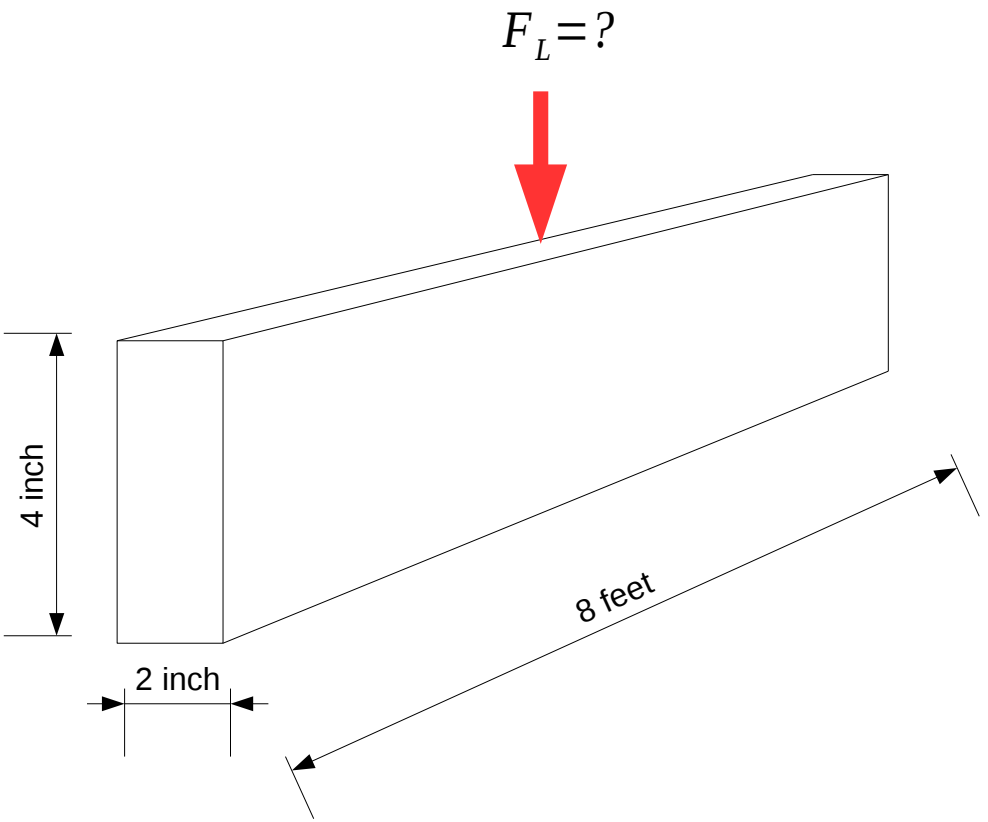
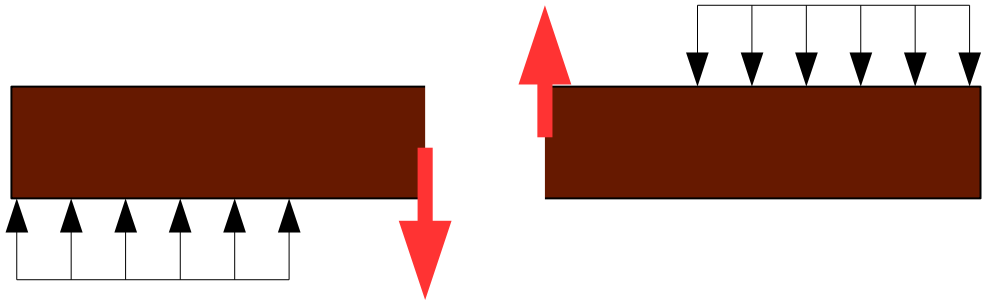
Beam Design



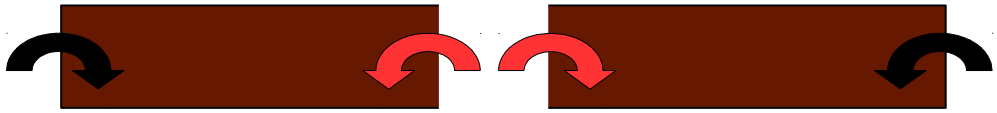
Stefan Bracher

Beam: A horizontal structural element with vertical loads

Shear Stress: An internal force caused by vertical loads.



Bending Moment: An internal bending stress caused by external forces.



Shear Force Diagram: The shear force V as a function of the distance x from the left side of the beam.

Bending Moment Diagram: The bending moment M as a function of the distance x from the left side of the beam.

Maximum Bending Moment: Occurs at the the location of zero shear force.

Beam Design - Overview

How to design beams:

1. *Draw the Shear Force and Bending Moment Diagrams to identify the maximum shear V_{max} and Bending M_{max}.*

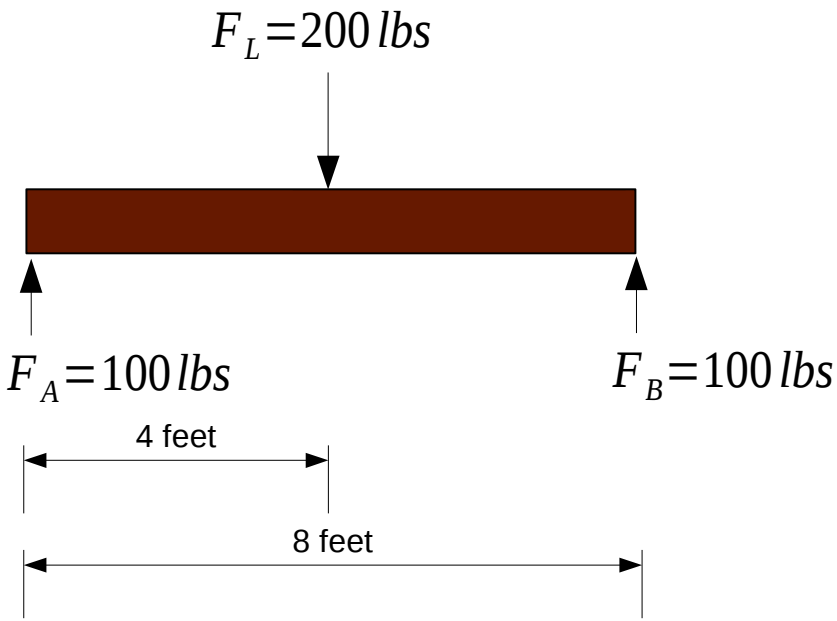
2. Look up the allowable shear stress σ_{sh} and bending stress σ_b for the selected material.

3. Calculate the minimal cross section area A_{min} and section modulus Z_{min}.

4. Select a nominal size with a higher cross section area and section modulus than the minimal values calculated in step 3.

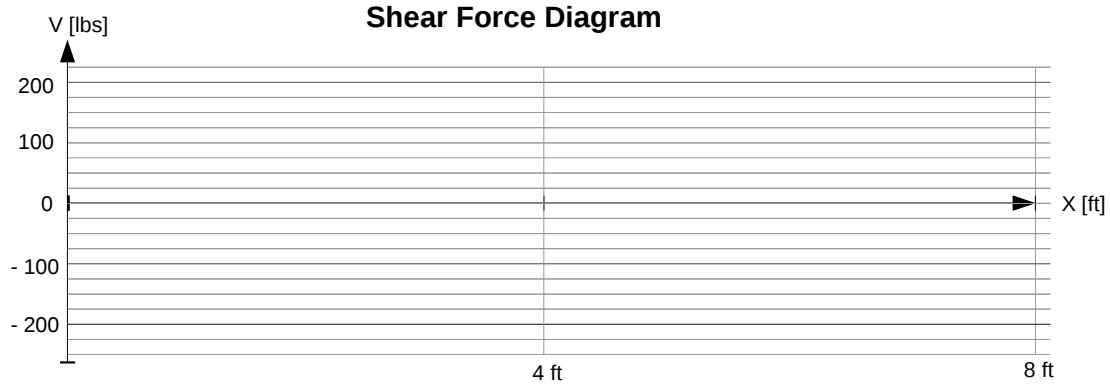
Example

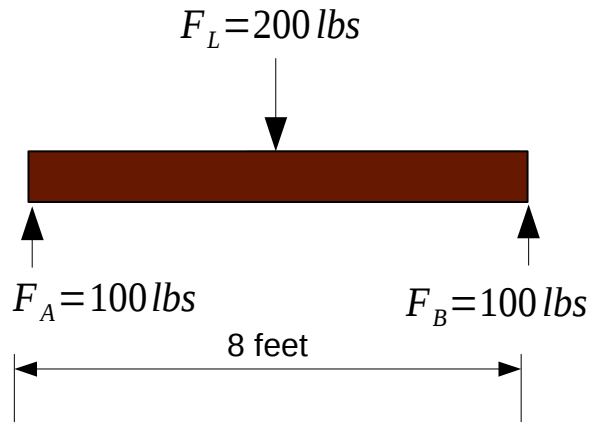
Design the most economical 8-feet timber beam to support a 200 lbs load at its center.

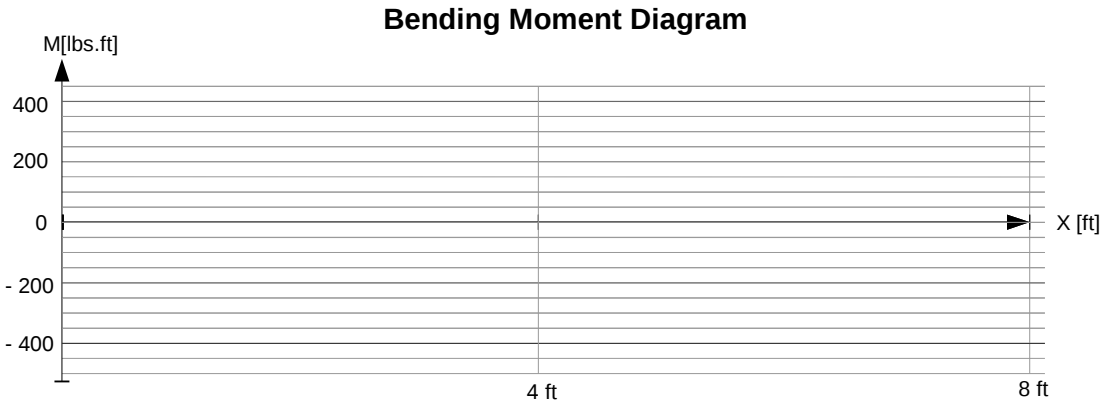


Beam Design - Example

1. Draw the Shear Force and Bending Moment Diagrams to identify the maximum shear V_{max} and Bending M_{max}.

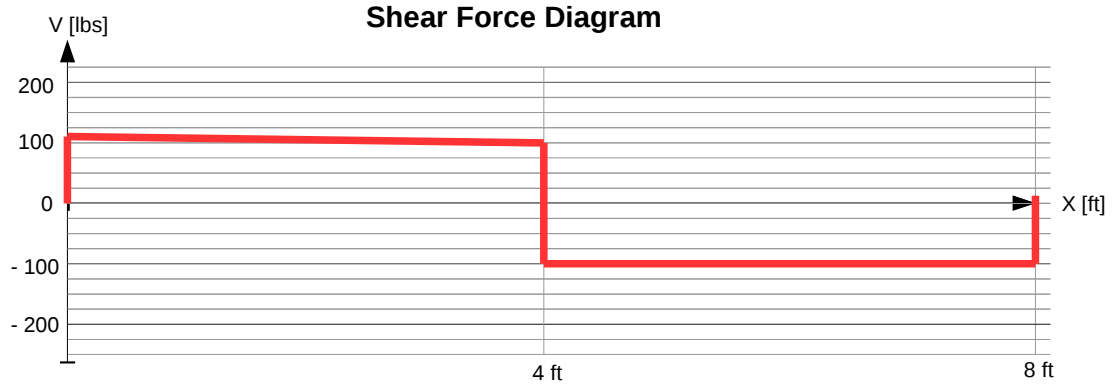


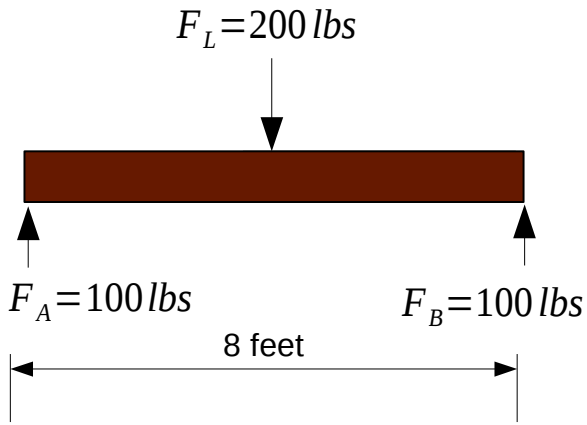


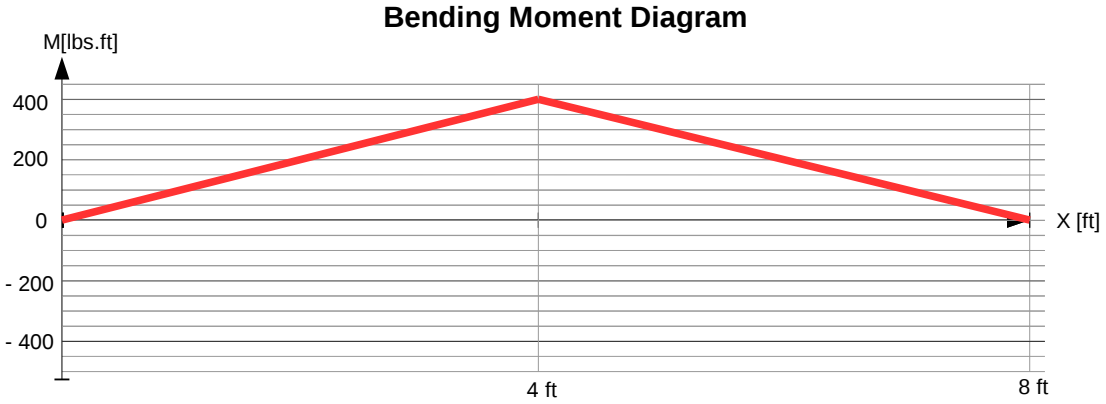


Beam Design - Example

1. Draw the Shear Force and Bending Moment Diagrams to identify the maximum shear V_{max} and Bending M_{max}.







→ V_{max} = 100 lbs M_{max} = 400 lbs.ft

2. Look up the allowable shear stress σ_{sh} and bending stress σ_b for the selected material.

Table 8-1

Material: Pine No1.

Allowable shear stress σ_{sh} = 65 psi or 0.45 MPa

Allowable bending stress σ_b = 925 psi or 6.4 Mpa

Notes on units for stress

General:	Stress = Force per Area	
American Unit:	psi = lb/in^2	
SI:	Pa = N/m^2	1 MPa = 10^6 Pa
Conversion:	1 psi = 6895 Pa	

3. Calculate the minimal cross section area A_{min} and section modulus Z_{min}.

Minimal cross section area for beams:

$$A_{min} = \frac{3 V_{max}}{2 \sigma_{sh}}$$

Minimal section modulus for beams:

$$Z_{min} = \frac{M_{max}}{\sigma_b}$$

For the example:

A_{min} = (3*100 lbs) / (2*65 lbs/in^2) = 2.3 in^2

Z_{min} = ((400 lbs ft) * (12 in/ft)) / (925 lbs/in^2) = 5.2 in^3

Unit conversion: 1 feet = 12 inch

4. Select a nominal size with a higher cross section area and section modulus than the minimal values calculated in step 3.

Cross Section: $A_{min} = 2.3\ in^2$

Section Modulus: $Z_{min} = 5.2\ in^3$

Table 8-1 → 2x6 inch

Result

To support 200 lbs in the middle of an 8 feet beam, a 2x6 inch (6 inch in height) Pine No. 1 beam is needed.