

$$y''(t) + \sin(y(t)) = 0, \quad y(0) = 1, \quad y'(0) = 0$$

$$y_2'(t) = -\sin(y(t)) = f(y)$$

$$k_1 = f(u_n) = -\sin(u_n)$$

$$k_2 = f(u_n + \frac{h}{2}k_1) = f(u_n - \frac{h}{2}\sin(u_n)) = -\sin(u_n - \frac{h}{2}\sin(u_n))$$

$$k_3 = f(u_n + \frac{h}{2}k_2) = f(u_n - \frac{h}{2}\sin(u_n - \frac{h}{2}\sin(u_n))) = -\sin(u_n - \frac{h}{2}\sin(u_n - \frac{h}{2}\sin(u_n)))$$

$$k_4 = -\sin(u_n - \frac{h}{2}\sin(u_n - \frac{h}{2}\sin(u_n - \frac{h}{2}\sin(u_n))))$$

$$u_{n+1} = u_n + \frac{h}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

$$= u_n + \frac{h}{6}(-\sin(u_n) - 2\sin(u_n - \frac{h}{2}\sin(u_n)) - 2\sin(u_n - \frac{h}{2}\sin(u_n - \frac{h}{2}\sin(u_n))) - \dots \\ \dots - \sin(u_n - \frac{h}{2}\sin(u_n - \frac{h}{2}\sin(u_n - \frac{h}{2}\sin(u_n))))$$

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is  $O(h^4)$ , i.e.  $|u_n - y_n| = O(h^4)$ .

4th order Runge-Kutta method

$$\begin{cases} k_1 = f(u_n) \\ k_2 = f(u_n + \frac{h}{2}k_1) \\ k_3 = f(u_n + \frac{h}{2}k_2) \\ k_4 = f(u_n + hk_3) \end{cases} \quad y' = f(y)$$

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