Beam Diagrams & Formulas for:

Moment
Shear
Deflection
Consider the diagram (a) of the unloaded beam.
Initially, the relationship between AB/CD/JF is that of equivalency.
As the beam bends under load:
• AB shortens (compression)
• CD lengthens (tension)
• JF stays the same (no stress = the neutral axis for this reason)
Beam in Bending: Stress & Strain Distribution

Due to the elongation/shortening of the extreme fibers, a beam will experience a strain profile through its cross-section.

- Maximum strain (+/-) occurs at the extreme fibers.
- Likewise, the maximum stress (C/T) occurs at the extreme fibers.

The strain & stress distribution is, therefore, triangular thru the cross section.

On the stress distribution diagram, by summing the area of the stress triangle the value of the total C force and T force can be calculated.
The equation to determine bending stress is: \( s_b = \frac{My}{I} \)

This equation lets us evaluate the value of the stress in the section at any point from the neutral axis.

The equation to determine the MAXIMUM bending stress (at extreme fibers) is: \( s_b = \frac{Mc}{I} \)

(a) Beam-side view  
(b) Section A-A

Stress distribution
There is a section property called the “Elastic Section Modulus” which is equal a cross section’s Moment of Inertia divided by the distance to the extreme compression fibers from the neutral axis.

\[ S_x = \frac{I}{c} \]

This may allow us to rewrite the flexure formula:

\[ S_b = \frac{Mc}{I} \quad \text{to} \quad S_b = \frac{M}{S} \]

Since most beam properties are listed in tables (I, Sx, d, etc.), we can use this relationship to select beams.

I.e. \( S_{x \text{ reqd}} = \frac{M}{S} \);

where, M is the moment in the beam from the applied loads and \( S_b \) is the allowable stress in the material.
Example: Bending Stress

The timber member is used as a simply supported beam and spans 16 feet. It carries a uniformly distributed load of 400 lb/ft. Calculate the maximum induced bending stress (neglect weight of beam).
Example: Bending Stress in Steel Beam

For the A36 beam shown, calculate the maximum bending stress.

W30 × 99

4 kips/ft

32′
Bending Stress in Non-Symmetric Section

The bending stress value will be different in the extreme fibers of a section that is not symmetric.

Example: Calculate the maximum bending stress in the composite beam shown.

(a) Load diagram

(b) Section A-A