

Spring/Mass Pendulum

$$k := 10^5 \frac{N}{m} \quad l_o := 0.1 \text{ m} \quad M := 0.25 \text{ kg}$$

$$\theta_o := 0.017 \text{ rad} = 0.97402825 \text{ deg} \quad \theta'_o := 0 \frac{1}{s} \quad r_o := l_o \quad r'_o := 0 \frac{m}{s}$$

$$t_o := 0 \text{ s}$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta_o'^2} = 632.456 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

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

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

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 0 \\ -0.0000245 \end{bmatrix} \text{ m}$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.667 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = 0 \frac{m}{s}$$

$$\Delta t := 0.005 \text{ s}$$

$$t_o := t_o + \Delta t = 0.005 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.008 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.97^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.456 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = -0.0207$$

$$b := \cos(\beta_o \cdot t_o) = -0.9998$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 5.07 \cdot 10^{-7} \\ 2.451 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.661 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = -5.421 \cdot 10^{-20} \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.01 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.017 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.964^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.4555 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = 0.041$$

$$b := \cos(\beta_o \cdot t_o) = 0.999$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} -1.014 \cdot 10^{-6} \\ -2.449 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.651 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = 0 \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.015 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.025 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.956^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.4555 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = -0.062 \quad b := \cos(\beta_o \cdot t_o) = -0.998$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 1.52 \cdot 10^{-6} \\ 2.447 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.636 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = -1.084 \cdot 10^{-19} \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.02 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.033 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.946^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.4555 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = 0.083$$

$$b := \cos(\beta_o \cdot t_o) = 0.997$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} -2.026 \cdot 10^{-6} \\ -2.443 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.618 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = -2.168 \cdot 10^{-19} \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.025 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.041 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.933^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.4555 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = -0.103$$

$$b := \cos(\beta_o \cdot t_o) = -0.995$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 2.531 \cdot 10^{-6} \\ 2.438 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.596 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = 0 \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.03 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.049 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.917^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.4555 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = 0.124$$

$$b := \cos(\beta_o \cdot t_o) = 0.992$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} -3.035 \cdot 10^{-6} \\ -2.433 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.57 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = (2.168 \cdot 10^{-19}) \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.035 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.057 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.9^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.4555 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = -0.144 \quad b := \cos(\beta_o \cdot t_o) = -0.99$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} 3.537 \cdot 10^{-6} \\ 2.426 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.54 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = (4.337 \cdot 10^{-19}) \frac{m}{s}$$

$$t_o := t_o + \Delta t = 0.04 \text{ s}$$

$$\theta'_o := \theta'_o + \theta''_o \cdot \Delta t = -0.065 \frac{1}{s}$$

$$\theta_o := \theta_o + \theta'_o \cdot \Delta t + \frac{1}{2} \cdot \theta''_o \cdot \Delta t^2 = 0.88^\circ$$

$$\beta_o := \sqrt{\frac{k}{M} - \theta'^2_o} = 632.4555 \frac{1}{s}$$

$$\gamma_o := g \cdot \cos(\theta_o) + k \cdot \frac{l_o}{M} = (4.001 \cdot 10^4) \frac{m}{s^2}$$

$$a := \sin(\beta_o \cdot t_o) = 0.165$$

$$b := \cos(\beta_o \cdot t_o) = 0.986$$

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

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

$$C := D^{(-1)} \cdot S = \begin{bmatrix} -4.038 \cdot 10^{-6} \\ -2.418 \cdot 10^{-5} \end{bmatrix} m$$

$$\theta''_o := \frac{-1}{r_o} \cdot (g \cdot \sin(\theta_o) + 2 \cdot r'_o \cdot \theta'_o) = -1.507 \frac{1}{s^2}$$

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

$$r'_o := \beta_o \cdot C_0 \cdot \cos(\beta_o \cdot t_o) - \beta_o \cdot C_1 \cdot \sin(\beta_o \cdot t_o) = (4.337 \cdot 10^{-19}) \frac{m}{s}$$