atures or for an extremely rarefied gas. This result can be extrapolated to the condensed phases as well. Although the photon gas is present within liquid and solid media, its property contributions are negligible in comparison to the contribution of the particles of matter and can be neglected. This does not mean that our study of photon propetties was inconsequential. We will find that photons are an important means of transport through evacuated, and frequently, dense gases and certain liquids and solids (see Unit IIIE).

B. Lattice Vibrations (the Phonon Gas)

Crystalline solids are characterized by relatively strong bonds between the atoms or molecules that occupy their lattice points, see Unit ICS. The principal energy storage mechanism in atomic lattice point crystals is in the form of vibration of each atom about its mean lattice position. Lattice vibrations have been successfuly modeled using two fundamentally different approaches. One is based on explicit consideration of the vibration of each atom. The second ignores the details of particle vibration. Instead, it considers the properties of the acoustical waves, or phonons that these vibrations generate. We begin with the vibrating atoms approach, using the *model* first proposed by *Einstein.*

1. The Einstein Model assumes that the N atoms or molecules that compose the crystal are fixed in position by independent "linear spring" forces in all three directions. That is, the complex lattice is resolved into 3N independent particles all vibrating at a *single (Einstein) frequency,* ν_E, see Fig. IIID-2.

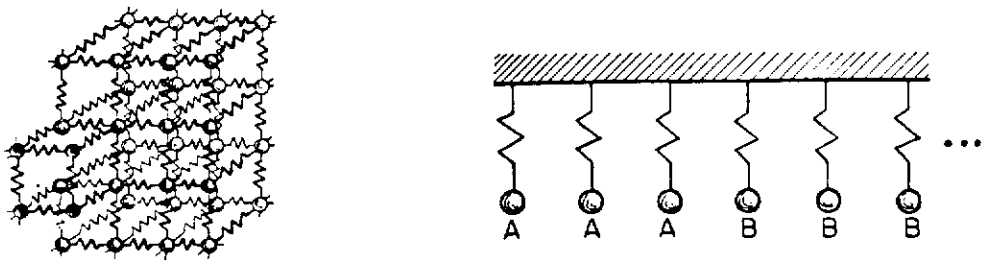

Fig. IIID-2. Schematic of an Actual Lattice and Its Resolved Einstein Form

The energy levels available to a linear oscillator were introduced in Sect. IIIB of Unit IIIC

$$\varepsilon_{v,\ell} = (\ell + \tfrac{1}{2})\, h\nu_E \qquad g_\ell = 1 \qquad \ell = 0, 1, 2, 3$$

Note that one can distinguish among the 3N linear oscillators by their positions and directions of vibration. The oscillators of the Einstein model are *Boltzons.* Thus the distribution, partition function, and properties under the Einstein model are the same as three modes of intermolecular vibration, see Sect. IIIB of Unit IIIC, with the *Einstein characteristic temperature*