

# Stress Analysis

Mechanics: Stress and strain

Stress and Strain

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## Topics

- Free Body Diagrams (Review)
- Stress
- Strain
- Deformation
- Hooke's Law
- Stress-Strain Diagrams
- Design: The Safety Factor

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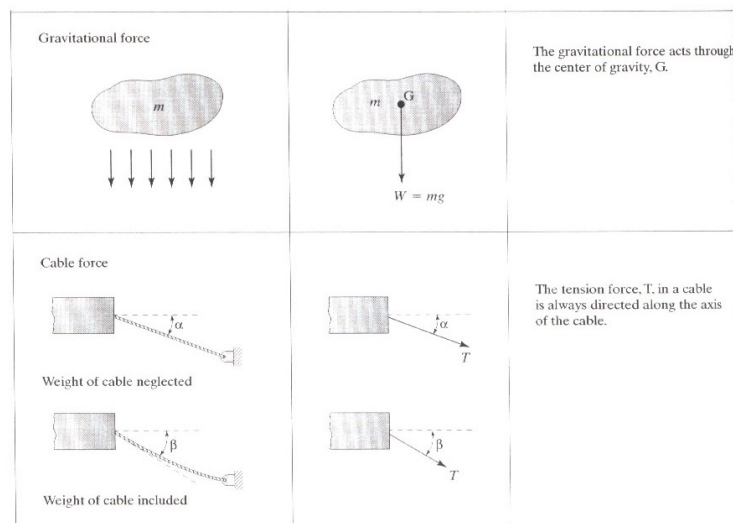
# Free Body Diagrams

- Shows all external forces acting on the body
- Procedure
  1. Identify the isolated body and draw it
  2. At all force locations draw the vectors
    - a. Supports
    - b. Connections
    - c. Contacts
  3. Add the Weight force
  4. Label forces with their value or a letter for unknowns
  5. Add a coordinate system
  6. Add geometric data (Lengths, angles, ... )

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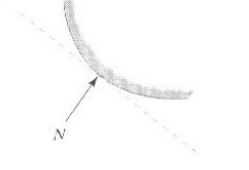
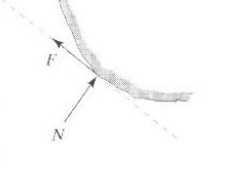
## Examples 1



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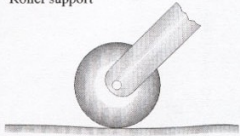
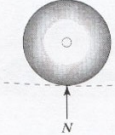
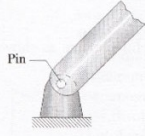
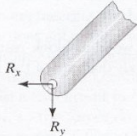
## Examples 2

|                 |   |  |
|-----------------|---|--|
| Contact force   |   |  |
| Smooth surfaces |  | <p>For smooth surfaces, the contact force, <math>N</math>, is toward the body, normal to the tangent drawn through the point of contact.</p>   |
| Rough surfaces  |  | <p>For rough surfaces, there are two forces, a normal force, <math>N</math>, and a friction force, <math>F</math>. These two forces are perpendicular to each other. The friction force, <math>F</math>, acts in the direction opposite of the impending motion.</p> |

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## Examples 3

| Configuration   | Free-body diagram   | Comments  |
|---|---|---|
| <p>Roller support</p>  |  | <p>A roller supports a normal force but no friction force because a friction force would cause the roller to rotate.</p>  |
| <p>Pin connection</p>  |  | <p>A pin connection can support a reaction force in any direction in the plane normal to the pin's axis. This force may be resolved into its <math>x</math> and <math>y</math> components, <math>R_x</math> and <math>R_y</math>.</p> |

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# Stress

- Internal Forces
  - Reaction to external forces
  - Distributed throughout volume of material
- Stress
  - Normal stress
    - Acts at right angles to a selected plane
    - The axial direction in a rod or cable
  - Shear stress: stays in the selected plane (advanced topic: Strength of materials course)
  - **Can a structure withstand the forces applied to it?**

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# Stress 2

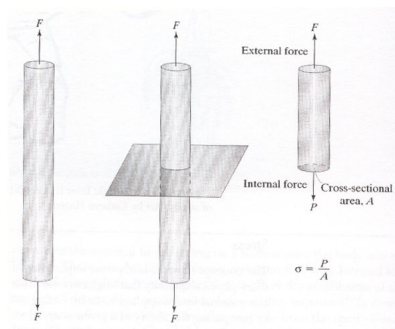
$$\sigma = P/A \text{ (Pascals)}$$

$\sigma$ : Average stress

P: Applied force

A: Cross section area

Tension / Compression



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# Strain

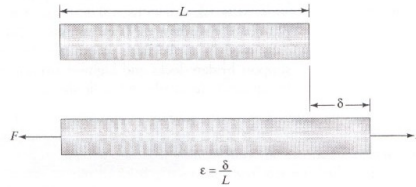
- Strain: deformation due to stress

$$\varepsilon = \delta / L$$

$\varepsilon$ : Normal strain

$\delta$ : Change in length

$L$ : Original (unstressed) length



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# Hooke's Law

- Springs

$$F = kx$$

$F$ : Applied Force

$k$ : Spring constant

$x$ : displacement

- Stress-Strain

$$\sigma = E\varepsilon$$

$\sigma$ : Stress

$E$ : Modulus of Elasticity

$\varepsilon$ : Strain

- Using

$$\sigma = P / A \text{ and}$$

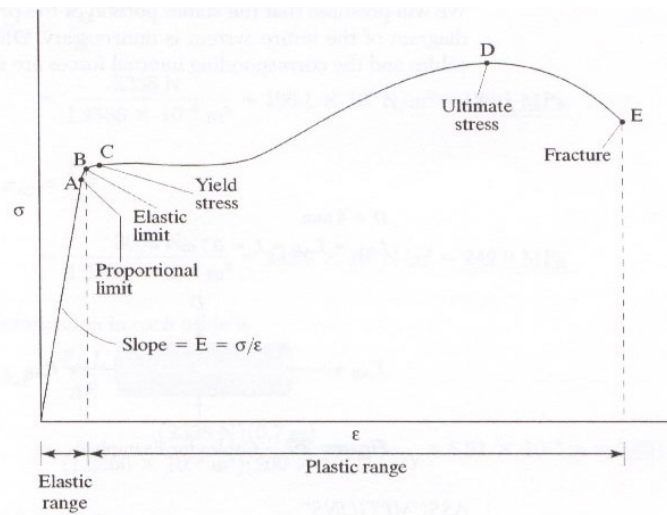
$$\varepsilon = \delta / L$$

$$\delta = \frac{P * L}{A * E}$$

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# Stress-Strain Diagram

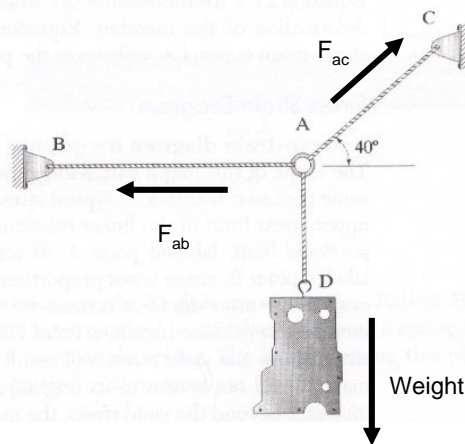


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## Example 6

- 200 kg engine block
- Cables
  - 0.7 m long
  - 4 mm diameter
  - $E = 200 \text{ GPa}$
- Find
  - Normal Stress
  - Axial Deformation



$$F = 200 \text{ kg} \cdot 9.8 \text{ m/sec}^2$$

$$F = 1960 \text{ newtons}$$

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