Chapter 6 Oscillations

The potential energy then reduces to

$$V = \frac{k}{2}(\eta_2 - \eta_1)^2 + \frac{k}{2}(\eta_3 - \eta_2)^2,$$

OF

$$V = \frac{k}{2}(\eta_1^2 + 2\eta_2^2 + \eta_3^2 - 2\eta_1\eta_2 - 2\eta_2\eta_3). \tag{6.49}$$

Hence, the V tensor has the form

$$\mathbf{V} = \begin{pmatrix} k & -k & 0 \\ -k & 2k & -k \\ 0 & -k & k \end{pmatrix}. \tag{6.50}$$

The kinetic energy has an even simpler form:

$$T = \frac{m}{2}(\dot{\eta}_1^2 + \dot{\eta}_3^2) + \frac{M}{2}\dot{\eta}_2^2,\tag{6.51}$$

so that the T tensor is diagonal:

$$\mathbf{T} = \begin{pmatrix} m & 0 & 0 \\ 0 & M & 0 \\ 0 & 0 & m \end{pmatrix}. \tag{6.52}$$

Combining these two tensors, the secular equation appears as

$$|\mathbf{V} - \omega^2 \mathbf{T}| = \begin{vmatrix} k - \omega^2 m & -k & 0 \\ -k & 2k - \omega^2 M & -k \\ 0 & -k & k - \omega^2 m \end{vmatrix} = 0.$$
 (6.53)

Direct evaluation of the determinant leads to the cubic equation in ω^2 :

$$\omega^{2}(k - \omega^{2}m)(k(M + 2m) - \omega^{2}Mm) = 0, \qquad (6.54)$$

with the obvious solutions

$$\omega_1 = 0$$
, $\omega_2 = \sqrt{\frac{k}{m}}$, $\omega^3 = \sqrt{\frac{k}{m} \left(1 + \frac{2m}{M}\right)}$. (6.55)

The first eigenvalue, $\omega_1 = 0$, may appear somewhat surprising and even alarming at first sight. Such a solution does not correspond to an oscillatory motion at all, for the equation of motion for the corresponding normal coordinate is

$$\ddot{\zeta}_1 = 0$$
,

which produces a uniform translational motion. But this is precisely the key to the difficulty. The vanishing frequency arises from the fact that the molecule

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Ilya J. Bakelman

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