# Quick Review

- <u>Ductility</u>: Ability of a material to be permanently deformed without breaking when a force is applied.

$$\% \text{ elongation} = \frac{l_f - l_0}{l_0} \times 100$$

$$\% \text{ reduction in area} = \frac{A_0 - A_f}{A_0} \times 100$$

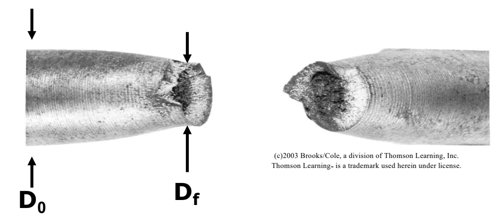
## Example:

- Initial diameter of bar $D_0$= 12.5 mm
- Final diameter at the fracture surface
  $D_f$ = 9.85 mm
- % RA = ? $\%RA = \frac{A_0 - A_f}{A_0}$

$$= \frac{\pi\left({12.5mm}/{2}\right)^2 - \pi\left({9.85mm}/{2}\right)^2}{\pi\left({12.5mm}/{2}\right)^2}$$

$$= 0.379 = 37.9\%$$

Measure $D_o$ prior to testing




- Exercise: <u>Sketch a engineering stress-strain curve for a metal and show the following on the curve</u>:

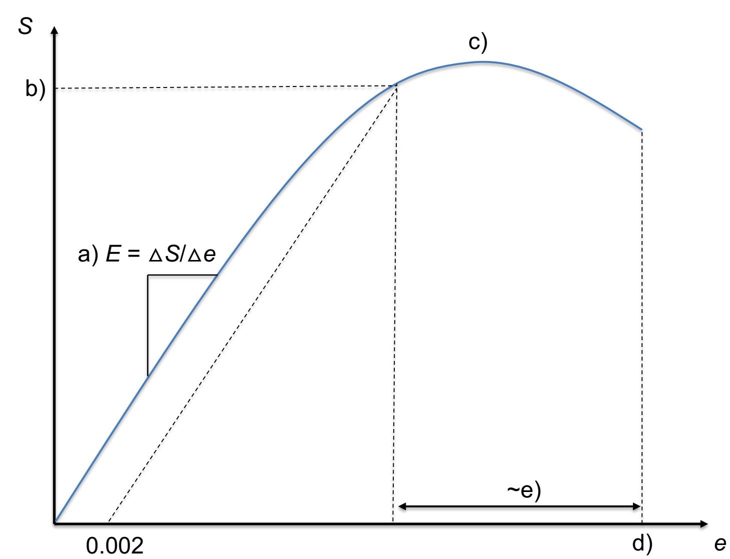
a) Elastic Modulus

b) 0.2% offset yield strength

c) The point at which necking happens

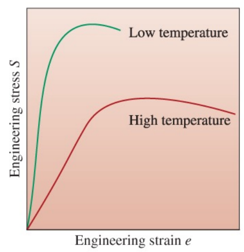
d) The strain at the breaking point

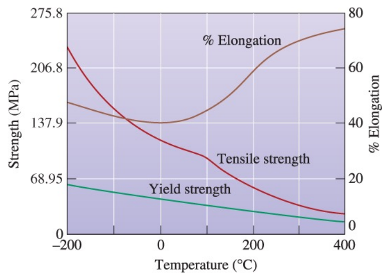
e) The permanent strain at the breaking point (i.e. failure)



# Quick Review

- As temperature increases:
  - YS, UTS, *E* decrease
  - Ductility increases



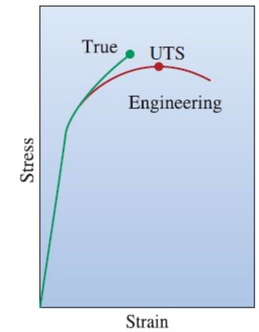

- Due to (↑ or ↓):
  - __ dislocation density
  - __ grain size
  - __ point defect density

# Quick Review

- <u>True</u> stress and strain: based on instantaneous specimen dimensions

$$\text{True stress} = \sigma = \frac{F}{A} \qquad \text{True strain} = \varepsilon = \int_{l_0}^{l} \frac{dl}{l} = \ln\left(\frac{l}{l_0}\right) = \ln\left(\frac{A_0}{A}\right)$$

$$\sigma = S(1+e) \qquad \varepsilon = \ln(1+e)$$




<u>Example</u>: Calculate the engineering and true stresses/strains for an Al-alloy rod (12.83 mm initial diameter, 50.8 mm initial length) that is subjected to a 35.584 kN load, resulting in a 12.46 mm diameter and 3.05 mm increase in length.

$$A_0 = \pi\left(\frac{12.83\ mm}{2}\right)^2 = 129.3\ mm^2$$

$$l_0 = 50.8\ mm$$

$$F = 35.584\ kN$$

$$\Delta l = 3.05\ mm$$

$$S = \frac{F}{A_0} = \frac{35.584kN}{129.3mm^2} = \frac{35.584\times10^3 N}{129.3\times10^{-6}m^2} = 275MPa$$

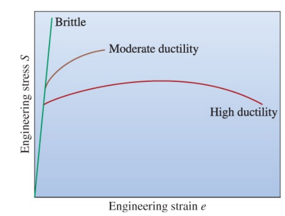
$$e = \frac{\Delta l}{l_0} = \frac{3.05mm}{50.8mm} = 0.06$$

$\sigma = S(1+e) = 275MPa(1.06) = 291.5MPa$ is the true stress

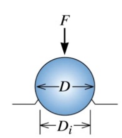
$\varepsilon = \ln(1+e) = \ln(1.06) = 0.058$ is the true strain

# Quick Review

- Very brittle materials
  - YS=UTS=Fracture strength



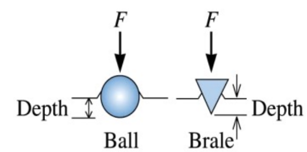

- Hardness test: measure of resistance to penetration by a hard indenter
  - Brinell, Rockwell, etc.




Brinell test

$$BHN = \frac{2F}{\left(\pi D\left[D - \sqrt{D^2 - D_i^2}\right]\right)}$$

F = applied load, kg
D = diameter of indenter, mm
$D_i$ = diameter of impression




Rockwell test

- A Brinell hardness test is performed using an indenter with a diameter of 10 mm and a load of 450 kg, resulting in an indentation of 3.7 mm on an Al-alloy. What is the BHN of the alloy?

$$BHN = \frac{2F}{\left(\pi D\left[D-\sqrt{D^2-D_i^2}\right]\right)}$$

F = 450 kg
D = 10 mm
$D_i$ = 3.7 mm

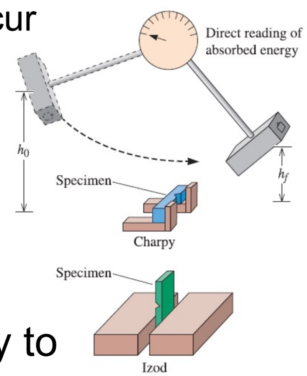
$$BHN = \frac{2(450\,kg)}{\pi(10mm)\left[10mm-\sqrt{(10mm)^2-(3.7mm)^2}\right]}$$

$$= \frac{900\,kg}{\pi(10mm)[0.71mm]}$$

= $40.4\ kg/mm^2$ (or 40.4 HB)

# Quick Review

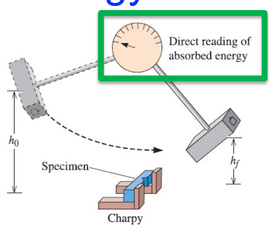
- Metals/alloys more brittle for high strain rates (impacts)
  - Insufficient time for slip to occur
- Impact tests:
  - Izod
  - Charpy




- Impact toughness: the ability to withstand an impact blow

- Measurements from a Charpy test (10 kg pendulum) on samples of a steel are provided. Calculate the impact energy for each test.

| Temp [C] | $h_0$ [m] | $h_f$ [m] | Impact energy [J] |
|---|---|---|---|
| -196 | 0.50 | 0.46 | 3.9 |
| -25 | 0.50 | 0.45 | 4.9 |
| 0 | 0.50 | 0.38 | 11.8 |
| 20 | 0.50 | 0.19 | 30.4 |
| 100 | 0.50 | 0.09 | 40.2 |



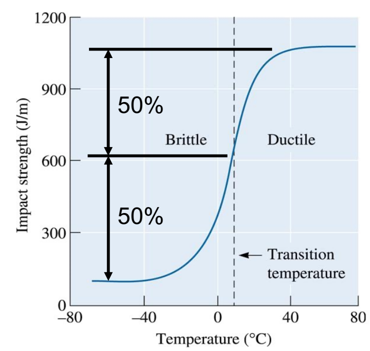

$E$ = mass x $g$ x $(h_0-h_f)$

$E$ = (10kg)(9.81m/s$^2$)(0.50m-0.46m)

$E$ = 3.9 J

# Quick Review

- Impact tests can identify the ductile-to-brittle transition temperature (DBTT)




- Want DBTT _____ $T_{operating}$ (< or > ?)

# Midterm review suggestions

- Review all lecture slides
- Review all study questions
  - Note ones you find challenging
- Review the “key concepts” in weekly summaries
  - Try explaining to yourself or someone else
- Review formula sheet
  - Explain each formula to yourself
- Attempt old exams provided on LEARN
  - Review solutions, identify material to review