

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN



WIRTSCHAFTS- UND
SOZIALWISSENSCHAFTLICHE
FAKULTÄT

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S414
Advanced Mathematical Methods
Exercises

INTEGRATION

EXERCISE 1 Indefinite Integrals

Find the indefinite integrals. Assume that the respective domains are given appropriately.

a) $\int x^{12} dx$

b) $\int x^{-4} dx$

c) $\int \frac{1}{x^3} dx$

d) $\int 5x^9 - 3x^7 dx$

e) $\int x \cdot \sqrt[3]{x} dx$

f) $\int 2e^{3x+1} - 1 dx$

g) $\int \frac{1}{1+x} dx$

h) $\int \frac{1}{1-x} dx$

i) $\int \frac{x+3}{x^2+x-6} dx$

j) $\int \frac{x-1}{\sqrt{x}-1} dx$

k) $\int \frac{(e^x)^2 - 1}{e^x + 1} dx$

EXERCISE 2 Definite Integrals

Compute the values of the definite integrals:

a) $\int_0^2 2 - x dx$

b) $\int_{-2}^0 |x+1| dx$

EXERCISE 3 Integration by Parts

Use partial integration to solve the indefinite integrals.

a) $\int x^2 \cdot \ln(x) dx$

b) $\int x \cdot \ln(x) dx$

c) $\int x^\rho \cdot \ln(x) dx \quad (\rho \neq -1)$

d) $\int \ln(x)^2 dx$

e) $\int x^2 \cdot e^x dx$

f) $\int \frac{x}{e^x} dx$

EXERCISE 4 Integration by Parts

Determine the values of the definite integrals.

$$\text{a) } \int_{-1}^1 x \ln(x+2) \, dx \qquad \text{b) } \int_0^2 x 2^x \, dx$$

EXERCISE 5 Integration by Substitution

Solve the following indefinite integrals:

$$\begin{array}{ll} \text{a) } \int \frac{x}{1+x^2} \, dx & \text{b) } \int \frac{1}{x \cdot \ln(x)} \, dx \\ \text{c) } \int \frac{\ln(x)^3}{x} \, dx & \text{d) } \int \frac{x}{\sqrt{1+x}} \, dx \\ \text{e) } \int x^5 \sqrt{4-x^3} \, dx & \end{array}$$

EXERCISE 6 Integration by Substitution

Determine the values of the following definite integrals:

$$\text{a) } \int_1^{2,5} (2x-1)^6 \, dx \qquad \text{b) } \int_{10}^{10.000} \frac{1}{x \cdot \ln(x)} \, dx \qquad \text{c) } \int_a^b \frac{f'(x)}{f(x)} \, dx$$

EXERCISE 7 Improper Integrals

Determine the values of the following improper integrals:

$$\begin{array}{ll} \text{a)} \int_1^{\infty} \frac{1}{\sqrt[3]{x^2}} dx & \text{b)} \int_0^{\infty} x e^{-ax} dx \quad a > 0 \\ \text{c)} \int_{-\infty}^{-1} \frac{3}{x^3} dx & \text{d)} \int_0^1 \frac{1}{\sqrt{x}} dx \\ \text{e)} \int_0^1 \ln(x) dx & \end{array}$$

EXERCISE 8 Multiple Integrals

Solve the following multiple integrals:

$$\begin{array}{ll} \text{a)} \int_0^2 \int_0^1 (2x + 3y + 4) dx dy & \text{b)} \int_0^a \int_0^b (x - a)(x - b) dx dy \\ \text{c)} \int_1^3 \int_1^2 \frac{x - y}{x + y} dx dy & \text{d)} \int_0^{1/2} \int_0^{2\pi} y^3 \sin(xy^2) dx dy \end{array}$$

EXERCISE 9 Multiple Integrals

Find

$$I = \int_0^1 \int_0^1 \cdots \int_0^1 (x_1^2 + x_2^2 + \cdots + x_n^2) dx_1 dx_2 \dots dx_n$$

Solution Exercise 1:

- a) $\frac{1}{13}x^{13} + C$
- b) $-\frac{1}{3}x^{-3} + C$
- c) $-\frac{1}{2x^2} + C$
- d) $\frac{1}{2}x^{10} - \frac{3}{8}x^8 + C$
- e) $\frac{3}{7}x^{\frac{7}{3}} + C$
- f) $\frac{2}{3}e^{3x+1} - x + C$
- g) $\ln(|1 + x|) + C$
- h) $-\ln(|1 - x|) + C$
- i) $\ln(|x - 2|) + C$
- j) $\frac{2}{3}x^{\frac{3}{2}} + x + C$
- k) $\int e^x - 1 dx = e^x - x + C$

Solution Exercise 2:

- a) 2
- b) 1

Solution Exercise 3:

- a) $\frac{1}{3}x^3 \ln(x) - \frac{1}{9}x^3 + C$
- b) $\frac{1}{2}x^2 \ln(x) - \frac{1}{4}x^2 + C$
- c) $\frac{1}{\rho+1}x^{\rho+1} \ln(x) - \frac{1}{(\rho+1)^2}x^{\rho+1} + C$
- d) $x(\ln(x)^2 - 2\ln(x) + 2) + C$
- e) $e^x(x^2 - 2x + 2) + C$
- f) $-e^{-x}(x + 1) + C$

Solution Exercise 4:

- a) $2 - \frac{3}{2} \ln 3$
- b) $\frac{8}{\ln 2} - \frac{3}{(\ln 2)^2}$

Solution Exercise 5:

- a) $\frac{1}{2} \ln(|1 + x^2|) + C$
- b) $\ln(|\ln(x)|) + C$
- c) $\frac{1}{4} \ln(x)^4 + C$
- d) $\frac{2}{3}(1+x)^{\frac{3}{2}} - 2\sqrt{1+x} + C$
- e) $\frac{-8}{9}(4-x^3)^{\frac{3}{2}} + \frac{2}{15}(4-x^3)^{\frac{5}{2}} + C^*$

Solution Exercise 6:

- a) $\frac{1}{14}(4^7 - 1^7) \approx 1,170.21$
- b) $[\ln(\ln(x))]_{10}^{10.000} \approx 1.3863$
- c) $\ln(|f(b)|) - \ln(|f(a)|)$

Solution Exercise 7:

- a) does not converge!
- b) $\frac{1}{a^2}$
- c) $-\frac{3}{2}$
- d) 2
- e) -1

Solution Exercise 8:

- a) 16
- b) $\frac{1}{6}b^2a(3a-b)$
- c) $8 \ln(4) - 5 \ln(5) - 3 \ln(3) = 16 \ln(2) - 5 \ln(5) - 3 \ln(3)$
- d) $\frac{1}{8} - \frac{1}{4\pi}$

Solution Exercise 9:

- $I = \frac{n}{3}$