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Table of basic integrals and derivatives

This article is about mostly indefinite integrals in calculus. For a list of definite integrals, see List of definite integrals. This article includes a list of general references, but it remains largely unverified because it lacks sufficient corresponding inline citations. Please help to improve this article by introducing more precise citations. (November 2013) (Learn how and when to remove this template message) Part of a series of articles aboutCalculus Fundamental theorem Leibniz integral rule Limits of functions Continuity Mean value theorem Rolle's theorem Differential Definitions Derivative (generalizations) Differential infinitesimal of a function total Concepts Differentiation notation Second derivative Implicit differentiation Logarithmic differentiation Related rates Taylor's theorem Rules and identities Sum Product Chain Power Quotient L'Hôpital's rule Inverse General Leibniz Faà di Bruno's formula Integral Lists of integrals Integral transform Definitions Antiderivative Integral (improper) Riemann integral Lebesgue integration Contour integration Integral of inverse functions Integration by Parts Discs Cylindrical shells Substitution (trigonometric, Weierstrass, Euler) Euler's formula Partial fractions Changing order Reduction formulae Differentiating under the integral sign Risch algorithm Series Geometric (arithmetico-geometric) Harmonic Alternating Power Binomial Taylor Convergence tests Summand limit (term test) Ratio Root Integral Direct comparison Limit comparison Alternating series Cauchy condensation Dirichlet Abel Vector Gradient Divergence Curl Laplacian Directional derivative Identities Theorems Gradient Green's Stokes' Divergence generalized Stokes Multivariable Formalisms Matrix Tensor Exterior Geometric Definitions Partial derivative Multiple integral Line integral Surface integral Volume integral Jacobian Hessian Specialized Fractional Malliavin Stochastic Variations Miscellaneous Precalculus History Glossary List of topics Integration Bee vte Integration is the basic operation in integral calculus. While differentiation has straightforward rules by which the derivative of a complicated function can be found by differentiating its simpler component functions, integration does not, so tables of known integrals are often useful. This page lists some of the most common antiderivatives. Historical development of integrals A compilation of a list of integrals (Integraltafeln) and techniques of integral calculus was published by the German mathematician Meier Hirsch [de] (aka Meyer Hirsch [de]) in 1810. These tables were republished in the United Kingdom in 1823. More extensive tables were compiled in 1858 by the Dutch mathematician David Bierens de Haan for his Tables d'intégrales définies, supplemented by Supplément aux tables d'intégrales définies in ca. 1864. A new edition was published in 1867 under the title Nouvelles tables d'intégrales définies. These tables, which contain mainly integrals of elementary functions, remained in use until the middle of the 20th century. They were then replaced by the much more extensive tables of Gradshteyn and Ryzhik. In Gradshteyn and Ryzhik, integrals originating from the book by Bierens de Haan are denoted by BI. Not all closed-form expressions have closed-form antiderivatives; this study forms the subject of differential Galois theory, which was initially developed by Joseph Liouville in the 1830s and 1840s, leading to Liouville's theorem which classifies which expressions have closed form antiderivatives. A simple example of a function without a closed form antiderivative is e−x2, whose antiderivative is (up to constants) the error function. Since 1968 there is the Risch algorithm for determining indefinite integrals that can be expressed in term of elementary functions, typically using a computer algebra system. Integrals that cannot be expressed using elementary functions can be manipulated symbolically using general functions such as the Meijer G-function. More detail may be found on the following pages for the lists of integrals: List of integrals of rational functions List of integrals of irrational functions List of integrals of trigonometric functions List of integrals of inverse trigonometric functions List of integrals of hyperbolic functions List of integrals of inverse hyperbolic functions List of integrals of exponential functions List of integrals of logarithmic functions List of integrals of Gaussian functions Gradshteyn, Ryzhik, Geronimus, Tseytlin, Jeffrey, Zwillinger, Moll's (GR) Table of Integrals, Series, and Products contains a large collection of results. An even larger, multivolume table is the Integrals and Series by Prudnikov, Brychkov, and Marichev (with volumes 1–3 listing integrals and series of elementary and special functions, volume 4–5 are tables of Laplace transforms). More compact collections can be found in e.g. Brychkov, Marichev, Prudnikov's Tables of Indefinite Integrals, or as chapters in Zwillinger's CRC Standard Mathematical Tables and Formulae or Bronshtein and Semendyayev's Guide Book to Mathematics, Handbook of Mathematics or Users' Guide to Mathematics, and other mathematical handbooks. Other useful resources include Abramowitz and Stegun and the Bateman Manuscript Project. Both works contain many identities concerning specific integrals, which are organized with the most relevant topic instead of being collected into a separate table. Two volumes of the Bateman Manuscript are specific to integral transforms. There are several web sites which have tables of integrals and integrals on demand. Wolfram Alpha can show results, and for some simpler expressions, also the intermediate steps of the integration. Wolfram Research also operates another online service, the Wolfram Mathematica Online Integrator. Integrals of simple functions C is used for an arbitrary constant of integration that can only be determined if something about the value of the integral at some point is known. Thus, each function has an infinite number of antiderivatives. These formulas only state in another form the assertions in the table of derivatives. Integrals with a singularity When there is a singularity in the function being integrated such that the antiderivative becomes undefined or at some point (the singularity), then C does not need to be the same on both sides of the singularity. The forms below normally assume the Cauchy principal value around a singularity in the value of C but this is not in general necessary. For instance in ∫ 1 x d x = ln ⁡ | x | + C {\displaystyle \int {1 \over x}\,dx=\ln \left|x\right|+C} there is a singularity at 0 and the antiderivative becomes infinite there. If the integral above were to be used to compute a definite integral between −1 and 1, one would get the wrong answer 0. This however is the Cauchy principal value of the integral around the singularity. If the integration is done in the complex plane the result depends on the path around the origin, in this case the singularity contributes −iπ when using a path above the origin and iπ for a path below the origin. A function on the real line could use a completely different value of C on either side of the origin as in:[1] ∫ 1 x d x = ln ⁡ | x | + { A if x > 0 ; B if x < 0. {\displaystyle \int {1 \over x}\,dx=\ln |x|+{\begin{cases}A&{\text{if }}x>0;\\B&{\text{if }}x1} ∫ arsech x d x = x arsech x + arcsin ⁡ x + C , for 0 < x ≤ 1 {\displaystyle \int \operatorname {arsech} \,x\,dx=x\,\operatorname {arsech} \,x+\arcsin x+C,{\text{ for }}0 0 (the Gaussian integral) ∫ 0 ∞ x 2 e − a x 2 d x = 1 4 π a 3 {\displaystyle \int _{0}^{\infty }{x^{2}e^{-ax^{2}}\,dx}={\frac {1}{4}}{\sqrt {\frac {\pi }{a^{3}}}}} for a > 0 ∫ 0 ∞ x 2 n e − a x 2 d x = 2 n − 1 2 a ∫ 0 ∞ x 2 (n − 1) e − a x 2 d x = (2 n − 1) ! ! 2 n + 1 π a 2 n + 1 = (2 n) ! n ! 2 2 n + 1 π a 2 n + 1 {\displaystyle \int _{0}^{\infty }x^{2n}e^{-ax^{2}}\,dx={\frac {2n-1}{2a}}\int _{0}^{\infty }x^{2(n-1)}e^{-ax^{2}}\,dx={\frac {(2n-1)!!}{2^{n+1}}}{\sqrt {\frac {\pi }{a^{2n+1}}}}={\frac {(2n)!}{n!2^{2n+1}}}{\sqrt {\frac {\pi }{a^{2n+1}}}}} for a > 0, n is a positive integer and !! is the double factorial. ∫ 0 ∞ x 3 e − a x 2 d x = 1 2 a 2 {\displaystyle \int _{0}^{\infty }{x^{3}e^{-ax^{2}}\,dx}={\frac {1}{2a^{2}}}} when a > 0 ∫ 0 ∞ x 2 n + 1 e − a x 2 d x = n a ∫ 0 ∞ x 2 n − 1 e − a x 2 d x = n ! 2 a n + 1 {\displaystyle \int _{0}^{\infty }x^{2n+1}e^{-ax^{2}}\,dx={\frac {n}{a}}\int _{0}^{\infty }x^{2n-1}e^{-ax^{2}}\,dx={\frac {n!}{2a^{n+1}}}} for a > 0, n = 0, 1, 2, ... ∫ 0 ∞ x e x − 1 d x = π 2 6 {\displaystyle \int _{0}^{\infty }{\frac {x}{e^{x}-1}}\,dx={\frac {\pi ^{2}}{6}}} (see also Bernoulli number) ∫ 0 ∞ x 2 e x − 1 d x = 2 ζ (3) ≈ 2.40 {\displaystyle \int _{0}^{\infty }{\frac {x^{2}}{e^{x}-1}}\,dx=2\zeta (3)\approx 2.40} ∫ 0 ∞ x 3 e x − 1 d x = π 4 15 {\displaystyle \int _{0}^{\infty }{\frac {x^{3}}{e^{x}-1}}\,dx={\frac {\pi ^{4}}{15}}} ∫ 0 ∞ sin ⁡ x x d x = π 2 {\displaystyle \int _{0}^{\infty }{\frac {\sin {x}}{x}}\,dx={\frac {\pi }{2}}} (see sinc function and the Dirichlet integral) ∫ 0 ∞ sin 2 ⁡ x x 2 d x = π 2 {\displaystyle \int _{0}^{\infty }{\frac {\sin ^{2}{x}}{x^{2}}}\,dx={\frac {\pi }{2}}} ∫ 0 π 2 sin n ⁡ x d x = ∫ 0 π 2 cos n ⁡ x d x = (n − 1) ! ! n ! ! × { 1 if n is odd π 2 if n is even. {\displaystyle \int _{0}^{\frac {\pi }{2}}\sin ^{n}x\,dx=\int _{0}^{\frac {\pi }{2}}\cos ^{n}x\,dx={\frac {(n-1)!!}{n!!}}\times {\begin{cases}1&{\text{if }}n{\text{ is odd}}\\{\frac {\pi }{2}}&{\text{if }}n{\text{ is even.}}\end{cases}}} (if n is a positive integer and !! is the double factorial). ∫ − π π cos ⁡ (α x) cos n ⁡ (β x) d x = { 2 π 2 n (n m) | α | = | β (2 m − n) | 0 otherwise {\displaystyle \int _{-\pi }^{\pi }\cos(\alpha x)\cos ^{n}(\beta x)dx={\begin{cases}{\frac {2\pi }{2^{n}}}{\binom {n}{m}}&|\alpha |=|\beta (2m-n)|\\0&{\text{otherwise}}\end{cases}}} (for α, β, m, n integers with β ≠ 0 and m, n ≥ 0, see also Binomial coefficient) ∫ − t t sin m ⁡ (α x) cos n ⁡ (β x) d x = 0 {\displaystyle \int _{-t}^{t}\sin ^{m}(\alpha x)\cos ^{n}(\beta x)dx=0} (for α, β real, n a non-negative integer, and m an odd, positive integer; since the integrand is odd) ∫ − π π sin ⁡ (α x) sin n ⁡ (β x) d x = { (− 1) (n + 1 2) (− 1) m 2 π 2 n (n m) n odd , α = β (2 m − n) 0 otherwise {\displaystyle \int _{-\pi }^{\pi }\sin(\alpha x)\sin ^{n}(\beta x)dx={\begin{cases}(-1)^{\left({\frac {n+1}{2}}\right)}(-1)^{m}{\frac {2\pi }{2^{n}}}{\binom {n}{m}}&n{\text{ odd}},\ \alpha =\beta (2m-n)\\0&{\text{otherwise}}\end{cases}}} (for α, β, m, n integers with β ≠ 0 and m, n ≥ 0, see also Binomial coefficient) ∫ − π π cos ⁡ (α x) sin n ⁡ (β x) d x = { (− 1) (n 2) (− 1) m 2 π 2 n (n m) n even , | α | = | β (2 m − n) | 0 otherwise {\displaystyle \int _{-\pi }^{\pi }\cos(\alpha x)\sin ^{n}(\beta x)dx={\begin{cases}(-1)^{\left({\frac {n}{2}}\right)}(-1)^{m}{\frac {2\pi }{2^{n}}}{\binom {n}{m}}&n{\text{ even}},\ |\alpha |=|\beta (2m-n)|\\0&{\text{otherwise}}\end{cases}}} (for α, β, m, n integers with β ≠ 0 and m, n ≥ 0, see also Binomial coefficient) ∫ − ∞ ∞ e − (a x 2 + b x + c) d x = π a exp ⁡ [b 2 − 4 a c 4 a] {\displaystyle \int _{-\infty }^{\infty }e^{-(ax^{2}+bx+c)}\,dx={\sqrt {\frac {\pi }{a}}}\exp \left[{\frac {b^{2}-4ac}{4a}}\right]} (where exp[u] is the exponential function eu, and a > 0) ∫ 0 ∞ x z − 1 e − x d x = Γ (z) {\displaystyle \int _{0}^{\infty }x^{z-1}\,e^{-x}\,dx=\Gamma (z)} (where Γ (z) {\displaystyle \Gamma (z)} is the Gamma function) ∫ 0 1 (ln ⁡ 1 x) p d x = Γ (p + 1) {\displaystyle \int _{0}^{1}\left(\ln {\frac {1}{x}}\right)^{p}\,dx=\Gamma (p+1)} ∫ 0 1 x α − 1 (1 − x) β − 1 d x = Γ (α) Γ (β) Γ (α + β) {\displaystyle \int _{0}^{1}x^{\alpha -1}(1-x)^{\beta -1}dx={\frac {\Gamma (\alpha)\Gamma (\beta)}{\Gamma (\alpha +\beta)}}} (for Re(α) > 0 and Re(β) > 0, see Beta function) ∫ 0 2 π e x cos ⁡ θ d θ = 2 π I 0 (x) {\displaystyle \int _{0}^{2\pi }e^{x\cos \theta }d\theta =2\pi I_{0}(x)} (where I0(x) is the modified Bessel function of the first kind) ∫ 0 2 π e x cos ⁡ θ + y sin ⁡ θ d θ = 2 π I 0 (x 2 + y 2) {\displaystyle \int _{0}^{2\pi }e^{x\cos \theta +y\sin \theta }d\theta =2\pi I_{0}\left({\sqrt {x^{2}+y^{2}}}\right)} ∫ − ∞ ∞ (1 + x 2 ν) − ν + 1 2 d x = ν π ⁡ Γ (ν 2) Γ (ν + 1 2) {\displaystyle \int _{-\infty }^{\infty }\left(1+{\frac {x^{2}}{u }}\right)^{-{\frac {u +1}{2}}}\,dx={\frac {{\sqrt {u \pi }}\ \Gamma \left({\frac {u }{2}}\right)}{\Gamma \left({\frac {u +1}{2}}\right)}}} (for ν > 0 , this is related to the probability density function of Student's t-distribution) If the function f has bounded variation on the interval [a,b], then the method of exhaustion provides a formula for the integral: ∫ a b f (x) d x = (b − a) ∑ n = 1 ∞ ∑ m = 1 2 n − 1 (− 1) m + 1 2 − n f (a + m (b − a) 2 − n) . {\displaystyle \int _{a}^{b}{f(x)\,dx}=(b-a)\sum \limits _{n=1}^{\infty }{\sum \limits _{m=1}^{2^{n}-1}{\left({-1}\right)^{m+1}}2^{-n}f(a+m\left({b-a}\right)2^{-n}).} The "sophomore's dream": ∫ 0 1 x − x d x = ∑ n = 1 ∞ n − n (= 1.29128 59970 6266 …) ∫ 0 1 x x d x = − ∑ n = 1 ∞ (− n) − n (= 0.78343 05107 1213 …) {\displaystyle {\begin{aligned}\int _{0}^{1}x^{-x}\,dx&=\sum _{n=1}^{\infty }n^{-n}&&(=1.29128\,59970\,6266\dots)\\[6pt]\int _{0}^{1}x^{x}\,dx&=-\sum _{n=1}^{\infty }(-n)^{-n}&&(=0.78343\,05107\,1213\dots)\end{aligned}}} attributed to Johann Bernoulli. See also Incomplete gamma function Indefinite sum List of limits List of mathematical series Symbolic integration References ^ Serge Lang . A First Course in Calculus, 5th edition, p. 290 ^ "Reader Survey: log|x| + C", Tom Leinster, The n-category Café, March 19, 2012 Further reading Abramowitz, Milton; Stegun, Irene Ann, eds. (1983) [June 1964]. Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables. Applied Mathematics Series. 55 (Ninth reprint with additional corrections of tenth original printing with corrections (December 1972); first ed.). Washington D.C.; New York: United States Department of Commerce, National Bureau of Standards; Dover Publications. ISBN 978-0-486-61272-0. LCCN 64-60036. MR 0167642. LCCN 65-12253. Bronstein, Ilja Nikolaevič; Semendjajew, Konstantin Adolfovič (1987) [1945]. Grosche, Günter; Ziegler, Viktor; Ziegler, Dorothea (eds.). Taschenbuch der Mathematik (in German). 1. Translated by Ziegler, Viktor. Weiß, Jürgen (23 ed.). 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