minimum : calculus: $\frac{dU}{dx} = 0$

physics: $F = -\frac{dU}{dx} = 0$!

$\Rightarrow$ equilibrium !

$\left.\frac{d^2U}{dx^2}\right|_{\text{minimum}} > 0$ means.... restoring force

stable equilibrium

$$\left.\frac{dU}{dx}\right|_{x_m} = -\frac{12a}{x_m^{13}} + \frac{6b}{x_m^7} = 0$$

$$\frac{6b}{x_m^7} = \frac{12a}{x_m^{13}}$$

$$\frac{x_m^{13}}{x_m^7} = \frac{12a}{6b} = 2\frac{a}{b}$$

$$x_m^6 = 2\frac{a}{b}$$

$$x_m = \left(2\frac{a}{b}\right)^{1/6}$$

$$-E_d = \frac{a}{\left(2\frac{a}{b}\right)^{\frac{12}{6}}} - \frac{b}{\left(\frac{2a}{b}\right)^1}$$

$$= \frac{a}{4\frac{a^2}{b^2}} - \frac{b^2}{2a} \qquad 1eV = 1.6 \cdot 10^{-19} J$$

$$-E_d = \frac{1}{4}\frac{b^2}{a} - \frac{1}{2}\frac{b^2}{a} = -\frac{1}{4}\frac{b^2}{a} = -9.8 \text{ eV}$$

$$\left.\frac{d^2U}{dx^2}\right|_{x_m} = \frac{13\cdot 12 a}{x_m^{14}} - \frac{7\cdot 6 b}{x_m^{8}} \qquad x_m = \left(\frac{2a}{b}\right)^{1/6}$$

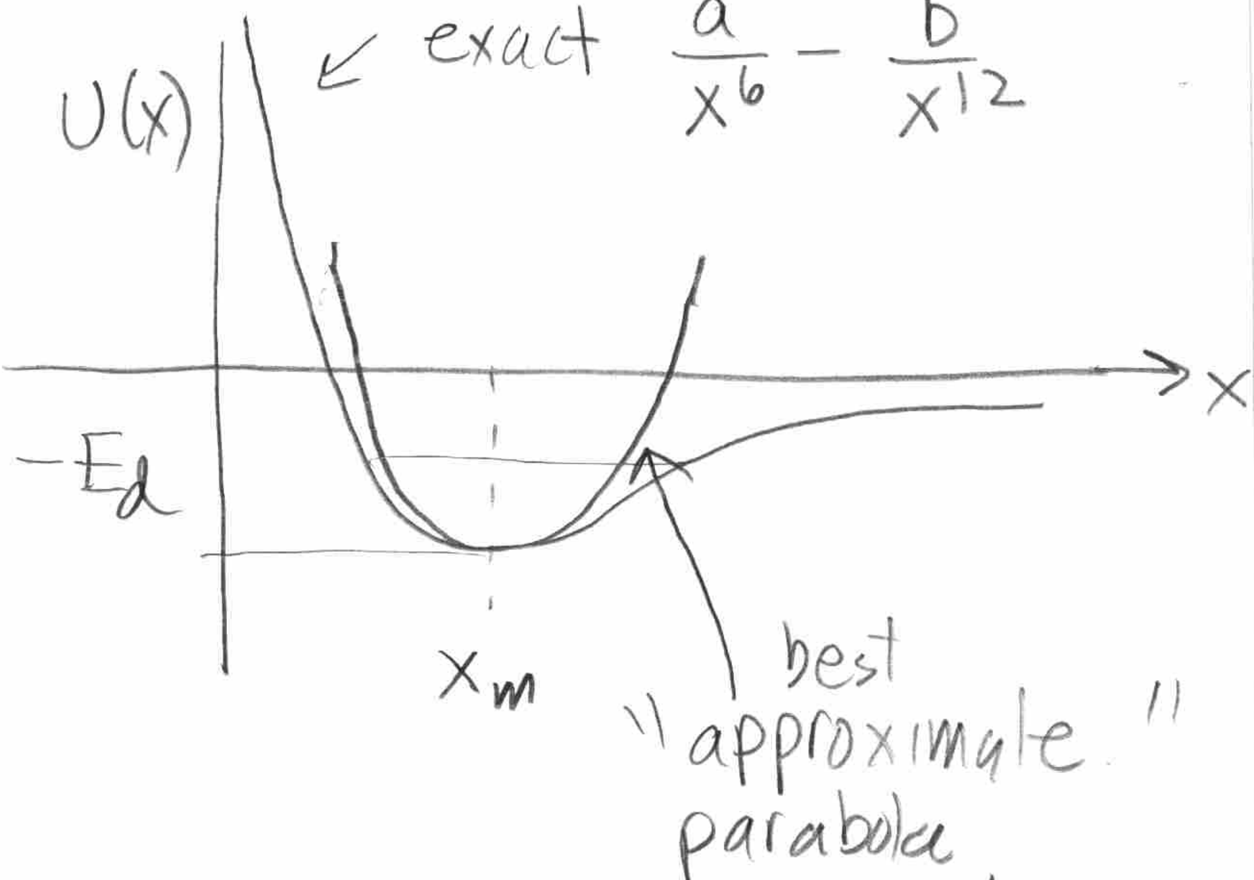
$$= \frac{1}{x_m^2}\left[\frac{13\cdot 12 \cdot a}{\left(\frac{2a}{b}\right)^{\frac{12}{6}}} - \frac{7\cdot 6 b}{\left(\frac{2a}{b}\right)^{\frac{6}{6}}}\right]$$

$$= \left(\frac{b}{2a}\right)^{1/3}\left[\left(\frac{13\cdot \cancel{12}^{3}}{\cancel{4}_{1}} - \frac{7\cdot \cancel{6}^{3}}{\cancel{2}}\right)\frac{b^2}{2a}\right]$$

$$39 - 21$$
$$= 18 \ (>0)$$

$$\left.\frac{d^2U}{dx^2}\right|_{x_m} = 9\left(\frac{b}{2a}\right)^{1/3}\frac{b^2}{a} > 0$$

Concept (THINK ABOUT)!



$$\cong -E_d + \frac{1}{2}\left.\frac{d^2U}{dx^2}\right|_{x_m}(x-x_m)^2$$

$$\cong -E_d + \frac{1}{2}\left(9\left(\frac{b}{2a}\right)^{1/3}\frac{b^2}{a}\right)(x-x_m)^2$$

Einstein : $E_0 = mc^2$! pp. 165 ↓ 168 RHK4

① dimensions... OK !

② How much energy in 1 kg ?

$c \cong 3 \cdot 10^8$ m/s

$E_0 = 1\,kg \cdot 9 \cdot 10^{16} \simeq 10^{17}$ Joules

<u>Hiroshima</u> $\simeq 6 \cdot 10^{13}$ Joules

10^{17} J .. like largest H-bomb ever

Bound N_2 has less mass than 2N separated by ∞!

How much? $E_d = 9.8\ eV = \Delta m\, c^2$

$$\Delta m = \frac{9.8 \cdot 1.6 \cdot 10^{-19}\ J}{9 \cdot 10^{16}}\ kg$$

$$\Delta m = 1.7 \cdot 10^{-35}\ kg$$

$$2 m_N = 4.6 \cdot 10^{-26}\ kg$$

$$\frac{\Delta m}{2 m_N} \simeq 0.38 \cdot 10^{-9} \quad (\simeq ppb)$$

$$U(r) = \text{constant} - \frac{GMm}{r}$$

Usual choice of constant:

make $U(\infty) = 0$, constant $= 0$

$$\boxed{U(r) = -\frac{GMm}{r}}$$