

$$\begin{aligned}
m_1 \ddot{\vec{r}}_1 &= \frac{Gm_1 m_2}{r_{12}^3} \vec{r}_{12} + \frac{Gm_1 m_3}{r_{13}^3} \vec{r}_{13} \\
m_2 \ddot{\vec{r}}_2 &= -\frac{Gm_1 m_2}{r_{12}^3} \vec{r}_{12} + \frac{Gm_2 m_3}{r_{23}^3} \vec{r}_{23} \\
m_3 \ddot{\vec{r}}_3 &= -\frac{Gm_1 m_3}{r_{13}^3} \vec{r}_{13} - \frac{Gm_2 m_3}{r_{23}^3} \vec{r}_{23}
\end{aligned}$$

$$\vec{r}_{12} = \vec{r}_2 - \vec{r}_1$$

$$r_{12} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$\begin{aligned}
\ddot{x}_1 &= \frac{Gm_2}{r_{12}^3} (x_2 - x_1) + \frac{Gm_3}{r_{13}^3} (x_3 - x_1) \\
\ddot{y}_1 &= \frac{Gm_2}{r_{12}^3} (y_2 - y_1) + \frac{Gm_3}{r_{13}^3} (y_3 - y_1) \\
\ddot{x}_2 &= -\frac{Gm_1}{r_{12}^3} (x_2 - x_1) + \frac{Gm_3}{r_{23}^3} (x_3 - x_2) \\
\ddot{y}_2 &= -\frac{Gm_1}{r_{12}^3} (y_2 - y_1) + \frac{Gm_3}{r_{23}^3} (y_3 - y_2) \\
\ddot{x}_3 &= -\frac{Gm_1}{r_{13}^3} (x_3 - x_1) - \frac{Gm_2}{r_{23}^3} (x_3 - x_2) \\
\ddot{y}_3 &= -\frac{Gm_1}{r_{13}^3} (y_3 - y_1) - \frac{Gm_2}{r_{23}^3} (y_3 - y_2)
\end{aligned}$$

$$\begin{array}{lll}
u_1 = x_1 & u_5 = x_2 & u_9 = x_3 \\
u_2 = y_1 & u_6 = y_2 & u_{10} = y_3 \\
u_3 = \dot{x}_1 & u_7 = \dot{x}_2 & u_{11} = \dot{x}_3 \\
u_4 = \dot{y}_1 & u_8 = \dot{y}_2 & u_{12} = \dot{y}_3
\end{array}$$

$$\dot{u}_1 = u_3$$

$$\dot{u}_2 = u_4$$

$$\dot{u}_3 = \frac{Gm_2}{r_{12}^3}(u_5 - u_1) + \frac{Gm_3}{r_{13}^3}(u_9 - u_1)$$

$$\dot{u}_4 = \frac{Gm_2}{r_{12}^3}(u_6 - u_2) + \frac{Gm_3}{r_{13}^3}(u_{10} - u_2)$$

$$\dot{u}_5 = u_7$$

$$\dot{u}_6 = u_8$$

$$\dot{u}_7 = \frac{Gm_1}{r_{12}^3}(u_1 - u_5) + \frac{Gm_3}{r_{23}^3}(u_9 - u_5)$$

$$\dot{u}_8 = \frac{Gm_1}{r_{12}^3}(u_2 - u_6) + \frac{Gm_3}{r_{23}^3}(u_{10} - u_6)$$

$$\dot{u}_9 = u_{11}$$

$$\dot{u}_{10} = u_{12}$$

$$\dot{u}_{11} = \frac{Gm_1}{r_{13}^3}(u_1 - u_9) + \frac{Gm_2}{r_{23}^3}(u_5 - u_9)$$

$$\dot{u}_{12} = \frac{Gm_1}{r_{13}^3}(u_2 - u_{10}) + \frac{Gm_2}{r_{23}^3}(u_6 - u_{10})$$

$$F = \frac{Gm_1m_2}{r^2}$$

$$\ddot{\vec{r}} = -\frac{G(m_1 + m_2)}{r^2}\hat{r}$$

$$\ddot{\vec{r}} = -\frac{1+q}{r^2}\hat{r}$$

$$\ddot{x} = -\frac{1+q}{r^3}x$$

$$\ddot{y} = -\frac{1+q}{r^3}y$$

$$u_1 = x$$

$$u_2 = y$$

$$u_3 = \dot{x}$$

$$u_4 = \dot{y}$$

$$\dot{u}_1 = u_3$$

$$\dot{u}_2 = u_4$$

$$\dot{u}_3 = -\frac{1+q}{r^3}u_1$$

$$\dot{u}_4 = -\frac{1+q}{r^3}u_2$$