

Center of Mass

$$M = m_1 + m_2 \quad (1)$$

$$\vec{R}_{cm} = \frac{1}{M} (m_1 \vec{r}_1 + m_2 \vec{r}_2) \quad (2)$$

Reduced Mass

$$\mu = \frac{m_1 m_2}{m_1 + m_2} \quad (3)$$

$$\vec{r} = \vec{r}_2 - \vec{r}_1 \quad (4)$$

$$(5)$$

Equations of Motion in Polar Coordinates:

$$\ddot{r} = \frac{1}{\mu} f(r) + \frac{\ell^2}{\mu^2 r^3} \quad (6)$$

$$\dot{\phi} = \frac{\ell}{\mu r^2} \quad (7)$$

Angular Momentum in Polar Coordinates:

$$\ell = \mu r^2 \dot{\phi} \quad (8)$$

Orbit Equation:

$$r = \frac{\alpha}{1 + \epsilon \cos(\phi - \delta)} \quad (9)$$

$$\alpha = \frac{\ell^2}{\mu k} \quad (10)$$

$$\epsilon = \sqrt{1 + \frac{2E\ell^2}{k^2\mu}} \quad (11)$$

Effective Potential:

$$U_{eff} = U(r) + \frac{\ell^2}{2\mu r^2} \quad (12)$$