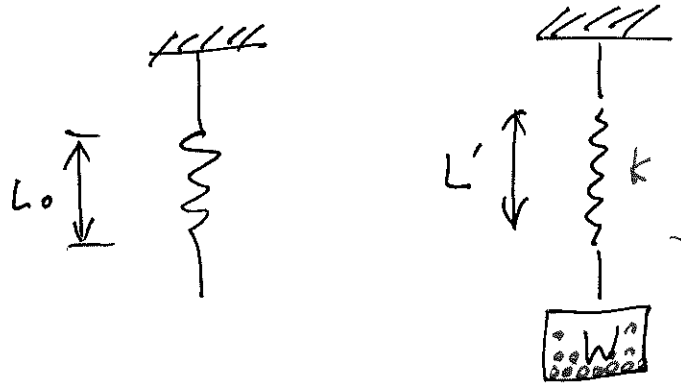
Chapter 3 Mechanical properties of Materials

- Constitutive law (solid mechanics)

  ⇒ relationship b/w stress & strain

- physics

  Force vs. Deformation



Hooke's law

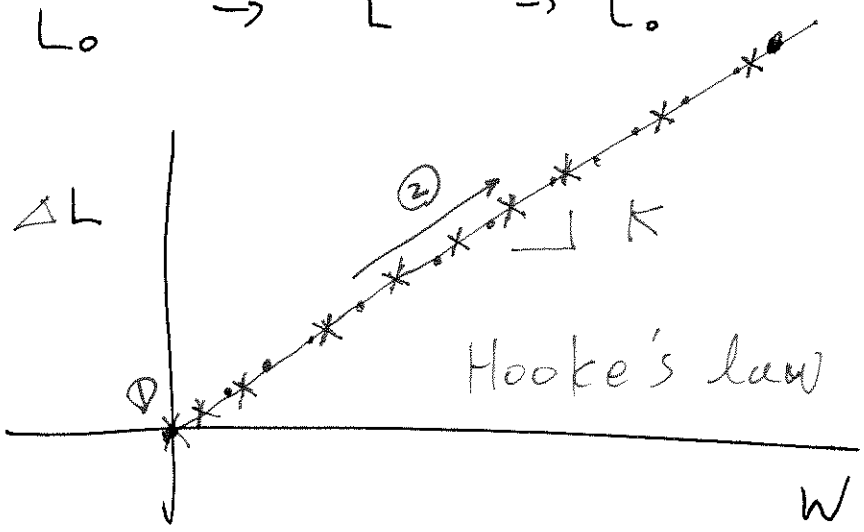
$$W = k(L' - L_o)$$

k: spring constant

Linear Elastic (assumption)

① initial ② loading ③ unloading

$L_o \rightarrow L' \rightarrow L_o$



$(\Delta L = L' - L_o)$

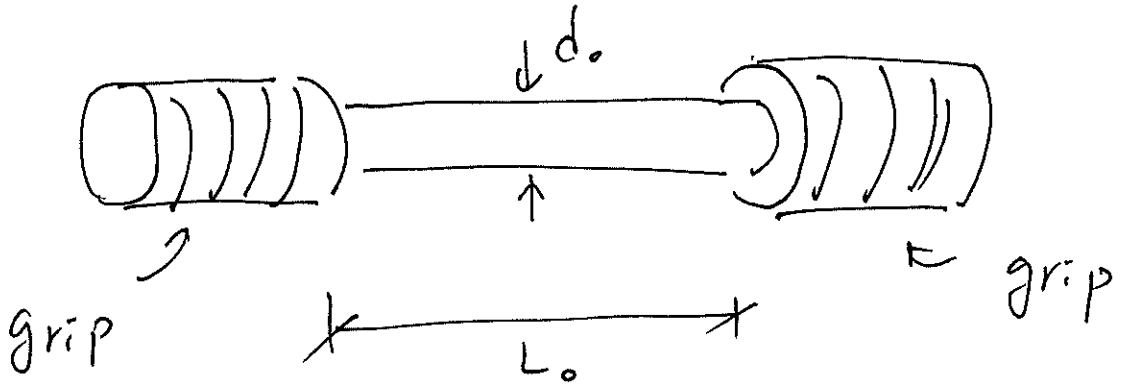
(• : loading, x : unloading)

3.1 Tension & Compression Test

(Uniaxial)

Refer to ASTM E8 ✓

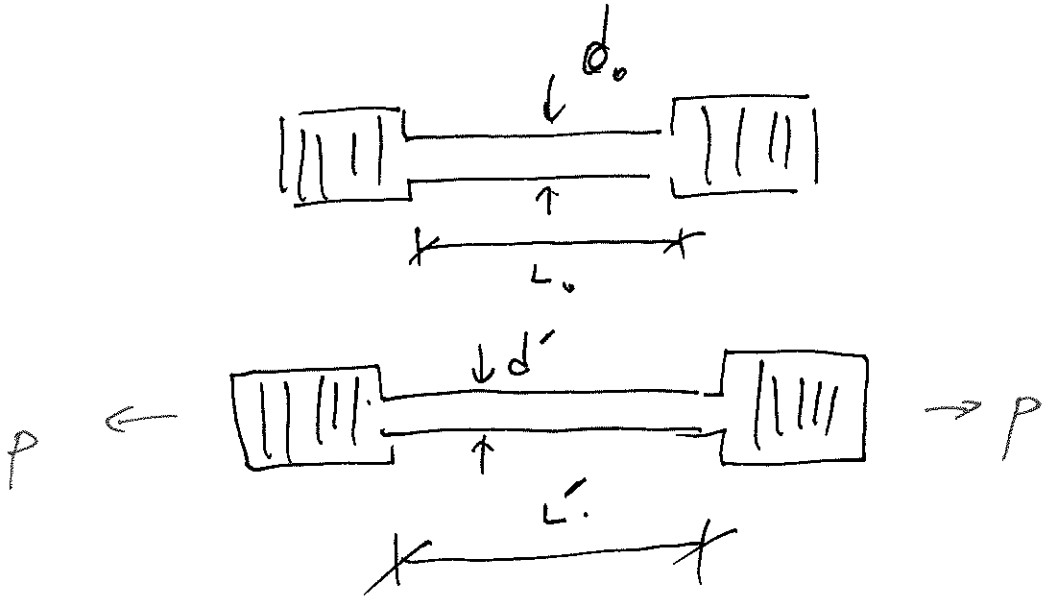
- Uniaxial Tension Test (e.g. steel)



Typical size

$d_o \sim 1/2$ in

$L_o \sim 2$ in

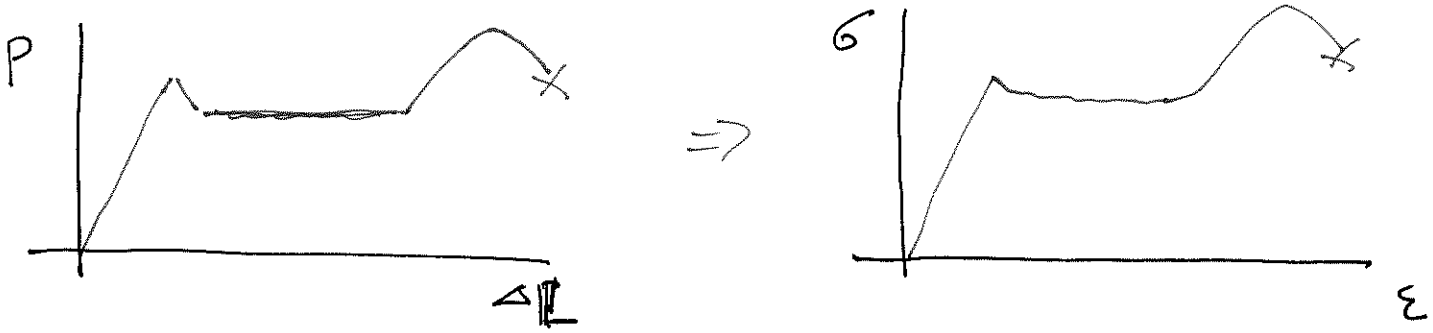


Load : P

Deform: $\Delta L = L' - L_o$

$$\sigma_{avg} = \frac{P}{\frac{\pi}{4} d_o^2}$$

3.2 Stress - Strain Diagram (Uniaxial Tension Test)



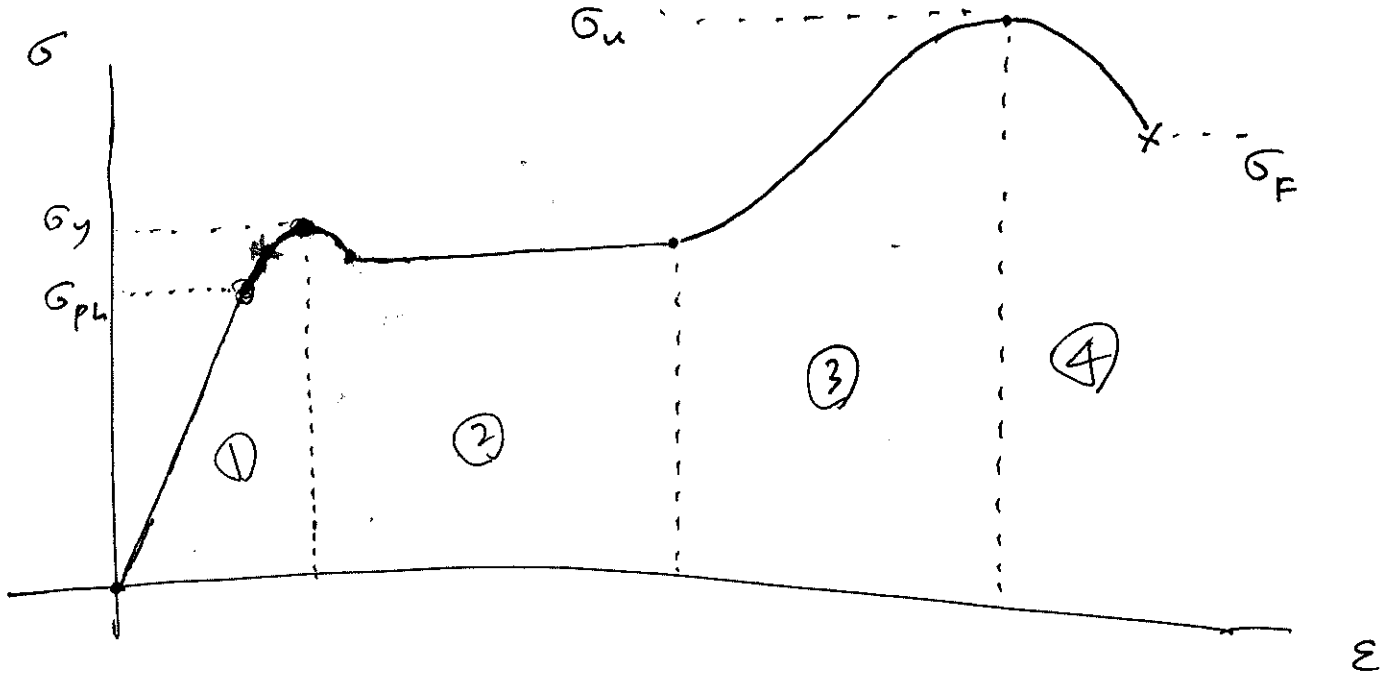
$P - \Delta L \Rightarrow \sigma - \varepsilon$

(force) vs. (Deform.)

$$\sigma_{avg} = \frac{P}{A_o} \qquad \left(A_o = \frac{\pi}{4} d_o^2\right)$$

$$\varepsilon_{avg} = \frac{\Delta L}{L_o}$$

$\sigma - \varepsilon$ diagram for a uniaxial tension test (steel)



① Elastic Behavior

σ_{PL} : proportional limit. ↑material

⇒ Below σ_{PL} : is linear elastic

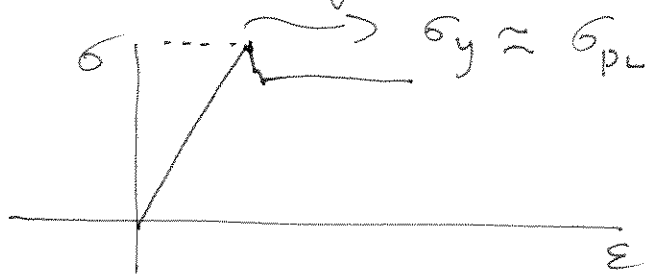
σ_y : yield point

up to σ_y : material is elastic

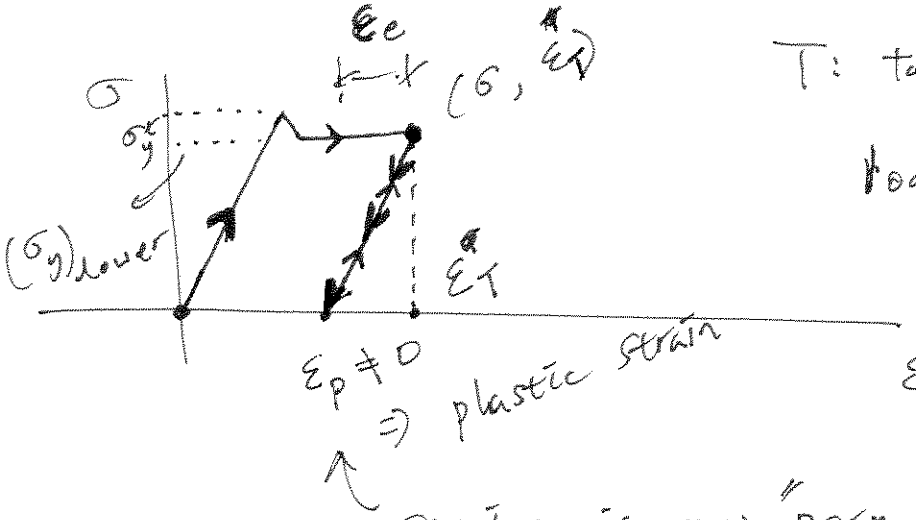
b/w σ_{PL} and σ_y : material is non-linear elastic

In some material, σ_y and σ_{PL} are close enough to be interchangeable

⇒



② yielding (plastic deformation)



T: total

loading – unloading – reloading

$\varepsilon_T = \varepsilon_p + \varepsilon_e$

ε_p: plastic strain ($\varepsilon_p \neq 0$ ⇒ plastic strain)

ε_e: elastic strain

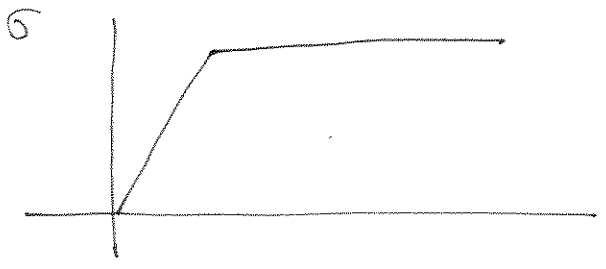
↑ specimen is now "permanently" deformed

⇒ plastic deformation occurred

- σ_y : a peak followed by a lower yield point which usually close to σ_y

$$\sigma_y \approx (\sigma_y)_{lower}$$

$$\Rightarrow \sigma_y \gg (\sigma_y - (\sigma_y)_{lower})$$



~~(elasto – perfect plastic)~~

- In segment ②, material deforms plastically.

⇒ permanent deformation

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③ Strain hardening

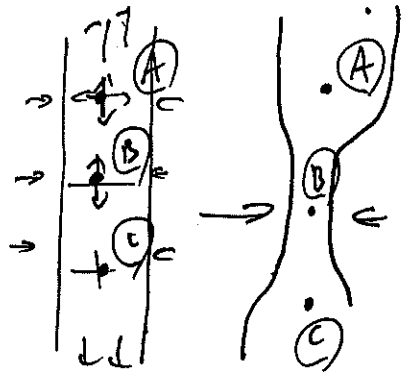
- After yield (②), material can support additional load (stress increases)
- Increases to σ_u, ultimate stress

stress

- σ_u : max. stress that the material can sustain

④ Necking (Strain Softening)

- ~~Beyond~~ Before σ_u, specimen is deforming uniformly
- Beyond (or Past) σ_u, cross-section is decreases in a specific region (⇒ necking)
- Specimen breaks at σ_F



before necky

necking

(Strain localized)

Constitutive Law

~~σ~~ vs. ~~ε~~ relationship

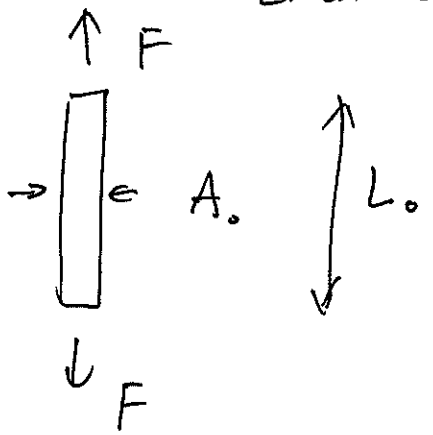
Stress Strain

ex) Hooke's law ($F = k\Delta L$)

↳ Linear Elastic spring

$F = k\Delta L$

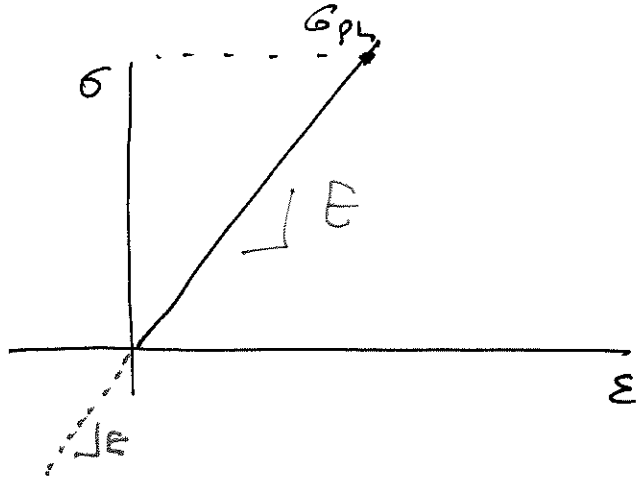
$\frac{F}{A_0} = \sigma$ $\varepsilon = \frac{\Delta L}{L_0}$



$\sigma A_0 = k(\varepsilon L_0)$

$\sigma = \frac{kL_0}{A_0}\varepsilon$

$\boxed{\sigma = E\varepsilon}$



where E is Young's modulus of material