9.3.5 Example: Accuracy and cost of Forward Euler, RK2, and RK4 simulations of coffee cooling

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MO2.4 MO2.6 MO2.7

We now compare convergence and order of accuracy for Forward Euler, RK2, and RK4 applied to the coffee cooling problem. As shown in Figure 9.3, the observed rates are as expected (i.e. $p = 1$, 2, and 4 for Forward Euler, RK2, and RK4) with substantial decreases in the error for RK4 compared to Forward Euler and RK2 at the same Δt. Note that the RK4 result appears to have a decreased rate at the small Δt values; however, what is actually happening is the machine precision is limiting the error from decreasing further.

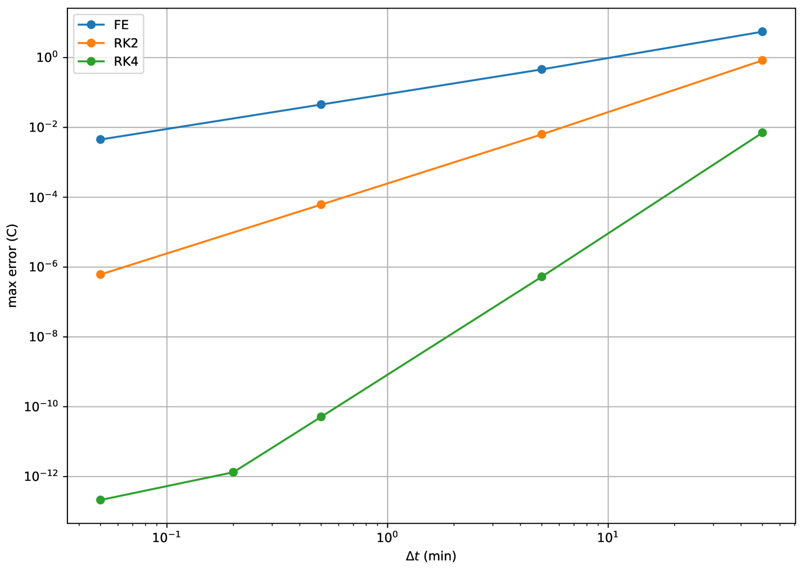

Figure 9.3: Error convergence versus Δt for Forward Euler, RK2, and RK4 methods applied to coffee cooling.

However, for most applications (which will be much more complex than this coffee cooling example), the dominant cost is the number of f evaluations. Thus, we should account for the fact that Forward Euler, RK2, ands RK4 require 1, 2, and 4 f evaluations per timestep. We can then plot the error as a function of f evaluations. This is shown in Figure 9.4. Even accounting for the increased cost per iteration, RK4 remains the clear best choice for this problem.

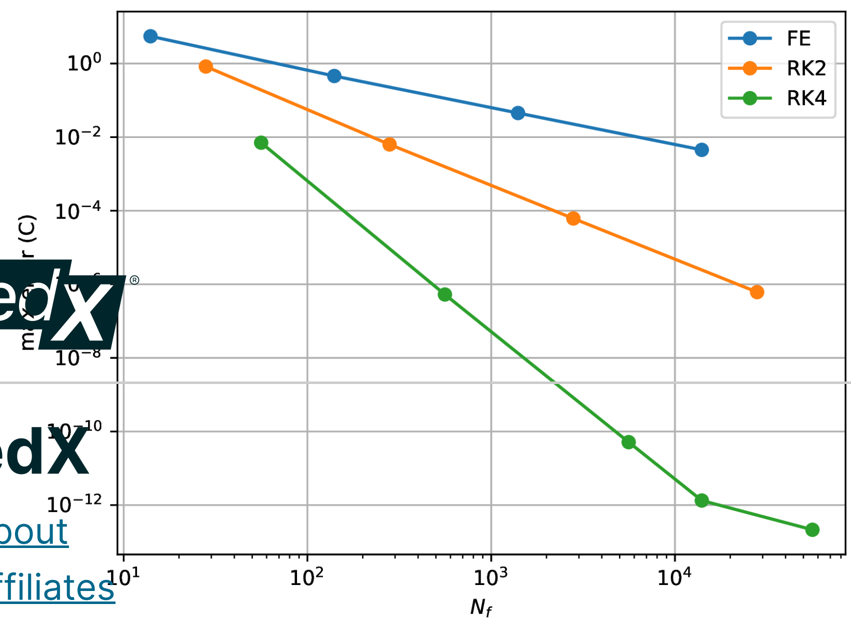

Figure 9.4: Error convergence versus N_f, i.e. the number of f evaluations for Forward Euler, RK2, and

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