5.2

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0}$$

$$F_T = \frac{k(+1)(-1)e^2}{(r-d)^2} + \frac{k(+1)(-1)e^2}{(r+d)^2} + \frac{2k(+e)(+e)}{r^2}$$

$$= ke^2\left[\frac{-1}{r^2-2dr+d^2} + \frac{-1}{r^2+2dr+d^2} + \frac{2}{r^2}\right]$$

$$= ke^2\left[\frac{-r^2(2r^2+2d^2)+2(r^2+d^2-2dr)(r^2+d^2+2dr)}{r^2(r^2+d^2+2dr)(r^2+d^2-2dr)}\right]$$

$$= ke^2\left[\frac{-r^2(2r^2+2d^2)+2(r^4+d^4-2d^2r^2)}{r^2(r^4+d^4-2d^2r^2)}\right]$$

neglect $d^2 \ll r^2$

$r^4 \gg d^4, 2d^2r^2$

$$\simeq ke^2\left[\frac{-6d^2}{r^4}\right] \quad \propto \frac{1}{r^4}$$

attractive force

5.4

$m=1,\ n=9$

$$r=r_0 \quad \left.\frac{dE}{dr}\right|_{r_0} = \frac{-9A}{r_0^{10}} + \frac{B}{r_0^2} = 0 \quad \rightarrow \quad A = \frac{Br_0^8}{9}$$

$$C = \frac{1}{9r_0}\left(\frac{90A}{r_0^{11}} - \frac{2B}{r_0^3}\right)$$

$$= \frac{1}{9r_0^4}(8B)$$

$$C = 1.88\times10^{10}\ N\,m^{-2} = \frac{1}{9r_0^4}\,8B \qquad \frac{1}{4\pi\varepsilon_0} = 9\times10^9$$

$$r_0^4 = \frac{1}{1.88\times10^{10}} \times \frac{8}{9} \times 1.75 \times (1.6\times10^{-19})^2 \times 9\times10^9$$

$$r_0 = 3.716\ \text{Å}$$

Engineer's Computation Pad

5.5 $E(r) = Ar^{-n} - Br^{-m}$

$$\frac{dE}{dr} = -nAr^{-n-1} + mBr^{-m-1}$$

$$\frac{d^2E}{dr^2} = n(n+1)Ar^{(-n-2)} - (m+1)mBr^{(-m-2)}$$

@ $r = r_0$ $\quad \frac{dE}{dr} = 0$ $\quad nAr_0^{-n-1} = mBr_0^{-m-1}$

$$A = \frac{m}{n} B r_0^{(-m+n)}$$

$$C = \frac{1}{qr_0}\left(\frac{\partial^2 E}{\partial r^2}\right)_{r=r_0}$$

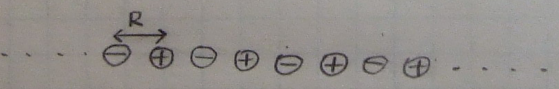
$$= \frac{1}{qr_0}\left[n(n+1)\frac{m}{n} Br_0^{-m-2} - (m+1)mBr_0^{(-m-2)}\right]$$

$$= \frac{1}{qr_0^3}\left[(mn+m)\frac{B}{r_0^m} - (m^2+m)\frac{B}{r_0^m}\right]$$

$$= \frac{-mn}{qr_0^3}\left[\frac{B}{r_0^m}\left(\frac{m}{n} - 1\right)\right]$$

$$= \frac{-mn}{qr_0^3} E_c$$

5.6



Assume the nearest-neighbor separation is R
Assume this binding is mainly due to electrostatic forces
The energy of a negative ion in a linearly chain of equally spaced ions is

counting 2 sides

$$2 \times \frac{e^2}{4\pi\epsilon_0}\left(\frac{-1}{R} + \frac{1}{2R} - \frac{1}{3R} + \frac{1}{4R} - \frac{1}{5R} + \cdots\right)$$

$$= \frac{-e^2}{2\pi\epsilon_0 R}\left(1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \frac{1}{5} + \cdots\right) = \frac{-e^2}{2\pi\epsilon_0 R} \ln 2 \quad \#$$

(since $\ln(1+x) = x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \frac{1}{4}x^4 + \cdots$)