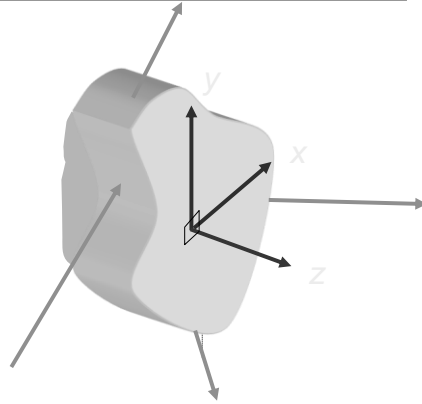


lecture
two

**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

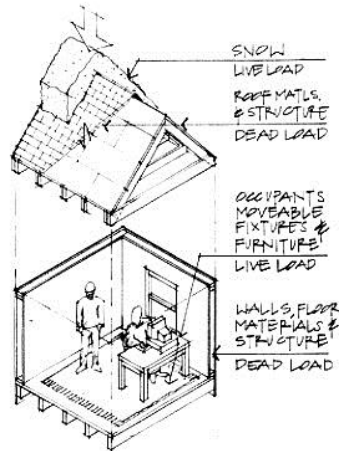


Figure 1.12 Typical building loads.

Structural Loads

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

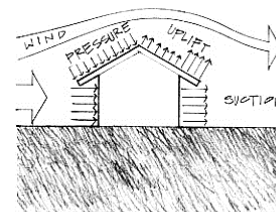
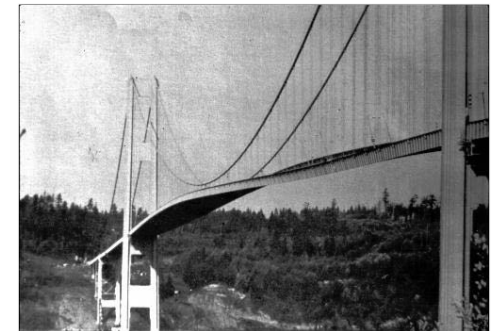


Figure 1.13 Wind loads on a structure.



Structural Loads

- earthquake loads
 - seismic, movement of ground

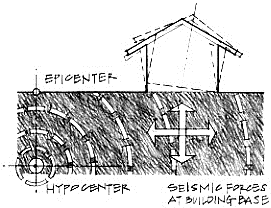
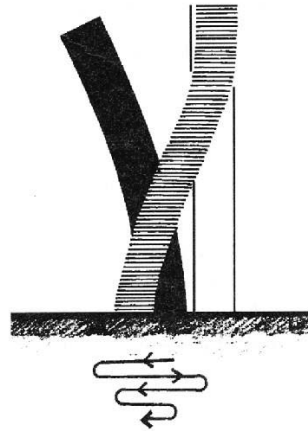


Figure 1.14 Earthquake loads on a structure.



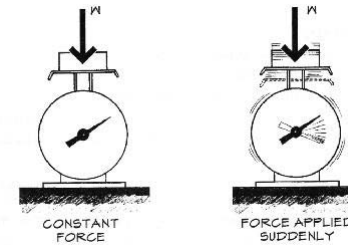
Forces 8
Lecture 3

Elements of Architectural Structures
ARCH 614

S2005abn

Structural Loads

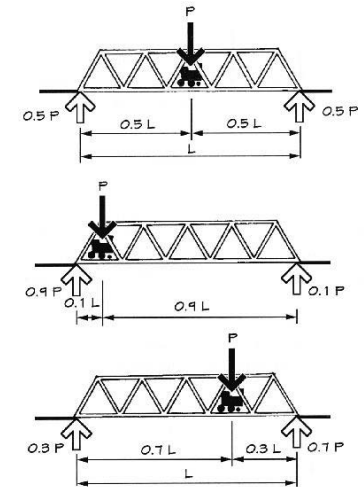
- impact loads
 - rapid, energy loads



Forces 9
Lecture 3

Elements of Architectural Structures
ARCH 614

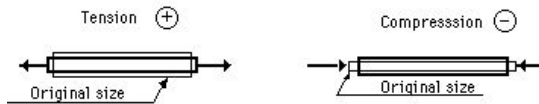
S2005abn



Forces

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

- motion
- tension
- compression



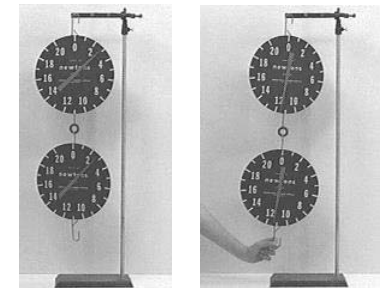
Forces 10
Lecture 3

Elements of Architectural Structures
ARCH 614

S2005abn

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://nisee.berkeley.edu/godden>

Forces 11
Lecture 3

Elements of Architectural Structures
ARCH 614

S2005abn

Force Vectors

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



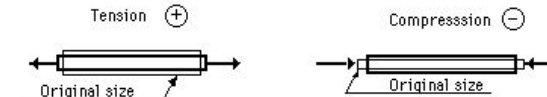
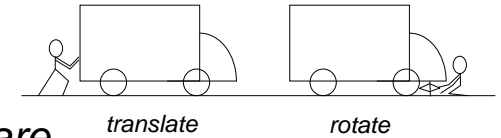
Forces 12
Lecture 3

Elements of Architectural Structures
ARCH 614

S2005abn

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



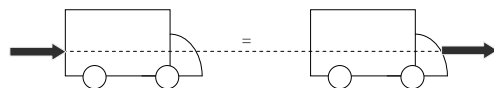
Forces 13
Lecture 3

Elements of Architectural Structures
ARCH 614

S2005abn

Transmissibility

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



- only valid for EXTERNAL forces

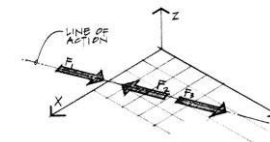
Forces 14
Lecture 3

Elements of Architectural Structures
ARCH 614

S2005abn

Force System Types

- collinear



Collinear—All forces acting along the same straight line.
Figure 2.17(a) Particle or rigid body.

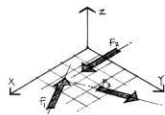
Forces 15
Lecture 3

Elements of Architectural Structures
ARCH 614

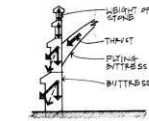
S2005abn

Force System Types

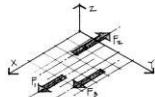
- **coplanar**



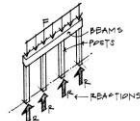
Coplanar—All forces acting in the same plane.
Figure 2.17(b) Rigid bodies.



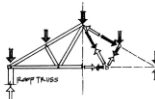
Forces in a buttress system.



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.



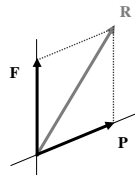
Coplanar, concurrent—All forces intersect at a common point and lie in the same plane.
Figure 2.17(d) Particle or rigid body.

Adding Vectors

- **graphically**

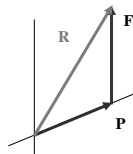
- parallelogram law

- diagonal
- long for 3 or more vectors



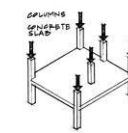
- tip-to-tail

- more convenient with lots of vectors



Force System Types

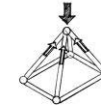
- **space**



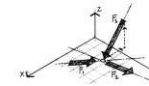
Column loads in a concrete building.



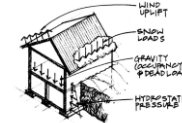
Noncoplanar, parallel—All forces are parallel to each other, but not all lie in the same plane.
Figure 2.17(e) Rigid bodies.



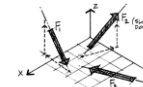
One component of a three-dimensional space frame.



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.

Force Components

- convenient to resolve into 2 vectors

- at right angles

- in a “nice” coordinate system

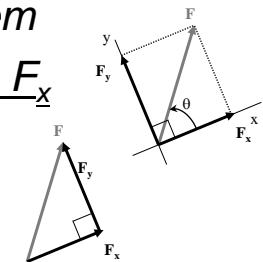
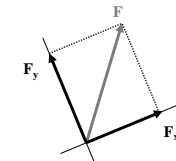
- θ is between F_x and F from F_x

$$F_x = F \cos \theta$$

$$F_y = F \sin \theta$$

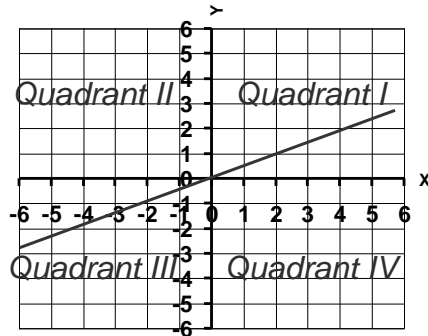
$$F = \sqrt{F_x^2 + F_y^2}$$

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



Trigonometry

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



Forces 20
Lecture 3

Elements of Architectural Structures
ARCH 614

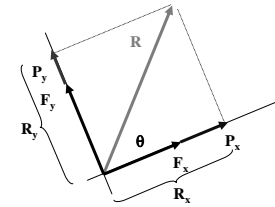
S2005abn

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

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

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



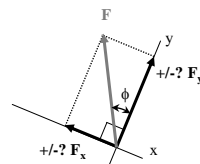
Forces 21
Lecture 3

Elements of Architectural Structures
ARCH 614

S2005abn

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



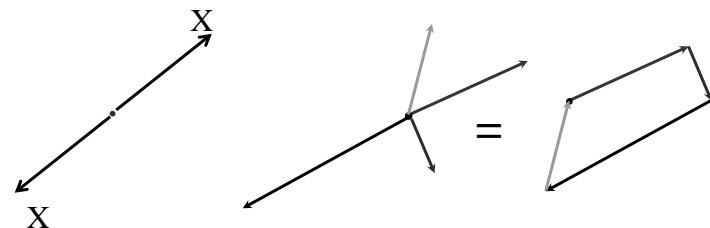
Forces 19
Lecture 3

Elements of Architectural Structures
ARCH 614

S2006abn

Static Equilibrium

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



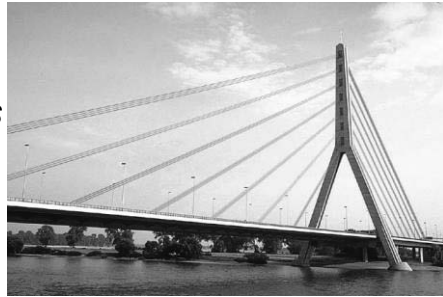
Equilibrium 2
Lecture 5

Elements of Architectural Structures
ARCH 614

S2006abn

Cables

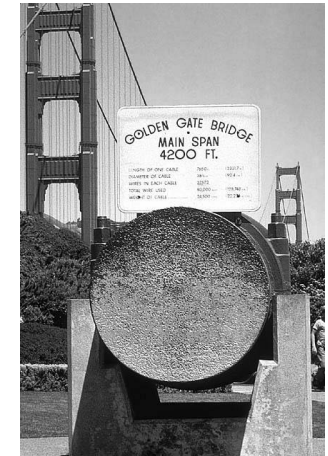
- simple
- uses
 - suspension bridges
 - roof structures
 - transmission lines
 - guy wires, etc.
- have same tension all along
- can't stand compression



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

Cables Structures

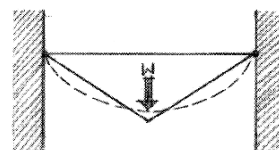
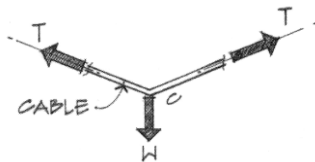
- use high-strength steel
- need
 - towers
 - anchors
- don't want movement



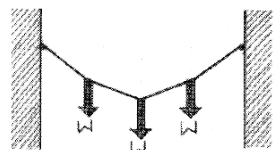
<http://nisee.berkeley.edu/godden>

Cable Loads

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



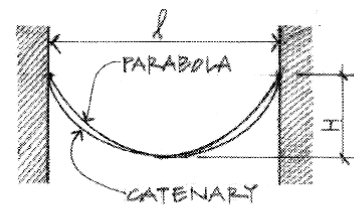
(a) Simple concentrated load—triangle.



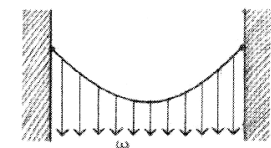
(b) Several concentrated loads—polygon.

Cable Loads

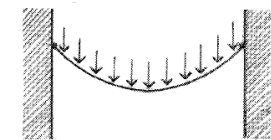
- shape directly related to the distributed load



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



(c) Uniform loads (horizontally)—parabola.

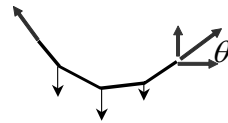


(d) Uniform loads (along the cable length)—catenary.

Cable Loads

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

$$T_y = T \sin \theta$$



- parabolic (catenary)

– distributed uniform load

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

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

