equation for r_1:

$$\frac{GM_1}{(R-r_1)^2} - \frac{GM_2}{r_1^2} = \left(\frac{M_1}{M_1+M_2}R - r_1\right)\frac{G(M_1+M_2)}{R^3}$$

Replace $r_1 = x_1 R$

$$\frac{\cancel{G}M_1}{(R-xR)^2} - \frac{\cancel{G}M_2}{x_1^2R^2} = \left(\frac{M_1}{M_1+M_2}R - x_1R\right)\frac{\cancel{G}(M_1+M_2)}{R^3}$$

$$\frac{M_1}{(R^2(1-x_1)^2)} - \frac{M_2}{R^2x_1^2} = \left(\frac{M_1}{\cancel{M_1+M_2}}\cancel{R}\cdot\frac{(\cancel{M_1+M_2})}{R^{\cancel{3}\,2}} - \frac{x_1\cancel{R}(M_1+M_2)}{R^{\cancel{3}\,2}}\right)$$

$$\frac{1}{\cancel{R^2}}\left[\frac{M_1}{(1-x_1)^2} - \frac{M_2}{x_1^2}\right] = \frac{1}{\cancel{R^2}}\left[M_1 - x_1(M_1+M_2)\right]$$

Replace M_1 and M_2: $\mu = \frac{M_2}{(M_1+M_2)}$ $\quad \mu(M_1+M_2) = M_2$

$(1-\mu)(M_1+M_2) = M_1$

$$\frac{(1-\mu)(\cancel{M_1+M_2})}{(1-x_1)^2} - \frac{\mu(\cancel{M_1+M_2})}{x_1^2} = (1-\mu)(\cancel{M_1+M_2}) - x_1(\cancel{M_1+M_2})$$

$$\frac{(1-\mu)}{(1-x_1)^2} - \frac{\mu}{x_1^2} = (1-\mu) - x_1$$

move to one side for computational purposes

$$\boxed{\frac{(1-\mu)}{(1-x_1)^2} - \frac{\mu}{x^2} - 1 + \mu + x_1 = 0}$$

equation for r_2:

$$\frac{\cancel{G}M_1}{(R+r_2)^2} + \frac{\cancel{G}M_2}{r_2^2} = \left(\frac{M_1}{M_1+M_2}R + r_2\right)\frac{\cancel{G}(M_1+M_2)}{R^3}$$

Replace $r_2 = x_2 R$

$$\frac{M_1}{(R+x_2R)^2} + \frac{M_2}{x_2^2R^2} = \left(\frac{M_1}{M_1+M_2}R + x_2R\right)\cdot\frac{M_1+M_2}{R^3}$$

$$\frac{M_1}{\cancel{R^2}(1+x_2)^2} + \frac{M_2}{x_2^2\cancel{R^2}} = \left(\frac{M_1(\cancel{M_1+M_2})}{\cancel{M_1+M_2}}\cdot\frac{\cancel{R}}{\cancel{R^3}\,2} + \frac{x_2\cancel{R}(M_1+M_2)}{\cancel{R^3}\,2}\right)$$

Replace M_1 and M_2: $\mu = \frac{M_2}{(M_1+M_2)}$ $\quad \mu(M_1+M_2) = M_2$

$(1-\mu)(M_1+M_2) = M_1$

$$\frac{(1-\mu)(\cancel{M_1+M_2})}{(1+x_2)^2} + \frac{\mu(\cancel{M_1+M_2})}{x_2^2} = (1-\mu)(\cancel{M_1+M_2}) + x_2(\cancel{M_1+M_2})$$

$$\frac{(1-\mu)}{(1+x_2)^2} + \frac{\mu}{x_2^2} = (1-\mu) + x_2 \longrightarrow \boxed{\frac{(1-\mu)}{(1+x_2)^2} + \frac{\mu}{x_2^2} - x_2 - 1 + \mu = 0}$$

equation for r_3:

$$\frac{\cancel{G}M_1}{(R-r_3)^2}+\frac{\cancel{G}M_2}{(2R-r_3)^2}=\left(\frac{M_2}{M_1+M_2}R+R-r_3\right)\frac{\cancel{G}(M_1+M_2)}{R^3}$$

Replace $r_3 = x_3 R$

$$\frac{M_1}{(R-x_3R)^2}+\frac{M_2}{(2R-x_3R)^2}=\left(\frac{M_2}{M_1+M_2}R+R-x_3R\right)\left(\frac{M_1+M_2}{R^3}\right)$$

$$\frac{M_1}{\cancel{R^2}(1-x_3)^2}+\frac{M_2}{\cancel{R^2}(2-x_3)^2}=\cancel{R}\left(\frac{M_2}{M_1+M_2}+1-x_3\right)\left(\frac{M_1+M_2}{\cancel{R^3}}\right)$$

$$\frac{M_1}{(1-x_3)^2}+\frac{M_2}{(2-x_3)^2}=\left(\frac{M_2}{\cancel{M_1+M_2}}\cancel{(M_1+M_2)}+(M_1+M_2)-x_3(M_1+M_2)\right)$$

Replace M_1, M_2: $\mu=\dfrac{M_2}{(M_1+M_2)}$ $\qquad \mu(M_1+M_2)=M_2$

$$(1-\mu)(M_1+M_2)=M_1$$

$$\frac{(1-\mu)\cancel{(M_1+M_2)}}{(1-x_3)^2}+\frac{\mu\cancel{(M_1+M_2)}}{(2-x_3)^2}=\mu\cancel{(M_1+M_2)}+\cancel{(M_1+M_2)}-x_3\cancel{(M_1+M_2)}$$

$$\frac{1-\mu}{(1-x_3)^2}+\frac{\mu}{(2-x_3)^2}=\mu+1-x_3$$

$$\boxed{\frac{1-\mu}{1-x_3^2}+\frac{\mu}{(2-x_3)^2}+x_3-\mu-1=0}$$