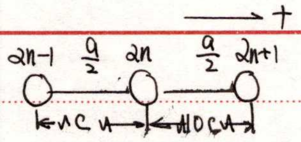
1.



$$m\ddot{u}_{2n} = 10c(u_{2n+1}-u_{2n}) - c(u_{2n}-u_{2n-1})$$

$$= \cancel{10c}\, c(10u_{2n+1} + u_{2n-1} - 11u_{2n})$$

$$m\ddot{u}_{2n+1} = c(u_{2n+2}-u_{2n+1}) - 10c(u_{2n+1}-u_{2n})$$

$$= c(u_{2n+2} + 10u_{2n} - 11u_{2n+1})$$

设 $u_{2n} = A\exp\left[i\left(\omega t - 2n\frac{a}{2}q\right)\right]$ $\quad u_{2n+1} = B\exp\left[i\left(\omega t - (2n+1)\frac{a}{2}q\right)\right]$

$$\therefore \begin{cases} -\omega^2 A = 10cB\exp\left(-i\frac{qa}{2}\right) + cB\exp\left(\frac{iqa}{2}\right) - 11A \\ -\omega^2 B = cA\exp\left(-\frac{iqa}{2}\right) + 10cA\exp\left(\frac{iqa}{2}\right) - 11B \end{cases}$$

$$\therefore \begin{cases} (11-\omega^2)A - \left(10c\cancel{B}\exp\left(-\frac{iqa}{2}\right) + c\cancel{B}\exp\left(\frac{iqa}{2}\right)\right)B = 0 \\ -\left(c\cancel{A}\exp\left(-\frac{iqa}{2}\right) + 10c\cancel{A}\exp\left(\frac{iqa}{2}\right)\right)A + (11-\omega^2)B = 0 \end{cases}$$

$$\therefore (11-\omega^2)^2 = c^2\left(10\exp(-iqa) + 100 + 1 + 10\exp(iqa)\right)$$

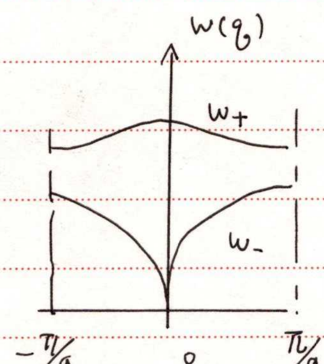
$$= c^2(101 + 20\cos aq).$$

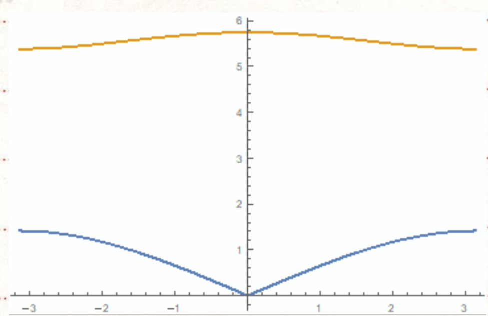
$$\therefore \omega^2 - 11 = \pm c\sqrt{101 + 20\cos aq}$$

$$\omega_\pm = \sqrt{11 \pm c\sqrt{101 + 20\cos aq}}$$

$q = 0$ 时. $\omega_\pm(q) = \sqrt{11 \pm 11c} = \begin{cases} \sqrt{11\pm11c} \\ \cancel{22} \quad (\omega_+) \\ \cancel{0} \quad (\omega_-) \\ \sqrt{11\pm\sqrt{101}\,c} \end{cases}$

$q = \pi/2.$ $\quad \omega_\pm(q) = \sqrt{11 \pm c\sqrt{101}}$





2. 设原子为 $\vec{R}\binom{l}{k}$ （第 l 个原胞 k 原子）

那么 $m\ddot{\vec{R}}\binom{l}{k} = -\underline{\underline{\beta}}\sum\limits_{l,k}^{N,n}\vec{u}\binom{l}{k}$.　　$\vec{u}\binom{l}{k} = \vec{A}_k \exp\left(i\omega t - i\vec{R}\binom{l}{k}\cdot\left(\frac{n_1\vec{b}_1}{N_1}+\frac{n_2\vec{b}_2}{N_2}+\frac{n_3\vec{b}_3}{N_3}\right)\right)$

$$m\ddot{R}_x\binom{l}{k} = -\sum_{l,k,\alpha}^{N,n,3}\beta_{x\alpha}u_\alpha\binom{l}{k}$$

$$= -\sum_{l,k,\alpha}^{N,n,3}\beta_{x\alpha}A_{k,\alpha}\exp\left(i\left(\omega t-\vec{R}\binom{l}{k}\cdot\left(\frac{n_1\vec{b}_1}{N_1}+\frac{n_2\vec{b}_2}{N_2}+\frac{n_3\vec{b}_3}{N_3}\right)\right)\right)$$

3. 一维单原子链，纵向运动？不明. 若考虑所有元胞 写出. 令

4. 略. 在pdf中有讨论.