

Second-Order Runge-Kutta
(Ralston's Method) $\mathbf{k}_1 = \mathbf{f}(\mathbf{q}_t, \dot{\mathbf{q}}_t, \boldsymbol{\tau}_t)$ $\mathbf{k}_2 = \mathbf{f}((\mathbf{q}_t, \dot{\mathbf{q}}_t) + \frac{2}{2} \Delta_t \mathbf{k}_1, \boldsymbol{\tau}_t)$

$$\mathbf{k}_{2} = \mathbf{f}((\mathbf{q}_{t}, \dot{\mathbf{q}}_{t}) + \frac{2}{3}\Delta_{t}\mathbf{k}_{1}, \boldsymbol{\tau}_{t})$$
$$\begin{bmatrix} \mathbf{q}_{t+1} \\ \dot{\mathbf{q}}_{t+1} \end{bmatrix} = \begin{bmatrix} \mathbf{q}_{t} \\ \dot{\mathbf{q}}_{t} \end{bmatrix} + \Delta_{t} \begin{pmatrix} \mathbf{k}_{1} + 3\mathbf{k}_{2} \\ 4 \end{pmatrix}$$