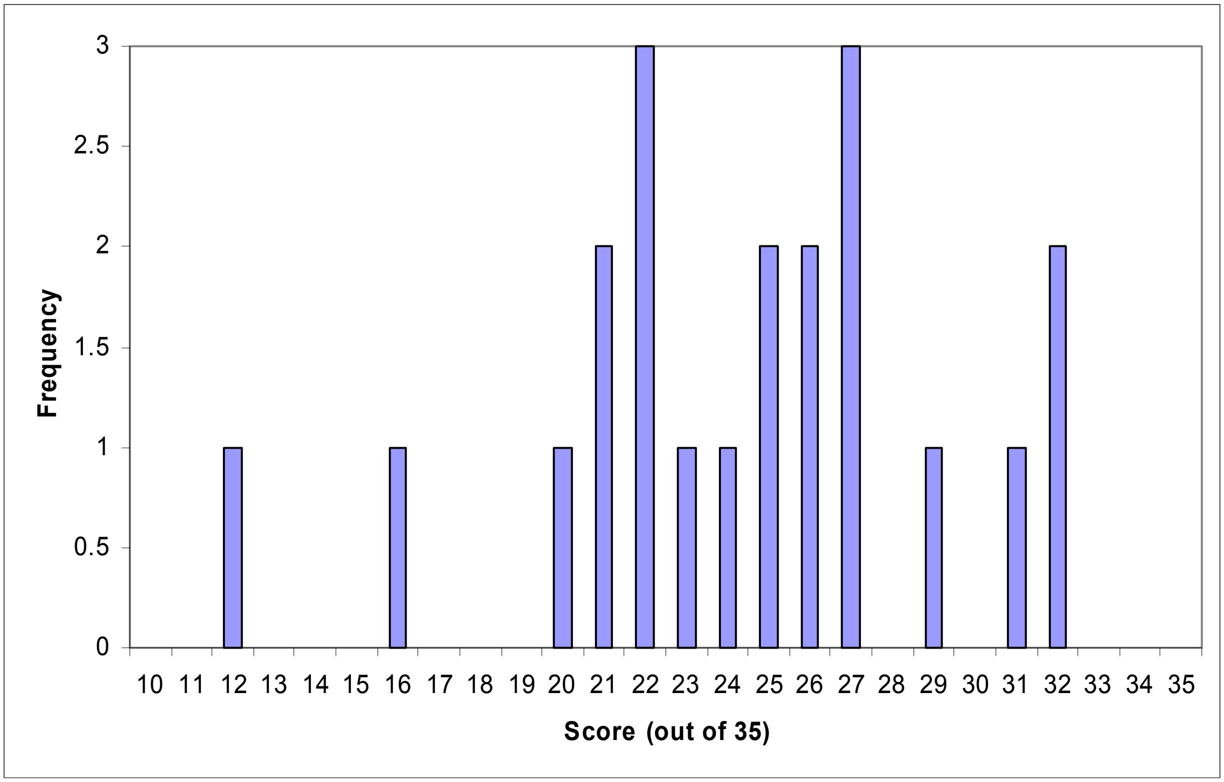
Department of Materials Science and Engineering
Massachusetts Institute of Technology
3.14 Physical Metallurgy – Fall 2003
Exam I

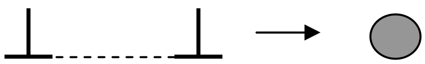


Class average: 24.0

Problem #1: Partial Dislocations and Cross-Slip

In an FCC metal, a screw dislocation approaches an obstacle and is momentarily stuck. After the stress is increased, the screw dislocation can bypass the obstacle by cross slipping:

Part A If the same screw dislocation were initially dissociated into two partials:

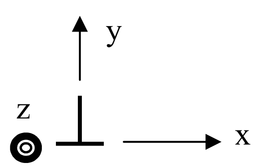


Can cross slip happen in this scenario? Why or why not?

Part B Would this obstacle be more effective in copper (low stacking fault energy) or aluminum (high stacking fault energy)?

Problem #2: Stress/Strain Field of a Dislocation

In class we discussed the strain and stress fields of edge and screw dislocations separately. In this problem you will draw a picture of the stress field around a mixed dislocation, which is *equally composed of edge and screw character*.



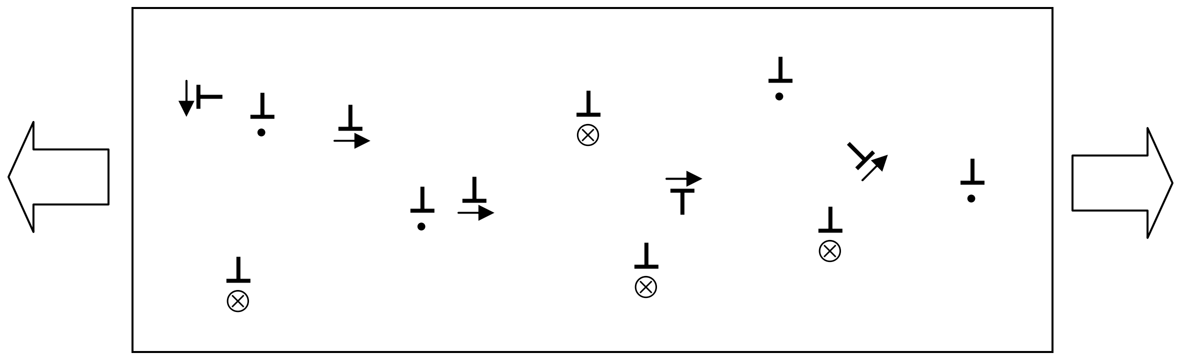
Please Note:
(i) at any point in space, the total stress is just the sum of the two contributions (edge and screw)
(ii) the equations for the edge and screw dislocations are given at the back, but you don't necessarily need them to answer this question; physical intuition will suffice.

Part A: Draw contours of the σ_{xx} stress component in the above coordinate system

Part B: Draw contours of the σ_{xz} stress component in the above coordinate system

Problem #3: Dislocation Dynamics

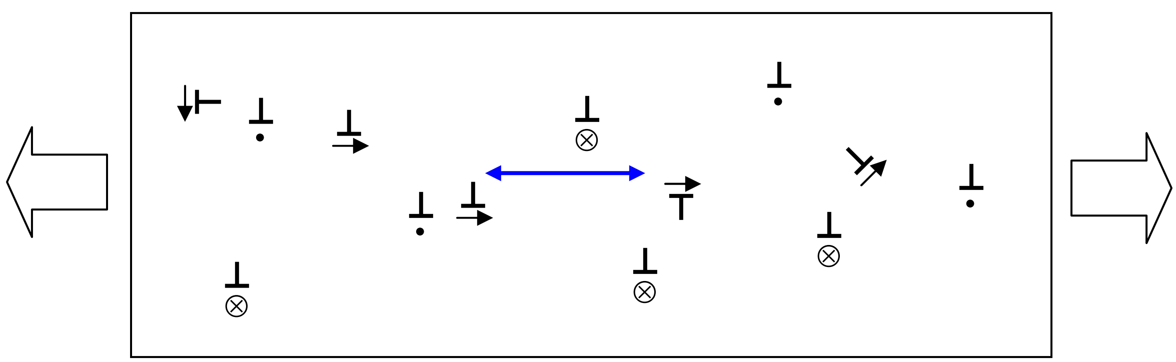
Here is a very little specimen that has only a handful of dislocations in it, all of which have their line vectors pointing into the page:



The Burger's vector is shown next to each dislocation; • is out of the page and ⊗ is into the page.

Part A: If a tensile stress is applied as shown, indicate on the above picture how each dislocation would move.

Part B: If the specimen were NOT deformed, but put directly into a furnace and annealed, draw how the configuration would change. Add some labels or description to note what mechanisms are occurring.



Problem #4: Microstructural Evolution During Annealing

A polycrystalline metal specimen is deformed and annealed, during which the following events occur in sequence:

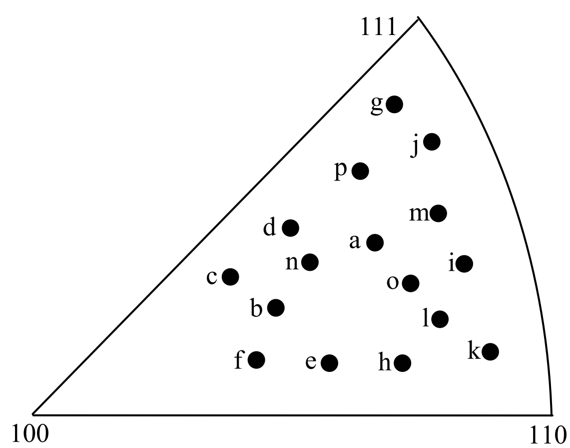
(i) recovery processes build a subgrain structure, which coarsens for some time
(ii) recrystallization commences
(iii) recrystallization runs to completion and structural coarsening continues

Draw two plots that depict (a) the average size of subgrains as a function of time and (b) the average size of legitimate grains, separated by high-angle boundaries, as a function of time. Synchronize the plots in time, and label each part of the curve with the events taking place.

Problem #5: Recrystallization Nuclei

Consider the assemblage of square subgrains shown below. There are sixteen unique grain orientations (labeled a-p). These orientations are all indicated on the stereographic triangle at the right.

p	m	n	o	p	m
d	**a**	**b**	**c**	**d**	a
h	**e**	**f**	**g**	**h**	e
l	**i**	**j**	**k**	**l**	i
p	**m**	**n**	**o**	**p**	m
d	a	b	c	d	a

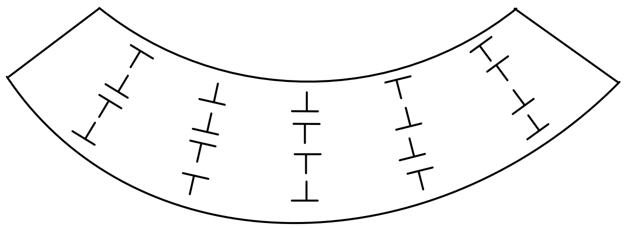


Five of the subgrains have been shaded. *From among these five*, which subgrain will most likely be a nucleus for recrystallization? Why?

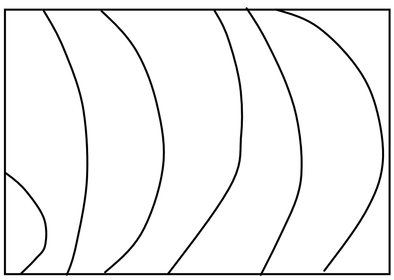
Problem #6: Unphysics

The four situations described below are all unphysical. For each, please identify with a short description the reason that it is unphysical.

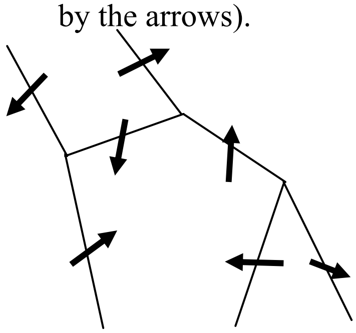
a. The picture below is of a specimen with large lattice curvature and the dislocation array that is present to accommodate the deformation.



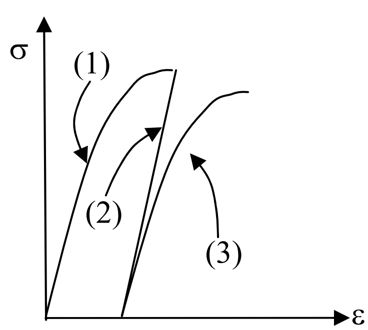
b. The microstructure below is the projection of the dislocations in an unstressed specimen.



c. The diagram below shows several dislocation lines and their burger's vectors (indicated by the arrows).

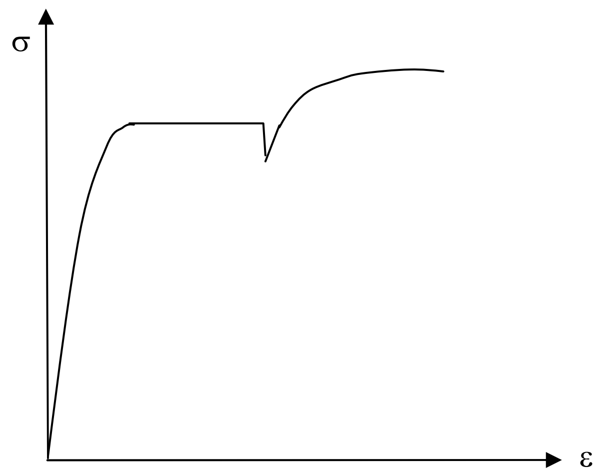


d. A uniaxial tensile stress is applied to a tungsten rod (body-centered cubic, density = 19.25 g/cm^3, coefficient of thermal expansion = 4.5 x 10^{-6} K^{-1}, melting temperature = 3695 K) and the stress-strain curve labeled (1) is recorded. The stress is then removed (2) and the W rod sits at room temperature for one day. The next day, a tensile stress is applied again (3) and the stress-strain behavior is shown on the same graph.



Problem 7: Deformation Mechanistics and Stress-Strain Behavior

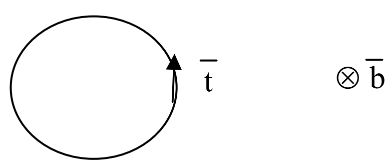
A single crystal of an HCP metal is loaded in uniaxial tension, and the following stress-strain curve is recorded:



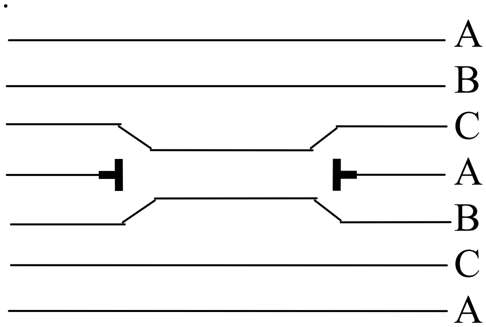
Using your vast knowledge of deformation physics in HCP metals, identify the likely mechanisms operating in this specimen over the course of the test. Be sure that your answer explains each detail of the above curve.

Problem #8: The Frank Loop Dislocation

The 'Frank Loop' dislocation is nothing more than a disk of vacancies that lies in a {111} plane of *an FCC crystal*. Looking down on the {111} plane it looks like a loop, with its Burger's vector pointing out of the page:



Looking at a cross section of the loop (i.e., looking edge-on to the {111} planes), it looks like this:



Where the stacking sequence of {111} planes is noted at the right.

Part A: Can Dr. Frank's dislocation move at low temperatures? Why or why not?

Part B: Can it move at high temperatures? Why or why not?