

C H 1 A P T E R 0

Numerical Solutions of Differential Equations

In previous chapters, various analytical methods are introduced to solve first-order and simple higher-order differential equations (Chapter 2), linear differential equations with constant coefficients (Chapters 4 and 6), systems of linear differential equations with constant coefficients (Chapter 7), and linear differential equations with variable coefficients (Chapter 9).

However, in practical applications, there are many equations, especially non-linear differential equations and differential equations with variable coefficients, which cannot be solved analytically. In these situations, numerical approaches have to be applied to obtain numerical solutions.

In this chapter, a number of classical numerical methods are presented, through which the concepts of error and stability are introduced.

10.1 Numerical Solutions of First-Order Initial Value Problems

Consider the first-order differential equation

$$\frac{dy}{dx} = f(x, y), \quad y(x_0) = y_0.$$

The solution $y(x)$ is required to satisfy the initial condition, i.e., $y = y_0$ at $x = x_0$. The differential equation, along with the initial condition, is therefore called an *initial value problem*, as discussed in Chapter 1. Discretize the independent variable x at points x_0, x_1, x_2, \dots , in which $x_{i+1} = x_i + h$, $i = 0, 1, 2, \dots$, and h is called the *stepsize*.

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