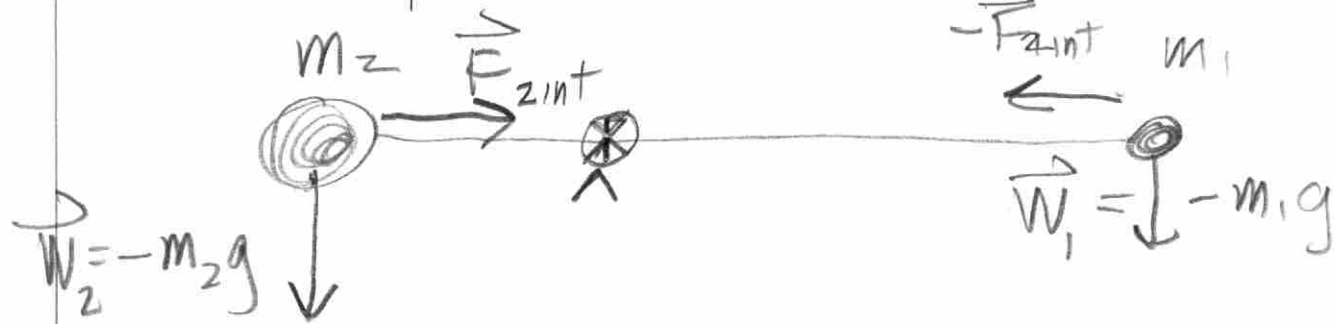
$\vec{R}$ is the Dumb-bell's balance point (in a uniform field).



$$\vec{F}_{2int} + \vec{W}_2 = m_2 \ddot{\vec{r}}_2$$

$$\vec{F}_{1int} + \vec{W}_1 = m_1 \ddot{\vec{r}}_1$$

$$\underbrace{0}_{N3} + \vec{W}_2 + \vec{W}_1 = (m_1 \ddot{\vec{r}}_1 + m_2 \ddot{\vec{r}}_2)$$

$$\underbrace{-(m_1+m_2)g\hat{z}}_{} = M\ddot{\vec{R}}$$

$$-g\hat{z} = \ddot{\vec{R}}$$

no dependence on $\vec{r}_1, \vec{r}_2$

<u>LOCATION</u> of NORMAL FORCE MATTERS HERE.

NOW TOSS THE Dumbell.

2 motions: Parabola $\otimes$

Rotation for 2 bells.

ABOOT CM

- Play with Applet
- "coordinate transformation" put origin on ⊗

$$0 = \frac{m_1 \vec{r}_1{}' + m_2 \vec{r}_2{}'}{m_1 + m_2}$$

$$\underset{\text{small}}{-f_1 \vec{r}_1{}'} = \underset{\text{big}}{f_2 \vec{r}_2{}'} = \frac{|\vec{r}_1{}'|}{|\vec{r}_2{}'|} = \frac{f_2}{f_1} \begin{matrix}\text{big}\\ \\ \text{small}\end{matrix}$$

$$|\vec{r}_1{}' - \vec{r}_2{}'| = \ell$$

$$\vec{r}_1 - \vec{r}_2 = \vec{r}_1{}' - \vec{r}_2{}'$$

$\vec{r}_2{}'$ $\quad \vec{r}_1{}' = f_2 (\vec{r}_1 - \vec{r}_2)$

$= -f_1 (\vec{r}_1 - \vec{r}_2)$

$$-f_1 f_2 (\vec{r}_1 - \vec{r}_2) \stackrel{?}{=} -f_2 f_1 (\vec{r}_1 - \vec{r}_2)$$

Interesting case: <u>Earth/Moon</u>

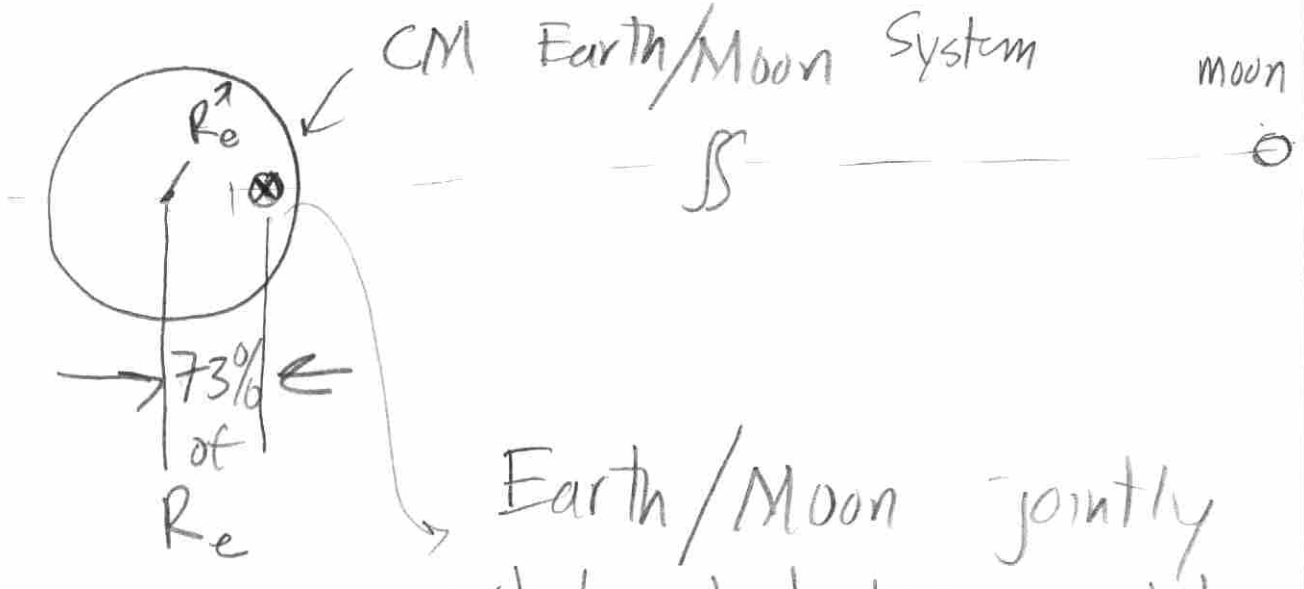
$M_e = 5.98 \cdot 10^{24}$ kg

$M_m = 7.36 \cdot 10^{22}$ kg

$$l = 3.82 \cdot 10^{8} \text{ m} = (60.0) \cdot \overbrace{6.37 \cdot 10^{6} \text{ m}}^{R_e}$$

$$f_m = \frac{0.0736 \cdot \cancel{10^{24}}}{(5.98 + 0.0736) \cdot \cancel{10^{24}}} \simeq \frac{1}{82.3}$$

$$f_m \cdot l = 4.64 \cdot 10^{6} \text{ m} \simeq 0.73 \cdot R_e$$



Earth/Moon jointly orbit about this point!

$$\underbrace{\vec{r}_1, \vec{r}_2}_{\text{2 vectors}} \Rightarrow \text{transform to } \vec{R}, \vec{r}_1 - \vec{r}_2 \quad \text{2 new vectors}$$