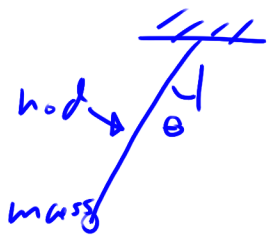
Loop Efficiency

data = [↺] random values

find max of data

Pendulums



$$\frac{d^2\theta}{dt^2} + \frac{g}{l}\sin\theta = 0$$

$$\frac{d^2\theta}{dt^2} = \frac{-g}{l}\sin\theta$$

$$\frac{d\dot{\theta}}{dt} = \frac{d^2\theta}{dt^2}$$

$$\boxed{\frac{d\dot{\theta}}{dt} = \frac{-g}{l}\sin\theta}$$

$$\boxed{\dot{\theta} = \frac{d\theta}{dt}}$$

$$\lim_{\Delta t \to 0} \frac{f(t+\Delta t) - f(t)}{\Delta t} = \frac{d}{dt} f(t)$$

if Δt small

$$\frac{f(t+\Delta t) - f(t)}{\Delta t} \approx \frac{d}{dt} f(t)$$

$$\frac{\theta(t+\Delta t) - \theta(t)}{\Delta t} = \frac{d\theta}{dt}$$

$$\theta(t+\Delta t) - \theta(t) = \Delta t\, \dot{\theta}$$

$$\boxed{\theta(t+\Delta t) = \theta(t) + \Delta t\, \dot{\theta}}$$

$$\frac{\dot{\theta}(t+\Delta t) - \dot{\theta}(t)}{\Delta t} = \frac{d\dot{\theta}}{dt} = \frac{-g}{l}\sin\theta$$

$$\dot{\theta}(t+\Delta t) - \dot{\theta}(t) = \Delta t\left(\tfrac{-g}{l}\right)\sin\theta$$

$$\boxed{\dot{\theta}(t+\Delta t) = \dot{\theta}(t) - \Delta t\, \frac{g}{l}\sin\theta}$$

$$\boxed{\begin{bmatrix}\theta \\ \dot{\theta}\end{bmatrix} = \begin{bmatrix}\theta \\ \dot{\theta}\end{bmatrix} + \Delta t \begin{bmatrix}\dot{\theta} \\ \frac{-g}{l}\sin\theta\end{bmatrix}}$$

Vectorization

$$\begin{bmatrix}\theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2 \\ \vdots\end{bmatrix} = \begin{bmatrix}\theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2 \\ \vdots\end{bmatrix} + \Delta t \left(\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ & & & \ddots \end{bmatrix} \begin{bmatrix}\theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2 \\ \vdots\end{bmatrix} - \frac{g}{l} \begin{bmatrix} 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ & & & \ddots \end{bmatrix} \sin\left(\begin{bmatrix}\theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2 \\ \vdots\end{bmatrix} \right) \right)$$

$$\begin{bmatrix}\theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2\end{bmatrix} = \begin{bmatrix}\theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2\end{bmatrix} + \Delta t \left(\underbrace{\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}}_{A} \begin{bmatrix}\theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2\end{bmatrix} - \frac{g}{l} \underbrace{\begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}}_{B} \sin\left(\begin{bmatrix}\theta_1 \\ \theta_2 \\ \vdots\end{bmatrix} \right) \right)$$