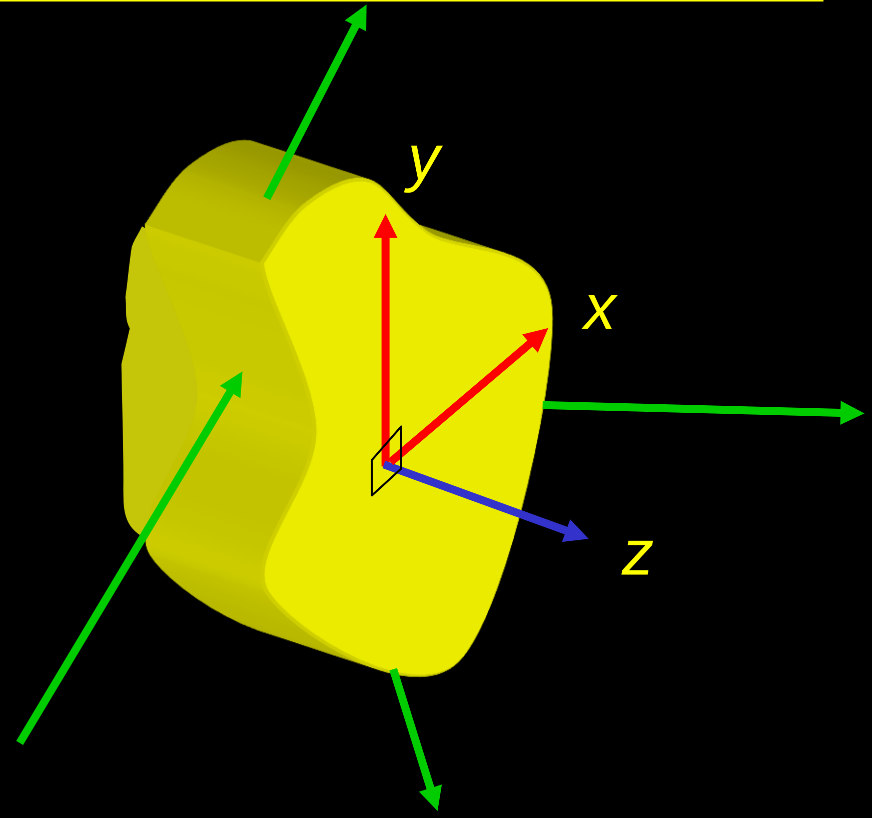
Elements of Architectural Structures: Form, Behavior, and Design

ARCH 614
Dr. Anne Nichols
Spring 2014

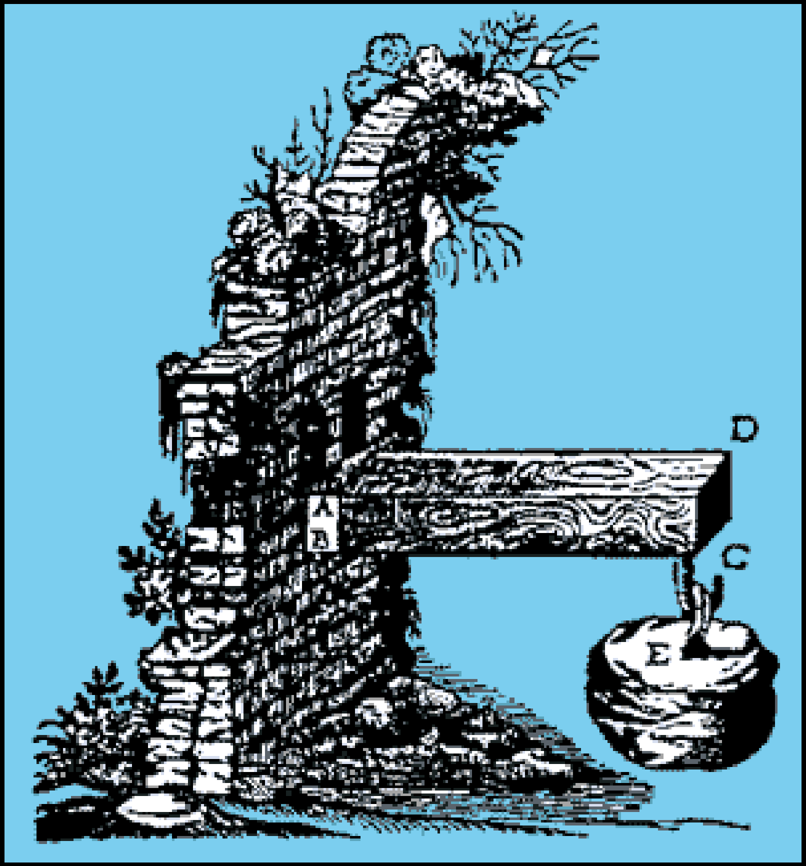
lecture
two

loads, forces and vectors



Structural Design

- *planning*
- *preliminary structural configuration*
- *<u>determination of loads</u>*
- *preliminary member selection*
- *analysis*
- *evaluation*
- *design revision*
- *final design*



Structural Loads

- *STATIC and DYNAMIC*
- *dead load*
  - *static, fixed, includes building weight, fixed equipment*
- *live load*
  - *transient and moving loads (including occupants), snowfall*

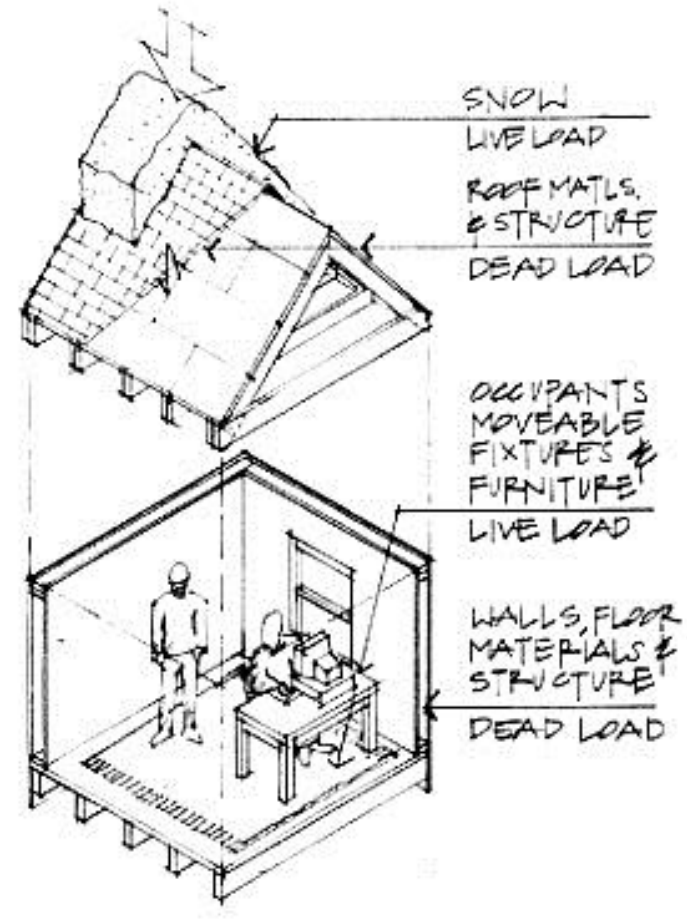


Figure 1.12 *Typical building loads.*

Structural Loads

- *wind loads*
  - *dynamic, wind pressures treated as lateral static loads on walls, up or down loads on roofs*

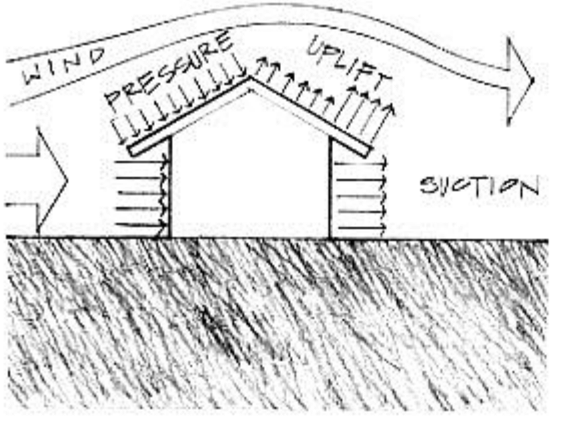


Figure 1.13 Wind loads on a structure.

Structural Loads

- earthquake loads
  - seismic, movement of ground ↕ ↔

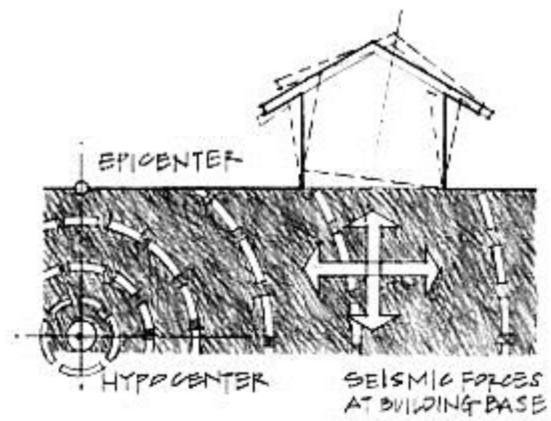
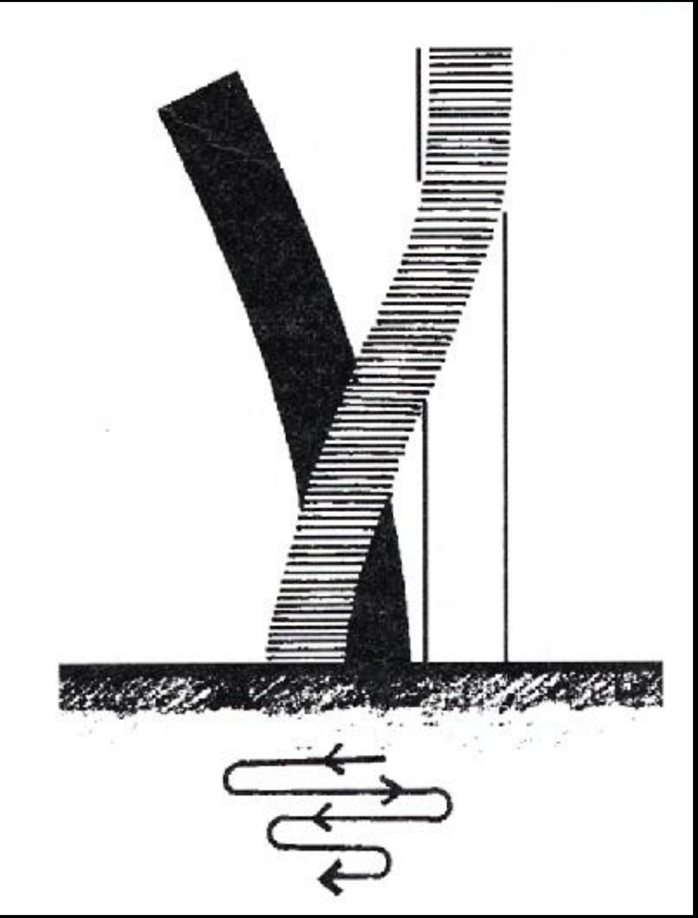
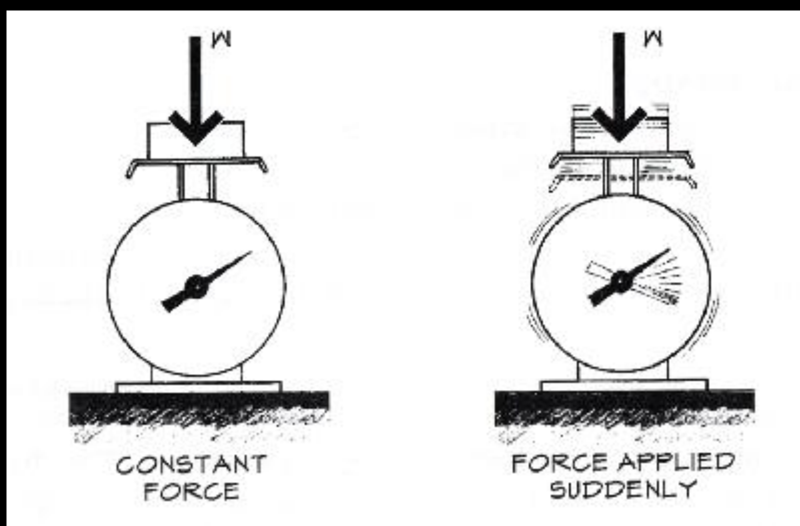


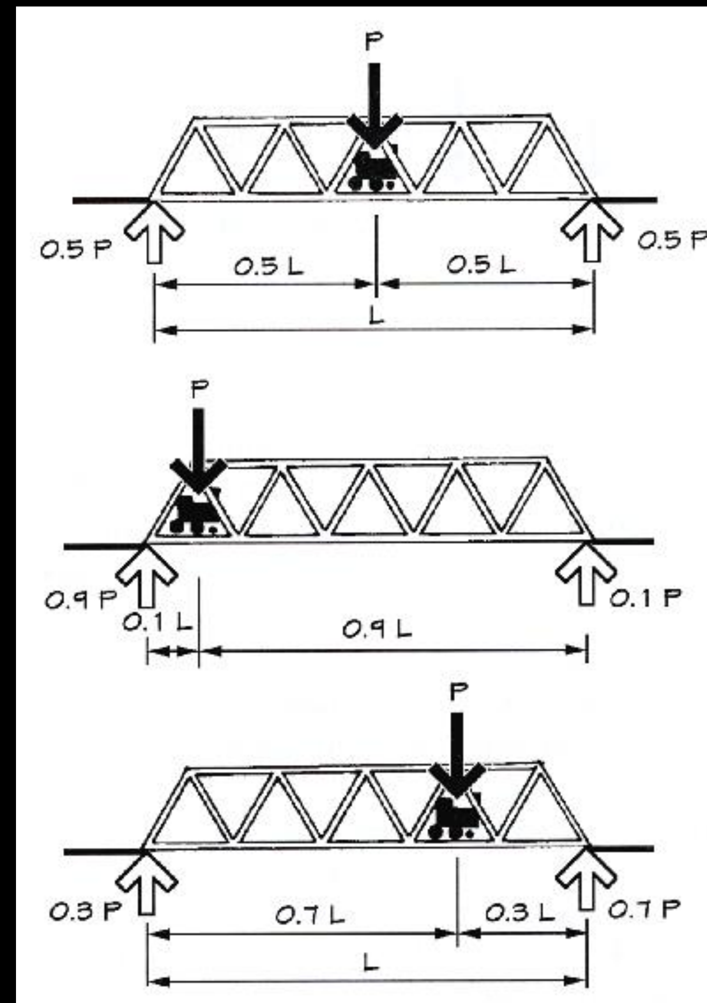
Figure 1.14 Earthquake loads on a structure.



Structural Loads

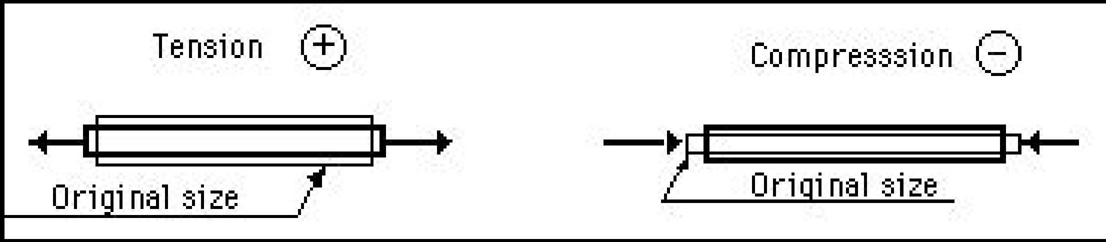
- *impact loads*
  - *rapid, energy loads*





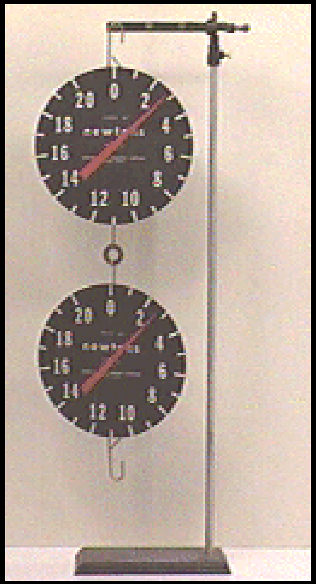
Forces

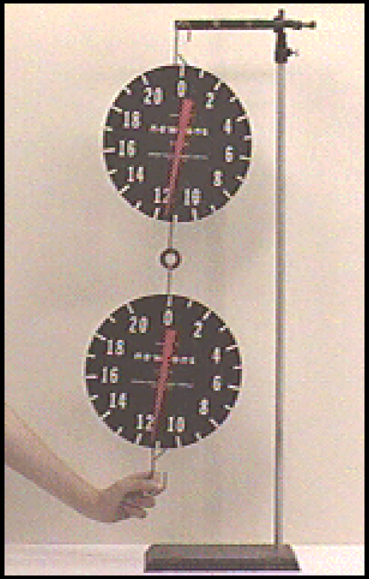
- *statics*
  - *physics of <u>forces</u> and reactions on bodies and systems*
  - *equilibrium (bodies at rest)*
- *forces*
  - *something that exerts on an object:*
    - *motion*
    - *tension*
    - *compression*



Forces

- *"action of one body on another that affects the state of motion or rest of the body"*
- *Newton's 3rd law:*
  - *for every force of action there is an equal and opposite reaction along the same line*

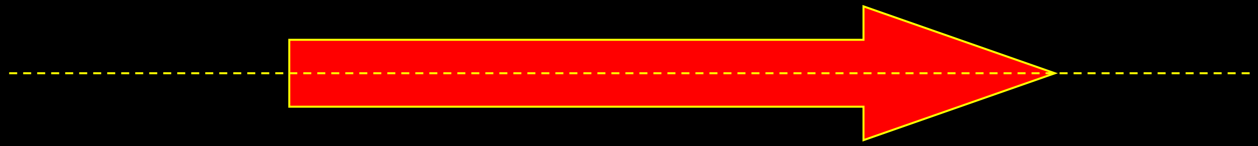




http://www.physics.umd.edu

Force Vectors

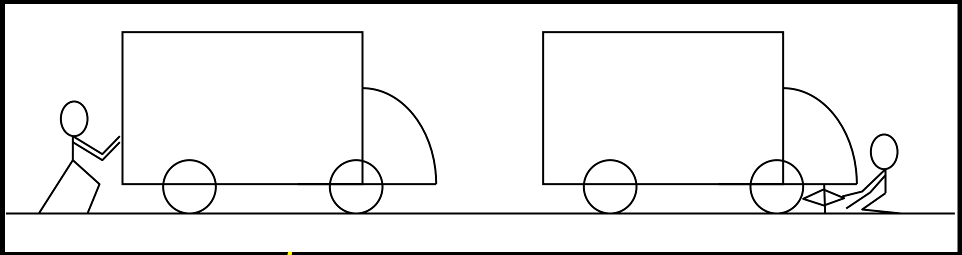
- applied at a point
- magnitude
  - Imperial units: lb, k (kips)
  - SI units: N (newtons), kN
- direction
- sense



(tail) (tip)

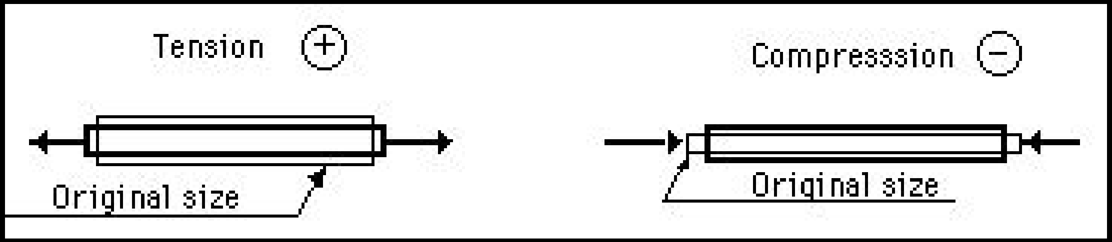
Forces on Rigid Bodies

- for statics, the bodies are ideally rigid
- can translate and rotate



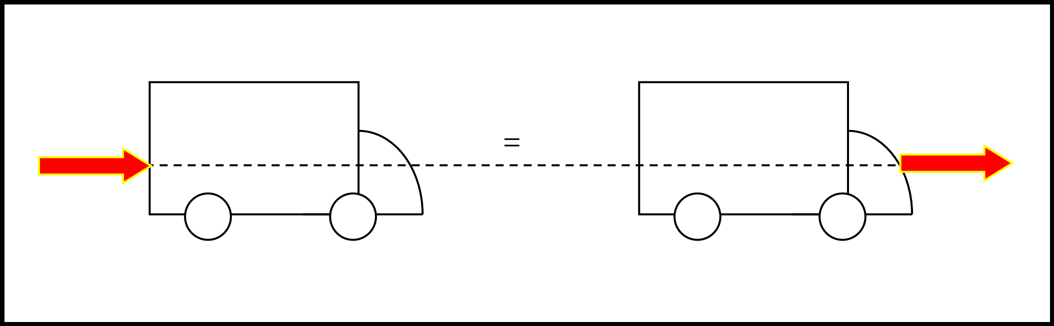
translate rotate

- internal forces are
  – in bodies
  – between bodies (connections)
- external forces act on bodies



Transmissibility

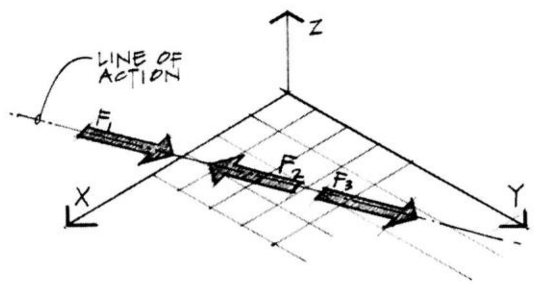
- the force stays on the same line of action
- truck can't tell the difference



- only valid for EXTERNAL forces

Force System Types

- *collinear*

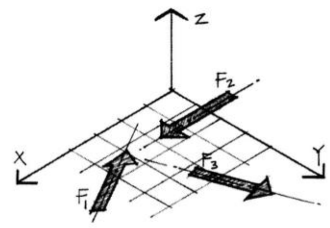


Collinear—*All forces acting along the same straight line.*

Figure 2.17(a) Particle or rigid body.

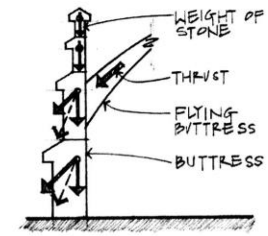
Force System Types

- *coplanar*

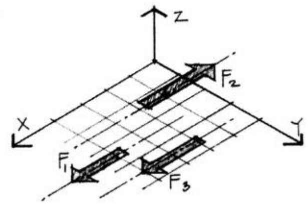


Coplanar—*All forces acting in the same plane.*

Figure 2.17(b) Rigid bodies.

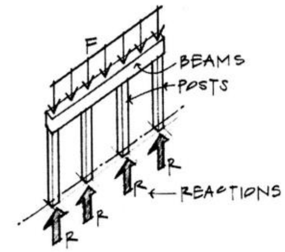


Forces in a buttress system.

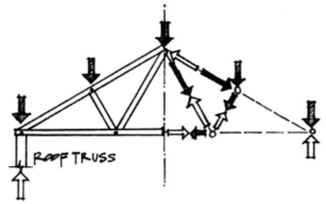


Coplanar, parallel—*All forces are parallel and act in the same plane.*

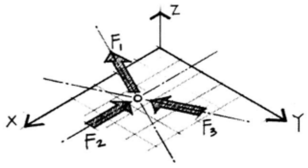
Figure 2.17(c) Rigid bodies.



A beam supported by a series of columns.



Loads applied to a roof truss.

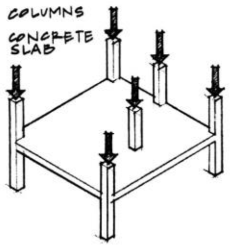


Coplanar, concurrent—*All forces intersect at a common point and lie in the same plane.*

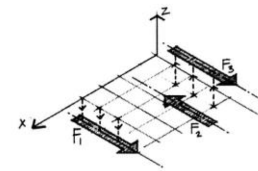
Figure 2.17(d) Particle or rigid body.

Force System Types

- *space*

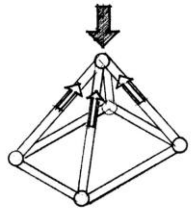


Column loads in a concrete building.

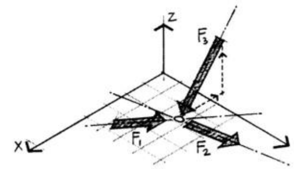


Noncoplanar, parallel—*All forces are parallel to each other, but not all lie in the same plane.*

Figure 2.17(e) Rigid bodies.

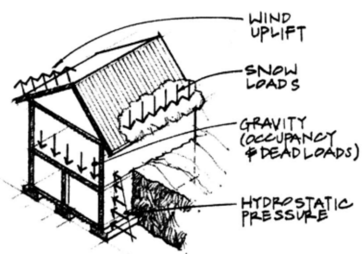


One component of a three-dimensional space frame.

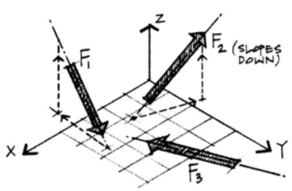


Noncoplanar, concurrent—*All forces intersect at a common point but do not all lie in the same plane.*

Figure 2.17(f) Particle or rigid bodies.



Array of forces acting simultaneously on a house.

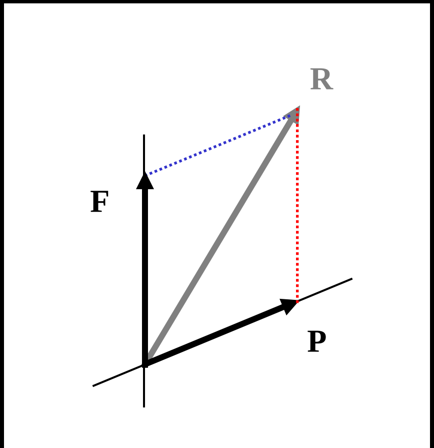


Noncoplanar, nonconcurrent—*All forces are skewed.*

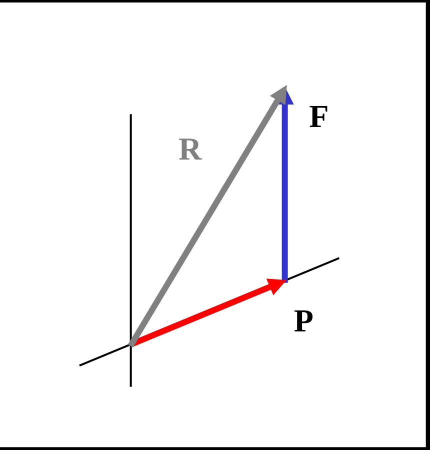
Figure 2.17(g) Rigid bodies.

Adding Vectors

- *graphically*
  - *parallelogram law*
    - *diagonal*
    - *long for 3 or more vectors*



  - *tip-to-tail*
    - *more convenient with lots of vectors*



Force Components

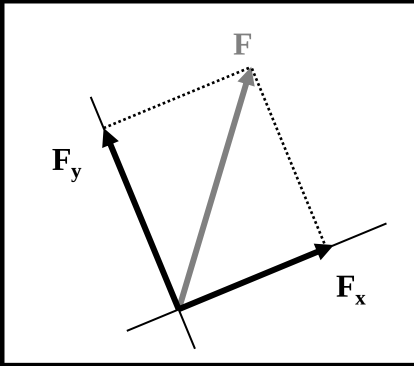
- *convenient to resolve into 2 vectors*
- *at right angles*
- *in a "nice" coordinate system*
- *θ is between F_x and F <u>from F_x</u>*

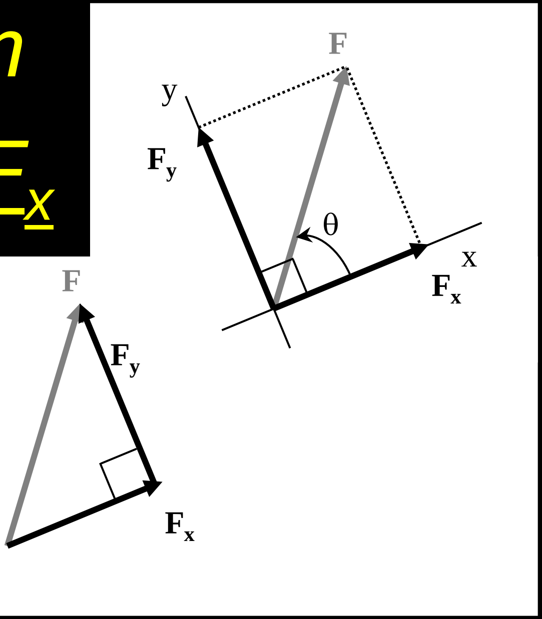
$$F_x = F\cos\theta$$

$$F_y = F\sin\theta$$

$$F = \sqrt{F_x^2 + F_y^2}$$

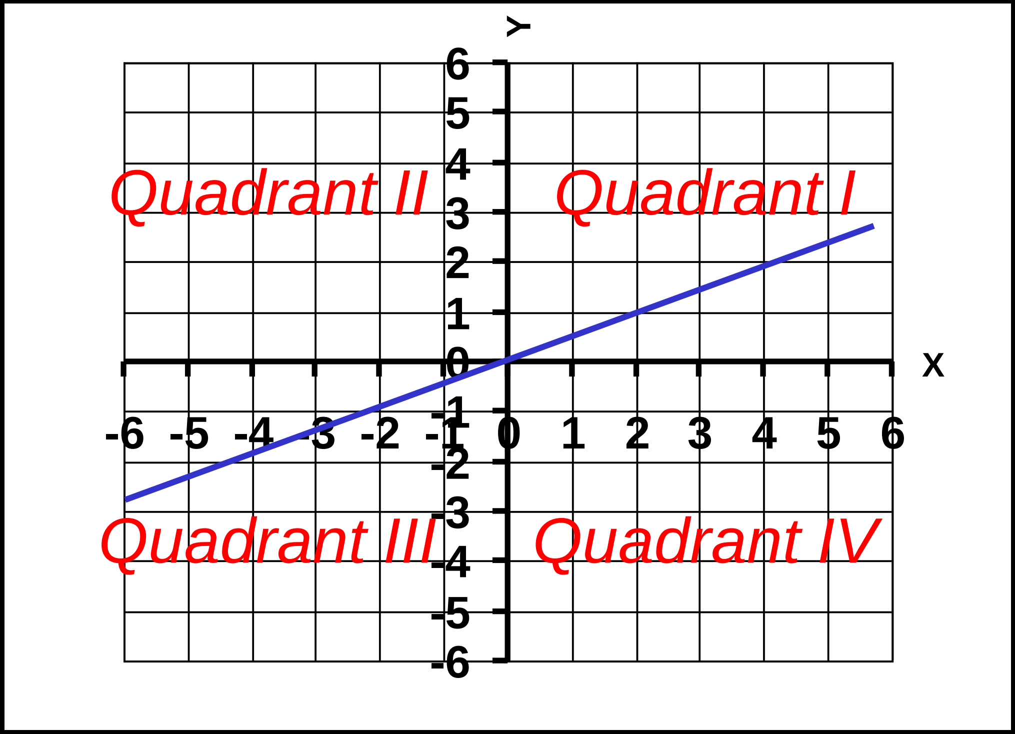
$$\tan\theta = \frac{F_y}{F_x}$$





Trigonometry

- F_x is negative
  - 90° to 270°
- F_y is negative
  - 180° to 360°
- tan is positive
  - quads I & III
- tan is negative
  - quads II & IV

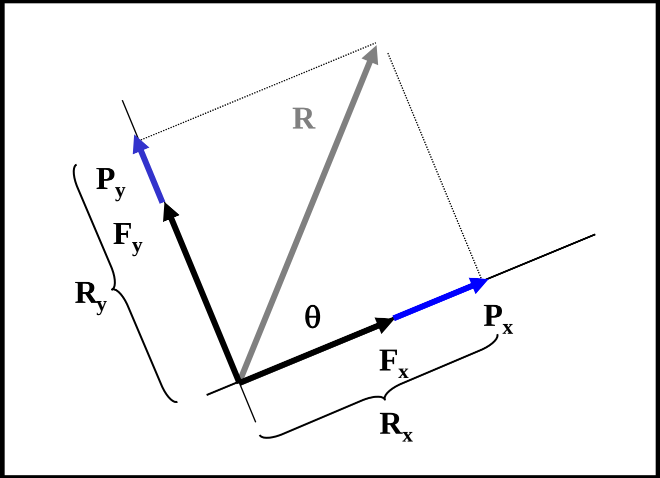


Component Addition

- *find all x components*
- *find all y components*
- *find sum of x components, R_x (resultant)*
- *find sum of y components, R_y*

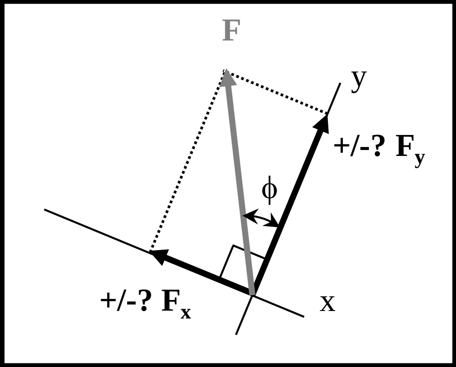
$$R = \sqrt{R_x^2 + R_y^2}$$

$$\tan\theta = \frac{R_y}{R_x}$$



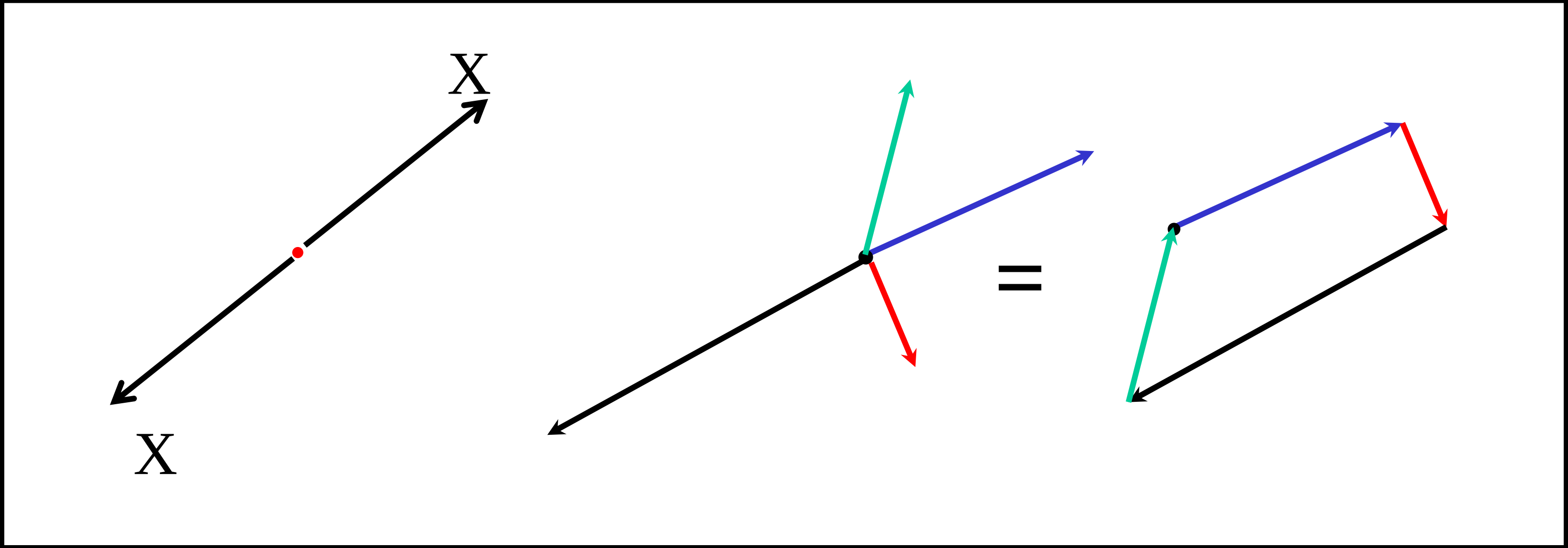
Alternative Trig for Components

- doesn't relate angle to axis direction
- ϕ is "small" angle between F and EITHER F_x or F_y
- no sign out of calculator!
- have to choose RIGHT trig function, resulting direction (sign) and component axis



Static Equilibrium

- *balanced & steady*
- *no motion or translation*
- *equilibrant opposite resultant*



Cables

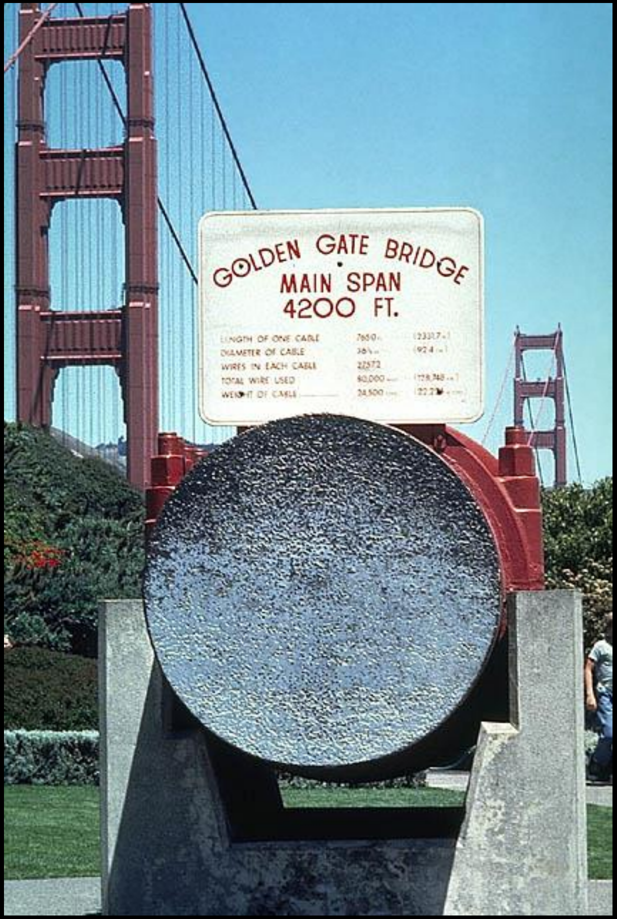
- *simple*
- *uses*
  - *suspension bridges*
  - *roof structures*
  - *transmission lines*
  - *guy wires, etc.*

http:// nisee.berkeley.ed/ugodden

- *have same tension all along*
- *can't stand compression*

Cables Structures

- use high-strength steel
- need
  - towers
  - anchors
- don't want movement



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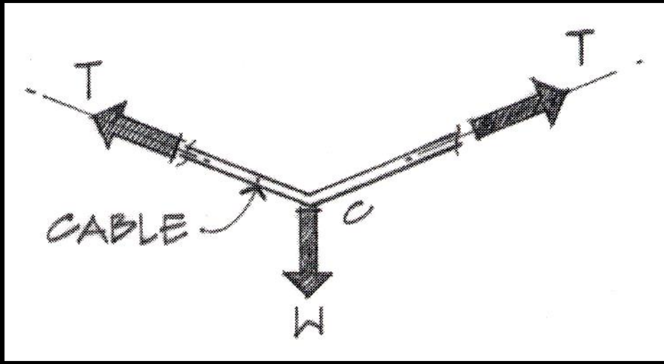
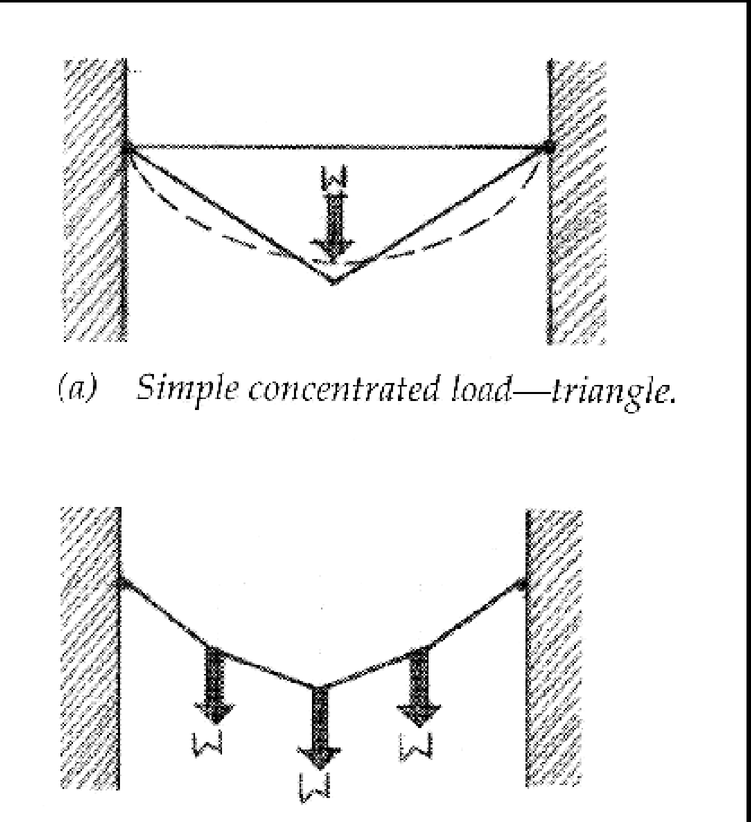
Cable Loads

- straight line between forces
- with one force
  - concurrent
  - symmetric



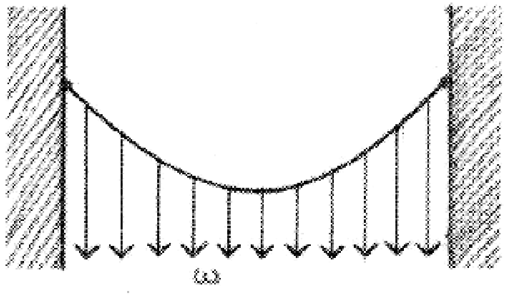


(a) Simple concentrated load—triangle.

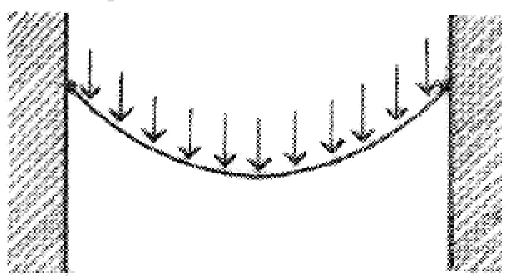
(b) Several concentrated loads—polygon.

Cable Loads

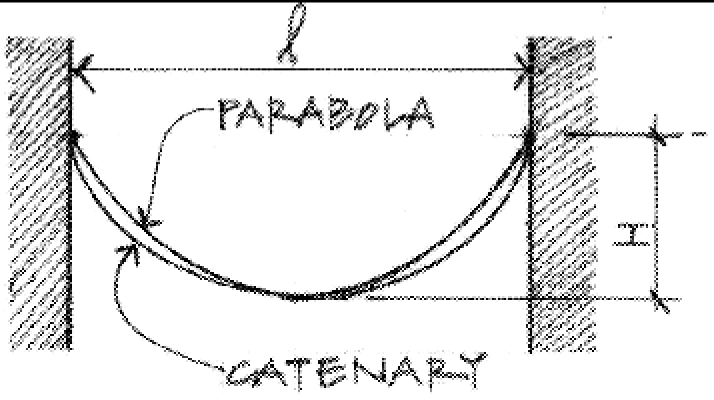
- *shape directly related to the distributed load*



(c) Uniform loads (horizontally)—parabola.



(d) Uniform loads (along the cable length)—catenary.



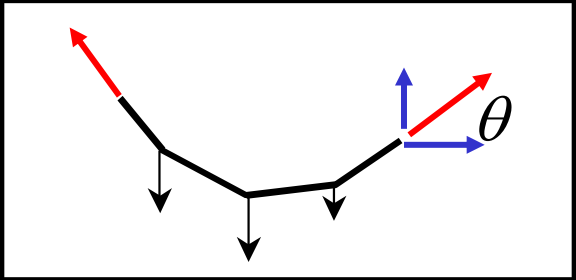
(e) Comparison of a parabolic and a catenary curve.

Cable Loads

- *trig:*

$$T_x = T\cos\theta$$

$$T_y = T\sin\theta$$



- *parabolic (catenary)*
  - *distributed uniform load*

$$y = 4h(Lx - x^2)/L^2$$

$$L_{total} = L(1 + \tfrac{8}{3}\, h^2\!/L^2 - \tfrac{32}{5}\, h^4\!/L^4)$$