

ODE Cheat Sheet

First Order Differential Equations

Separable

$$y'(x) = f(x)g(y)$$

$$\int \frac{dy}{g(y)} = \int f(x)dx$$

Linear

$$y'(x) + p(x)y(x) = g(x)$$

$$\mu(x) = e^{\int p(x)dx}$$

Exact:

$$M(x, y)dx + N(x, y)dy = dW(x, y) = 0$$

$$\text{Exactness condition: } M_y = N_x$$

Non-Exact

$$\mu(x) = \int \frac{M_y - N_x}{N} dx$$

$$\mu(y) = \int \frac{N_x - M_y}{M} dy$$

Change of variables

$$y' = f\left(\frac{y}{x}\right)$$

$$\text{let } u = y/x$$

$$y' + p(x)y = g(x)y^n$$

$$\text{let } u = y^{1-n}$$

$$y' = f(ax + by + c)$$

$$\text{let } u = ax + by + c$$

Existence and Uniqueness theorem for First Order Differential equations

Let the functions f and $\partial f / \partial y$ be continuous in some rectangle $a < t < \beta$, $\gamma < y < \delta$ containing the point (t_0, y_0) . Then, in some interval $t_0 - h < t < t_0 + h$ contained in $a < t < \beta$, there is a unique solution $y = \varphi(t)$ of the initial value problem

$$y' = f(t, y), \quad y(t_0) = y_0$$

Second Order Homogeneous Linear Differential Equations

General linear Homogeneous Second Order

$$y'' + p(x)y' + q(x)y = 0$$

If y_1 and y_2 are solutions to the DE and are linearly independent, y_1 and y_2 form a fundamental set of solutions. The general solution is: $y = c_1 y_1 + c_2 y_2$.

Wronskian

$$W[y_1, y_2] = \begin{vmatrix} y_1 & y_2 \\ y_1' & y_2' \end{vmatrix}$$

If $W \neq 0$, y_1 and y_2 are linearly independent.

Abel's Theorem

$$W[y_1, y_2](x) = c \exp\left(-\int p(x)dx\right)$$

Linear Homogeneous Constant Coefficients

$$ay'' + by' + cy = 0$$

$$\text{Characteristic equation: } ar^2 + br + c = 0$$

$$\text{Distinct and real roots: } y = c_1 e^{r_1 x} + c_2 e^{r_2 x}$$

$$\text{Repeated roots: } y = (c_1 + c_2 x)e^{rx}$$

$$\text{Complex roots: } y = (c_1 \cos \beta x + c_2 \sin \beta x)e^{\alpha x}$$

Cauchy-Euler Equations

$$ax^2 y'' + bxy' + cy = 0$$

$$\text{Characteristic equation: } ar(r-1) + br + c = 0$$

$$\text{Distinct and real roots: } y = c_1 x^{r_1} + c_2 x^{r_2}$$

$$\text{Repeated roots: } y = (c_1 + c_2 \ln x)x^r$$

$$\text{Complex roots: } y = (c_1 \cos(\beta \ln x) + c_2 \sin(\beta \ln x))x^\alpha$$

Second Order Non-Homogeneous Linear Differential Equations

General linear Homogeneous Second Order

$$y'' + p(x)y' + q(x)y = g(x)$$

Suppose y_h is the general solution to the homogenous differential equation and y_p is a particular solution to the differential equation. The general solution is: $y = y_h + y_p$

Method of Undetermined Coefficients

$$g(x)$$

$$y_p(x)$$

$$P_N(x)$$

$$x^s \sum_{n=0}^N A_n x^n$$

$$P_N(x)e^{\alpha x}$$

$$x^s e^{\alpha x} \sum_{n=0}^N A_n x^n$$

$$P_N(x)e^{\alpha x} \begin{cases} \sin \beta x \\ \cos \beta x \end{cases}$$

$$x^s e^{\alpha x} \left(\sin \beta x \sum_{n=0}^N A_n x^n + \cos \beta x \sum_{n=0}^N B_n x^n \right)$$

Variation of Parameters

$$y_p = u_1 y_1 + u_2 y_2 \quad \text{where} \quad \begin{cases} u_1' y_1 + u_2' y_2 = 0 \\ u_1' y_1' + u_2' y_2' = g \end{cases}$$

Reduction of order

If y_1 is a solution to the homogeneous differential equation, the general solution can be found by substituting $y = u y_1$ and solving the reduced differential equation.

Series Solutions

Ordinary Points

If $p(x)$ and $q(x)$ are analytic at x_0 , one can find a solution a power series solution about x_0 with $R \geq \min\{R_p, R_q\}$.

$$y = \sum_{n=0}^{\infty} a_n (x - x_0)^n$$

Singular Points

If $p(x)$ and $q(x)$ are not analytic at x_0 , x_0 is a singular point. The point x_0 is a regular singular point if

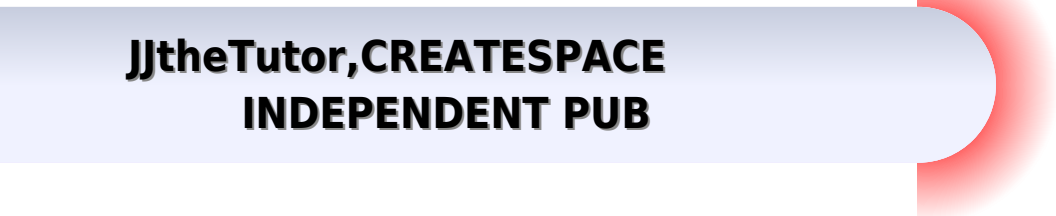
$$\lim_{x \rightarrow x_0} (x - x_0)p(x) = p_0$$

$$\lim_{x \rightarrow x_0} (x - x_0)^2 q(x) = q_0$$

where p_0 and q_0 are finite numbers.

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