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
Structural Loads

• wind loads
  – dynamic, wind pressures treated as lateral static loads on walls, up or down loads on roofs

• earthquake loads
  – seismic, movement of ground

• impact loads
  – rapid, energy loads
Force

- “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
Force Characteristics

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

(tail) (tip)
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

- 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
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(c) 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

\[ F_x = F \cos \theta \]
\[ F_y = F \sin \theta \]
\[ F = \sqrt{F_x^2 + F_y^2} \]
\[ \tan \theta = \frac{F_y}{F_x} \]
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 \textit{EITHER} $F_x$ or $F_y$
- no sign out of calculator!
- have to choose \textit{RIGHT} trig function, resulting direction (sign) and component axis