

Integral Calculus Sample Problems With Solution

$$\begin{aligned}
 3. \int_0^2 \frac{x^3 dx}{\sqrt{4+x^2} + \sqrt{2^2+x^2}} \\
 x = 2 \tan \theta \\
 dx = 2 \sec^2 \theta d\theta \\
 x^3 = 8 \tan^3 \theta \\
 = \int \frac{8 \tan^3 \theta (2 \sec^2 \theta d\theta)}{\sqrt{4+4 \tan^2 \theta}} \\
 \downarrow \\
 \sqrt{4(1+\tan^2 \theta)} \\
 \downarrow \\
 \sqrt{4 \sec^2 \theta} \\
 \downarrow \\
 2 \sec \theta \\
 = \int \frac{8 \tan^3 \theta (2 \sec^2 \theta d\theta)}{2 \sec \theta} \\
 = 8 \int \tan^3 \theta \sec \theta d\theta \\
 = 8 \int \tan \theta \sec \theta (\sec^2 \theta - 1) d\theta \\
 = 8 \int \tan \theta \sec^3 \theta - \tan \theta \sec \theta \\
 = \left[\frac{8 \sec^3 \theta}{3} - 8 \sec \theta + C \right]_0^2 \\
 = \frac{8}{3} \left(\frac{\sqrt{4+x^2}}{2} \right)^3 - 8 \frac{\sqrt{4+x^2}}{2} + C \Big|_0^2 \\
 = \frac{1}{3} \left(\sqrt{4+x^2} \right)^3 - 4 \sqrt{4+x^2} + C \Big|_0^2 \\
 = \left[\frac{1}{3} (\sqrt{4+2^2})^3 - 4 \sqrt{4+2^2} \right] - \left[\frac{1}{3} (\sqrt{4+0^2})^3 - 4 \sqrt{4+0^2} \right] \\
 = \frac{16\sqrt{2}}{3} - 8\sqrt{2} - \frac{8}{3} + 8 \\
 = \frac{16 - 8\sqrt{2}}{3}
 \end{aligned}$$

$$\begin{aligned}
 4. \int_1^2 (\ln x)^2 dx \\
 u = \ln x \quad \int v = \ln x dx \\
 du = \frac{1}{x} dx \quad v = \int \ln x dx \\
 v = x \ln x - x \\
 = \ln x (x \ln x - x) - \int \frac{1}{2} (x \ln x - x) dx \\
 = x \ln^2 x - x \ln x - \int \ln x dx + \int dx \\
 = x \ln^2 x - x \ln x - x \ln x + x + x + C \Big|_1^2 \\
 = x \ln^2 x - 2x \ln x + 2x + C \Big|_1^2 \\
 = [2 \ln^2 2 - 2(2 \ln 2) + 2(2)] - [(1 \ln^2 1) - 2(1 \ln 1) + 2(1)] \\
 = 2 \ln^2 2 - 4 \ln 2 + 4 - 2 \\
 = 2 \ln^2 2 - 4 \ln 2 + 2 //
 \end{aligned}$$

Integral calculus sample problems with solution are essential for understanding the application of integration in various fields of mathematics and science. Integral calculus involves the study of integrals, which are mathematical objects that represent the accumulation of quantities. Whether you're dealing with area under curves, displacement, or total accumulation, mastering integral calculus is crucial for advanced studies in mathematics, physics, engineering, and economics. This article will delve into various sample problems, providing step-by-step solutions to enhance comprehension and practical skills.

Understanding the Basics of Integral Calculus

Integral calculus can be broadly categorized into two main types: definite integrals and indefinite integrals.

Indefinite Integrals

Indefinite integrals are functions that represent the family of antiderivatives of a function. The general form of an indefinite integral is:

$$\int f(x) \, dx = F(x) + C$$

where $F(x)$ is the antiderivative of $f(x)$ and C is the constant of integration.

Definite Integrals

Definite integrals, on the other hand, calculate the accumulation of quantities, typically over a specific interval $[a, b]$. The notation for a definite integral is:

$$\int_a^b f(x) \, dx$$

The result of a definite integral is a number that represents the net area under the curve of $f(x)$ from $x = a$ to $x = b$.

Sample Problems and Solutions

Below are several sample problems that illustrate the application of integral calculus, along with detailed solutions.

Problem 1: Indefinite Integral

Evaluate the indefinite integral:

$$\int (3x^2 - 4x + 1) \, dx$$

Solution

To solve this integral, we apply the power rule for integration, which states that:

$$\int x^n \, dx = \frac{x^{n+1}}{n+1} + C$$

for $(n \neq -1)$.

1. Break down the integral:

$$\int (3x^2) \, dx = \int (4x) \, dx + \int (1) \, dx$$

2. Integrate each term:

- For $\int (3x^2) \, dx = 3 \cdot \frac{x^{2+1}}{2+1} = x^3$
- For $\int (4x) \, dx = 4 \cdot \frac{x^{1+1}}{1+1} = 2x^2$
- For $\int (1) \, dx = x$

3. Combine the results:

$$x^3 - 2x^2 + x + C$$

Thus, the solution is:

$$\int (3x^2 - 4x + 1) \, dx = x^3 - 2x^2 + x + C$$

Problem 2: Definite Integral

Calculate the definite integral:

$$\int_1^3 (2x + 1) \, dx$$

Solution

To evaluate a definite integral, follow these steps:

1. Find the indefinite integral:

$$\int (2x + 1) \, dx = x^2 + x + C$$

2. Apply the Fundamental Theorem of Calculus, which states that if $F(x)$ is an antiderivative of $f(x)$, then:

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

3. Evaluate the antiderivative at the bounds:

- $F(3) = 3^2 + 3 = 9 + 3 = 12$
- $F(1) = 1^2 + 1 = 1 + 1 = 2$

4. Calculate the definite integral:

$$\int_1^3 (2x + 1) \, dx = F(3) - F(1) = 12 - 2 = 10$$

Thus, the solution is:

$$\int_1^3 (2x + 1) \, dx = 10$$

Problem 3: Area Between Curves

Find the area between the curves $y = x^2$ and $y = 4$ from $x = 0$ to $x = 2$.

Solution

To find the area between two curves:

1. Determine the points of intersection:

Set $x^2 = 4$ to find intersections:

$$x = 2 \quad \text{(since we are only considering } x = 0 \text{ to } x = 2 \text{)}$$

2. Set up the integral:

The area A is given by the integral of the top function minus the bottom function:

$$A = \int_0^2 (4 - x^2) \, dx$$

3. Compute the integral:

$$A = \int_0^2 4 \, dx - \int_0^2 x^2 \, dx$$

- Calculate each integral:

$$\begin{aligned} - \int_0^2 4 \, dx &= 4x \big|_0^2 = 4(2) - 4(0) = 8 \\ - \int_0^2 x^2 \, dx &= \frac{x^3}{3} \big|_0^2 = \frac{2^3}{3} \\ - \frac{0^3}{3} &= \frac{8}{3} \end{aligned}$$

4. Combine the results:

$$A = 8 - \frac{8}{3} = \frac{24}{3} - \frac{8}{3} = \frac{16}{3}$$

Thus, the area between the curves is:

$$\left[A = \frac{16}{3} \text{ square units} \right]$$

Problem 4: Integration by Parts

Evaluate the integral:

$$\int x e^x \, dx$$

Solution

To solve this integral, we use integration by parts, which is based on the formula:

$$\int u \, dv = uv - \int v \, du$$

1. Choose u and dv :
 - Let $u = x$ and $dv = e^x \, dx$
 - Then, $du = dx$ and $v = e^x$

2. Apply the integration by parts formula:

$$\int x e^x \, dx = x e^x - \int e^x \, dx$$

3. Compute the remaining integral:

$$\int e^x \, dx = e^x$$

4. Combine the results:

$$\int x e^x \, dx = x e^x - e^x + C = e^x (x - 1) + C$$

Thus, the solution is:

$$\int x e^x \, dx = e^x (x - 1) + C$$

Conclusion

Integral calculus is a powerful mathematical tool with a wide range of applications. By practicing various sample problems, such as those involving indefinite and definite integrals, areas between curves, and integration by parts, you can enhance your understanding and proficiency in this subject. The problems and solutions provided in this article serve as a foundation for tackling more complex integral calculus challenges. Continue to practice, and

you'll find that your skills will improve, making you more adept at handling real-world applications of integral calculus.

Frequently Asked Questions

What is the integral of x^2 with respect to x ?

The integral of x^2 with respect to x is $(1/3)x^3 + C$, where C is the constant of integration.

How do you solve the integral of $\sin(x) dx$?

The integral of $\sin(x) dx$ is $-\cos(x) + C$, where C is the constant of integration.

What is the definite integral of 0 to 1 of $3x^2$?

The definite integral from 0 to 1 of $3x^2$ is $[x^3]$ from 0 to 1 = $1^3 - 0^3 = 1$.

How can we evaluate the integral of e^x ?

The integral of e^x with respect to x is $e^x + C$, where C is the constant of integration.

What is the integral of $1/x dx$?

The integral of $1/x dx$ is $\ln|x| + C$, where C is the constant of integration.

How do you solve the integral of $\cos(2x) dx$?

The integral of $\cos(2x) dx$ is $(1/2)\sin(2x) + C$, where C is the constant of integration.

What is the process to find the area under the curve using integral calculus?

To find the area under a curve, you set up the definite integral of the function over the interval of interest, compute the integral, and evaluate it at the boundaries.

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