

DIFFERENTIAL EQUATIONS

A differential equation is a mathematical equation that relates some function with its derivative. In applications the function usually represent physical quantities, the derivatives represent their rate of change.

Examples of differential equation are

$$\frac{dy}{dx} = y, \frac{d^2y}{dx^2} + 4 \frac{dy}{dx} + 8 = 0, \frac{dy}{dx} = \sin x + \cos x, \text{ Etc.}$$

Order of a differential equation

The order of a differential equation is the order of the highest derivative appearing in that equation.

For example:

$$(1). \quad \frac{dy}{dx} = x + y, \frac{dy}{dx} = \sin x + \cos x, \\ y - \frac{dy}{dx} = x, \text{ etc}$$

are all first order differential equations

$$(2). \quad \frac{d^2y}{dx^2} = 5 + x, 5 \frac{d^2y}{dx^2} - \left(\frac{dy}{dx}\right)^2 = 7, \\ 7 \left(\frac{d^2y}{dx^2}\right)^2 + x \frac{dy}{dx} + 6 = 0$$

are all second order differential equation

$$(3). \quad \frac{d^3y}{dx^3} + \sin x = 0, \left(\frac{d^3y}{dx^3}\right)^2 + 5 \left(\frac{dy}{dx}\right)^2 + \sin x = 0$$

Are all third order differential equations.

The Degree of a Differential Equation

The degree of a differential equation is the highest integral power to which the highest order derivative is raised when a differential equation is written as a polynomial in unknown function and its derivative.

Example:

$$(i) \quad \frac{dy}{dx} - xy = 0, \frac{d^2y}{dx^2} + 2 \left(\frac{dy}{dx}\right)^2 + 2 = 0 \\ \frac{y}{x} \cdot \frac{dy}{dx} = 1, \frac{d^3y}{dx^3} = \sin x - \cos x$$

are all first degree differential equations

$$(ii) \quad \left(\frac{dy}{dx}\right)^2 + xy = 0, 2 \left(\frac{d^2y}{dx^2}\right)^2 + 6x \left(\frac{dy}{dx}\right)^3 = 0$$

Are all second degree differential equations

$$(iii) \quad \left(\frac{d^3y}{dx^3}\right)^2 = 5 \left(\frac{dy}{dx}\right) + \sin x,$$

$$\left(\frac{dy}{dx}\right)^3 + x \left(\frac{dy}{dx}\right)^4 + xy = 0$$

Are all third degree differential equations.

Example

Determine the order and the degree of the following differential equations

$$(a) \quad \frac{dy}{dx} + xy = 5x$$

$$(b) \quad \frac{d^2y}{dx^2} - 5x \frac{dy}{dx} = e^x + x^2$$

$$(c) \quad x^2 \left(\frac{d^3y}{dx^3}\right)^2 + 3x \frac{d^2y}{dx^2} + 7x = 0$$

$$(d) \quad y - 5x \left(\frac{dy}{dx}\right)^2 = e^x + x^2 \cos x$$

Solution

(a) First order, first degree differential equation

(b) 2nd order, first degree differential equations

(c) third order second degree differential equation.

(d) first order second degree differential equation.

A Solution of a Differential Equation

A solution to a differential equation is defined as any relationship connecting the two variables of the equation and not involving their derivatives. A solution to a first order differential equation is said to be general solution (complete solution). If an arbitrary constant remains in the solution. The solution obtained by giving a particular value to an arbitrary constant is called a particular solution.

First Order Differential Equations

(1) Method of separating the variables

Example I

Find the general solution of the following differential equations

$$a) \quad (a) \quad \frac{dy}{dx} = y$$

$$b) \quad (x + 2) \frac{dy}{dx} = y$$

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