Definitions, Equations and Material Properties Sheet

**Force** – an influence that causes a body to deform or accelerate (lb) or (kips)  
Note: 1 kip = 1000 lbs

**Tension Force** – causes stretching (elongation) of an element

**Compression Force** – causes squishing (shortening) of an element

**Stress** – the internal reaction; force per unit area (lb/in^2 or psi) or (ksi)

\[ \text{Stress, } \sigma = \frac{\text{Force}}{\text{Area}} = \frac{P}{A} \]
where \( P \) = axial force applied (lbs or kips) and \( A \) = cross-sectional area (in^2)

**Strain** – a deformation caused by stress; can be an elongation or a shortening (in/in – unitless)

\[ \text{Strain, } \varepsilon = \frac{\text{Change in Length}}{\text{Original Length}} = \frac{\text{Deformation}}{\text{Original Length}} = \frac{\delta}{L} \]

**Modulus of Elasticity, E** – a measure of a material’s resistance to deformation (lb/in^2 or psi)  
(low E values indicate that a material will deform more under an applied load)

**Hooke’s Law for Linear, Elastic Materials** – Stress is proportional to Strain; Modulus of Elasticity, E, is a constant for linear material behavior; i.e. E is the slope of the \( \sigma vs \varepsilon \) diagram.

\[ \sigma = E \times \varepsilon \]

**Allowable Stress, \( \sigma_{\text{allow}} \) and Modulus of Elasticity, E, of Common Structural Materials**

<table>
<thead>
<tr>
<th>Material</th>
<th>Allowable Stress (psi)</th>
<th>Modulus of Elasticity (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>1,400</td>
<td>1,400,000</td>
</tr>
<tr>
<td>Steel</td>
<td>30,000</td>
<td>29,000,000</td>
</tr>
<tr>
<td>Concrete (Compression)</td>
<td>3,000</td>
<td>3,000,000</td>
</tr>
<tr>
<td>Concrete (Tension)</td>
<td>450</td>
<td>3,000,000</td>
</tr>
</tbody>
</table>

**Factor of Safety**

The amount by which the ultimate stress that a material could carry without yielding or fracturing is greater than the stated allowable stress that a member is actually designed to carry. The actual member stress in a member due to a force must be less than the allowable stress to have a safe design. The Factor of Safety is 1.5, 1.6, 2.0 or even 3.0 depending on the level of uncertainty that exists regarding material properties, section properties, structural behavior and actual load conditions.

\[ \text{Factor of Safety } = \text{F.S. } = \frac{\text{Ultimate Stress}}{\text{Allowable Stress}} = \frac{\sigma_{\text{ult}}}{\sigma_{\text{allow}}} \]

**General Design Criteria**  
Actual Member Stress < Allowable Stress of Material  
(to Ensure a Safe Design under Uncertainty)

**Mass & Weight SI and US Customary Units**

1 kilogram = 2.20462262 pounds

To find mass in kilograms, take your weight in lbs and divide by 2.2 (this means a weight of 2.2 lbs corresponds to a mass of 1.0 kg or a weight of 220 lbs corresponds to a mass of 100 kg.). Recall that the weight of 1 kg is 9.81 newtons. To find your weight in Newtons, take your mass in kilograms and multiply by 9.81.

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**Buckling of Slender Compression Members**

**TABLE C-A-7.1**

<table>
<thead>
<tr>
<th>Approximate Values of Effective Length Factor, K</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Buckled shape of column is shown by dashed line} )</td>
</tr>
<tr>
<td>Theoretical K value</td>
</tr>
</tbody>
</table>

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