

6 INTEGRÁLNÍ POČET

6.1 Primitivní funkce. Neurčitý integrál

Definice 6.1. Řekneme, že funkce $F(x) = F(x)$ definovaná na otevřeném intervalu J platí: $F'(x) = f(x)$ pro každé $x \in J$, říkáme, že $F(x)$ je primitivní funkce k funkci $f(x)$ na J .

Věta 6.1. Je-li $f(x)$ spojitá na J , pak k ní existuje na J funkce primitivní.

Je-li $F(x)$ primitivní k funkci $f(x)$ na J , $a \in J$ libovolné číslo, pak

$$F(x) = C + \int_a^x f(t) dt = f(x),$$

takže i každá funkce $F(x) = C$ je na J funkcí $f(x)$ primitivní.

Definice 6.2. Množinu všech primitivních funkcí k funkci $f(x)$ na J nazýváme neurčitý integrál funkce $f(x)$. Píšeme: $\int f(x) dx = F(x) + C$ a nazýváme $\int$ — integrační znak, $f(x)$ — integrand, C — integrační konstanta.

Je-li integrand ve tvaru součinu, přičeme v integračním znaku obvykle zkráceně např. $\int (x + \sin x) dx$. Je-li ve tvaru součinu, zkráceně napíšeme — např. $\int x \sin x dx$.

Názvem primitivní funkce nazýváme integrand. Je to opak derivování. Ne součinu a podílu a pro integraci složené funkce. Vzorce pro integrál (provozní se zjednoduší na tzv. převody integrál pomocí vlastností neurčitých integrálů (vizuální P1 a P2) a vzorci $\sqrt{1-x^2}$, $\sqrt{x^2-1}$, $\sqrt{x^2+a^2}$.

$$P1 \quad \int (f(x) + g(x)) dx = \int f(x) dx + \int g(x) dx$$

$$P2 \quad \int k \cdot f(x) dx = k \cdot \int f(x) dx$$

24

6. Integrální počet

Aby bylo možné použít základní vzorce, je většinou třeba integrand upravit například rozkladem na dva zlomky nebo rozložením.

$$\text{Příklad 6.5.} \quad \int \frac{2x^2-1}{x} dx = \int \left(\frac{2x^2}{x} - \frac{1}{x} \right) dx = \int (2x - \frac{1}{x}) dx = 2 \int x dx - \int \frac{1}{x} dx = \sqrt{2} \sqrt{3} - 2 \frac{x^2}{2} - \ln|x| = x^2 - \ln|x| + C.$$

$$\text{Příklad 6.6.} \quad \int x \left(\sqrt{x} - \frac{1}{\sqrt{x}} \right) dx = \int \left(x\sqrt{x} - \frac{1}{\sqrt{x}} \right) dx = \int (x^{3/2} - x^{-1/2}) dx = \frac{2}{5} x^{5/2} - \frac{2}{3} x^{3/2} + \frac{2}{1} x^{1/2} + C.$$

Často používanou úpravou je rozdělení integrované funkce vhodnou konstantou.

$$\text{Příklad 6.7.} \quad \int \frac{x^2}{x^2+1} dx.$$

Řešení. Abychom mohli použít VB, musí být v čitateli zlomku derivace jeho jmenovatele. V tomto případě $2x$. Rozdělíme proto funkci 2.

$$\text{Dostaneme:} \quad \frac{1}{2} \int \frac{2x^2}{x^2+1} dx = \frac{1}{2} \sqrt{3} - \frac{1}{2} \ln|x^2+1| + C.$$

Racionální nerovné lomené funkce je třeba rozložit.

$$\text{Příklad 6.8.} \quad \int \frac{x^2}{x-2} dx.$$

Řešení. Je to integrál z nerovné lomené racionální funkce, proto napíšeme pro-
vedeme dělení:

6. Integrální počet

25

$$V1 \quad \int dx = x + C$$

$$V2 \quad \int x^n dx = \frac{x^{n+1}}{n+1} + C, \quad n \neq -1$$

$$V3 \quad \int \frac{1}{x} dx = \ln|x| + C$$

$$V4 \quad \int \sin x dx = -\cos x + C$$

$$V5 \quad \int \cos x dx = \sin x + C$$

$$V6 \quad \int e^x dx = e^x + C$$

$$V7 \quad \int x^a dx = \frac{x^{a+1}}{a+1} + C$$

$$V8 \quad \int \frac{f'(x)}{f(x)} dx = \ln|f(x)| + C$$

$$V9 \quad \int f(ax+b) dx = \frac{1}{a} f(ax+b) + C$$

$$\text{Příklad 6.1.} \quad \int (3x^2 + 2x^2 - 4) dx = \int 5x^2 dx - \int 4 dx = \frac{5}{3} x^3 - 4x + C = \frac{5}{3} x^3 - 4x + C.$$

Integrační konstantu zapisujeme obvykle až po ukončení integrace a špič-
kách výsledné funkce.

Příklad 6.2.

$$\int (\sqrt{x} + 2^x) dx = \int x^{1/2} dx + \int 2^x dx = \frac{2}{3} \sqrt{x} + \frac{2^x}{\ln 2} + C = \frac{2}{3} \sqrt{x} + \frac{2^x}{\ln 2} + C$$

$$\text{Příklad 6.3.} \quad \int \frac{\cos x}{\sin x + 2} dx = \frac{1}{\ln 2} \ln|\sin x + 2| + C.$$

VB je vzorec pro integrál speciálního tvaru složené funkce. Používáme ho v kombinaci s ostatními vzorci.

$$\text{Příklad 6.4.} \quad \int e^{2x} dx = \frac{1}{2} e^{2x} + C.$$

$$\text{b) } \int \frac{1}{\sqrt{4x+5}} dx = \int (4x+5)^{-1/2} dx = \frac{1}{2} \sqrt{4x+5} + C.$$

6. Integrální počet

26

6.2 Určitý integrál

Historickou motivací pro vznik integrálního počtu bylo zavedení pojmu určitého inte-
grálu. Cílem bylo určit obsah „křivočarého lichoběžníku“. Na-
zývá se tak plocha (obr. 6.1)
omezená křivkou $y = f(x)$,
osou x a přímkami $x = a$, $x = b$.



Obr. 6.1

Definice 6.3. Necht funkce $f(x)$ je spojitá na uzavřeném intervalu $[a, b]$.
Newtonův určitý integrál od a do b z funkce $f(x)$ je číslo $F(b) - F(a)$, kde $F(x)$ je
funkce primitivní k funkci $f(x)$ na intervalu $[a, b]$. Píšeme

$$\int_a^b f(x) dx = F(b) - F(a)$$

Číslo a nazýváme dolní integrační mez, číslo b horní integrační mez.

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Table of Contents Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike

1. Understanding the eBook Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - The Rise of Digital Reading Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Advantages of eBooks Over Traditional Books
2. Identifying Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - User-Friendly Interface

4. Exploring eBook Recommendations from Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Personalized Recommendations
 - Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike User Reviews and Ratings
 - Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike and Bestseller Lists
5. Accessing Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike Free and Paid eBooks
 - Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike Public Domain eBooks
 - Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike eBook Subscription Services
 - Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike Budget-Friendly Options
6. Navigating Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike eBook Formats
 - ePub, PDF, MOBI, and More
 - Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike Compatibility with Devices
 - Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Highlighting and Note-Taking Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Interactive Elements Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
8. Staying Engaged with Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
9. Balancing eBooks and Physical Books Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Setting Reading Goals Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Fact-Checking eBook Content of Problema Simmetriia Integraly Dvizheniia V Analiticheskoi Dinamike
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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