

Numerical Methods Notes

1.1 Numerical Methods (Introduction):

- Methods for solving problems using **computers**. Given a mathematical problem, there are 2 ways to get the solution to the problem: **Analytical Methods and Numerical Methods**

Analytical Methods:

- What has been taught before: $ax^2 + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
- Gives a solution in **closed form**. However, in most problems, the analytical methods are not known. For example, solve the following for x : $\sin x - x^2 = 0$

Numerical Methods:

- Using computer to generate "approximate" solution to the required precision
- Numerical solution to a problem is quite different from the analytical solution. As an example, consider the problem:

$$\frac{d^2 y}{dx^2} + 4y = 0 \quad , \quad y(0) = 1 \quad , \quad y'(\pi) = 2$$

- Analytical Solution: $y(t) = \sin 2t + \cos 2t$
- Any value of t would determine the value of $y(t)$
- On the other hand, numerical method gives $y(t)$ at **specific values of t** , for example:
 $y(0.1) = 1.1787$, $y(0.2) = 1.3105$, $y(0.3) = 1.3900$, ...

- Note that these values are only **approximations** of the true values given by (1)

1.2 Sources of Errors:

- **Truncation Error**: When a limiting process is **truncated** before one has reached the limiting value.

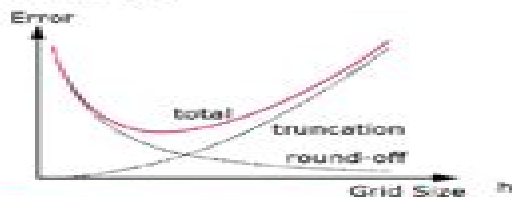
Infinite Series Example: $\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \frac{x^9}{9!} - \dots$ is truncated to give the approximation: $\sin x \approx x - \frac{x^3}{3!} + \frac{x^5}{5!}$

Taylor Series Example: $y(x+h) = y(x) + h y'(x) + \frac{h^2}{2!} y''(x) + \dots$ is truncated to give the approximation:

$$y(x+h) \approx y(x) + h y'(x)$$

Here, the **truncation error decreases with decreasing step size, h** .

- **Round-off Error**: **Limited accuracy** of the calculator/computer used to perform the numerical calculations. Can be **reduced by using higher precision**. Decreasing step size, h results in **larger number of arithmetic operations** and hence **higher roundoff error accumulated**.



1.3 Absolute & Relative Errors:

- Let \tilde{a} be an approximate value of the exact value a .
- The **absolute error** in \tilde{a} : $\epsilon = a - \tilde{a}$
- The **relative error** in \tilde{a} : $r = \frac{\epsilon}{a} = \frac{a - \tilde{a}}{a}$
- (Often Used) A number which is **correct to n decimal places** has an absolute error: $|\epsilon| < 0.5 \times 10^{-n}$
- A number which is **correct to n significant digits** has a relative error: $|r| < 0.5 \times 10^{1-n}$

Example 1:

- Consider $a = \frac{1}{3}$ and $\tilde{a} = 0.333$. Clearly, \tilde{a} is correct to 3 decimal places and 3 significant digits.

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