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On Methods of Searching for Generalized Solutions of Simple Differential Equations

Kamoliddin Shodiyev
Samarkand State Institute of Architecture and Construction, Uzbekistan

Abstract. The article discusses methods for solving simple differential equations of generalized functions.

Keywords: generalized function, differential equations, simple, solution, example

Examples of finding generalized solutions of simple differential equations using classical solutions are given.

Suppose we have a simple *m*-order differential equation

$$\sum_{k=0}^{m} a_k\,(x) y^{(k)} = f(x)\ (1)$$

Here $a_k(x) \in C^{(\infty)}(R^1)$ va $f \in D^{'}(R^1)$.

Definition:Optional $\varphi(x)$ for $\in D(R^1)$in the generalized sense of equation (1), i.e.

$$\left(\sum_{k=0}^{m} a_k\,(x) y^{(k)}, \varphi\right) = (f, \varphi)$$

A generalized function $y(x) \in D^{'}(R^1)$ satisfying the equation is called a generalized solution to equation (1).

Consider examples of finding generalized solutions to simple differential equations.

1-Example. Find a generalized general solution of the equation $y^{'}$=0 in the space $D^{'}(R^1)$?

Solution. Suppose there is a solution $y \in D^{'}$. Anyway in this case The following equation is valid for a principal function $\varphi \in D$.

$$(y^{'}, \varphi^{'}) = 0 \qquad (2)$$

It is known that for an arbitrary function $\varphi_0(x)$ satisfying the condition , $\int_{-\infty}^{+\infty} \varphi_0(x)dx = 1$, an arbitrary function φ ∈D(R^1) can be expressed as follows:

$$\varphi(x) = \varphi_0 \int_{-\infty}^{+\infty} \varphi(x)dx + \varphi_1^{'}(x)\ , \varphi_1 \in D(R^1), \qquad (3)$$

Considering (3), we can write the following:

$$(y, \varphi) = \left(y, \varphi_0 \int_{-\infty}^{+\infty} \varphi(x)dx + \varphi_1^{'}(x)\right) =$$

$$= (y, \varphi_0) \int_{-\infty}^{+\infty} \varphi dx + (y, \varphi_1^{'}) \qquad (4)$$

From here we take (2) and form $(y, \varphi_1^{'}) = 0$ va $(y, \varphi_0^{1}) = c$. In this case

$$(y, \varphi) = c \int_{-\infty}^{+\infty} \varphi dx = (c, \varphi), \quad \forall \varphi \in D$$

that is, we create $y = c$.

2-Example. $y^{(m)} = 0, m = 2, 3, \dots \dots$

Solution. The equation $y^{(m-1)} = z, y^{(m-2)} = z,$ ...can be reduced to solving a simple differential equation of the form $z' = f(x)$.

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Using the result of Example 1, we see that the general solution of a simple differential equation of order m has the following form:

$y(x) = c_0 + c_1 + \cdots \ldots + c_{m-1}x^{m-1}$.

Now let's look at simple differential equations with variable coefficients:

1. $xy' = 1$; 2. $x^2y' = 0$; 3. $y'' = \delta(x)$

4. $(x+1)y'' = 0$; 5. $(x+1)^2y'' = 0$; 6. $(x+1)y''' = 0$

To solve these equations, we use $\theta(x)$- in the cavity and $\delta(x)$ −Dirac functions δ and their derivatives; It is known that the equation $\theta'(x) = \delta(x)$ is true.

According to the definition of a generalized solution and the rules for calculating generalized products, generalized solutions of the above equations have the following form.

1. $y(x) = c_0 + c_1\theta(x) + ln|x|$
2. $y(x) = c_0 + c_1\theta(x) + c_3\delta(x)$
3. $y(x) = c_0 + c_1x + x\theta(x)$
4. $y(x) = c_0 + c_1(x) + c_2\theta(x+1)(x+1)$
5. $y(x) = c_0 + c_1(x) + c_2(x+1) + c_3\theta(x+1)(x+1)$
6. $y(x) = c_0 + c_1(x) + c_2x^2 + c_3\theta(x+1)(x+1)^2$

We present an equation for finding generalized general solutions of homogeneous simple differential equations with a constant second-order coefficient and their solution:

$af''(x) + bf'(x) + cf(x) = m\delta(x) + n\delta'(x)$

Example 1. $f''(x) + 2 * f' + f(x) = 2\delta(x) + \delta'(x)$

Solution. $f(x) = \theta(x)\, e - x\,(1 + x)$.

Example 2. $f''(x) + 4f(x) = \delta(x)$

Solution. $f(x) = \frac{1}{2}\theta(x)sin2x$.

Example 3. $f''(x) - 4f(x) = \delta(x) + \delta'(x)$

Solution. $f(x) = \theta(x)e^{2x}$.

The solutions to these equations are found by searching in the form $f(x) = \theta(x)z(x),\ z \in C^2(R')$.

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