Spring/Mass Pendulum

$k := 10^{20}\ \frac{N}{m}$ $l_o := 0.1\ m$ $M := 0.25\ kg$

$\theta_o := 1\ ° = 0.017$ $\theta'_o := 0\ \frac{1}{s}$ $r_o := l_o$ $r'_o := 0\ \frac{m}{s}$

$t_o := 0\ s$

$\beta_o := \sqrt{\frac{k}{M} - \theta'^{2}_o} = (2 \cdot 10^{10})\ \frac{1}{s}$ $\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4 \cdot 10^{19})\ \frac{m}{s^2}$

$\Delta t := 0.01\ s$

$a := \sin(\beta_o \cdot t_o) = 0$ $b := \cos(\beta_o \cdot t_o) = 1$

$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix}$ $S := \begin{bmatrix} r_o - \frac{\gamma_o}{\beta_o^2} \\ r'_o \end{bmatrix}$

$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix} m$

$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.711\ \frac{1}{s^2}$

$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.017\ \frac{1}{s}$ $\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.985\ °$

$r_o := C_0 \cdot \sin(\beta_o \cdot (t_o + \Delta t)) + C_1 \cdot \cos(\beta_o \cdot (t_o + \Delta t)) + \frac{\gamma_o}{\beta_o^2} = 0.1\ m$

$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot (t_o + \Delta t)) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot (t_o + \Delta t)) = 0\ \frac{m}{s}$

$$t_o := t_o + \Delta t = 0.01\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'_o{}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = -0.6771 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.7359$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \frac{\gamma_o}{\beta_o{}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.686\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.034\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.961\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{\beta_o{}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.02\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'_o{}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = 0.997 \qquad b := \cos\left(\beta_o \cdot t_o\right) = 0.083$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{\beta_o{}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.645\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.05\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.927\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{\beta_o{}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.03\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = -0.79 \qquad b := \cos\left(\beta_o \cdot t_o\right) = 0.614$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.587\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.066\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.885\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.04\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'_o{}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = 0.166 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.986$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{\beta_o{}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.514\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.081\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.834\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{\beta_o{}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.05\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = 0.546 \qquad b := \cos\left(\beta_o \cdot t_o\right) = 0.838$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.427\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.096\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.775\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.06\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = -0.969 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.247$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.326\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.109\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.709\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.07\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = 0.88 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.474$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \frac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.213\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.121\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.636\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.08\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = -0.327 \qquad b := \cos\left(\beta_o \cdot t_o\right) = 0.945$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \frac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -1.088\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.132\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.557\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.09\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = -0.4 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.917$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -0.953\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.142\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.473\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.1\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = 0.915 \qquad b := \cos\left(\beta_o \cdot t_o\right) = 0.404$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -0.81\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.15\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.385\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.11\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = -0.947 \qquad b := \cos\left(\beta_o \cdot t_o\right) = 0.322$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \frac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -0.659\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.156\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.294\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.12\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = 0.479 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.878$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -0.503\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.161\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.2\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$t_o := t_o + \Delta t = 0.13\ s$

$\beta_o := \sqrt{\frac{k}{M} - \theta'_o{}^2} = \left(2 \cdot 10^{10}\right) \frac{1}{s}$

$\gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right) \frac{m}{s^2}$

$\Delta t := 0.01\ s$

$a := \sin\left(\beta_o \cdot t_o\right) = 0.242$

$b := \cos\left(\beta_o \cdot t_o\right) = 0.97$

$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix}$

$S := \begin{bmatrix} r_o - \frac{\gamma_o}{\beta_o{}^2} \\ r'_o \end{bmatrix}$

$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix} m$

$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -0.342 \frac{1}{s^2}$

$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.165 \frac{1}{s}$

$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.105\ °$

$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{\beta_o{}^2} = 0.1\ m$

$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0 \frac{m}{s}$

$$t_o := t_o + \Delta t = 0.14\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = -0.835 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.55$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \frac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -0.179\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.166\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.009\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.15\ s$$

$$\beta_o := \sqrt{\frac{k}{M} - {\theta'_o}^2} = \left(2 \cdot 10^{10}\right)\ \frac{1}{s} \qquad \gamma_o := g \cdot \cos\left(\theta_o\right) + k \cdot \frac{l_o}{M} = \left(4 \cdot 10^{19}\right)\ \frac{m}{s^2}$$

$$\Delta t := 0.01\ s$$

$$a := \sin\left(\beta_o \cdot t_o\right) = 0.987 \qquad b := \cos\left(\beta_o \cdot t_o\right) = -0.161$$

$$D := \begin{bmatrix} a & b \\ \beta_o \cdot b & -\beta_o \cdot a \end{bmatrix} \qquad S := \begin{bmatrix} r_o - \dfrac{\gamma_o}{{\beta_o}^2} \\ r'_o \end{bmatrix}$$

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ 0 \end{bmatrix}\ m$$

$$\theta''_o := \frac{-1}{r_o} \cdot \left(g \cdot \sin\left(\theta_o\right) + 2 \cdot r'_o \cdot \theta'_o\right) = -0.015\ \frac{1}{s^2}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.167\ \frac{1}{s} \qquad \theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = -0.087\ °$$

$$r_o := C_0 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + C_1 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) + \frac{\gamma_o}{{\beta_o}^2} = 0.1\ m$$

$$r'_o := \beta_o \cdot C_0 \cdot \cos\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) - \beta_o \cdot C_1 \cdot \sin\left(\beta_o \cdot \left(t_o + \Delta t\right)\right) = 0\ \frac{m}{s}$$