Syllabus & Student Understandings
Course Description

- **statics**
  - physics of forces and reactions on bodies and systems
  - equilibrium (bodies at rest)

- **structures**
  - something made up of interdependent parts in a definite pattern of organization
Course Description

- mechanics of materials
  - external loads and effect on deformable bodies
  - use it to answer question if structure meets requirements of
    - stability and equilibrium
    - strength and stiffness
  - other principle building requirements
    - economy, functionality and aesthetics
Structure Requirements

• stability & equilibrium
  – STATICS

Figure 1.16 Equilibrium and Stability?—sculpture by Richard Byer. Photo by author.
Structure Requirements (cont)

• strength & stiffness
  – concerned with stability of components
Structural System Selection

- kind & size of loads
- building function
- soil & topology of site
- systems integration
- fire rating
- construction ($$, schedule)
- architectural form
Knowledge Required

- external forces
- internal forces
- material properties
- member cross sections
- ability of a material to resist breaking
- structural elements that resist excessive
  - deflection
  - deformation

Figure 2.34 An example of torsion on a cantilever beam.
Problem Solving

1. STATICS:
   equilibrium of external forces, internal forces, stresses

2. GEOMETRY:
   cross section properties, deformations and conditions of geometric fit, strains

3. MATERIAL PROPERTIES:
   stress-strain relationship for each material obtained from testing
Relation to Architecture

“The geometry and arrangement of the load-bearing members, the use of materials, and the crafting of joints all represent opportunities for buildings to express themselves. The best buildings are not designed by architects who after resolving the formal and spatial issues, simply ask the structural engineer to make sure it doesn’t fall down.”

-Onouye & Kane

Statics and Strength of Materials for Architecture and Building Construction
Architectural Structures

- incorporates
  - stability and equilibrium
  - strength and stiffness
  - economy, functionality and aesthetics

- uses
  - sculpture
  - furniture
  - buildings
Architectural Space and Form

- evolution traced to developments in structural engineering and material technology
  - stone & masonry
  - timber
  - concrete
  - cast iron, steel
  - tensile fabrics, pneumatic structures......
The “Fist”
Detroit, MI
AISC (Steel) Sculpture
College Station, TX
“Jamborie”
Philadelphia, PA
Daniel Barret
Exploris Mobile
Heath Satow
“Telamones”
Chicago, IL
Walter Arnold
“Free Ride Home” 1974
Kenneth Snelson
"Zauber"
Laudenslager, Jeffery
Conference Table
Heath Satow
Bar Stool
“Stainless Butterfly”
Daniel Barret
Chair
Paul Freundt
End Tables
Rameu-Richard
Steel House, Lubbock, TX

Robert Bruno
Guggenheim Museum Bilbao
Frank Gehry (1997)
Tjibaou Cultural Center, New Caledonia
Renzo Piano

Photographer: John Gollings
Padre Pio Pilgrimage Church, Italy

Renzo Piano

Photographer: Michel Denancé
Athens Olympic Stadium and Velodrome
Santiago Calatrava (2004)
Milwaukee Art Museum
Quadracci Pavilion (2001)
Santiago Calatrava
Airport Station, Lyon, France
Santiago Calatrava (1994)
Centre Georges Pompidou, Paris
Piano and Rogers (1978)
Hongkong Bank Building (1986)

Foster and Partners
Meyerson Symphony Center
Dallas, TX
Pei Cobb Freed & Partners
Crystal Cathedral, LA
Philip Johnson (1980)
Federal Reserve Bank
Minneapolis, MN
Gunnar Birkerts & Associates
Hysolar Research Building
Stuttgart, Germany (1986-87)
Gunter Behnisch
Notre Dame Cathedral
Paris, France
Maurice de Sully
Habitat 67, Montreal
Moshe Safdie (1967)
Villa Savoye, Poissy, France
Le Corbusier (1929)
Riola Parish Church
Riola, Italy
Alvar Aalto (1978)
Kimball Museum, Fort Worth
Kahn (1972)
Structural Math

• quantify environmental loads
  – how big is it?

• evaluate geometry and angles
  – where is it?
  – what is the scale?
  – what is the size in a particular direction?

• quantify what happens in the structure
  – how big are the internal forces?
  – how big should the beam be?
Structural Math

• physics takes observable phenomena and relates the measurement with rules: mathematical relationships

• need
  – reference frame
  – measure of length, mass, time, direction, velocity, acceleration, work, heat, electricity, light
  – calculations & geometry
## Physics for Structures

- **measures**
  - *US customary & SI*

<table>
<thead>
<tr>
<th>Units</th>
<th>US</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>in, ft, mi</td>
<td>mm, cm, m</td>
</tr>
<tr>
<td>Volume</td>
<td>gallon</td>
<td>liter</td>
</tr>
<tr>
<td>Mass</td>
<td>lb mass</td>
<td>g, kg</td>
</tr>
<tr>
<td>Force</td>
<td>lb force</td>
<td>N, kN</td>
</tr>
<tr>
<td>Temperature</td>
<td>F</td>
<td>C</td>
</tr>
</tbody>
</table>
Physics for Structures

- **scalars** – any quantity
- **vectors** - quantities with direction
  - like displacements
  - summation results in the “straight line path” from start to end
  - **normal vector** is perpendicular to something
Language

- symbols for operations: +, -, /, x
- symbols for relationships: (), =, <, >
- algorithms
  - cancellation
  - factors
  - signs
  - ratios and proportions
  - power of a number
  - conversions, ex. $1X = 10Y$
  - operations on both sides of equality

\[
\begin{align*}
\frac{2}{5} \times \frac{5}{6} &= \frac{2}{6} = \frac{2}{2\times3} = \frac{1}{3} \\
x &= \frac{1}{6} = \frac{1}{3} \\
10^3 &= 1000 \\
1X \text{ or } 10Y &= \frac{10Y}{1X} = \frac{1X}{10Y} = 1
\end{align*}
\]
On-line Practice

• Vista / Resources

Math Practice
Anne B Nichols
Started: August 31, 2007 10:47 AM
Questions: 20

Instructions
This assessment is only for self-grading.

1. **Force - metric to US (kN)** (Points: 10.0)
   Convert the force 6.85 kN to pounds (1) and kips (2).
   [Provide the number without the units.]

   1. 
   2. 
   Check Answer

   Question Status
   - Un answered
   - Answer not saved
   - Answered

   1 2 3 4 5
   6 7 8 9 10
   11 12 13 14 15
   16 17 18 19 20

Finish Help
Geometry

• angles
  – right = 90°
  – acute < 90°
  – obtuse > 90°
  – \( \pi \) = 180°

• triangles
  – area = \( b \times h \) \( \frac{1}{2} \)
  – hypotenuse
  – total of angles = 180°

\[ AB^2 + AC^2 = BC^2 \]
Geometry

• lines and relation to angles
  – parallel lines can’t intersect
  – perpendicular lines cross at 90°
  – intersection of two lines is a point
  – opposite angles are equal when two lines cross
Geometry

– intersection of a line with parallel lines results in identical angles

– two lines intersect in the same way, the angles are identical
Geometry

- sides of two angles are parallel and intersect opposite way, the angles are **supplementary** - the sum is 180°

\[ \alpha \ \gamma = 90° \]

- two angles that sum to 90° are said to be **complimentary**

\[ \beta + \gamma = 90° \]
Geometry

- sides of two angles bisect a right angle (90°), the angles are complimentary

\[ \gamma + \alpha = 90° \]

- right angle bisects a straight line, remaining angles are complimentary
Geometry

– similar triangles have proportional sides

\[
\frac{AB}{AD} = \frac{AC}{AE} = \frac{BC}{DE}
\]

\[
\frac{AB}{A'B'} = \frac{AC}{A'C'} = \frac{BC}{B'C'}
\]
Trigonometry

• for right triangles

\[
\sin \alpha = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{AB}{CB}
\]

\[
\cos \alpha = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{AC}{CB}
\]

\[
\tan \alpha = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{AB}{AC}
\]

Simplified: **SOHCAHTOA**
Trigonometry

- cartesian coordinate system
  - origin at 0,0
  - coordinates in (x,y) pairs
  - x & y have signs

[Diagram of Cartesian coordinate system with quadrants labeled Quadrant I, Quadrant II, Quadrant III, and Quadrant IV.]
Trigonometry

- for angles starting at positive x
  - sin is y side
  - cos is x side

\[
\begin{align*}
sin&<0 \text{ for } 180-360^\circ \\
\cos&<0 \text{ for } 90-270^\circ \\
\tan&<0 \text{ for } 90-180^\circ \\
\tan&<0 \text{ for } 270-360^\circ
\end{align*}
\]
Trigonometry

- for all triangles
  - sides A, B & C are opposite angles $\alpha$, $\beta$ & $\gamma$
  - LAW of SINES
    \[
    \frac{\sin \alpha}{A} = \frac{\sin \beta}{B} = \frac{\sin \gamma}{C}
    \]
  - LAW of COSINES
    \[
    A^2 = B^2 + C^2 - 2BC \cos \alpha
    \]
Algebra

- equations (something = something)
- constants
  - real numbers or shown with a, b, c...
- unknown terms, variables
  - names like R, F, x, y
- linear equations
  - unknown terms have no exponents
- simultaneous equations
  - variable set satisfies all equations
Algebra

• solving one equation
  – only works with one variable
  – ex:
    • add to both sides
    • divide both sides
    • get x by itself on a side

\[
\begin{align*}
2x - 1 &= 0 \\
2x - 1 + 1 &= 0 + 1 \\
2x &= 1 \\
\frac{2x}{2} &= \frac{1}{2} \\
x &= \frac{1}{2}
\end{align*}
\]
Algebra

• solving one equations
  – only works with one variable
  – ex: \[2x - 1 = 4x + 5\]
    • subtract from both sides
      \[2x - 1 - 2x = 4x + 5 - 2x\]
    • subtract from both sides
      \[-1 - 5 = 2x + 5 - 5\]
    • divide both sides
      \[-6 = -3 \cdot 2 \Rightarrow \frac{2x}{2} = \frac{2x}{2}\]
    • get x by itself on a side
      \[x = -3\]
Algebra

• solving two equation
  – only works with two variables
  – ex:
    \[2x + 3y = 8\]
    \[12x - 3y = 6\]
    • look for term similarity
    • can we add or subtract to eliminate one term?

• add
  \[2x + 3y + 12x - 3y = 8 + 6\]
  \[14x = 14\]
  • get x by itself on a side
  \[\frac{14x}{14} = \frac{14}{14} = x = 1\]