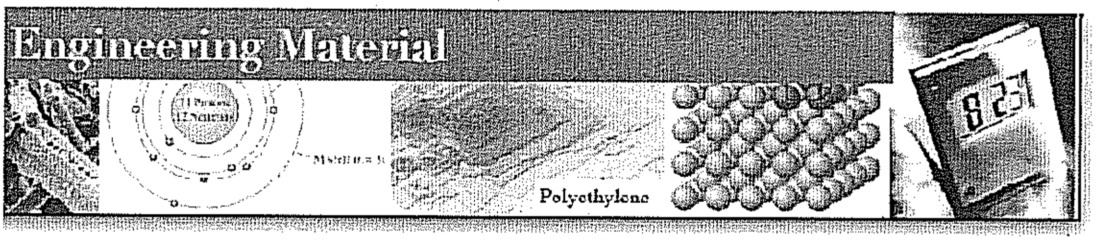
SOLUTION



AMERICAN UNIVERSITY OF BEIRUT

ENGINEERING MATERIALS-MECH 340

MIDTERM (II)

April-16-2013

STUDENT NAME:

ID:

DURATION: 2H00

20

Question 1. (30 pts- Only one answer is correct)
During elastic deformation, a metal experiences
1. Necking.
2. Bond breaking
3. Bond stretching.

Plastic deformation in metallic alloys is the result of
1. Necking.
2. Dislocation motion.
3. The uni-axial tensile test.

Hardness is a measure of :
1. Resistance to surface penetration.
2. Resistance to deformation in the elastic limit.
3. Resistance to formation of circular indentations.

Young's modulus characterizes what property of a material?
1. Slope.
2. Rigidity.
3. Elasticity.

Materials with the greatest toughness
1. Have the greatest ductility
2. Have the highest Young's modulus.
3. Have a combination of strength and ductility.

The percent elongation of a material at failure defines its:
1. Fracture strength.
2. Toughness.
3. Ductility.

Structural engineering steels are sometimes found to be brittle
1. At high values of strain
2. At low ambient temperatures
3. At moderate concentrations of carbon.

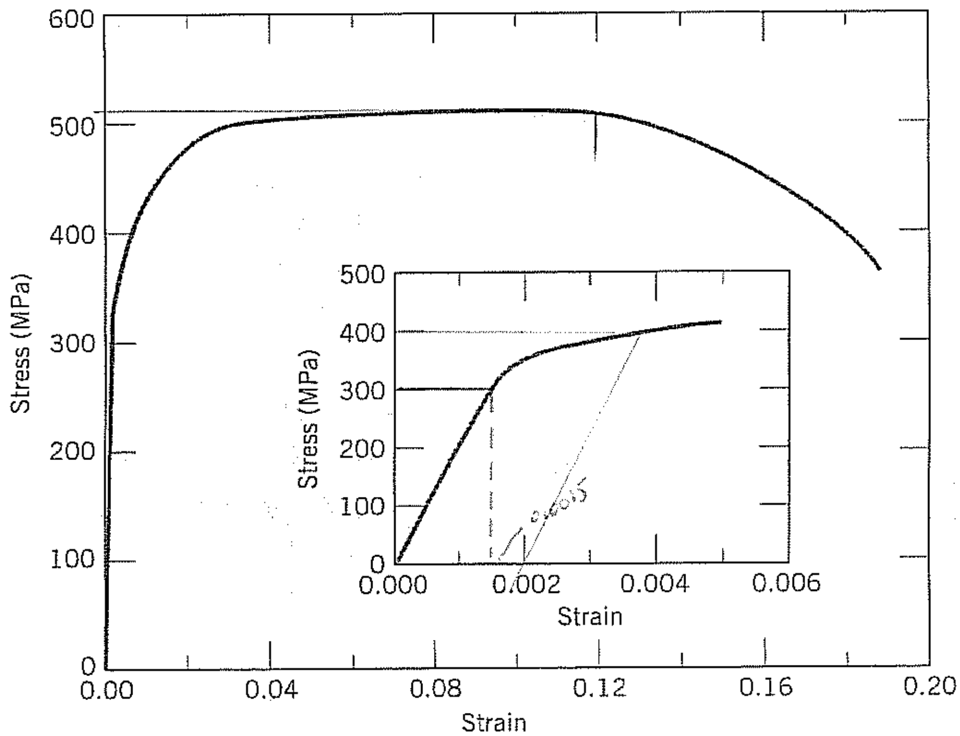
Edge and screw dislocations differ in what way?
1. Magnitude of their Burgers vectors.
2. Line direction is straight (edge) or curved (screw).
3. Angle between Burgers vector and line direction

Interstitial defects at low ambient temperatures.
1. Are usually associated with vacant lattice sites.
2. Are found between lattice sites.
3. Come from impurity atoms on lattice sites

Poisson's Ratio
1. Characterizes Elasticity
2. Characterizes plasticity
3. Relates axial and lateral deformations

QUESTION 2 *(20 pts)*

From the given tensile stress–strain behavior of a steel specimen, determine the following:



a. The modulus of elasticity $E = 300/0.0015 = 200\ 000$ MPa

b. The yield strength → 400 MPa ? check.

c. The ultimate tensile strength → 510 MPa

d. The radius of the specimen if its initial length is 75 mm and it elongates 0.075 mm when a tensile load of 20,000 N is applied?

$P = 20000$

$E = 2\times10^5$ MPa

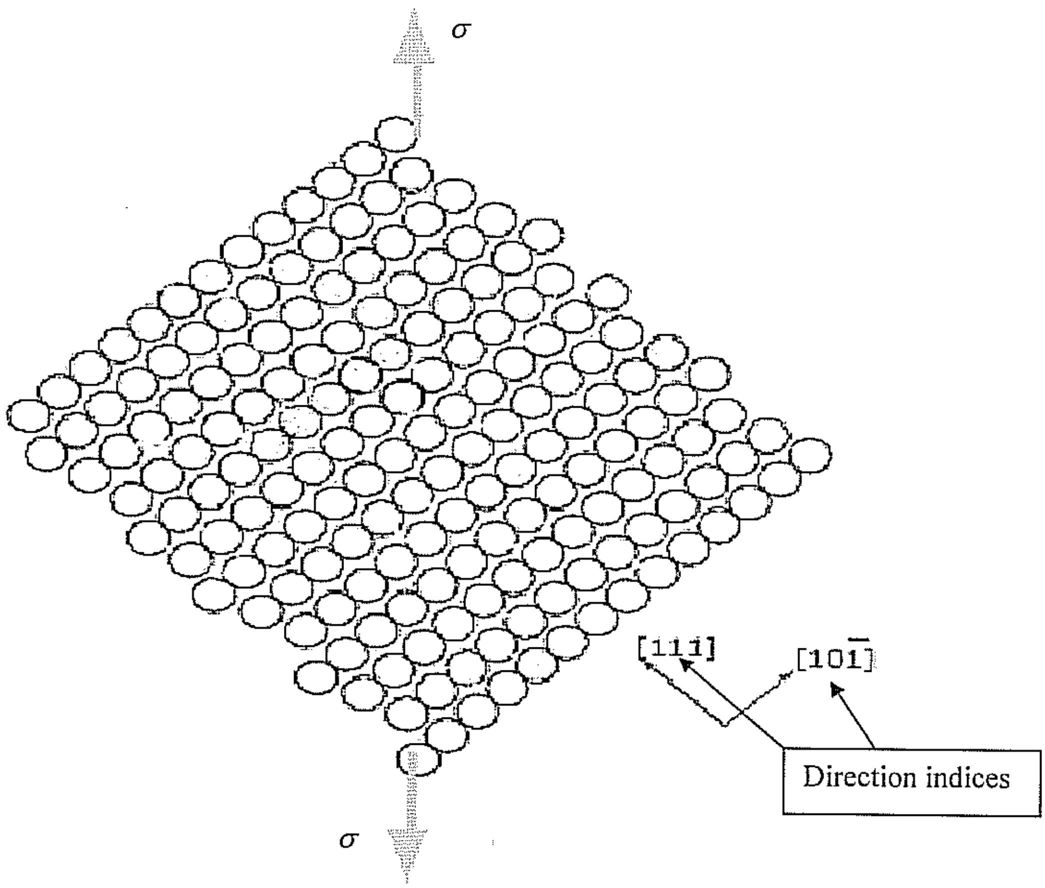
$\sigma = \frac{P}{A} = \frac{20000}{\pi d^2/4} = 200$ → $d = 3\cancel{5}.7$ mm 11.28 $r = 5.64$ m

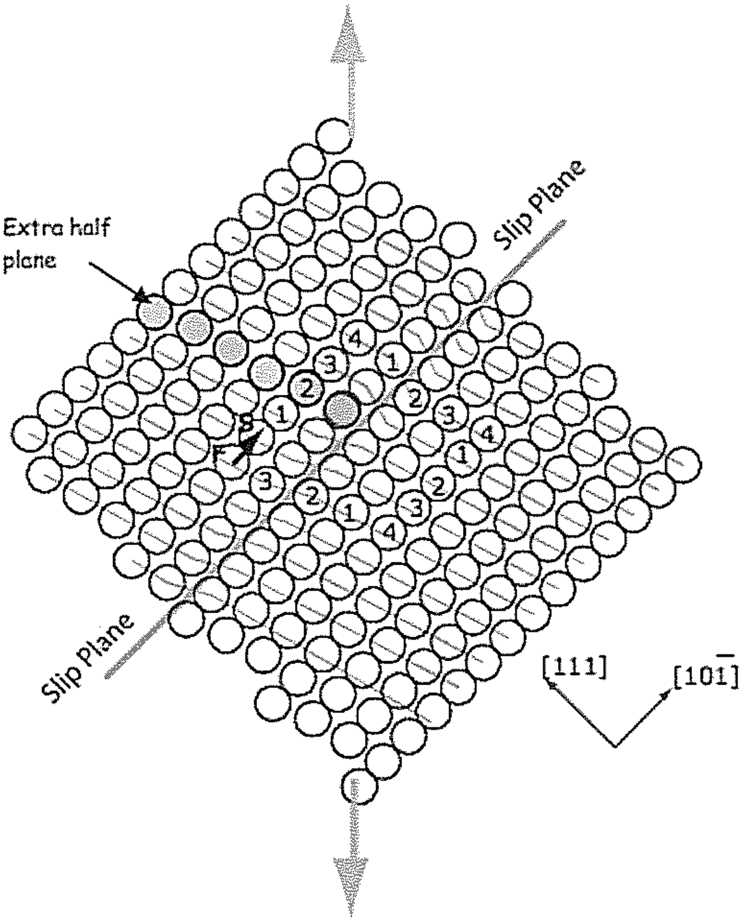
$\frac{\Delta L}{L_o} = \frac{0.075}{75} = \varepsilon = 1\times10^{-3}$ → $\sigma = E \cdot \varepsilon = 200$ MPa.

Problem 3-(20 pts)

Consider the following schematic of the atomic arrangements in an FCC crystal (lattice constant = *a*) that has been subjected to an external load of sufficient magnitude to exceed the critical resolved shear stress for motion of dislocations on the slip plane pictured here. Find the *edge dislocation* in the FCC crystal illustrated below...

1. Locate and label the extra half plane (5 points).
2. Locate and label the slip plane (5 points).
3. Trace the Burgers circuit and draw the Burger vector (5 points).
4. Now specify the Burger vector's magnitude and direction with respect to the FCC crystalline coordinate system indicated here (5 points).
5. Remember that b is a lattice vector representing the shortest lattice translation.





Burgers vector: $\vec{b} = \frac{a}{2}[10\bar{1}]$.

Note that this is exactly one interatomic spacing along the close-packed direction of slip shown above.

QUESTION 4 *(15 pts)*

A cylindrical specimen of a hypothetical metal alloy is stressed in compression. If its original and final diameters are 20.000 and 20.025 mm, respectively, and its final length is 74.96 mm, <u>compute its original length if the deformation is totally elastic</u>. The elastic and shear moduli for this alloy are 105 and 39.7 GPa, respectively.

$d_0 = 20$

$d_F = 20.025$ $\quad L_F = 74.96\,mm$

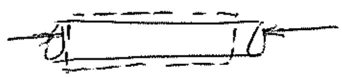
$E = 105000$ $\quad \nu =$

$G = 397000\ MPa$ $\quad G$

$$G = \frac{E}{2(1+\nu)}$$

$$\frac{E}{2G} = 1+\nu$$

$$\nu = \frac{105000}{39700 \times 2} - 1 = 0.322$$



$$\varepsilon_{lat} = -\nu \cdot \varepsilon_{longit}$$

$$\varepsilon_{long} = -\frac{\varepsilon_{lat}}{\nu} = -3.1\ \varepsilon_{lat}$$

$$\varepsilon_{long} = -3.1\left(\frac{20.0 - 20.025}{20}\right)$$

$$\varepsilon_{long} = -3.875 \times 10^{-3} = \frac{L_F - L_0}{L_0}$$

$$L_F - L_0 = L_0(-3.875 \times 10^{-3})$$

$$L_F = L_0 + L_0(-3.875 \times 10^{-3})$$

$$L_0 = \frac{74.96}{1 - 3.875 \times 10^{-3}} = 75.25\ mm$$

QUESTION 6 *(15 pts)*

A single crystal of a metal that has the FCC crystal structure is oriented such that a tensile stress is applied parallel to the [~~001~~] direction. If the critical resolved shear stress for this material is 1.75 MPa, calculate the magnitude(s) of applied stress(es) necessary to cause slip to occur on the (111) plane in each of the $[1\bar{1}0]$, $[10\bar{1}]$ and $[01\bar{1}]$ directions.

For each of these slip systems, ϕ will be the same i.e, the angle between directio of applied stress. [100] and normal to (111) plane that is [111] direction

$$\phi = \cos^{-1}\left[\frac{u_1u_2 + v_1v_2 + w_1w_2}{\left(\sqrt{(u_1^2 + v_1^2 + w_1^2)(u_2^2 + v_2^2 + w_2^2)}\right)}\right]$$

100 $\Rightarrow$ $u_1 = 1$, $v_1 = 0$, $w_1 = 0$

111 $\Rightarrow$ $u_2 = 1$ $v_2 = 1$, $w_2 = 1$.

$$\phi = \cos^{-1}\left[\frac{0 + 0 + 1}{\sqrt{(1)(1^2 + 1^2 + 1^2)}}\right] = 54.7^\circ$$

determine λ For each slip system

$[\cancel{00}\bar{1}]$ & $[1\bar{1}0]$ and

$$\lambda_{[100]-[1\bar{1}0]} = \cos^{-1}\left[\frac{0 + 0 + 1}{\sqrt{(1)(1+1)}}\right] = \frac{1}{\sqrt{2}}$$

$= 45^\circ$

solve for yield.

$$\sigma_y = \frac{\tau_{cr}}{\cos\phi \cos\lambda} = \frac{1.75}{} = 4.28 \text{ M}$$

λ for (111) & $[10\bar{1}]$ system

$[100]$

$$\lambda = \cos^{-1}\left[\frac{1+0+0}{\sqrt{(1)(1^2+1^2)}}\right] = \frac{1}{\sqrt{2}} = 45^\circ$$

$\therefore \sigma_y = 4.28$

λ for (111) & $(01\bar{1})$

(100)

$$\lambda = \cos^{-1}\left[\frac{0}{\sqrt{1(1+1)}}\right] = 90$$

$\underline{\lambda = 90^\circ}$

$\sigma_y = \infty \rightarrow$ never slip on this.

QUESTION 6 *(15 pts)*

Steady-state creep rate data are given in the following table for nickel at 1000 degrees C (1273 K):

$\dot{\epsilon}_s$ (s^{-1})	σ [MPa (psi)]
10^{-4}	15 (2175)
10^{-6}	4.5 (650)

If it is known that the activation energy for creep is 272,000 J/mol and R= 8.31 J/mol-K, compute the steady-state creep rate at a temperature of 850 degrees C (1123 K) and a stress level of 25 MPa (3625 psi).

$$\dot{\varepsilon}_s' = \alpha k_2 \, \sigma^n \exp\left(-\frac{Q_c}{RT}\right)$$

$$\ln \dot{\varepsilon}_s' = \ln k_2 + n \ln \sigma - \frac{Q_c}{RT}$$

$$\ln 10^{-4} = \ln k_2 + n \ln 15 - \frac{272000}{8.31\,(1273)} \quad — 1$$

$$\ln 10^{-6} = \ln k_2 + n \ln 4.5 \quad — 2$$

$$-9.21 = \ln k_2 + n \cdot 2.7 - 25.71$$

$$\ln k_2 + 2.7\,n = 16.5 \quad — (1)$$

$$-13.8 = \ln k_2 + 1.5\,n - 25.71$$

$$-\ln k_2 - 1.5\,n = -11.91 \quad + (2)$$

$$n = 3.825$$

$$k_2 = 4693 \,/\text{sec}$$

$$\dot{\varepsilon}_s = 479.3\,(25)^{3.825}\, e^{\left(-\frac{272000}{8.31\,(1123)}\right)}$$

$$\dot{\varepsilon}_s' = 2.35 \times 10^{-5} \,/\text{sec}$$

Formulae sheet

b(FCC)=(a/2).length of direction(uvw)………. b is burger vector length and (uvw) is the direction indices along the slip line.

$\sigma = \dfrac{F}{A_0}$	Engineering stress
$\epsilon = \dfrac{l_i - l_0}{l_0} = \dfrac{\Delta l}{l_0}$	Engineering strain
$\sigma = E\epsilon$	Modulus of elasticity (Hooke's law)

$$\boxed{G = \frac{E}{2(1+\nu)}}$$

E modulus of elasticity and G is the shear modulus

$\tau_R = \sigma \cos \phi \cos \lambda$	Resolved shear stress
$\tau_{crss} = \sigma_y(\cos \phi \cos \lambda)_{max}$	Critical resolved shear stress

$\dot{\epsilon}_s = K_2 \sigma^n \exp\left(-\dfrac{Q_c}{RT}\right)$	Dependence of creep strain rate on stress and temperature (in K)

Stress in MPa

K_2 in s^{-1}