BMEN 343 **NAME:**______________________________________

ID #:____

HOMEWORK #4 (85 PTS)

DUE: <u>26 October 2009</u> at the BEGINNING OF CLASS:

There are 2 pages (front and back) to this homework. Answers should be given neatly, in order, and in the space provided or in stapled attached pages if necessary. <u>Show work for full credit</u>. Put the final answer in a box when appropriate.

<u>True or False:</u>

1. **(2 pt)** T F Dislocation density decreases with cold-working.
False

2. **(2 pt)** T F Motion of dislocations lead to plastic deformation in metals.
True

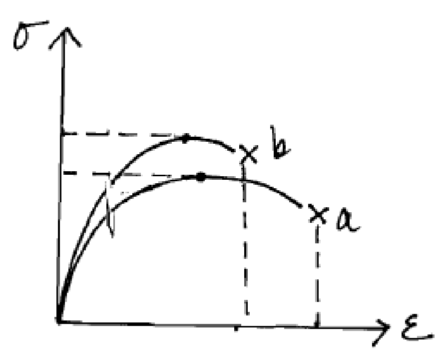
3. **(2 pt)** T F A course-grained metal will have a higher tensile strength than the corresponding fine-grained metal.
False

<u>Brief Answer</u>:

4. **(4 pts)** Provide a brief definition of "slip".

The shear displacement of two adjacent planes of atoms (also, motion of dislocations in response to shear stress).

5. **(10 pts)** <u>Draw</u> a typical stress-strain curve for a metal: **(a)** before cold-rolling and **(b)** after cold-rolling [label axes, curves as "a" and "b"] **(6 pts)**. Which curve represents a metal with higher dislocation density ("a" or "b")? **(4 pts)**.



"b" has a higher dislocation density. Note: cold-working produces a high level of plastic deformation and hence dislocations to a metal. A higher dislocation density inhibits dislocation motion and thus the metal becomes stronger but less ductile; this means that TS and yield strength increase but %EL is reduce – graph must reflect this. Modulus does not change.

Calculations 6-10: Answers should be completed on *separate pages* and ***stapled* to this sheet**. Show all work for full credit. **Provide answers in a neat and orderly fashion (PLEASE!)**. Place a box around each final answer. Consult Table 6.1 as needed.

6. **(10 pts)** A tensile stress is to be applied along the long axis of a tungsten cylindrical rod that has a diameter of 1.7 mm. Determine the force required to produce a reduction in diameter of 0.002 mm if the deformation is entirely elastic.

Cylindrical rod : $A_0 = \pi \left(\frac{d_0}{2}\right)^2 = \frac{\pi d_0^2}{4}$

$$\boxed{\sigma} = \frac{F}{A_0} = \frac{F}{(\pi d_0^2)/4} = \boxed{E \varepsilon_z}$$

$$\varepsilon_z = -\frac{\varepsilon_x}{\nu} = \frac{\Delta d / d_0}{\nu} = -\frac{\Delta d}{\nu d_0}$$

$$\frac{F}{\left(\frac{\pi d_0^2}{4}\right)} = E\left(-\frac{\Delta d}{\nu d_0}\right)$$

$$F = \frac{-d_0 \, \Delta d \, \pi \, E}{4\nu}$$

$$= \frac{-(.0017\,m)(2 \times 10^{-6}\,m)(\pi)(407 \times 10^{9}\,N/m^2)}{4\,(0.28)}$$

$$F = \boxed{3881\ N}$$

7. **(10 pts)** A cylindrical rod of steel having a yield strength of 210 MPa is to be subjected to a load of 12,000 N. If the length of the rod is 500 mm, what must be the diameter to allow an elongation of 0.25 mm?

$$A_0 = \pi r_0^2 = \pi \left(\frac{d_0}{2}\right)^2 = \frac{\pi d_0^2}{4}$$

$$\sigma = \frac{F}{A_0} = \frac{F}{\pi\left(\frac{d_0^2}{4}\right)} = E\varepsilon_z = E\frac{\Delta L}{L}$$

solve for d_0:

$$d_0 = \sqrt{\frac{4 l_0 F}{\pi E \Delta l}}$$

$$= \sqrt{\frac{4(.5\,m)(12{,}000\,N)}{\pi(207 \times 10^9\,N/m^2)(.00025\,m)}}$$

$$= .012\,m = \boxed{12\,mm}$$

8. **(10 pts)** A cylindrical rod of titanium (diameter = 8 mm) undergoes elastic deformation when subjected to a tensile force of 4000 N. This process reduces the diameter by 0.002 mm. Calculate Poisson's ratio for Ti.

$$E_{Ti} = 107\ GPa = 107 \times 10^9\ N/m^2$$

$$\nu = \frac{\varepsilon_x}{\varepsilon_z} \qquad \varepsilon_z = \frac{\sigma}{E}$$

$$\varepsilon_z = \frac{\sigma}{E} = \frac{F}{A_0 E} = \frac{F}{\pi\left(\frac{d_0}{2}\right)^2 E} = \frac{4F}{\pi d_0^2 E} \checkmark$$

$$\varepsilon_x = \frac{\Delta d}{d_0}$$

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\left(\Delta d / d_0\right)}{\left(\frac{4F}{\pi d_0^2 F}\right)} = -\frac{d_0 \Delta d \pi E}{4F}$$

$$= -\frac{(0.008m)(-2 \times 10^{-6} m)(\pi)(107 \times 10^9\ N/m^2)}{(4)(4000 N)}$$

$$= \boxed{.336} \quad \text{(agrees w/ Table 6.1)}$$

9. **(10 pts)** Consider a cylindrical steel rod (diameter = 3 mm). What is the force required to produce a reduction in diameter of 0.003 mm. Assume the deformation is entirely elastic.

$$A_0 = \pi \left(\frac{d_0}{2}\right)^2 = \frac{\pi d_0^2}{4}$$

$$\sigma = \frac{F}{A_0} = \frac{F}{\pi d_0^2/4} = E\varepsilon_z$$

$$\varepsilon_z = \frac{-\varepsilon_x}{\nu} = \frac{-d/d_0}{\nu} = -\frac{\Delta d}{\nu d_0}$$

so:

$$\frac{F}{\pi d_0^2/4} = E\left(\frac{-\Delta d}{\nu d_0}\right)$$

$$F = \frac{-d_0 \Delta d \pi E}{4\nu}$$

$$F = \frac{-(.003\,m)(3\times10^{6}\,m)(\pi)(207\times10^9\,N/m^2)}{4(.30)}$$

$$= \boxed{4877\ N}$$

10. **(10 pts)** (Question 6.30 from book) A cylindrical metal specimen having an original diameter of 12.8 mm (0.505 in.) and gauge length of 50.8 mm (2.000 in.) is pulled in tension until fracture occurs. The diameter at the point of fracture is 8.13 mm (0.320 in.), and the fractured gauge length is 74.17 mm (2.920 in.). Calculate the ductility in terms of percent reduction in area and percent elongation.

$$\%RA = \left(\frac{A_o - A_f}{A_o}\right) \times 100$$

$$= \frac{\pi\left(\frac{d_o}{2}\right)^2 - \pi\left(\frac{d_f}{2}\right)^2}{\pi\left(\frac{d_o}{2}\right)^2} \times 100$$

$$= \frac{\pi\left(\frac{12.8\text{ mm}}{2}\right)^2 - \pi\left(\frac{8.13\text{ mm}}{2}\right)^2}{\pi\left(\frac{12.8\text{ mm}}{2}\right)^2} \times 100$$

$$= \boxed{60\%}$$

$$\%EL = \left(\frac{L_f - L_o}{L_o}\right) \times 100$$

$$= \left(\frac{74.17\text{mm} - 50.8\text{ mm}}{50.8\text{ mm}}\right) \times 100$$

$$= \boxed{46\%}$$