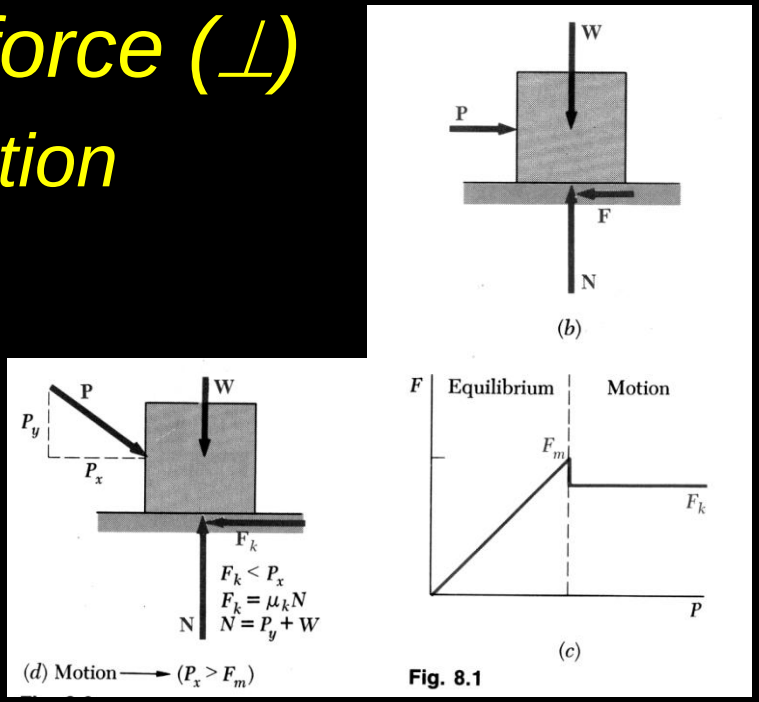
- *result of applying force*
- *unknown size*
- *connection or support type*
  - *known direction*
  - *related to motion prevented*



Friction

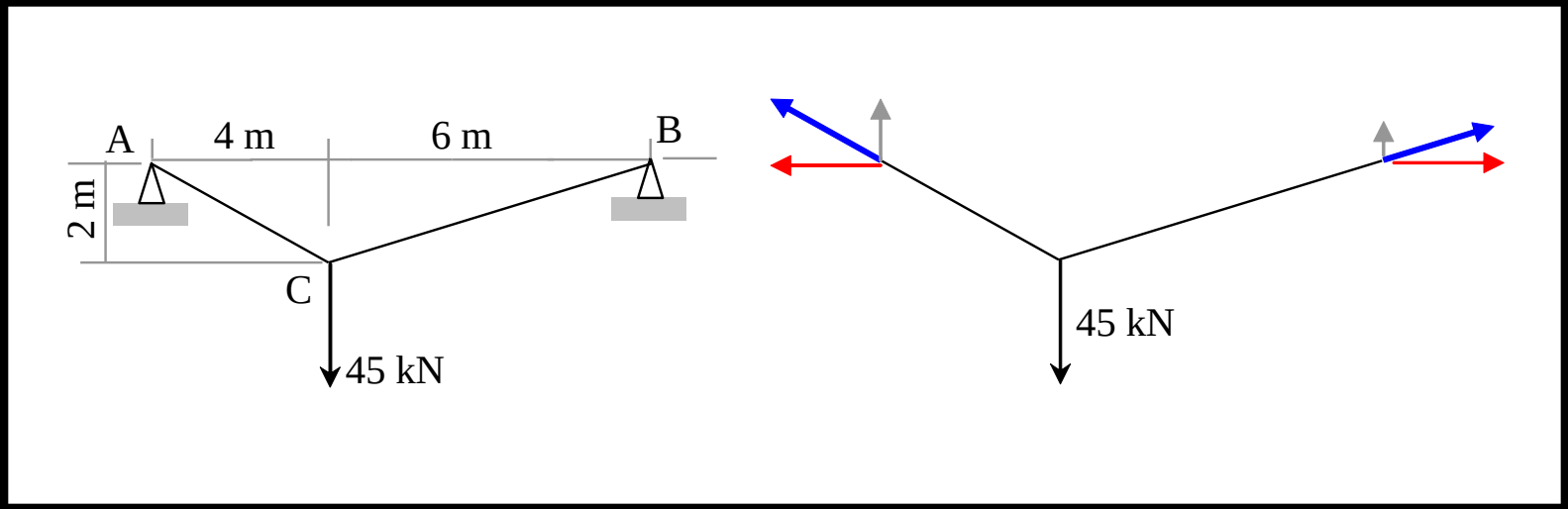
- *resistance to movement*
- *contact surfaces determine μ*
- *proportion of normal force ($\perp$)*
  - *opposite to slide direction*
  - *static > kinetic*

$$F = \mu N$$



Cable Reactions

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

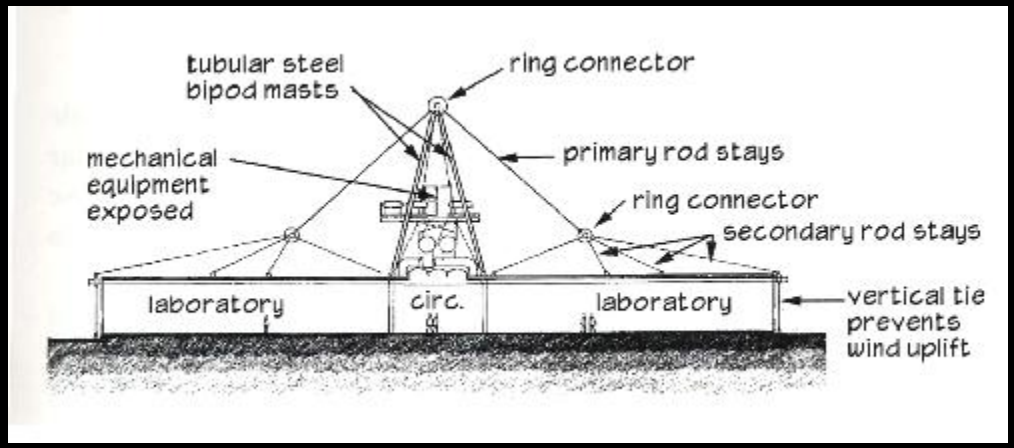


Cable-Stayed Structures

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

Patcenter, Rogers 1986

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



Patcenter, Rogers 1986

- *dashes – cables pulling*

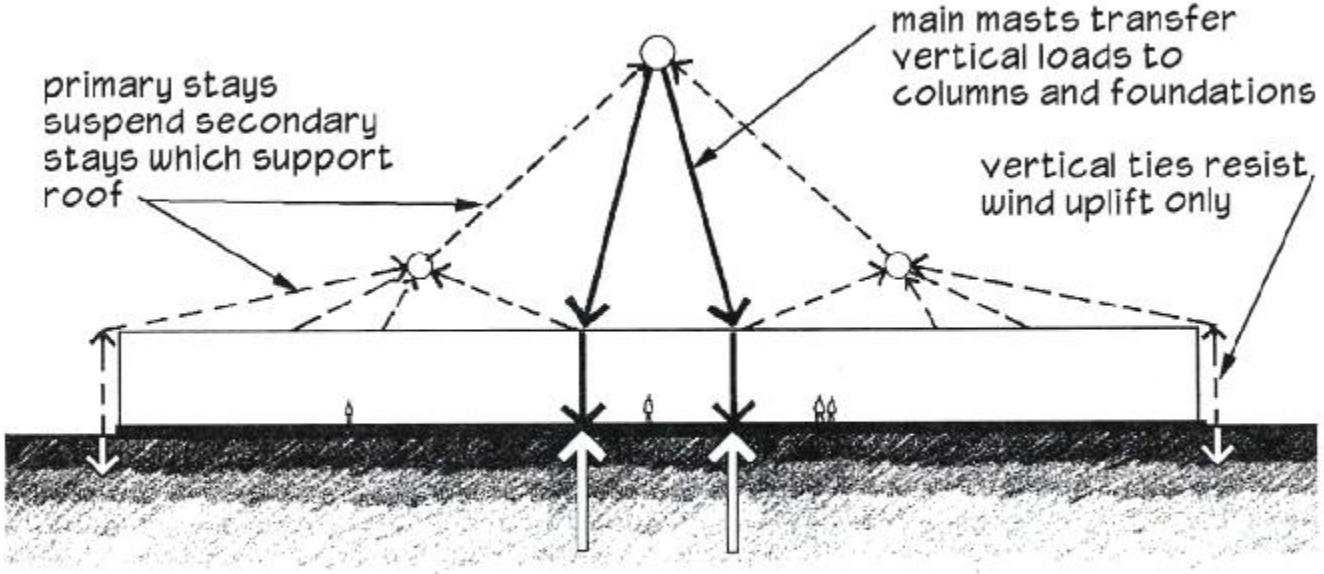


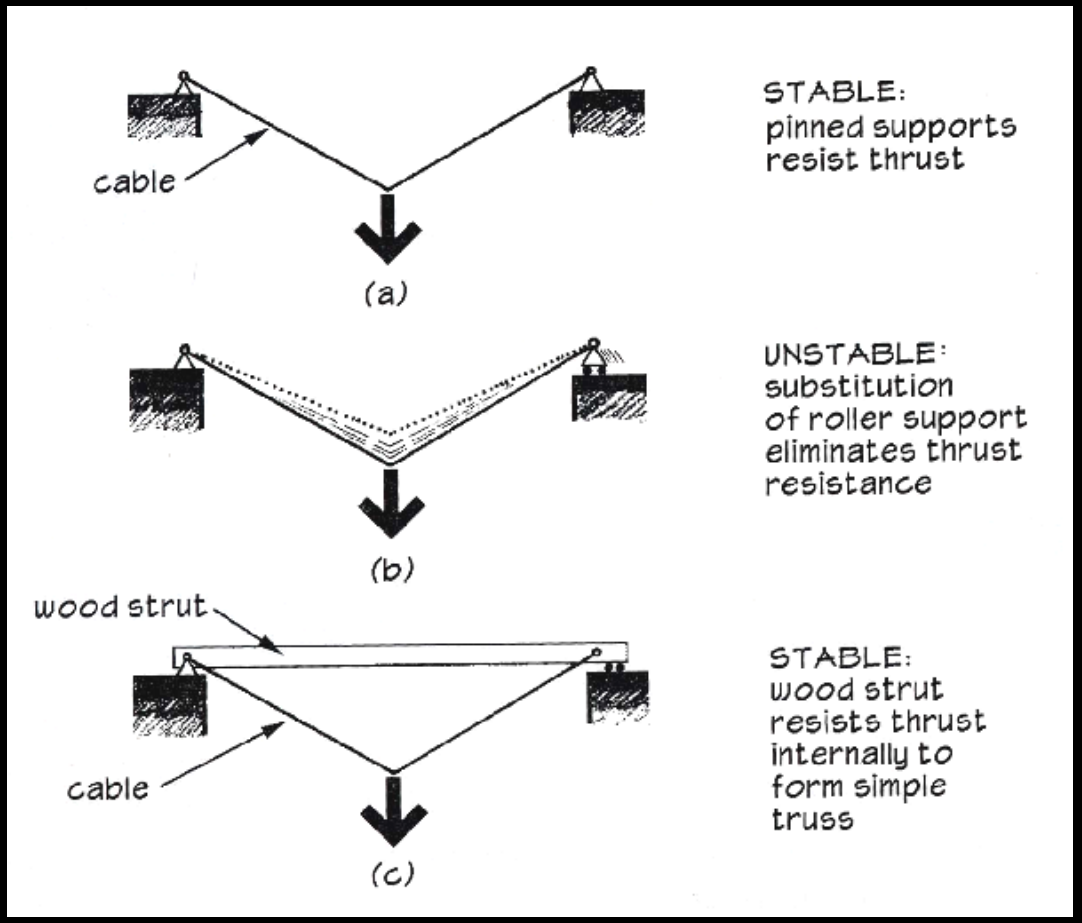
Figure 3.5: Patcenter, load path diagram.

Truss Structures

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

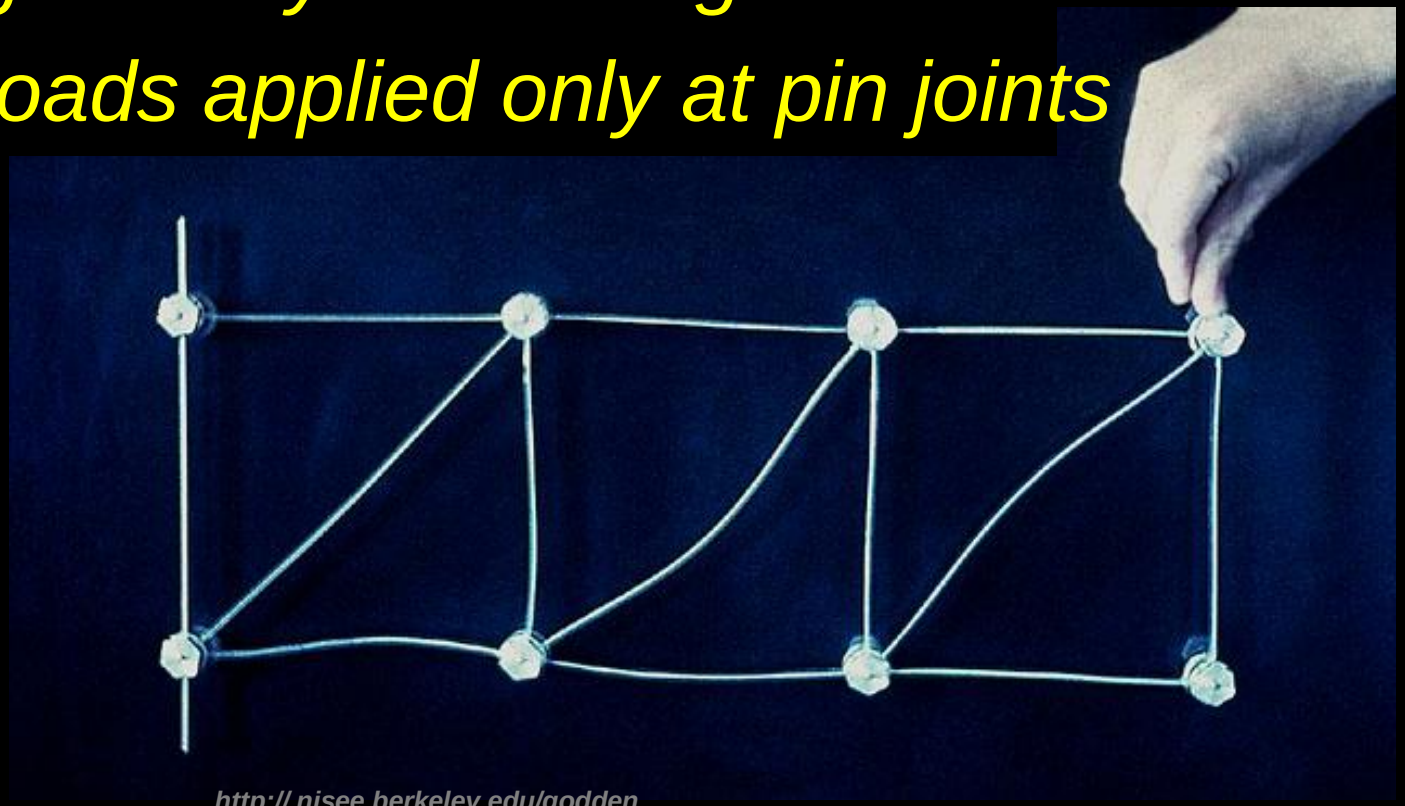
Truss Structures

– analogous to cables and struts



Truss Structures

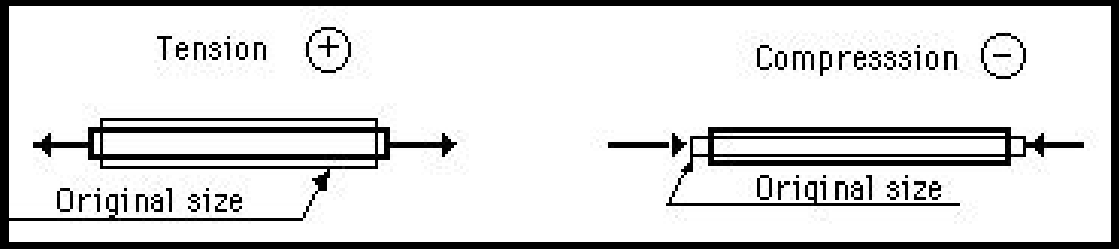
- *comprised of straight members*
- *geometry with triangles is stable*
- *loads applied only at pin joints*



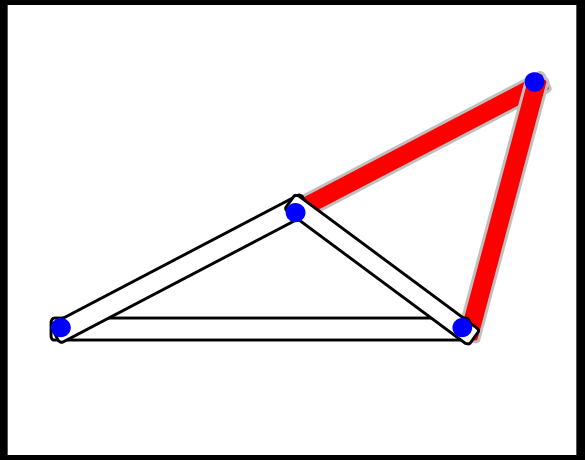
http:// nisee.berkeley.edu/godden

Truss Structures

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

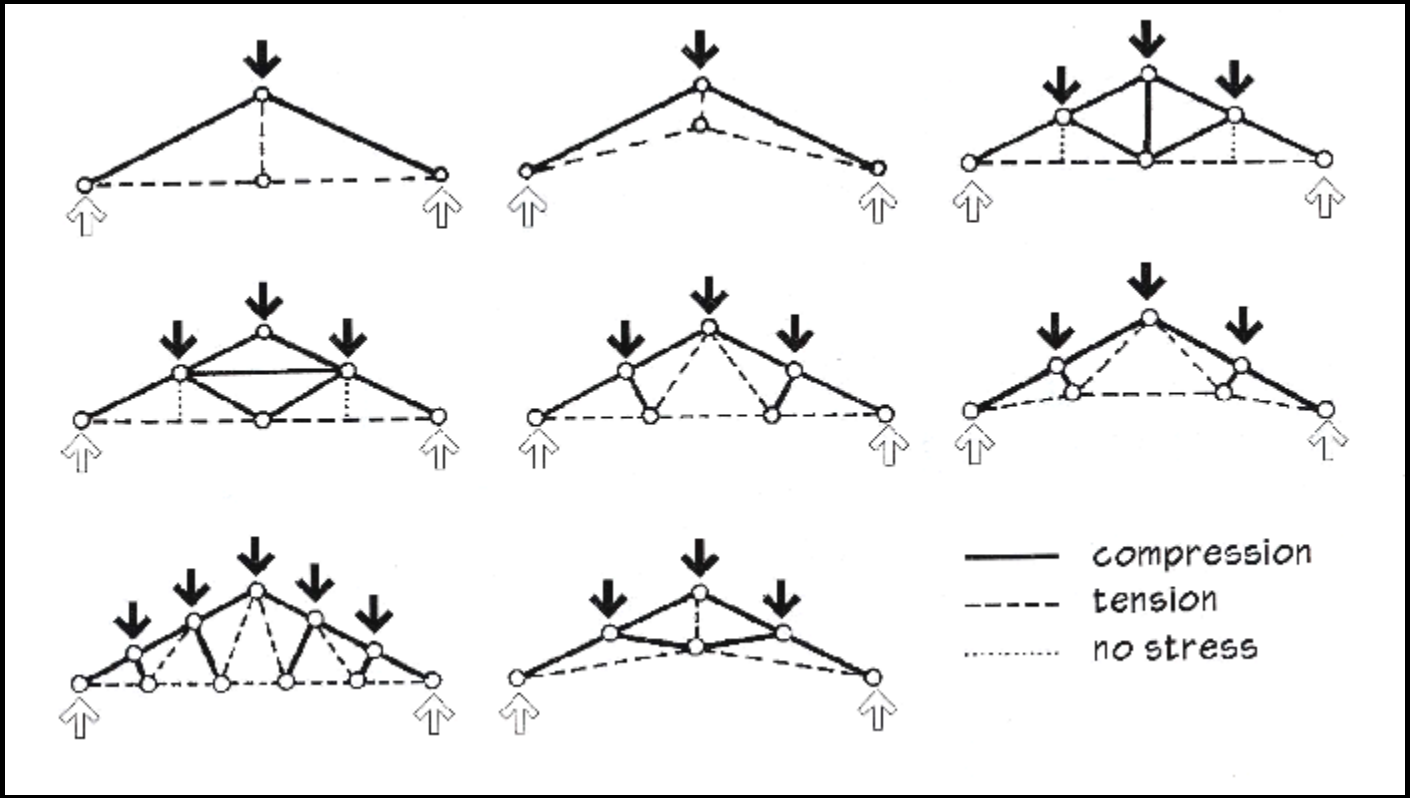


- *3 members connected by 3 joints*
- *2 more members need 1 more joint* $b = 2n - 3$



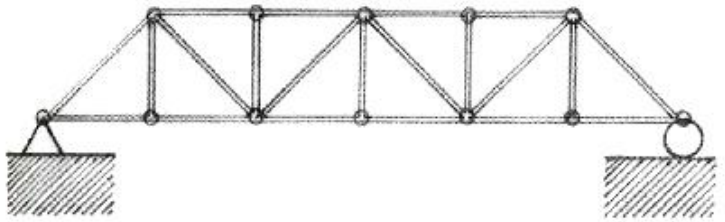
Truss Structures

- *compression and tension*



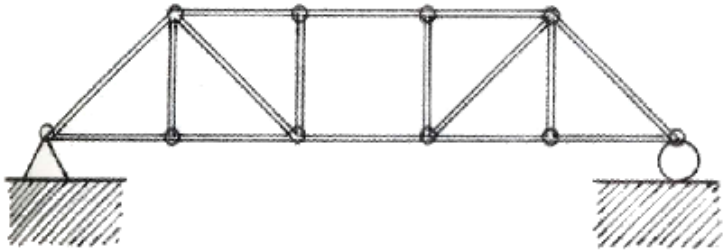
Truss Structures

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



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

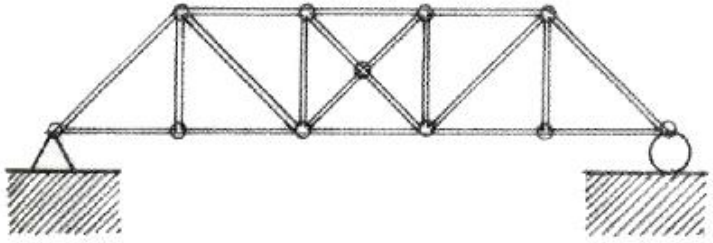
(a) Determinate.



b = 16 n = 10 b = 16 < 2(10) – 3 = 17

(Too few members—square panel is unstable)

(c) Unstable.



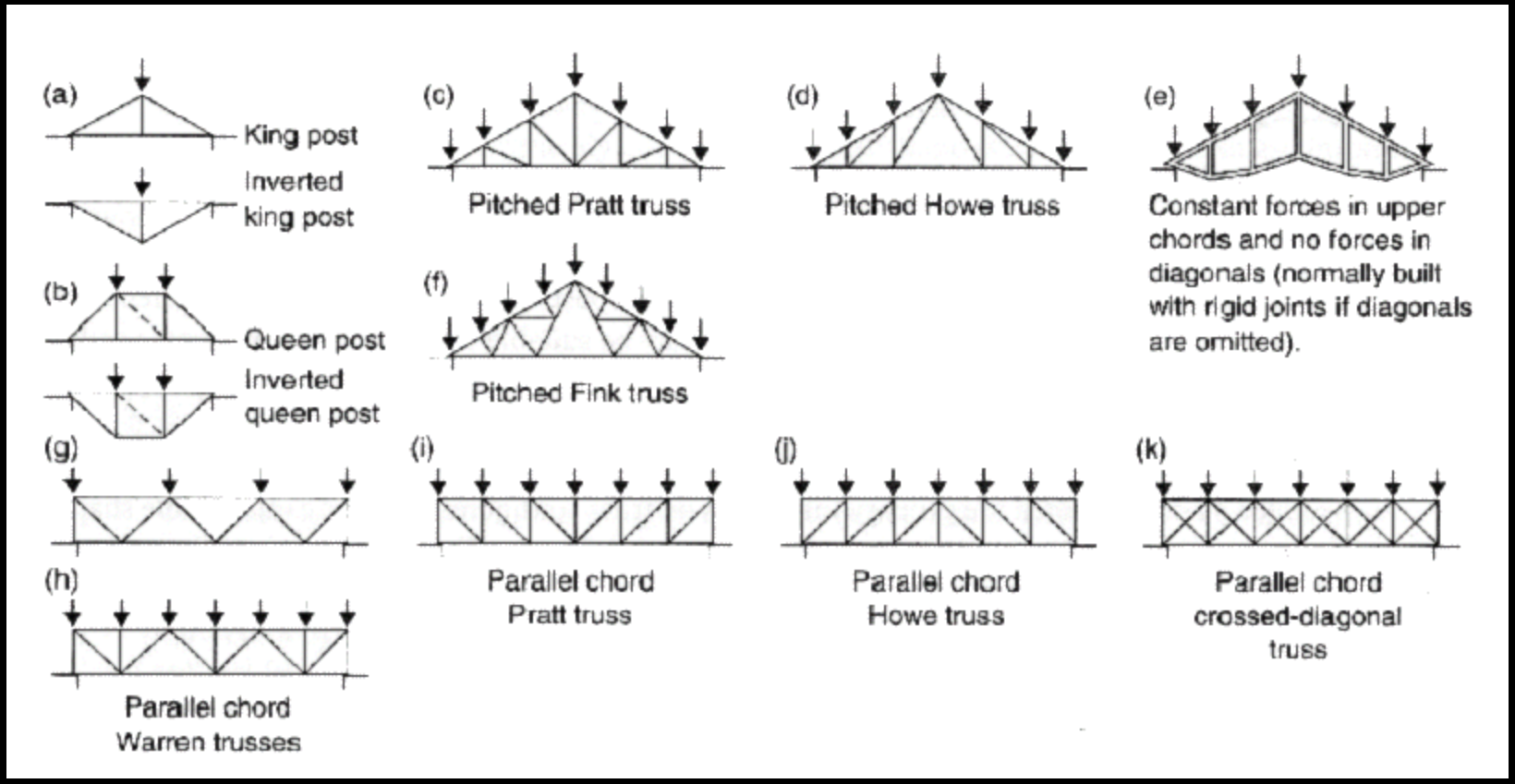
b = 18 n = 10 b = 18 > 2(10) – 3 = 17

(Too many members)

(b) Indeterminate.

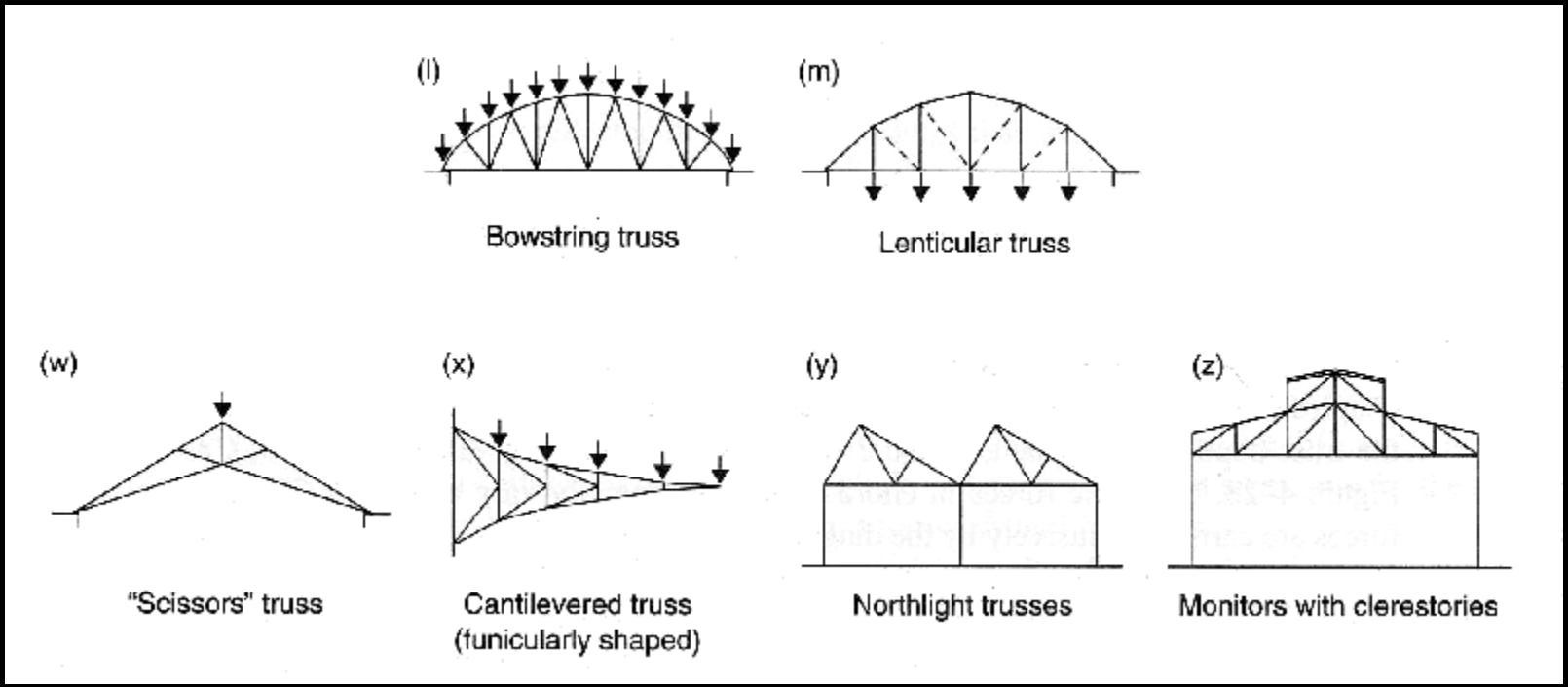
Trusses

- *common designs*



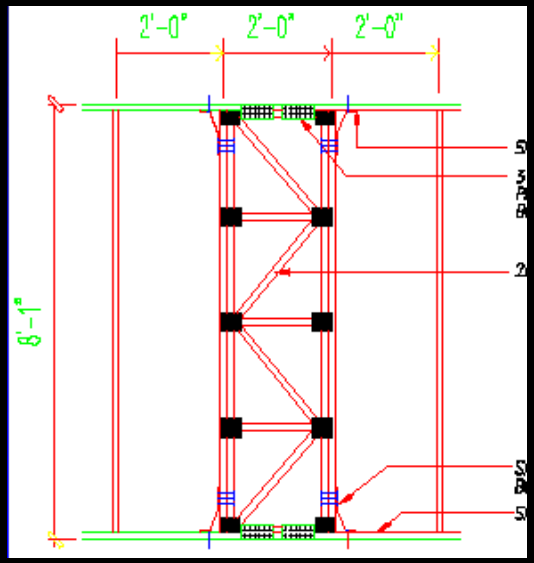
Trusses

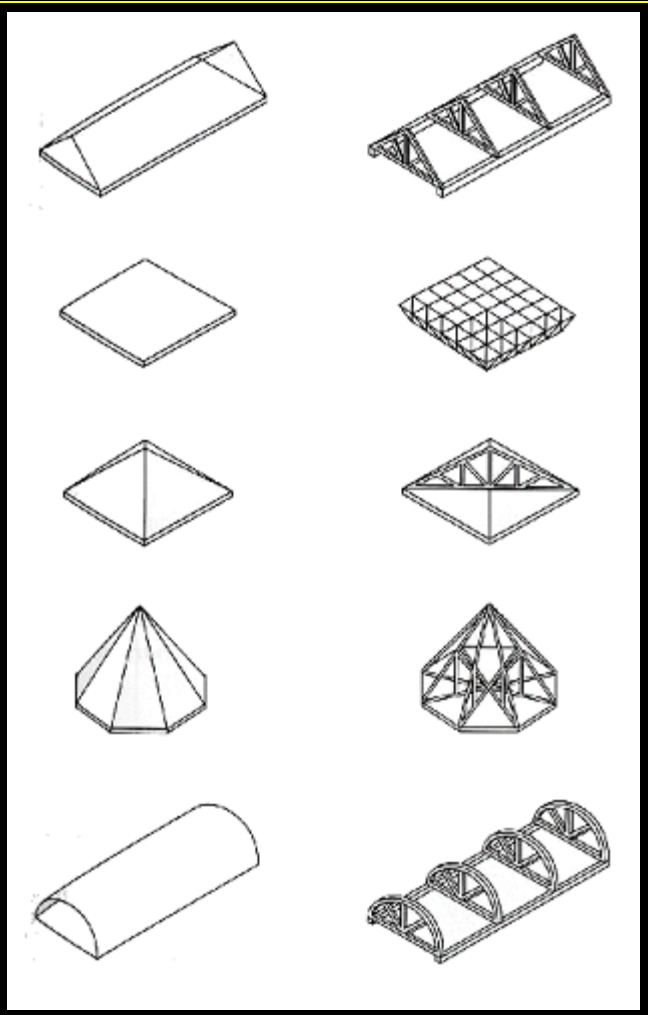
- *common designs*



Trusses

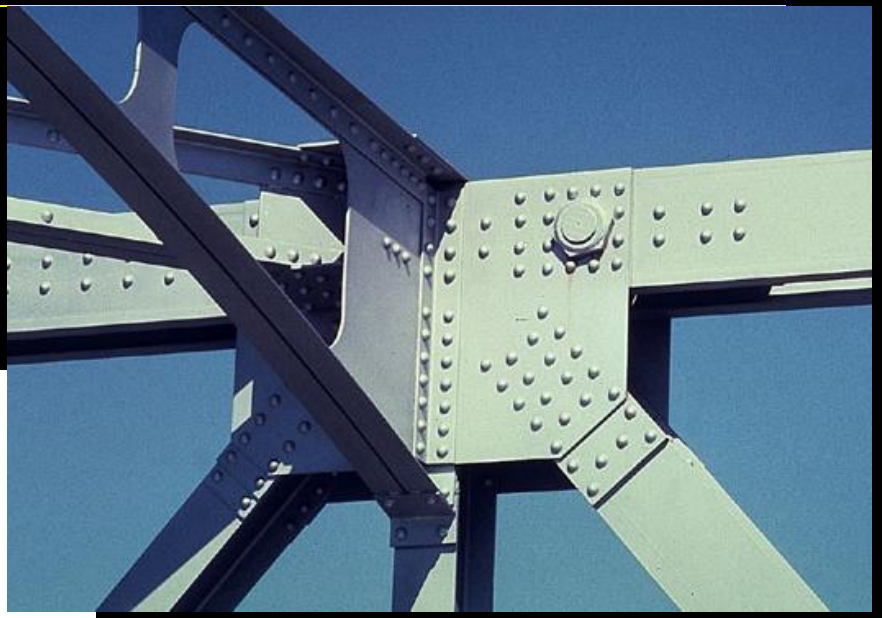
- *uses*
  - *roofs & canopies*
  - *long spans*
  - *lateral bracing*





Truss Connections

- *"pins"*



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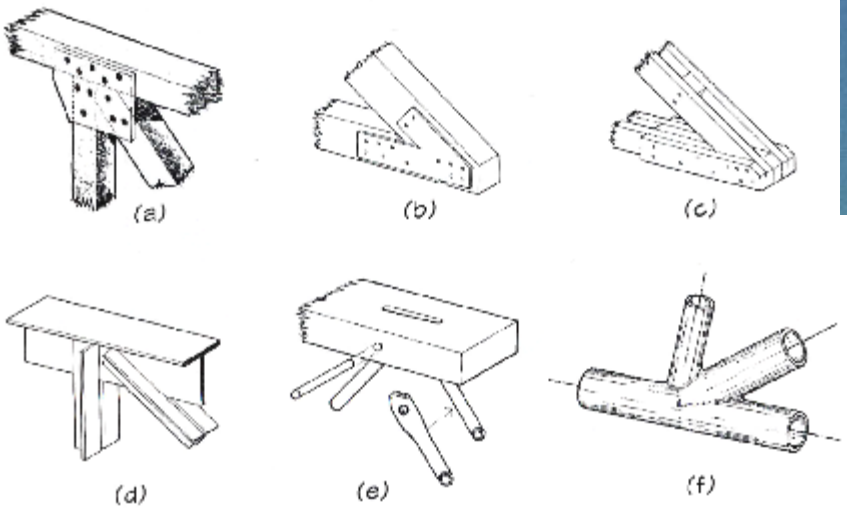
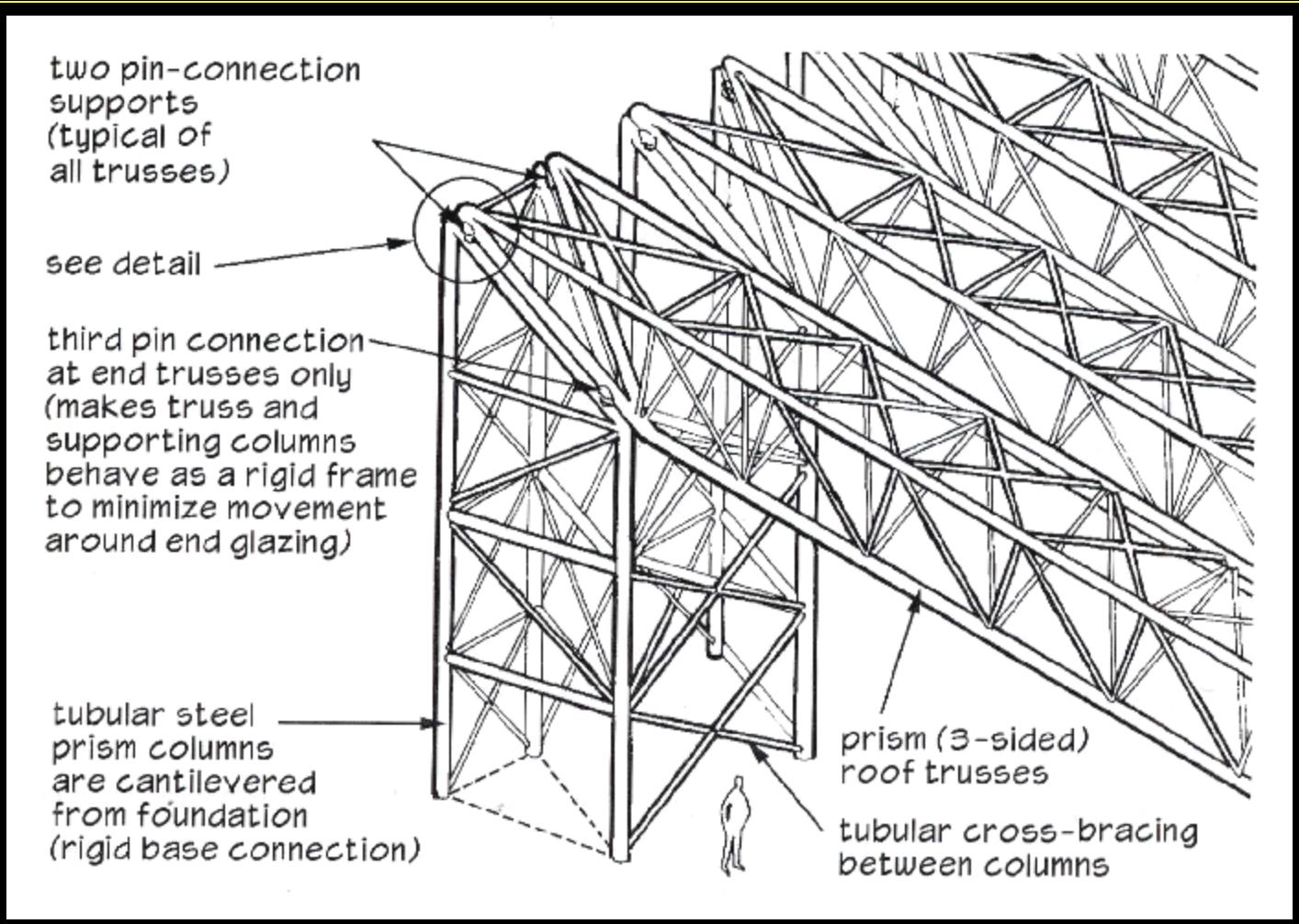


Figure 4.8: Truss joints.

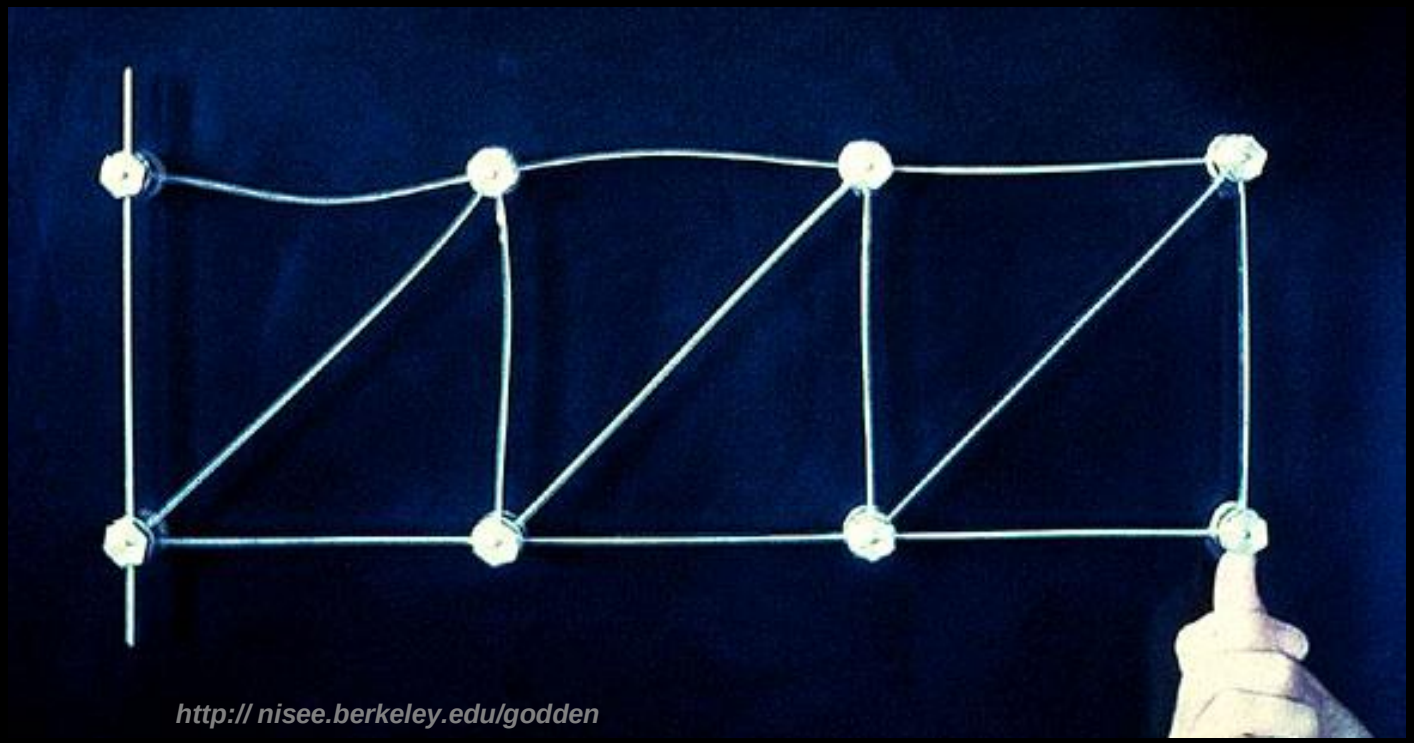
Sainsbury Center, Foster 1978

Sainsbury Center, Foster 1978



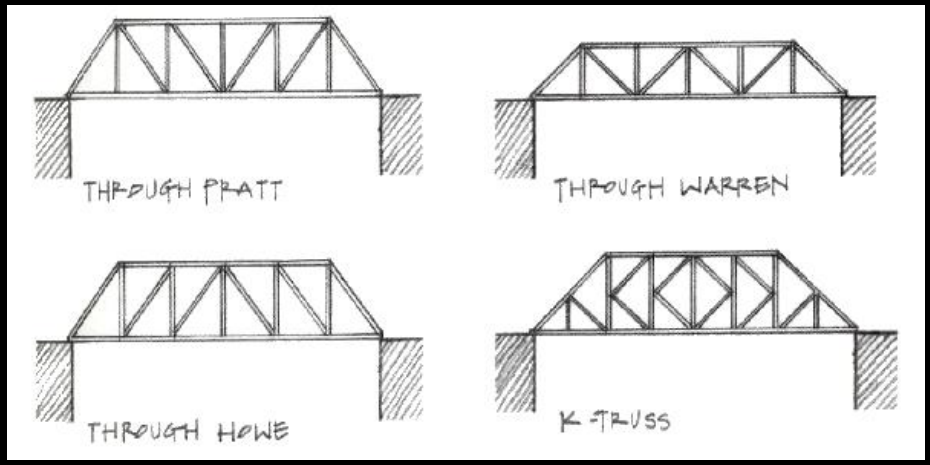
Truss Analysis

- *visualize compression and tension from deformed shape*

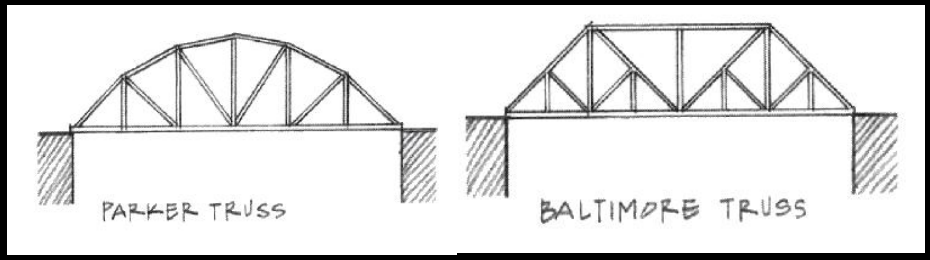


Truss Analysis

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



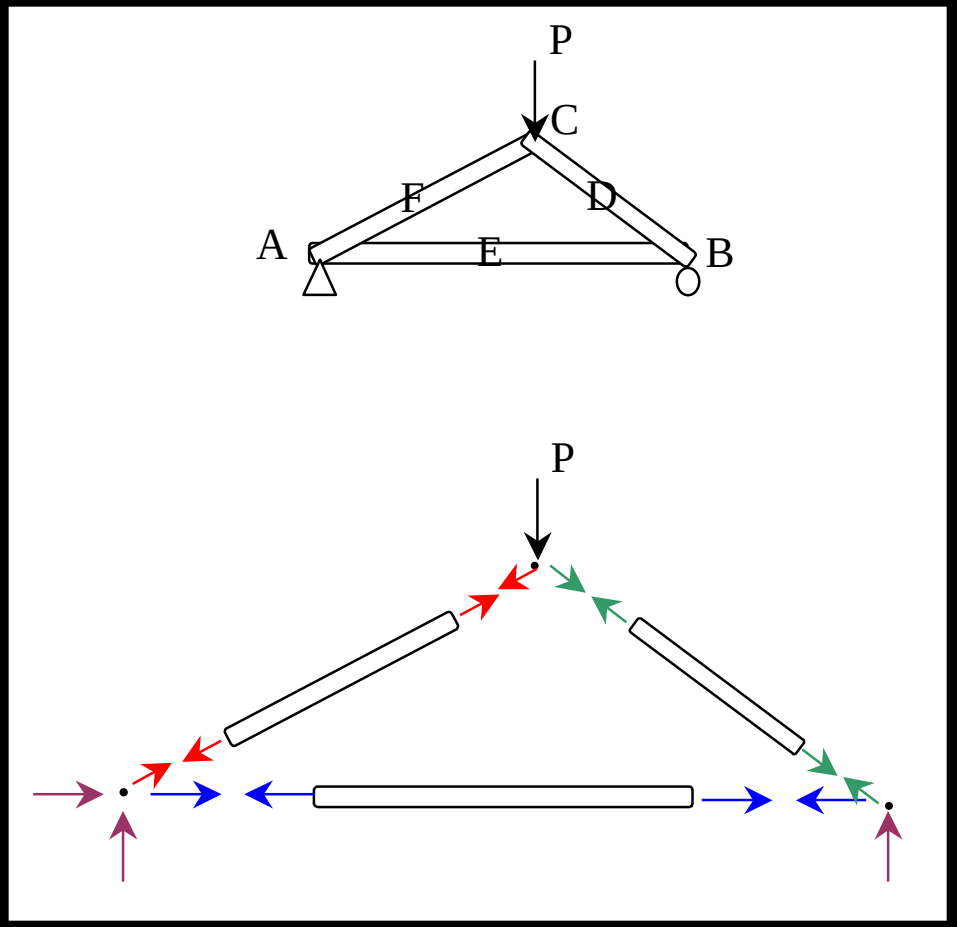
- *all rely on equilibrium*
  - *of bodies*
  - *internal equilibrium*



Method of Joints

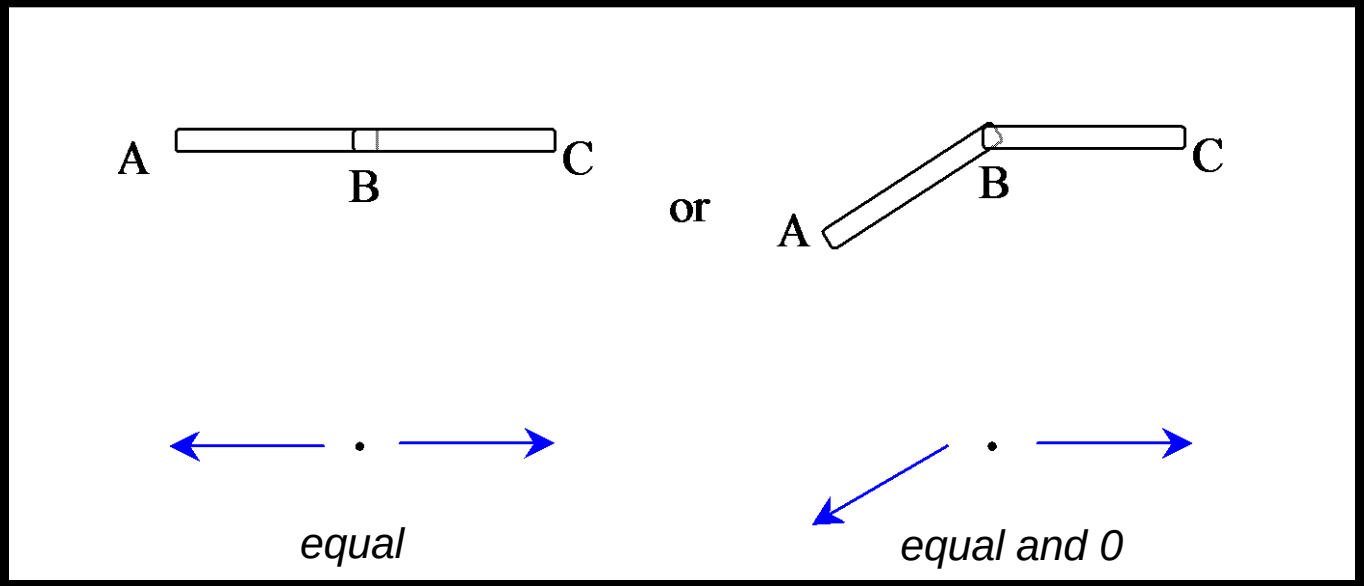
- *isolate each joint*
- *enforce equilibrium in F_x and F_y*
- *can find all forces*

- *long*
- *easy to mess up*



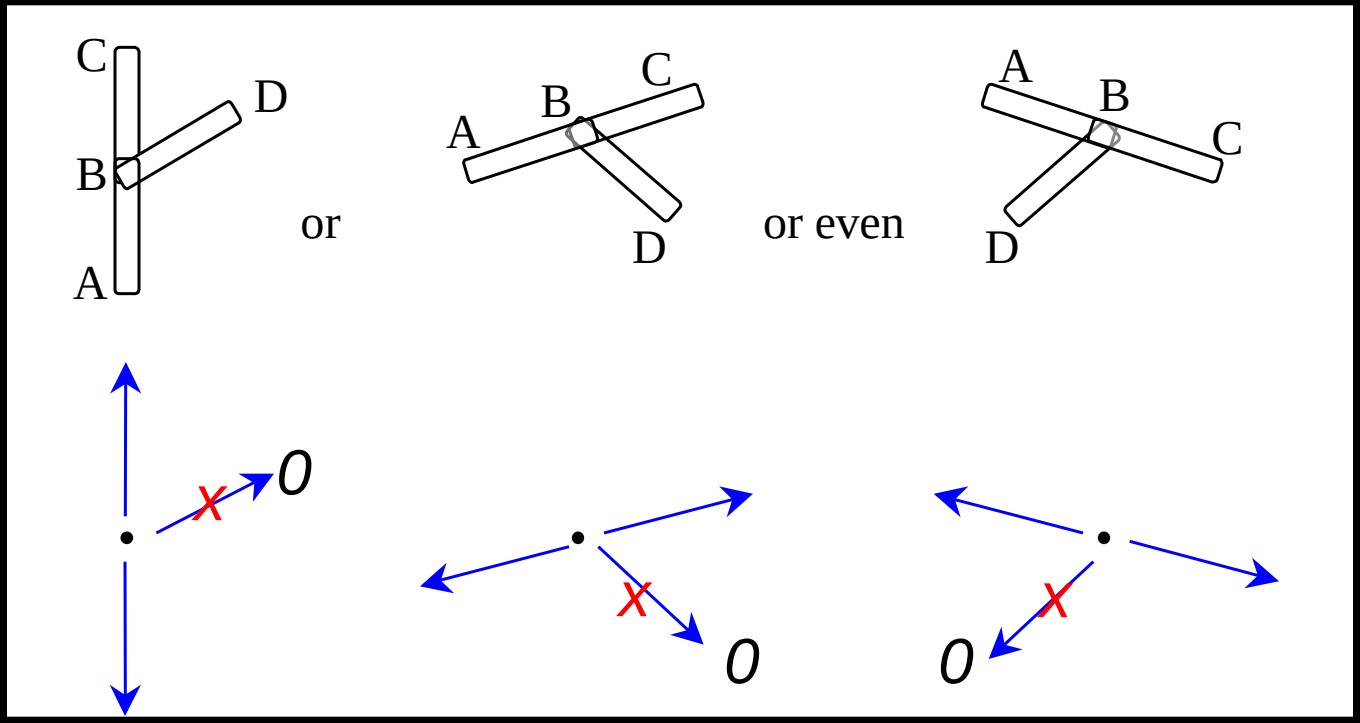
Joint Cases

- *two bodies connected*



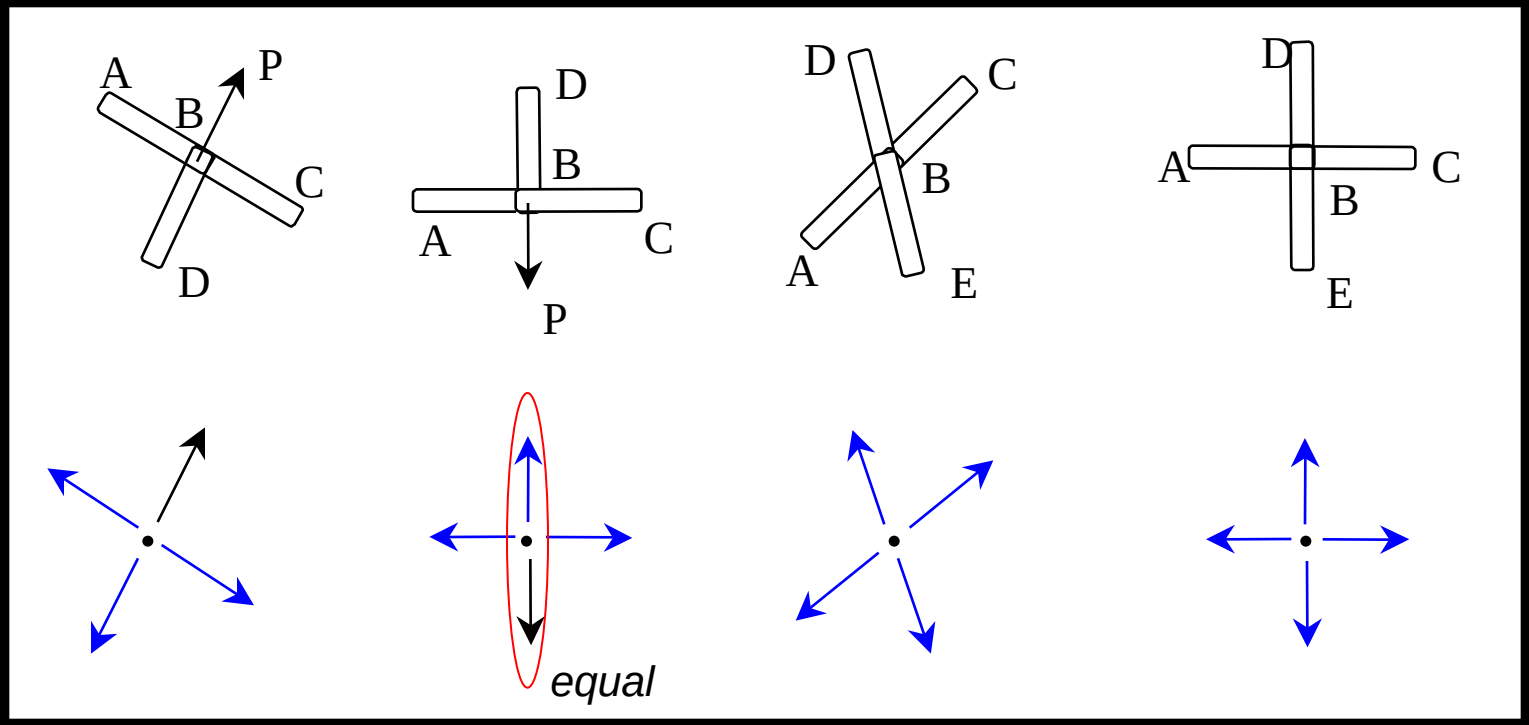
Joint Cases

- *three bodies with two in line*



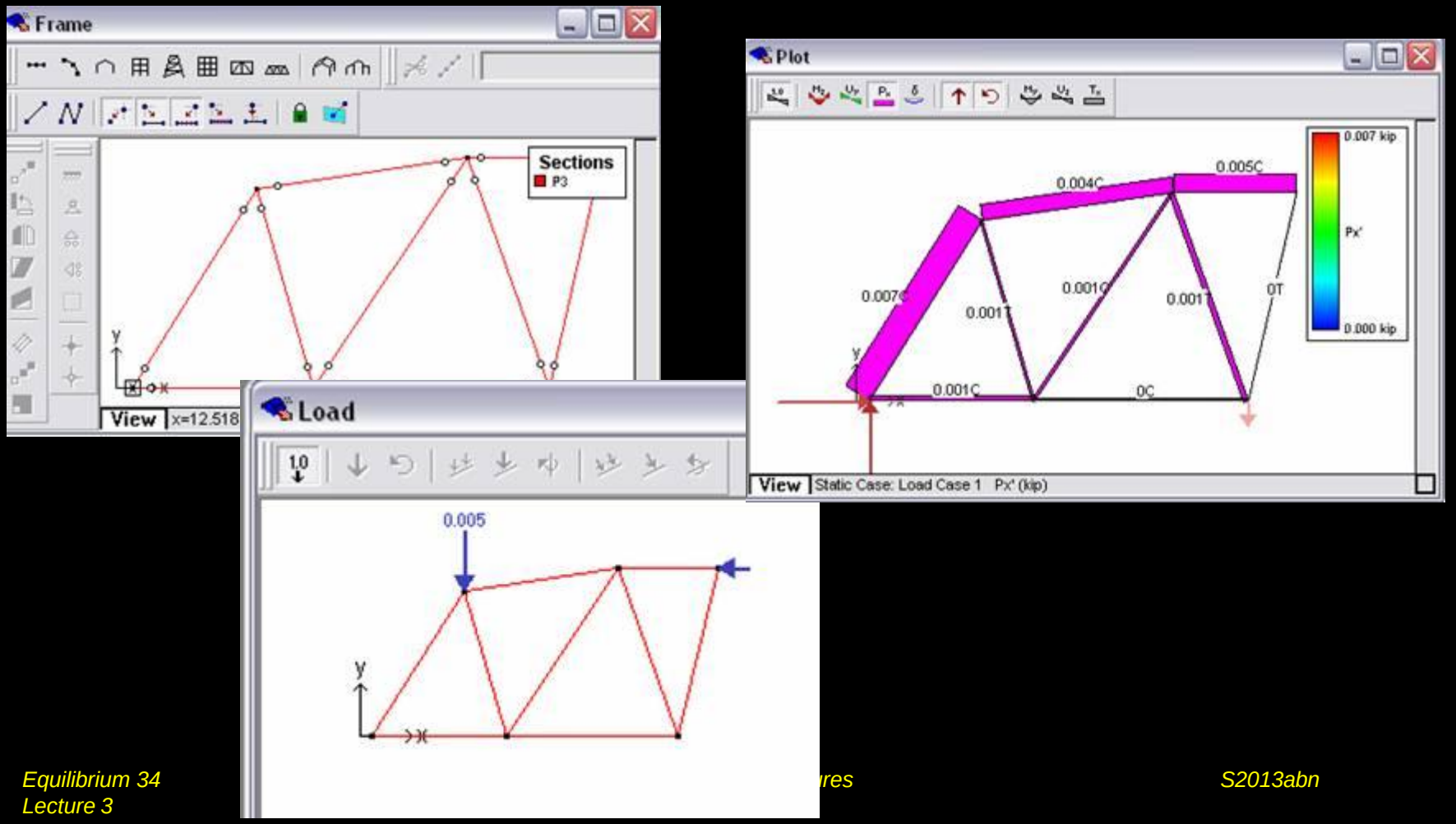
Joint Cases

- *crossed*



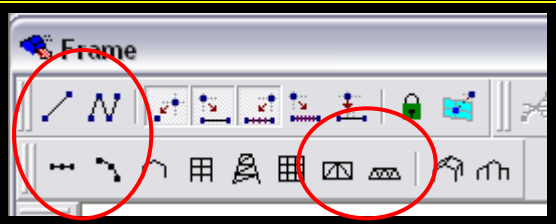
Tools – Multiframe

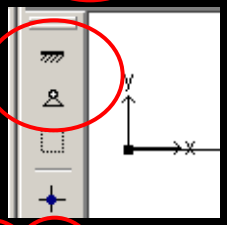
- *in computer lab*

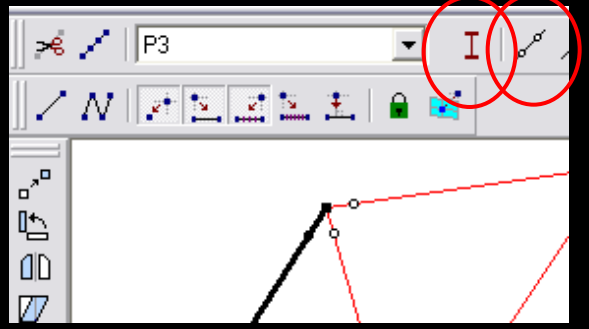


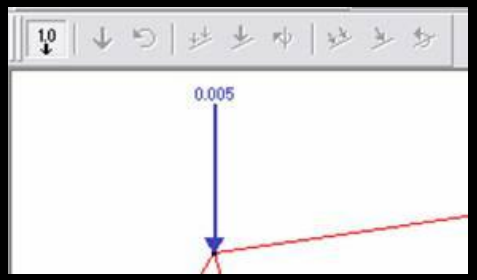
Tools – Multiframe

- *frame window*
  - *define truss members*
    - *or pre-defined truss*
  - *select points, assign supports*
  - *select members, assign 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*