Note that the strain energy for the edge dislocation differs from that of the screw dislocation by a factor of $1/(1 - \nu)$. Since ν for most metals is near 1/3, the strain energy for the edge dislocation is thus about 50 percent larger than that for the screw dislocation.

PROBLEMS

4.1 Prove that 1,000 psi = 6.9 MPa using conversion factors given in Appendix D.

4.2 A single crystal of copper yields under a shear stress of about 0.62 MPa. The shear modulus of copper is approximately 7.9×10^6 psi. With these data compute an approximate value for the ratio of the theoretical to the experimental shear stresses in copper.

4.3 Make a model of a left-hand screw dislocation following the technique shown in Fig. 4.11.

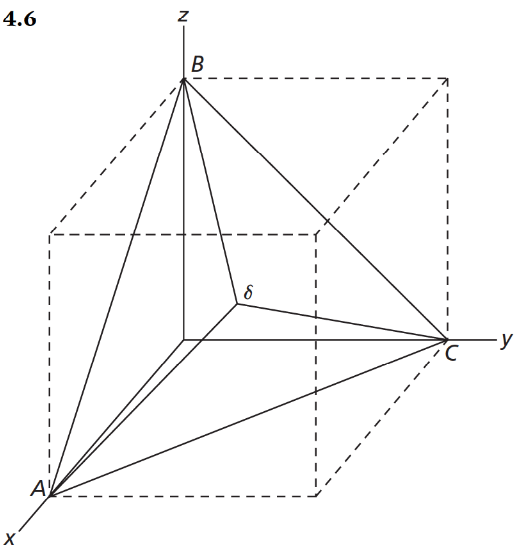
4.4 (a) Using an RHSF Burgers circuit, illustrate how to determine the true Burgers vector of an edge dislocation.

(b) Is the sense of the Burgers vector direction in part (a) of this problem the same as that of the RHFS local Burgers vector in Fig. 4.19

4.5 (a) How many equivalent $\{111\}\langle 1\bar{1}0\rangle$ slip systems are there in the fcc lattice?

(b) Identify each system by writing out its slip plane and slip direction indices.

4.6



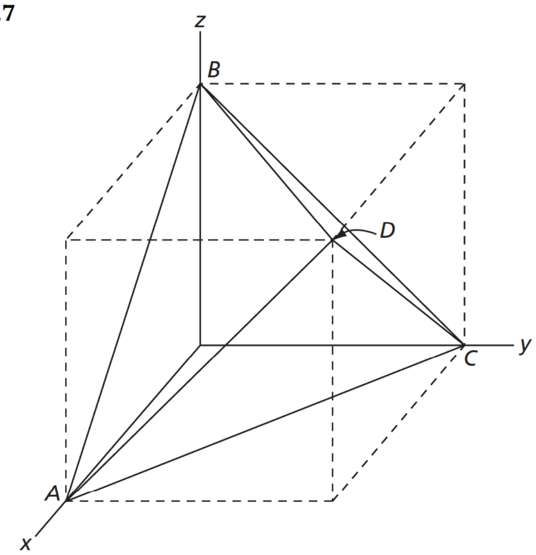
Assume that the triangle in the drawing lies on the (111) plane of a face-centered cubic crystal, and that its edges are equal in magnitude to the Burgers vectors of the three total dislocations that can glide in this plane. Then, if δ lies at the centroid of this triangle, lines $A\delta$, $C\delta$, and $B\delta$, accordingly, correspond to the three possible partial dislocations of this plane.

(a) Identify each line (AB, $A\delta$, etc.) with its proper Burgers vector expressed in the vector notation.

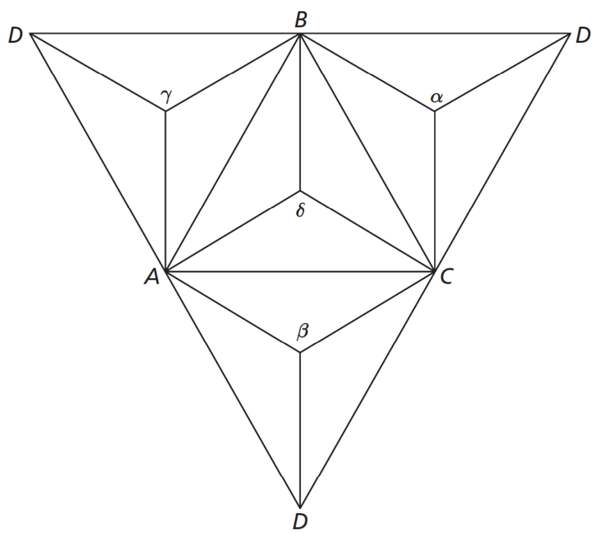
(b) Demonstrate by vector addition that

$$B\delta + \delta C = BC$$

4.7



(A)



(B)

Figure A represents the Thompson tetrahedron as seen in three dimensions. In Fig. B., the sides of the tetrahedron have been hypothetically folded out so that all four surfaces can be easily viewed. The symbols α, β, γ, and δ represent the centroid of each face, respectively. As in Problem 4.6, lines such as BD represent total dislocations, that is, $\frac{1}{2}[110]$, and lines such as $B\gamma$ represent partial dislocations, that is, $\frac{1}{6}[21\bar{1}]$.

(a) Write the Miller indices symbols for CD and DC.

(b) Do the same for BD and DB.

(c) Show that $BD + DC = BC$.

4.8 List all the primary or total Burgers vectors available for slip in a fcc crystal. Use the vector or Miller indices notation to describe each Burgers vector.

4.9 An important slip plane in the hexagonal metals, titanium and zirconium, is the $\{11\bar{2}2\}$ plane on which dislocations with a $\frac{1}{3}\langle 11\bar{2}\bar{3}\rangle$ Burgers vector may move. Prove that the $\frac{1}{3}\langle 11\bar{2}\bar{3}\rangle$ Burgers vector can be considered as the sum of a basal slip Burgers vector and a unit Burgers vector in the c-axis direction.

4.10 (a) If a vacancy disc forms on a basal plane of a hexagonal close-packed metal, what stacking sequence of basal planes would result across the disc?

(b) Why would the strain energy of the resulting stacking fault be very high?

(c) Explain how a simple shear along the basal plane, equal to that of a Shockley partial, could eliminate this high-energy stacking fault and replace it with one of lower energy.

(d) What then would be the stacking arrangement of the basal planes at the fault?

(e) Is the result in (d) unique or are there several basic possibilities? Explain.

4.11 (a) Write a simple computer program that gives the shear stress of a screw dislocation as a function of the perpendicular distance from the dislocation (see Eq. 4.8). Assuming the shear modulus of iron is 86 GPa and the Burgers vector is 0.248 nm, use the program to obtain the shear stress at the following values of r: 50, 100, 150, and 200 nm, respectively. Plot the resulting τ versus r data, and with the aid of this curve, determine the distance from the dislocation where τ is 4000 psi, the shear stress at which an iron crystal will begin to undergo slip.

(b) To how many Burgers vectors does this distance correspond?

4.12 Equations 4.9 are the stress field equations of an edge dislocation, in Cartesian coordinates. Write a computer program based on these equations that gives simultaneous values of σ_{xx}, σ_{yy}, τ_{xy} for an edge dislocation in an iron crystal assuming $\mu = 86$ GPa, $b = 0.248$ nm, $\nu = .3$, and $r = 40b$, and letting $x = r\cos\theta$ and $y = r\sin\theta$. Simplify the equations so that they can be expressed as a function of only the angle θ. Now develop a figure in which curves are plotted for all three of the stress components over the range of angles from 0 to 2π radians.

4.13 Now solve Problem 4.11 using the stress field equations of an edge dislocation expressed in polar coordinates.

4.14 (a) Consider that two infinitely long parallel positive edge dislocations are viewed on a simple two-dimensional x, y diagram such as Fig. 4.36. One dislocation is located at $x = 0$, $y = 0$. Since this is a positive edge, its slip plane is horizontal and contains the x axis. The other dislocation also lies in a horizontal slip plane but this plane is separated from that of the first dislocation by a vertical distance (y) of $10b$, where b is the Burgers vector for both dislocations. Now assume the first dislocation is fixed in place and the second can move parallel to the x axis. With the aid of a computer, plot F_x, the x component of the force (per unit length) between the dislocations, as a function of x from $x = -240$ nm to $x = +240$ nm. Let $\mu = 86$ GPa, $b = 0.248$ nm, and $\nu = 0.3$.

(b) Discuss the significance of the variation of F_x with distance as the mobile dislocation is moved from $x = -\infty$ to $= +\infty$.

4.15 The strain energy of a dislocation normally varies as the square of its Burgers vector. One may see this by examining Eqs. 4.19 and 4.20. This relationship between the dislocation strain energy and the Burgers vector is known as *Frank's rule*. Thus, if $b = a[hkl]$, where a is a numerical factor, then

$$\text{Energy/cm} \sim a^2\{h^2 + k^2 + l^2\}.$$

Show that in an f.c.c. crystal the dissociation of a total dislocation into its two partial dislocations is energetically feasible. See Eq. 4.4.

4.16 The c/a ratio of the hcp zinc crystal is 1.886. Determine the ratio of the strain energy in zinc of a dislocation with a $\frac{1}{3}\langle 11\bar{2}3\rangle$ Burgers vector to that of a basal slip dislocation.

4.17 (a) Consider Eq. 4.19, which gives the strain energy per unit length of a screw dislocation. Assume that one has a very large square array of long, straight, parallel screw dislocations of alternating signs so that the effective outer radius r' of the strain field of a dislocation may be taken as $1/2\sqrt{\rho}$. With the aid of a computer determine the strain energy per unit length of a screw dislocation as a function of the dislocation density, ρ, between $\rho = 10^{11}$ and $\rho = 10^{18}$ m/m^3.

(b) Plot the line energy against the dislocation density. Assume that $\mu = 86$ GPa and $b = 0.248$ nm.

(c) Now plot the energy per unit volume as a function of ρ, assuming that the former can be equated to ρw, where w is the energy per unit length of the screw dislocations.

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