### Center of Mass

$$M = m_1 + m_2 \tag{1}$$

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

### Reduced Mass

$$\mu = \frac{m_1 m_2}{m_1 + m_2} \tag{3}$$

$$\vec{r} = \vec{r}_2 - \vec{r}_1 \tag{4}$$

$$\tag{5}$$

### Lagranian Mechanics

$$\mathcal{L} = KE - PE \tag{6}$$

$$\frac{d}{dt}\frac{\partial}{\partial \dot{q}}\mathcal{L} = \frac{\partial}{\partial q}\mathcal{L} \tag{7}$$

### Equations of Motion in Polar Coordinates:

$$\ddot{r} = \frac{1}{\mu}f(r) + \frac{\ell^2}{\mu^2 r^3} \tag{8}$$

$$\dot{\phi} = \frac{\ell}{\mu r^2} \tag{9}$$

### Angular Momentum in Polar Coordinates:

$$\ell = \mu r^2 \dot{\phi} \tag{10}$$

### Orbit Equation:

$$r = \frac{\alpha}{1 + \epsilon\cos(\phi - \delta)} \tag{11}$$

$$\alpha = \frac{\ell^2}{\mu k} \tag{12}$$

$$\epsilon = \sqrt{1 + \frac{2E\ell^2}{k^2\mu}} \tag{13}$$

### Effective Potential:

$$U_{eff} = U(r) + \frac{\ell^2}{2\mu r^2} \tag{14}$$