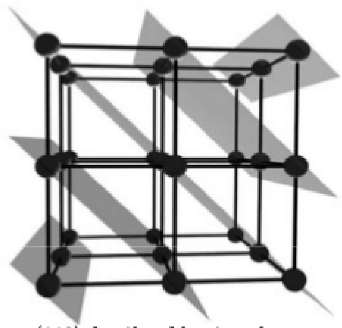
به نامِ خدا

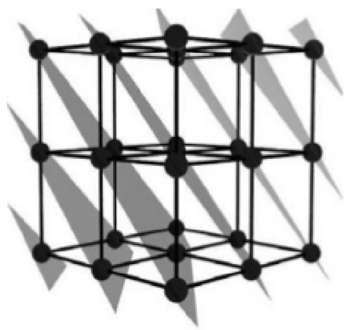
دانش‌گاهِ صنعتی‌یِ اصفهان – دانش‌کده‌یِ فیزیک

تصاویر فصل ۱۳

(010) family of lattice planes

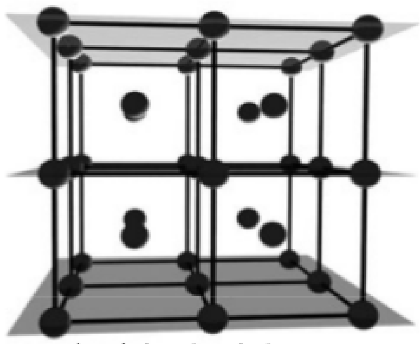


(110) family of lattice planes

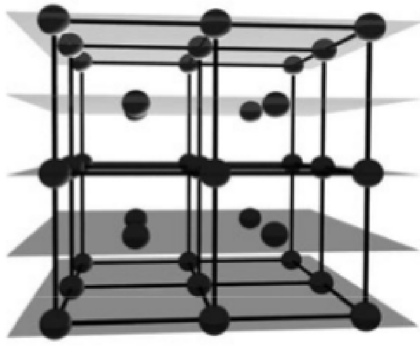


(111) family of lattice planes

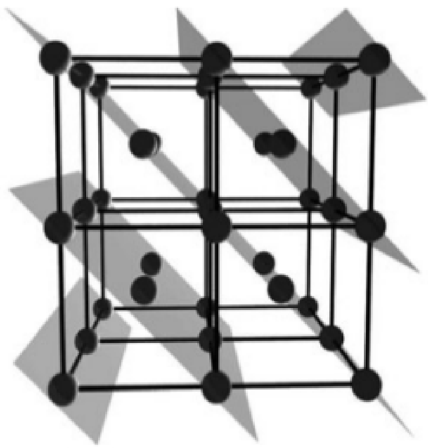
Fig. 13.1 Examples of families of lattice planes on the cubic lattice. Each of these planes is a lattice plane because it intersects at least three non-collinear lattice points. Each picture is a family of lattice planes since every lattice point is included in one of the parallel lattice planes. The families are labeled in Miller index notation. **Top** (010); **Middle** (110); **Bottom** (111). In the top and middle the x-axis points to the right and the y-axis points up. In the bottom figure the axes are rotated for clarity.



(010) family of planes
(not all lattice points included)



(020) family of lattice planes



(110) family of lattice planes

Fig. 13.2 Top: For the bcc lattice, the (010) planes are not a true family of lattice planes since the (010) planes do not intersect the lattice points in the middle of the cubes. **Middle:** The (020) planes are a family of lattice planes since they intersect all of the lattice points. **Bottom** The (110) planes are also a family of lattice planes.

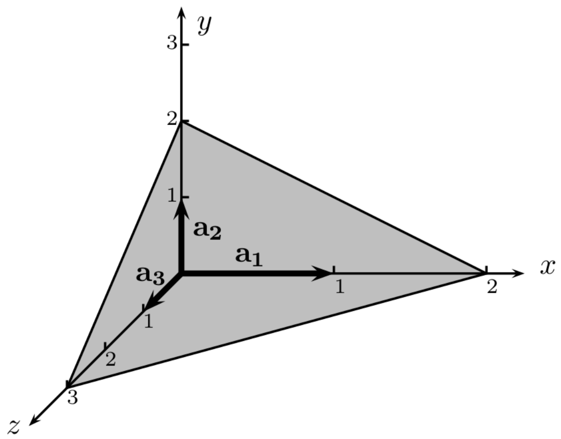


Fig. 13.3 Determining Miller indices from the intersection of a plane with the coordinate axes. This plane intersects the coordinate axes at $x = 2$, $y = 2$ and $z = 3$ in units of the lattice constants. The reciprocals of these intercepts are $\frac{1}{2}, \frac{1}{2}, \frac{1}{3}$. The smallest integers having these ratios are $3, 3, 2$. Thus the Miller indices of this family of lattice planes are (332). The spacing between lattice planes in this family would be $1/|d_{(233)}|^2 = 3^2/a_1^2 + 3^2/a_2^2 + 2^2/a_3^2$ (assuming orthogonal axes).

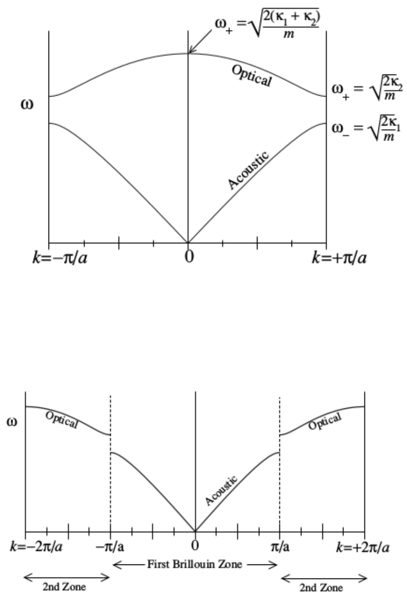


Fig. 13.4 Phonon spectrum of a diatomic chain in one dimension. **Top:** Reduced zone scheme. **Bottom:** Extended zone scheme. (See Figs. 10.6 and 10.8.) We can display the dispersion in either form due to the fact that wavevector is only defined modulo $2\pi/a$, that is, it is periodic in the Brillouin zone.

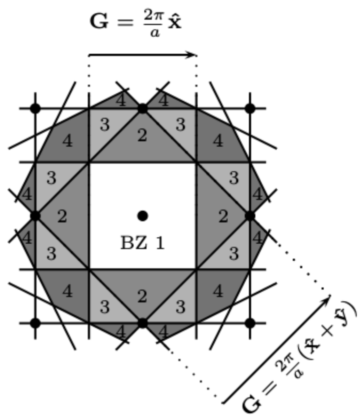


Fig. 13.5 First, second, third, and fourth Brillioun zones of the square lattice. All of the lines drawn in this figure are perpendicular bisectors between the central point **0** and some other reciprocal lattice point. Note that zone boundaries occur in parallel pairs symmetric around the central point **0** and are separated by a reciprocal lattice vector.

[17]Here's the proof for a square lattice. Let the system be N_x by N_y unit cells. With periodic boundary conditions, the value of k_x is quantized in units of $2\pi/L_x = 2\pi/(N_x a)$ and the value of k_y is quantized in units of $2\pi/L_y = 2\pi/(N_y a)$. The size of the Brillouin zone is $2\pi/a$ in each direction, so there are precisely $N_x N_y$ different values of $\mathbf{k}$ in the Brillouin zone.

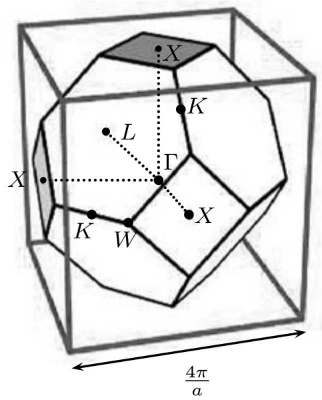


Fig. 13.6 First Brillouin zone of the fcc lattice. Note that it is the same shape as the Wigner–Seitz cell of the bcc lattice, see Fig. 12.13. Special points of the Brillouin zone are labeled with code letters such as X, K, and Γ. Note that the lattice constant of the conventional unit cell is $4\pi/a$ (see Exercise 13.1).

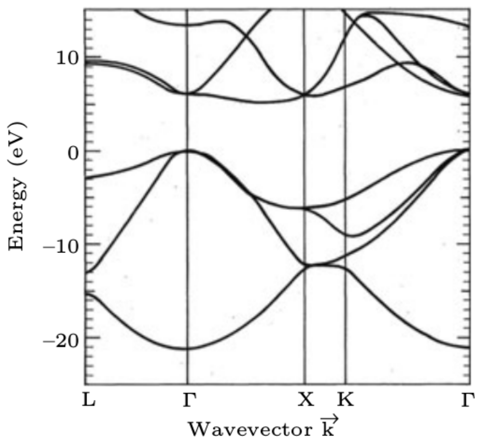


Fig. 13.7 Electronic excitation spectrum of diamond ($E = 0$ is the Fermi energy). The momentum, along the horizontal axis is taken in straight line cuts between special labeled points in the Brillouin zone. Figure is from J. R. Chelikowsky and S. G. Louie, *Phys. Rev. B* **29**, 3470 (1984), http://prb.aps.org/abstract/PRB/v29/i6/p3470_1. Copyright American Physical Society. Used by permission.

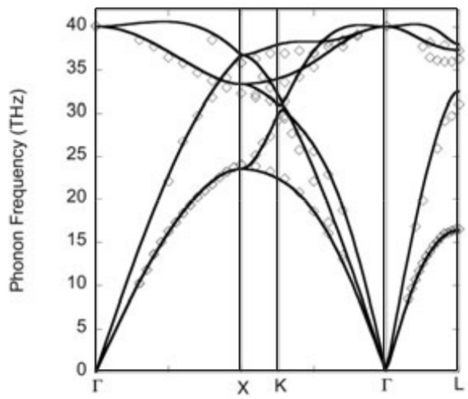


Fig. 13.8 Phonon spectrum of diamond (points are from experiment, solid line is a modern theoretical calculation). Figure is from A. Ward et al., *Phys. Rev. B* **80**, 125203 (2009), http://prb.aps.org/abstract/PRB/v80/i12/e125203, Copyright American Physical Society. Used by permission.

- The reciprocal lattice is a lattice in k-space defined by the set of points such that $e^{i\mathbf{G}\cdot\mathbf{R}} = 1$ for all $\mathbf{R}$ in the direct lattice. Given this definition, the reciprocal lattice can be thought of as the Fourier transform of the direct lattice.
- A reciprocal lattice vector $\mathbf{G}$ defines a set of parallel equally spaced planes via $\mathbf{G} \cdot \mathbf{r} = 2\pi m$ such that every point of the direct lattice is included in one of the planes. The spacing between the planes is $d = 2\pi/|\mathbf{G}|$. If $\mathbf{G}$ is the smallest reciprocal lattice vector parallel to $\mathbf{G}$ then this set of planes is a family of lattice planes, meaning that all planes intersect points of the direct lattice.
- Miller Indices (h, k, l) are used to describe families of lattice planes, or reciprocal lattice vectors.
- The general definition of Brillouin zone is any unit cell in reciprocal space. The first Brillouin zone is the Wigner–Seitz cell around the point $\mathbf{0}$ of the reciprocal lattice. Each Brillouin zone has the same volume and contains one k-state per unit cell of the entire system. Parallel Brillouin zone boundaries are separated by reciprocal lattice vectors.