

# ELEMENTS OF ARCHITECTURAL STRUCTURES:

## FORM, BEHAVIOR, AND DESIGN

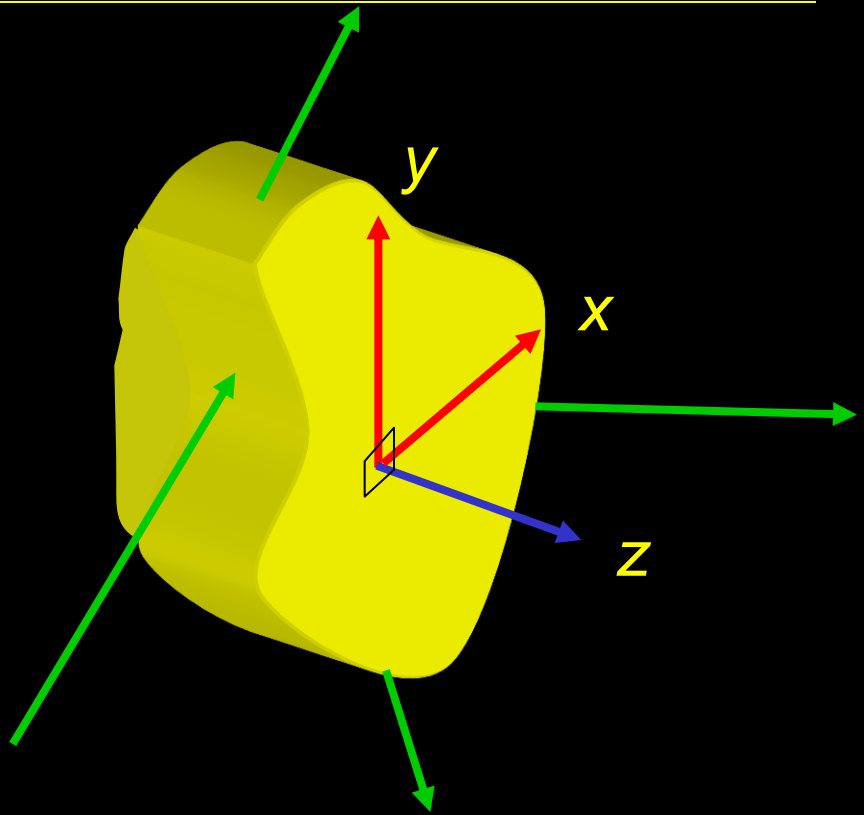
ARCH 614

DR. ANNE NICHOLS

SPRING 2013

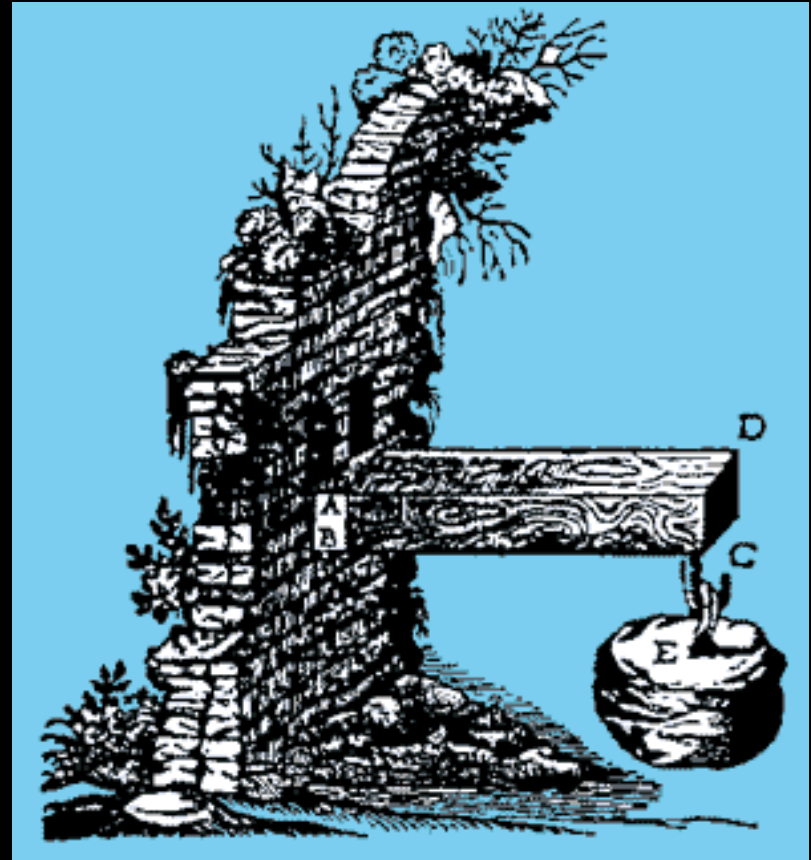
### lecture *two*

# loads, forces and vectors



# Structural Design

- *planning*
- *preliminary structural configuration*
- *determination of loads*
- *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

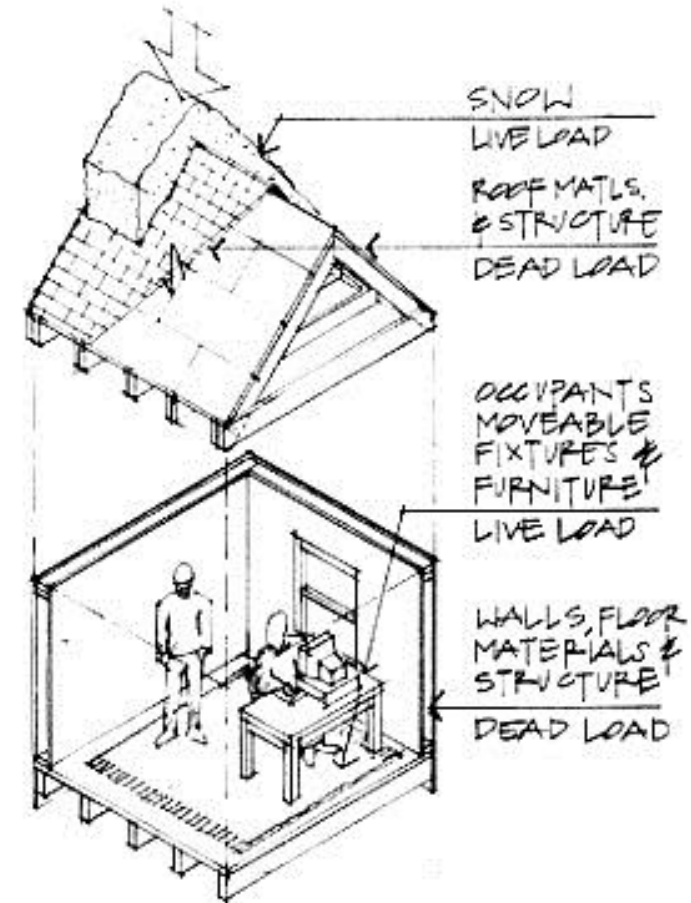
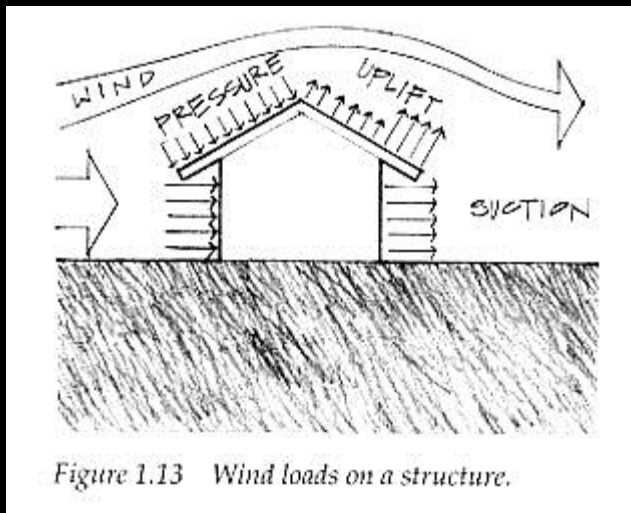


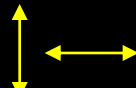
Figure 1.12 Typical building loads.

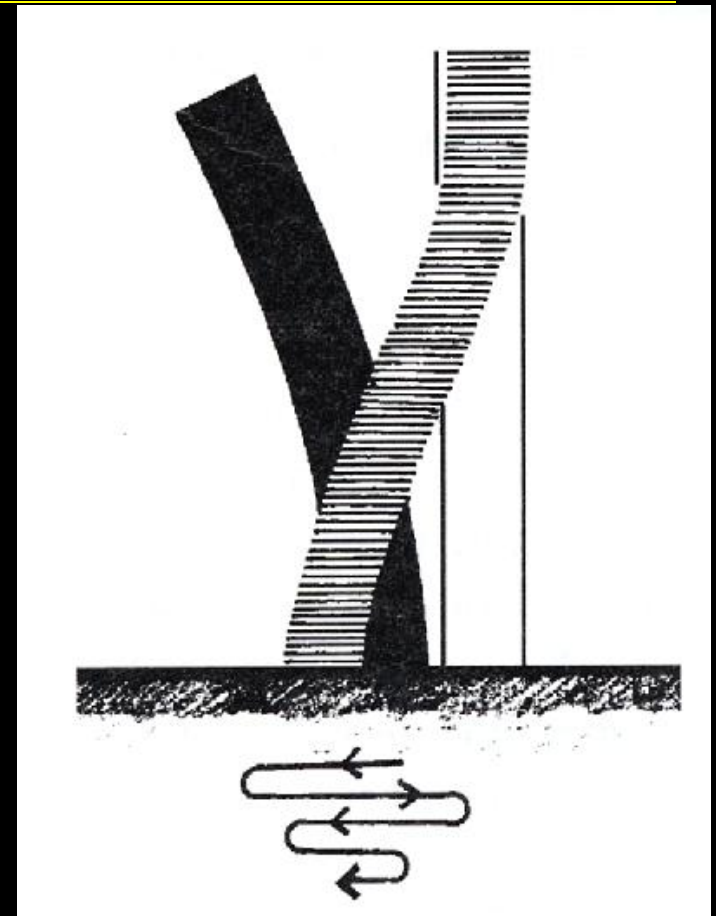
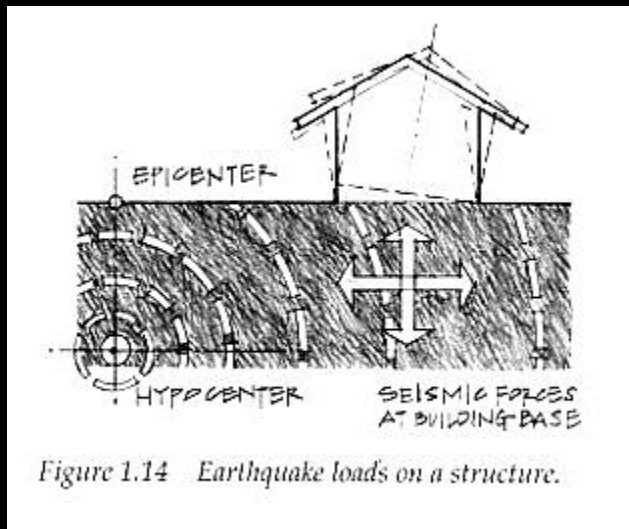
# Structural Loads

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



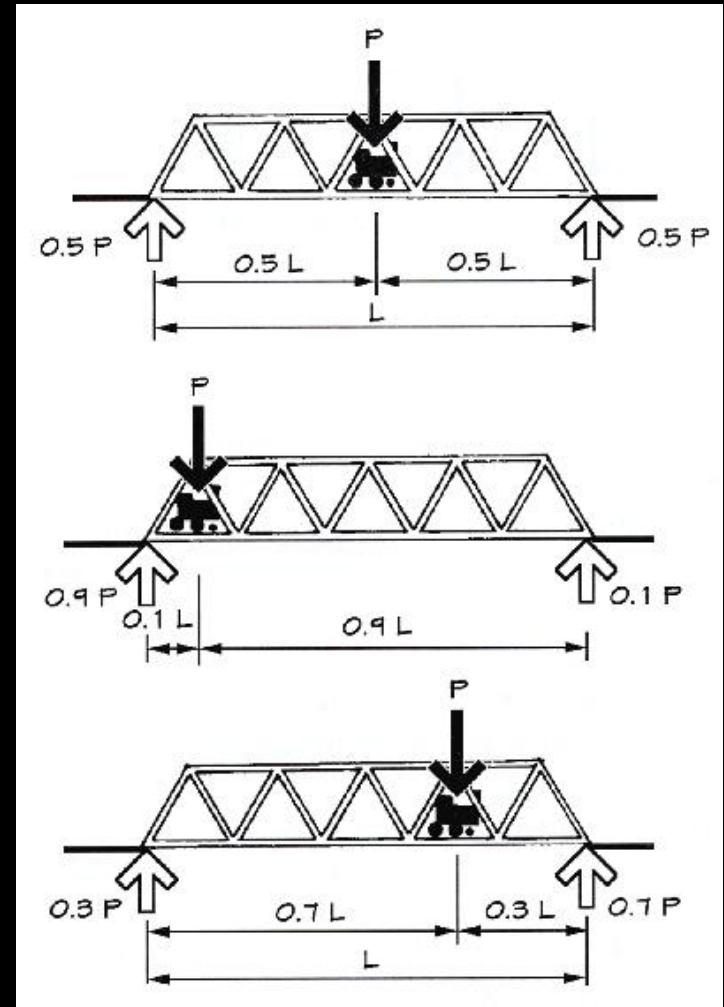
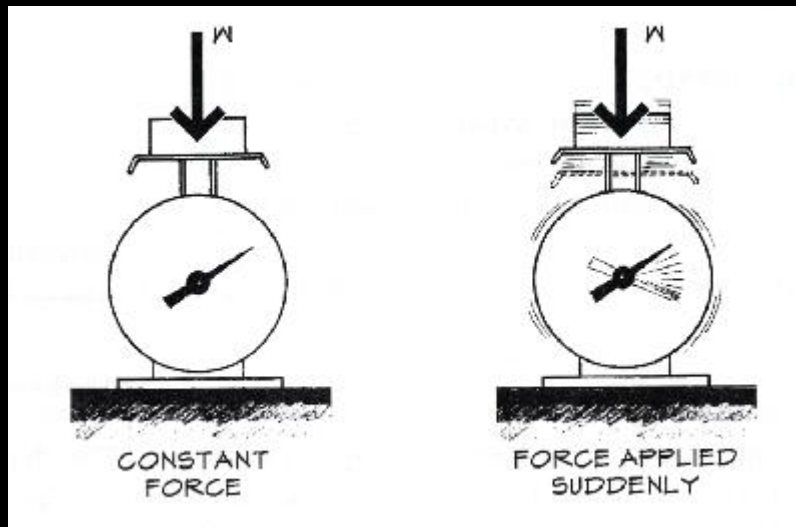
# Structural Loads

- *earthquake loads*
  - *seismic, movement of ground* 



# Structural Loads

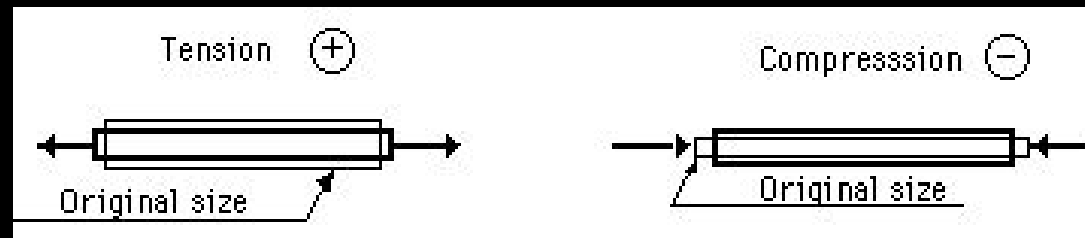
- *impact loads*
  - *rapid, energy loads*



# Forces

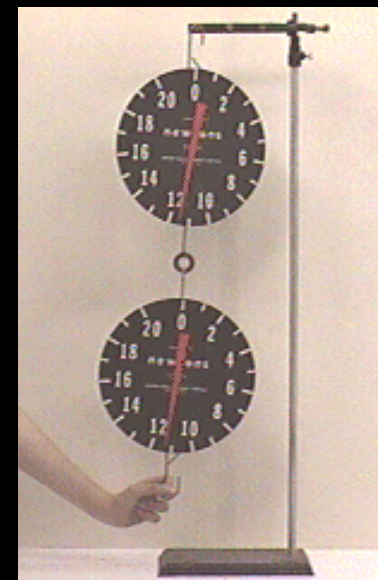
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- *statics*
  - *physics of forces and reactions on bodies and systems*
  - *equilibrium (bodies at rest)*
- *forces*
  - *something that exerts on an object:*
    - *motion*
    - *tension*
    - *compression*



# Forces

- *“action of one body on another that affects the state of motion or rest of the body”*
- *Newton’s 3<sup>rd</sup> law:*
  - *for every force of action there is an equal and opposite reaction along the same line*



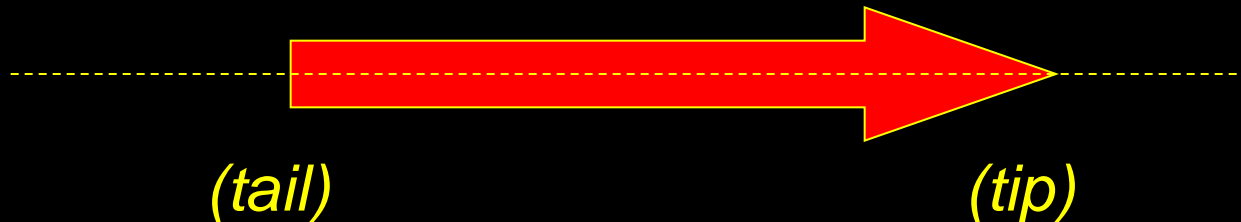
<http://www.physics.umd.edu>



# Force Vectors

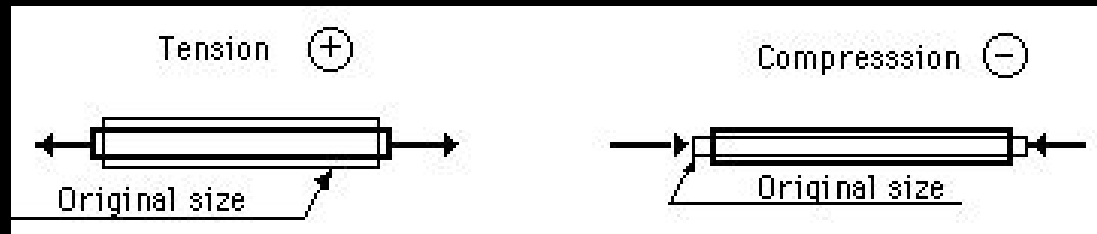
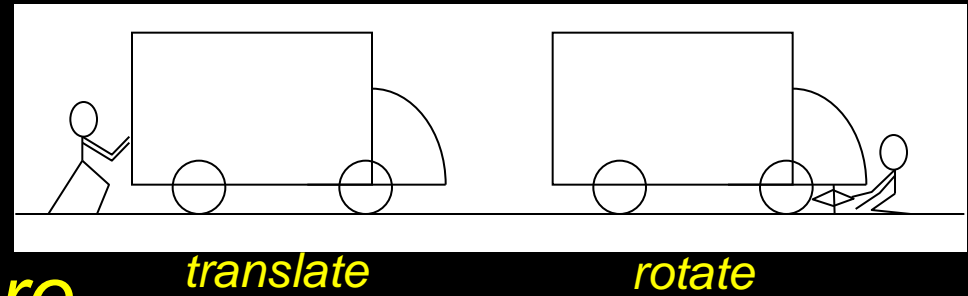
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- *applied at a point*
- *magnitude*
  - *Imperial units: lb, k (kips)*
  - *SI units: N (newtons), kN*
- *direction*
- *sense*



# Forces on Rigid Bodies

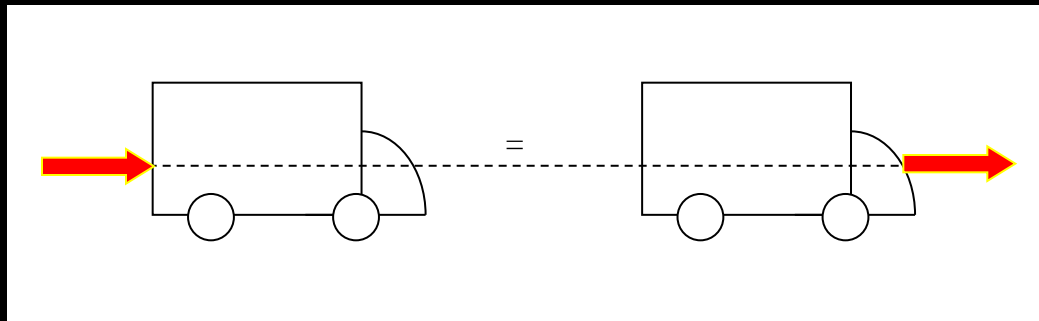
- *for statics, the bodies are ideally rigid*
- *can translate and rotate*
- *internal forces are*
  - *in bodies*
  - *between bodies (connections)*
- *external forces act on bodies*



# Transmissibility

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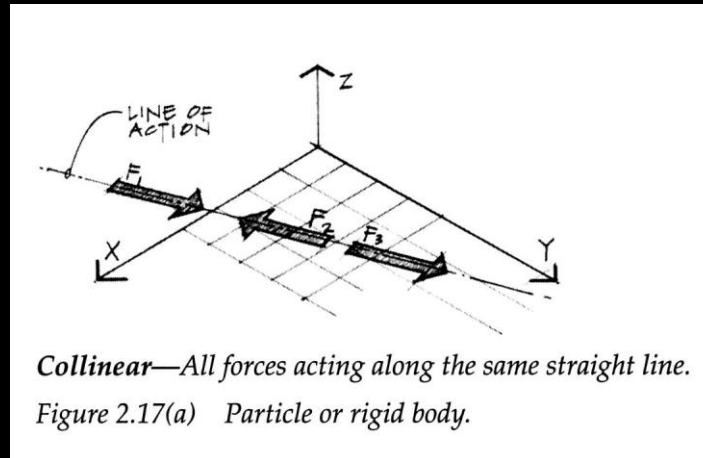
- *the force stays on the same line of action*
- *truck can't tell the difference*



- *only valid for EXTERNAL forces*

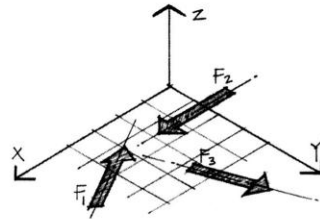
# Force System Types

- *collinear*



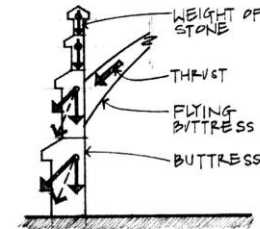
# Force System Types

- *coplanar*

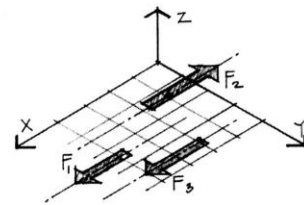


**Coplanar**—All forces acting in the same plane.

Figure 2.17(b) Rigid bodies.

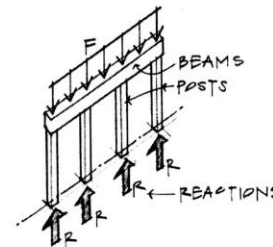


Forces in a buttress system.

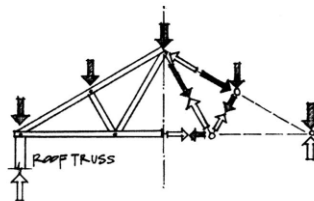


**Coplanar, parallel**—All forces are parallel and act in the same plane.

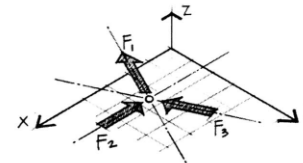
Figure 2.17(c) Rigid bodies.



A beam supported by a series of columns.



Loads applied to a roof truss.

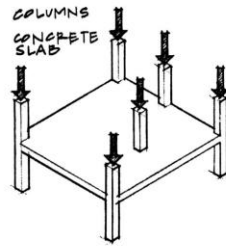


**Coplanar, concurrent**—All forces intersect at a common point and lie in the same plane.

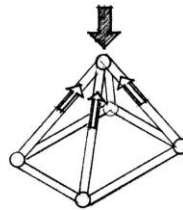
Figure 2.17(d) Particle or rigid body.

# Force System Types

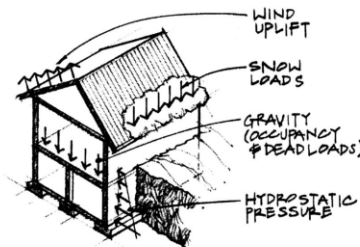
- *space*



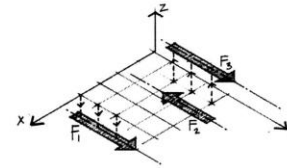
Column loads in a concrete building.



One component of a three-dimensional space frame.

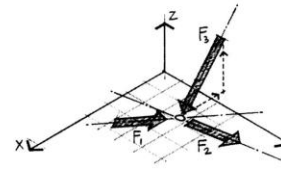


Array of forces acting simultaneously on a house.



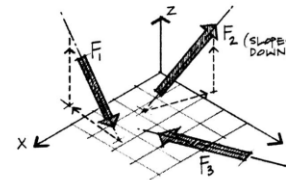
**Noncoplanar, parallel**—All forces are parallel to each other, but not all lie in the same plane.

Figure 2.17(e) Rigid bodies.



**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.

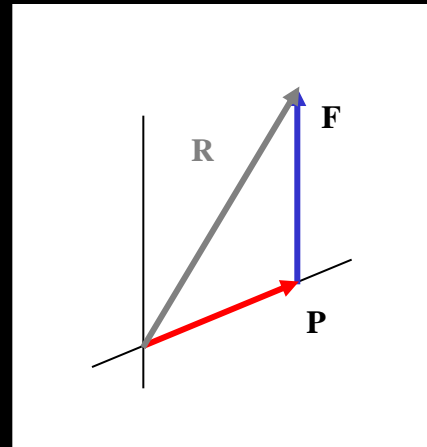
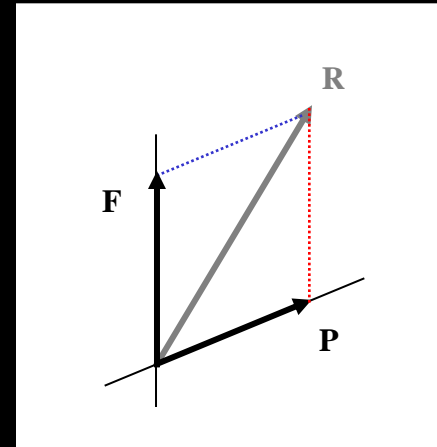


**Noncoplanar, nonconcurrent**—All forces are skewed.

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

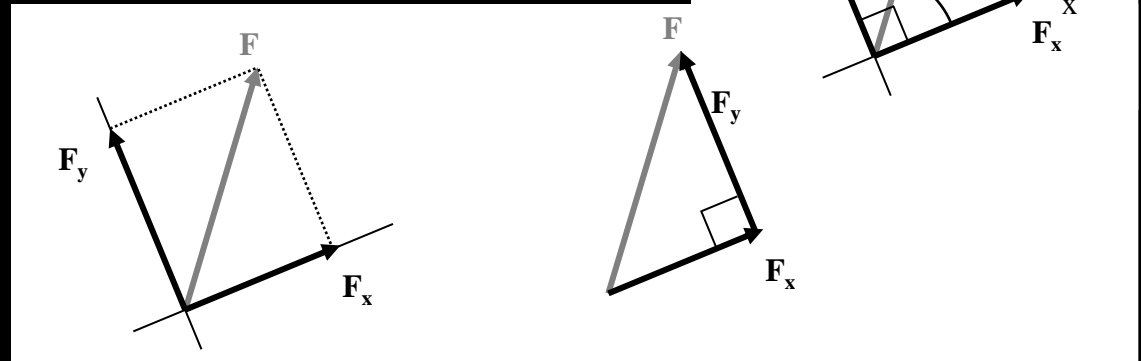
- convenient to resolve into 2 vectors
- at right angles
- in a “nice” coordinate system
- $\theta$  is between  $F_x$  and  $F$  from  $F_x$

$$F_x = F \cos \theta$$

$$F_y = F \sin \theta$$

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

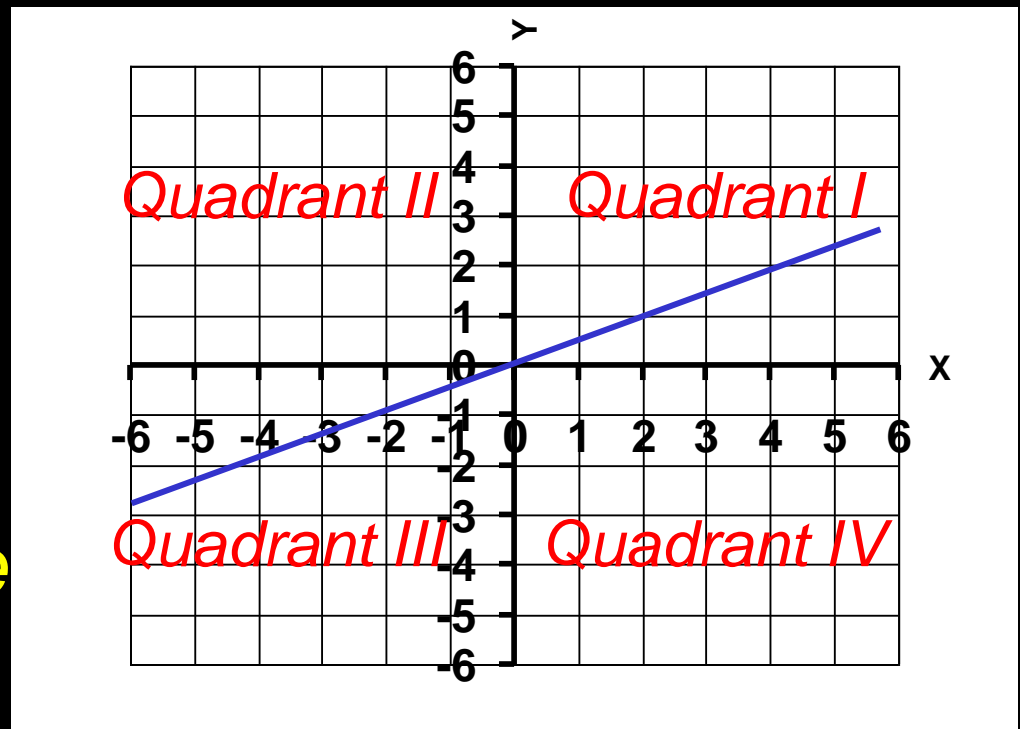
$$\tan \theta = \frac{F_y}{F_x}$$





# Trigonometry

- $F_x$  is negative  
–  $90^\circ$  to  $270^\circ$
- $F_y$  is negative  
–  $180^\circ$  to  $360^\circ$
- $\tan$  is positive  
– quads I & III
- $\tan$  is negative  
– quads II & IV

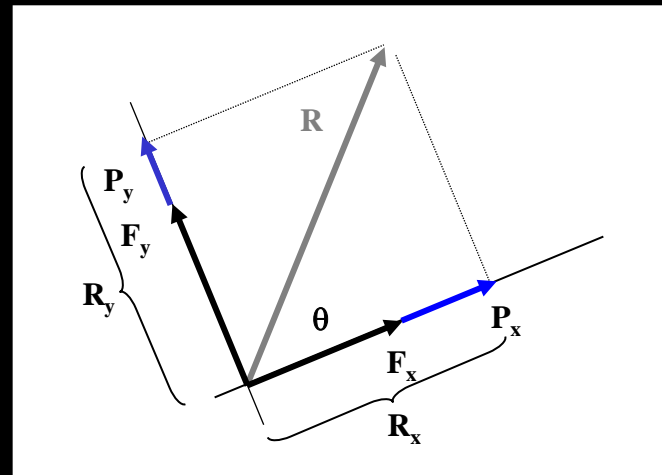


# Component Addition

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

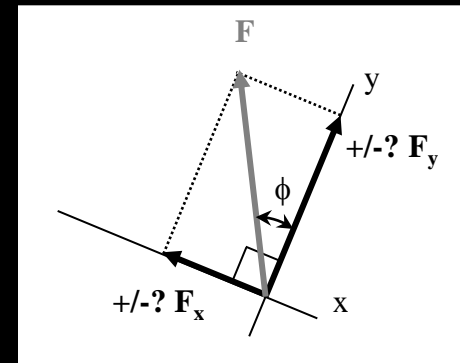
$$R = \sqrt{R_x^2 + R_y^2}$$

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



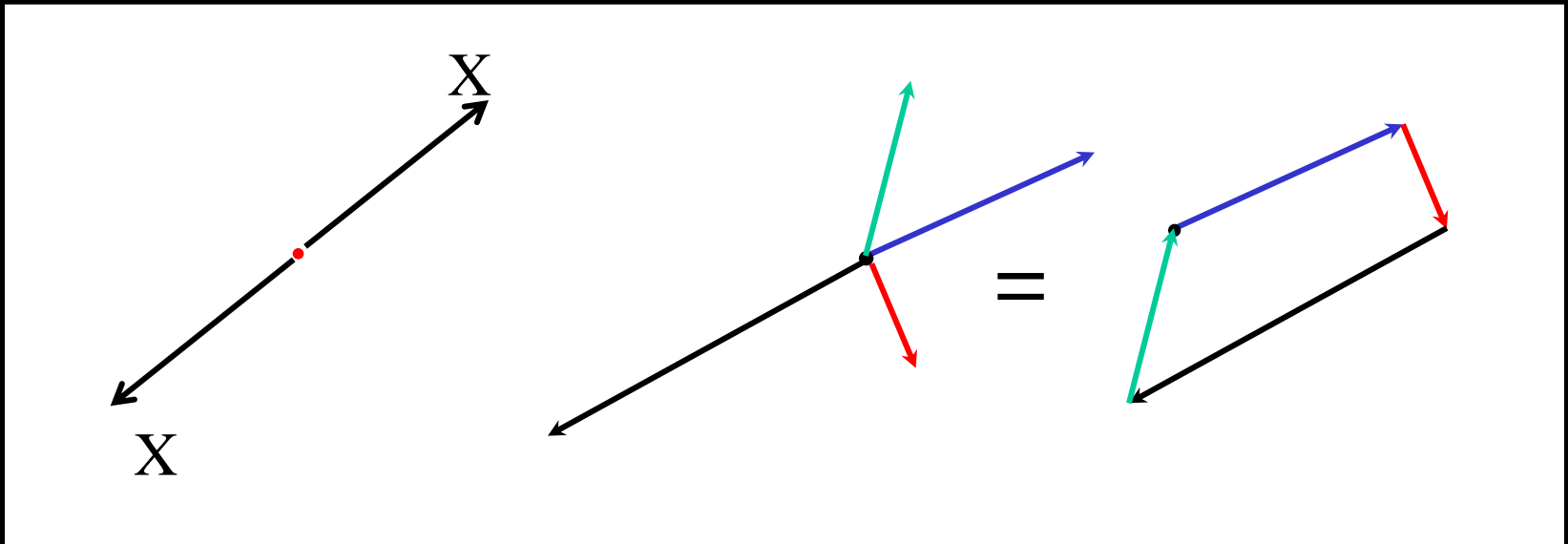
# Alternative Trig for Components

- *doesn't relate angle to axis direction*
- *$\phi$  is "small" angle between  $F$  and  $F_x$  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

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- *simple*
- *uses*
  - *suspension bridges*
  - *roof structures*
  - *transmission lines*
  - *guy wires, etc.*
- *have same tension all along*
- *can't stand compression*



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

# Cables Structures

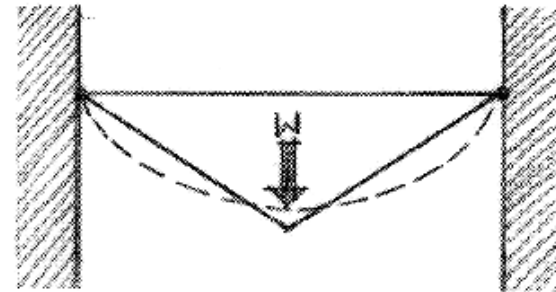
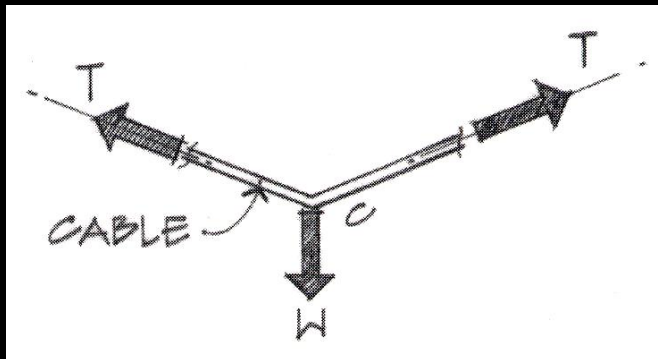
- *use high-strength steel*
- *need*
  - *towers*
  - *anchors*
- *don't want movement*



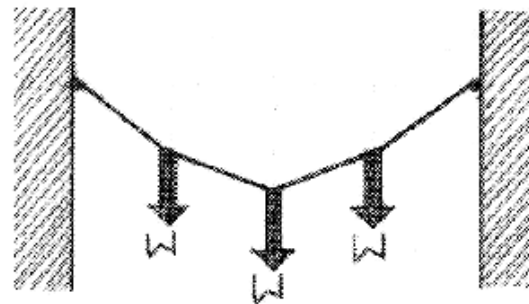
<http://nisee.berkeley.edu/godden>

# Cable Loads

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



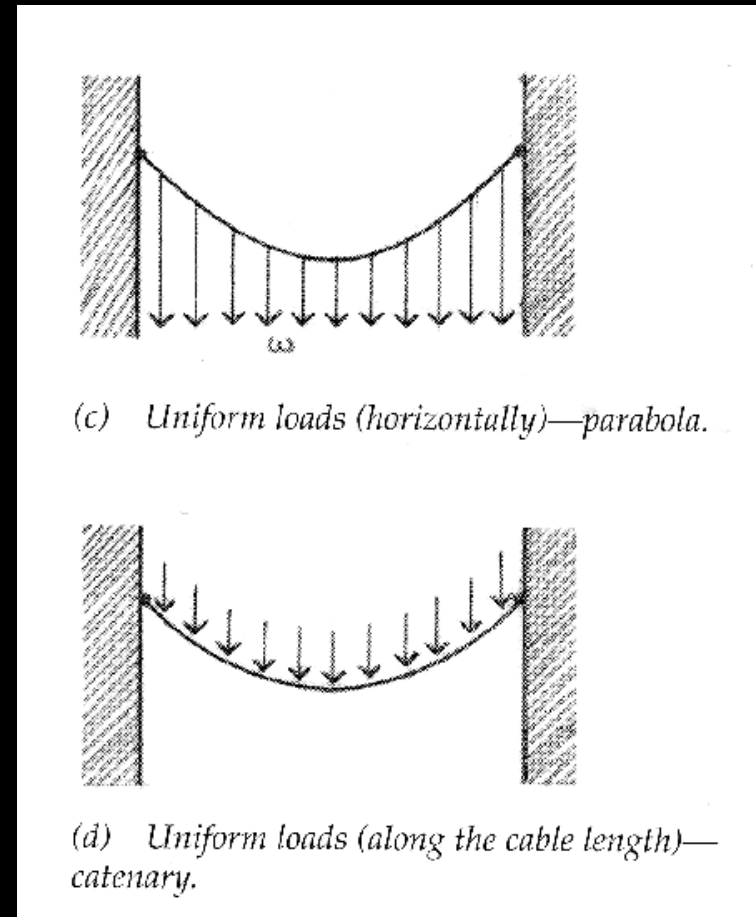
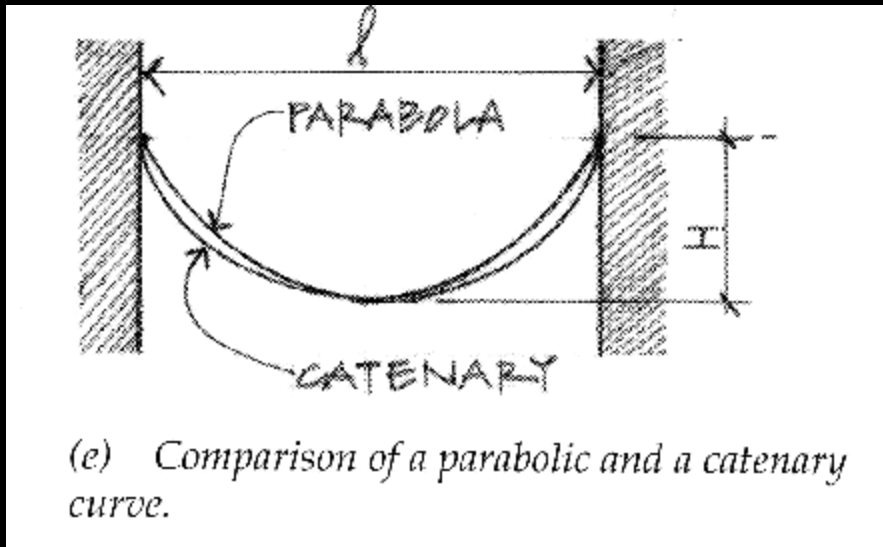
(a) *Simple concentrated load—triangle.*



(b) *Several concentrated loads—polygon.*

# Cable Loads

- *shape directly related to the distributed load*





# Cable Loads

- *trig:*  $T_x = T \cos \theta$

$$T_y = T \sin \theta$$

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

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

$$L_{total} = L \left( 1 + \frac{8}{3} \frac{h^2}{L^2} - \frac{32}{5} \frac{h^4}{L^4} \right)$$

