3.30 Within a cubic unit cell, sketch the following directions:
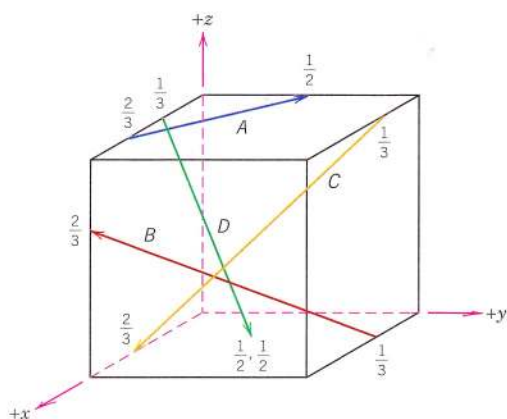
(a) $[\bar{1}10]$ (e) $[\bar{1}\bar{1}1]$

(b) $[\bar{1}\bar{2}1]$ (f) $[\bar{1}22]$

(c) $[0\bar{1}2]$ (g) $[1\bar{2}\bar{3}]$

(d) $[1\bar{3}3]$ (h) $[\bar{1}03]$

3.31 Determine the indices for the directions shown in the following cubic unit cell:
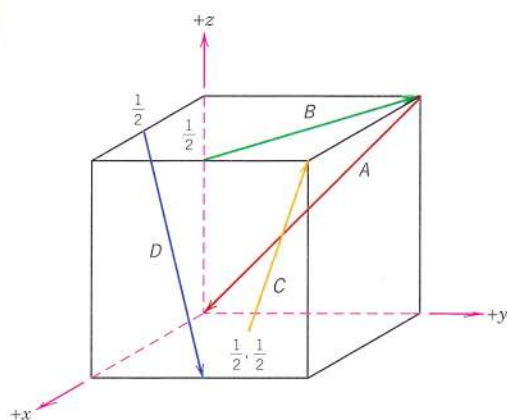
3.32 Determine the indices for the directions shown in the following cubic unit cell:
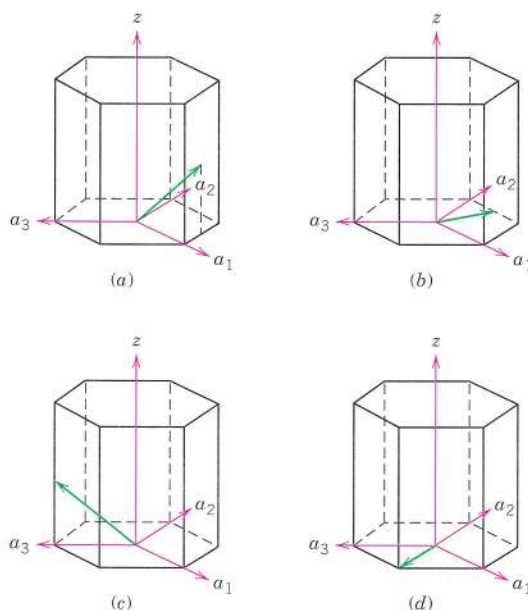

3.33 For tetragonal crystals, cite the indices of directions that are equivalent to each of the following directions:

(a) [001]

(b) [110]

(c) [010]

3.34 Convert the [100] and [111] directions into the four-index Miller–Bravais scheme for hexagonal unit cells.

3.35 Determine indices for the directions shown in the following hexagonal unit cells:

**3.36** Sketch the $[\bar{1}\bar{1}23]$ and $[10\bar{1}0]$ directions in a hexagonal unit cell.

3.37 Using Equations 3.6a, 3.6b, 3.6c, and 3.6d, derive expressions for each of the three primed indices set (u', v', and w') in terms of the four unprimed indices (u, v, t, and w).

Crystallographic Planes

3.38 (a) Draw an orthorhombic unit cell, and within that cell a (210) plane.

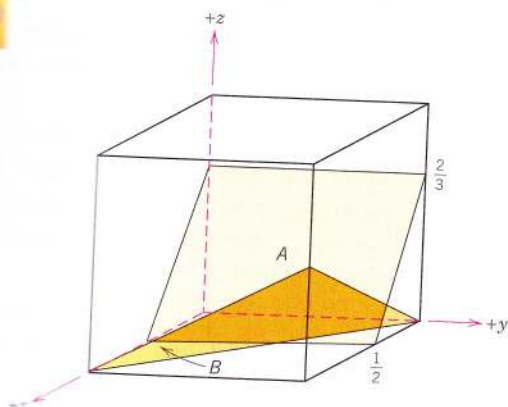(b) Draw a monoclinic unit cell, and within that cell a (002) plane.

3.39 What are the indices for the two planes drawn in the following sketch?
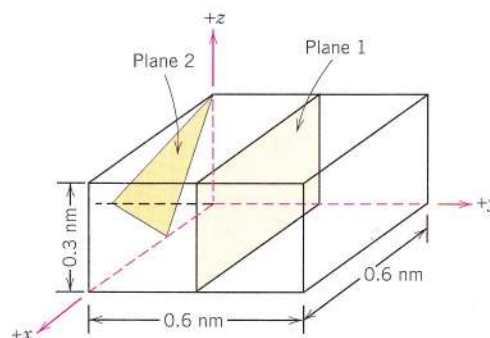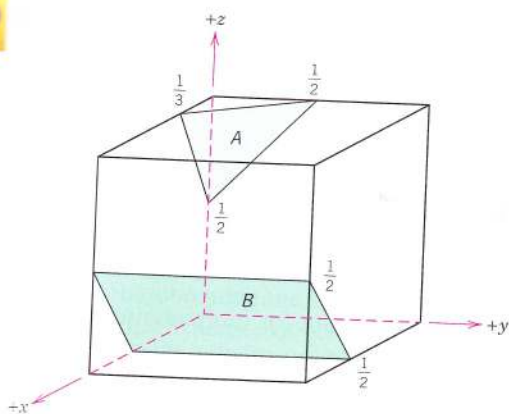
3.40 Sketch within a cubic unit cell the following planes:

(a) $(0\bar{1}\bar{1})$ **(c)** $(10\bar{2})$ **(e)** $(\bar{1}1\bar{1})$ **(g)** $(\bar{1}2\bar{3})$
(b) $(11\bar{2})$ **(d)** $(1\bar{3}1)$ **(f)** $(1\bar{2}\bar{2})$ **(h)** $(0\bar{1}3)$

3.41 Determine the Miller indices for the planes shown in the following unit cell:
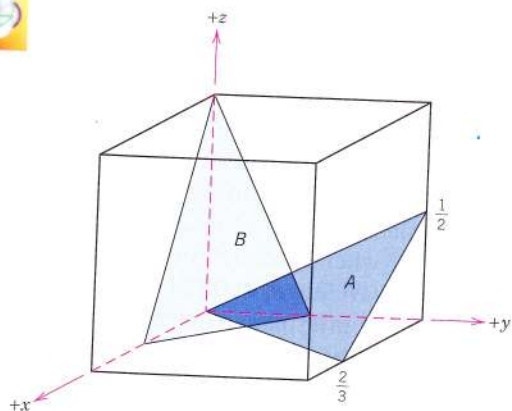

3.42 Determine the Miller indices for the planes shown in the following unit cell:

3.43 Determine the Miller indices for the planes shown in the following unit cell:


3.44 Cite the indices of the direction that results from the intersection of each of the following pairs of planes within a cubic crystal: **(a)** the (100) and (010) planes, **(b)** the (111) and $(11\bar{1})$ planes, and **(c)** the $(10\bar{1})$ and (001) planes.

3.45 Sketch the atomic packing of **(a)** the (100) plane for the BCC crystal structure, and **(b)** the (201) plane for the FCC crystal structure (similar to Figures 3.11*b* and 3.12*b*).

3.46 Consider the reduced-sphere unit cell shown in Problem 3.20, having an origin of the coordinate system positioned at the atom labeled *O*. For the following sets of planes, determine which are equivalent:

(a) $(00\bar{1})$, (010), and, $(\bar{1}00)$

(b) $(1\bar{1}0)$, $(10\bar{1})$, $(0\bar{1}1)$, and $(\bar{1}\bar{1}0)$

(c) $(\bar{1}\bar{1}\bar{1})$, $(\bar{1}1\bar{1})$, $(\bar{1}\bar{1}1)$, and $(1\bar{1}1)$

3.47 The accompanying figure shows the atomic packing schemes for several different crystallographic directions for a hypothetical metal. For each direction, the circles represent only the atoms contained within a unit cell; the circles are reduced from their actual size.
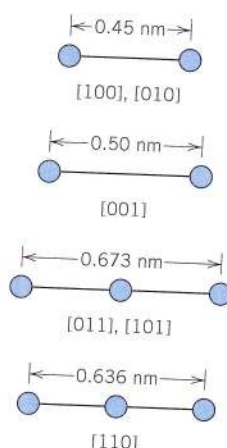
(a) To what crystal system does the unit cell belong?

(b) What would this crystal structure be called?

**3.48** The accompanying figure shows three different crystallographic planes for a unit cell of a
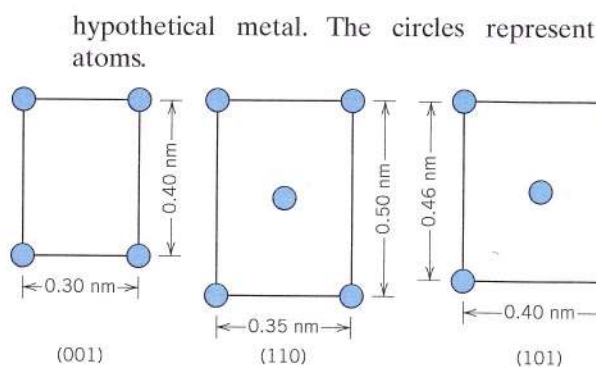
hypothetical metal. The circles represent atoms.

(001)   (110)   (101)

(a) To what crystal system does the unit cell belong?

(b) What would this crystal structure be called?

(c) If the density of this metal is 8.90 g/cm³, determine its atomic weight.

3.49 Convert the (010) and (101) planes into the four-index Miller–Bravais scheme for hexagonal unit cells.

3.50 Determine the indices for the planes shown in the following hexagonal unit cells:

(a)   (b)

(c)   (d)
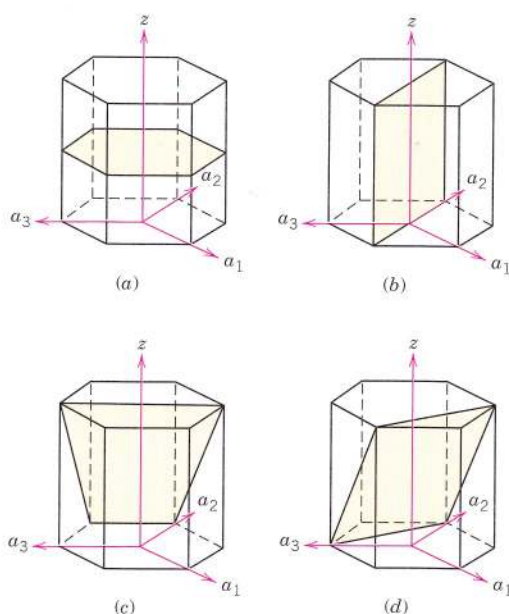
3.51 Sketch the ($1\bar{1}01$) and ($11\bar{2}0$) planes in a hexagonal unit cell.

Linear and Planar Densities

3.52 (a) Derive linear density expressions for FCC [100] and [111] directions in terms of the atomic radius R.

(b) Compute and compare linear density values for these same two directions for silver.

3.53 (a) Derive linear density expressions for BCC [110] and [111] directions in terms of the atomic radius R.

(b) Compute and compare linear density values for these same two direction for tungsten.

3.54 (a) Derive planar density expressions for FCC (100) and (111) planes in terms of the atomic radius R.

(b) Compute and compare planar density values for these same two planes for nickel.

3.55 (a) Derive planar density expressions for BCC (100) and (110) planes in terms of the atomic radius R.

(b) Compute and compare planar density values for these same two planes for vanadium.

3.56 (a) Derive the planar density expression for the HCP (0001) plane in terms of the atomic radius R.

(b) Compute the planar density value for this same plane for magnesium.

Polycrystalline Materials

3.57 Explain why the properties of polycrystalline materials are most often isotropic.

X–Ray Diffraction: Determination of Crystal Structures

3.58 Using the data for molybdenum in Table 3.1, compute the interplanar spacing for the (111) set of planes.

3.59 Determine the expected diffraction angle for the first-order reflection from the (113) set of planes for FCC platinum when monochromatic radiation of wavelength 0.154 nm is used.

3.60 Using the data for aluminum in Table 3.1, compute the interplanar spacings for the (110) and (221) sets of planes.

3.61 The metal iridium has an FCC crystal structure. If the angle of diffraction for the (220) set of planes occurs at 69.20° (first-order reflection) when monochromatic x-radiation having a wavelength of 0.154 nm is used, compute **(a)** the interplanar spacing for this set of planes and **(b)** the atomic radius for an iridium atom.
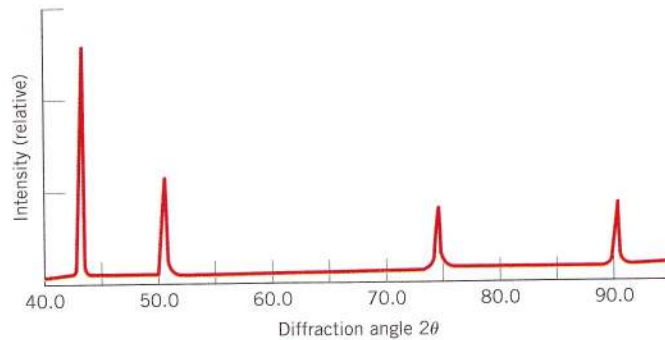
Figure 3.25 Diffraction pattern for polycrystalline copper.

3.62 The metal rubidium has a BCC crystal structure. If the angle of diffraction for the (321) set of planes occurs at 27.00° (first-order reflection) when monochromatic x-radiation having a wavelength of 0.071 nm is used, compute **(a)** the interplanar spacing for this set of planes and **(b)** the atomic radius for the rubidium atom.

3.63 For which set of crystallographic planes will a first-order diffraction peak occur at a diffraction angle of 46.21° for BCC iron when monochromatic radiation having a wavelength of 0.071 nm is used?

3.64 Figure 3.22 shows an x-ray diffraction pattern for α-iron taken using a diffractometer and monochromatic x-radiation having a wavelength of 0.154 nm; each diffraction peak on the pattern has been indexed. Compute the interplanar spacing for each set of planes indexed; also determine the lattice parameter of Fe for each of the peaks.

3.65 The diffraction peaks shown in Figure 3.22 are indexed according to the reflection rules for BCC (i.e., the sum $h + k + l$ must be even). Cite the $h, k,$ and l indices for the first four diffraction peaks for FCC crystals consistent with $h, k,$ and l all being either odd or even.

3.66 Figure 3.25 shows the first four peaks of the x-ray diffraction pattern for copper, which has an FCC crystal structure; monochromatic x-radiation having a wavelength of 0.154 nm was used.

(a) Index (i.e., give $h, k,$ and l indices for) each of these peaks.

(b) Determine the interplanar spacing for each of the peaks.

(c) For each peak, determine the atomic radius for Cu and compare these with the value presented in Table 3.1.

Noncrystalline Solids

3.67 Would you expect a material in which the atomic bonding is predominantly ionic in nature to be more or less likely to form a noncrystalline solid upon solidification than a covalent material? Why? (See Section 2.6.)

Spreadsheet Problem

3.1SS For an x-ray diffraction pattern (having all peaks plane-indexed) of a metal that has a unit cell of cubic symmetry, generate a spreadsheet that allows the user to input the x-ray wavelength, and then determine, for each plane, **(a)** d_{hkl} and **(b)** the lattice parameter, a.