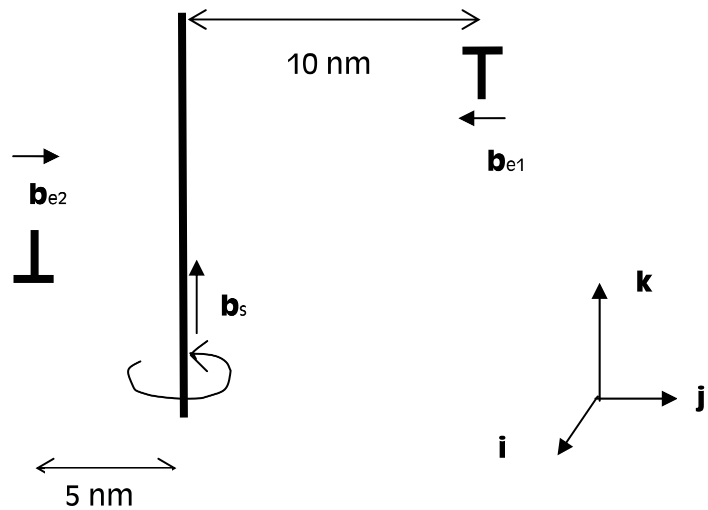
3.40J / 22.71J

Modern Physical Metallurgy

Problem Set 3
Due 03.19.04

1. Dislocation intersection

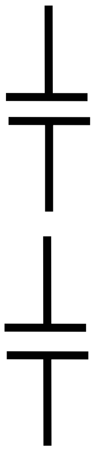
(a) Consider a screw dislocation and 2 edge dislocations as shown below. What is/are the additional stress/es imposed on the screw by the presence of these two edge dislocations?



(b) These dislocations are in Ni. What are the Miller indices of the Burgers vectors?
(c) A shear stress of magnitude > f is applied in the –**j** direction. Draw each of the three dislocations after they have responded to this shear stress. As a first approximation, assume that the screw and second edge are relatively slow moving as compared to the first edge dislocation. Label the dislocation line vector, Burgers vector, and clearly indicate any jogs or kinks.

2. In PS2, you considered a stable dislocation configuration of vertically aligned positive edge dislocations – a model of a tilt boundary. Now consider a similar configuration, but where every other dislocation is a negative edge dislocation.

Through a series of images, show how the interdislocation forces can cause annihilation (disappearance) of these dislocations through combinations of glide and climb.



3. Dislocation energetics

(a) You have a single crystal sample of Pb oriented with the $(1\bar{1}1)$ normal to the surface. If the $[110](1\bar{1}1)$ slip system is active, what are the possible partial dislocations that could form in the presence of an obstacle to full slip?

(b) Show that it is energetically favorable for these partials to form.

(c) If there is an obstacle that impedes the partial that contains no mixed signs, ie, it has either all positive indices or all negative indices, but no obstacle in the other direction, what is the reaction you would predict to occur for full slip to proceed. Hint: Another slip system will become active.

(d) If it is energetically favorable for full dislocations to dissociate into partials, why would partials recombine to form full dislocations? Why do full dislocations exist at all, if partials can alleviate strain?

4. Low vs. High angle grain boundaries

(a) How do low and high angle grain boundaries differ?

(b) Consider a 70.8^{o} rotation about the $<110>$ in Al. Show how such a rotation can lead to a high angle grain boundary of relatively low energy.

(c) We discussed in class that low angle grain boundaries are generally considered those for which $\theta < 10 - 20^{0}$. Prove this by assuming the following form for general (ie, including high angle) grain boundary energy:

$\gamma = W_e/d = ½ \int Gb/2\pi(1-\nu)\ [\pi x / \sinh^2[\pi x/d]$ from r_0 to ∞

from our lecture notes. Consider the small angle limit, where $\theta = b/d$ and $\pi b/\alpha d \rightarrow 0$, where $x = b/\alpha$ and plot the resulting small angle grain boundary energy γ as a function of θ. Compare this quantitatively with the general form of γ to determine the angle at which the small angle approximation deviates from the general form.

(d) Relation of in-plane misorientation angle θ and dislocation spacing in a simple grain boundary relies on the assumption that sin $\theta = \theta$. What is the angle at which this ceases to be a good approximation? What does this say about how well we can define low angle grain boundaries through experiments?

(e) Ni has a lattice parameter *a* of 0.35 nm. By high resolution TEM, a tilt boundary is observed that has an in-plane misorientation of 0.58^{o}. What is the interdislocation spacing along this boundary?