

Exercise walk-through

5.4

Substitution, parts and partial fractions

International Baccalaureate · IB Diploma · Mathematics: Analysis and Approaches

5.4 Substitution, parts and partial fractions

Name: _____ Class: _____ Date: _____ **Total: 13 marks**

KEY WORDS integration by parts

Objective

Substitution, parts and partial fractions. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

1 Key knowledge and worked examples

■ Can we integrate the two factors separately?

- A simple-looking product such as xe^x cannot be integrated by separately integrating each factor.
- This lesson studies **integration by parts** : An integration method based on the derivative of a product.

■ **Choose the mathematical structure**

- Use substitution when an inner derivative appears as a factor. By parts, $\int u v' = uv - \int u' v$. For a rational function, divide first if needed, then decompose into partial fractions.
- State the allowed inputs and units before calculating. An equation should express the relationship, not just record a calculator entry.

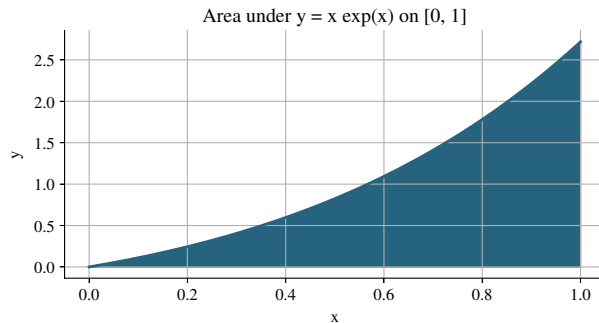
■ **Work through a checked case**

$$\int uv' dx = uv - \int u'v dx$$

- Check the result against the starting quantities. Substitute into the original relation, or compare the graph and numerical answer where appropriate.

Example:

For integral $x e^x dx$, take $u=x$ and $v' = e^x$. Then the integral is $x e^x - e^x + C$. For integral $2x/(x^2+1) dx$, substitute $w=x^2+1$, $dw=2x dx$; the answer is $\ln(x^2+1)+C$.



■ **Test a tempting shortcut**

- Choosing u and v prime well matters: the remaining integral should become simpler. In a definite substitution, either change the limits or return to x before applying the original limits.
- When a shortcut fails, identify the assumption it breaks. Keep an exact value until the requested final rounding.

Warn:

The integral of a product equals the product of its separate integrals. This claim is false. Explain which definition or assumption it violates.

■ **Interpret a new situation**

- Check by differentiating. For volumes of revolution around the x -axis use $V = \pi \int y^2 dx$; do not confuse the square of a function with the integral of the function.
- A complete solution gives the mathematical result and explains what it means. Check that it is possible in the stated context.

■ **Use this in your course**

- Current first-assessment-2021 Analysis and Approaches HL. This is authored concept support; the full guide is needed to certify every objective.
- Give the method before the final answer, and use the paper's calculator and formula rules. Review a wrong answer by locating the first invalid step.

Key:

An integration method based on the derivative of a product. Choose the relationship, show the method, check its assumptions and interpret the result.

Exercises 2.1·2.3

2.1 Evaluate the integral of xe^x from 0 to 1. Show the relation, substitution and units. [2]

2.2 Find the coefficient of $\ln(x^2+1)$ in the integral of $2x/(x^2+1)$. Show the relation, substitution and units. [2]

2.3 Find the volume divided by π when $y=x$ is revolved about the x-axis from 0 to 3. Show the relation, substitution and units. [2]

Exercises 2.1·2.3

2.1 Evaluate the integral of xe^x from 0 to 1. Show the relation, substitution and units. [2]

2.1 An antiderivative is $(x-1)e^x$. At 1 and 0 it gives 0 and -1, so the integral is 1.

2.2 Find the coefficient of $\ln(x^2+1)$ in the integral of $2x/(x^2+1)$. Show the relation, substitution and units. [2]

2.2 Substitution $w=x^2+1$ gives $dw=2x dx$, so the coefficient of $\ln(x^2+1)$ is 1.

2.3 Find the volume divided by π when $y=x$ is revolved about the x-axis from 0 to 3. Show the relation, substitution and units. [2]

2.3 $V/\pi = \int_0^3 x^2 dx = [x^3/3]_0^3 = 9$.

Exercises 2.4·2.5

2.4 Decide whether this claim is true and justify: The integral of a product equals the product of its separate integrals. [2]

2.5 Which description correctly defines integration by parts? Choose one answer.

- **A** An integration method based on the derivative of a product.
- **B** A numerical answer that needs no assumptions or interpretation
- **C** A rule that remains valid even when its required conditions fail

[1]

3 Exam-style questions

Exercises 2.4·2.5

2.4 Decide whether this claim is true and justify: The integral of a product equals the product of its separate integrals. [2]

2.4 False. Choosing u and v prime well matters: the remaining integral should become simpler. In a definite substitution, either change the limits or return to x before applying the original limits.

2.5 Which description correctly defines integration by parts? Choose one answer.

- **A** An integration method based on the derivative of a product.
- **B** A numerical answer that needs no assumptions or interpretation
- **C** A rule that remains valid even when its required conditions fail [1]

3 Exam-style questions

2.5 A An integration method based on the derivative of a product.

Exercise 3.1

3.1 Evaluate integral of $x \ln x$ from 1 to e by parts and differentiate the antiderivative as a check. [4]

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3.1 Evaluate integral of $x \ln x$ from 1 to e by parts and differentiate the antiderivative as a check. [4]

3.1 Take $u = \ln x$, $dv = x \, dx$: antiderivative $(x^2/2)\ln x - x^2/4$. Bounds give $(e^2 + 1)/4$. Differentiation returns $x \ln x$; domain $x > 0$ matters.